Galina Setlak, Krassimir Markov
(editors)

Methods and Instruments of Artificial Intelligence

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Galina Setlak, Krassimir Markov (ed.)

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G. Setlak, K. Markov

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MeL	V-th International Conference "Modern (e-) Learning"
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FUZZY ARTMAP NEURAL NETWORKS FOR COMPUTER AIDED DIAGNOSIS

Anatoli Nachev

***Abstract**: The economic and social values of breast cancer diagnosis are very high. This study explores the predictive abilities of Fuzzy ARTMAP neural networks for breast cancer diagnosis. The data used is a combination of 39 mammographic, sonographic, and other descriptors, which is novel for the field. By using feature selection techniques we propose a subset of 21 descriptors that outperform the full feature set and outperforms the prediction model based on the most popular MLP neural networks. We also explored the model performance by ROC analysis and used metrics, such as max accuracy, area under the ROC curve, and area under the convex hull. Due to lack of specificity, many diagnosis tools entail unnecessary surgical biopsies, which motivated us to explore the clinically relevant metrics partial area under the ROC curve where sensitivity is above 90% and specificity at 98% sensitivity. In conclusion we find that the Fuzzy ARTMAP neural network is a promising prediction tool for breast cancer diagnosis. To the best of our knowledge, the Fuzzy ARTMAP neural networks have not been studied in that area until now.*

***Keywords**: data mining, neural networks, Fuzzy ARTMAP, heterogeneous data; breast cancer diagnosis, computer aided diagnosis*

***ACM Classification Keywords**: I.5.1- Computing Methodologies - Pattern Recognition – Models* - Neural Nets

Introduction

Breast cancer ranks first in the causes of cancer deaths among women in developed countries and is second in developing countries [Parker, 1997], [Lacey et al., 2002]. The best way to reduce deaths due to breast cancer is to treat the disease at an earlier stage. Earlier treatment requires early diagnosis, and early diagnosis requires an accurate and reliable diagnostic procedure that allows physicians to differentiate benign from malignant lesions. The economic and social values of breast cancer diagnosis are very high. Some studies show that only a third of suspicious masses are determined to be malignant and many surgical biopsies are unnecessary [Jemal et al., 2005]. Breast cancer diagnosis is a typical machine learning problem for many years. It has been dealt with using various machine learning algorithms and computer aided detection/diagnosis (CAD) tools. The problem is nontrivial and difficult to solve as the data set is noisy and relatively small. Techniques which rely on a large training data set would not work well for this problem.

A considerable amount of research in the area has been done based on rich variety of modalities and sources of medical information, such as: digitized screen-film mammograms, sonograms, magnetic resonance imaging (MRI) images, and gene expression profiles, etc. [Jesneck et al. 2006]. Current computerized breast cancer diagnosis tend to use only one information source, usually mammographic data in the form of descriptors defined by the Breast Imaging Reporting and Data System (BI-RADS) lexicon [BI-RADS, 2003]. Initially, BI-RADS was developed for standardization of mammographic descriptors only, but recently the American College of Radiology included a breast sonography extension, which standardizes various sonographic descriptors of lesions. Jesneck et al. [2007] have used a specific combination of BI-RADS mammographic and sonographic descriptors and some proposed by Stavros et al. [1995] to build a predictive model. Their study was pioneering in using such a combination and they report that predictive abilities of the linear discriminant analysis (LDA) and multi-layer preceptrons (MPL) are similar in the context of using either all 39 descriptors or a suggested subset of 14 descriptors. MLP have been largely applied to breast cancer diagnosis applications, but they have a drawback: the model assumes predefined network architecture, including connectivity and node activation functions, and training algorithm to learn to predict. The issue of designing a near optimal network architecture can be formulated as a search problem and still remains open.

This paper describes an alternative approach based on Fuzzy ARTMAP neural networks which feature well established architecture and fast one-pass online learning. To the best of our knowledge Fuzzy ARTMAP neural networks has not been used to date for breast cancer diagnosis with a combination of mammographic and sonographic descriptors.

The paper is organized as follows: Section 2 provides an overview of the Fuzzy ARTMAP neural network architecture used build a predictive model; Section 3 introduces the dataset used in the study, its features, and preprocessing of data; Section 4 presents and discuses the experimental results; and Section 5 gives the conclusions.

Fuzzy ARTMAP Neural Networks

ARTMAP systems are based on the Adaptive Resonance Theory (ART) for neural network modeling [Grossberg, 1976]. ARTMAP architectures are neural networks that develop stable recognition codes in real time in response to arbitrary sequences of input patterns. They were designed to solve the stability-plasticity dilemma that every intelligent machine learning system has to face: how to keep learning from new events without forgetting previously learned information. Fuzzy ARTMAP networks were designed to accept real-valued input patterns [Carpenter et al., 1992]. They learn by either simultaneously establishing suitable categories in both input and output space (tasks carried out within the so-called ARTa and ARTb modules respectively) or linking input and output categories according to joint occurrence and predictive success (the linkages being stored in a special unit called the map field or ARTab (see Figure 1). Modules are made of fields, which consist of neurons (nodes). Each ART module a comparison layer (F_1), and a recognition layer (F_2) with m and n neurons, respectively. All categorization and learning are achieved by sequentially modifying the connection weights, between the layers (black circles in the figure). In Fuzzy ARTMAP systems data can be processed with either natural or complement coding [Carpenter et al., 1992]: if natural coding is used, a data item is processed as it is, otherwise, it is augmented with its complement to 1. Thus, if a data sample *d* is an *n*-dimensional vector, system actually works on a *2n*-dimensional vector.

The numbers of weights in the ARTa and ARTb modules are system parameters determining the number and dimension of weights in the ARTab module. During training, a sample and the category label are provided as input to the ARTa and ARTb modules, which causes an activation to flow from the excited neurons (categories) in ARTa and ARTb into ARTab and then eventually back to ARTa. During testing a given input vector activates (predicts) a single category in the ARTb and ARTab modules. Whenever a pattern *A* activates a layer F1, it propagates through weighted connections w_{ij} to layer F2. Activation of each node *j* in the F2 layer is determined by the function:

$$T_j(A) = \frac{|A \wedge w_j|}{\alpha + |w_j|} \tag{1}$$

where $\wedge$ is the fuzzy AND operator: $(A \wedge w_j) \equiv \min(A_i, w_{ij})$. The F2 layer produces a winner-take-all (WTA) pattern of activity such that only the node $j=J$ with the greates t activation value remains active. Node J propagates its top-down expectation, or prototype vector w_J, back onto F1 and the vigilance test is performed. This test compares the degree of match between w_J and A against the dimensionless vigilance parameter ρ (rhobar). Within a given ARTa or ARTb module, the system decision to commit new neurons, as opposed to using previously commited neurons, is controlled by the vigilance parameter. When ρ is large, the system tends to commit neurons more easily: otherwise, relatively fewer and therefore larger categories are constructed.

The system learns an input sample *a* by updating the vector of weights w_J associated with the prototype:

$$w'_J = \beta(A \wedge w_J) + (1-\beta)w_J \qquad (2)$$

where β is a fixed learning rate parameter. Then a new association between the F2 node *J* and ARTab field takes place.

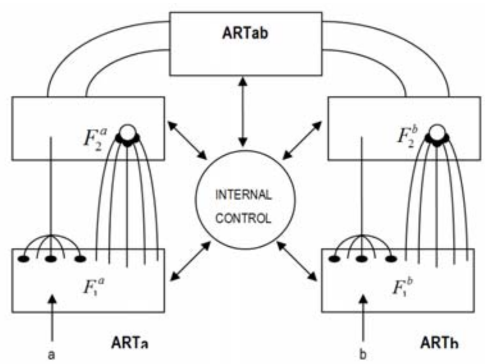


Figure 1. Simplified structurel of a Fuzzy ARTMAP neural network

Data, Features, and Preprocessing

The data used in this study consists of mammographic and sonographic examinations collected from 2000 to 2005 at Duke University Medical Centre [Jesneck et al., 2007]. Samples included in the dataset are those selected for biopsy only if the lesions corresponded to solid masses on sonograms and if both mammographic and sonographic images taken before the biopsy were available for review. The data set contains 803 samples of which 296 malignant and 507 benign. Information about patient physical examination findings, family history of breast cancer, and personal history of breast malignancy has been available to each radiologist to reproduce a realistic clinical situation.

Out of 39 features in total, 13 are mammographic BI-RADS features, 13 are sonographic BI-RADS features, six are sonographic features suggested by Stavros et al. [1995], four are other sonographic features, and three were patient history features [BI-RADS, 2003], [Jesneck et al., 2007], [Nachev & Stoyanov, 2010]. The features are as follows: mass size, parenchyma density, mass margin, mass shape, mass density, calcification number of particles, calcification distribution, calcification description, architectural distortion, associated findings, special cases (as defined by the BI-RADS lexicon: asymmetric tubular structure, intramammary lymph node, global asymmetry, and focal asymmetry), comparison with findings at prior examination, and change in mass size. The sonographic features are radial diameter, antiradial diameter, anteroposterior diameter, background tissue echo texture, mass shape, mass orientation, mass margin, lesion boundary, echo pattern, posterior acoustic features, calcifications within mass, special cases (as defined by the BI-RADS lexicon: clustered microcysts, complicated cysts, mass in or on skin, foreign body, intramammary lymph node, and axillary lymph node), and vascularity. The six features suggested by Stavros [Stavros et al., 1995] are mass shape, mass margin, acoustic transmission, thin echo pseudocapsule, mass echogenicity, and calcifications. The four other sonographic mass descriptors are edge shadow, cystic component, and two mammographic BI-RADS descriptors applied to sonography—mass shape (oval and lobulated are separate descriptors) and mass margin (replaces sonographic descriptor angular with obscured). The three patient history features were family history, patient age, and indication for sonography.

The Fuzzy ARTMAP neural network we use require a specific input format, which presumes preprocessing of the original dataset. We applied two linear transformations: normalization and rescaling. The normalization addresses a problem of the input variables – they differ significantly in their values due to different units in which they are expressed. This difference can lead to poor classification as some variable dominate others. By calculating the deviation of each variable value from the variable mean, normalized by its standard deviation, we obtained the new values of the dataset using (3) and (4).

$$\tilde{x}_i^n = \frac{x_i^n - \bar{x}_i}{\sigma_i} \qquad (3)$$

where $\tilde{x}_i^n$ is the new value, x_i^n is the original one, and

$$\bar{x}_i = \frac{1}{N}\sum_{n=1}^{N} x_i^n, \qquad \sigma_i^2 = \frac{1}{N-1}\sum_{n=1}^{N}(x_i^n - \bar{x}_i)^2 \qquad (4)$$

The second transformation, rescaling, maps the dataset values into [0, 1] using (5) as this is a requirement of the NN.

$$\hat{x}_i^n = \frac{(\tilde{x}_i^n - \tilde{x}_i^{\min})}{(\tilde{x}_i^{\max} - \tilde{x}_i^{\min})} \qquad (5)$$

where $x_i^{\max}$ and $x_i^{\min}$ are the max, and min values of the variable x_i , respectively.

Experimental Results and Discussion

A series of tests was carried out in order to investigate how a trained Fuzzy ARTMAP NN predicts breast cancer decease, based on a set of descriptors outlined above. In order to validate our experiments we used 5-fold cross-validation (CV) technique which avoids bias in selection of the training and test sets. It does so by creating 5 copies of the classifier, and testing each on 20% (1/5) of the data set, after training it on the remainder. The classification error estimate is computed as the average of the values obtained for each test set.

The experiments were focused to two aspects of the model functioning: reduction of dimensionality of the data and optimal values of the network parameters.

We considered and experimented with various feature selection techniques, such as best first, genetic search, subset size forward selection, race search, and scatter search, and sults showed that best feature selection technique is genetic search [Goldberg, 1989] combined with a set evaluation technique that considers individual predictive ability of each feature along with the degree of redundancy between them [Hall, 1998]. The feature set we obtained as best consists of the following 21 descriptors: patient age, family history, mass margin, architectural distortion, associated findings, comparison with prior examinations, anteroposterior diameter, mass shape, mass orientation, mass margin, lesion boundary, calcification within mass, special cases, mass shape, mass margin, thin echo pseudocapsule, mass echogenicity, edge shadow, cystic component, mass shape, and mass margin. We also tested the model with three other feature sets: the full set of 39 descriptors (s39), the set of 14 features obtained by [Jesneck et al., 2007] by stepwise feature selection method, and the set of 17 features (s17) proposed by [Nachev & Stoyanov, 2010] for MLP neural networks.

In order to estimate the Fuzzy ARTMAP performance with different network parameters, we explored each of them individually. Results show that the parameters baseline vigilance, signal rule, and the learning fraction provide the model with best discriminatory power by values $\rho_{test} = 0$, $\alpha = 0.01$, $\beta = 1.0$, and regardless of the feature selection. The vigilance parameter ρ (rhobar), however, shows dependency to each selected feature set.

For each set the model was trained and tested with 42 vigilance parameter values from 0 to 1 with step of increment 0.025. Figure 2 shows the prediction accuracy of the four sets with all values of the vigilance parameter. The sets show similar performance, but certain values of the parameter cause picks of accuracy with best result of 84.4% achieved by s21 at $\rho = 0.225$.

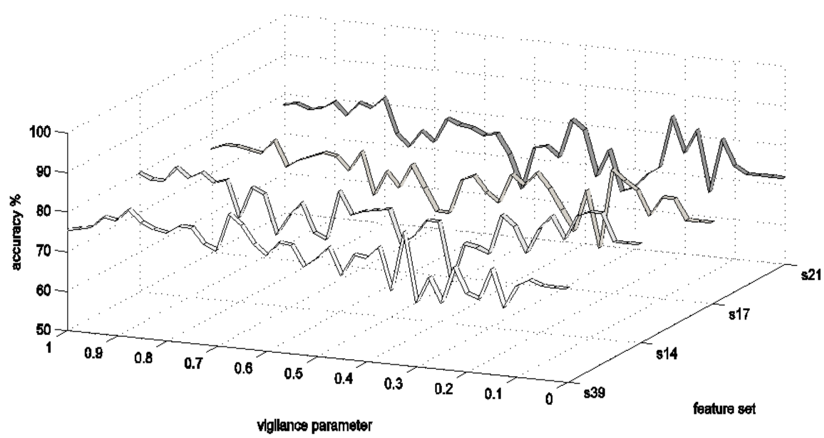
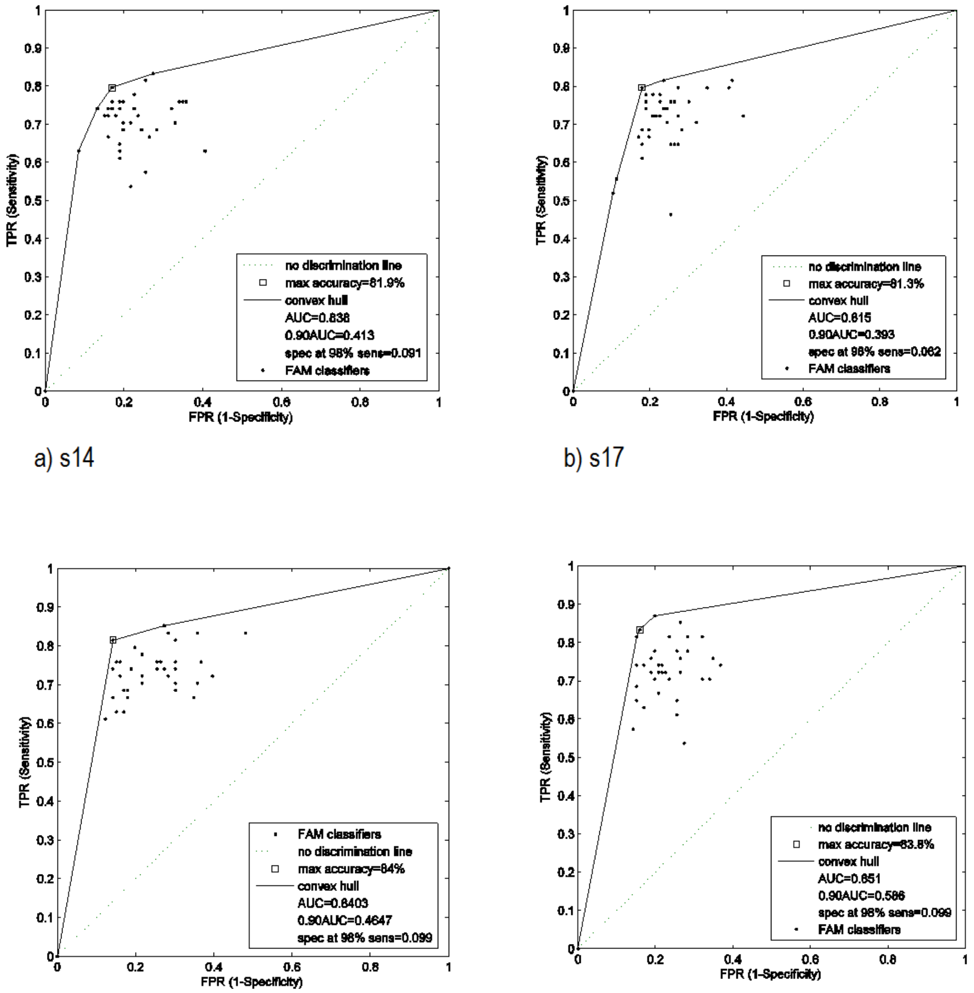


Figure 2. Accuracy of Fuzzy ARTMAP with four feature sets and vigilance parameter (rhobar) values from 0 to 1 with step of increment 0.025

Accuracy is the most common estimator used to date, but it can be misleading if the distribution of the classes is skewed, or if errors of type I and type II have different clinical implications and different cost. Taking into account those drawbacks we did Receiver Operating Characteristics (ROC) analysis of the results. ROC curves describe the relation between true positive rate (TPR) and false positive rate (FPR) [Fawcett, 2006]. In the case of crisp classifiers, such as Fuzzy ARTMAP, each classifier is represented by one point on the ROC space. By varying a parameter, such as the vigilance one, we generate an aggregation of points (Figure 3). The solid line represents the ROC convex hull (ROCCH), a line made up by connecting the most northwest points and the two trivial classifiers (0,0) and (1,1). All the candidates for optimal classifier lie on the convex hull as these are the most northwest point with minimum FPR and maximum TPR. All other classifiers that are ‘capped’ by the ROCCH can be ignored as they cannot be optimal. Each ROCCH line section between two adjacent corner points represents a continuum of possible intermediate classifiers that can be constructed by randomly weighting both corner classifiers giving more or less weight to one or the other. The optimal classifiers in terms of ROC are the most ‘northwest’ or most distant from the no-discrimination line. These are the square points on Figure 3 and they are the same that give maximal accuracy, which confirms that best in terms of accuracy is best in terms of ROC.



a) s14 b) s17

c) s21 d) s39

Figure 3. ROC analysis of Fuzzy ARTMAP with feature set of: a) 14 descriptors [Jesneck, 2007]; b) 17 descriptors [Nachev & Stoyanov, 2010]; c) 21 descriptors proposed in this study; d) all 39 descriptors. Each point represents a classifier determined by a value of the vigilance parameter that varies from 0 to 1 with step of increment 0.025

ROC analysis also allows to calculate metrics that estimate a model performance, such as area under the ROC curve (AUC), partial AUC ($_{0.90}$AUC of sensitivity above 0.90), and specificity at 98% sensitivity. AUC represents the overall model performance regardless the choice of vigilance; $_{0.90}$AUC shows the model performance at high values of sensitivity, which is important from a clinical viewpoint; specificity at 98% sensitivity is also important from a clinical perspective. Figure 3 shows the ROC space and the performance metrics for each of the four sets.

The figures are compared in Table 1, that shows that Fuzzy ARTMAP has max accuracy 84.4% with the 21 descriptor set and vigilance parameter value 0.225. The model also outperforms predictors based on the most popular neural networks – MLP, which yield 82.5% accuracy [Nachev & Stoyanov, 2010]. Second best is the set of 39 descriptors, which means that collecting and processing all the data is time consuming and not necessary. Lowest accuracy is obtained by using the 17 and 14 feature sets, which suggests that despite those sets give good results with LDA and MLP, they don't work well with another model, such as Fuzzy ARTMAP. AUC and

$_{0.90}$AUC show that the full feature set outperforms the selection of 21 descriptors and all features should be used if sensitivity above 90% is required.

Table 1. Accuracy of Fuzzy ARTMAP with four feature sets and vigilance parameter (rhobar) values from 0 to 1 with step of increment 0.025.

Performance Metric	*39 attr. Set*	*21 attr Set*	*17 attr. set*	*14 attr set.*
AUC	0.851	0.840	0.815	0.838
$_{0.90}$AUC	0.586	0.465	0.393	0.413
Spec at 98% sens	0.099	0.099	0.082	0.091
Acc_{max}	0.838	0.844	0.813	0.819

Conclusion

Computer-aided breast cancer diagnosis is a typical classification problem which was approached over the years by many techniques and methods, and algorithms.

This paper explores the discriminatory power of Fuzzy ARTMAP neural networks in differentiation between malignant and benign lesions based on data from mammographic and sonographic examinations. We used a data collected at Duke University Medical Centre which contains 39 descriptors. In order to improve the model performance we did reduction of dimensionality by applying various feature selection techniques.

We found that a subset of 21 descriptors outperforms the full descriptor set, as well as two other subsets used with the same dataset in other studies. A careful adjusted Fuzzy ARTMAP neural network outputs 84.4% prediction accuracy of the dataset versus 82.5% of the MLP neural network with the same dataset.

The model performance was also estimated by ROC analysis and the metrics such as area under the ROC curve, partial area under the ROC curve above 90% sensitivity, and specificity at 98% sensitivity.

In conclusion we find that the Fuzzy ARTMAP neural network is a promising technique for diagnosis, but when used it requires a careful reduction of dimensionality and well tuned network parameters. The model also provides additional benefits such as one-pass online learning that retains already acquired knowledge, in contrast to the widely used MLP neural networks. To the best of our knowledge Fuzzy ARTMAP neural networks has not been used to date for breast cancer diagnosis in combination with both mammographic and sonographic descriptors.

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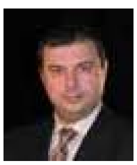

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HYBRID SYSTEMS OF COMPUTATIONAL INTELLIGENCE EVOLVED FROM SELF-LEARNING SPIKING NEURAL NETWORK

Yevgeniy Bodyanskiy, Artem Dolotov

Abstract: *Computational intelligence paradigm covers several approaches for technical problems solving in an intelligence manner, such as artificial neural networks, fuzzy logic systems, evolutionary computation, etc. Each approach provides engineers and researchers with the smart and powerful tools to handle various real-life concerns. Even more powerful tools were designed at the joint of different computational intelligence approaches. Neuro-fuzzy systems, for example, are well-known and advanced intelligent tool that combines capabilities of neural networks and fuzzy systems together in a synergetic way. Among them, one of the prominent hybrid systems type is self-learning fuzzy spiking neural networks. They were evolved from fuzzy logic systems and self-learning spiking neural networks, and revealed considerable computational capabilities. There were proposed several architectures of self-learning fuzzy spiking neural networks, each handling a particular kind of data processing tasks (processing fuzzy data, fuzzy probabilistic and possibilistic clustering, batch and adaptive methods, new clusters detection, irregular form clusters detection, etc). In this paper, known architectures of self-learning hybrid systems based on spiking neural network are reviewed, compared, and summarized. A generalized architecture and learning algorithm for self-learning fuzzy spiking neural networks are proposed.*

Keywords: *computational intelligence, hybrid systems, self-leaning spiking neural network, fuzzy clustering, temporal Hebbian learning, 'Winner-Takes-More' rule, control theory, inductive modelling, clusters merging, new clusters detection, hierarchical clustering .*

ACM Classification Keywords: *I.2.6 [Artificial Intelligence]: Learning – Connectionism and neural nets; I.2.8 [Artificial Intelligence]: Problem Solving, Control Methods, and Search – Control theory; I.5.1 [Pattern Recognition]: Models – Fuzzy set, Neural nets; I.5.3 [Pattern Recognition]: Clustering – Algorithms.*

Introduction

Same as any well-established science, each of primary scientific directions of computational intelligence paradigm develops in two fundamental manners, namely, in intensive way – by improving present methods and approaches, and in extensive way – by adopting achievements of adjacent directions. Considering artificial neural networks direction, prominent result of the former is the third generation of neural networks, known as spiking neural networks [Gerstner, 2002; Maass, 1997]. Well-known result of the latter is hybrid neuro-systems, among them the most advanced are neuro-fuzzy systems [Jang, 1997].

Neuro-fuzzy systems successfully combine capabilities of neural networks of the second generation and fuzzy systems in a synergetic way and provide researchers and engineers with powerful tools to handle various technical problems. Following this notion, hybrid systems of self-learning spiking neural networks and fuzzy logic methods were introduced and shown to be effective in data processing [Bodyanskiy, 2009b]. The third generation of artificial neural networks appeared to be capable of being combined with fuzzy logic approach on different levels of architecture, and that led to different types of hybrid systems, each solving a certain kind of data processing tasks. Having particular hybrid systems evolved from self-learning spiking neural network, the synthesis of generalized architecture of self-learning fuzzy spiking neural network is of theoretical interest, and that is the main purpose of the paper.

Before proceeding any further, it is worth to note that spiking neural networks differ from neural networks of the second generation essentially. Whereas conventional neural networks are driven by value of signal and disregard time in the most cases, spiking neural networks utilize time as the only computational resource, and that makes the third generation of neural networks related to biological neural systems in higher degree than networks of the previous generations are. Such difference becomes sharper if one considers both generations from control theory point of view. In this case, conventional artificial neural networks are nothing other than pulse-amplitude systems, and spiking neural networks are pulse-position ones [Bodyanskiy, 2009b]. Hybrid systems evolved from spiking neural networks introduce concept of time as a computational resource through spiking neural networks into other areas of computational intelligence, and that will confidently lead to new discoveries in future.

Self-Learning Spiking Neural Networks

The first notion of spiking neurons as self-learning systems was stated by J. Hopfield in [Hopfield, 1995]. He discovered that spiking neuron acts as a radial basis function, namely, its response depends on distance between incoming pattern and one encoded into the neuron's synapses (it is named as spiking neuron center). The closer pattern is to the center, the earlier neuron fires. If pattern is far from the center, the neuron does not fire at all. Here the distance is treated not in common sense, it reflects degree of coincidence (synchrony) of spikes emitted in synapses and incoming to soma. Among the simple ways to calculate the distance, there are two commonly known ones, they are generalized in [Bodyanskiy, 2009d].

By adjusting synaptic weights of spiking neuron, one can encode center of a certain data cluster into neuron's center. Several neurons adjusted this way and linked with lateral inhibitory connections allowing only one neuron to fire (the one that is closer to incoming pattern) can successfully perform crisp data clustering. The first known architecture of network with spiking neurons layer that is applicable for data processing tasks solving was proposed by T. Natschlaeger and B. Ruf in [Natschlaeger, 1998]. The network consists of input neurons layer that transforms input patterns into spikes and spiking neurons layer that performs data clustering. The proposed self-learning spiking neural network is able to detect clusters in input data set successfully only in cases when number of clusters does not exceed number of input dimensions. S. Bohte, J. Kok, and H. La Poutre improved spiking neural network clustering capabilities by introducing the layer of population coding [Bohte, 2002] instead of layer of Natschlaeger-Ruf input neurons. Now Bohte's self-learning spiking neural network is the base for any further modifications and improvements.

It is remarkable that spiking neuron functioning can be described from control theory perspective, in terms of Laplace transform [Bodyanskiy, 2009b]. By this means spiking neuron synapse is nothing other than a second-order critically damped response unit, and spiking neuron soma is a threshold-detection unit. Description of spiking neuron functioning in terms of the Laplace transform makes it possible to state spiking neural network architecture on a general technical ground that can be used in the following for constructing various hardware implementations of self-learning spiking neural network and hybrid systems evolved from it.

Fuzzy Clustering Based on Spiking Neurons

Fuzzy clustering is the more advanced approach for unsupervised data processing as compared to crisp clustering. It allows of successful data processing under a prior and current uncertainty thus providing researchers and engineers with flexible tool to handle various complex technical problems. Fuzzy clustering analysis covers several techniques. Among them, algorithms based on objective function are the most mathematically rigorous [Bezdek, 1981]. Such algorithms solve data processing tasks by optimizing a preset cluster quality criterion. As a rule, the criterion rests on a certain distance between input patterns and cluster centers. Considering different distance metrics, one can originate various fuzzy clustering algorithms. For example, Euclidean metric originates well-known and widely used conventional FCM and PCM algorithms [Bezdek, 2005].

Within scope of the paper subject, it is instructive to find the way of how self-learning spiking neural networks can be combined with fuzzy clustering approaches. Such uniting factor was originally proposed in [Bodyanskiy, 2008a] on the base of spiking neurons firing time. As far back as the first architectures of self-learning spiking neural network, it has been noted that firing time of spiking neuron accounts for similarity ([Natschlaeger, 1998]) or distance ([Bohte, 2002]) between the neuron center and input pattern. Using this notion, fuzzy clustering algorithm was introduced for spiking neurons layer as follows:

$$\mu_j(x(k)) = \frac{\left(t_j^{[1]}(x(k))\right)^{\frac{2}{1-\zeta}}}{\sum_{\iota=1}^{m}\left(t_\iota^{[1]}(x(k))\right)^{\frac{2}{1-\zeta}}}, \tag{1}$$

where $x(k)$ is the input pattern ($k = 1, 2, ..., k, ..., N$ is a pattern number), $\mu_j(x(k))$ is the membership level of pattern $x(k)$ to the *j*-th cluster, $t_j^{[1]}(x(k))$ is the firing time of the *j*-th spiking neuron in the layer ('1' indicates number of spiking neuron layer, layer of population coding is marked by '0'), $\zeta \geq 0$ is the fuzzifier, *m* is number of clusters (and number of spiking neurons in the layer).

Hybrid system based on self-learning spiking neural network for accomplishing fuzzy clustering task (self-learning fuzzy spiking neural network) includes three layers, namely, population coding layer, spiking neurons layer (lateral connections are eliminated), and layer that performs fuzzy partitioning (1). Obviously lateral connections in the second hidden layer should be eliminated in order fuzzy clustering layer to receive information on distances from all spiking neurons. The major advantage of the proposed network is its rapidity in data clustering as compared to conventional FCM algorithm. As it was shown [Bodyanskiy, 2008a-b], fuzzy spiking neural network requires about 3-4 epochs to successfully process satellite images while FCM requires about 30-50 epochs for the same tasks. One more advantage of the hybrid system is that it needs not to calculate cluster's centroids explicitly thus simplifying the clustering algorithm.

Developing the proposed notion further, possibilistic clustering on self-learning spiking neural network base was put forth [Bodyanskiy, 2008d]. Its form is similar to PCM algorithm but firing time is used as distance between input pattern and cluster center:

$$\mu_j(x(k)) = \left(1 + \left(\frac{\left(t_j^{[1]}(x(k))\right)^2}{\lambda_j}\right)^{\frac{1}{\zeta-1}}\right)^{-1}, \tag{2}$$

$$\lambda_j = \frac{\sum_{k=1}^{N}\mu_j^{\zeta}(x(k))\left(t_j^{[1]}(x(k))\right)^2}{\sum_{k=1}^{N}\mu_j^{\zeta}(x(k))}, \tag{3}$$

where $\lambda_j \geq 0$ is *j*-th penalty term.

Both (1) and (2), (3) are algorithms for data processing in batch mode that implies the data set is defined before neural network learning stage. Every so often new data arrive in the course of learning (on-line mode). This case requires adaptive form of clustering algorithms. Utilizing adaptive version of conventional PCM [Bodyanskiy, 2005] in the same way as it was shown above for batch mode PCM, self-learning spiking neural network can be tuned to accomplish possibilistic clustering in on-line mode [Bodyanskiy, 2008c].

The proposed modification in spiking neurons layer requires the network learning algorithm to be updated. The original learning algorithm of self-learning spiking neural network is based on two rules, namely, on 'Winner-Takes-All' rule and temporal Hebbian rule [Gerstner, 1996; Natschlaeger, 1998; Bohte, 2002; Berredo, 2005]. 'Winner-Takes-All' rule is applied to define which spiking neuron to be updated: the one that fired first for the provided input pattern. Temporal Hebbian rule is used to update the neuron so that its center is moved closer to input pattern. A learning epoch of the algorithm consists of two phases. Spiking neurons compete to respond to input pattern on the first phase. Synaptic weights of the neuron-winner are adjusted on the second phase. Centers of spiking neurons of the learned network represent centriods of data clusters so the network can successfully perform crisp data clustering. In order to accomplish fuzzy clustering (1) or (2), (3), the output layer should received information on distances from input patters to all spiking neurons centers so evidently the learning algorithm should take into account that information on each learning epoch as well. Such consideration leads us to the generalized version of learning algorithm [Bodyanskiy, 2009b] where 'Winner-Takes-All' rule is replaced with 'Winner-Takes-More' rule as follows:

$$w_{jli}^{p}(K+1) = w_{jli}^{p}(K) + \eta_w(K)\varphi(\left|\Delta t_{\tilde{j}j}\right|)L(\Delta t_{jli}^{p}), \tag{4}$$

where K is the epoch number, w_{jli}^{p} is the synaptic weight of the p-th subsynapse between the li-th receptive neuron and the j-th spiking neuron, $\eta_w(\bullet) > 0$ is the learning rate, $\varphi(\bullet)$ is the neighbourhood function, $\left|\Delta t_{\tilde{j}j}\right|$ is the difference between the neuron-winner $\tilde{j}$ firing time and the j-th neuron firing time, $L(\bullet)$ is the learning function [Gerstner, 1996], Δt_{jli}^{p} is the time delay between delayed spike $t_{li}^{[0]}(x_i(k)) + d^p$ and spiking neuron spike $t_j^{[1]}(x(k))$. Learning algorithm (4) naturally fits spiking neural network architecture where lateral inhibitory connections are eliminated.

Thus, as is evident from the foregoing, layer of spiking neurons can be easily "fuzzified". Firing time of spiking neuron appeared to be a good ground to link new type of neural networks and conventional clustering algorithms considerably reducing data processing time. This is the most obvious and easy to implement notion of evolving hybrid systems from self-learning spiking neural network. More sophisticated approached are stated in the following sections.

Layer of Fuzzy Receptive Neurons

Except the main purpose of input layer of spiking neural network that is transforming input signal into spikes, population coding layer of Bohte's self-learning spiking neural network was designed also to improve the network computational capabilities [Bohte, 2002]. Population coding layer consists of several pools of receptive neurons. Number of pools corresponds to number of components (dimensions) of input signal. Each pool of receptive neurons processes a certain input component, thus distributing information over pool neurons and increasing the input dimensionality.

Receptive neuron is so constructed that input signal of either pulse-amplitude or continuous-time form is transformed to pulse-position form. Receptive neuron's activation function is bell-shaped. The closer input signal is to the activation function center, the earlier receptive neuron emits spike. Generally the transformation can be expressed as follows (for pulse-amplitude signal):

$$t_{li}^{[0]}(x_i(k)) = \begin{cases} \left\lfloor t_{\max}^{[0]}\left(1 - \psi\left(\left|x_i(k) - c_{li}^{[0]}\right|, \sigma_{li}\right)\right)\right\rfloor, & \psi\left(\left|x_i(k) - c_{li}^{[0]}\right|, \sigma_{li}\right) \geq \theta_{\text{r.n.}}, \\ -1, & \psi\left(\left|x_i(k) - c_{li}^{[0]}\right|, \sigma_{li}\right) < \theta_{\text{r.n.}}, \end{cases} \tag{5}$$

where $x_i(k)$ is the *i*-th component of input pattern $x(k)$, $t_{li}^{[0]}(x_i(k))$ is the spike emitted by the *l*-th receptive neuron of the *i*-th pool, $t_{\max}^{[0]}$ is the maximum possible firing time for a neuron in the input layer, $\lfloor \bullet \rfloor$ is the floor function (ceiling function can be used as well), $\psi(\bullet,\bullet)$, $c_{li}^{[0]}$, σ_{li}, and $\theta_{\text{r.n.}}$ are respectively the receptive neuron's activation function, center, width, and dead zone, -1 is used to indicate not fired neuron.

Originally it was proposed to set receptive neurons in a pool so that their activation functions were uniformly shifted and overlapped [Bohte, 2002; Berredo, 2005]. In addition neurons with narrow and wide activation functions were considered. One can see that the way of receptive neurons setting has nothing to do with the input data nature. In the absence of a priori knowledge of problem being solved, the cited method is acceptable. However, if researcher or engineer possess some knowledge regarding the problem, it would be worthwhile to consider it when setting neural network parameters in order to improve the network performance.

It is common knowledge that fuzzy logic rule-based systems allow for ease of their strucutre interpretation, thus providing researchers with ability to incorporate knowledge of the problem being solved into the system. Let's look at population coding layer of spiking neural network from fuzzy inference systems perspective [Bodyanskiy, 2009b]. One can readily see that pool of receptive neurons is closely similar to a certain linguistic variable, and receptive neuron in the pool is similar to a linguistic term. Using this notion, we can consider activation function $\psi_{li}(x_i(k))$ of receptive neuron as membership function of corresponding linguistic term. Obviously in this context bell-shaped form is no longer requirement for activation function. It can be trapezoidal, or triangular, or any other that is the best suited to express expert knowledge. By this means population coding layer can be treated as the one that transforms input data set to a fuzzy set that is defined by values of activation-membership functions $\psi_{li}(x_i(k))$ and is expressed over time domain in form of firing times $t_{li}^{[0]}(x_i(k))$. Firing time $t_{li}^{[0]}(x_i(k)) = 0$ indicates that input $x_i(k)$ belongs to the *l*-th linguistic term of the *i*-th linguistic variable in the highest degree. And vice versa firing time $t_{li}^{[0]}(x_i(k)) = -1$ means $x_i(k)$ does not belong to the linguistic term at all.

Thus, interpretation of population coding layer as a fuzzification layer allows researchers to incorporate a priori knowledge into layer structure, and that may be resulted in better clusters partitioning. Here it makes sense to note that the preset linguistic terms can be occasionally lacking of necessary density of overlapping activation-membership functions. In this case researcher should observe balance between customizing activation functions of receptive neurons regarding his knowledge and keeping the required density, but that is the subject for another research.

Adjustable Architectures of Self-Learning Spiking Neural Network

Efficiency of data clustering depends to a large degree on quality of corresponding mathematical model chosen by researcher. One of the challenging problems in area of effective mathematical model designing is varying number of clusters in data being processed. That case can be successfully handled by adaptive models that are capable of adjusting not only their parameters but also their structure. Idea of designing optimal in some respect structures underlies the scientific direction known as inductive modelling. From this point of view, it may be supposed that combining methods of inductive modelling and computational intelligence together would increase quality of data processing in the presence of varying number of clusters or when clusters are of irregular form. It is possible to apply the following inductive modelling methods to self-learning spiking neural network:

- clusters merging by decreasing number of spiking neurons;
- new clusters detecting by adding new spiking neurons to layer;
- hierarchical clustering on the base of multilayered self-learning spiking neural network.

One of the efficient methods for clusters merging was proposed by Yo. Nakamori and M. Ryoke [Nakamori, 1996] the essence of which was minimizing sum of concentration hyperellipsoid volumes. In [Bodyanskiy, 2009c], Nakamori-Ryoke merging procedure was improved on the base of experimental design solutions and successfully applied to self-learning fuzzy spiking neural network. Thus, the proposed hybrid system overcame the problem of necessity to set correct number of clusters initially, before data processing. Researcher just needs to set a certain number of clusters that is exactly higher than actual number of clusters, and the merging procedure will automatically decrease number of spiking neurons to the proper one.

New clusters detection procedure for self-learning spiking neural network was proposed in [Dolotov, 2010] on the basis of fuzzy possibilistic clustering algorithm. The procedure analyses output of fuzzy clustering layer on each step of data processing, and if the sum of membership levels over all clusters is less than the preset threshold, a new neuron is added to spiking neurons layer. The proposed hybrid system can handle new clusters only in case if patterns of one new cluster only appear at a time.

Multilayered spiking neural network for hierarchical clustering (and for complex clusters detecting correspondingly) was originally proposed in [Bohte, 2002]. Feed-forward adjustable lateral connections in hidden layers of spiking neurons and learning algorithm for them were suggested in the architecture. The spiking neural network brought out remarkable results in detecting clusters of irregular form. Nonetheless improved architecture of multilayered self-learning spiking neural network was proposed later on [Bodyanskiy, 2009a]. Instead of two learning algorithms (one for interlayer connections, another for lateral connections), it was proposed to use the generalized learning algorithm (4). Updating not only neuron-winner, but also its neighbours made it possible to eliminate lateral connection from the network and thus to simplify its architecture.

A Generalized Architecture of Self-Learning Fuzzy Spiking Neural Network

A generalized architecture of self-learning fuzzy spiking neural network that incorporates approaches to design hybrid systems on the base of spiking neural network that are outlined above is depicted on Figure 1.

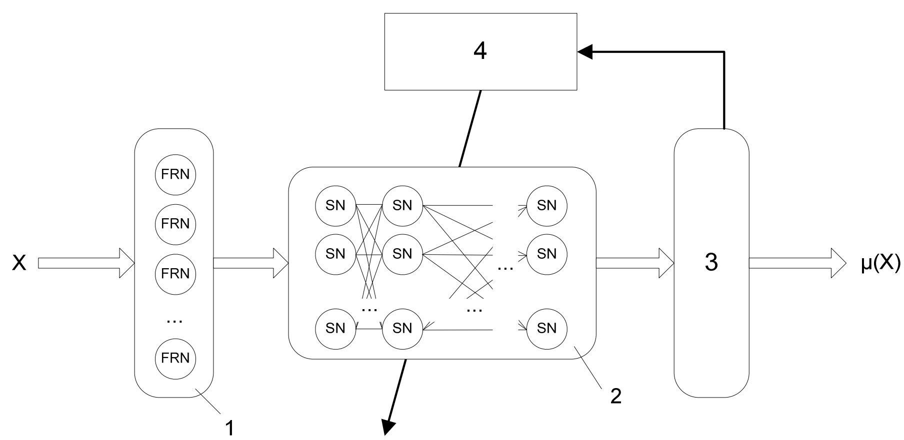

Figure 1. Architecture of a generalized self-learning fuzzy spiking neural network: 1 is the fuzzification layer; 2 is the hierarchical clustering subsystem; 3 is the output fuzzy clustering layer; 4 is the subsystem for adaptive number of clusters controlling; X is the input data set; FRN is a fuzzy receptive neuron; SN is a spiking neuron; $\mu(X)$ *is the fuzzy partition of X*

Its first layer (fuzzification layer) transforms input data into spikes having regard to a priori knowledge of the problem being solved. In the absence of such knowledge, fuzzy receptive neurons are set automatically, and the layer becomes properly a conventional population coding layer. Hierarchical clustering subsystem consists of several layers of spiking neurons. Number of layers depends on the data processing task complexity and again on a priori knowledge of the problem. The output fuzzy clustering layer performs fuzzy partitioning of input data either using probabilistic (1) or possibilistic (2), (3) approach in batch or adaptive mode. The subsystem for adaptive number of clusters controlling adjusts number of spiking neurons in the last layer of the hierarchical clustering subsystem. The hybrid system is learned with the generalized learning algorithm (4). If it is suggested to implement the system on hardware base, the Laplace transform description of the system functioning can be used.

On the one hand, the described hybrid system architecture is a generalized sketch allowing researchers and engineers to derive a certain specific hybrid system subject to the problem being considered. On the other hand, it can be used for solving complex real-life problems where several approaches are required to be applied.

It is necessary to stress that the proposed architecture is not absolutely complete. There are still some open questions. Interpretation of firing time of fuzzy receptive neurons output as membership level can be further developed. Suggestion criteria to select proper number of layers of spiking neurons and methods to control number of neurons in each of the layers would be a significant improvement. Other approaches for merging and new clusters detection can be considered for the system as well.

Conclusion

The known methods to construct self-learning hybrid systems on spiking neural network base are reviewed. The generalized architecture of self-learning fuzzy spiking neural network is proposed. Further directions of research are suggested.

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Major Fields of Scientific Research: Spiking neural networks and hybrid systems based on them

CONCEPTUAL MODEL OF DECISION SUPPORT SYSTEM IN A MANUFACTURING ENTERPRISE

Monika Piróg-Mazur, Galina Setlak

Abstract: *The article presents a concept of advisory system supporting decision-making processes in a manufacturing enterprise operating in the glass industry. The purpose of the system is to support operators and production line managers in recognising defects of finished products (bottles) and to propose methods of eliminating these defects. Basic purposes and assumptions regarding the development of this system as well as a description of its operation have been presented. The knowledge has been recorded in a knowledge base and is represented by rules and facts. The structure of the knowledge base and the reasoning process have been presented.*

Keywords*: decision support systems, knowledge base, knowledge representation, reasoning process.*

ACM Classification Keywords*: I. Computing Methodologies, I.2.1 Applications and Expert Systems, J. Computer Applications,*

Introduction

The use of proper tools which support decision making on all stages of a production system operation is indispensable for managing a modern enterprise [Setlak, 2002].

In the recent years a great number of enterprises have made large investments in developing modern tools of computer support of production. These tools were to compete with expensive and complicated systems available on the market. However, these works did not bring satisfactory results. The main drawback of majority of solutions was oversimplified modelling of objects and processes using these objects [Euwe, 1997]. Thus, what was necessary was a fundamental change of approach to the systems solving complex problems of modern production. Systems should not only process data and information but first of all they should be based on an expert's knowledge.

A decision-making process is an organised set of activities, realized on the basis of an algorithm, whose function is to precisely determine conditions and limitations of a decision-making situation and choose the optimal variant. Efficiency and effectiveness of decision making is a key factor of success of every undertaking. Intelligent decision-making systems in the form of expert systems play an important role in supporting decision-making processes [Buchalski, 2006, Zieliński, 2000].

The advantage of advisory systems based on expert systems is simplicity of their usage, which comes down to sessions of questions and answers between the computer programme and the user. Sessions can be repeated any number of times by changing input data, which allows to examine a lot of solutions (results) and gives the system features of a simulation program [Piróg-Mazur, 2010].

The structure and essence of an expert system operation

An expert system is a computer program using knowledge and reasoning procedures to solve problems that require human experience (of an expert), which has been acquired in the course of long-term activity in a given field.

In general, the idea of operation of expert systems consists in transferring specialized knowledge of an expert to a knowledge base, designing an inference engine on the basis of information possessed and adding user's interface, which is the tool of communication [Rutkowski, 2009].

The structure of an expert system can be very varied. Basically, it is dependent of a field of application. A schema of an expert system is shown in Fig. 1. It is assumed that every such a system should consist of at least three modules presented below [Mulawka, 1997]:

- knowledge base – a collection of knowledge within a given field arranged according to a selected method of its representation;

- reasoning mechanism – it searches the knowledge base and determines the order of analysing elements of knowledge which will be applied to formulate an answer given by the system;

- interface – it enables the user to communicate with the system in dialogue mode; the way of conducting this dialogue corresponds to the way of solving a problem by an expert.

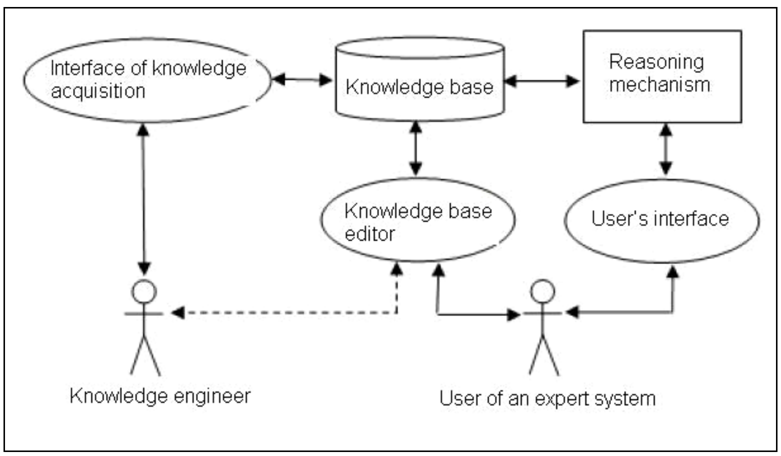

Figure 1. The structure of an expert system

Basic purposes and tasks of individual elements:

- **User's interface:**
  - accepting a task,
  - generating messages prompting the user to give additional information concerning the task,
  - modifying a task description formulated by the user according to the internal format,
  - generating explanations and answers addressed to the user, managing the dialogue with the user while solving a problem.
- **Reasoning mechanism:**
  - searching for a solution using the knowledge stored in the knowledge base,
  - sending messages on the state of a task,
- **Explaining module:**
  - accepting the user's questions (through the user's interface),
  - searching for answers to the user's questions,
  - preparing the answer.

- **Knowledge base:**
  - permanent knowledge (terms, permanent facts, definitions, interpretations, photos),
  - changeable knowledge, corresponding to the current task,
  - a set of reasoning rules [Białko, 2005, Stefanowicz, 2003].

The concept of developing a decision support system

Designing decision support systems for manufacturing enterprises is methodologically very complex (it concerns the issues of modelling and synthesis of technological knowledge, techniques of data processing and supporting decisions). This issue is quite difficult to sort out in academic conditions. Therefore, the elaboration on conceptual model of decision support system on the basis of technological documentation of a manufacturing enterprise operating in the glass industry has been prepared. It will be possible to test in practice and apply the results of the work in this enterprise, limiting the scope of research to supporting the process of quality control of finished products.

The purpose of development of a decision-making system is to create an interactive tool supporting the decision-making process while trying to eliminate defects of finished products (here bottles). Making a decision during emergency state in the manufacturing enterprise is connected with serious consequences because of a large number of finished products, high temperature and high pressure in the equipment used in this production process.

The assumptions underlying the system development include:

- the system should identify problems occurring during the manufacturing process (production) on the basis of causes of occurrence of these problems,
- the system should propose solutions within a particular scope - providing support in solving decision-making problems related to the process of quality control of finished products, i.e. classification of products (here: bottles) defects as well as analysis and a choice of a proper technique of their elimination, which will allow to improve the technological process,
- the system should provide expert opinions and advice in emergency situations in the scope of reasons for their occurrence,
- the system should be friendly for the end-user, who is not necessarily an expert in a given field; the interface will be based on questions and answers in a natural language,
- the system should provide access to texts, drawings, possibly simulations - data bases in the form of text and graphic files, which contain additional or more complete explanations.

The assumptions presented above and the fact that domain knowledge is often organised in the form of tables (engineering guides, data from measuring points, analyses) and partly algorithmised, for example, a choice of a method of defect elimination, allowed to create the concept of the expert system development and its actual implementation.

An advisory system should enable to create the classification of product defects and to choose a suitable (the most advantageous) method of their elimination. The system should support an operator and a production line manager in a comparable way as a highly-qualified specialist (expert) does.

In the result of dialogue, on the basis of data entered by the user and data from measuring points the advisory system will realize the process consisting of:

Step 1: Recognising a defect of a product (here: a bottle) and classifying it into a suitable group (e.g. Group 0 - critical defect - leaking bottle finish, bottle finish/collar overblown, cracks in a bottle finish/collar),

Step 2: Recognising and determining the reason for the defect occurrence (failure of the moulding process, the equipment, machine configuration),

Step 3: Determining ways of methods of eliminating the defect,

Step 4: A selection (of the optimal solution out of the ways or methods determined earlier).

On the basis of the process presented above the system will propose a method of eliminating product defects occurring on the production line. The user can accept, modify or reject the variant proposed by the system.

Advisory systems, having access to the recorded knowledge of a specialist in a selected field, can use it effectively many times. Simultaneously, it allows an adviser (an expert) to free themselves of repeating similar expert opinions and focus on more creative tasks. A special advantage of such systems is a possibility of solving certain tasks without direct participation of a specialist as well as a possibility of accumulating knowledge of a numerous group of specialists in one system [Cholewa, 2002].

The enterprise for whose needs the system is being developed specialises in glass packaging production. In total, 14 production lines are operated in the Glassworks. Production in the enterprise is realized in the three-shift system seven days a week. During one shift one production line is able to produce 200 000 items of finished product.

Acquisition and representation of knowledge

Acquisition of data and knowledge for decision support systems are realized using both traditional and formal methods [Pondel, 2003]. Data on materials, the means of production are acquired from standards, catalogues, literature, documentation of the enterprise and data bases which already exist in the enterprise. The traditional method of knowledge acquisition consists in observing a production engineer and having talks with him. A knowledge engineer plays a key role in this method. This is a person who observes an expert solving a problem, analyses his or her knowledge on the basis of given instructions and real tasks solved and accumulates the knowledge using analogy. Then, the knowledge engineer selects and arranges the knowledge communicated by specialists so that it can be stored and effectively applied using a computer [Zieliński, 2000].

Technological knowledge is a collection of information on a technological process performed in the precisely defined realities of a given enterprise. Technological knowledge is a dynamic collection, i.e. it changes in time as parameters of the technological process change. It is assumed that technological knowledge can be processed in a way typical of phases of an advisory system development. This process consists of the following phases:

- acquiring technological knowledge,
- preparing models of technological knowledge representation,
- storing the knowledge in the technological knowledge base of the system.

Participation of the expert in building the advisory system is necessary as using his or her experience concerning both the tasks solved in the past as well as the ways of solving particular tasks and the way of selecting suitable methods of solving them, is indispensable.

The knowledge engineer takes into account the following sources of knowledge:

- information necessary to carry out work (materials from non-serial and serial publications),
- information on all processes realized in the production system (materials collected in the Glassworks, consultations with Plant Manager of O-I Poland, consultations with employees specialising in different phases of technological process – an expert's knowledge),

- methods of quality assessment of finished products (ideal standard and permissible standard),
- allowable variants of development (purchase of new machines, modernization of current machines, new technologies, new materials, etc.),
- assessment criteria of the system development variants.

Development and application of expert systems are strictly connected with the process of knowledge processing. The purpose of this process is to acquire resources of knowledge and experience corresponding to the range of tasks within a particular field of application from identified sources of knowledge and to record them in the knowledge base in a way that enables to effectively support human activities while solving problems within this field [Knosala, 2007].

We distinguish two basic types of symbolic knowledge representation: procedural and declarative representation. Procedural representation consists in determining a set of procedures whose operations reflect the knowledge about a particular field whereas declarative representation consists in defining a set of facts, statements and rules specific for the field considered. The advantage of procedural representation is high effectiveness of representation of processes; however, declarative representation is easier to describe and formalize. Thus, these two methods are very often combined within one method of knowledge representation [Knosala, 2007].

Development environments for building advisory systems usually offer a collection of forms of knowledge representation: rules, semantic networks, frameworks, scenarios and others. Currently, availability of many forms of knowledge representation within one development environment for building advisory systems has become a standard.

Different ways of knowledge representation allow to present the reality of a particular problem in many ways. Some methods allow to describe the existing relationships more precisely, others allow to express an expert's knowledge easier and more concisely.

Out of the methods listed above knowledge representation in the form of rules (they link relationships between objects and their properties) is the most popular because of its effectiveness and intuitiveness. It uses the rules of the type:

```
IF the_list_of_conditions THEN the_conclusion
```

Conditions are usually connected with the logical operator "AND". Some systems also allow to use the operator "OR"; however, it decreases readability of the knowledge base and does not increase the system capabilities because it can be easily replaced by adding the second rule with another list of conditions [Michalik, 1998].

One of the most frequent forms of knowledge representation are rules. They consist of two elements: a premise and a conclusion.

```
IF <the premise> is true
THEN <the conclusion> is true
```

A very important feature of knowledge representation based on rules is the possibility of nesting rules, i.e. using a conclusion of one rule as a premise for the next one. The possibility of nesting rules allows to express knowledge more clearly and in a more readable manner.

IF the defect occurs in a continuous cycle

AND a number of defect occurrences in the second measuring point is similar

AND there is the cold kier in the area of moulding the finish

AND the cooling pipe touches the internal edge of finish

THEN the invert arms open too fast.

The sample rule presented above shows that in view of the expert first it should be checked if the defect occurs in a continuous cycle, than the results should be compared with the results obtained in the second measuring point and then the position of the kier and the cooling pipe should be checked.

All the collected and pre-formalized knowledge using the knowledge obtained from the plant expert, expressed in the form of a model, was recorded in the knowledge base. In order to create the base of rules within this scope the expert was asked to provide key information and domain knowledge. Domain knowledge are facts, theories, heuristics within a particular field of a system application, strictly adjusted to the realities of a particular enterprise.

The knowledge base of a decision-making system contains the base of facts and the base of rules. The base of facts contains names of defects, basic quantities and technical parameters prepared by production engineers. The base of rules contains information necessary for operation of the reasoning mechanism.

Facts, called premises, are expressed in the form of questions which can be answered by two to several answers. Below there are several examples of facts, possible answers to the questions are in brackets:

- Does the defect belong to the group of critical defects {yes, no}?
- Was a number of the defect occurrences checked? {yes, periodically, systematically, no}
- Was the mould number localized on the automatic machine? {yes, no}

The rules consist of one or several premises with answers to the asked questions and the final information about the order of actions to be carried out to eliminate a defect. The final information is also called a conclusion. Below there are some examples of rules included in the base.

- Defect: vertical cracks in the bottle finish

  Is the time of the kier contact sufficient? {yes, no}

  Is the pressing pressure correct? {yes, no}

  Is there the cold kier within the area of the finish moulding? {yes, no}

  Does the cooling pipe touch the internal edge of the finish? {yes, no}

- Defect: glass adhered

  Is the design of takeout tongs suitable? {yes, no}

  Is the design of the side guide of sweep-off gear suitable? {yes, no}

  Do the takeout tongs slide out entirely on time? {yes, no}

  Do the bottles contact each other on the pusher rail? {yes, no}

Reasoning process

In the advisory system being created progressive reasoning strategy (forward) will be applied. A block diagram of the algorithm is shown in Fig. 2 [Mulawka, 1996, Buchalski, 2008].

The algorithm of reasoning forward begins with placing a hypothesis on the task stack. Then, the system searches the list of facts in the knowledge base checking if there is an answer for the hypothesis formulated. If the fact which can be adjusted to the hypothesis is already in the knowledge base, the system ends the process of reasoning and generates a suitable message, which contains an order of actions to be carried out to eliminate the defect. In the case when after searching the base of facts the system is unable to give an answer to the hypothesis formulated, some steps are undertaken, which result in generating new facts. The rules whose premises are true are enabled. The system determines a set of rules which can be applied in a particular phase of reasoning. One of the rules is selected and activated. The process of reasoning is continued as long as the purpose is achieved or more rules cannot be activated [Buchalski, 2008, Mulawka, 1996].

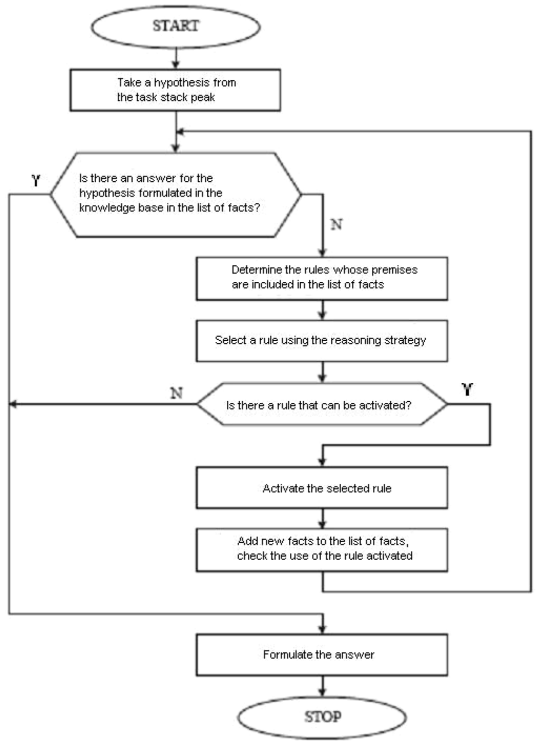

Figure 2. The algorithm of reasoning forward

The example of reasoning for a moulding process failure resulting in a critical defect - vertical cracks in the finish:

- Defect:

  vertical cracks in the finish
- Possible failure:

  kier mechanism
- Questions asked by the system:

  Is the time of the kier contact sufficient? (check in technical specification)

  Is the pressing pressure correct? (check in technical specification)

  Is there the cold kier within the area of the finish moulding? (check a position of the kier)

  Does the cooling pipe touch the internal finish edge? (check a position of the finish edge)
- The method of the defect elimination:

  Correct the kier mechanism - it is not set up correctly
- Additional information:

  Open vertical cracking which runs through the finish wall, from the sealing surface towards the neck. This defect can be detected by catching a reflection of strong source of light while turning a bottle. The defect should be removed immediately as the use of a bottle with the defect may cause a customer's injury.

The example of reasoning for failures occurring in the moulding part resulting in a critical defect – glass adhered:

- Defect:

  glass adhered

- Possible failure:

  takeout tongs

- Questions asked by the system:

  Is the design of takeout tongs suitable? (check in technical specification)

  Is the design of the side guide of sweep-off gear suitable? (check in technical specification)

  Do the takeout tongs slide out entirely on time? (check visually)

  Do the bottles contact each other on the pusher rail? (check visually)

- The method of the defect elimination:

  Replace inserts in takeout tongs - they are broken

- Additional information:

This is a piece of glass, usually a very sharp one, adhered to the external wall of a product. This is one of the most critical defects. All measures must be undertaken to avoid this defect. If because of any reasons we deal with such a defect, we cannot let such products reach the annealing furnace. We should also inform the Cold End section about a number of the mould which can cause problems so that they can prepare and reject faulty products. The defect should be removed immediately as the use of a bottle with the defect may cause a customer's injury.

The steps of reasoning presented above are a form of generalization of the procedure.

Conclusion

Computer systems are computer programs designed to solve specialized problems that require professional expertise. Application of expert systems allows to improve the quality of products, achieve substantial savings and increase productivity [Mulawka, 1996].

Using the Decision Support System by the Glassworks in the production process will enable to solve complex problems occurring within the production system faster and more effectively and to make necessary decisions in a much shorter time than now, which may be of a great importance for the innovation and improvement of their competitiveness.

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Intelligent Agents and Multi-Agent Systems

TOWARD THE REFERENCE MODEL FOR AGENT-BASED SIMULATION OF EXTENDED ENTERPRISES

Jakieła Jacek, Litwin Paweł, Olech Marcin

Abstract: *The main aim of the research which partial results are presented in this paper is to develop full-blown reference model for creating simulation experiments supporting management of Extended Enterprises. Such framework can be used by modeler who would like to ask questions related to modeled business architecture in the context of managing part of the enterprise (e.g. supply chain) or the whole structure of Extended Enterprise. These questions may be answered with the use of computational analysis conducted with simulation model prepared according to proposed framework and simulation experiment process. The analysis may consider existing organization or the structure that is virtually designed and will be implemented after all characteristics are tuned. In order to facilitate the modeling process and reduce semantic gap between business architecture and model developed, agent orientation has been adopted as a modeling paradigm. Finally, the case study showing how the reference model may be used for analyzing the bullwhip effect in supply chain has been elaborated, and simulation experiment's results visualized and interpreted.*

Keywords: *Agent Based Modeling and Simulation, Extended Enterprise Modeling, Supply Chain Management, Agent-Oriented Computing.*

ACM Classification Keywords: *I. Computing Methodologies; I.2 ARTIFICIAL INTELLIGENCE; I.2.11 Distributed Artificial Intelligence; Multi-Agent Systems*

Introduction

Interaction and coordination costs have always been affecting the process of shaping business organizations structures and relationships they form with their partners. Development of Digital Economy and e-Business solutions has increased interaction abilities as well as reduced costs of coordination. All these phenomena have led to transformation of contemporary enterprises behavioral and structural characteristics and development of completely new and very complex business architectures. Now it is easier and cheaper to cooperate with business partners in industrial value chain than with departments inside organization [ITGI, 2005]. Therefore outsourcing became the commonplace and Extended Enterprises structures started to emerge. Managing of such enterprises as well as process of developing them requires really good understanding of the ways they operate and how the changes in their characteristics will affect the behavior of the structure as a whole. It is usually possible only with the use of organization's model and proper analysis method. In case of such dynamic structures analysis, simulation is often best suited approach. Due to the complexity of many Extended Enterprises, simulation is one of the few tools that can capture the dynamic nature of contemporary business structures in a realistic manner. The simulation process enables to conduct experiments with the model to understand the behavior of the system and evaluate strategies for its operation.

Simulation may be conducted according to several approaches which take into consideration different dimensions of simulation model e.g. evolution of the system over time – static vs. dynamic models, randomness element –

deterministic vs. stochastic models, how the state of the simulation changes – discrete vs. continuous models, how the system state is partitioned – system dynamics vs. multi-agent simulation [Paolucci et al., 2005]. Recently agent oriented approach to simulation – Multi-Agent Based Simulation (MABS) – is gaining wider and wider acceptance and its models and their advantages have been extensively described in many publications e.g. [North et al., 2007], [Weyns et al., 2009], [Yilmaz et al., 2009]. Contributions to the MABS domain are periodically published among others in Springer's LNAI series on Multi-Agent Simulation [Jakieła, Litwin, Olech, 2010], [Nuno et al., 2009]. Using agents in simulation models is based on the idea that it is possible to represent the behavior of active entities in the world in terms of the interactions of an assembly of agents with their own operational autonomy. The possibility to model complex situations whose overall structures emerge from interactions between individual entities and to cause structures on the macro level to emerge from models at the micro level is making agent paradigm a critical enabler in the modeling and simulation of complex adaptive systems [Yilmaz et al., 2009]. As will be shown later in the paper the Extended Enterprise is the problem space where agent oriented simulation is the best suited approach.

The process of simulation model development, when done from scratch, is usually related to quite big effort. It would be great if modeler will have the generic, ready to use structure and process that could be followed whenever new simulation model and experiment are elaborated. This is the place where reference model idea comes into play. The reference model may be treated as a comprehensive framework that facilitates the process of creating simulation model and experiment. The paper presents such a model for Agent-Oriented Simulation of Extended Enterprises. The presentation starts with the analysis of business architectures of contemporary enterprises and changes that are taking place with regard to their structures and behavior. Then the idea of reference model is explained as well as motivations why agent orientation is used. Finally the detailed description of proposed reference model follows.

Business Architectures of Contemporary Enterprises

Before the nuts and bolts of reference model will be presented, the organizational principles it is based on will be carefully analyzed and described. As there will be shown, the structure of reference model as well as modeling constructs are driven by several changes in contemporary organizations business architectures. Therefore the first issue the paper tackles is the concept of business architecture.

What is Business Architecture?

Enterprise architectures are commonly viewed as being mainly for ICT infrastructure; however today's organizations realized that the architecture in such a meaning hinders business rather than supports it. The main issue is to have the architecture that will eliminate semantic gap between business requirements and software support. The new approach focuses on unifying concept – the business architecture – that removes boundaries between business processes and ICT infrastructure [McCormack et al., 2003]. Business architecture dictates the shape of ICT support and is related to the knowledge that defines the business, the information necessary to operate business processes and ICT architecture needed to support organizational operations. It is rather difficult to clearly define the term business architecture, however we can use the following operational definition developed by Eriksson and Penker [Eriksson et al., 2000]:

Business architecture is an organized set of elements with clear relationships to one another, which together form a whole defined by its functionality. The building blocks of business architecture represent the structural and behavioral components of an enterprise system and show abstractions of the key processes and structures in the business. Good business architecture has the following characteristics:

- *captures the real business as truthfully and correctly as possible,*

- *focuses on key processes and structures of an organization at an appropriate level of abstraction,*
- *adapts easily to changes and extensions.*

Creating good business architecture requires taking into consideration the characteristics of contemporary enterprises. The next sections show the main shifts that have taken place recently with regard to enterprises structure and behavior. These trends have been called accordingly: From Hierarchy to Process Orientation and From Single Organization to Extended Enterprise.

From Hierarchy to Process Orientation

Functional orientation (see Fig. 1) means the focus on departments and tasks within departments. This functional mentality may be traced back to work of Adam Smith who first described the concept of breaking industrial work into simplest tasks [Smith, 1776].

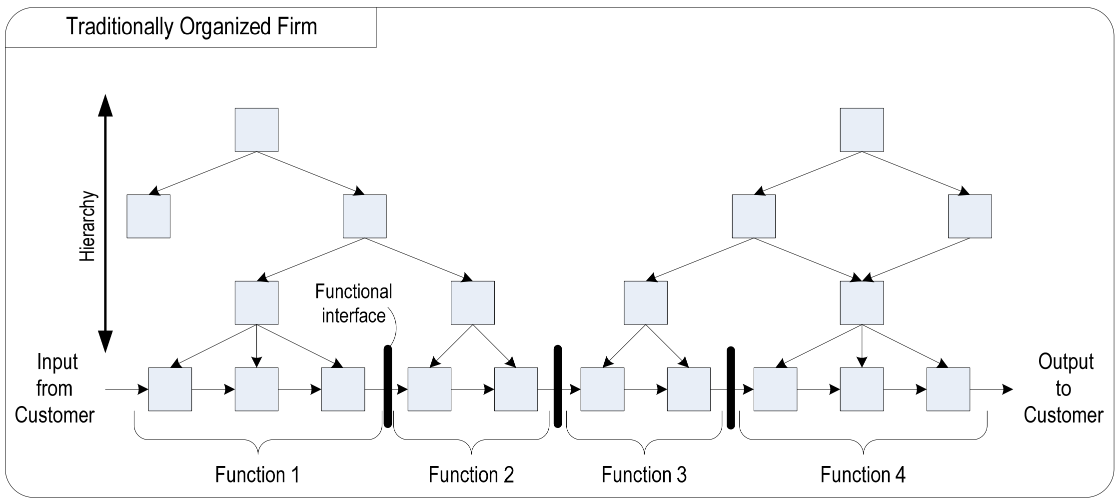

Figure 1. Traditionally organized firm [McCormack et al., 2003]

Organizations were following this model of business for almost 200 years. The main problem with functionally oriented firms is related to the lack of internal coordination of functions working together to satisfy customers.

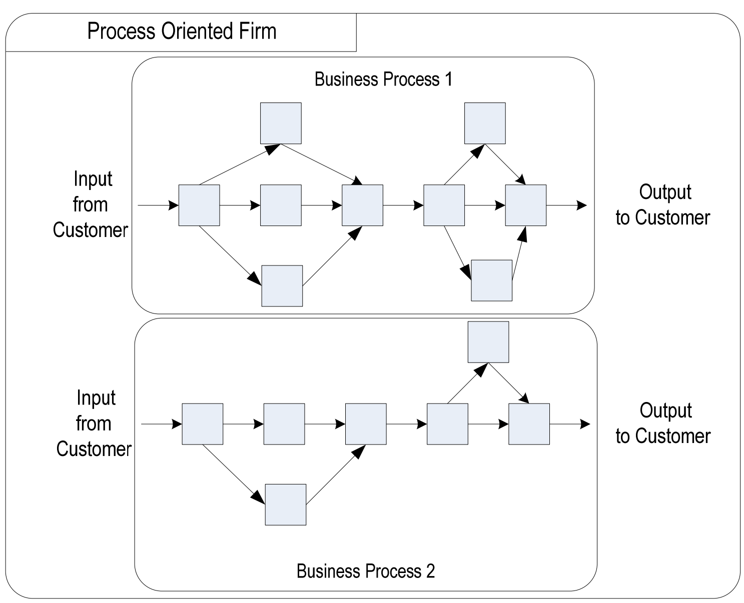

Figure 2. Structure of Process Oriented Firm

All the activities leading to performance improvement are linked to functional interfaces – the points where the control is passed from one function to another. These interfaces, if not properly designed, may be the source of poor quality, high costs and dissatisfied customers.

In order to improve functional interactions the business view should be reengineered. Organizational activities may be grouped in a manner describing them as a continuous process connected on one end with suppliers and on the other with customers (see Fig. 2).

The reengineering movement has been initiated by Michael Hammer in 1990 [Hammer, 1990]. According to his seminal work, the old, hierarchical organizational model is no longer relevant and something entirely different is needed. He developed the idea of process thinking, which is based on the process concept. Business process is defined as collection of activities that takes one or more kinds of input and creates an output that is of value to the customer. The process thinking is cross-functional, outcome-oriented and essential to customer orientation.

Bearing in mind all the issues mentioned above it could be assumed that contemporary business architectures, in order to be efficient and effective, should be composed of strategic, customer focused processes that start with customers and emphasize the outcome. As Thomas Davenport suggested organizations must be viewed according to key business processes, not in terms of functions, divisions and products [Davenport, 1995].

Process orientation also affects the role of organizational actors and organizational structure of the process oriented firms. Process oriented firms are composed of autonomous, goal oriented organizational actors, who cooperate in business process teams to achieve the process goals. Organizational structures of process oriented firms usually take a form of adhocracy and are operating more on social principles than on mechanistic rules.

From Single Organization to Extended Enterprise

Contemporary enterprises have flexible, dynamic and more extensive boundaries than ever. Because of inherent complexity of today business, organizations must focus on whole processes, reaching out to business partners, suppliers and customers. Modern business architectures must be agile, otherwise they will not be able to cope with constant market changes. These changes are inextricably linked to the development of New Economy, which has three main characteristics: it's global, favors intangible assets (information, relationships, ideas) and is intensely interlinked. New Economy increases global competition what turns organizations to virtual integration enabling them focus on processes they can perform the best and someone outside the entity performs the rest. This phenomenon of extending an organization outside its traditional boundaries is commonly called Extended Enterprise. Extended Enterprise is a form of networked organization that is driven by standard enabling the network of participants to interact with significant interaction cost savings and high level of inter-firm connectedness. Extended Enterprise focuses on common goals and earns significantly greater value than its peers [IT GI, 2005].

To understand the evolution of such business architectures it may be useful to look at changes in interaction and coordination costs, which are playing a crucial role in shaping contemporary organizations, affecting the ways companies organize themselves and the relationships they build.

The standard business forms were based on the assumption that it was easier and less costly to interact with the departments of the firm than between outside entities.

ICT development pace has dramatically reduced interaction costs and increased interaction capabilities. It leaded to situation where it is easier and less costly to interact with business partners in industrial value chain than with business units inside the firm. Outsourcing became the commonplace and building and managing network of companies is a new competitive battleground. Because of all these changes Extended Enterprises are inherently decentralized and distributed [McCormack et al., 2003].

The Idea of Reference Model

Creating simulation model as well as planning an experiment from scratch is demanding and time consuming task; however it may be facilitated by providing modeler with the framework consisting of the generic structure of the simulation model, formalized behavior of its basic building blocks and the step by step process showing how to plan and conduct simulation experiment. The following sections present the reference model for agent-oriented simulation of Extended Enterprises.

What is Reference Model?

Unfortunately various papers and books describe very different things under reference model title. Reference model is often used to designate theoretical statements, technical architectures, or documentations of enterprise systems. The table 1 presents several definitions of the reference model concept.

Table 1. Definitions of Reference Model [Fettke et al., 2006]

Author	Definition
Bernus (1999)	Reference models capture characteristics common to many enterprises within or across one or more industrial sectors.
	Reference components provide normalized descriptions of key concepts of a given domain. They can be used a starting point for developing new applications similar to applications developed before in the domain thus extending reuse to the early development.
Fettke & Loos (2003)	Reference model represents a class of domains.
Frank (1999)	A generic reference model represents a class of domains.
Mertins, Bernus (1998)	An information system reference model is…a typical, or paradigmatic model, which describes the Information System or well identified part of it.
Mišic & Zhao (2000)	A reference model is a conceptual framework for describing system architecture, thus providing high-level specification for a class of systems.
Rosemann (2003)	Reference models are generic, conceptual models that formalize recommended practices for certain domain.
Schütte (1998)	A reference information model is a result of construction created by modeler who declares for IT and business people universal elements and relationships of a system as a recommendation with the help of a language in one point of time so that a point of reference is created.
vom Brocke (2003)	A reference model is an information model that people develop or use for supporting the construction of application models, though the relationship between the reference and application model can be characterized by the fact that object or content of the reference model is reused by the construction of the object or content of the application model.

Besides the problems with determining one generally accepted definition of reference model there are also other important aspects worth to mention. First issue is that different dimensions of business are addressed in the process of building reference models. The first dimension of the reference model is related to data models. Data models are considered reference models because they contain type entity classes describing organizational configurations. In general it is harder to find universal processes that are common to all businesses, and therefore process models are much rarer than data models.

Next issue is that the reference model, doesn't matter data or process, may be developed at different levels of abstraction. It usually depends on the scope that is covered by the model. If the whole industrial enterprise is modeled then only the high level of function or data breakdown is presented. More detailed description is possible if the modeler focuses on small problem domain e.g. reference model for inbound logistics.

Another aspect is related to descriptive or prescriptive character of the reference model, or to put it differently, is it the enterprise description enabling to better understand how it operates or it is the specification that can be used for system development or business process reengineering.

Finally from practical perspective, reference modeling can be used in different applications scenarios [Fettke et al., 2006]:

- Deriving a particular enterprise model – reference model can be adapted to the needs of particular enterprise.
- Validating enterprise specific models – reference model can be used as a benchmark for analyzing enterprise specific models and determine the gaps between them.
- Developing applications and simulations – reference model can be used as a framework for developing applications or computational representations of the enterprises created for simulation purposes. This is the scenario used in this paper.
- Selecting off-the-shelf package – reference model can be used as a tool for assessing different functionalities of off-the-shelf packages from the perspective of specific enterprise application.

For the purposes of this paper the following definition has been elaborated by merging several definitions from table 1.

Reference model captures characteristics common to many enterprises within or across one or more industrial sectors. It is also a conceptual framework for describing system (enterprise) architecture, thus providing high-level specification for a class of systems. Components of the reference model provide normalized descriptions of key concepts of a given domain. They can be used a starting point for developing new applications similar to applications developed before in the domain thus extending reuse to the early development. The reference model is supposed to answer the following questions:

1. *What are the main assumptions related to modeling scope?*
2. *What is a goal of developing the reference model?*
3. *How the conceptualization process is conducted and what are the basic modeling constructs the reference model has been based on?*
4. *How the structural and behavioral aspects are modeled?*

The above mentioned questions will be answered in the section of the paper describing the structure of developed reference model.

Because reference model presented regards agent based simulation, the next issues addressed are related to simulation as a method and agent approach to modeling and simulation.

Simulation as an Only Workbench for Extended Enterprises

Extended enterprises are very complex systems. This kind of business structures includes several components related to supplying, manufacturing, distribution, wholesaling and retailing. There are well documented reasons why simulation is only workbench for analysis and understanding behavior of Extended Enterprises. North and Macal [North et al., 2007] propose the following motivations:

- No one is able to understand how all parts of the system interact and add up to the whole.
- No one is able to imagine all the possibilities that the real system could exhibit.
- No one is able to foresee the full effects of events with limited mental models.
- No one is able to foresee novel events outside of their mental models.
- Decision makers want to get insights into key variables and their causes and effects.
- Decision makers want to make predictions of how system will behave. Thank to simulation they can get educated guesses and be provided with the range of possible futures.

Simulation can be used to address all these motivations. As will be shown in the next section, agent-based simulation provides new ways and insights not achievable with traditional simulation approaches.

Simulation Approaches

If we consider simulation of Extended Enterprises which can be treated as non-linear socio-economic complex systems, there are predominately two schools focusing on modeling, understanding and prediction of such systems behavior [Shieritz et al., 2003]. These methods are System Dynamics and Multiagent-based Simulation.

System Dynamics is a modeling method used mainly for the analysis of poorly structured problems, with a large number of interdependencies among the components of problem domain. This method has been derived from the cybernetic approach to systems analysis and allows one to describe systems in the form of interactive and combinational links. The method originally developed by Forrester is based on management theory, cybernetics and computer simulation [Forrester, 1961].

In System Dynamics approach, the real world processes are modeled as stocks, flows between stocks, and information indicating the size of flows [Forrester, 1968]. The main assumption is that internal cause and effect relationships determine the dynamic properties of the system. Most important impact on the functioning of the system has a structure within which decisions are made, rather than individual decisions and external turmoil [Shieritz et al., 2003]. Abstracting from single events and concentrating on policies instead, System Dynamics takes an aggregate view [Forrester, 1961]. Mathematically System Dynamics is a system of integral equations. The solution of such multi-equational system, describing nonlinear dependencies and use it to predict consequences of decisions under consideration, is usually possible only with an appropriate numerical method. System Dynamics gives reasonable tools to build models that provide information about the behavior of the system as a whole, enabling to improve the system development strategy.

Another widely used approach to analyze and understand business systems is Multiagent-based Simulation (MABS). Multiagent-based Simulation can be defined as the modeling and simulating of real world system or phenomena. In this approach the model consists of agents cooperating with one another in carrying out tasks and achieving goals. According to Davidsson [Davidsson, 2000] "[…] multiagent-based simulation should not be seen as a completely new and original simulation paradigm [...] it is influenced by and partially built upon some existing paradigms, such as parallel and distributed discrete event simulation, object-oriented simulation, as well as dynamic micro simulation […]". In fact, if the agents are considered as an extension of objects, MABS model can be seen as a consequence of defining the object-oriented system as a collection of autonomous entities, i.e. agents. The advent of Multiagent-based modeling has introduced an important innovation: behavior of complex systems with many active entities can be simulated by modeling individual entities and their interactions. Importantly, the operation of the system need not be defined a priori as set of equations, terms or logical statements, but the whole behavior emerges from individual objects behaviors, their interactions and impact of the environment. In MABS individual behaviors of agents adapt to environment and organize themselves.

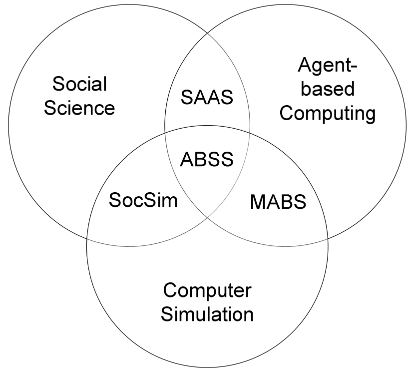

Figure 3. Map of the agent oriented research areas [Davidsson, 2002]

According to AgentLink Roadmap [Luck, 2003] “[…] Agent-based Simulation is characterized by the intersection of three scientific fields, namely, agent-based computing, the social sciences and computer simulation" (See Fig. 3).

Table 2. Characteristics of System Dynamics and Multiagent-based Simulation (MABS)

Feature	System Dynamics	Multiagent-Based Simulation
Model components	Stocks, flows between stocks with data indicating the size of flows.	Agents and their environment. With every agent the set of behaviors is connected. These behaviors enable agents to collectively achieve their goals.
Behavior	The behavior of a model is the result of structure. The structure is fixed and must be defined in advance. System Dynamics models are not capable of adaptation (structure modification with a goal to better perform in given environment [Holland, 1975])	System behavior is the result of interaction among agents. System components that are modeled as agents can communicate with one another, receive stimuli from the environment and exhibit a proactive behavior, which determines the way the system operates. Multiagent-based models can adapt by self-organization or with the use of genetic or evolutionary algorithms.
Modeling approach	Top-down approach is used. Aggregation is imposed by the modeler. The model represents the characteristics of the system as a whole. System Dynamics represents a group of macro modeling approaches.	Bottom-up approach is used. Multiagent-based modeling allows performing in-depth study of the macro level, which results from the actions undertaken by agents at the micro level.
Mathematical notation	System Dynamics Model is a system of coupled, non-linear first-order integral equations [Saleh, 2000]	There is no universally accepted mathematical formalism as a framework for Multiagent-based Simulation. Most researchers tend to logic-based formalisms [Inverno et al., 1997]

Agent-based computing is scientific area corresponding to computer science, in particular to modeling, designing and programming multiagent-based systems. Social science is the scientific field dealing with social entities interactions. It includes organization and management theory, social psychology and some areas of biology. Computer simulation is an area connecting the techniques of simulation with computer systems. According to Davidsson [Davidsson, 2002] the intersection of the areas mentioned above demarcates fields occupied by Agent-based Social Simulation (ABSS), Multiagent-based Simulation (MABS), Social Simulation (SocSim) and Social Aspects of Agent Systems (SAAS). Location of MABS at the intersection of agent-based computing and computer simulation can be accepted if we consider the application of MABS in simulation of manufacturing systems and processes. Due to the fact that vast majority of cases requires the inclusion of human factor in simulation of real world system or phenomena (e.g. manufacturing systems, Extended Enterprises, supply chains), it is assumed that social science also affects the MABS. Typical applications of MABS include simulations of business and social processes , as well as biological systems.

Selected differences between System Dynamics and Multiagent-based Simulation are presented in the table 2.

Approaches presented above represent important differences in the way the modeling process is conducted and possible applications are introduced. A major advantage of Multiagent-based Simulation is the ability to model emergency phenomena: behavior of a system as a whole is a result of the actions and interactions of autonomous, heterogeneous agents, while System Dynamics Model constitutes an indivisible whole. In the case of Extended Enterprise simulation, Multiagent-based approach makes it possible to better understand the business processes and their impact on the functioning of the enterprise as a whole. Very important feature of the simulation environment used for modeling today's enterprises is the ability to adapt to changing conditions without having to rebuild the model. Classical enterprise modeling tools, such as System Dynamics, do not take into account all the dimensions of modern organizations analysis (distributed nature of companies composing the Extended Enterprise, decisional autonomy, interaction dynamics). The advantages of Multi-agent Systems are a strong prerequisite for using this platform for developing and running the Extended Enterprise simulations.

Why Agent-Based Simulation?

This paper assumes that an agent paradigm is best suited for modeling and simulation of Extended Enterprises. This assumption was based on in-depth analysis of contemporary business architectures and insights provided by North and Macal [North et al., 2007], who answered the question: *When an Agent-Based Models are appropriate*? According to their hints using of agents should be considered in the following circumstances:

- Problem has a natural representation as consisting of interacting agents.
- Decisions and behaviors can be defined discretely, that is, with well defined boundaries.
- It is important that agents change their behavior and adapt.
- It is important that agents engage in dynamic strategic behavior.
- It is important that agents have dynamic relationships with other agents, and agent relationships form and dissolve.
- It is important that agents form organizations, and adaptation as well as learning are important at organizational level.
- The past may be a poor predictor of the future.
- Scaling up is important, and scaling up consists of adding more agents and agent interactions.
- Process structural change needs to be a result of the model, rather than an input to the model.

Besides motivations presented above, the following equally important have been added:

- Semantic proximity between contemporary structures and behavior of Extended Enterprises and multi-agent systems, what enables to reduce semantic gap between modeling constructs and organizational components. Multi-agent system is therefore very intuitive modeling metaphor that can be easily used in the process of building simulation model of Extended Enterprise.
- Better complexity management when agent paradigm techniques are used.

All these issues have been extensively discussed in [Jakieła, 2006], [Jakieła, Pomianek, 2009].

The Structure of the Reference Model for Agent-Based Simulation of Extended Enterprises

Main Assumptions and General Structure of Reference Model

Bearing in mind the results of analysis conducted the following assumptions have been formulated:

1. The model describes process–oriented organizations. It means that organizational activities are grouped in a business processes connected on one end with suppliers and on the other with customers.
2. Every process has a goal which is of value to customer.
3. Processes are conducted by autonomous organizational actors who interact in order to achieve the goal of the business process. Every actor has its own goals which are sub-goals of the business processes. In order to achieve the process goal, actors goals have to be achieved.
4. Organizations may form partnerships and integrate processes what leads to a structure of Extended Enterprise.
5. Reference model describes structural and behavioral aspects of Extended Enterprise.
6. The core of the reference model is a generic supply chain structure.
7. The model has hierarchical structure which is composed of three following levels:
   a. The highest level is the most general one and shows the basic components of supply chain as well as flows. These components, as will be shown later, have been mapped into multi-agent system architecture. Agents that constitute the system communicate according to flows patterns.
   b. The lower level covers the business logic of supply chain. This logic has been transformed into behavioral rules of the identified agents.
   c. The lowest and most detailed level describes the operations carried out by a producer.
8. The model does not take into consideration the following issues:
   a. Time elapsed between the moment when demand occurred and supplier takes note of it.
   b. Minimal quantity of an order – order is always fulfilled, doesn’t matter how many items it contains.
   c. Minimal quantity of production order – production runs without any constraints related to economic quantity of items produced.
   d. Some operations and internal activities conducted by supply chain components such as: production planning, determining production capacity and demand forecasting.
9. The reference model is descriptive and prescriptive at the same time. It is descriptive because the analysis of its basic building blocks enables to better understand the business logic of Extended Enterprises. It may also be used as a specification for developing the agent-based simulation and therefore is prescriptive.

Problem Domain Conceptualization and Basic Modeling Constructs

According to Nilsson and Genesereth formalization of knowledge regarding specific problem domain begins with a conceptualization [Genesereth et al., 1987]. It includes the objects presumed or hypothesized to exist in the world and their interrelationships. The notion of object used here is quite broad and assumes that the objects can be concrete (merchandise sold) or abstract (order). Objects can be primitive (number of products in stock) or composite (agents). In general, an object can be anything about which it is important to say something. The set of objects about which knowledge is being expressed is called universe of discourse. Conceptualization defines also interrelationship between objects in the form of functions and relationships. Although many interrelationships may be defined usually only some are emphasized and others ignored.

The core of every Extended Enterprise is its supply chain. Therefore the reference model conceptualization has been based on the generic components of supply chain and their interrelationships (see Fig. 4).

Supply chain has several stages as is shown on the figure 4. It involves almost every aspect of production and provision of goods and services. Basic components are related to the stages and named accordingly supplier, manufacturer, retailer and consumer.

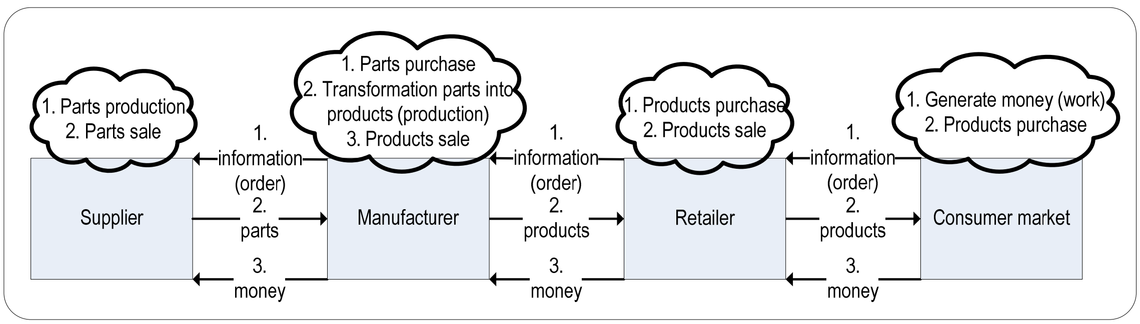

Figure 4. The Model of Supply Chain

There are also flows between basic stages. Two directions may be identified: downstream and upstream. Products flow downstream in response to orders that flow upstream as in case of payments. Real supply chains are dynamic business structures that form complex network between companies. The main problem is that such a network of interrelationships is the state of constant flux. That is the main reason why this reference model is simulation oriented.

After the conceptualization is defined, the next step is to select properly sensitive modeling constructs used in the process of developing the model. As it was mentioned before, different aspects of business can be taken into consideration in reference model. To some extent it determines modeling constructs used. For example if data aspect is considered modeler uses mainly entity type concept. When organizational processes are taken into consideration than functions are basic modeling constructs. Some more up-to-date reference models are using object concept as a basic modeling construct.

This paper proposes the approach that uses agents as a modeling metaphor. Next sections show the process of agents identification as well as agents' behavior definition.

Discovering Agents

The main features that make the system element candidate to be modeled as agent are the capability of the component to make independent decisions, the goal to focus the decision and the ability of other components to tag or individually identify the component [North et al., 2007].

When discovering the agents for the problem domain is worth to remember that each agent in agent based simulation has unique properties. Thank to this we can model the system as a set of interacting heterogeneous components. The uniqueness of each agent may be related to its behaviors, position it holds or resources it uses. Therefore building the model for agent-based simulation requires properly identifying the agents, defining the behaviors and taking into consideration the interaction patterns.

Discovery of agents has been based on the roles identification technique [Jakieła, 2006]. According to this approach it is assumed that every business organization is composed of the set of organizational positions. Every position is related to the set of business roles, that have goals organizational actors are responsible to achieve. In order to achieve specific goal, an actor has to have proper capabilities that may be based on the behavioral rules which are the topic of next section.

Based on the conceptualization presented in the previous section four agents have been discovered:

- Supplier Agent,
- Manufacturing Agent,
- Retailer Agent ,
- Market Agent.

Every agent has behavioral rules that drive its behavior during the simulation process.

Discovering Agents Behaviors

After all agents have been identified, the next challenge is to discover key abstractions for agents' behaviors.

Usually this stage is supported with knowledge engineering techniques for eliciting and organizing the knowledge of experts which is related to problem domain under consideration. These techniques are mainly based on structured interviews including focused questions domain experts are provided with. The results may contain some errors and biases but are often useful nonetheless. The behavioral rules presented in this paper are not derived as a part of knowledge engineering effort but have been drawn from the conceptual model developed by Vieira [Vieira et al., 2005].

It is important to remember that the knowledge engineering process should extend into fully specified model. This is possible thank to properly selected modeling methods. For this purpose, the UML activity diagram notation for specifying agents' behaviors has been selected. UML language is gaining widespread acceptance as a software modeling and design language and commonly used standard. It defines 12 types of diagrams (version 2.0) that can be used for visualizing different aspects of the system under consideration. As has been shown many times, combination of these diagrams may be used to fully document designs of agent based models as well as underlying knowledge [Padgham et al., 2004].

The diagrams presented on the figures show the business logic formalized in agents' behavioral rules and visualized with activity diagram notation.

Supplier's behavioral rules

Supplier Agent operates according to the doubling the order's quantity policy. This policy assumes that the demand in the next period will be equal of the demand in the current period.

If *q* denotes the number of items ordered, the quantity of delivery should equal *2q*. It is required to cover current producer's request and to have the final stock level enabling to cover future demand.

Figure 5. shows how the Supplier Agent operates. Firstly, it compares the doubled quantity of order received with the current stock level. Then, if it is greater than doubled quantity of order, the requested components are immediately sent to producer. Remaining number of items is greater than the number of items sent, and therefore supplier is prepared for the next order.

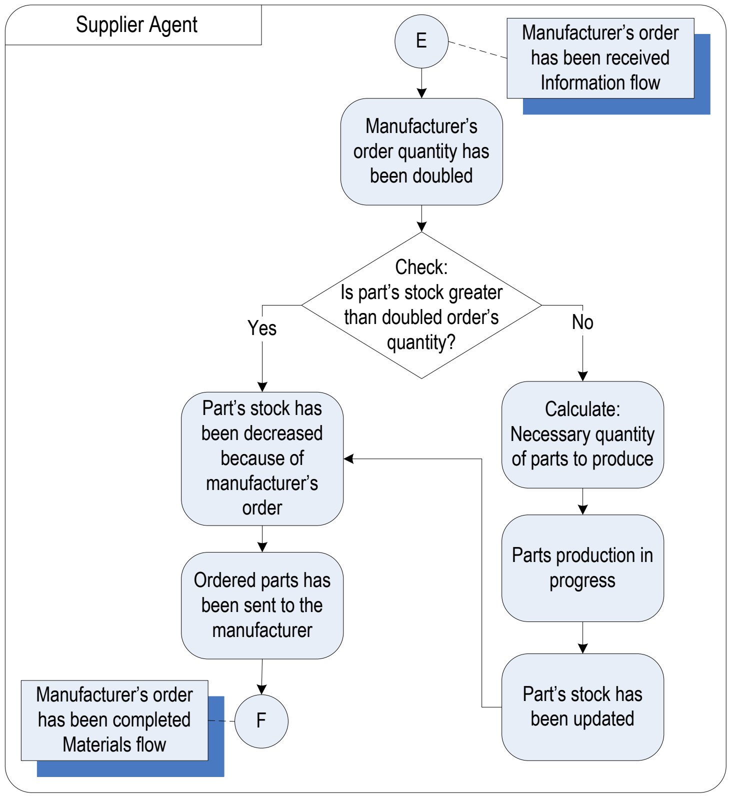

Figure 5. Behavioral rules for Supplier Agent

If the stock level is less than the doubled number of items ordered, supplier starts production of components (or orders items) right after current order is fulfilled.

Otherwise Supplier Agent has to start production process of components. Only after the required number of items is produced the producer's order may be fulfilled.

Producer's Behavioral Rules

An order received from Retailer Agent is an event that triggers proper behavioral rules of producer (See Fig. 6.).

In the first step Producer Agent doubles the number of items ordered to be prepared for the future demand. It guarantees that stock level will cover orders from the next period. As in case of Supplier Agent, Producer Agent compares the number of items in stock, and if it is greater than doubled number of items in current order the delivery is carried out, the stock level is decreased, and the whole process is finished. If the stock level is less than the doubled number of ordered items but enough to fulfill the order the items are sent to Retailer Agent. After that the Producer Agent calculates how many products are required to replenish the stock and fulfils the current order. Then production process starts and if there is lack of components (materials) needed, the order is sent to Supplier Agent.

Production process proceeds when all needed materials are received. It means that required number of components is taken from the stock and allocated to production. Final products are than used to replenish the products' stock level. The logic of production is depicted on figure 7.

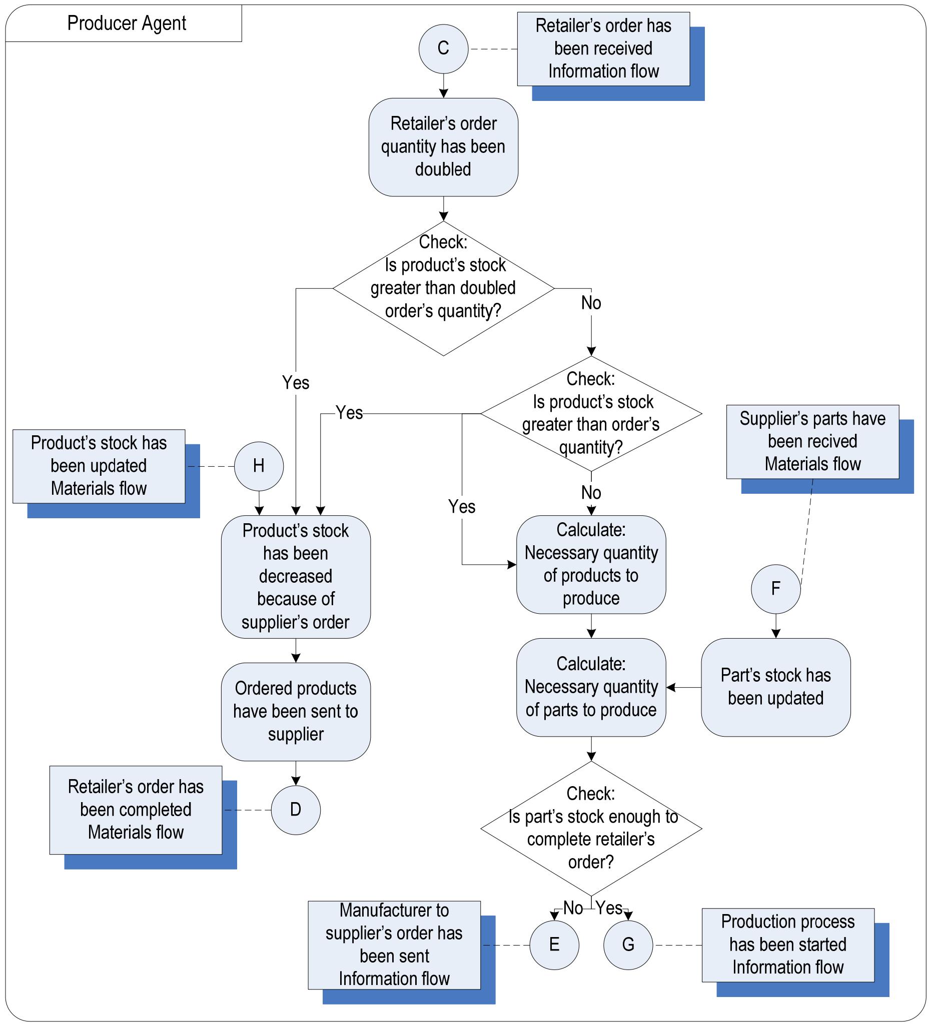

Figure 6. Producer Agent's Behavioral Rules

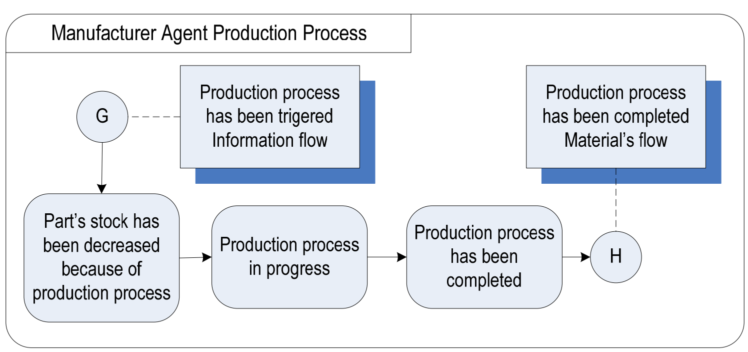

Figure 7. Procedure of Production Process

Retailer's Behavioral Rules

Structure and behavior of the Retailer Agent (see Fig. 8) is quite similar to the Producer Agent except for the business logic related to production and ordering processes. The starting point of Retailer Agent is the moment when an order is received, but in this case its source is the market. After the order is received and the number of order items is doubled, the retailer compares calculated value with its stock level. If the stock level is greater than the doubled number of order items, Market Agent is provided with products and process ends. In case the stock level is less than calculated value, but is enough to fulfill the order, the products are delivered and an order is placed to replenish the stock to the planned level. If the Retailer Agent does not have requested number of products it sends an order to Producer Agent and waits for delivery. When products are delivered, Retailer Agent fulfils the market demand and replenishes its stock level.

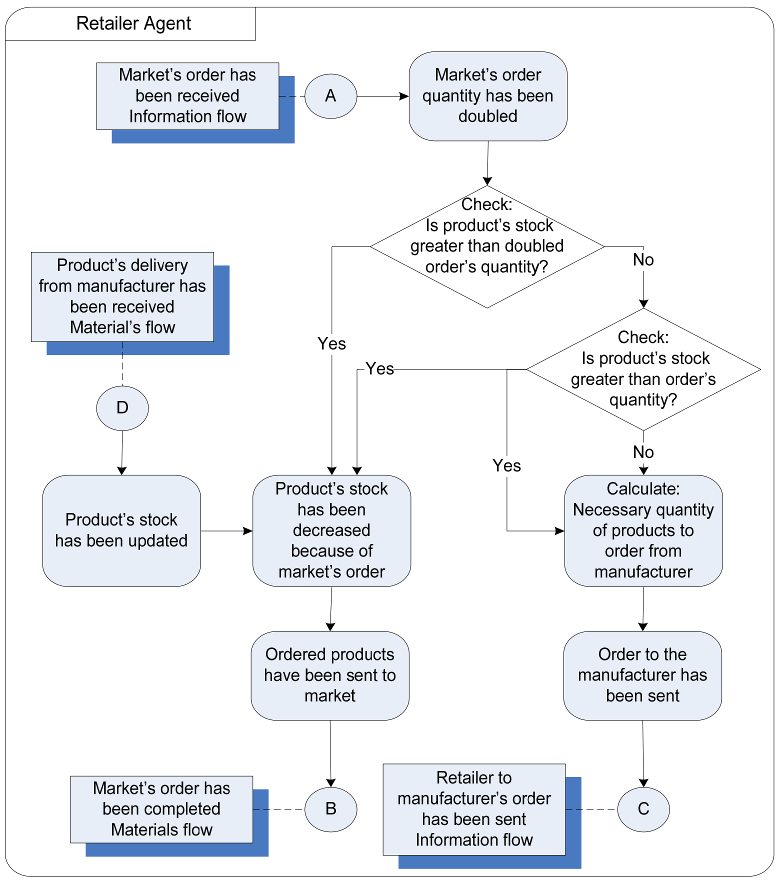

Figure 8. Retailer Agent's Behavioral Rules

Market Behavioral Rules

The Market Agent has only one goal – to generate the demand for products (see Fig. 9). This activity triggers the operation of the whole supply chain. The demand may be generated in three ways: according to demand forecasts, may be based on historical data or in the random manner with the specific density function of demand's distribution.

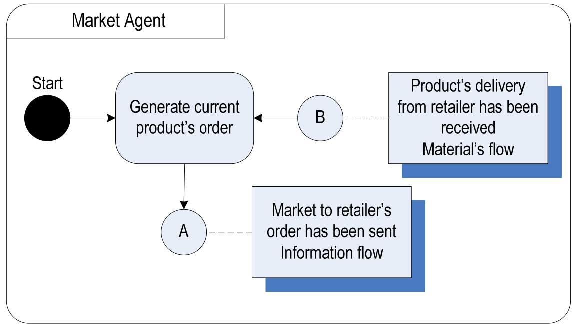

Figure 9. Market Agent Behavioral Rules

The Simulation Structure

The generic model of the simulation process is presented on the figure 10. The B connector comes from the environment preparation section (Warm-up Section) which is responsible for creating basic simulation model components (e.g. agents) and setting their initial parameters. It is specific to modeling and simulation environment selected. How it has been solved for the reference model under consideration is presented in the next section entitled Implementation of the Reference Model.

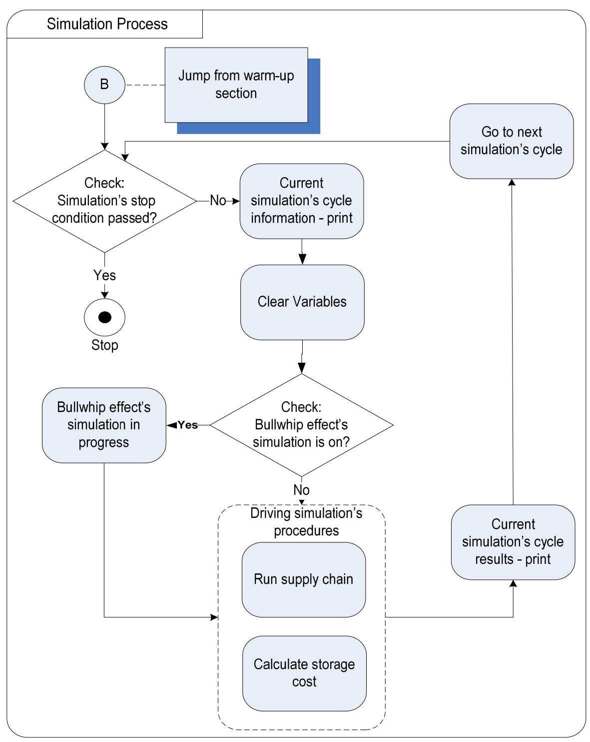

Figure 10. The generic model of simulation process

The first decision node is for checking if the stop condition has been met – if not, simulation proceeds. Simulation runs in the loops. Every loop constitutes the simulation cycle. Every simulation cycle has its own unique number assigned, which is automatically incremented by *Go to Next Simulation's Cycle* procedure. The number of simulation cycles may vary and lies in range from 1 to 1000. After next cycle starts, data related to it are printed on the system's console out. Just before Supply Chain procedures are run, variables values are set to initial states.

Next decision node checks if the cycle should include bullwhip effect phenomenon. After this decision is made, the procedures responsible for supply chain operation simulation are executed. The final procedure prints the results of current simulation cycle out. The printed data have the structure presented on the figure 11.

9 | 30 ; -26.7 ; 0 ; 0 | 4 ; 7 ; 92.36 ; 0 ; 3 | 3 ; 14.6 | 9.999985062E7 ; 0 ; Yes | 4.9

Figure 11. The row of data describing simulation cycle results

There are two data separators used in every row: "|" and ";". The former is put to separate the data related to supply chain components and the latter separates different values of the specific cycle's parameters. The table 3 presents interpretation of the values.

Table 3. Interpretation of simulation results

Values	Interpretation
9	Simulation cycle number
30	Number of parts the supplier has in stock
-26.7	Profit | Loss of Supplier
0	The number of parts, the supplier is supposed to deliver to producer in current simulation cycle.
0	The number of parts, supplier has to produce in order to fulfill producers demand as well as to replenish the stock level.
4	Producer Final Products' stock level
7	Producer Components' stock Level
92.36	Producer's Profit
0	Number of products, producer is supposed to manufacture in the current cycle (to cover the order and replenish the stock)
3	Number of products ordered by Retailer in current cycle
3	Final products' stock level at Retailer
14.6	Retailer's Profit
9999985062E7	The value of Market's Financial Resources
0	Market demand for current cycle
Yes	Flag showing if the products have been bought by the market in the current cycle
4.9	Time of the order fulfillment by producer (in hours)

The core of the simulation process is section responsible for Supply Chain operation (see Fig. 12). As is shown it consists of two main elements which are called Generate Market's Order and Fulfill the Order with Supply Chain.

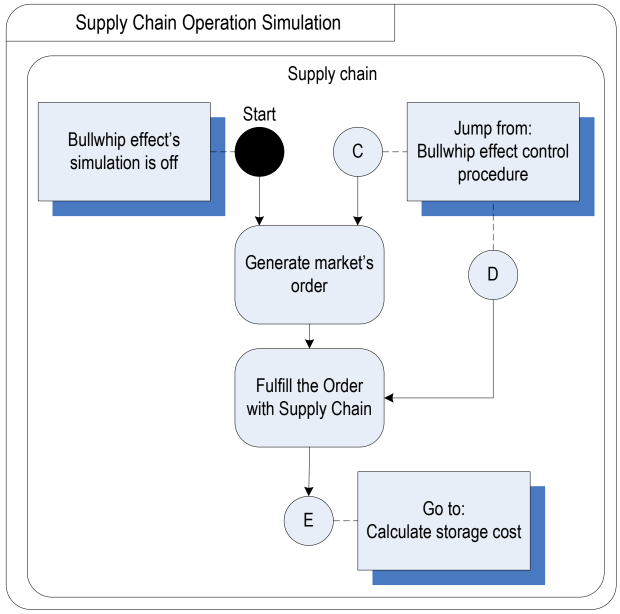

Figure 12. Supply Chain Operation Simulation procedure

The procedure entitled *Generate Market's Order* is depicted on the figure 13. It includes several decision nodes that check parameters such as demand level and market financial resources (money) level. If all conditions are met, the procedure *Try to place an order* is executed; otherwise the procedure called *Lack of an order in current cycle* is run.

After the order is generated by the market, its fulfillment is driven by the procedure *Fulfill the Order with Supply Chain*. The first step in this procedure is responsible for saving the fact that order has been placed. It supports the results' analysis because one can easily determine if the products have been delivered (or not) in the current cycle. Checking if Retailer Agent has enough level of stock is done according to behavioral rules presented in the previous section. Depending on the level of order's coverage, the following cases are possible:

1. Retailer Agent has proper level of stock to fulfill the current order and the number of products left equals the number of items currently ordered – *Fulfill the Order with Supply Chain* procedure is run.
2. Retailer Agent has enough products to fulfill the order, but the stock level left will be less than the number of items in current order – *Fulfill the Order with Supply Chain* and *Order Products* procedures are executed. Because the order has been fulfilled, the order status parameter is set to "closed" and therefore after ordered products are delivered they are not sent to the market. What is more, the variable Factor of Ordered Products is set to 1. It is used in the procedure of determining the number of products that have to be ordered.
3. Retailer doesn't have enough number of products to cover the current order – *Order Products* procedure is run, the order status is set to "open" and the order will be fulfilled after the delivery of producer will take place. The variable Factor of Ordered Products is set to 2, what means that number of products ordered has to be doubled. It is required to provide market with products demanded as well as to replenish the stock level.

The activity diagrams presented so far have been prepared on the high level of abstraction. It is obvious that in order to run the simulation several more detailed procedures were needed. Therefore every activity on the high-level diagrams has been further decomposed into next levels diagrams. The hierarchy of procedures required to running the Supply Chain Simulation is showed below.

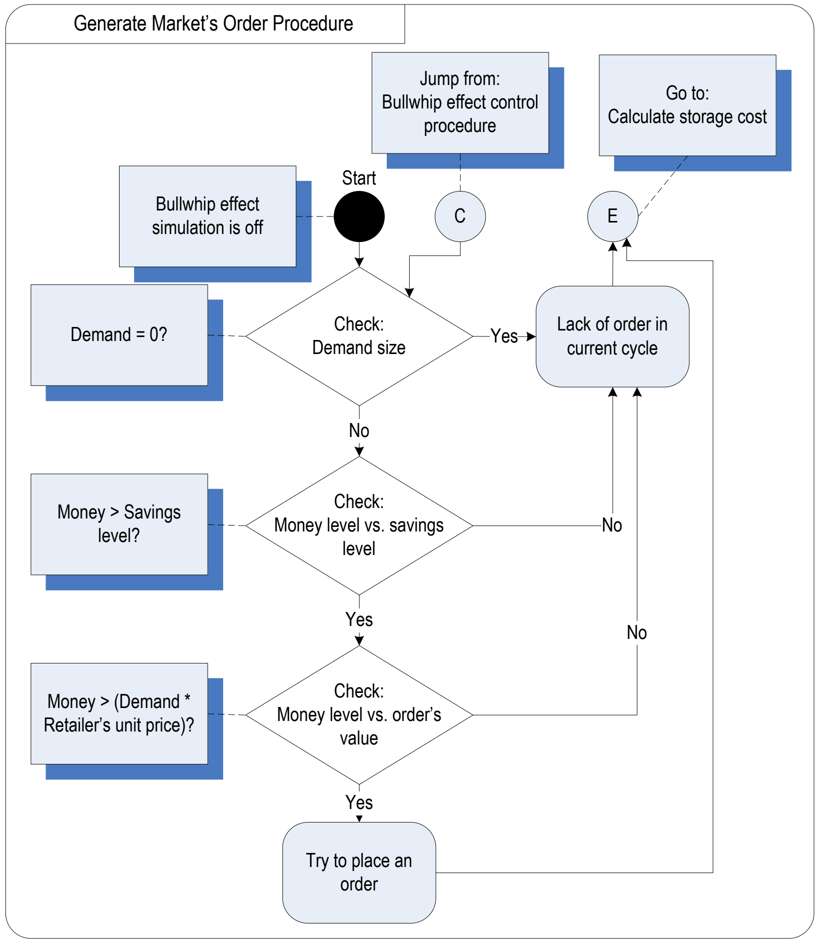

Figure 13. Generate Market's Order procedure

Run Supply Chain:

- Generate Market's Order
  - Lack of an Order in Current Cycle
  - Try to Place an Order
- Fulfill the Order with Supply Chain
  - Execute Market's Order
  - Order Products
    - Check Part's Stock Level at Supplier
    - Send Products to Retailer
      - Send Delivery to Retailer
      - Manufacturer's Production has been started
        - Manufacturer's Production process in progress
        - Order Parts from Supplier
          - Send Delivery to Manufacturer
          - Production at Supplier has been started

Indents show the hierarchy of procedures defined for simulation.

The Simulation Experiment Basic Steps

When using simulation, the experiment creation process is of great significance. The reference model presented in the paper assumes that experiment will be done according to the following steps.

1. **Identify and formulate a problem that is to be solved with simulation experiment.** It is important to have the list of questions articulated, which are supposed to be answered with the use of simulation runs.
2. **Create the model.** Definition of the real system model, which should provide a compromise between the detailed mapping of real system (impeding its implementation and validation), and simplification that suppresses the similarity between the model and real system, but making model easier to build. This step is extensively supported by reference model presented in the paper.
3. **Choose the metrics**. After the problem is formulated it is important to have set of indicators to monitor the state of the modeled system and to draw conclusions as well as to find hidden rules or laws.
4. **Set the initial values for simulation parameters**. The sample parameter is duration of simulation or number of simulation cycles. During every cycle all necessary tasks will be done, of course, only if their preconditions are met. The example of other parameters may be demand distribution (Normal, Poisson or Exponential distribution), parts and products prices or stock levels.
5. **Run the simulation**. After model is fully elaborated, and all variables are set up, the simulation may start and operate the predefined number of cycles during which values of variables are captured and saved.
6. **Calculate the metrics**. Metrics enable to better understand modeled object or process. Based on this data the simulation analysis is done.
7. **Interpret simulation results**. The last phase is related to the careful analysis of simulations results and calculated values of variables. It may lead to discovering new rules or dependencies that may be used in the real system management process.
8. **Validate the model**. It is based on a comparison of real system results and results of simulation, carried out with parameters corresponding to the actual operation of the system. The model can be considered valid (verified positive) if it (repetitively) reflects the behavior of real system.

Next sections present case study that shows how to use this scenario in Supply Chain analysis.

Implementation of the Reference Model

Selection of an Implementation Environment

Although one can implement model with a conventional programming language (most frequently Java; however other languages also can be used) this is usually hard way to start. Because simulation models involve similar building blocks (only small variations are present), commonly used elements have been put together in the form of the libraries, frameworks or full-blown environments. The best known are Swarm, Repast and Mason. They can be integrated with .Net Framework and programs written in C#, VB and Pyton as well as with Java environments. The main problem with these solutions is that they are quite complex and it can take months before one take an advantage of the full range of features they offer. What is more, the modeler has to use rather low level languages such as Java or C# what can be really daunting.

It is worth to mention that environments intended for other purposes can also be used for agent-based simulation. There are many examples of simulation done in Ms-Excel, statistics package R, MatLab or Mathematica. Nevertheless, the easiest and most effective way of conducting agent-based simulation is to use the package dedicated to this purpose [Gilbert, 2007].

Because main assumption of the reference model is to decrease the complexity associated with the modeling process, more suited are modeling environments that provide complete systems in which models can be created, executed and visualized. In this area the best known are StarLogo, AgentSheets and NetLogo.

The Reference Model proposed in the paper has been implemented in NetLogo, which is considered as the most popular simulation environment. It includes several facilities such as tools for building user interface or system dynamics modeler. The environment is free of charges for educational and research purposes. The comparison of modeling environments is shown in the table 4.

Implementation Process

The Multi-Agent simulations implemented in NetLogo IDE consist of three following stages:

1. Definitional part – includes definitions of agents' types ("breed"), global variables ("globals") and variables related to every agent (e.g. agent's name).
2. Preparatory part (to setup) – procedures setting up the environment for simulation.
3. Simulation definition part (to go) – procedures definition that drive the core of the simulation process.

All the parts and their temporal relationships are shown on figure 14.

Table 4. The comparison of agent-based simulation environments [Gilbert, 2007]

	Swarm	Repast	Mason	NetLogo
License	GPL	GPL	GPL	Free but not open source
Documentation	Patchy	Limited	Improving but limited	Good
User Base	Diminishing	Large	Increasing	Large
Modeling Language	Objective-C, Java	Java, Pyton	Java	NetLogo
Speed of Execution	Moderate	Fast	Fastest	Moderate
Support for GUI Development	Limited	Good	Good	Easy to create
Built-in ability to create movies and animations	No	Yes	Yes	Yes
Support for systematic experimentation	Some	Yes	Yes	Yes
Ease of Learning and Programming	Poor	Moderate	Moderate	Good
Ease of installation	Poor	Moderate	Moderate	Very easy
Link to GIS	No	Yes	Yes	No

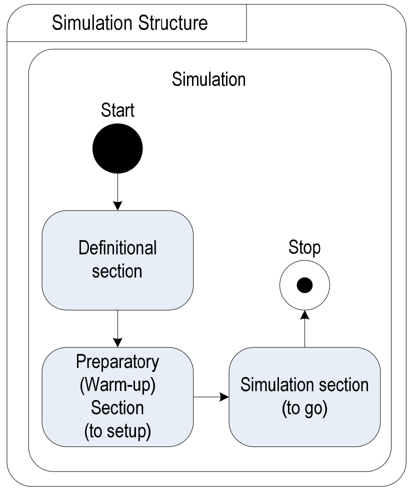

Figure 14. The Simulation Structure

<u>Definitional Part</u>

According to conceptualization described in previous section this part defines four types of agents: Market Agent, Retailer Agent, Manufacturer Agent and Supplier Agent (see Figure 15).

Every agent has the set of variables defined. All variables are presented below.

Supplier Agent has such variables as:

- components_level – number of components in stock,
- components_price – the component's unit price,
- components_cost – the component's production cost,
- profit – supplier's profit.

Manufacturer Agent's variables are the following:

- prod_stock_level – product's stock level,
- prod_price_level – product's unit price,
- components_level – component's stock level,
- components_price – component's unit price,
- to_deliver – number of products ordered by Retailer Agent in current cycle,
- to_produce – number of products to manufacture in current cycle,
- profit – producer's profit.

Retailer Agent's variables are:

- prod_stock_level – product's stock level,
- price – product's unit price,
- profit – retailer's profit.

Market Agent's variables are:

- money – market's financial resources,
- savings_level – the level of saving on the market,
- earnings – financial resources generated by market during one simulation cycle,
- demand – market's demand.

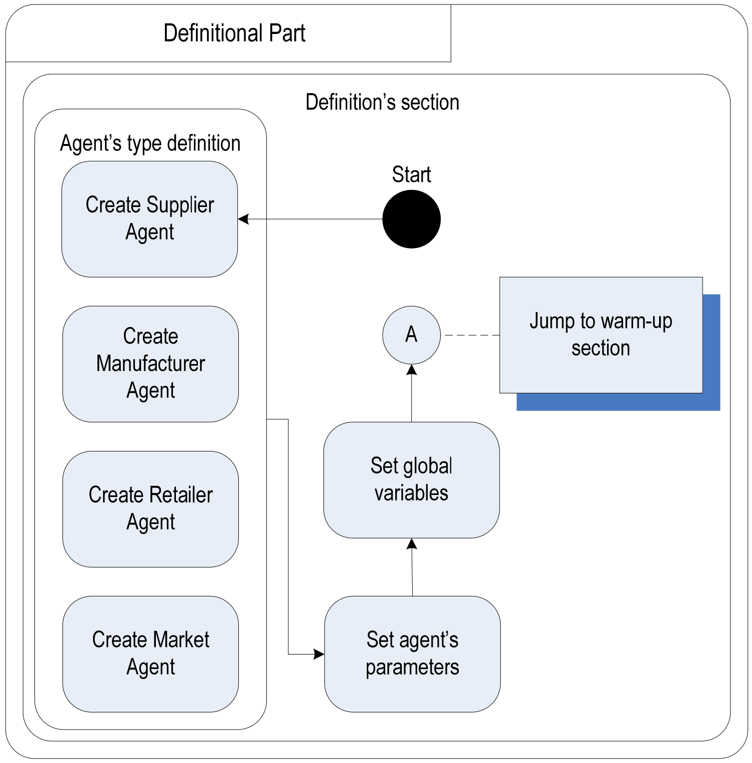

Figure 15. The structure of Definitional Part

Besides the agents' variables, this section includes also the definition of global variables that are available during the whole simulation process. Global variables defined for the simulation have been listed below.

- prod_price – unit price of final product at manufacturer (producer),
- comp_price – unit price of component at supplier,
- dmd – market's demand,
- production_quantity – number of products to be manufactured by producer,
- components_to_order – number of components ordered by producer,
- components_to_produce – number of components produced by supplier,
- factor – the quantity factor related to components ordered by retailer,
- production_factor – the quantity factor related to products manufactured by producer,
- components_factor – the quantity factor related to components produced by supplier,
- orders_state – order's state at retailer,
- components_delivery_state – order's state at supplier,
- prod_to_retailer_order_state – order's state at producer,
- text – variable used for saving simulation results,
- temp_text – auxiliary variable used for concatenation,
- purchase – flag used for showing that in the current cycle products were sold,
- time – used for measuring time needed for order fulfillment,
- bull – used for showing that bullwhip effect will take place in the current cycle.

All presented variables have been defined in simulation environment and used in agents behavioral rules during implementation stage.

Preparatory Section

This section is responsible for setting up the simulation environment. *Clear simulation* procedure is predefined in NetLogo environment and is used to clear the memory for storing new simulation results data.

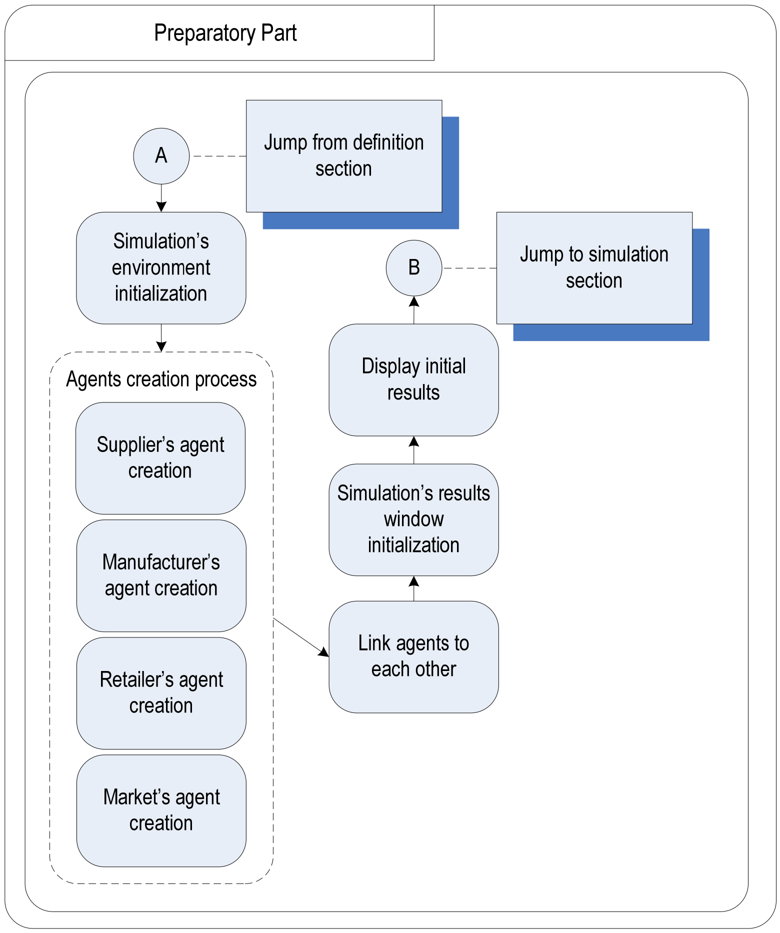

Figure 16. Structure of Preparatory Part

Procedures that instantiate agents are responsible for setting up initial values for variables defined in definitional section. Next procedure creates visual connections between communicating agents. Finally presentation layer procedures prepare the simulation window and write down simulation initial values as well as simulation results what helps in results analysis process.

The final step of this stage was implementation of simulation procedures according to agent behavioral rules and simulation structure described in the previous sections.

Described activities are depicted on the figure 16.

Case study – Bullwhip Effect in Supply Chain Analysis

The following paragraphs present short case study, which illustrates how the multi-agent-based simulation can be used as a tool supporting supply chain management process.

The simulation experiment has been elaborated in the steps presented below. All the steps have already been explained in the section entitled *The Simulation Experiment Basic Steps*. Description of each step reveals the design decisions which have been made with regard to Supply Chain modeling and simulation processes.

1. **Identify and formulate a problem that is to be solved with simulation experiment**. The main goal of the multi-agent based simulation is to check *how the bullwhip effect may influence the retailer's delivery time.*

2. **Create the model**. The application of multi-agent approach to the process of simulation model development has been based on the framework presented in the paper. The conceptualization has led to four main model components:
   - consumer market agent – this element is responsible for buying and consuming products,
   - retailer agent – its main goal is to buy products from manufacturer and to sell them to consumers,
   - manufacturer agent – it is obliged to purchase materials from supplier, transform them to final products and sell final products to retailer,
   - supplier agent – this component produces materials and sells them to manufacturer.

Very important part of the model is the logic of agents' operation, which is formalized with behavioral rules presented in the previous sections. During the runtime, agents communicate using the following flows:

- goods flow – in the direction from the supplier through manufacturer and retailer to consumers,
- orders (information) flow – from consumers through retailer and manufacturer to supplier.
- money flow – shows how the money circulates in supply chain.

3. **Choose the metrics**. The equation (1) describes total delivery time measured from the moment when the retailer has ordered products to the moment when products have arrived to retailer.

$$T_T = T_D + T_P + T_{DC} + T_{PC} \qquad (1)$$

where:

T_T – total delivery time, T_D – time of delivery between manufacturer and retailer, T_P– production time at manufacturer's floor (it's skipped if manufacturer has products' stock greater than the order lot), T_{DC} – time of delivery between supplier and manufacturer (included only if manufacturer product's stock is smaller than order lot, what is more, supplier has enough part's to fulfill manufacturer's order), T_{PC} – part's production time at supplier's floor (included only if supplier part's stock is not sufficient to fulfill manufacturer's order).

The algorithm realizing this function is implemented in main part of the simulation process. Metrics' values are calculated automatically at a runtime.

What is more, during simulation experiments other metrics have been calculated e.g. average time of different delivery types – it will be described in the step number 7.

4. **Set the initial values for simulation parameters**. Because the goal of the simulation experiment is to compare how the bullwhip effect may influence total delivery time of retailer, minimum two simulation runs have to be executed. The first run does not include the bullwhip effect and the second one takes it into consideration.

This case study contains two simulation experiments and two runs in each of them. Initial parameters of simulation runs are presented below.

- First experiment:
  - duration of the simulation: 300 cycles,
  - part's price: 2.50,
  - demand distribution: Normal,
  - mean of distribution: 6.0,
  - standard deviation of distribution: 1.5,
  - safety part's stock at supplier: 25 pcs.,

- safety part's stock at manufacturer: 20 pcs.,
- "bullwhip effect" simulation: first run - Off, second run - On,
- cycle when bullwhip effect occurs: first run – N/A, second run - 250,
- strength of the bullwhip effect: first run – N/A, second run - 20,

- Second experiment:
    - duration of the simulation: 500 cycles,
    - part's price: 2.00,
    - demand distribution: Poisson,
    - mean of distribution: 5.0,
    - standard deviation of distribution: N/A,
    - safety part's stock at supplier: 25 pcs.,
    - safety part's stock at manufacturer: 20 pcs.,
    - "bullwhip effect" simulation: first run - Off, second run - On,
    - cycle when bullwhip effect occurs: first run – N/A, second run - 450,
    - strength of the bullwhip effect: first run – N/A, second run - 20,

5. **Run the simulation.** The simulation has been run four times, with parameters values as presented in previous step. The results have been saved in text files and used in the process of metrics calculation.

6. **Calculate the metrics.** Collected data was re-formatted (precision, conversion of dots to commas) before the calculation process. After that, some statistical operations were done such as: search maximum, minimum and calculate average. The final results of the experiment will be presented and interpreted in the next section.

7 . **Interpret simulation results.** In this step the most interesting results will be visualized and presented.

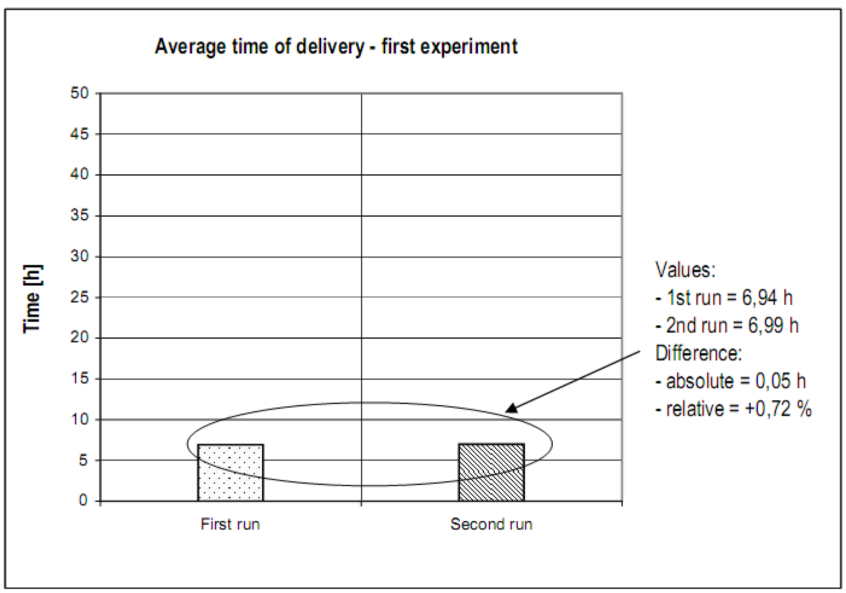

Figure 17. Average delivery's time in the first experiment

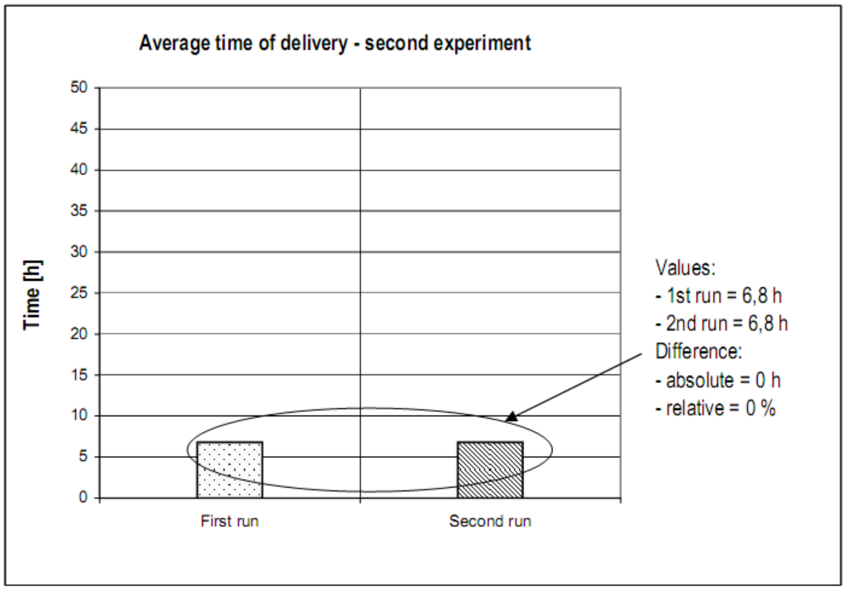

Figure 18. Average delivery's time in the second experiment

As one can see on the figures 17 and 18, an average time of deliveries in the first and second experiment was almost the same – around 7 hours.

What is more, turning on the bullwhip effect simulation did not have a spectacular influence on the results (compare first and second run on the graphs 17 and 18). Figures 19 and 20 show direct deliveries between manufacturer and retailer (A type delivery) – transported goods are final products. Average time of those deliveries was approximately 4 hours, and also here, the bullwhip effect did not have an important influence. One can notice strange situation on the figure 20. Average time of direct deliveries is shorter if the bullwhip effect simulation was enabled, and it is because of randomly generated pattern demand in the first and second experiment as well as in the first and second run. To make the whole analysis process more clear and understandable, static pattern demand should be considered.

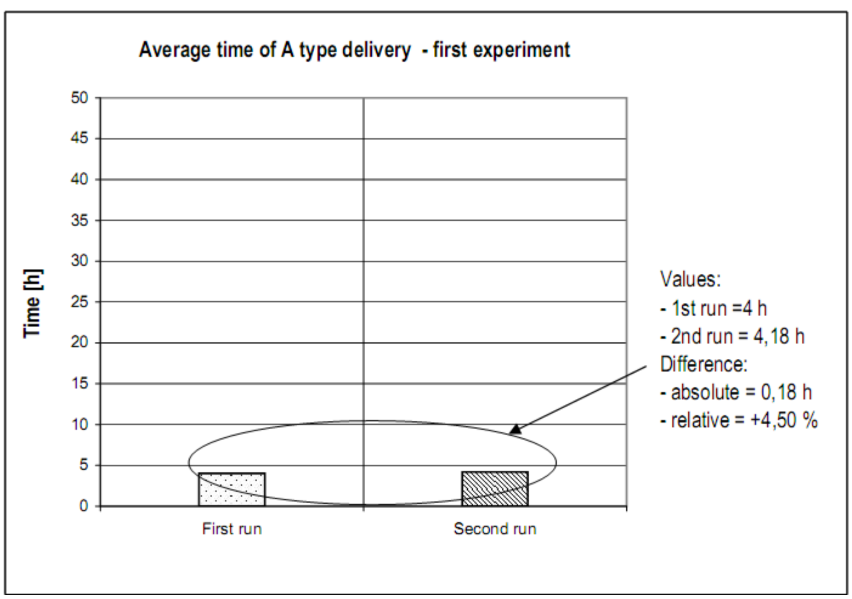

Figure 19. Average A type delivery's time in the first experiment

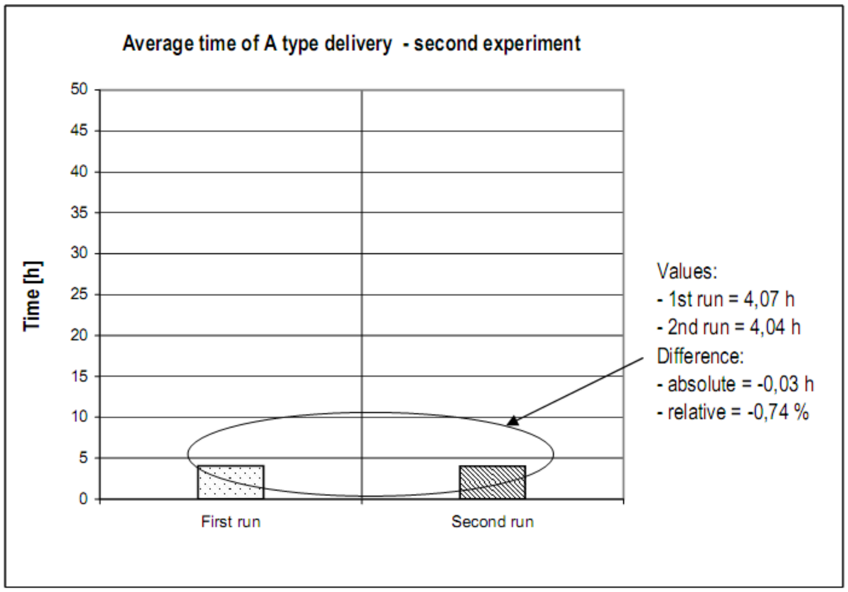

Figure 20. Average A type delivery's time in the second experiment

Next two graphs (Fig. 21 and Fig. 22) show average time of deliveries in B category. It is composed of three stages:

1. delivery of parts between supplier and manufacturer,
2. transformation of parts into products (manufacturer's production process),
3. delivery of products between manufacturer and retailer.

Average delivery time in this case was equal around 9 hours.

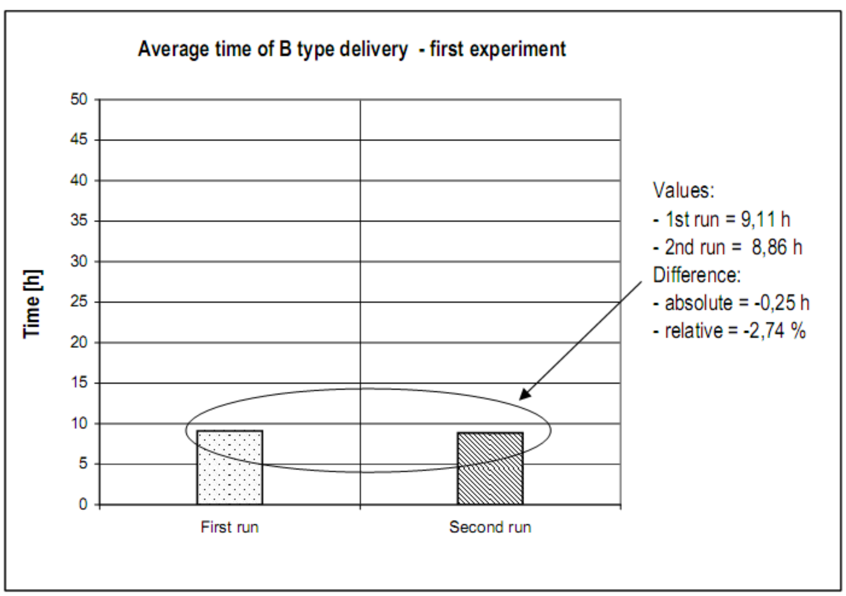

Figure 21. Average B type delivery's time in the first experiment

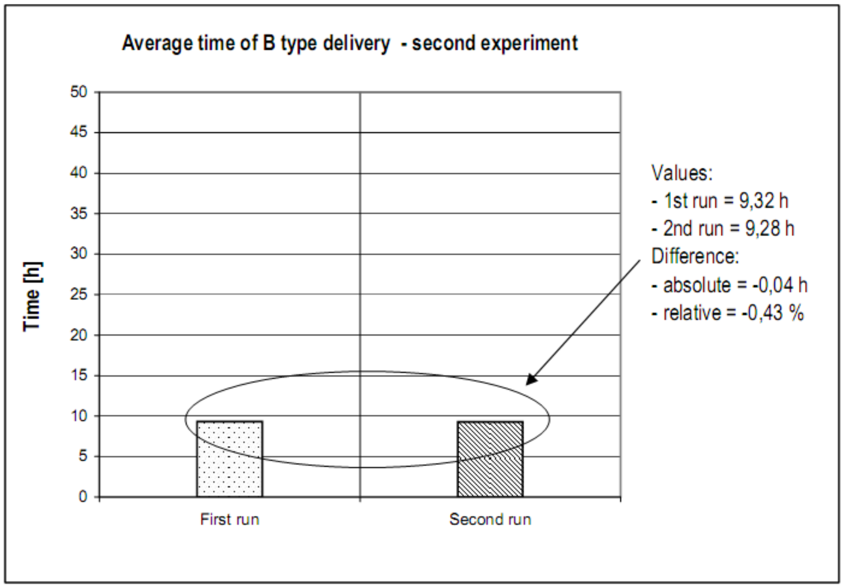

Figure 22. Average B type delivery's time in the second experiment

Figures 23. and 24. show C category deliveries, which consist of the following stages:

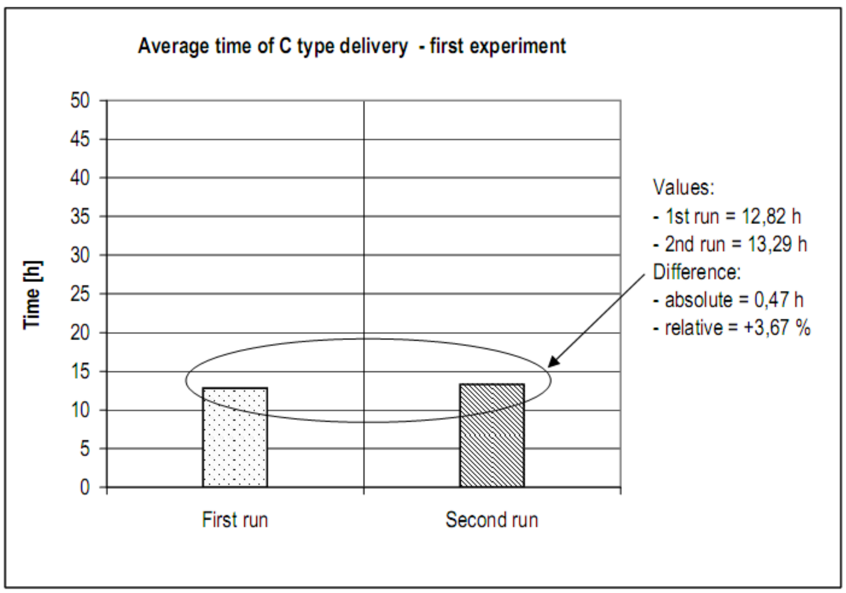

Figure 23. Average C type delivery's time in the first experiment.

1. parts production (supplier's production process),
2. delivery of parts (between supplier and manufacturer),
3. transformation of parts into final products (manufacturer's production process),
4. delivery of products (between manufacturer and retailer).

Average delivery time in this case equals approximately 13 hours in the first experiment and 14.5 hour in the second experiment. Simulated bullwhip effect has not had an important influence on B and C categories.

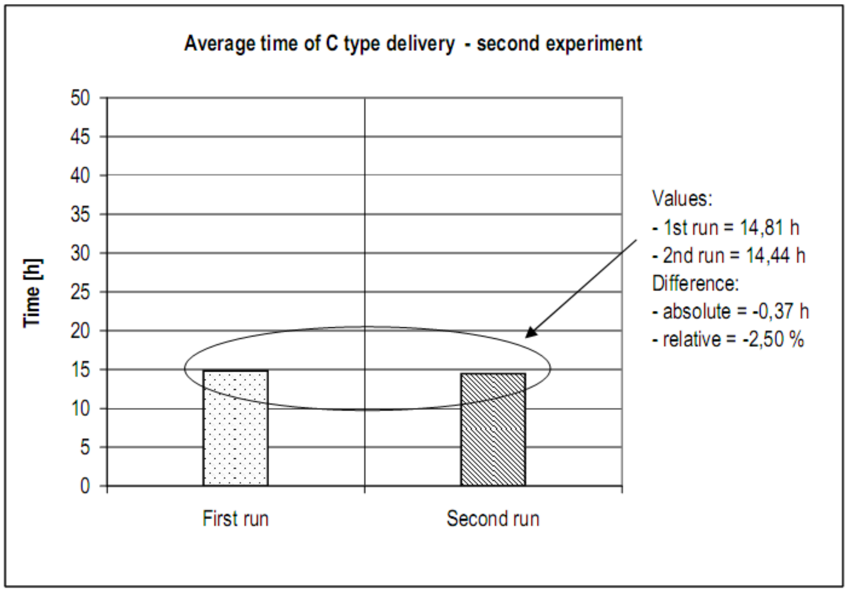

Figure 24. Average C type delivery's time in the second experiment

Figures 25. and 26. show very interesting and spectacular results. Both graphs illustrate the longest delivery time in whole simulation's process. In the first experiment difference between longest delivery time (if the bullwhip effect was simulated or not) is equal 10.2 hours, so it means 39.53%. In the second experiment the difference was even bigger: 12.3 hours – 47.49%. To prove that randomly generated demand pattern did not have important influence on the results, it is worth to compare longest delivery time in first run in both simulation's experiments, which is about 26 hours.

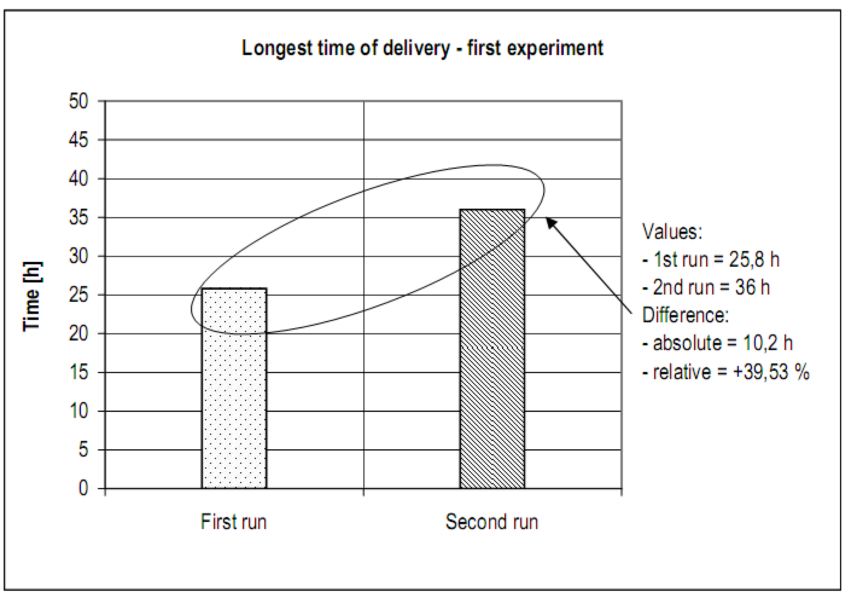

Figure 25. The longest delivery time in the first experiment

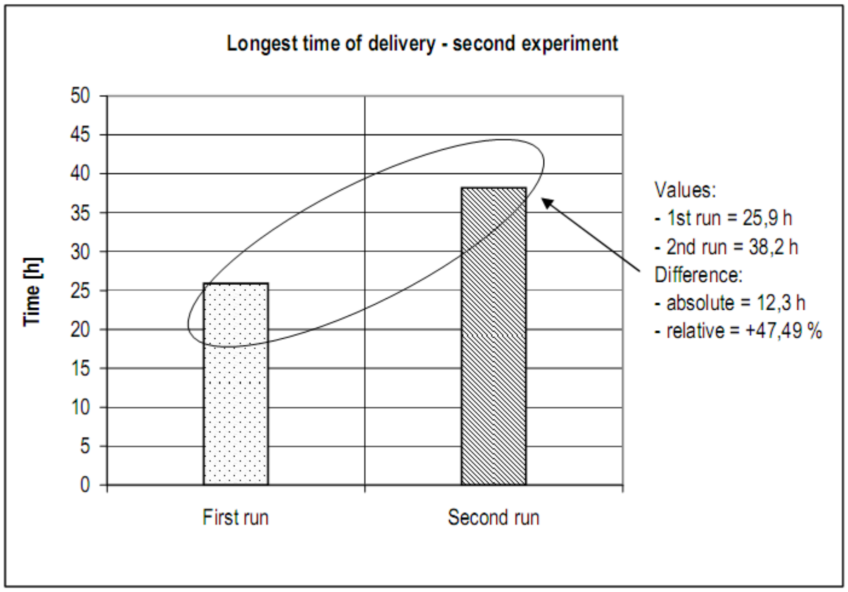

Figure 26. The longest delivery time in the second experiment

To conclude there is no doubt that the bullwhip effect causes longer delivery time, it is clearly shown on the figures 25 and 26. In the implemented simulation, in both experiments and both runs, bullwhip effect was simulated only once during simulation's process (which was quite long). We can suppose that if bullwhip effect occurs more frequently, negative effect of it will be bigger and much more serious. To prove this thesis, another research should be conducted with 30 – 50 simulation cycles, and number of bullwhip effect simulations should be changed from 1 to different values.

The experiment has been focused on the time dimension of bullwhip effect influence on supply chain. Of course is it possible to examine different aspects of the supply chain operation such as: productivity of very long and very short supply chains, influence of bullwhip effect on production stability or money resources.

Conclusions

The nature of business organizations and characteristics of their environments have changed. More flexible and sensitive constructs are needed to deal with modeling of business architectures which operate rather on social principles than on mechanistic rules. What is more, because of complexity of such structures as Extended Enterprises, simulation seems to be only reasonable analysis method for understanding existing business models as well as designing new ones. Simulation offers an effective analytical tool for organizations that need to understand their behavior and measure the performance of cycle time in the environment of Extended Enterprise. As is shown in a paper agent orientation is powerful paradigm for modeling contemporary enterprises and conducting simulation experiments. Proposed reference model provides modeler with step-by-step process as well as detailed structure and shows how to develop simulation model and experiment with it. The reference model elements have been implemented in NetLogo environment and used during supply chain analysis described in the case study. The framework is not claimed to be exhaustive or complete. It is intended to be a core on which further research will be done.

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Software Engineering and Development

SOFTWARE DEVELOPMENT PROCESS DYNAMICS MODELING AS STATE MACHINE

Leonid Lyubchyk, Vasyl Soloshchuk

***Abstract**: Software development process modeling is gaining increasing interest among academic researchers and IT-industry practitioners alike as an approach for analyzing complex business questions of software production from the strategic management of software development, to supporting process improvements. A number of simulation models of software dynamics have been developed based on system dynamic approach with the use of special simulation programming tools. At the same time analytical software development modeling are of great interest as a tool of process optimization and control. In this paper the software development processes model based on the state machine and queuing network approach is proposed. The goal is the software development process dynamics modeling t hat is the evaluation of software product readiness progress in the course of time. Software product is considered as a set of system requirements, and software development process is represented as consecutive transition of each system requirement through the states of the defined state machine. The state machine model is a queuing network with service nodes which correspond to a number of implementers of system requirements on each stage of the development. Implementers are business analytics, architectures, developers, testers, etc. In general, the state machine is defined according to the used software development methodology. The markovian processes theory is further used for the queuing network modeling and quality indexes estimation. The proposed model can be used as a basis for modeling the dynamics of a software project development to get estimations of the following project parameters: effort, duration, cost, resources usage, development schedule, etc.*

***Keywords**: software development process dynamics, software engineering, production modeling, state machine, project management*

***ACM Classification Keywords**: D. Software – D.2 SOFTWARE ENGINEERING – D.2.8 Metrics (Process metrics, Product metrics), D.2.9 Management (Cost estimation, Life cycle, Productivity, Software process models, Time estimation); K. Computing Milieux – K.6 MANAGEMENT OF COMPUTING AND INFORMATION SYSTEMS – K.6.1 Project and People Management (Life cycle, Staffing), K.6.3 Software Management (Software process), K.6.4 System Management (Management audit)*

Introduction

Currently, the problem of estimating the parameters of software development projects using different mathematical and statistical techniques is relevant, because it allows minimizing uncertainty in the planning, which significantly reduces the risk of project failure [McConnell, 2006]. However, most models estimating parameters of software development projects are static and do not allow to estimate progress dynamics of project. To analyze the dynamics of the project progress such methods as system dynamics and simulation modeling are applied [Abdel-Hamid, Madnick, 1991], [Lakey, 2004], [Madachy, 1996]. For modeling the dynamics of software development the development models of complex engineering product by the engineering team are also used [Soo-Haeng Cho, Eppinger, 2005]. The product itself, team parameters and the process of development hold many uncertainties. To cover all the processes of the project both the effort that brings to the increase of the developed product (programming, documentation) and work that do not directly contribute to increasing the size of the product (testing, control) should be taken into account [Han, Lee, Fard, Pena-Mora, 2007]. Mathematical model for analyzing the dynamics of the project progress must be practically applicable, i.e. it must take into account real-world objects and processes that can be clearly identified and measured in a real project. Classical methods of identification of operations models can be used for these purposes [Pervozvansky, 1975]

Structure of software development project

There are many methodologies for software development, but there are a number of basic objects, which are present in the project structure for any methodology [Sommerville, 2001].

Software product requirements. There are different levels of detail and description of the requirements for a software product, namely the business requirements, user requirements, functional and nonfunctional requirements. Functional and nonfunctional requirements are essential for further usage in the project. One of the most convenient requirements classifications for a software product is a FURPS model, which means:

- Functionality – feature set, capabilities, generality, security;
- Usability – human factors, aesthetics, consistency, documentation;
- Reliability – frequency/severity of failure, recoverability, predictability, accuracy, mean time to failure;
- Performance – speed, efficiency, resource consumption, throughput, response time;
- Supportability – testability, extensibility, adaptability, maintainability, compatibility, configurability, serviceability, installability, localizability, portability;

Project and process requirements. Project requirements are development process requirements, i.e. what methodology will be used, what is the structure of development stages, the length of iterations, the structure of roles in the project, the distribution of effort between the various processes and stages of the project, etc. This also includes the definition of project requirements, i.e. how the developer will perform the target system creation tasks.

Work Breakdown Structure (WBS). WBS – hierarchical work decomposition conformed to distribution results. This work decomposition should be performed to achieve the objectives of the project and agreed distribution results delivery [PMBOK, 2004]. With the help of hierarchical work structure the entire contents of the project is structured and defined. WBS divides the project to smaller and more manageable parts, where each lower level of WBS provides a more detailed definition of project works. For planned operations conformable to the lower-level WBS elements (they are called work packages), time schedule and cost estimates can be determined as well as operations monitor and control can be performed.

Team structure and resources calendar. The structure of the team specifies what resources, i.e. what specialists are available for project performing. Each task needs its own kind of resources. Resources classification may vary for different software development methodologies. It should be noted that each single resource can combine multiple roles and, accordingly, can be used to perform various types of operations. Resources calendar is the calendar of working days and days off that determines dates in which each resource may or may not be used. Usually it includes working and nonworking periods of each resource [PMBOK, 2004].

Project time schedule includes a calendar schedule of project stages performance in accordance with WBS and availability of resources from the resource calendar. In this case the following parameters for the work should be stated: sequence number of work according to WBS, name of work in accordance to WBS, resource assigned for the job performance, the duration of performance, date and time of starting the work and its completion, previous and subsequent operations. Also, the time schedule states the milestone of the project. Project time schedule can be presented as a table or using Gantt charts (sometimes a term horizontal bar chart is used) [PMBOK, 2004].

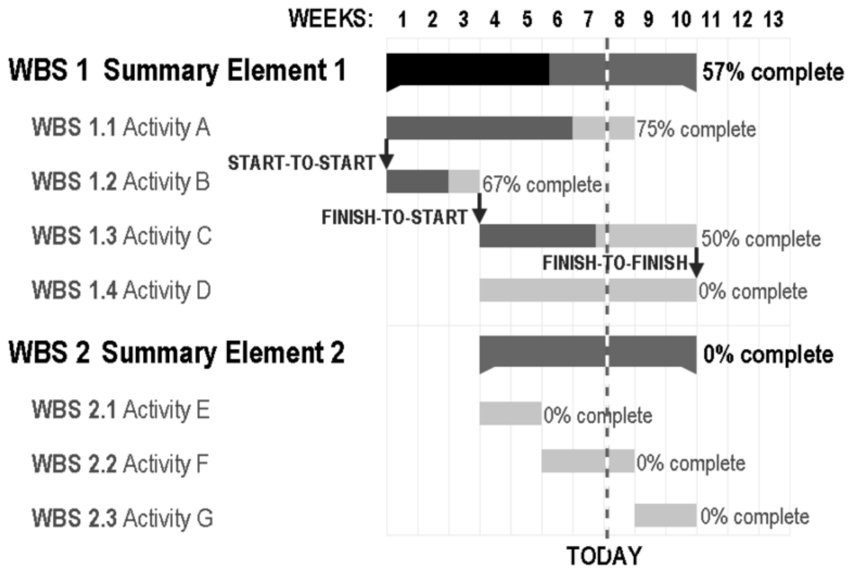

Figure 1. A Gantt chart showing three kinds of schedule dependencies (in red) and percent complete indications

Problem definition

To simulate the dynamics of the project progress the structure of the project should be formally described on the basis of mentioned above elements, which are included in the structure of the software development project. The project structure should also include a model of product requirements transition from one state of product readiness to another. Transitions from one state of product requirements readiness to another depend on the methodology of project development.

Parameters and elements of mathematical model of software development project

In accordance with the described project structure following formal objects and project parameters description can be introduced.

Objects to describe the structure of process requirements. These objects should take into account specificity of development methodology, which is used in a simulated project:

- L – set of operations (types of work), which obtain in the selected development methodology;
- S – set of states of product requirements readiness;
- $W = \{w_{ij}\}$ – matrix with the types of work for the transition of requirements between the states;
- w_{ij} – type of work to transit requirements from i to j state, where $i \in S$, $j \in S$, $w_{ij} \in L$;
- $P = \{p_{ij}\}$ – probability of transition between states matrix;
- p_{ij} – probability of transition from i to j state, where $i \in S$, $j \in S$;
- $\sum_{i \in S} p_{ij} = 1$ – condition for the completeness exit from any state;

- *A* – set of artifacts that can be developed during the project.

Example of set of works L = {1, 2, 3, 4, 5, 6, 7, 8}, where:

- 1: specified requirements;
- 2: software architecture design (business logic, user interface, data and database structure);
- 3: programming;
- 4: quality assurance / testing;
- 5: sending requirements for revision, defect description
- 6: approval of programmed requirement;
- 7: correction of detected defects;
- 8: version release, which will include the requirement;

Example of set of readiness states S = {1, 2, 3, 4, 5, 6, 7, 8}, where:

- 1: identified requirement (found but not yet described in detail);
- 2: specified requirement (analyzed and included into requirements specification of developing software product);
- 3: designed requirement (included into developing software product architecture description);
- 4: programmed requirement (programmed and included into the current working software product version);
- 5: tested requirement (checked for defects and compliance with requirements included into developed software product);
- 6: defective requirement (defects identified in functioning or incorrect requirements implementation);
- 7: approved requirement (has been tested and approved for inclusion into the current product version);
- 8: released requirement (included into formal software product package).

Transitions between states, which are set by matrix *W*, are defined by using development methodology and may be represented as a network. An example of such a network is shown in Fig. 2.

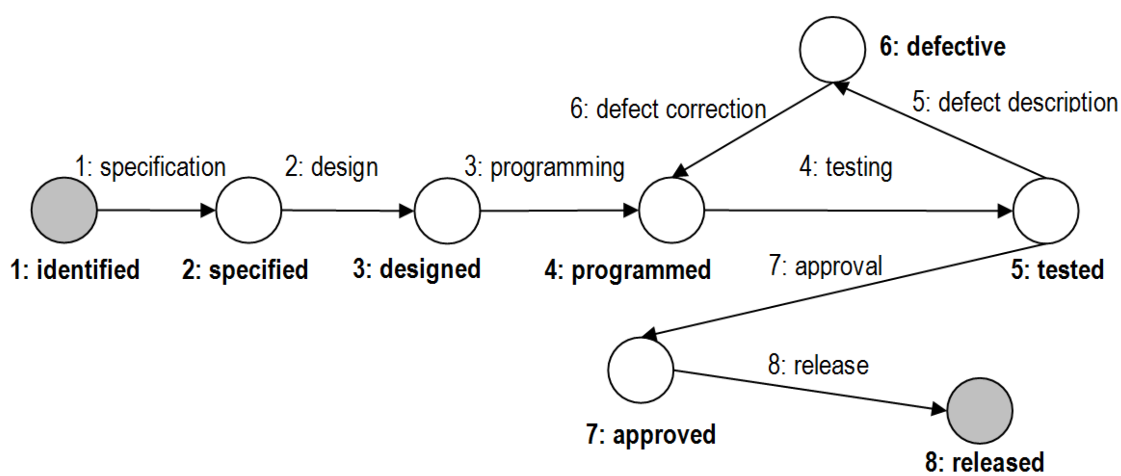

Figure 2. Network of transitions between software product requirements states

Objects to describe structure of product requirements. Let us introduce the notation to describe the parameters of the software product requirements:

- *Q* – set of requirement types;
- *R* – set of software product requirements;
- M_r – set of requirements that must be implemented before the start of the *r*-th requirement, $r \in R$;
- $A = \{b_r\}$ – set the types for each requirement, $r \in R$;
- a_r – type of *r*-th requirement, $r \in R$, $a_r \in Q$;
- $B = \{b_r\}$ – set with the current state of readiness for each requirement, $r \in R$;
- b_r – state of readiness for *r*-th requirement, $r \in R$, $b_r \in S$;
- z_r – size of *r*- th requirement, $r \in R$;
- c_r – priority of implementing of the *r*-th requirement, $r \in R$.

Objects to describe resources and resources calendar. Let us introduce the notation for describing the resources parameters:

- *K* – set of available resources;
- $V_k = \{v_{kql}\}$ – matrix of productivity for *k*-th resource;
- v_{kql} – productivity performance when *l*-th work for *q*-th requirement type is done using *k*-th resource, where $q \in Q$, $k \in K$, $l \in L$.

If the *k*-th resource is not able to perform *l*-th type of work for the *q*-th requirement type, then: $v_{kql} = 0$. If the *k*-th resource is able to perform *l*-th type of work for the *q*-th requirement type, then the function of productivity performance is a complex function of many variables:

$$v_{kql} = v(k, q, l, z, \ldots) \qquad (1)$$

where *z* – size of requirement.

Available time intervals for performing the work of *k*-th resource:

- T_k – set of initial moments of the working periods of time;
- D_k – set working time intervals duration.

Project schedule. Project schedule is a schedule of requirements transfer from initial states to final states with fixation of specific values for all the probability variables and uncertainties.

The basis for project schedule is time required for each work to perform requirements transition from one state to another. The duration of *r*-th requirement transition from *i*-th state to *j*-th state can be set with following functions:

$$d_{rij} = \frac{z_r}{v(k, q, w_{ij}, z_r, \ldots)} \qquad (2)$$

where $i \in S$, $j \in S$, $q \in Q$, $k \in K$, $w_{ij} \in L$,

z_r – size of requirement for r-th requirement, $r \in R$,

k – number of the resource, which performs this work;

q – requirement type;

w_{ij} – type of work to transit i-th state to j-th state.

Project schedule should also include estimation of the sequence of requirements state changes, taking into account the transition probability matrix *P*.

Constructing technique for model of project progress dynamics

Solution of this problem should include:

- estimation of project parameters: duration, effort costs, resource costs, quality level;
- estimation of resource needs and their time loading;
- estimation of project schedule;
- estimation of dynamics in the state of requirements readiness transition and estimation of requirements size in each state.

Formal project structure model described above can be used to solve these problems. However, this requires completion of the model with the following features:

- select methods and algorithms for modeling;
- develop method to estimate resources productivity, i.e. method of $v_{kql} = v(k, q, l, z, \ldots)$ function constructing;
- develop function of dynamic changes in the set of requirements R with time R = R (t).

The estimation of each option is best to give as a series of values indicating the confidence level of each value, i.e. probability of achieving such values. Fig. 3 shows the chart estimating date of project completion, which depends on the possibilistic project duration. Similar valuations should be issued for effort, cost, quality and other parameters.

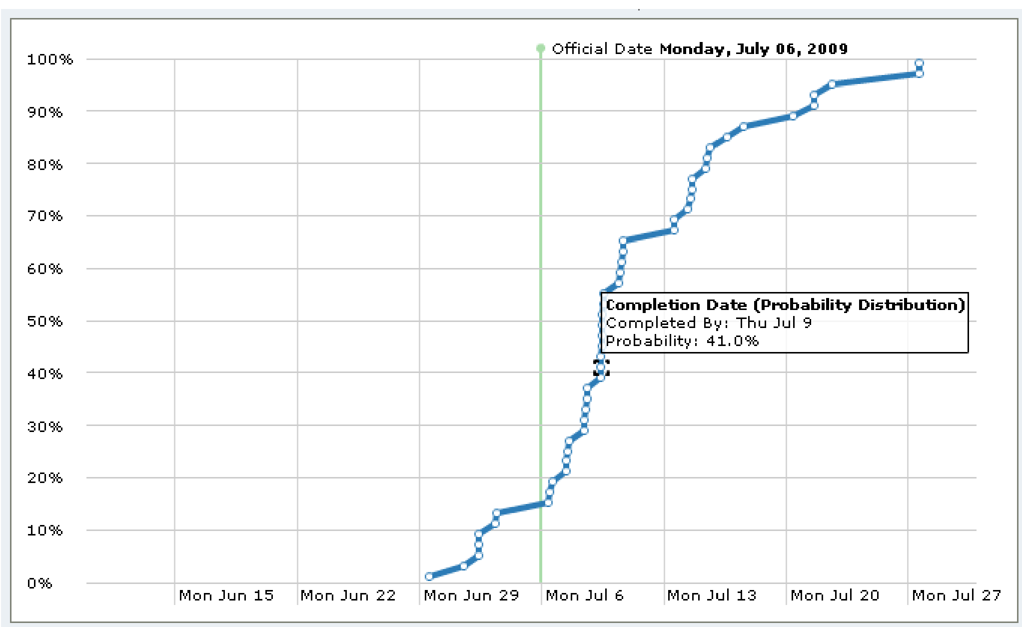

Figure 3. Example of estimating completion date (Probability Distribution)

Solution of project progress dynamics modeling problem will also give an opportunity to estimate requirements states transition dynamics and estimate requirements size in each of the states in the form presented in Fig. 4.

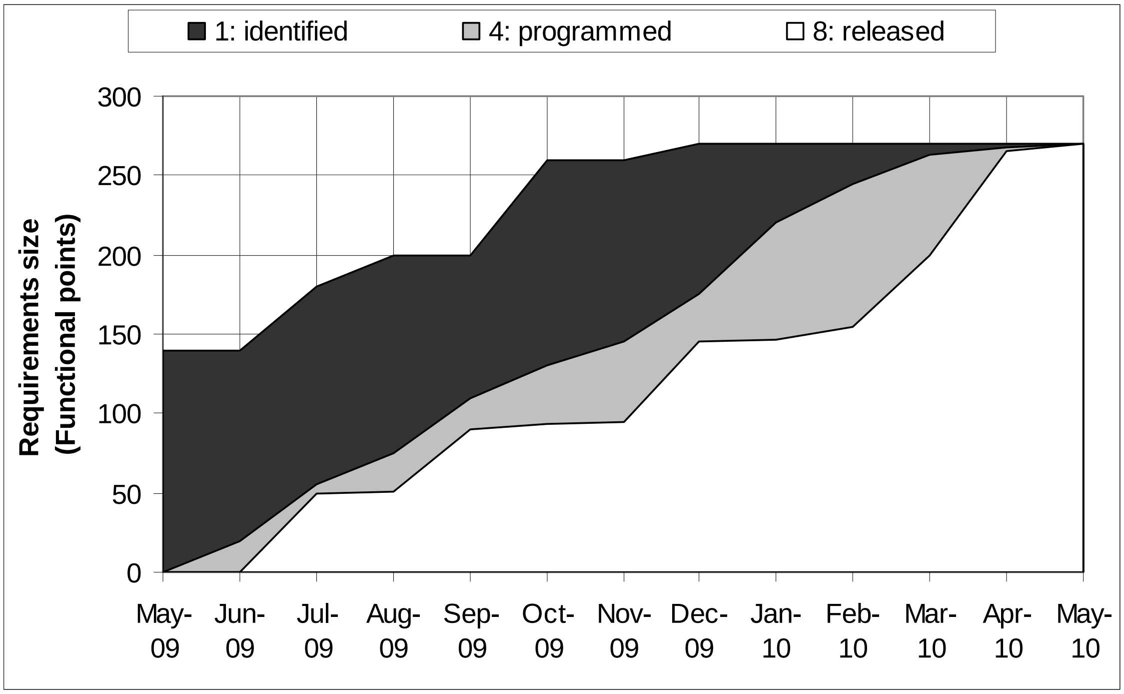

Figure 4. Dynamics of requirements size changing in different readiness states

Conclusion

This article reflects a method of formal description of the model of the software development project structure. In addition, problem of forecasting the dynamics of the project progress was formulated. The problem can be solved using developed project model. Developed model includes software product requirements state transition model. From mathematical point of view, we have got a model that has several important properties:

- software product requirements are objects that may have several states;
- objects state varies according to stated algorithm from generating state to the absorbing state;
- transition from one state to another is stated by certain transition probability;
- object always possesses some state for a period of time;
- new requirements can occur with the lapse of time, i.e. new objects can be generated;
- process is finite.

Mentioned properties allow to state that this process can be described by Markovian process model. In future we plan to use simulation techniques of Markovian process to solve stated problems of modeling project progress dynamics.

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Major Fields of Scientific Research: Software engineering, Production modeling, Project management, System modeling and simulation

SYSTEM OF SOFTWARE PRODUCTION MANAGEMENT

Galina Setlak, Sławomir Pieczonka

***Abstract**: The paper presents the concept of managing the production and maintenance of software in a medium-sized and large business, whose main aims are: modeling, designing and analyzing production processes, and monitoring resources and performed works. The process of making changes to software was used as an example to present the **System of Software Production Management (SSPM)**, which due to its capabilities to define processes and resources of a business as well as forms with automatic generation of a database schema can be used both as a tool aiding management at all manufacturing stages, with the use of various methodologies for creating software, and an integrated environment for building and running applications.*

***Keywords**: information system, application development, Petri nets*

***ACM Classification Keywords**: J. Computer Applications, J.6 Computer-aided engineering, K.6 Management of Computing and Information Systems*

Introduction

Software manufacturing is a complex process that requires performing numerous tasks at various stages of system building. The aim of a modern *System of Software Production Management* (*SSPM*) for large and medium-sized businesses is creating a *RAD* (*Rapid Application Development*) environment which will allow to design and implement successive tasks in the production process and manage data and resources associated with them. *SSPM* will make it easier to model, automate, control and monitor resources and performed works through distributing tasks and information among participants in a project according to established rules and procedures. Easy access to information and sharing it in a system will improve the process of communication between participants in a project of software production.

Figure 1 shows the structure of the *System of Software Production Management* which was designed in such a way as to allow, in a short period of time, without engaging teams of programmers, to create software solutions oriented to the needs of production process, at the same time reducing resources needed to provide technical support required by traditional systems.

SSPM as a system designed for businesses creating software with the use of both traditional and light methodologies, such as extreme programming (XP), must meet their functionality requirements at each stage of creating and maintaining a system (conception, analysis, design, implementation, testing, deployment, technical support etc.), which can be described as follows:

- managing production processes,
- capability to define and modify a process (*Process Definition Module*), data and user interface (*Forms Definition Module*),
- synchronous performance of tasks and processes,
- support for rule-based manual and automatic tasks,
- support for sub-processes,
- algorithm for assigning a person to perform a task based on roles and abilities,
- list of user tasks, managing and displaying a list of tasks,
- definition of the structure of a business, resources (users, products, versions etc.), relations between them, roles (*Resources Definition Module*),
- support for handling emergency situations (escalation, notification),

– informing about critical data in the form of reports,
– tracing and displaying a set of defined reports, detailed and summary information about data describing production process, activity, progress in performing assigned tasks,
– system monitoring, registering events and changes in the system,
– administration of the system, user accounts.

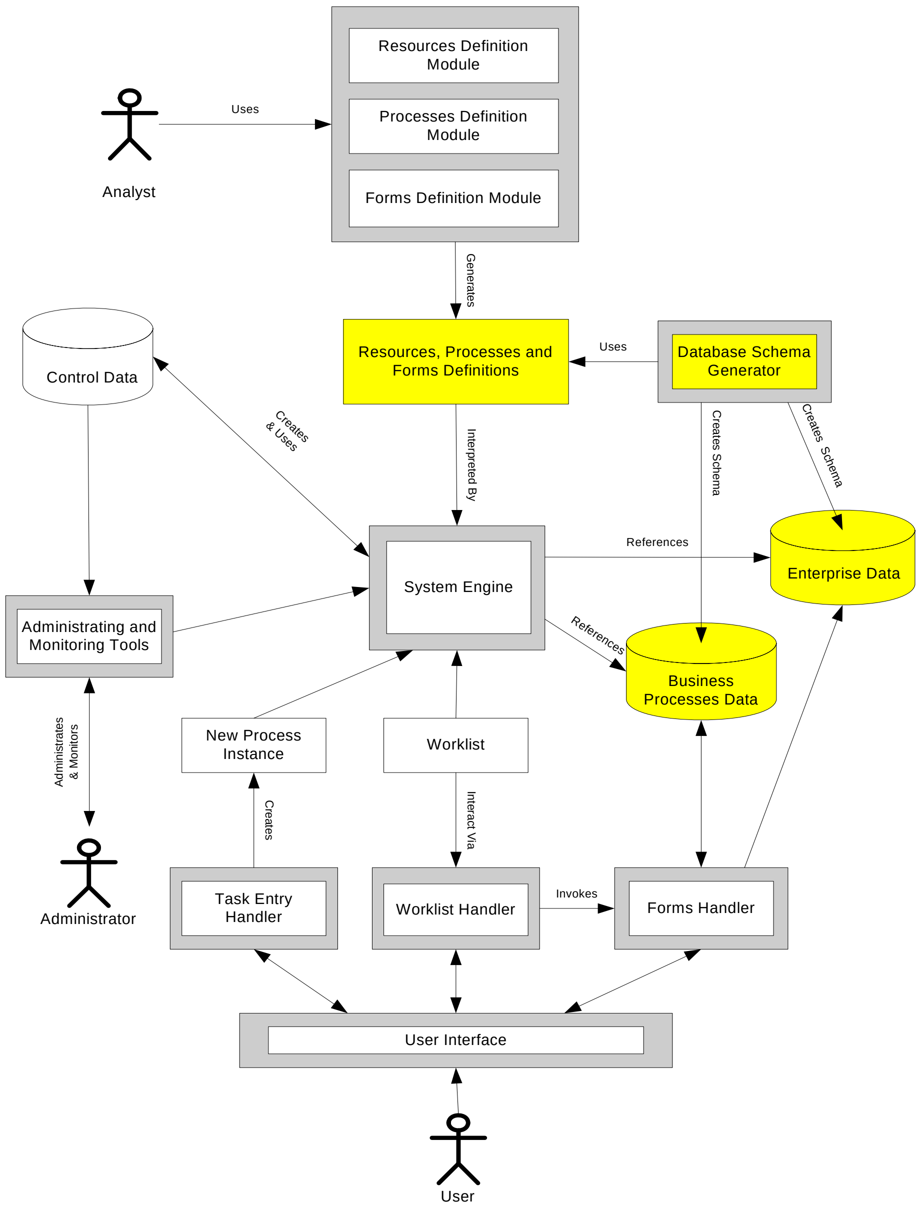

Figure 1. Context diagram of the System of Software Production Management (SSPM)

Making changes to software was used as an example presenting the application of the *SSPM*. Management of changes is a key element in manufacturing information systems and its aim is to increase the quality and effectiveness of activities. The tools (processes) created in the *SSPM* should ensure steady and efficient performance of tasks making use of the abilities of all participants in a project.

Figure 2 shows a simplified diagram of this process, from the moment of Requesting a change by a person related to the product, e.g. system user, tester, programmer, as a result of an error detection or request of adding new functionality to the system, up to the moment of completing tests confirming the correctness of the changes made.

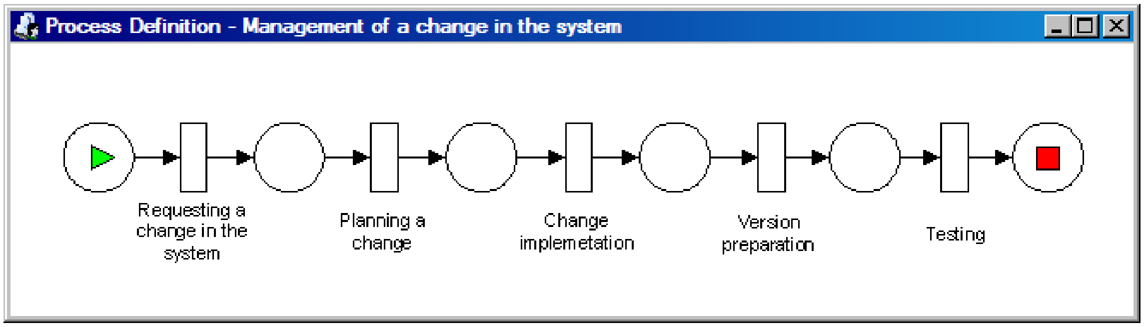

Figure 2. Simplified diagram of the process Management of a change in the system

Process Perspective

A Petri net was used as a language of process description in the *SSPM*. Classic Petri nets were proposed in the 60s by C. A. Petri [Petri, 1962]. Since that time, they have been used to, among others, model and analyse various types of processes, such as communication protocols, hardware, in-built systems, industrial systems, business systems.

The most important reasons for which Petri nets were chosen include:

- *graphical representation*. As a graphical language it is intuitive and easy to use, and can be understood by end users;
- *formal description*. The process of software production management has an accurate definition as Petri nets are formally defined;
- *extensibility and flexibility*. All constructions of modern management systems can be presented in the form of Petri net;
- *analysis*. Possibility of using various techniques in an analysis of the properties of a process that are provided by Petri nets allows to check, among others, waiting and response time, whether network is secure, whether there are any deadlocks.

Classic Petri nets were extended, forming new classes of coloured nets, and over time – hierarchical, logical ones. These extensions were of great importance, especially for very complex systems in which an important role was played by such factors as data and time. Examples of application of such extensions can be found among others in [Van der Aalst, 1994], [Van der Aalst, 1995], [Van der Aalst, 1996]. For the purposes of the *SSPM*, the *WorkFlow* (*WF-net*) class of net was used. The description of manufacturing process using this class of Petri net appears to be quite simple: *tasks* are presented as *transitions*, *states* and *conditions* as *places,* and *cases* are described by *markers*.

A formal definition of *WorkFlow* nets can be found among others in [Van der Aalst, 1998]. This chapter presents only two most important requirements that this net must meet.

- *WorkFlow* net has one input place *i* (in diagrams it is represented as a circle with triangle inside) and one output place *o* (represented as a circle with square inside). A *marker* put at input place corresponds to a *case* that is to be handled. A *marker* put at output place means a *case* that has just been handled.
- In *WF-net* there are no so called dangling *places* or *transitions*. Each *task* and each *condition* must be taken into account during processing a *case*. In other words, each *transition* and each *place* should be on one of the paths running from input place to output place.

Definition of the process of *Management of a change to the system*, used as an example here, created in *Process Definition Module* is shown in figure 3.

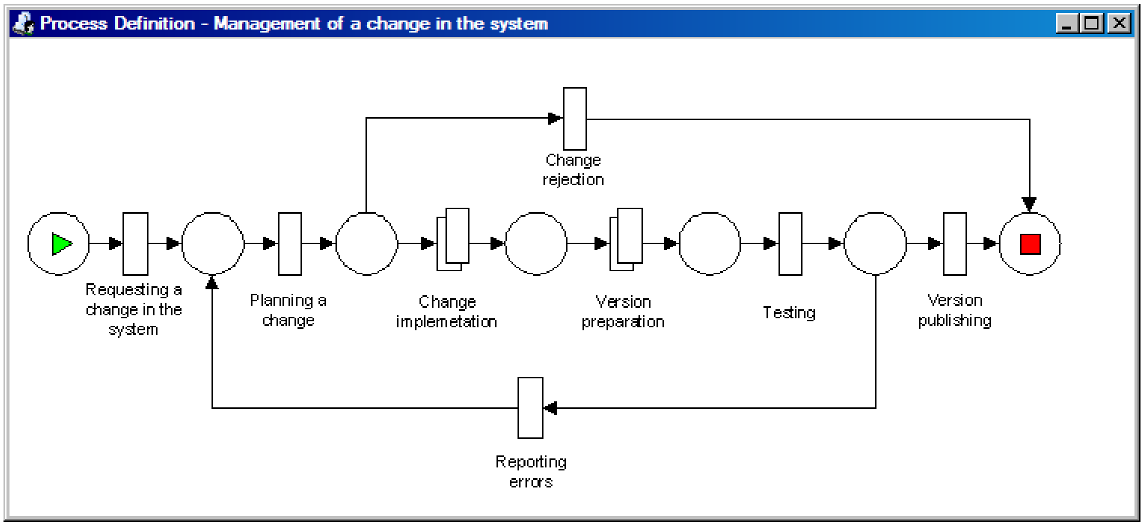

Figure 3. Diagram of the process Management of a change in the system

The process presented consists of both manual tasks, such as *Requesting a change in the system*, *Planning a change*, *Testing*, *Reporting errors*, *Change rejection*, *Version publishing*, and sub-processes (complex tasks), such as *Change implementation*, *Version preparation*. It is also possible to define automatic tasks.

Management of a change in the system (*marker* at input place) begins with execution of the task *Requesting a change in the system*, made by any user of the system, and then the task *Planning a change*, which consists in, for example, specifying in which version of the product a change should be made or deciding if a change should be made in the first place (change approval). If the change is not approved, the task *Change rejection* is performed, after which *marker* will be at output place and the process will be completed. If the change is approved, the sub-processes *Change implementation* and *Version preparation* will be then performed, followed by *Testing*. If testing is successfully completed, *Version publishing* follows and the process is completed, otherwise the task *Reporting errors* is performed, which leads to repeating the tasks performed starting with the task *Planning a change*.

Figure 4 shows the diagram of the sub-process *Change implementation*. When a change is to be introduced in the system, *marker* is at input place. Performance of the task *Implementation of changes* means execution and approval of changes. Then the task *Development testing* is performed. If it is completed successfully, the task *Code reviewing* will be then performed. If testing or code reviewing is not completed successfully, the task *Reporting errors* is performed, and it is necessary to make additional changes (*Change correction*). The task *Change publishing* is the last task of the sub-process (*marker* is at output place) and can be performed only if testing and code reviewing is successful.

Figure 5 shows the diagram of the sub-process *Version preparation*, which precedes testing. When a new version of the product is to be installed, *marker* is at input place *Version preparation*. It is then possible to perform the task *Preparation of installation parameters*, in which properties of an installation environment will be defined, such as for example, on which computer the product is to be installed, versions of operating system and other programs working with the product installed, type of the installation (from scratch, upgrading etc.)

The task *Starting the installation* can be performed after the task *Preparing installation parameters* is completed or directly, after staring performing the sub-process *Version preparation* (installation parameters are not necessary to define the way of installation or they are known at the moment of starting the sub-process, e.g. we use the setting of previous installation). Performance of the task *Starting installation* sets the status of the process to *Installation is under way*. The last task *Finishing the installation* completes the sub-process of installation (*marker* will be at output place *Version installed*).

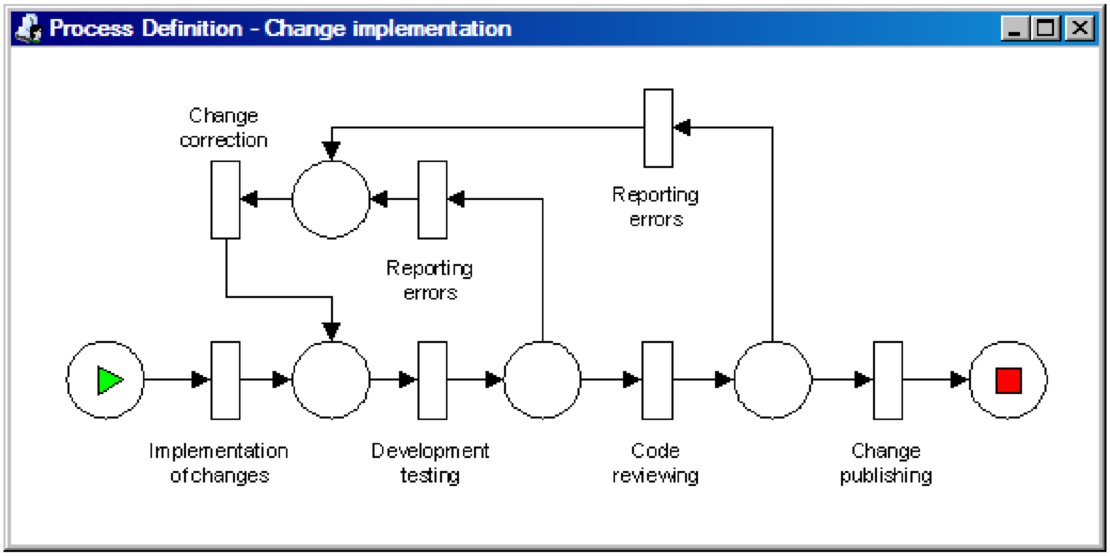

Figure 4. Diagram of the sub-process *<u>Change implementation</u>*

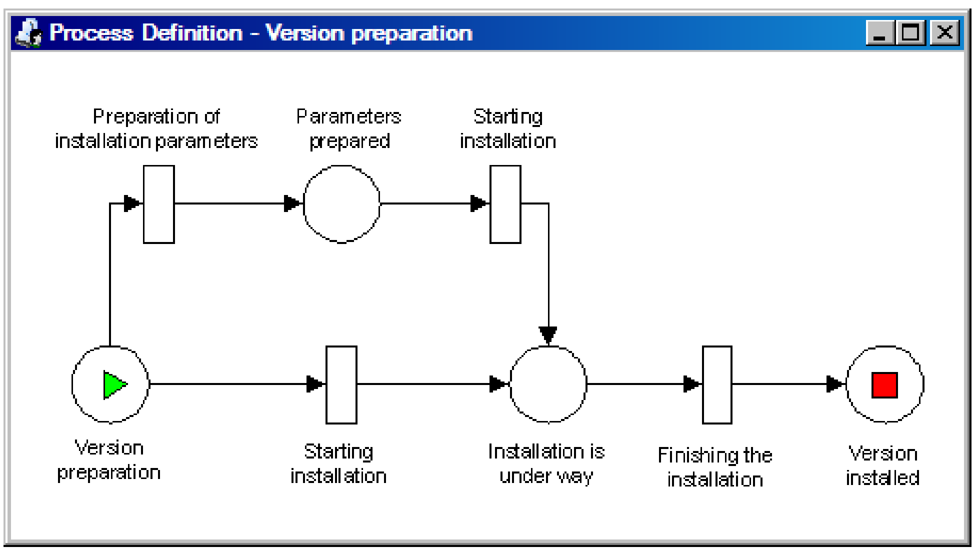

Figure 5. Diagram of the sub-process Version preparation

Resource Perspective

In many systems of software production management, process structure modeling is separated from an organizational model of a business and resources that are used. This division results from, among others, high complexity of a system and possibility of modifying a process without necessity to change the organizational model of a business. In this case, definition of a process consists in specifying what tasks are to be performed and in which order, without specifying the resources of a business that are used in this process. For assigning resources, the *SSPM* uses an algorithm based on definitions of the structure of a business, roles and skills and relation between them created in *Resource Definition Module* and directly connected with the definition of a process. Each task has a person assigned to perform it.

Figure 6, window *Task properties* (field *Assign to:*) shows how the task *Preparation of installation parameters* is assigned a person to perform it. In the example shown, the function **getResourceWithExperience()** assigns a person to perform the task based on two arguments, where:

- **getResourcesForRole("Installer")** is a set of all possible resources for the role *Installer*.
- **"Senior"** is a skill required from the resource.

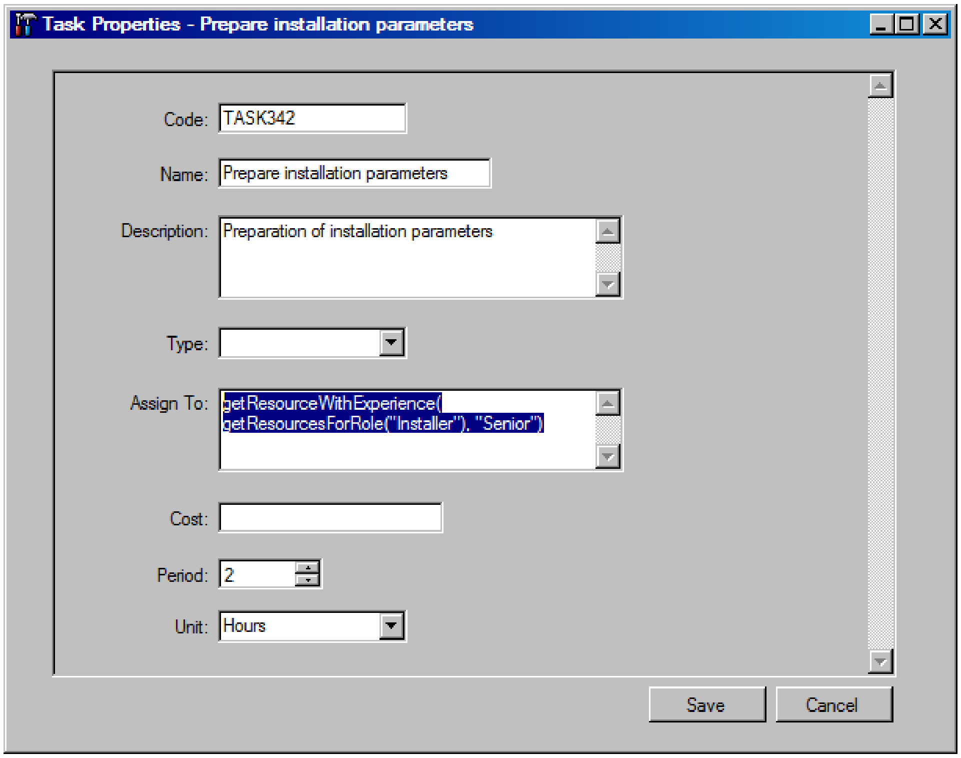

Figure 6. Window of properties of the task Prepare installation parameters

Data Perspective

Each manual task must have a form defined (*Form Definition Module*). During defining a form we can use both simple elements, such as text fields, edition fields, buttons, drop-down lists, panels, selection options etc., which are usually associated with single fields in database tables, and complex elements, such as tables allowing a simultaneous access to many records in a database. Definition of a database can be generated (modified) based on the elements in a form.

Fig. 7 shows a launched form for the task *Requesting a change in the system.* Each launched form (task) has additional in-built button bar (*Save, Finish, Calculate, Print, Cancel, Properties*) which allows to perform on a task such actions as saving partial changes, approving and finishing performance of a task, or cancelling a task.

Conclusion

The chapter describes the *System of Software Production Management* in a large and medium-sized business, using the process of managing changes in software as an example. Due to its capabilities of creating processes, defining forms with data, and automatic generation of database schema, the *SSPM* ranks among *RAD* (*Rapid*

Application Development) systems and can be used not only as a tool for software production management but also as an integrated environment for creating and running any types of applications.

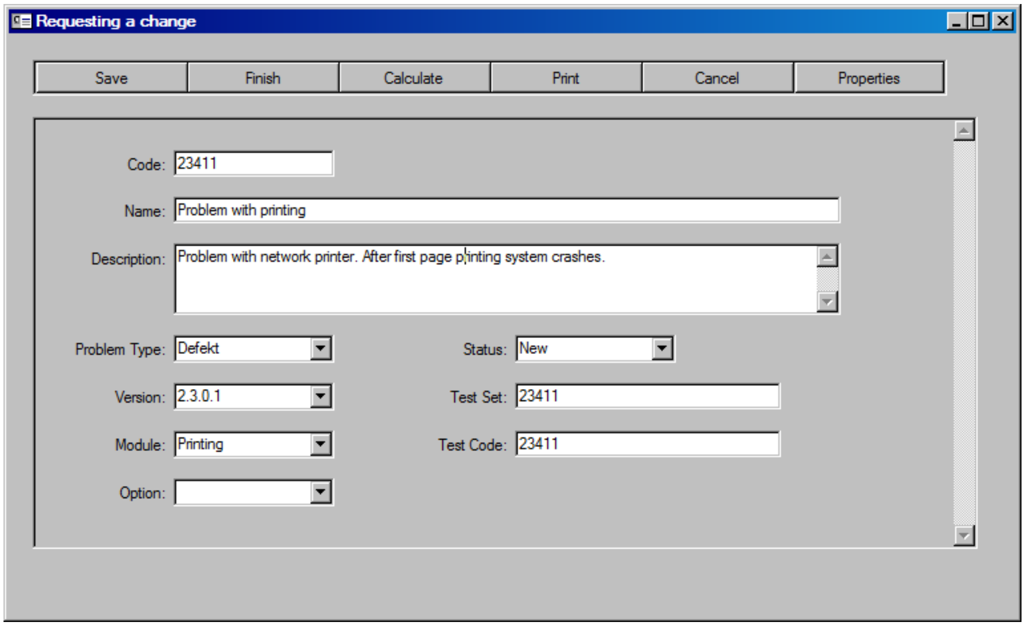

Figure 7. Window of a launched form Requesting a change defined for the task Requesting a change in the system

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Major Fields of Scientific Research:

Knowledge Representation and Management

SELECTION OF KNOWLEDGE MANAGEMENT MODELS AND USE OF THE INTRODUCTION OF TELE WORKING MODEL OF DISABLED

Tatjana Bilevičienė, Eglė Bilevičiūtė

***Abstract**: The main aim of knowledge management is the knowledge of substantial developments relationships, adaptation, learning facilitation, development and innovation support. Knowledge management is concerned with innovation, peer relationships, ideas, competencies, structures. Knowledge management promotes and enhances the dissemination of experience and choice of optimal solutions. Most knowledge management processes in one way or another are concerned with information management major elements: information technology and information systems. Fundamentals of knowledge management could be used for organisation of telework of disabled persons, solving economical problems of state. Knowledge management could help to increase productiveness of employees, expanding sources of reachable for them knowledge. During the examination of the disabled telework opportunities in Lithuania, T. Bilevičienė found that the current disability vocational rehabilitation and employment system does not provide people with disabilities by telework. However, research has shown that this system can be modernized and adapted the disabled telework model, the experts mentioned changes. These changes show that the necessary human resources management and knowledge management models are for synthetic application. In their article authors examine knowledge management models and its structure of vocational rehabilitation opportunities for persons with disabilities, organization of telework.*

***Keywords**: knowledge society, knowledge management model, disabled persons, telework.*

***ACM Classification Keywords**: K.4.2. Social issues - Employment*

Introduction

Transformation of modern society into a knowledge society and the transition to a knowledge economy, a completely new global society and economy, which requires different management than the previous principles, skills, abilities, competencies. Competition has increased and deepening international economic cooperation, development, public priorities, values and attitudes change - that such a transformation, giving rise to a new phenomenon - a knowledge-based economy. The knowledge economy focuses on a man, his skills, knowledge and opportunities for their use.

Knowledge society and knowledge economy challenges change the management models for a scientifically based analysis of a country or organization merits and drawbacks of the strategic advantage in the development area. Elements of information and knowledge management are in each of the modern field of management: process management, time and space management, change management, crisis and conflict management, organizational learning in management, quality management, and others. Information and knowledge management of information science and communication system of complementary managerial disciplines of information science is going perfectly to the modern management concepts. It focuses on all aspects of knowledge-related activities and processes which improves the firm's ability to function effectively. The most knowledge management processes in one way or another are concerned with information management major elements: information technology and information systems. Dissemination of information technology is changing the nature of the quality of the work specifics.

In knowledge society the public service management is becoming a common part of the market and begins to integrate with the private sector. Seeking to use the efficiency of public sector management techniques, which originate from the private sector, these methods differ only in the goals.

The EU is actively implementing the integration of disabled persons in the labor market projects to use ICTs and distance work. Telework in certain circumstances constitutes a useful option for disabled people. This is especially important for people who become disabled have already gained some practical skills and competencies. Employers often provide a telework plans as a cheap alternative workplaces. The telework provides possibility of expanding the potential labor and affordable workspace [Bailey, Kurland, 2002]. Knowledge management is a management discipline that seeks to increase aid effectiveness by adapting the business people, processes and technology synergies. Knowledge management principles can be used for people with disabilities telework, addressing the country's economic problems.

The importance of knowledge management practices

Modern management, as well as the general public itself is a mixed and heterogeneous. There is a growing and changing management methods and methodological arsenal diversity. Information management approach integrates many elements of the holistic education space. In the information space the most diverse social and economic life principles and models are formed and exist [Augustinaitis, 2005].

The effective knowledge management organization depends on technology, techniques and human interaction [Bhatt, 2001]. The former only addition to the information and technology management, knowledge management has evolved into a distinct and autonomous region, the fundamental purpose of it is the organization's resources intangible as intellectual capital, knowledge workers, organizations and other images management. New information technologies have facilitated a number of global business operations and the types of learning, the emergence of roadside business to a new level, giving the growing importance of knowledge. Knowledge of the different parts into a strategic management of intellectual capital brings people to the new boundaries of knowledge management practices in the information age. Knowledge management is the optimal theoretical and practical knowledge into business processes - in order to achieve the most durable advantage over competitors and can be realized by the firm's stakeholders - investors, workers, managers of higher profits, and hence the overall public good. [McGinn, 2001].

N. Thom and A. Ritz [Thom, Ritz, 2004] indicates that the response to past age of the last decade took place in the structures and processes of change highlights the need for public sector human resource management. Public sector organizations, human resources are a key element to any deliberate human performance, the main changes should be made to public sector performance, the most important and sensitive resource areas. Knowledge economy and knowledge society in terms of human resource development and effective human resource management theory of mobility models for the coordination and efficiency of their practical application depends on the ability of organizations to integrate human resource management and knowledge management models.

The main aim of knowledge management is knowledge of substantial developments relationships, adaptation, learning facilitation, development and innovation support. Knowledge management is concerned with innovation, peer relationships, ideas, competencies, structures. Liudmila Lobanova [Lobanova, 2008] argues that it is appropriate to talk not only about the human resource management models for the transformation of knowledge management models, as far as their means of rapprochement or synthesis. In knowledge economy and knowledge-based societies the human resource development and effective human resource management theory of mobility models for the coordination and efficiency of their practical application will depend on the ability of organizations to integrate human resource management and knowledge management models.

Disabled telework model

In Lithuania number of patients with various diseases and socio-economic problems is increasing, so the number of people with disabilities is increasing too. These circumstances require assumptions correctly and efficiently to provide social protection for disabled people and bring them to work, restoration of independence and integration into society. In Lithuania, like in other EU countries, the transition from the protective and declaratory assistance to those disabled people empowerment techniques is establishing themselves in the social integration model for people with disabilities [Dromantienė 2005]. Disabled persons in order to restore or enhance their employability, professional competence and ability to participate in the labor market are providing by vocational rehabilitation services.

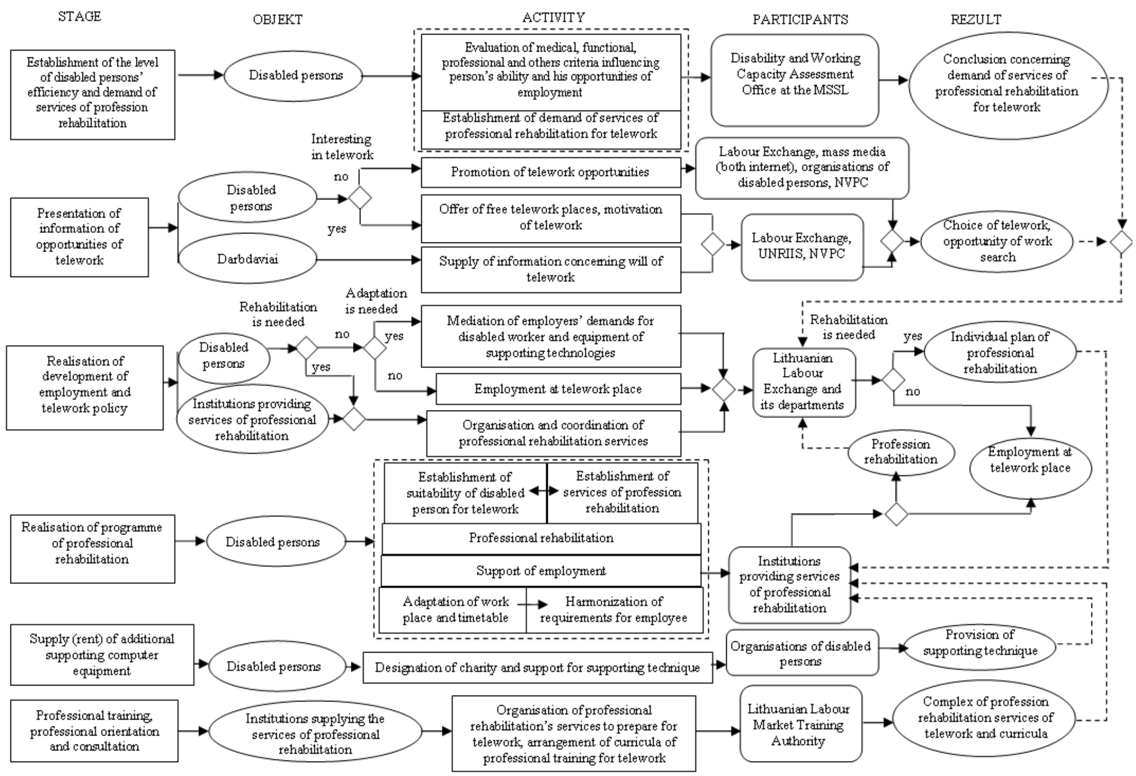

Figure 1. Organizational model of disabled persons' telework

Telework and the recruitment of tele workstations in the current Lithuanian vocational rehabilitation system are foreseen. However, this system can be used as the basis for the development of remote working model for people with disabilities. To sum up the theoretical and empirical studies, we can identify six major disability distance jobs stages: the level of work disability and vocational rehabilitation services, the need for identification, the promotion of teleworking, remote working motivation, and fitness for a remote job evaluation, job requirements and job opportunities for disabled laws, training, recruitment and maintenance work. In view of the Lithuanian people with disabilities the vocational rehabilitation and employment opportunities system was developed with disabilities telework model [Bilevičienė, 2009]. The model scheme is presented in Figure 1. Design of it was discussed with disability rehabilitation and professional integration, employment practitioners.

During 2009 January-February authors carried out the analysis of Lithuanian disabled vocational rehabilitation and employment opportunities system and the Lithuanian people with disabilities vocational rehabilitation and employment applications by persons with disabilities the working model of telework [Bilevičienė, 2009]. The experts interviewed persons with disabilities in special organizations; who are responsible for vocational rehabilitation of disabled persons, social work professionals - academics, business representatives. Expert analysis of the survey results helped to determine what they believe change is needed in each disability vocational rehabilitation and employment system stage for the successful application of a single disability organization working distance model (see Table 1).

Table 1. Lithuanian disabled vocational rehabilitation and employment system changes needed for application of disabled persons' telework model

Stage	Demand	
	New programs	Additional skilled workers
1. Establishment of the level of disabled persons' efficiency and demand of services of profession rehabilitation	Needed	Needless
2. Presentation of information of opportunities of telework	Needed	Partly needed
3. Realisation of development of employment and telework policy	Needed	Partly needed
4. Realisation of programme of professional rehabilitation	Needed	Partly needed
5. Professional training, professional orientation and consultation	Needed	Partly needed

The analysis of these changes shows that there is the necessity for new programs, procedures, staff training, acquisition of new competencies, so there is the necessary of human resources management and knowledge management models for synthetic application. Lithuanian vocational rehabilitation system for people with disabilities could use the telework for purpose to organize the work using only the basic principles of knowledge management: knowledge creation, knowledge dissemination, knowledge utilization. Analysing the disabled telework model we can notice that a knowledge management model is to be made for continuous updating of knowledge and feedback.

Selection of knowledge management model

Giorgos Papavassiliou [Papavassiliou at al., 2002] argues that business process management can be distinguished in business management tasks and knowledge management tasks. Similarly, in public management process we can identify the organization's management and knowledge management tasks. Knowledge management describes the tasks of knowledge creation, storage, application and distribution business (management) during the process. Knowledge management in organization is understood as knowledge-building, coupled with new products, new methods and new organizational behavior. This requires a radical organizational change. Knowledge management should to ensure continuous flow of information interaction. Knowledge management is the activity that aim is the improvement of the current model of an organization's knowledge processes and its outcomes [Goldman, 2009].

Knowledge management is a complex process. Sandra Rodney McAdam and McCreedy argue that there are many definitions of knowledge management models. The examination of an existing system definitions and classifications of KM show a wide spectrum of Viewpoint. They examined the different knowledge management models from I. Nonaka, K. Takeuchi and M. Demeresto adaptive, P. Clark, N. Stauntono model. These ranges from the more mechanistic to more socially orientated. The mechanistic type of definitions and classifications assume an intellectual capital approach (knowledge viewed as an asset) while the social type assumes a social constructionist approach where knowledge is constructed in the social relationships within organisations [McAdam, McCreedy, 1999]. On Figure 2. (A) you can see the proposed modified M. Demeresto knowledge management model that uses a holistic approach to the scientific and social knowledge management paradigms. This model takes a balanced approach between scientific and socially constructed knowledge. Also the uses of KM are viewed as both emancipatory and as business oriented. Knowledge streams in this model are not only coherent, but feedback is forecasted in such knowledge system. The black arrows show the main knowledge streams. According opinion of artickle's authors, such model could be properly applied for processes of knowledge management in disabled persons telework organisation system.

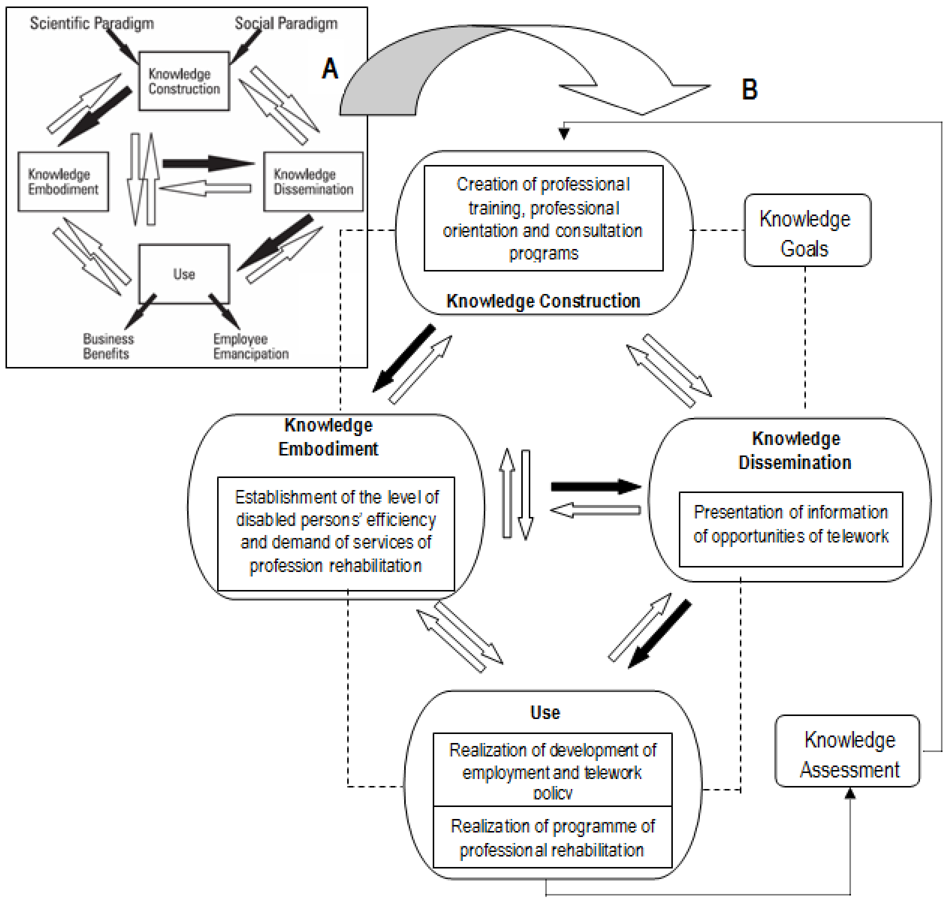

Figure 2. Modified version of Demerest's knowledge management model [McAdam, McCreedy, 1999] (A) and its application to persons with disabilities telework (B)

Adriana Maria Ortiz Laverda [Ortiz Laverda at al., 2003] also examines the set of knowledge management models. Among them can distinguish the Probst model, called *The building blocks of knowledge management*, involves eight components that form two cycles, one inner cycle and other outer cycle. The inner cycle is composed by the building blocks of Identification, Acquisition, Development, Distribution, Utilization and Preservation of knowledge. These blocks not a lot differ from model of Rodney McAdam and Sandra McCreedy. There are two other processes in the outer cycle, Knowledge Goals and Knowledge Assessment, which provide the direction to the whole Knowledge Management cycle. Knowledge Goals determine which capabilities should be built on which level, Knowledge Assessment completes the cycle, providing the essential data for strategic control of Knowledge Management [Probst, 2002].

Knowledge management principles are still rarely used in the development of disabled persons's rehabilitation process. Disabled telework model implementation needs to start new programs for all persons with disabilities telework stages. Bearing in mind that the programs can be successfully applied only to qualified personnel, their training should be organized in parallel. Each stage of software development and professional training must be linked with other similar-step process. New management program must be subject to professional rehabilitation facilities and a vocational rehabilitation process. It must be programs to provide continuous updating of professional skills development, not only in connection with developments in ICT and management development, but also with the work.

On the basis of knowledge management models examined in this article the authors has developed a knowledge management model, which can be applied in disabled telework process (see Figure 2. (B)). In this model, organisation stages of people with disabilities telework are associated with Rodney and Sandra McCreedy McAdamas model processes. This model is added by Probst model external processes: Knowledge Goals and Knowledge Assessment. The model provides continuous feedback for all stages. This is because the telework organization of people with disability is associated with the application of ICT. These technologies and the development of continuous improvement require a permanent disability telework, improvement of programs and methodologies.

Knowledge Goals determine which capabilities should be built on which stage. These capabilities must be established for the examination of persons with disabilities telework areas in the section ACTIVITY and PARTICIPANTS (see Figure 1). For example, the *Establishment of the level of disabled persons' efficiency and demand of services of profession rehabilitation* stage in basic skills - to people with disabilities in particular the remote computerized fitness for work, because teleworking can be recommended for people with a disability level of not more than 25 percent. This is often the only way available to them working. At the same time, the *Disability and Working Capacity Assessment Office at the MSSL* staff must be able to determine whether a person with a disability such work will have any harmful effects. Knowledge Assessment is apllied in the assessment process, as the result of action against the entire update cycle. This process is of paramount importance for people with disabilities working knowledge of organization management model because it allows not only the feedback system, but after each cycle to assess the performance and result in a higher increase, an improved level of knowledge creation.

Conclusion

Knowledge management is concerned with innovation, peer relationships, ideas, competencies, structures. This supports the management of individual or group learning, promotes and enhances the spread of experience, failures and best practices sharing, selection of optimal solutions. Knowledge management principles are still rarely used in the development of disabled persons' rehabilitation process. However, the authors of studies show that the current system of vocational rehabilitation of persons with disabilities can adjust the telework organization only through knowledge management principles.

T. Bilevičienė has created the telework model of disabled that is suitable for Lithuanian people with disabilities and improvement of vocational rehabilitation system. Total disability telework scheme is applied for the determination of disability for work on all vocational rehabilitation and employment stages. This model should be applied as a single system, which provides a constant feedback. According to experts, the model can be successfully implemented to improve the current system of rehabilitation of disabled persons. To this end, there is necessary for the new program and new skilled workers managing the knowledge management techniques.

For disabled telework knowledge management can be applied the McAdamas Rodney and Sandra McCreedy modified version of Demerest's knowledge management model. This approach needs to be supplemented by

Probst model external processes: Knowledge Goals and Knowledge Assessment. It is collected not only support of the feedback system, but after each cycle to assess the performance and result in a higher increase, an improved level of knowledge creation.

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ADVANCED DECISION MAKING FUNCTIONS AND SOME METHODS OF INFORMATION PROCESSING FOR SOCIO ECONOMIC CLUSTERS

Anatolij Krissilov, Viacheslav Chumachenko

***Abstract**: New organizational and algorithmic instruments in the area of municipal (and regional) management are described. There is a brief overview of such tools as effective methods of quantitative decision support and the territorial cluster creation. Also some ideas are presented on how the information exchange between territorial clusters' participants might look like.*

***Keywords**: goals of city development, decision grounding, dependent features, territorial cluster.*

***ACM Classification Keywords**: H.1 Models and Principles – H.1.1 – Systems and Information Theory – General Systems Theory, I.1.4 Development Simulation.*

Introduction

Problem of large city formation, in its entering the path of rational and harmonious development is, as always, quite important. City, as a very complicate system needs authorities, functions of which are no less complicate than the managed system itself. This take place not only for the municipality, but also for major, for the city council, council of trade unions and for other managing and supervisory bodies.

Let us consider the difficulties that appear in the management of a large city with population of over a million inhabitants, and each of them has own requests and needs.

The work of city authorities involves, as usually, a number of challenges:

• budget planning; legislative aspects;
• distribution of resources (human, financial, material, etc.);
• support the state of operability of urban technical (and other) infrastructure systems;
• planning further optimal development of the city;
• monitoring of the municipality' activity as a complex system;
• creation of the optimal decision making system in urban governance in general;
• political, environmental aspects, social affairs, and much more.

Strictly saying just due to our objects are very complicate, we have to use the system representations, the methodological approach to system analysis, etc. Among these tools and the problems of certain structural-and-functional mechanisms creation, the main stages are: goal-setting, self-determination, primary structurization, etc.

Work with the municipality's goals and some new mechanisms

Almost all directions of municipality's activity can be reflected as the structure with a lot of vectors or directions of work. The main problem here is the great numbers of these vectors are opposite and compete with each other. Such competition is not always useful for the city. Talking about the tree of the aims in the work of the city municipality and the city mayor it is necessary to define two groups of aims:

1) the improvement of the city and people prosperity;
2) the development of the social production, and the increasing of its effectiveness.

Partly these purposes supplement each other, but there are some "tight" places, where they compete with each other, e.g. in getting financial resources, official personnel's attention, human resources, area etc.

For this reason the third aim appears:

3) balances solving of previous two aims: creating of circumstances, strategies and plans. The realization of them could provide the harmonious advancement of society to their aims.

The municipality has to elaborate its own organizational instrument to control the balance of all these divisional parts and for resources distribution between them. All these things have to be done for the reducing of the negative return influence in this system. So, the first step must be to transform the conflict mechanism (confrontation) into the cooperation mechanism, using this type of mediator. And the next stage will be the straight collaboration. The working out of this type of mechanisms has to become one of the first mayor's and municipalities' assignment.

The next key factors can be related to them:

- economical (facilities, bonuses, fines etc.);
- organizational (new structures, agencies, bureaus, associations etc.);
- administrative (orders, regulations, instructions etc.);
- informational (announcements, popularization, clarifications, TV programs etc.);

So, summarizing the main aim of the cooperation between the mayor and municipality in city we must tell that the good and equal collocation of all important structures has to be the result of "the top manager's" work.

Decision making rules for situations both with independent and dependent features

Preliminary Notes

A lot of tasks, due to automatization and algorithmization different kinds of activity, deep computing and so on, – need now the effective decision rules application. There are dozens of works devoted to this problem, among them, particularly, [Banerji, 1978], [Schlaifer, 1979], [Gladun, 2000], [Zagoruiko, 1976], many oth.

There are certain works describing data processing by means special spaces, e. g. [Krissilov V., 1998], [Krissilov, 2005]. It may be seen, that using geometrical explanation and imagination is very fruitful approach in various AI tasks and in complicated data processing.

Various decision functions and rules, that are applied in tasks of pattern recognition and support of the administrative decisions, are constructed in the assumption of independence of attributes (features) being used for description of analyzed and/or recognized objects. Desire to take into account dependence between parameters leads to the very large expenses of time and memory, or, at the best, comes to final fixing, for example, only of pair dependences. Besides it happens seldom when users or developers have the information on real values of dependences features' presence or absence from each other in various processes, classes etc.

At the same time it is difficult to imagine a task, in which the description of analyzed objects is made by means of parameters independent in aggregate. Especially it looks clear by putting medical diagnosis [Popov, 1971], in solving the environmental monitoring tasks, etc. In these last cases, e. g., analyzing a natural situation or estimating anthropogenous influence, the expert operates with such characteristics, as moisture of ground, water table level etc., are dependent from each other certainly.

Then if we have the problem to build full-scale monitoring system (and while another tasks solving) alongside with other means of processing of the information, it is necessary to use decision functions, which are able to take into consideration relations and dependencies between the features without using a big system resources.

Decision Functions working with independent features (1st learning stage)

Let some *k*'s object, having evaluated or recognized, is described by *n*-dimensional vector [Krissilov, 1962, 1984]

$$f_k = \{\nu_1, ..., \nu_i, ..., \nu_n\},$$

where - $i = \overline{1, n}$ is number of feature;

- ν_i is the measured value of ***i'***s feature in the ***k'***s object.

Dealing with classification problem we can obtain (as result of learning stage) the matrix

$$C_n = \|p_{ji}\|,$$

where - j is number of class;

- p_{ji} is probability of i's feature in j's class.

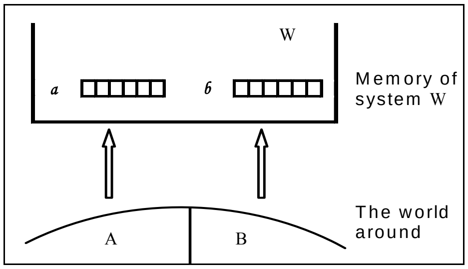

Figure 1. Creation of the memory (1st stage)

So, we see, that objects recognizing have statistical nature. 1st step in learning is shown on Fig. 1.

The pattern recognition stage is provided by means of some decision rules. One of them, namely the rule maximizing a right classification probability [Krissilov, 1984, 2000] can be proposed for our problem solving. This decision function is as follows:

$$f_k \in M_j / R_f = \max_j P(M_j / f_k) = \max_j \prod_i^n p_{ji}^{(\nu_i)}, \tag{1}$$

where - f_k is k's unknown object which must be classified;

- M_j is class with number j;
- $P(M_j / f_k)$ is probability of M_j when this concrete set of features f_k is presented;
- $p_{ji}^{(\nu_i)}$ equals to p_{ji} if $\nu_t=1$, and to $1-p_{ji}$ if $\nu_t=0$. And it is probability of measured value ν_t, if the feature isn't binary.

In expression (1) the value R_f, being found as the maximum of the value $\prod p_{ji}^{(\nu_i)}$ for various classes (j changes from 0 (unknown class!) up to S), – shows the class that can generate the present vector f_k with the most probability, – in a case the features are independent each from another.

But there are a lot of tasks, as it was told, where depending features describe the objects. So we have to construct corresponding decision rule. For these purposes the second learning stage must be introduced.

Decision Function Strengthening (2nd learning stage)

The curves of probability distribution of concrete characteristics of examined objects are applied to this task solution. These curves are obtained as results of the additional training stage by means of the representative choosing of objects/classes should be recognized.

Showing known objects from class M_j to recognizing system, we can find for each f_k the value $x_{kj} = \prod_i^n p_{ji}^{(\nu_i)}$ and fix the probabilities $P(x_{kj}/M_j)$ and organize its memory consequently (see Fig. 2).

Then the following decision rule may be proposed:

$$f_k \in M_j / R_\Sigma = \max_j P(x_{kj} / M_j), \tag{2}$$

-- accordingly this function of decision is made on the ground of a maximum probability of belonging the present input gamma of features (given f_k) to definite class, and comparing these probabilities for all classes.

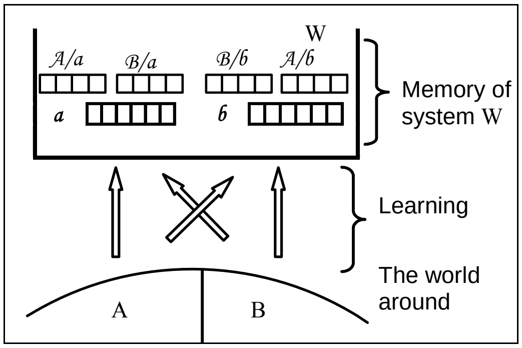

Figure 2. Second learning stage.

It needs to be noted, that we measure in this case the values of probability obtained by using only one line from matrix C_n, – for each class, i. e. using the sample of one class only.

The next our step can be generalizing this approach by means of extending the number of samples, of lines our matrix, being included in process, using for these purposes similar samples of classes and, lastly, all lines from matrix C_n entirely.

Then final version of decision rule looks as follows (in this expression $r = \overline{1, S}$):

$$f_k \in M_j / R = \max_j \prod_{r=1}^{s} \left[P(x_{kr} / M_j) \right], \tag{3}$$

Thus we obtained the multidimensional decision function (MDDF) that allows using deeper data in comparison with previous rules of decision, as it is shown at Fig. 3.

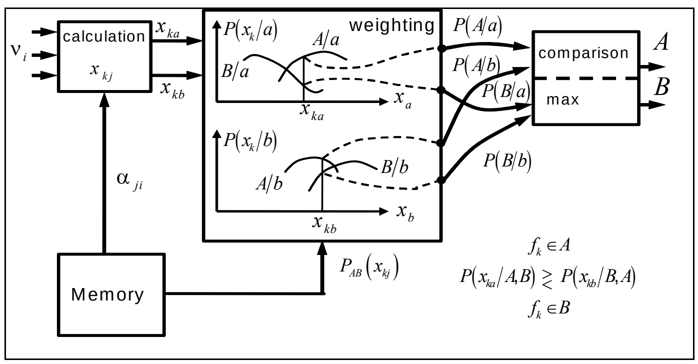

Figure 3. Using the probability distribution curves for advanced decision.

MDDF Interpretation

Multidimensional Decision Function' using and applying corresponding procedures form/build the memory of recognizing system in manner of holographical one, distributed and developed.

Indeed, in cases when decision rule in expression (1) is realized, then each class' sample in memory unit consists information regarding that class. This information is represented by features' probabilities for objects belonging to given class.

When decision function expressed by (2) is realized, then the information which forms each sample becomes more complicated. It includes now the curve of probability' distribution of appearance certain values x_{kj} (results of evaluation) being measured/ weighed on definite line of matrix (with number j) by showing objects from corresponding class. These curves of probability distribution (for all our classes), as it was told, are obtained as results of the additional training stage showing the representative sets of objects/classes should be recognized. And we have for each class one curve only. Decision by (2) is made by means of the finding maximum of evaluation among classes compared, – it is maximum probability of belonging just that combination of features (in this concrete recognizing object f_k) to given class.

And, finally, when rule (3) is used, the sample of each class includes (in form of certain curves of probability distribution) the indices of estimates/assessments x_{kj}, which shows the results of weighing various objects from *given* class *on samples all other* classes. Just this result we obtain in 2nd stage of training.

It looks as if just one object or situation is observed by means of several perception inputs, from different points of view, or is passed in parallel through various filters or prisms (see Fig. 2 and Fig. 3).

It was found some years ago, in certain neurobionic studies that information from *each* mouse' vibrissa on its nose reflects (is sent) not only *in one* corresponding pull of neurons in mouse' brain, but it is in *all of them*; very close to the way being realized in holographic system (see Fig. 4).

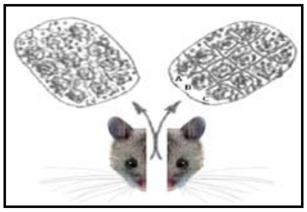

Figure 4. Structure of mouse memory

We may say that increasing of grounding and quality of decision making is got in this case in our decision or assessment system as result of more entire extraction of information about classes should be recognized, about interrelations between classes and latent links between its features. Besides it must be pointed out that such results are obtained due to some fuller and better disposing the knowledge mentioned above when MD Decision Functions in various managerial and control problems are used, due to better use the "context information".

Some Concluding Remarks

Decision functions mentioned above was successfully used by solving various tasks:

- evaluation of the socio-economic level for some administrative territories (life quality);
- comparison of development level for south regions of Ukraine;
- risk assessment and estimation of various protective devices' effectiveness;
- recognition of printed and handwritten letters, either some voice commands;
- data interpretation in geophysical exploration (known task "Oil – Water Recognition");
- medical diagnostics, staff management, and so on.

Interesting and hopeful results were obtained in all tasks listed above ([Krissilov, 1984, 2000, 2007] and other).

The system could recognize the different situations and objects, to make grounded decisions, is able to simulate monitored situations. Some important properties of outworked system were displayed:

- ability of work with qualitative and quantitative features;
- obtaining of aggregated, generalized evaluations for monitored processes, objects or situations in a case of action of various local or depending factors;
- ability of classification of the objects and situations, forecast variants evaluation, to provide support and quantitative decision making.

The territorial cluster

Now let us discuss level of some city objects and social organizations. The increasing of the competitiveness of some factories, municipal structures, and the city as a whole is lying on the way of improvement of the level of their work. The quality of production, service and information has to become the source of the added tax.

How is it possible to achieve it? The answer is the creation of equal competitive possibilities will lead to the searching of the optimal development ways by the city organizations. They will look for the minimization of the consumption, for increasing of labor quality, for attracting of some new clients, their products and service.

The next step is the subsequent development of the competitive enterprises into the harmonious cooperation in the city. The territorial cluster is one of the kinds of the cooperation. It has shown itself as the effective structure.

Making of cooperation will bring the opportunity to increase the reliability and firmness of the functioning of some field. It will also help to continue the innovating activity on the new level, when the enterprises make the combined elaborations to improve the effectiveness of work.

The results of the transformation of the socio-economic situation in the city will be harmonious city development. It will be seen in the evolution of the small business. The city will pass the complicated stages of the development, such as “Confrontation – Competitiveness – Cooperation”. There will be the increasing of the investment and innovation activity level and, the important point? - the socialization of the actions.

Our comprehension of this cluster is it`s the entente cordiale for the territorial feature of the producers with the suppliers. Such collaboration’s aim is to increase the individual and combined economic profit after the satisfaction of their production needs and customer’s inquiries. So, the creating of the territorial cluster means the combining of the manufactures from the different fields and the objects of social sphere.

The municipality in the necessary component of this cluster, which has the important role in the development of the branch on the territorial-administrative level and has certain influence on the working out of the normative – lawful base, which directly regulates the development of the city infrastructure.

The suggested model allows to include not only technical side but to show how active it interacts with the sphere of finances, jurisprudence, social sphere and the local administration [Chumachenko V., 2008].

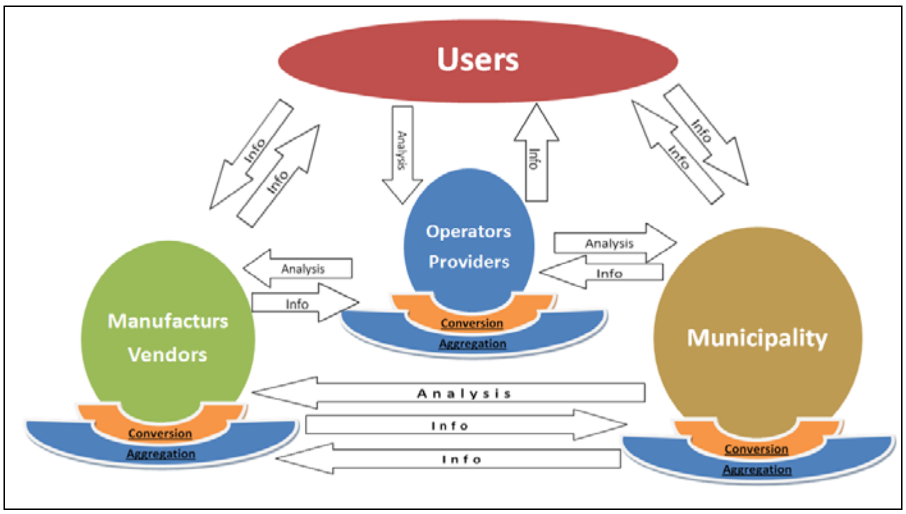

Figure 5. Example of data and documents changing (relatively the model of the territorial cluster)

It is necessary to work in practice the Internet, to implement the liberalization of the telecommunication market, to develop the Internet trade, to make the access to the Global Web for the society, and to increase their level of computer knowledge, especially for young people. All these things are very important for the providing of the city competitiveness in the informational – telecommunication sphere. The information technologies have to favour the local and regional development, the environmental protection and saving of the cultural treasures preservation. These technologies have to provide the access to the information about the working of the body of local executive power and body of local self-government.

Cluster system advantages

Clusters, unlike business systems, connect much bigger number of participants e.g. assistance institutes, producing and commercial structures. So one can see here the producers, suppliers, distributors and regional and national governments.

The level of these advantages increases a lot, combining with new information technologies. The development of clusters is the tool for the rising competitiveness strategy, which is consisted from the standard approaches.

The social part of the economical transformations plays the very important role in the conversion to the new economy. It is necessary to define the aims which are true for the interests of the people. It is also important to get the data for the necessary basis for the mobilization of the social potential in order to get the certain aim.

It is expedient to divide the created cluster for some subclusters, to consider the cluster structure in detail. Such division allows working out the different cluster parts more effective as different subclusters and their members will have different demands and possibilities. The question about the social importance of some objects (administrations, law enforcement, emergency service, ecological organizations and some civil defense sectors) is also very actual. The subsequent improvement of the scheme foresees the participation of the managing stuff to exposure of some particular features in the interaction of definite areas in the territorial cluster.

The elaborated scheme will allow to forecast the social changes more effective, to build the connections between some organizations etc. The cluster approach connected with the economy development is able to rise from the solitary and isolated activity which is fixated only on one project in some period of time, to the stable and integrative process.

The creation of the same information system and its effective exploitation make the cluster advantages much bigger. Except the above-listed advantages we should mention the new forms with the new relationships and structures which lead to the regulation improvement which are the feature of the well-developed system of the market members' interaction. It has the maximum influence on the socio–economic territory development, the increasing of its importance in the city and opening of some new investing ways.

We should mention also that the creation the territorial cluster, not brunch cluster, will become one of the confident steps to the preparation for the self-government territory, authority decentralization. Economic indexes become the stimulus for getting of the economic effect (looking for, elaboration, and saving of information, reducing of the transport cost etc.) stability growth due to the reservation.

The possibility of the creating the territorial clusters in Odessa or Odessa region is confirmed by the effective activity of the Ukrainian clusters and world leaders in the different areas of the industry and service, with the influence of following factors:

- demographical situation (more number of enterprises appears when number of young people is more);
- prosperity (the higher its level the more chances to create the companies which owns the capital or they are able to have it up);
- the level of the professionalism and education and the ways of the working force in the city;
- the good popularity of the small companies in city;
- the infrastructure city advantages, which help to have more infestations for city so on.

Conclusion

We should mention the offered points in creation of competitiveness mechanisms, algorithmic and cluster approaches as a tool of the socio–economic city development will be able to solve a lot of problems. These problems are very actual nowadays for the mayor, for municipality, so they are:

- the increasing of the cooperation effectiveness between government and people;
- improvement of the social-and-economical and cultural city development;
- employment and solving the problem of unemployment;
- increasing the attractiveness of city' investment;
- the use of the information technologies as the way of activity optimization of the local self-government.

The clusterization will definitely lead to the socialization of activity – bringing of the population in the production, increase member' number, creating of the "open" society, which will be satisfied morally, financially and mentally.

It would be wrong to assume that administrative bodies have the easy way to build the new system of municipal management. However they have no alternative but to learn new system methods, to use both new organizational forms and technological instruments, to think radically new way.

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COMPUTER-AIDED DESIGN OF EXPERIMENTS IN THE FIELD OF KNOWLEDGE-BASED ECONOMY

Dorota Dejniak, Monika Piróg-Mazur

Abstract: *This article is devoted to chosen aspects of designing experiments in the innovative economy. The contemporary theory of experiment has become a vast field of knowledge. Its methods and applied mathematical devices often surpass the capabilities of researcher's perception, who does not wish to waste time comprehending them. Computer systems that aid to the experiment are a solution to this problem. STATISTICA that contains the used in this article module named Design of experiments finds place among those computer programs.*

Keywords*: planning experience, knowledge-based economy,*

ACM Classification Keywords*: K. Computing Milieux, K.1 THE Computer Industry, Statistics, J.7 Computers In Other Systems, Industrial control*

Introduction

The rapid development of science and technology means the need for introducing more and more radical changes almost in every sphere of life. It concerns, above all, the field of business activity. To develop effectively and dynamically, changes of an innovative character are required: new organizational and management systems, marketing, new manufacturing technologies but, above all, new products that would better satisfy the more and more rapidly changing consumer's needs.

In the field of knowledge-based economy, those organizations achieve success that manage well the process of seeking new ideas and technologies, and transferring them to the solutions that constitute the market value. Innovation in activities finds reflection in a better evaluation and perception of enterprises by markets. Economy relying on production, distribution and the use of knowledge and information – the most important factors that result in economy development.

Advanced technologies (like computer science and telecommunications), as well as sectors employing qualified employees (like finances or education) constitute the foundation of the Knowledge-Based Economy. Four pillars of Knowledge-Based Economy can be distinguished: institutional and legal surrounding, innovation, communication infrastructure, education and trainings, which allow to take pride of qualified employees.

During the recent years, many enterprises have made great investments in the development of modern computer devices that aid to planning and production control. Majority of solutions oversimplified the modelling of production reality both in case of modelling the objects as well as the processes they were subject to, which constituted their shortcoming [Euve, 1997, Knosala, 2007]. A new approach to working out planning systems, which could solve complex problems of contemporary production, appeared to be indispensable [Knosala, 2007]. Computer systems that aid to an experiment has appeared to be a solution. Design of Experiment (DOE) is a method that by means of eliminating external factors allows to find such an arrangement of controlled process parameters that the process can be as optimal as it is possible.

Design of experiments

Theory of experiment was formulated to gain in a relatively short time and at limited costs knowledge needed for a new or improved technological process. It is highly significant in case of knowledge-based economy. During each technological process, questions about the quality of the product as well as the optimisation of costs emerge. Only scientific research studies result in experiments that need to be carried out as quickly as it is possible and aim to obtain a product of desired qualities. Design of experiments (DOE) is an interdisciplinary field of science, which combines applied mathematics, statistics and computer science. Its aim is to answer the question: how to design an experiment to gather as much information as it is possible at the lowest possible costs.

Studying the role of the theory of experiment in the knowledge-based economy, two circumstances need to be taken into consideration [Polański, 1984]:

- In the event when the concept of creating new quality emerges, the theoretical and empirical research studies are required the most frequently. Each of these researches is important and indispensable; the empirical studies are, in addition, expensive and time consuming.
- In the event when it is important to cut the costs and carry out empirical studies in shorter time, the methods of the theory of experiment need to be applied, including the design of experiment and statistical analysis of results.

The subject of a research may, for instance be a device, a technological process as well as an economic dependency etc. Input parameters specified by a researcher, as well as output parameters that are observed and measured characterize the quality of a selected product. Despite the controlled inputs, the investigated process is influenced by factors that are beyond the researcher's control.

The aim of the research is to determine an approximate relation that describes the reaction of the object to the introduced input changes. The relation is an approximation of a connection inside the object. Calculations of the methods of the theory of experiment are so complex that computer is indispensable to make them. Once the input parameters have been determined, it is checked whether there is a qualitative relation between them and the output quantities. The relation needs to be described by means of a model, and the values of input parameters that will ensure optimal output values have to be found. For that purpose, for instance fractional factorial design, compositional design, Latin square, Taguchi method can be applied.

During the research studies, it is indispensable to carry out a series of experiments that aim to investigate the response of an object to specified input values. In a traditional meaning, the variation interval of each input variable would be divided into equal segments and all the possible combinations of their values would correspond to particular experiments. The complexity of the contemporary processes has made the traditional method ineffective. For instance, an object of 8 input parameters would constitute 28=256 of experiments. An analogical program of researches, designed in compliance with the theory of experiments, consists of only 16 experiments. ANOVA analysis of variance and Pareto chart are used to analyse results obtained by means of computer-aided design of experiments.

A quality management systems certification needs to be mentioned at that point. The methodology of designing experiments has become one of the devices that aim to design a process that meets a standard. In the result, the standard – ISO 35344-3 that covers statistical methods was extended by a part referring to the design of experiments.

Computer experiment and data analysis

The aim of the research is to improve the efficiency of a certain technological process. The process is controlled by four input variables. The investigation of it can be carried out by applying the so called complete block design that covers all the possible variations (16 combinations) or the fractional factorial design that embraces only the chosen part of the complete block design (8 combinations) [Pietraszek, 2004]. It needs to be assumed that factors influencing the process acquire two values. In figure 1. is describe two values -1,1. The fractional factorial design was chosen and the obtained results of measurements are displayed below.

	variable 1	variable 2	variable 3	variable 4	performance
1	-1	-1	-1	-1	45
2	1	-1	-1	1	31
3	-1	1	-1	1	44
4	1	1	-1	-1	32
5	-1	-1	1	1	50
6	1	-1	1	-1	31
7	-1	1	1	-1	44
8	1	1	1	1	30
9	-1	-1	-1	-1	45
10	1	-1	-1	1	31
11	-1	1	-1	1	43
12	1	1	-1	-1	31
13	-1	-1	1	1	49
14	1	-1	1	-1	30
15	-1	1	1	-1	44
16	1	1	1	1	30

Figure 1. Table containing fractional factorial design and obtained results of measurements

From such a perspective, the object of research studies has a universal character and is mainly characterized by:

- input parameters that may acquire different values of the selected intervals

- output parameter that depends on the input parameters and creates the so called function of the research object; it is the function of research object that constitutes the main scientific information.

Once the data have been entered and the analysis by means of the STATISTICA program commenced, the issue – Conclusion: Evaluation of effects need to be considered.

evaluate the effects ; Variable.:variable output.; R^2= ,96439;Correct:,95144 (sweet1) 2**(4-1) plan (scheme) , Residue MS=2,977273 variable output.

	effect	standard error	t(11)	p	(-95%) - confidence limits	(+95%) - confidence limits	factor, coefficient.	standard error - factor.	(-95%) - confidence limits	(+95%) - confidence limits
average/constant	38,1250	0,431369	88,3813	0,000000	37,1756	39,0744	38,12500	0,431369	37,17556	39,07444
(1)variable 1	-14,7500	0,862739	-17,0967	0,000000	-16,6489	-12,8511	-7,37500	0,431369	-8,32444	-6,42556
(2)variable 2	-1,7500	0,862739	-2,0284	0,067433	-3,6489	0,1489	-0,87500	0,431369	-1,82444	0,07444
(3)variable 3	0,7500	0,862739	0,8693	0,403240	-1,1489	2,6489	0,37500	0,431369	-0,57444	1,32444
(4)variable 4	0,7500	0,862739	0,8693	0,403240	-1,1489	2,6489	0,37500	0,431369	-0,57444	1,32444

Figure 2. Table containing the evaluation of effects

Figure 2. contains the evaluation of effects. The displayed effects are statistically significant at the accepted significance level of 5%. Accepting the assumption of the linear model, applied by a two-level fractional factorial design, the first variable has a significant influence on efficiency. The increase in the value of the first factor will

significantly lower the efficiency. The other effects are not statistically significant. The chart – Pareto of standardized effects presents it graphically (Figure 3.). Pareto chart is used to identify and evaluate the significance of analysed issues by marking on the chart columns that correspond to the frequency of the particular categories.

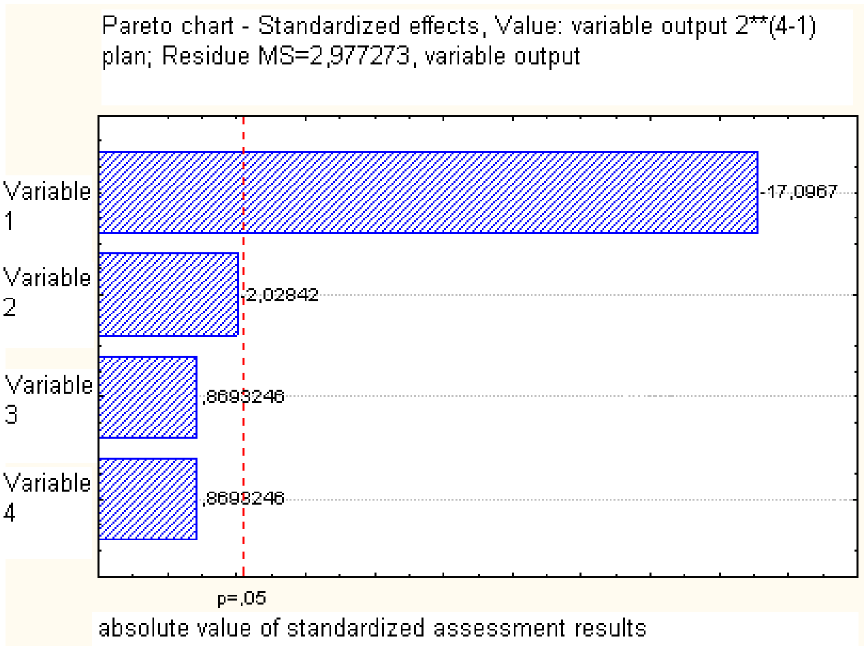

Figure 3. Pareto chart

Analysis of variance (ANOVA) is a group of statistical methods used to compare a few populations. In general, this is a technique of studying results (experiments, observations) that depend on one or a few factors that are activated simultaneously.

The statistically significant effects are clearly separated from the insignificant ones. It correspond to the chosen significance level of 5%. The ANOVA (Figure 4.). table displays qualitative information about the influence of the particular effects on the complete response variation of the research object.

ANOVA; Variable.:Variable output.; R^2= ,96439;Correct:,95144 (sweet1) 2**(4-1) plan (scheme); residue MS=2,977273 Variable output					
	SS	**df**	**MS**	**F**	**p**
(1)variable 1	870,25	1	870,25	292,2977	0
(2)variable 2	12,25	1	12,25	4,1145	0,067433
(3)variable 3	2,25	1	2,25	0,7557	0,40324
(4)variable 4	2,25	1	2,25	0,7557	0,40324
error	32,75	11	2,9773		
total SS	919,75	15			

Figure 4. Table including ANOVA analysis

In figure 5. is describe normality diagram. Diagnostic normality diagram has on the horizontal axis the remainder values and on the vertical axis the normal values calculated for the ordered sequence of remainder values. The lines refer to the arrangement of an ideal normal distribution.

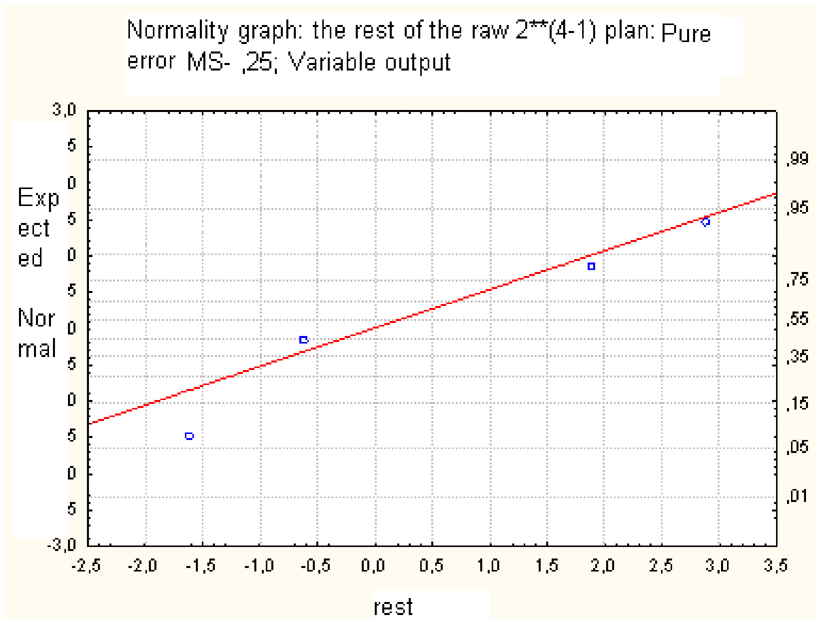

Figure 5. Normality diagram

To conclude, a scheme of a cube with calculated forecast values (Figure 6.) for the particular vertexes need to be illustrated. Due to the type of the task – maximization of efficiency – the vertex with the highest forecast value need to be found. The presented below diagram refers to the first three variables.

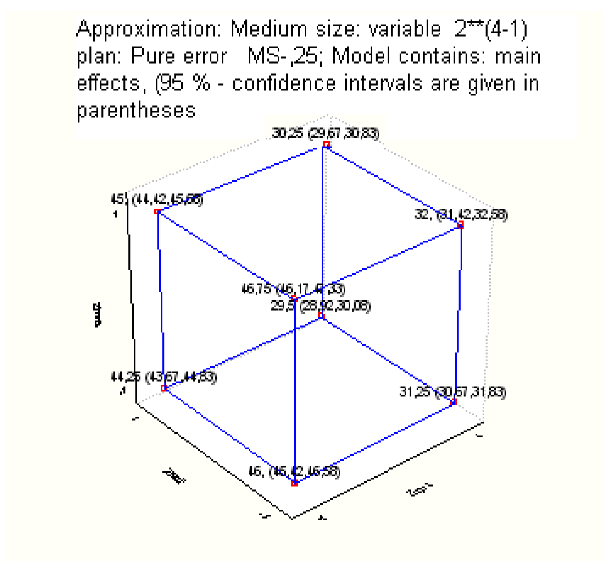

Figure 6. Scheme of a cube with calculated forecast values

The analysis covers a sequence of undertakings connected with the qualitative and quantitative analysis of the problem and aims to specify – from the standpoint of formulated aims – the best variants of enterprise development, including the improvement of the efficiency of a technological process.

Conclusion

The growing competition on the market requires frequent, even worked out on the spot, decisions connected with the course of the technological process. The growing requirements in reference to shortening the time of calculations that are indispensable to design a production plan result in the need for applying new methods and devices that enable to work out a production planning. Methods and models are mainly created by the use of simulation modelling. The possibility to test and evaluate alternative decisions, strategies and policies before they are applied in the existing enterprises is the main reason for making use of computer simulation [Witkowski, 2000].

Technical innovations belong to the main responsibilities of knowledge-based economy. The presented process of computer-aided design of experiments enables to single out input variables that significantly influence the investigated process. It allows to build an appropriate and reliable mathematical model in a short time. A significant purpose of the presented plan is also to specify the influence of variance of the particular input parameters on the variance of the entire process. It allows to identify sensitive points of the studied process.

In further analysis, experimental data taken from a technological process of an enterprise that functions in the sector of glass-making industry will be used.

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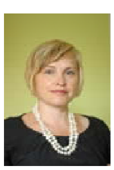

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REALIZATION OF INTERDISCIPLINARY LINKS BETWEEN DISCIPLINES CONNECTED TO INFORMATION TECHNOLOGIES

Marina Solovey

Abstract: *The article is devoted to the problem of improving the educational process of teaching "Information Systems in Economics" and "Information Management" courses. One path of solving the problem is to create the interdisciplinary links between courses. The algorithm of creation these links is presented.*

Keywords*: information system, information management, educational process, course, link,*

ACM Classification Keywords*: Economics, Management*

Introduction

Teaching of the IT-disciplines is very difficult for several reasons. The first reason is that a different level of computer skills of students, who start to study these disciplines are needed. Hence, it is necessary to organize an individual approach to each student in auditorium. The second problem is a fast progress in the given scientific domain. Therefore, that content of discipline which was actual, for example, two years ago, now it is necessary to be upgraded. The third reason is, that teaching of IT courses requires high qualification of the teacher or lecturer. The teacher should be competent, capable of lifelong learning, constantly to learn the development of tendencies and directions in the area of information technologies. The fourth reason (it is typical for Russian high schools) is a problem of maintaining the teaching process by material resources. It is necessary to have constant access to the Internet, good hardware and software, etc.

Lecturers and teachers can solve some problems, in particular, by using of modern pedagogical methods in auditoriums, participating in conferences and the seminars devoted to development IT, participating in realization of real business - processes for the concrete enterprises, constant studying scientific, public, Internets - resources on the given sphere. It demands big physical effort and material as well as financial resources from the teacher, and also understanding and support from the university management.

I think, that creation of interdisciplinary links between courses and using of modern pedagogical methods can become the one of the possible ways of the decision of the problems connected with teaching IT.

The necessity and opportunity of creation of interdisciplinary links is offered to be considered by the example of two disciplines “Information technologies in economics” and “Information management”. As the contents of any discipline in Russian higher education system is regulated by state standards, the contents of educational standards of these courses is applied in separate documents to the application.

Creation of the interdisciplinary integrated links between courses should be realized in the following steps sequence:

1) Definition of necessity and statement of the purposes for realization of interdisciplinary links.
2) Studying content of educational standards of disciplines.
3) Revealing opportunities of realization of interdisciplinary links by defining of the common or similar themes in content of standards.
4) Studying the curricula, definition of terms of the beginning and the completing of each discipline.
5) Statement and revealing of necessary common students’ skills before the beginning of studying of each of integrated courses.
6) Creation of common integrated part for both courses.
7) Choice of training methods and teaching technologies for the common part of courses.

8) Updating terms of curricula.
9) Creation of an individual part of each course.
10) Choice of training methods and teaching technologies for the individual part of courses.
11) Definition of necessary skills which should be received by students after finishing of each course (common plus individual parts) and methods of evaluation.

Schematically, process of realization of interdisciplinary links within the framework of several courses is presented on figure 1.

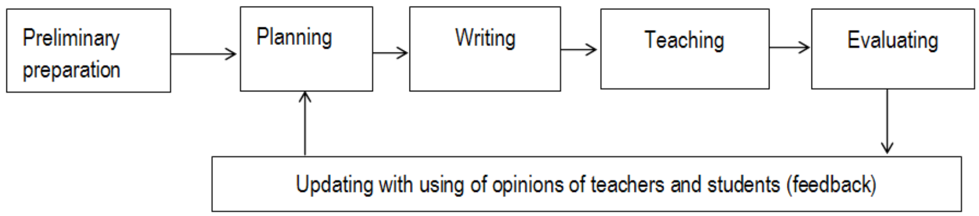

Figure 1. The scheme of realization of interdisciplinary links process

Structure of teaching integrated course according to teaching purposes (ITE – course “Information Technologies in Economics”, IM – “Information Management”) is presented on figure 2.

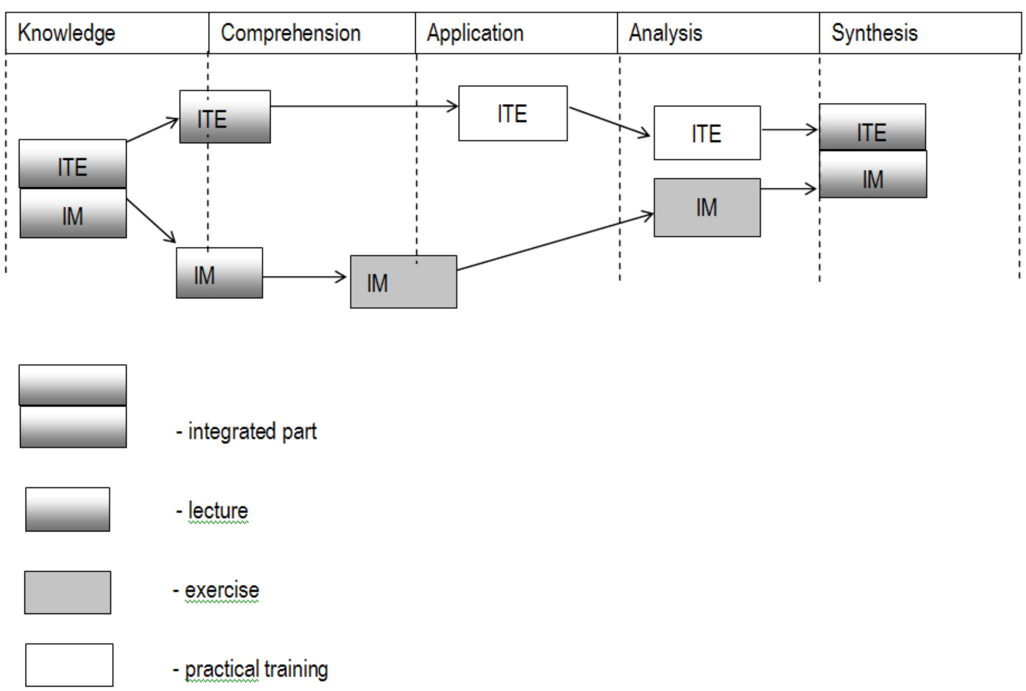

Figure 2. Structure of teaching integrated course

These two disciplines are chosen on purpose in the given project. The first discipline “Information Technologies in economy” is taught at the end of the third year of the training and the second discipline - at the end of the fourth year of training. Knowledge and skills, received in the first discipline, are lost in part to the beginning of training on the second discipline. The student does not feel continuity between courses. The teacher is compelled to waste time on an explanation of a material which has been already investigated one year ago.

The first discipline assumes significant part of practical training and develops the skills of work with the economic software. The second discipline assumes the analysis of opportunities of use of information systems and technologies in economic processes and the processes of making decisions. If these two training processes can be parallel in the same time, it will be useful for students by the following reasons. First, students learn opportunities of concrete information technologies and analyze, how these opportunities and functionality of IT can be applied for the various kinds of enterprises, what are the benefits of using these IT , what opportunities are more important, and what are less important. What difficulties the enterprise can face to train employees for work with the given information technologies, etc.

Parallel learning of two courses will allow improving students' skills at work with IT, and, simultaneously, creating student's opinion about value and utility of the program related to management or decision-making. Students learn IT and consider questions of information management at the same time. Students recollect constantly about functionalities and features at these or other programs, which they had studied one year ago, to make a conclusion for using and choosing of software within the framework of teaching discipline "Information management" discipline.

Conclusions

Thus, creation of the integrated courses allows to improve process of training of students in IT related subjects, and therefore to raise quality of educational process as a whole.

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PRESENTATION OF PRODUCTION ORIENTED DATA AND KNOWLEDGE

Arkadiusz Rzucidło

Abstract: *This article describes a concept of presentation of knowledge and information in a manufacturing company. The main idea of application mechanism construction is technique of graphic presentation and visualization, which is system's key feature. Technological descriptions and interactive data base play here complementary role.*

Keywords*: Knowledge base, Data mining,*

ACM Classification Keywords*: E.Data, E.5.Files, E.5.6. Sorting, searching*

Introduction

Information management systems equipped with a graphical data presentation are one of tools to support the production process. Their goal – wieldy understand - is to provide possibility to monitor production process up to date by managers. The action may also relate to activities within production process directly. Such systems play complementary role by completing lacks in information about production. Other very important feature is production personnel training. This is achieved by introduction of production automation based on modern software and systems support in production designing and management as well as systems of presentation and knowledge exchange. All these actions are related to information visualization methods for better understanding subject of deliberations and analysis.

Visual representation of information

For a long time people were using abstract symbols as essential tools allowing to transfer knowledge or to describe more accurately reality and phenomena in surrounding world. It often appeared that such a message carries more information than most accurate verbal descriptions. Such message was appreciated by scientific community. Detailed scientific analysis allow for easier interpretation of obtained measurements on condition that they will be presented as images and pictures. For this purpose one should use advanced techniques allowing for conversion of obtained data into a static graphical format or dynamic animation. Techniques presenting data in visual form provide better effectiveness of analysis of information. This is direct result of human physiology. Human brain receives information from surrounding world with two hemispheres. Left hemisphere coordinates analytical operations, understanding of symbols and verbal communication. Right hemisphere is responsible for intuition, understanding of space and thinking in global terms. This allows us to see complexity of the world around us and correlation between phenomena.

Presenting data as graphic allows for understanding reality in terms of the right hemisphere. This situation enables achieving generalized picture of data by person analyzing studied problem. Afterword during the research process by using more analytical methods it is possible to find various types of regularity, relations and anomalies. It is highly probable, that humans brain development had been shaped by signals transmitted by sense of sight. Information in form of image, dominates in all signals received by all senses. The above especially relates to humans and in consequence determines possibilities of human thinking.

Using visualization and graphic presentation techniques in building of data base and knowledge systems is therefore highly appropriate and advisable. Reality acceptation in a way described above allows to better understand this issues.

Information and knowledge

Information and knowledge systems made for production processes purposes are not new concept. They are part of group known as KM (Knowledge Management). The goal of this kind of applications is to cluster both information and knowledge.

Information as procedures, instructions available in the process is its general available part, easy to formalize. They can be described by methods that are widely used in presentation systems as text, sound, image, animation etc.

Knowledge however is an intellectual potential, which can be used by a company through its employees. It is difficult to formalize and sometimes even impossible to put in database. Knowledge presentation systems are intelligent applications, whose task is to learn and evolve [Grudzewski 2005].

Creation of universal application which presents both information and knowledge is very difficult. Building process of such tools is determined not only by diversity of production technologies but also specific and individual approach to production management. Often this approach is a secret. Secret that makes the company competitive and is strictly protected. Thus one could say that statement that knowledge and information management systems for companies are individual solutions "custom made". Selection of technology is a secondary issue here because many available programming techniques offers similar solutions. Information and knowledge are included in general accepted presentation methods and thus these elements are joined together by designers in a way they like.

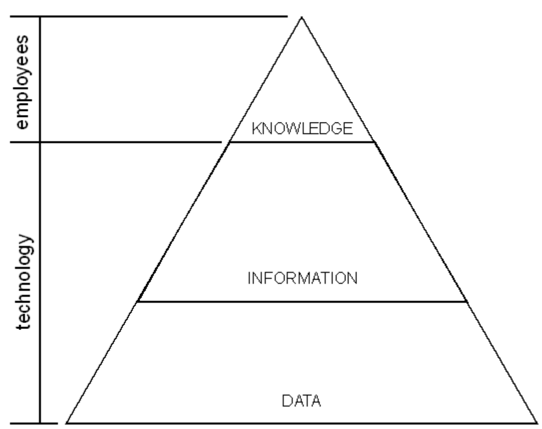

Figure 1. Pyramid hierarchy of knowledge [Alter 1996]

Looking at the pyramid of "hierarchy of knowledge" (fig.1) through prism of production, one can see that data are observed facts, images, and events. Annotated data (interpretation) are becoming information, going further categorized information one can take as certain pattern. Description of information functioning (pattern) and its application gives possibility of its practical use. Thus, use of such information is considered as knowledge. By generalizing, summery of cases and methods of solving problems related to those cases gathered in informatics frames can be called base of knowledge. Assuming that the base of knowledge is to be source describing reality as accurately as possible, to describe such defined knowledge it is necessary to have resources that would give the best view. Knowledge-orientated companies are applying solutions of corporate portals, which are integrated systems used in efficient communication within company. These systems offer full functionality to its users and enable them compact access to distributed information. Knowledge management relies on information obtained from corporate portals, thus building advanced subject data base available within the community. The solution is already successfully used in practice eg. SAP software. These systems are very complex. For some cases eg. In production, existence of information and knowledge base may be associated with particular technological application and don't have to be connected with extensive portal application. For small businesses wanting to implement management of information and knowledge methods it is sufficient to use properly prepared mechanism with most needed components – that is basic technological base containing information about produced goods. As a supplement such base (correctly and reasonable prepared) makes basis for employees training. By applying techniques of presentation and visualization it is a complete tool to support production and data exchange between technologists and production workers. Like any well designed software tool it has high efficiency in terms of speed of reaction and firm answer. Additionally equipped with elements of presentation and visualization allows for a full description of problem. Such technological base of information and knowledge is a tool which is easy to implement in any manufacturing company. Advantages of implementation are easy to imagine.

Information and knowledge exchange platform

Information and knowledge exchange platform should be a system which is open within the enterprise and focused on its activity. Presented materials, visualizations and tools forming mechanisms of the organization with knowledge contained in the system should be somehow derivative of technology, which company uses on an ongoing basis. Such approach has several advantages. One of the upsides is clarity and transparency of the knowledge exchange environment, which is fundamental element for cooperating teams. Discussions and references to specified visualization environment both designing (CAD) as well as training presentations, allow for quick and accurate assignment of topics and comments. Explanations of components and production techniques form a compact base understandable to the production level employees as well as technologists as a group of experts. Another advantage of using visualization technology is easiness of generating materials, which will be used to build examples data base. Those examples are used in experiences exchange platform. General schemes of devices or mechanisms produced in a company, enriched by decomposition for subsystems and components will help to get familiar with their design. It is very important both for employees actively involved in production process and new people trained as new company resource. According to the argument listed above one can say that increase of quantity of graphic materials will lead to increased assimilation of presented information avaibility of technological documentation related to presented detail will allow for quick reference to the norms, manuals and production remarks [Tufte, 2001]. This will allow for an easy way to find a solution for problems occurred during production process. Platform for sharing with observations (problems in production process) will feed data base with presumptive problems, they will also help to identify defects of production process and possible imperfections occurred during designing. Thanks to such solution there is a possibility to create feedback loop between production and design phase.

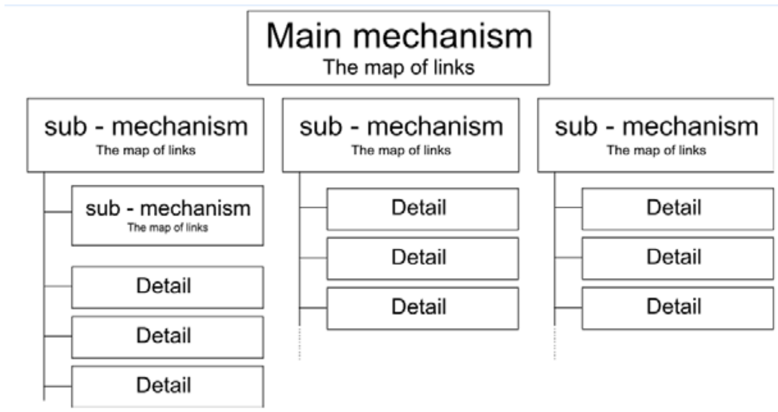

Figure 2. Cascade system layout

Construction of information and knowledge exchange data base has a cascade layout. This layout bases on decomposition described elements (fig.2). The starting points in gathered categories are blueprints of produced mechanisms. Decomposition means, marking components in blueprint and attach detailed description to specified detail. If the detail is still a complex structure, decomposition occurs in a next level. There are as many levels as components (individual). Invariably, the starting point is graphic presentation and visualization of given level of decomposition. Graphic presentations consist of drawings, 3D animations and pictures of whole element or production critical parts. Each element is shown as a 3D animation in order to present detail as accurate as possible (fig.3) Elementary components have dimensional drawings. The key is to show and specify particular important operations in production as an animation.

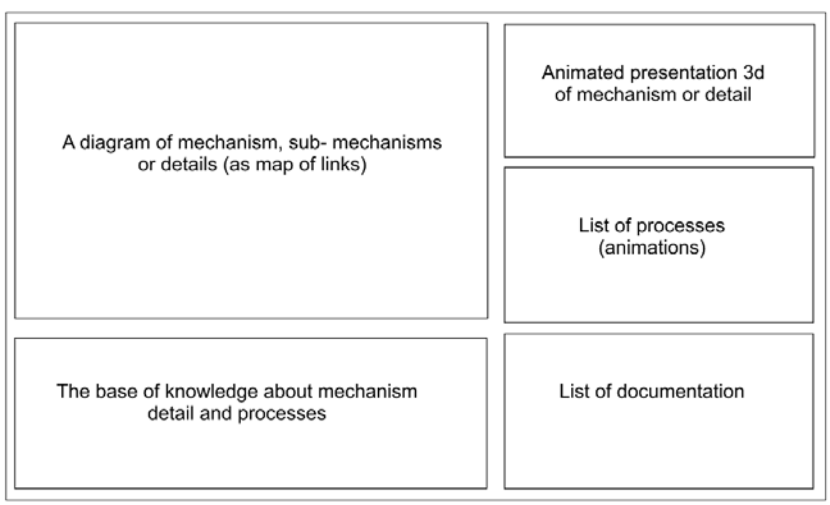

Figure 3. A window diagram of one of the levels in the system.

Every level has its technological description analogical to its complexity. If this is a mechanism, than the characteristic contains essential information about mechanism itself. If described element is a detail, its characteristic is analogical to the one above but extended eg. by technological description associated with used material and detailed dimensional drawing. To each level of decomposition there is assigned a set of rules and instructions, which can be important in reading of description. An essential element in such designed application are smart tags which are links to some key words in specific descriptions of detail, operation or standards or instructions linked directly to specific level. Since the documents (instructions, norms, procedures) can be set shared between different levels and details, in information data base they occur as relations multivalent to described elements. Such a system allows to assign all necessary documents in a transparent matter.

So far there were presented mechanisms of data presentation includes in production information data base but in order to the system has characteristic of knowledge data base it has to enable possibility to record this knowledge and allow for an easy access to it. Each level has list of experts and knowledge data base, which draws attention to possible problems with production, assembly, storage, etc. This is an open list continuously updated. Roles of experts are entrusted to managing production personnel. Managers role is to moderate each levels and details of processes. Role of experts can be established fixable. To make knowledge data base easily updated its users (production personnel) should have possibility of asking questions and adding comments to threads that have been set up within the knowledge data base by experts or production workers themselves. All questions and comments are recorded in knowledge data base and are moderated by experts. Moderation should make the information clear and complete in order to fulfill production needs. Marking key words for each discussion is responsibility of appropriate expert. This shapes topics and comments in a way to make searching mechanism in an easy way. Data searching mechanism allows for using multi criteria queries categorized by levels, processes, details, tasks, etc. using key words and free returns. The effect of search is a list of items with easy access to the source in a form of a reference to discussion or found production information. Through the link, system operator moves to the level in which discussion had been registered. Operating system developed by these assumptions is an application with controlled access to resources which allows identifying currently logged on users. This helps users to determine availability and readiness of individual experts.

Conclusion

Described system includes basic structure, which allows to create simple form information and knowledge database in manufacturing company. Such data base is built mainly of multimedia presentation and visualization. It becomes a tool to support production which is easy to receipt. Technology descriptions are a supplement that makes proposed construction easy to use and functional mechanism. Knowledge data base is an complement to the system adding very important feature of flexibility allowing for constant problems record and enabling production modification by adjusting it to the technological needs and requirements.

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Intelligent Robots

TELEOPERATION AND SEMIAUTONOMY MOVEMENT MODES OF IBIS ROBOT

Piotr Bigaj, Maciej T. Trojnacki, Jakub Bartoszek

Abstract: *The work presented in this study is concerned on a subject of simulation and implementation of teleoperation and semiautonomy modes for IBIS mobile robot. The construction of the robot as well as used sensors have been described. The unique algorithm for semiautonomy mode has been elaborated and depicted here. Software simulation environment based on Matlab/Simulink package with Simulink 3D Animation toolbox and research activity has been presented as well as practical experimental results of proposed method for real, outdoor conditions of IBIS operation.*

Keywords: *mobile robot, navigation, teleoperation, semiautonomy, computer simulation, experimental research.*

ACM Classification Keywords: *I.2.9 Robotics - Autonomous vehicles, Operator interfaces, Sensors.*

Introduction

Autonomous robot movement in unknown environment is one of key issues nowadays for mobile robotics. The problem is already taken up for over two decades amongst different research and developments centers all over the world. The most popular of these includes a task of mobile robot movement from the starting point to a destination point and simultaneously omitting obstacles. The key issue when solving the task is to perform a movement in a collision-free way whilst the planned path should be optimal under some criteria [Trojnacki, 2008].

Going towards a goal point task fall into three consecutive phases: building environment representation, localization, movement planning and movement implementation [Ghorbani, 2009],[Wang, 2008]. In some cases building environment representation is overlooked [Xing-Jian, 2005]. It is justified in these situations when the dynamics of environment changes is comparable or greater than dynamics of map generation and decision-making process. In such cases generated map is not a reliable source of information since it is not up-to-date.

Localization process is based on the knowledge of static environment map, different types of inertial systems, satellite based navigation, heading sensors etc. The usage of odometry for localization purposes [Selekwa, 2008] proves correct if only robot performs its movement on a flat surface without skids and when the movement is performed on short distances, as the error accumulates with time. If only the robot runs in the area where sufficient satellites constellation can be seen the localization can be based on satellite navigation systems supported by INS.

Robot path planning can be considered as local or global task. Global methods demand the knowledge of environment map whilst local methods use information about close surroundings. The global map can be available before the start of movement realization or be created during it.

Path planning methods and movement performing use wider and wider artificial intelligence (AI) methods e.g. genetic algorithms [Ghorbani, 2009] for the fact that path planning can be seen as finding optimum for some cost function. For movement execution a fuzzy inference [Van-Quyet, 2008],[Selekwa, 2008],[Wang, 2008] and neural networks [Boren 1988] are preferred. Additionally literature presents reinforcement learning approaches and nature based algorithms e.g. behavioral control. One of the most interesting tendencies nowadays is to join different types of AI methods and to create hybrid solutions [Baturone, 2007].

Autonomous movement realization based on behavioral control deals with orders that are often contradictory e.g. “go to the target” and “omit obstacles” – therefore a hierarchical structure of control block has to be used in such situations i.e. superior control block for behavior coordination and lover-level methods for realization of particular behaviors and controlling of robot’s drivers.

The majority of literature describing autonomous robots movement that deals with laboratory conditions. Examples of these can be found in [Selekwa, 2008],[Wang, 2008]. Only some of publications are concerned on mobile robots or UGVs in open field conditions. It corresponds to the fact that difficulty of solving such problem increases – in every step of path planning - starting from building environment representation and ending on locomotion that has to deal with more complicated terrain since new-third dimension occurs.

For obstacle detection and classification different types of sensors are used. In laboratory conditions ultrasonic [Van-Quyet, 2008] or near infra-red sensors are preferred. That kind of sensors cannot be used in real outdoor conditions because they are very sensitive to variable ambient conditions. Far better results are obtained by the use of laser based sensors [Selekwa, 2008] and recently radars and lidars.

Video cameras can be considered as a special type sensor. Visible light and thermal used for obstacle detection and building environment representation require image processing algorithms [Kyriacou, 2005] demanding however high computational resources.

Obstacle detection devices detect objects that are prominent and are projecting over the ground surface. Rarely hollow surfaces (hole type) are taken into account. In obstacle classification one of key-issue is to single out a human as a specific type of obstacle. It is important if robot can surmount smaller obstacles, then it can treat a laying person as surmountable obstacle. Next type of special-care obstacles are moving objects [Xing-Jian, 2005]. In case of omitting such, robot has to take into account not only the current position, but also the predicted displacement of object.

Special attention that has to be paid to the issue of autonomous movement is to provide robot good viable features in different terrain (e.g. stairway), power autonomy and operator’s post that controls the robot.

The IBIS mobile robot

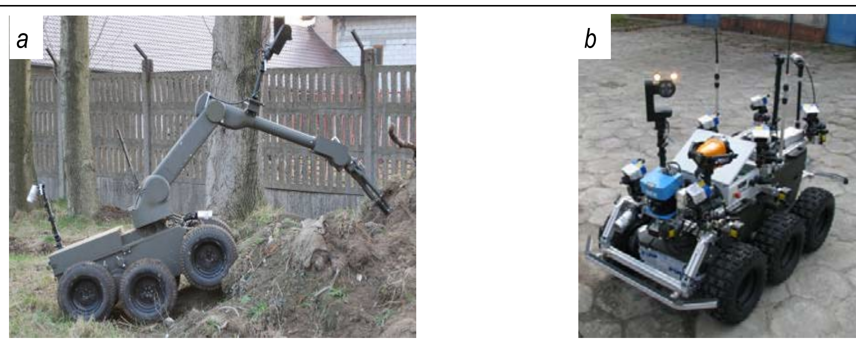

Figure 1. IBIS mobile robot: the commercial version (a), testbed version for autonomy method development (b)

The commercial version of IBIS (Fig. 1a) is designed for pyrotechnical and combat missions to operate in diverse terrain like sand, snow or rocky bulk. High speed of the robot allows performing dynamic missions. The manipulator attached to the robot provides long distance operations whilst precision drive system gives fluidity of the movement of every part of the robot, even during fast ride. The basic technical features of the robot are as following: mass: 295 kg, dimensions (length x width x height) 1.3 m x 0.85 m x 0.95 m, maximum velocity: 8.5 km/h, manipulator's maximum load 30 kg, manipulator range: 3.15 m [IBIS, 2010].

For research activity a new version of IBIS robot without manipulator has been designer (Fig.1b).

IBIS robot has been equipped with a frame with sensors forming the modular structure. Sensor's frame is a module that allows operation in semiautonomy mode and it consists of navigation controller which is a main computer of a robot, position controller that provides information about robot's position and orientation, a set of four video cameras and obstacle-sensing devices.

Robot can perform in one of two modes: teleoperation in which the movement of the robot is controlled by the operator, and semiautonomy in which the robot follows a path omitting obstacles.

Robot's sensors

Mobile base of IBIS is equipped with a sensor's frame that allows precise mounting positions of each sensors, navigation and position controller. The architecture of the system consists of four blocks functionally and physically separated of each other i.e.: sensors, position controller, navigation controller and drivers' controller. The robot control in teleoperation is provided by ISM modem whilst semiautonomy trajectory is fully calculated onboard.

Localization sensors - placed on position controller - are used to determine robot's position and orientation. IBIS position is defined in three dimensions: latitude, longitude and altitude over the Earth geoide according to NMEA specification. Therefore it can be presented in every GIS software.

For actual robot's position an L1 GPS receiver supported by INS has been used. The position in WGS-84 system is achieved by Kalman filtering of GPS coordinates and inertial navigation based on gyroscopes. The azimuth for of true-north readings is provided by digital magnetic compass with tilt compensation. Pitch and roll angles are calculated by inclination sensors: inclinometers and accelerometers.

The frame has been equipped with four types of obstacle detecting sensors: 2D laser scanner, laser rangefinders, true-presence radar sensors and tactile sensors. Their position – shown in Fig.2 – has been settled in the way that sensors cover the whole area around the robot and the main information concerns the area in front of IBIS.

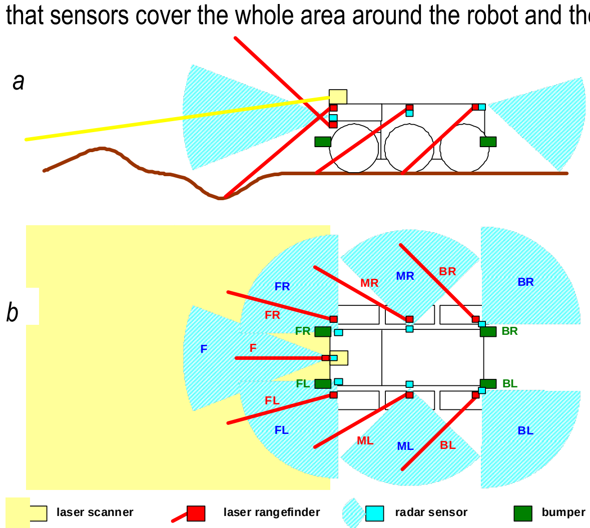

Figure 2. Orientation and placement of the sensors for semiautonomy mode: left hand side view (a) and top view (b)

2D scanner's task is to sense obstacles in front of the robot. Its angle scope has been set to 100° and 1° angle resolution. The maximum range is 80 m and is a physical limit of the sensor, but the present LOS depends on the tilt angle of the sensor's beam. For this research the beam is tilted down which allows to sense obstacles below the level of sensor.

Laser rangefinders are used to discover the area in close distance to the robot. They are mounted with different tilt angles that allows sensing obstacles that are both concave and convex. The front rangefinder is pointed with positive tilt which allows sensing obstacles that are too low for the robot to enter underneath.

Radar true-presence sensors are dedicated to sense obstacles in long distance (15 m). They output the binary information whether the obstacle is present or not on the beam. They allow obstacles early notification.

Tactile sensors' task is to sense the obstacles passed over the former sensors and to stop the robot in case of emergency hit.

Teleoperation mode

Teleoperated motion in the research is performed with a usage of operator's post that consists in laptop, joystick, emergency stop button and communication module.

In dedicated software on the operator's post a view from cameras are presented (single camera, PiP and quad modes), the map of terrain, sensors indications and robot's orientation in form of artificial horizon window. With the help of this application both teleoperation and semiautonomy modes are realized. The change between these two modes is made with a help of single button.

The robot control in teleoperation mode is performed by joystick position change or/and keyboard buttons. The joystick allows also change in position of main PTZ robot's camera.

Semiautonomy mode

None of presented in the literature autonomy algorithms ensures faultless operations. This is due to the fact of the impossibility of predicting each type of situation whilst sensors are not able to detect and classify all kind of obstacles. For this situation autonomy movement idea was replaced by semiautonomy that describes a situation in which robot performs its movement whilst the operator supervises it and robot's activity can be interrupted in every moment.

The main aim of research presented in this article was to create simulation environment and elaborate an algorithm that would allow IBIS to omit obstacles and simultaneously reach particular destination point.

The software module responsible for global path planning is installed on the operator's post and is based on the map of surroundings where robot's position and planned trajectory are drawn. The maps consists of number of layers what contain information about buildings, roads, rivers ect. Additionally several layers are editable which allows robot trace drawing, or placing points of interest with description. The robot's trace consists of an ordered set of points without the limit in number. The information about nearest intermediary or final destination point is provided to the robot which is a base of semiautonomy movement.

The local movement in semiautonomy is fully calculated by the software and hardware on the mobile robot. The semiautonomy module allows performing one of multiple behaviors such as "go to the target" or "go to the target omitting obstacles".

In case when radars and tactile sensors sense no obstacle the movement is performed with full speed and "go to the target" behavior is executed.

Default and Threshold values of laser sensors are ones that decide whether the sensed obstacle has to be omitted or just surmounted. DefaultValue contains information about regular terrain for particular sensor mounting i.e. when robot is placed on flat surface. Threshold value defines the maximum height/depth of obstacle that can be surmounted by the robot. It is assumed that IBIS can easily surmount obstacles of 20 cm height/depth.

In situation that some obstacle has been sensed robot switches its behavior to „go to the target omitting obstacles" and discriminates the velocity of movement according to distance to obstacle. For mention behavior a hybrid method is used in which the movement is realized based on sub-behaviors. Each sub-behavior defines different wheels control and has a particularly set weighting function in total robot behavior.

The first sub-behavior is connected with setting robot's heading towards destination point.

The second one is connected with setting the value of velocity that depends on the distance between robot and nearest obstacle.

The third behavior is connected with laser scanner, that is treated as 101 single laser beams. For data processing a modified version of VFH method [Boren 1988],[Ulrich, 1998] is used.

Data gathered from laser scanner are compared with corresponding DefaultValues. The next step is to build polar histogram based on prefiltered values. Histogram is then modified to take into consideration robots dimensions. The next step is to find valleys in the histogram and their middle points that correspond to new possible robot headings. The valley that is closest to the aim is chosen as a next heading of the robot.

If all laser scanner beams are occupied by the obstacles a new heading is calculated based on the distance of two extreme beams and the robot turns towards the beam of higher distance to obstacle.

The fourth behavior is connected with laser rangefinders. The wheels control for each side of the robot is in this case calculated as a weighting sum of lasers indications multiplied by weighting factor for particular sensor.

This sub-behavior is patterned on Braitenberg algorithm that bases on direct connection of sensors with actuators where each sensor has its own weighting factor.

The indication of each sensor is multiplied by appropriate weighting factors that for both sides of the robot are modulusly equal but with opposite signs.

Sensors placed on the left hand side of the robot have positive weighting factors for left hand side wheels and negative for right ones which lead to the situation where in case of obstacle sensing robot turns is a proper direction avoiding collision.

Described method of „go to the target omitting obstacles" behavior realization does not always lead the robot to the destination point. In some cases change of behavior (e.g. for "follow the obstacle on the left hand side" behavior) is necessary. The failure of particular behavior is indicated by a mechanism called Water Tank. As the robot moves towards the goal i.e. a distance between current position and destination position is decreasing with a speed over some threshold the virtual water container is empted and if this speed is below threshold the container is filled up. Therefore if current behavior is not effective in leading the robot towards goal the container is overflowed and behavior switch appear.

The next behavior selection is made based on quality estimation of current situation e.g. if during "go to the target omitting obstacles" behavior there are obstacles in front whilst the destination is places in the front-right side the robot can switch to "follow the obstacle on the left hand side" behavior. After the behavior is switched the Water Tank is emptied.

The simulation research

A dedicated software environment has been created for autonomy method testing and evaluating. It is based on Matlab/Simulink package. This approach allowed to parallel work concerning mobile base assembly and semiautonomy method elaboration.

The software responsible for surroundings simulation and virtual sensors indications has been separated from semiautonomy method. The latter one was written in the way that ease migrating the code to navigation controller's microcontroller.

The robot's surrounding was prepared with a help of V-Realm Builder (Fig.3).

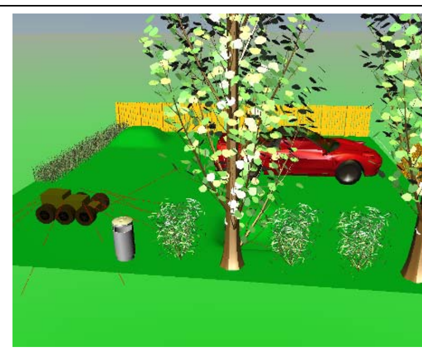

Figure 3. An example view of robot's surrounding built in V-Realm Builder

During simulation research, robot's behavior was tested under variety of conditions and sensor's placement on the mobile base. Both convex (e.g. trees, railings) and concave (holes, pits) obstacles were taken into account. In this article, results of one simulation have been presented. On the robot's path four obstacles existed and robot executed "go to the target omitting obstacles" behavior.

Simulation results are presented in Fig. 4. The animation of robot's movement can be found in [youtube, 2010]. The laser rangefinders in Fig. 4e are labeled in the same way as in Fig. 2 whilst laser scanner beams are marked in the way that Lα, where α is an angle in ° denotes a particular beam of α displacement from longitudinal axis of the scanner. For a clear view, every 10th beam indication of the scanner is shown in Fig 4f.

Basing on a performed simulation one can say that elaborated method allowing omitting obstacles and getting to defined destination point. Robot follows a path with variable speed: the speed is decreased, as the robot gets closer to obstacle (Fig. 4c). During the whole movement, the distance to obstacle is decreased (Fig. 4b). During the movement, the readings of all sensors are being changed. The effectiveness of this approach can be evaluated by Water Tank value that has highest number whilst robot is among obstacles (compare Fig. 4c and Fig. 4b).

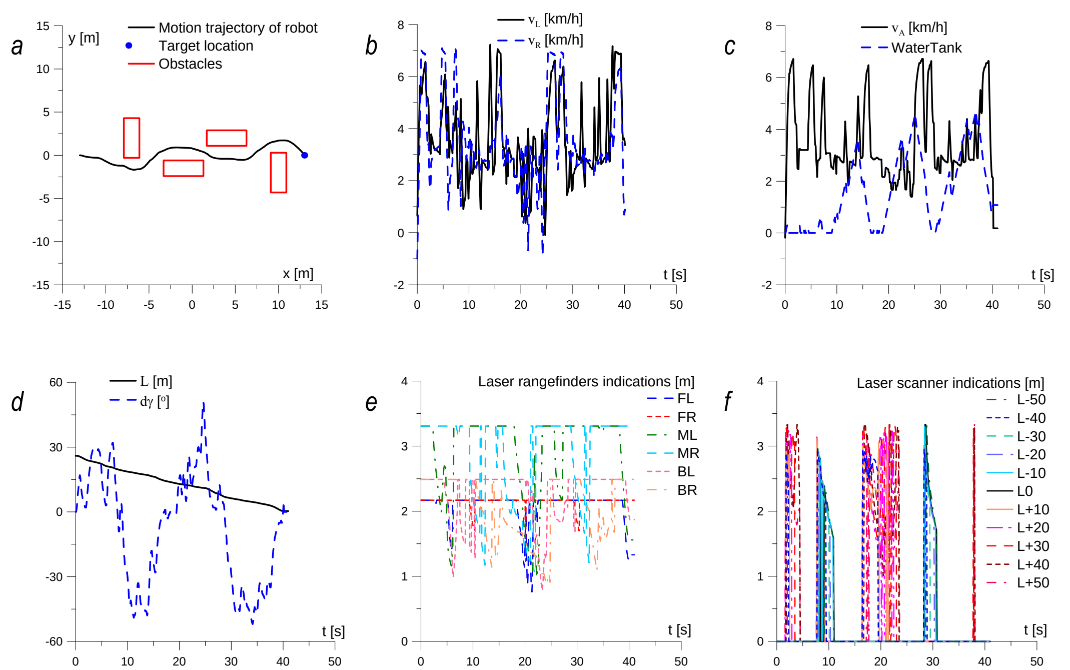

Figure 4. Data plots from simulation results: robot's trajectory (a), linear velocities values (b), IBIS's velocity and Water Tank parameter value (c), the distance to the target and robot's heading error (d), laser rangefinders indications (e), laser scanner indications for 11 beams (f)

The experimental research

During experimental researches a „go to the target omitting obstacles" behavior have been tested for different obstacles placement configuration.

The result from example of experiment is illustrated in Fig.5 whilst movies from omitting obstacles can be seen at [youtube, 2010]. The method can be used in real operation which is based on assessment of trajectory of movement of Fig. 5a that leads robot to the aim preserving safe distances from surrounding obstacles. In Fig. 5b, one can see signals controlling the robot for left and right side of it. It has to be noted that robot is a nonlinear object. It is caused by the fact of nonlinearity of suspension system and skids when making a turn that is in following connected with its kinematical structure. Therefore, the velocities of wheels differ from the control level.

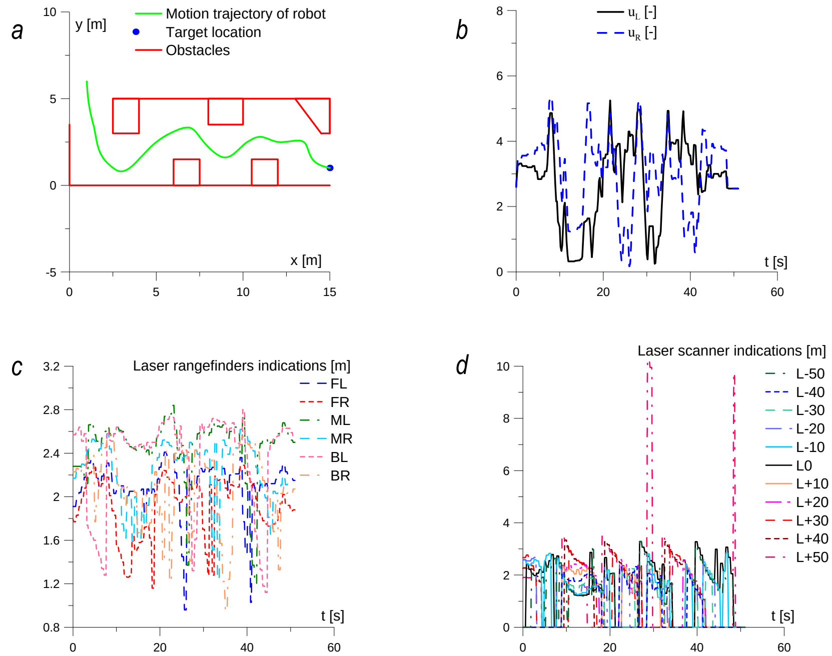

Figure 5. Experimental results: approximated robot's movement trajectory with starting and destination point (a), left and right wheels control signals (b), laser rangefinders indications (c), scanner beams readings (each 10th beam) (d)

Summary and conclusion

In the scope of presented work a computational effective semiautonomy method of the target approaching and obstacle omitting based on data fusion from different types of sensors is presented. This method can be applied to mobile robots that operate in highly urbanized terrain where robot mostly deals with flat terrains, but also for natural environment with its characteristic terrain's shape. Due to different sensors usage and their proper positioning obstacles of different cubature are sensed.

Simulation research has been held for elaborating method. These simulations were carried out using Matlab/Simulink package. Then, the method was optimized in sense of computational requirements and finally implemented in embedded system for checking the convergence of simulation and real robot operation in complex environment.

For the need of experiments a set of mobile robot and operator's post that create complete evaluation system for autonomy method testing have been designed. Modularity of software allows implementation of different other autonomy methods so that IBIS can be used as a testbed for autonomy movement and different method assessment.

Simulations and real experiments show that the method can effectively realize the behaviors „go to the target omitting obstacles" and „go ahead omitting obstacles"

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Intelligent Manufacturing Systems

THE INTELLIGENT PRINCIPLE OF VIRTUAL LABORATORIES FOR COMPUTER AIDED DESIGN OF SMART SENSOR SYSTEMS

Iliya Mitov, Anatolij Krissilov, Oleksandr Palagin, Peter Stanchev, Vitalii Velychko, Volodymyr Romanov, Igor Galelyuka, Krassimira Ivanova, Krassimir Markov

Abstract*: A distinguish principle for Virtual Laboratories for Computer Aided Design of Smart Sensor Systems (VLCAD-SSS) is proposed. This is the "intelligence" of the VLCAD-SSS. This principle is based on the investigation in the area of the General Information Theory (GIT) and especially of the Theory of Infos, which is a part of GIT. The understanding the VLCAD-SSS as intelligent system gives possibility to develop appropriate functions and models.*

Keywords*: Virtual Laboratories for Computer Aided Design; Smart Sensor Systems; Intelligence; Intelligent Systems.*

ACM Classification Keywords*: J.6 Computer-Aided Engineering –Computer-Aided Design (CAD); F.1.1 Models of Computation - Self-modifying machines*

Introduction

The concept of Virtual Laboratories (VL) originates and is based on the idea for remote access to some resources via world computer net. In the beginning VL are aimed to support educational process and were called Remote Laboratories (RL). Traditionally, Remote Laboratories have been focused on specific solutions for specific problems. We can find a wide range of RL in the literature [Gravier et al, 2008], assisting very different types of subjects (electronics, robotics, optics, fluids mechanics...), but commonly bound to a restricted set of requirements. Little attention has been paid on working on a scalable, maintainable, secure, open architecture that addresses the requirements of a wide set of experiments, and that could be open enough to support or adapt itself to new experiments. [García-Zubia et al, 2008].

[Gravier et al, 2008] present wide literature review and expose four major issues for the leverage of remote laboratories. These are reusability, interoperability, collaborativeness and convergence with Learning Management Systems. Those functionalities are pieces of a large picture, but they can be handled independently. Future research directions are merely called to address some of these issues. [Gravier et al, 2008] see in each of these paths a serious possibility to blow away a lot of problems of remote laboratories, thereby providing a richer learning experience to the students, but also to the teacher.

The indecently of the used learning theory (constructivism or behaviorism) the Remote Laboratories are aimed to support reproduction of the knowledge. A widespread learning theory today is constructivism, which emerged from cognitive science. Constructivism is usually opposed to behaviorism [Jonassen and Wang, 1993]. Behaviorism focuses passive transfer of knowledge between teachers and learners, trying to interpret knowledge acquisition as a settlement of a permanent change in learner's behavior, face to a given problem. On the opposite, constructivism try to make students learn from their own observations, using discussions with the teacher but also with their peers (sometimes referred as social-constructivism).

The support of knowledge discovery needs different tools and approaches. This scientific area is well known as Computer Aided Design [Farin et al, 2002]. The complexity of the problems to be solved causes emerging the Virtual Laboratories for Computer Aided Design (VLCAD) [Palagin et al, 2007]. Special types of VLCAD are the Virtual Laboratories for Computer Aided Design of Smart Sensor Systems (VLCAD-SSS) [Palagin et al, 2009]. Due to very specific creative area of design of the smart sensor systems, the software support needs to be “intelligent”. In other words, the methods and instruments of the Artificial Intelligence need to be implemented in VLCAD-SSS. The goal of this paper is to outline this very important principle for VLCAD-SSS.

In the next section we discuss the main characteristics of the concept “intelligence”. Section three describes the VLCAD-SSS as an intelligent system. Last section concludes.

The intelligence

About the intelligence, Schlesinger and Hlavach wrote “You and we altogether should not see such a great nonsense in that one can learn about something, which has never been observed. The entire intellectual activity of individuals, as well as that of large human communities, has for long been turned to those parameters which are inaccessible to safe observation. We will not be speaking about such grandiose parameters as good and evil. We will choose something much simpler at first glance, for example the temperature of a body, which is regarded as an average rate of motion of the body's molecules.

The path leading to knowledge about directly unobservable phenomena is nothing else than an analysis of parameters which can be observed, and a search for a mechanism (model) explaining the relations between the parameters. This means an effort of exploring the relations between the observed parameters and the impossibility to explain them in another way (or more simply) than as an existence of a certain unobservable factor that affects all the visible parameters and thus is the cause of their mutual dependence. Recall astronomers who have been predicting a still unobservable planet by encountering discrepancies in observations from assumed elliptical orbits of observable planets since Kepler laws have been known. Such an approach is a normal procedure for analyzing unknown phenomena. The capability of doing such exploring has since long ago been considered to be a measure of intelligence.” [Schlesinger and Hlavach, 2002], p.262.

The reality cannot be given in one definition. There exist many definitions of the concept "**intelligence**". For instance, a definition given from practical point of view is given in [Fritz, 1997]: the "intelligence is the ability to reach ones objectives. A system is more intelligent if it reaches its objectives faster and easier. This includes the ability to **learn** to do this. The intelligence of a system is a property of its mind. The mind is the functioning of its brain. An **intelligent system** is a system that has its own main objective, as well as senses and actuators. To reach its objective it chooses an action based on its experiences. It can learn by generalizing the experiences it has stored in its memories. Examples of intelligent systems are persons, higher animals, robots, extraterrestrials, a business, a nation. An **artificial intelligent system** is a computer program. We can say that it is like the proverbial black box; it has inputs and **learns** which outputs get the most approval by human beings. It stores experiences in its memory, generalizes them, and thus can deal with new circumstances (new inputs)".

The philosophical and practical points of view are two sides of the same idea. Nevertheless, from these definitions it is not clear what the main characteristics of the intelligence are. We need definition that is more detailed and in the same time to be universal to cover natural and artificial intelligence. The correct understanding of the concept of intelligence gives possibility to organize the process of design in proper way. This needs to be one of the main features of VLCAD-SSS.

The application of intellectual methods of information processing in smart sensors systems’ problems/tasks is conditioned at least by three groups of factors.

- First, this information is complicated: it comes from various sources, in a considerable volume and irregularly, it has various nature, ranges and units of measurements.
- Second, data that is being collected relates to the significantly important areas of implementing the smart sensors systems – monitoring the quality of water and air, danger of fires and level of ground waters, weather and climatic anomalies, sharp dangerous situations and "creeping" accidents, etc.
- Third, processing of this information in general requires application of such operations, as estimation, comparison, analysis, classification etc.

All this area, i.e. the specified information, its collection and processing, its analysis and decision-making, management and taking actions, control and estimation of results – all this is in general poorly structured, has more likely qualitative rather than quantitative nature and therefore is insufficiently formalized, and is beyond usual methods of representation and computer processing.

Within the last decades and especially due to the introduction of personal computers, researches and application results of new methods of work with complicated information in difficult conditions were started in a variety of areas (management, economics, business, computer science, etc.). They have got the name of intellectual methods, and it is not always a metaphor.

We may define the intelligence as "ability to think abstractly", as "ability to operate effectively in the present conditions", "ability to react correctly to certain problems", "ability to study", "ability to receive knowledge from experience", "skill to get the abilities that lead to desirable results", "ability to adaptation", etc.

In Webster dictionary, the dictionary of authority, there is the following interesting definition: intelligence is an ability to be taught (to be learned) or to achieve the comprehension due to experience. Another definition from the same source is to have a ready and quick apprehension.

In Oxford dictionary of current English (ed. A. Hornby) which is an excellent source, the following definitions (besides others) are presented: intellectual – having or showing good reasoning power; intelligence – the power of perceiving, learning, understanding and knowing.

We will consider the methods of information processing as intellectual which are as a rule referred to rational activity particularly. These are functions in which comparison, estimation, generalization, systematization, aggregation and decision-making are realized – in difficult conditions, when there is a lack of information, time etc.

In general, the definitions of the intelligence are covered by next definition [Mitov et al, 2010], which follows from the General Information Theory [Markov et al, 2006] and especially from the Theory of Infos [Markov et al, 2009].

The intelligence is synergetic combination of:

- **(primary) activity for external interaction**. This characteristic is basic for all open systems. Activity for external interaction means possibility to reflect the influences from environment and to realize impact on the environment. For instance, in Walter Fritz' definition [Fritz, 1997] these are "senses" and "actuators";
- **information reflection and information memory**, i.e. possibility for collecting the information. It is clear; memory is basic characteristic of intelligence for "the ability to **learn"**;
- **information self-reflection**, i.e. possibility for generating "secondary information". The generalization (creating abstractions) is well known characteristic of intelligence. Sometimes, we concentrate our investigations only to this very important possibility, which is a base for learning and recognition. The same is pointed for the intelligent system: "To reach its objective it chooses an action based on its experiences. It can learn by generalizing the experiences it has stored in its memories";
- **information expectation** i.e. the (secondary) information activity for internal or external contact. This characteristic means that the prognostic knowledge needs to be generated in advance and during the interaction with the environment the received information is collected and compared with one generated

in advance. This not exists in usual definitions but it is the foundation-stone for definition of the concept "intelligence";

- **resolving the information expectation**. This corresponds to that the "intelligence is the ability to reach ones objectives". The target is a model of a future state (of the system) which needs to be achieved and corresponding to it prognostic knowledge needs to be "resolved" by incoming information.

In summary, ***the intelligence is creating and resolving the information expectation*** [Mitov et al, 2010].

VLCAD-SSS as intelligent system

Creating of Virtual Laboratory for Computer Aided Design of Smart Sensor Systems (VLCAD-SSS) is very important scientific-technical problem. Based on received experience and wide analysis of world literature [Palagin et al, 2009] separate out the next main principles of VLCAD-SSS:

1. ***VLCAD-SSS is man-machine system***. All design systems, which had been developed and will be developed, are computer-aided, and designer is the main part of these systems. Human in such systems has to solve tasks, which cannot be well defined, and problem, which human by using own heuristic abilities may solve better and more effective than computer. Close interaction between human and computer during the design process is one of principles of development and exploitation of any CAD systems for computer device designing.

2. ***VLCAD-SSS is hierarchical system***, which use comprehensive approach to automation of all design levels. The level hierarchy is presented in the system structure as hierarchy of subsystems.

3. ***VLCAD-SSS is a set of informational-concerted subsystems***. This principle refers not only to connections between large subsystems, but to connections between separate parts of subsystems. Informational compliance means, that almost all possible sequences of design tasks are served by informational-concerted programs. One program is informational-concerted if all data in this program are part of numeric arrays and do not need transformations during sending from it to another program and inversely. So, the results of one program can be incoming data for another program.

4. ***VLCAD-SSS is an open system***, which are permanently expanding. Permanent progress of technology, designed objects, computer technology and computational mathematics lead to appearance of new, more perfect mathematical models and programs, which replace old analogs. VLCAD-SSS has to be open system and be able to use new methods and tools.

5. ***VLCAD-SSS is specialized system with maximum using of unified units***. Requirements of high efficiency and universality for any system are, as a rule, conflicting or competitive. It is reasonable to develop VLCAD-SSS on the base of unified parts. Necessary condition of unification is searching of common principles in the modeling, analysis and synthesis of technical objects.

Now we are able to add a new principle:

6. ***VLCAD-SSS is an intelligent system***. This means that VLCAD-SSS has to cover all given above characteristics of the intelligent systems:

- **VLCAD-SSS (primary) activity for external interaction**. This follows from principle 4 - VLCAD-SSS is an open system and it is clear, the activity for external interaction means possibility to reflect the influences from environment and to realize impact on the environment. VLCAD-SSS needs to have "senses" and "actuators" which may be of different types starting from trivial computer keyboard and screen;
- **VLCAD-SSS information reflection and VLCAD-SSS information memory**, i.e. the possibility for collecting the information. Memory is basic characteristic of intelligence for “the ability to **learn”.** VLCAD-SSS is based on special kind of multi-dimensional memory organization [Markov, 2004], which gives new possibilities to support computer intelligent processes;

- **VLCAD-SSS information self-reflection**, i.e. possibility for generating "secondary information". The VLCAD-SSS needs to be able to find regularities in the stored data to have possibility to classify the received information in proper classes and to prepare basis for further decision making;
- **VLCAD-SSS information expectation** i.e. the (secondary) information activity for internal or external contact. During the information interaction with the end user, the VLCAD-SSS needs to be able to use the regularities in the data found during self-reflection. It is important to discover regularities in the incoming data to have possibility to classify the received information in proper classes and to prepare basis for further decision making. The prognostic knowledge is generated in advance and during the interaction with the environment the received information is collected and compared with one generated in advance;
- **VLCAD-SSS resolving the information expectation**. VLCAD-SSS needs to create appropriate targets as models of the future states of the creating systems which need to be achieved and corresponding to it prognostic knowledge to be "resolved" by incoming information. The manual and/or automatic experiments with the generated models have to be achieved and corresponding to it prognostic knowledge needs to be "resolved" by incoming resulting information.

Conclusions

A distinguish principle for Virtual Laboratories for Computer Aided Design of Smart Sensor Systems (VLCAD-SSS) was proposed. This is the “intelligence” of the VLCAD-SSS. This principle is based on the investigation in the area of the General Information Theory (GIT) [Markov et al, 2006] and especially of the Theory of Infos [Markov et al, 2009], which is a part of GIT. The understanding the VLCAD-SSS as intelligent system gives possibility to develop appropriate functions and models.

The principle of intelligence pointed above is a basis for further work. The provided corresponded prototype realization and experiments with an intelligent machine learning system called PaGaNe [Mitov et al, 2009] shows good results to be implemented in the VLCAD-SSS. The intelligence of VLCAD-SSS may be realized using intelligent system PaGaNe because it is based on the same advanced multi-dimensional model of memory organization [Markov, 2004] which is proposed for VLCAD-SSS [Palagin et al, 2009].

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APPLICATION OF ARTIFICIAL INTELLIGENCE TOOLS TO THE CLASSIFICATION OF STRUCTURAL MODULES

Galina Setlak, Tomasz Kożak

***Abstract**: The purpose of this paper is to present the fundamental algorithms and procedures by which processes of clustering and classification of elements, assembly units and parts of installed product devices are carried out in the system of computer-aided design of modular technology of assembly.*

There will also be presented a basic tool that has been used for classification of structural modules - the self-organizing Kohonen network.

***Keywords**: Artificial intelligence, group technology formatting rules, fuzzy logic, classification method.*

***ACM Classification Keywords**: I. Computing Methodologies, I.2 Artificial Intelligence, J. Computer Applications, J.6 Computer Aided Engineering*

Introduction

Modular technology of assembly can be defined as a set of technology modules that cover specific assembly operations, which are structurally enclosed part of technological process in the manufacture of some object (product or its component, structural element). The technological module of assembly is considered as a set of integral operations of major and minor assembly, which is carried out in a specific sequence at one position and is characterized by its use of a specific set of tools for combining surface, components, subassemblies, assemblies [Szabajkowicz, 2000].

Designing of modular technology is an appropriate choice of technological modules, their task is to work out an applicable structural module of the product. Therefore, the modular process combines the advantages of both the separate process which takes into account the characteristics of the specific unit, as well as features of group process. That enables connecting different units in the groups and makes the process flexible. In particular, it allows to minimize various technological means of the assembly, as well as avoiding duplication of work as regards the technological preparation of production [Szabajkowicz, 1998]

Currently, the modular technology is the basic and the most promising direction of development of modern assembly techniques, it is based on the principles of group technology manufacture. In recent years, the flexible module assembly design is the main problem of scientific research centres, as well as design offices of leading manufacturing companies. This design is performed on the basis of modular technology of assembly [Szabajkowicz, 2000].

The purpose of this paper is to present the fundamental algorithms and procedures by which processes of clustering and classification of elements, assembly units and parts of installed product devices are carried out in the system of computer-aided design of flexible, technological modules of assembly.

There will also be presented a basic tool that has been used for classification of structural modules - the self-organizing Kohonen network.

Classification and grouping issues of the modular technology of assembly

While designing products for assembly using modular technology, the principle of structural modularization of the product needs to be applied. This means that when designing assemblies, subassemblies and components, the following steps should be followed:

- specify and isolate parts as well as base areas,
- use the typical patterns and methods of assembly,
- strive to match the new product to such construction to be able to use existing structural modules and technological modules.

In the process of designing flexible assembly systems based on modular technology of assembly, operations for classification and clustering are performed repeatedly, at different stages, namely:

- classification of objects into groups and subgroups of elements,
- classification of assembly units, which are technologically similar
- extracting from the technological schemes, autonomous, integrated assembly actions, followed by grouping separate assembly units, depending on instrumentation equipment on which these actions could be performed;
- grouping of elementary modules and selection of appropriate, possible options of the technological modules and structural modules;
- classification of elementary, technological modules of the assembly [Setlak, 2003].

In order to classify and group the assembled components, apart from manufacturability other basic structural features are highlighted such as construction, ways of orienting and basing of parts. The projects concerning the planning technological processes of assembly present different methods of the parts classification of assembled products to develop a typical, unified, structural modules.

Among others, in the given study there will be used classification of the combined elements, taking into account their functional characteristics [Szabajkowicz, 2000] (isolating base parts, connected parts and fasteners) and classification of the part which takes into account the characteristics such as shape, variety of shapes, symmetry, way of orienting or arranging them in terms of the complexity of their automatic orienting.

Using the appropriate method of classification of installed products and components, it is possible to develop common technological modules of assembly and choose the typical technical equipment and assembly instrumentation [Rampersad, 1997].

For this purpose, the following classification criteria have been chosen:

- structural and technological use of elements (this criterion divides the assembled elements into groups),
- repeatability in the construction of objects (distinguishes typical and unique parts),
- shapes of the components of assembled product (division on types: shafts, wheels, bushings, brackets, etc.).

Similarity research methods

The main methods used to study the similarities of elements of the designed products and assembly units are classification and clustering [Setlak, 2003].

Classification is the assignment of an object to a standard class on the basis of selected characteristics. The process of classification may occur when classes will be defined before the division, to which set of input will be distributed. The classification also means assigning the input images to proper sets, defined as classes [Knosala, 2002].

Methods of classification:

- standard method,
- image recognition based on patterns of classes,
- image recognition based on sequence of learning,
- method of real characteristics.

The standard classification is characterized by the process of division into classes, implemented on the basis of the division of value of characteristic features. Before the classification, there should be selected those features that are used to attain the objectives of the classification process. This is an important aspect, because the wrong choice of features describing the tested items may result in erroneous classification outcomes, while very large number of them can demonstrate that some of them do not relate to the classification aim [Knosala, 2002]. The real characteristics method indicates only initial recognition, which determines to which (general) class the given item belongs.

It is also worth mentioning that in the case of image recognition, the concept of classification is defined as the relation describing a destruction of sets of items into the collection of equivalence classes corresponding to individual images. In the process of recognition, the most important issue is to calculate the membership function.

Checking the similarity of the structural modules can provide information that are relevant to the organization of industrial production. This information can be obtained by clustering similar items.

Clustering is the original action in relation to the classification, since it leads to the definition of classes. Clustering takes place when the number of groups is not specified and range of characteristics is not known before the division of the input set. Clustering means bringing together similar objects and separating different. Clustering is the process of splitting a set of elements into subsets without previous arrangement what will be the bands of characteristics and the number of these subsets.

In determining the subsets, called clusters, two basic conditions have to be accomplished:

- data which belongs to the same cluster should be most similar,
- data which belongs to different clusters should be most dissimilar (varies to the greatest extent).

For this purpose, the similarity research methods are used. Without the application of these methods, the full production cycle of element involves a design and construction process, preparation of production and manufacturing. In many cases, the method of studying the similarity can allow a simplification of these processes, or even eliminate some of them, when a new element is taken into account (one of these three cases may occur):

- eliminating the need to design a new element occurs in the case when the newly designed element is identical to that which has already been produced,
- situation where a few changes have to be made, while a new item is being produced, it happens when the newly designed element has common features with the one which was produced before,
- if the newly designed element does not have common features with the one produced before, then a complete structural and technological documentation has to be done.

This method allows to avoid certain limitations associated with the process of classification. It is not always possible to determine the values division of characteristics that describe the class, moreover, classification systems can be created in two directions, as a specialized tools for analyzing very small group or more universal systems, but of little opportunity to study similarity. The classification depends on the criteria, due to which it is maintained. Method of clustering is devoid of all these restrictions, because the criteria for division into groups take place automatically, on the basis of features detected in the analyzed element.

In order to fully demonstrate the methods of studying similarity, the exact duties of each of the methods ought to be specified (apart from the general presentation).

The study of similarity should consider such problems as:

- define the similarity between elements,
- find similarity of a given element to the set of classes,
- use the data to find similar elements [Knosala, 2002].

Currently, the methods of artificial intelligence are used to solve the tasks of classification and clustering, including artificial neural networks and fuzzy clustering algorithms [Setlak, 2000].

Application of Kohonen neural networks for clustering of structural elements

Kohonen networks are one of the basic types of self-organizing networks. The capacity of self-organization gives completely new opportunities - an adaptation to previously unidentified input data of which very little is known. This seems to be a natural way of learning. Kohonen networks are synonym of the entire network group in which learning takes place by a self-organizing competitive method. It involves giving the network input signals, and then selecting through the competition a victorious neuron that best corresponds to the input vector.

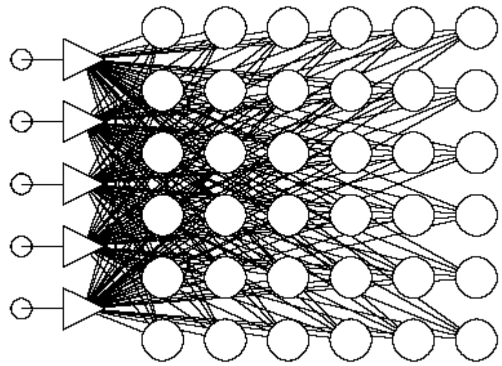

Figure. 1 Kohonen network
[Zurada, Barski, Jędruch, 1996]

The exact pattern of Kohonen neural network architecture presents the following figure (Fig. 1).

The structure of neural network is very important issue. A single neuron is very simple mechanism and thus able to do a little. Only a combination of many neurons enables to carry out any complicated actions [Zurada, Barski, Jędruch, 1996].

The aim of such networks is clustering or classification of input patterns. This is done in accordance with the principle that similar input signals raise the same output unit of neural networks. Algorithm, from which a whole class of networks was called are self-organizing Kohonen maps. The network copies the input in the form of one-dimensional or multidimensional vector of characteristics into the one-dimensional or multidimensional output [Kohonen T,1990].

$$w_{i^*j}(t+1) = w_{i^*j}(t) + \eta(t)(x_j^{\mu} - w_{i^*j}(t)), \tag{1}$$

where:

$\eta(t)$ - network learning factor,

t - iteration's number,

x_j^{μ} - j's value of this feature μ-this pattern of input,

w_{ij} - weight value of input connection of j node with i output neuron.

Kohonen proposed two types of neighborhood: rectangular and Gaussian.

$$\begin{cases} 1 \;\; for \quad d(i,j^*) \le \lambda \\ 0 \;\; for \quad d(i,j^*) > \lambda \end{cases} \tag{2}$$

$$\lambda(i,i^*) = exp\left(-\frac{d^2(i,i^*)}{2\sigma(t)^2} \right) \tag{3}$$

Gaussian function is the most often applied neighborhood function. It gives a good convergence of Kohonen algorithm [Knosala ,2002].

Distance d_j is calculated to the input signal for all neurons and the best neuron is selected on the basis of the formula:

$$j^* = \arg\min_j d_j = \arg\min_j \sum_{i=0}^{N-1} \left(x_i(t) - w_{ij}(t)\right)^2 \tag{4}$$

where x_i – i's input node in a time moment t,

$w_{ij}(t)$ — synaptic weight from i's input element to j's neuron in a time moment t.

Instruments must be standardized before neural network learning. For this purpose, input vectors are normalized as follows:

- redefinition of the input vector components:

$$x_j \leftarrow \frac{x_j}{\sqrt{\sum_{j=1}^{N} x_j^2}} \tag{5}$$

- increase the input space size by one, i.e. RN → RN 1, where

$$\sum_{j=1}^{N+1} x_j^2 = 1 \tag{6}$$

In the process of neural network learning, in accordance with the Kohonen algorithm, the adaptation of synaptic value weights of neural network is performed in such a way, that the error is minimized, it is given by the formula:

$$\delta\{ w_{ij} \} = \frac{1}{2}\sum_{ijk} M_j^{\mu}(x_j - w_{ij})^2 = \frac{1}{2}\sum_{\mu}\left| x^{\mu} - w_{j^*} \right| \tag{7}$$

where M_j^{μ} is a checking function, which checks whether pattern x^{μ} activates the neuron as the winning unit j* and is calculated by the formula:

$$M_j^{\mu} = \begin{cases} 1 & if \quad j = j_{\mu}^* \\ 0 & \end{cases} \tag{8}$$

In order to increase the convergence of the basic Kohonen network learning algorithm, it was modified in the algorithm "winner takes most." In the weight algorithm, successful neurons and neighbouring neurons are updated according to the so-called neighbourhood function, which on the one hand, acts as arresting connections and on the other hand, activates the output of neighboring neurons.

Based on the relation that the Gaussian function is mostly used neighborhood function depending on η (t), Kohonen rule increases the function value in all dependencies, until it reaches the minimum. Therefore, the learning rate η (t) is very important:

$$\eta(t) = \eta_0 \left| e^{-\alpha t} cos(\frac{\pi}{2T_z} K(t)t) \right| \tag{9}$$

To investigate the accuracy of networks learning, inequality coefficient of neurons was introduced, which is based on the nodes of input and output connection weights. This factor's task is to analyze changes of the vector weight in the vicinity of each of the output nodes in relation to the neighbouring vectors. When the coefficient value is less, then the input object is better recognized.

In order to improve the quality of the clustering process, modified learning algorithm can be applied, in which new forms of neighborhood function were used $\Lambda(t)$ radius of neighbourhood $\lambda(t)$ and learning rate $\eta(t)$. A function of an error is used for analysis of the speed dynamics of network learning $\varepsilon(t)$ and a measure of inequality of the network $\theta(t)$. The most important function of the learning process in the Kohonen algorithm is the neighbourhood function. It decides about the adaptation of winning node weights and nodes in the neighborhood. As it has already been mentioned, Kohonen algorithm has many limitations, such as:

- achieving local minimum by a network,
- occurrence of dead nodes,
- low speed of learning.

In order to analyze the behavior of the network through learning processes and to explore its optimal parameters, the principal criteria for evaluation need to be defined. The criteria for these neural networks are:

- the criterion of minimum error or maximum objective function,
- the criterion of maximum organization of the network or minimum not clear.

These criteria set the end of the learning process and optimization of the learning parameters, applied to the problem [Knosala, 2002].

Conclusion

The basis for the design of flexible assembly modules are the classification and clustering of components, assembly units and parts of assembled products. Selection of appropriate methods and tools for solving these tasks is particularly important in the design process.

The paper presents issues which are only a part of the carried out studies, they require additional testing and even wider range of experience, especially practical applications.

On the basis of the presented algorithm, it can be concluded that some artificial intelligence tools for grouping structural components - Kohonen neural networks give very promising results. In order to perform more detailed studies, there should be developed algorithms which automatically record geometric features of structural components in a form of input matrix of features for the neural network. It is also required to have tools and methods for the detailed interpretation of the results of neural network work.

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VISUALIZATION OPTIONS OF ASSEMBLY PROCEDURE

Jana Jedináková, Marek Kočiško, Slavomír Gajdarik

***Abstract**: A current computing performance of PC technique and software support allows to virtual model and test of an entire production process, saving considerable financial and human resources that would by necessary to design and test of this entire system. The paper deals with a problem of assembly technology and how to make it more effective and simpler through the visualization of assembly procedures from the CAD system with an animation software up to design by using a special tool of virtual reality. The use of virtualization assembly tools provides more effective, simpler and faster understanding of the entire assembly process.*

***Keywords**: formatting rules*

***ACM Classification Keywords**: J. Computer application - Manufacturing*

Introduction

In the current period of continuous cost reduction, it is very important to prepare new production, so all technological production processes or assemblies will be achieved, providing fast, cheap and technically the most accurate and the most simple production or assembly.

Therefore, preparation of production is becoming one of the foremost activities, where construction and technological preparation of production was currently preferred.

Actual computing output of PC technology and software support enables virtual modelling and testing of the whole production process, thus saving significant financial and human resources. Therefore, 'digital factory' term is currently becoming highly actual. Digital factory is a virtual picture of the real production, which pictures production processes in virtual world. It serves for planning, simulation and optimisation of production of more complex products. At all time, assembly is one of the most important components of product developments. Visualization of assembly process would radically change the model of design and manufacture.

Visualization and animation

The visualisation can be utilised in technological preparation of production, where the whole production process or assembly can be virtually simulated and thus cost reduction for production testing can be achieved and consequent collisions in particular operations can be avoided; work conditions and all availability of all assembly points can be tested, as well as collision of robots with any parts or appliances can be avoided.

Animations can be created in particular software, e.g. 3Dmax, Blender, Maya, Cinema 4D, etc. Weak point of the abovementioned software is complicated drawing of the whole 3D model in vector graphics and consequent de-animation. The preparation of animated videos is dealt by companies which, in accordance with customer's needs, design and create computer animation. Animations are created by computer graphic designers who are not engineers that, once understood the requirements, model the scene through 3D modelling software, as well as through existing 3D models, and eventually animate it. The difficulty here is correctly identifying the involved parts, how they move and which "cause-effect" relationships characterize them. Not all users require the same quantity and quality of information; specific information can be, according to the different role of the worker, essential or useless. For example, focusing on the manufacturing sector, a machine operator needs to have an overall understanding of the machine and of the parameters for the manufacturing process, while a maintenance worker needs the detail of the internal parts, e.g. electric cables, which are not needed by the former user-type and instead could cause confusion to non experts. Therefore, animation authoring must be able to manage different level of details and apply the correct one to the correct user-type, which can be depicted as a “role.” [Kocisko, 2009]

In production, it is better to use CAD software, which, however, has limited animation possibilities. It can de-animate simple animations, usually transfer part from point A to point B in connection with pre-set “stop points” or can animate work activities of individual tools which machine the product and pictures constructer or technologists the whole process of part machining in particular operation. The other way of animation is the assembly and disassembly procedure, where CAD programs can picture the formation in disassembly position. It is in fact simple animation, which only moves disassembled parts to complex formation. Even these animations are simple, the offer the user basic (and in some cases sufficient) idea of formation and the way of its assembly.

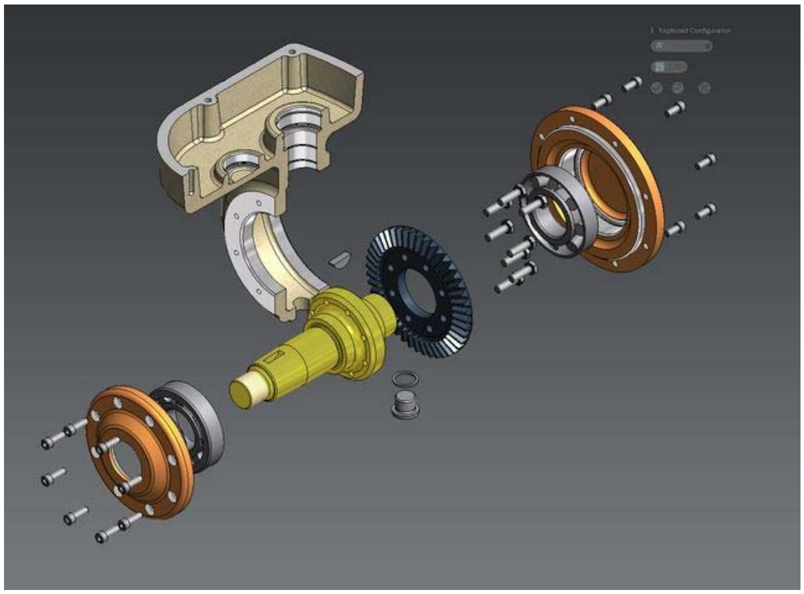

Figure 1. Assembly/disassembly animation

One of the possibilities of assembly procedure visualisation is the use of CAD program, e.g. Catia, ProEngineer, SolidWorks and other, and by its connection with animation program Macromedia Flash MX or newer version of Adobe Creative Suite.

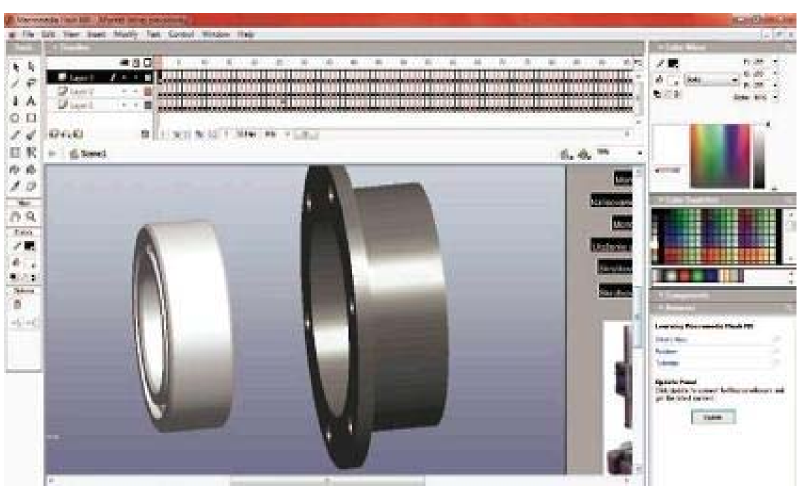

Figure 2. Creation of animation procedure in Macromedia Flash MX

Cortona3D is a powerful server-based solution with a 3D repository that manages the entire process of reusing existing 3D source data (CAD) to create, update and publish 3D interactive content including visualizations and simulations for Product Maintenance & Training. In addition, users in the field can tag and feedback structured data related to the operation/maintenance of a specific part of equipment for analysis.

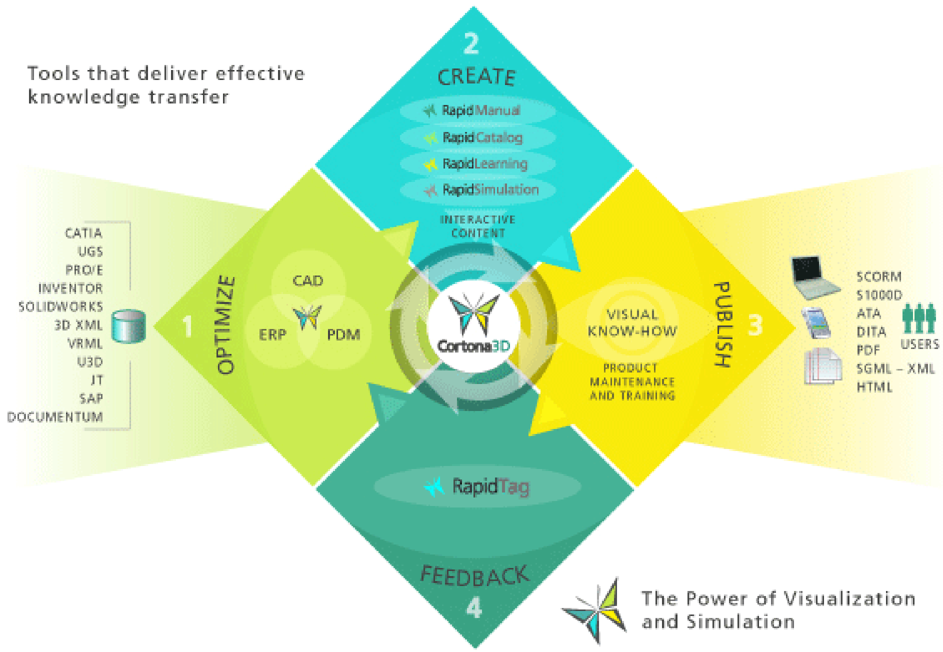

Figure 3. Cortona3D

Cortona3D feeds design data from CAD, PDM and ERP into powerful 3D authoring tools that integrate ‘Visual Know-How’ into product documentation. It's intuitive interface enables users with no 3D expertise to create compelling simulations and associated text simultaneously, dramatically reducing effort and timelines. Users in the field can then feedback data, about parts or assemblies, into a central repository, for analysis and troubleshooting. [cartona, 2010]

Other, more complex method is the use of highly-specialised software designed for production systems projecting, with complex animation of individual operations and activities on output.

Leader in the field of production process projecting with the use of virtual reality is Dassault Systèmes Group.

With their product **Delmia**, they specialise on planning and production of complicated and complex products.

Delmia covers wide range of activities related to projecting and animation.

It can be divided to:

- **Production processes planning**

- definition of relations among parts, operations and devices
- sequence of operation graph
- time limits for operations
- devices setting planning

Figure 4. Delmia

● **Production processes simulation**

- production process modelling with random occurrence consideration
- production simulation
- other ways of production testing

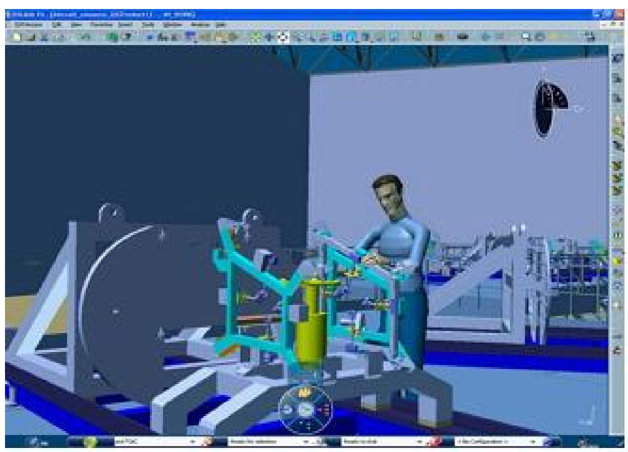

Figure 5. Production process simulation

● **Ergonomics (Delmia Human)**

- complex modelling of human body
- simulation of work activities and feasibility of work operations

● **Robotics**

- elaboration of robotised workplaces studies (robot coverage, detection of collisions,…)
- dynamic occurrence simulation
- offline programming [cartona, 2010]

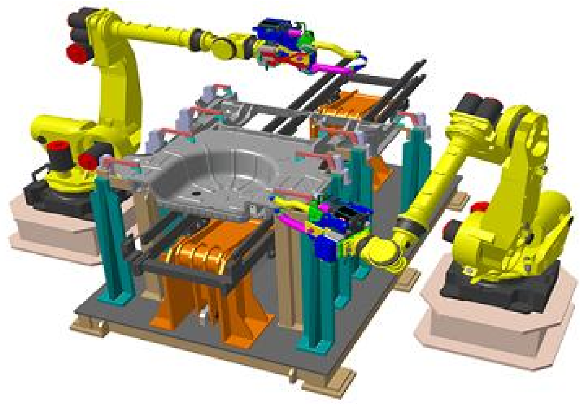

Figure 6. Design and animation of robotized workplace.

Conclusion

Although the market operates a many of software to visualize the assembly and associated manufacturing activities is not necessarily take into account many factors entering. Irrelevant just a question of price but also the optimal ratio and other ingredients. The final decision rests almost always a given company and, as in other computer aided reflects the current situation and market position.

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VHDL-MODELING OF A GAS LASER'S GAS DISCHARGE CIRCUIT

Nataliya Golian, Vera Golian, Olga Kalynychenko

***Abstract**: Usage of modeling for construction of laser installations today is actual in connection with automation of manufacture. The automated designing is used at forecasting behavior of modeled objects That is why at the certain stage of development CAD there was a necessity of creation of standardized language of the description of the equipment, one of which is VHDL. It allows to describe the behavior of digital circuits, as well as to perform and also to spend the hierarchical functional-structural description of the big integrated systems and at the same time has all signs of the programming language of high level – allows to create the types of the data, has a wide set of arithmetic and logic operations. The paper suggests synthesis of a VHDL – model of a gas laser gas-discharge circuit efficiently distributing RTL- circuits to create a new list of connections with a minimum number of components. Models of GDC lasers consist of three subtasks: a logic conclusion, optimization received RTL structures and its distribution on structural elements technology mapping*

***Keywords**: model of a gas laser, gas-discharge circuit, VHDL – model, gas discharge circuit*

***ACM Classification Keywords**: C.4 Performance of systems - Modeling techniques*

Introduction

Designing long scale integrations (LSIC) is impossible without the availability of powerful CADs. Developing CAD means of a gas laser gas-discharge circuit is critical problem.

Modern CAD have is functional-block structure, in accordance with which different stages of a design cycle are performed by corresponding subsystems. This has led to the appearance of individual systems frequently developed by a variety of manufacturers majoring in the , performance only one of stages (for example, a synthesis stage).

In addition, CAD is becoming a through one: all the design stages – microcircuits modeling, synthesis, implementation and programming are carried out in a common medium. [Ovezgeldyev, 2002]

It permits to verity devices at all the design stages, which enables to reduce the probability of emergence of errors. Therefore at a definite stage of CAD development there appeared a need for developing standardized – languages of equipment description, one of which is VHDL.

VHDL is a powerful language which allows to describe the behavior of digital circuits, as well as to perform and also to spend the hierarchical functional-structural description of the big integrated systems and at the same time has all signs of the programming language of high level – allows to create the types of the data, has a wide set of arithmetic and logic operations [Golian, 2003].

Designing of a gas laser gas-discharge circuit

In designing the following parameters must be provided:

- the pressure at the gas discharge circuit (GDC) input shell of 14 mm (base = K). There is exist a possibility to set value of K within 3... 15. This parameter will define a range of representation of size of pressure value $0 \le A \le K - 1$ and the number of bits at the GDC output (to must be sufficient to place the greatest number Amax =) K – 1;
- the GDC structure must change depending upon the mentioned parameters.

Consider the generalized GDC structure. The device interface is shown in Fig 1.

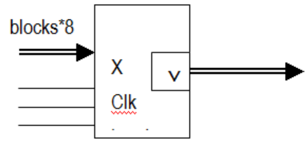

Figure 1. Tthe device Interface

The description of ports is resulted the table 1.

Table 1. Description of ports

X ((blocks*8-1): 0)	input	Blocks – 8 digit; data bus through which loading code takes place
Reset	input	Signal with an actual bag level, providing the reset of discharge counter an accumulator and on output buffer register
Clk	input	Synchronizing signal (active leading edge)
Load	input	Signal providing the selection of a source of input data in operational automatus block as well as the rest of a accumulator to at the beginning of each new conversion
Y(47:0)	output	48 – digit data bus though which the GDC code is rolled out

Purpose and possibilities of synthesis GDC a VHDL-model

Problem of the synthesis of system is effective distribution of the RTL-circuit with the aim of creating a new list of connections with a minimum number of circuit components used. Each component of the new list will correspond to the physical hardware block in the FPGA (elements of configured logical blocks, anticipated carry logic).

Hierarchical designs are synthesized in an ascending regime when components of the lower level are synthesized up to those of a upper level.

The device model in the language of describing VHDL equipment must be adapted for synthesis and implementation on FPGA chip of the XILINX firm.

The problem of a choosing on hardware platform is of great important for the designer. The right choice will enable:

- to reduce material cost in the implementation of the device ;
- to attain optimum functioning and speed of operation .

According to the technical requirement the GDC model must be adapted for synthesis and implementation on the FPGA of the Xilinx firm. In choosing FPLD of most of the focus is on the relation between its cost and productivity. Besides it is necessary to take into account the crystal which will be occupied by the synthesized device. [Cardoso, 2003]

FPGA (Field Programmable Gate Arrays) were first developed by the Xilinx firm in 1985. Tuning a FPGA on the specified functioning is carried out each time before the start of its operation. The required setup program is preliminary recorded in ROM (RAM).

Loading information from ROM and FPGA automated initialization after turning on power supply (for this the FPGA contains the required logic circuits). One can also carry out FPGA tuning under the control of a microprocessor or microcontroller.

FPGA has typical structure of a gate array. Fig. 2 shows the Xilinx firms FPGA - Spartan II (XC2S30 model). The Xilinx firms EPLD of FPGA type are implemented on the base SRAM in accordance with MOS technology. They are characterized by high flexibility of structure and abundance on a crystal of triggers. Thus the logic is realized by means of a matrix so-called LUT - tables (Look Up Table), and internal interconnections - by means of the branched out hierarchy of the metal lines switched by special high-speed transistors.

The considerable cost of FPGA micro circuits with built in RAM in comparison with an embedded RAM in comparison to that of custom microcircuits restricts the use of FPGA for manufacturing pilot models or small-scale production. This defect of the FPGA has been eliminated by firm Xilinx firm by manufacturing a new series of microcircuits FPGA - series Spartan and Spartan-II. The parameters of the Spartan II (model XC2S30) are given in table 2 (logic cells, the number of system gates, CLB array dimensions, CLB number etc.).

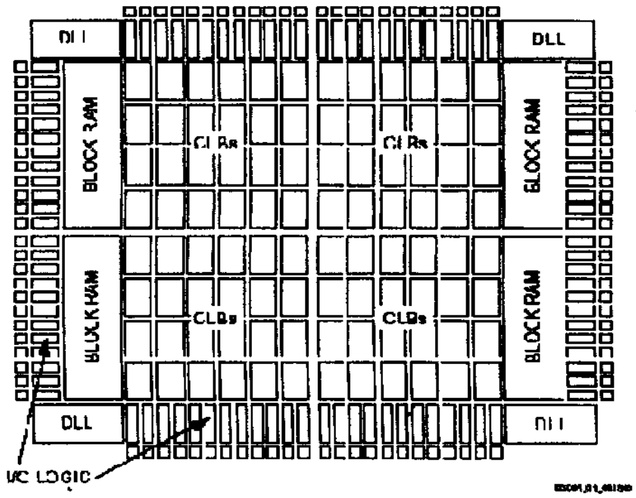

Figure 2. Structure of Spartan-II chip

Table 2. Parameters of FPGA Spartan-II family

Logic Cells	System Gates (Logic and RAM)	CLB Array (CxR)	Total CLBs	Maximum Available User I/O	Total Distributed RAM Bits	Total Block RAM Bits
972	30000	12x18	216	132	13824	24K

The FPGA Spartan-II family has a record low cost per a gate on the density of packing up to 200 thousand gates. In a crystal there is four blocks of the RAM each having 4KBits, besides it in possible to implement 16 bits of memory on each 4 input functional generator. The Spartan-II device combine lines of flexible regular architecture which include a CLB matrix surrounded by programmable input – output blocks inter connected by a hierarchy of high – speed, multi – sided resources by a history of high-speed, multi – sided recourses of interconnections.

The Spartan-II devices have high productiveness in comparison to the previous FPGA families. The designs can operate at a system synchronization frequency of up 200 MHz, including input/conclusion blocks (Input/Output-I/O).

Besides, Spartan-II chips are distinct in a large variety of advantages, namely:

- relatively low of crystal cost;
- big chip dimensions (up to 200 000 system gates);
- high speed of operation.

The Spartan-II, shown in fig. 2, covers configured logic blocks (configurable logic blocks - CLBs) and input-output blocks (IOBs). CLB blocks serve for creation of functional logic elements, and blocks IOBs create on interface between microchip contacts and CLBs.

Configurable logic block (CLB). A logic cell (Logic Cell – LC) is the basic structural elements of a CLB. The logic element includes 4-input functional generator, high – speed carry logic and a memory element. The output of functional generator is connected to the output logic of the CLB-block and D-input of a trigger. Each CLB in the

Spartan-II series contains four logic cells organized in the form of two identical slices. Fig.3 shows one slice in more details.

In addition to four base logic cells, the CLB-block of series Spartan-II contains logic that allows to combine resources of functional generators for realization of functions from five or six inputs.

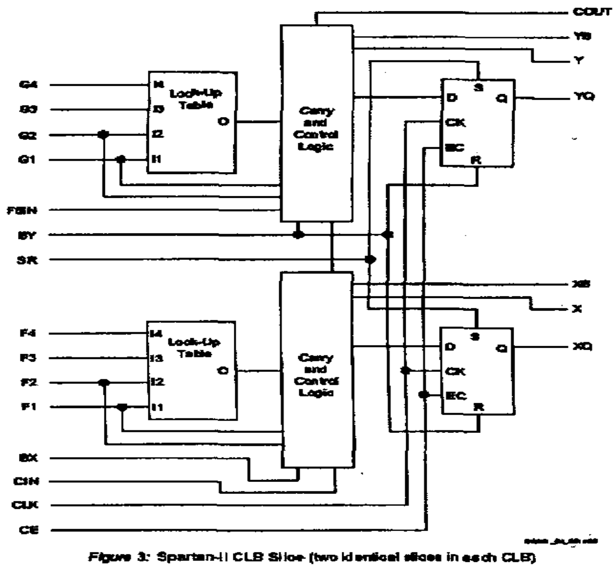

Figure 3. Vi cell of FPGA Spartan-II

Look-Up Tables (LUT). The functional generators are implemented in the form of 4 - input functional tables (LUT). In addition to the use as functional generators, each LUT-element can also be used as synchronous RAM of 16x1 bit dimension. Moreover is more, out of two LUT-elements within one slice one can implement either synchronous RAM of 16x2 a bat or 32x1 bit dimension or two-port synchronous RAM of 16x1 bit dimensions.

A 16-bit shift chain, which perfectly fits to capture high-speed or both data flows, can be implemented on the basis of a Spartan-II microcircuit LUT-element. The regime can also be used to story data in such appendices as digital signal processing (Digital Signal Processing - DSP).

Memory elements (ME). MEs in each slice of a Spartan-II CLB can be configured as dynamic triggers (sensitive to wave - front) or doors sensitive to signal strength. A trigger D-input can be controlled either from a functional generator within the same slicer of a CLB, or directly the inputs of this slice.

Additional logic in a CLB. A F5 multiplexer in each slice combines the outputs of a converter.. This combination enables to implement any function of 5 variables or some functions of up to nine variables. In the same way a F6 multiplexer combines the outputs of all four output in CLB. They allows to implement any function of 6 variables as some functions of to 19 variables. Each CLB has four direct paths. These paths provide additional data input lines or additional routing which allows to save logic resources.

<u>Arithmetic logic.</u> Special transfer logic provided an opportunity of fast transfer in implementing arithmetic functions. The Spartan-II CLB supports two individual transfer chains, one for each CLB slice. The dimension of transfer chains are two bits per a CLB.

<u>RAM block.</u> A special block memory is embedded in the FPGA Spartan-II. It is created in addition to a distributed small - capacity (Select RAM) memory, implemented on functional tables (Look Up Table RAM - LUTRAM).

<u>Choice of instruments.</u> The firm Synplicity software product Synplify 7,0 is chosen for synthesizing the design as it has following advantages programs of other manufacturers:

- high speed of synthesis;
- visual representation of the results of synthesis;
- availability of libraries for the present- day element base of the biggest world manufacturers.

The design analyzed is synthesized into a library repertoire of primitives.

The list of connections after the stage of a logic output is made out of abstract logic elements, such as accumulators, counters, multipliers, receivers as well as gates and synchronous triggers. These circuit elements must be further placed in structural components of the EPLD technology used. This process also is called as technological distribution on FPGA-chip.

In order to make sure that the system agrees with the specification, it is necessary to verify, i.e. to model it (Fig. 4)

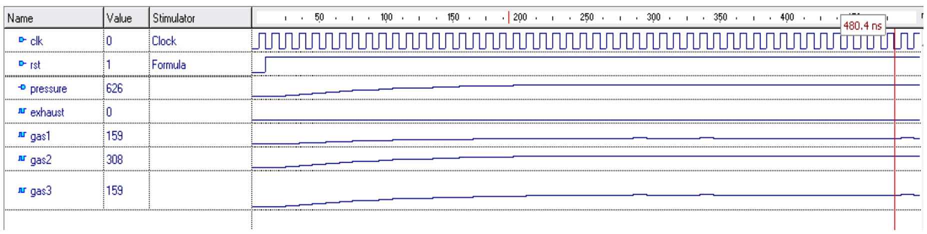

Figure 4. Result of modeling a gas –discharging

Conclusion

The possibilities of the syntheses VHDL - models of GDC lasers, which will consist of three subtasks: a logic conclusion, optimization received RTL structures and its distribution on structural elements technology mapping.

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Business Intelligence Systems

BUSINESS INTELLIGENCE AS A DECISION SUPPORT SYSTEM

Justyna Stasieńko

Abstract. *Nowadays, we are bombarded with information which has an immense influence on our decisions. It is more and more difficult to use it effectively. BI systems are very helpful. They support enterprises while carrying analyses and conducting researches. They make it possible to reach unambiguous decisions in the right time, they minimize the costs and they also provide the opportunity to verify and correlate the decisions with the entire enterprise's strategy. BI Systems help to integrate and analyze the data coming from different sources and as a result they render it easier to reach decisions. This article presenting above issues aims at showing engines which have a positive influence on the management of information in different organizations.*

Keywords: *information, Business Intelligence, Management Information Systems, decision support*

ACM Classification Keywords*: K.6 MANAGEMENT OF COMPUTING AND INFORMATION SYSTEMS - K.6.0 General Economics*

Introduction

Many organizations start to use IT applications in order to implement transaction systems supporting the current activity. As the organizations are in the constant process of development, the time is ripe for implementing integrated systems. The more data there is, the more difficult it is to keep it organized and coherent.

The automation of many processes makes gathering the data simple. The process of sorting them out, analyzing and making reports so that they can help us to make right decisions, especially strategic and long-term ones, is the most difficult task.

Nowadays, it is noticeable that our attitude towards the role and the meaning of information has changed. The information has been treated so far as a by-product or as a product common to some business processes carried out at a particular time. The information is now one of the most important constituent of organization. The information is a factor that increases our general knowledge about the surrounding reality [Flakiewicz, 2002] or a immaterial good, which along with the economic improvement and development of social communication becomes more and more important changing the structure of many traditionally organized economies in the world [Niedzielska, 2003].

The meaning of information in modern world should be analyzed in many aspects. We can even say that the information is a vehicle for each field of human's life. The increasing development of technology to large extent depends on the rapidity and quality of the information. The use of the information can tell us a lot about its quality. It should be easily accessible. The most characteristic features of a good solution, which fulfills the organization's needs of keeping and analyzing information, is the integration with computer science systems, the possibility of adjusting it to the organization's needs, distributing the protection on the organization scale and the opportunity to administer it via the Internet.

In theory, the information plays four roles: it supports the process of management, it enables the institution's members to communicate with each other, it enriches our general knowledge and establishes relations with the surroundings.

Currently, each organization has to deal with a vast amount of data coming from various databases. Starting with official information from sorted data sources to RSS channels the information is sent by electronic mail. The excess of data, the lack of its coherence, as well as unclear and incomplete data makes it impossible to come to a decision. Each worker would like to have an access to the suitable information in the due time, analyze it and make reports which help us to keep up with the changing economic goals and use the tools which are helpful while making the right decisions. Unfortunately, the ERP systems existing in different organizations, data warehouses or any other systems do not provide the possibility of using the accessible information while reaching the decision. The effective decisions depend on if the events taking place inside and outside the organization would be interpreted properly. That is why, the search for and the improvement of methods and tools that streamline data processing, gathering and analyzing is so popular. Business Intelligence (BI) dating back to 90. provides the tools and technologies used for making reports and carrying out information either organized or unordered.

Business Intelligence is the most important point of contact between information technology and business which seems to be inevitable. BI environment combines the business's strategy with the strategic information and data with decisions.

In practice, BI systems are used with the aims of creating and improving the relationship with a customer, enhancing the effectiveness of management and the last one refers to the analysis and the correctness of operating efficiency.

The essence of Business Intelligence systems

The new quality in the conception of the management is Business Intelligence, which does not have commonly accepted polish equivalent. The term "intelligence" consists of many factors. We can enumerate the following: the knowledge about the market and the possibility of gaining and using it, the flexibility of adjusting the changes taking place on the market, realization of the organization's aims, the creativity and involvement of a particular organization's members. Business Intelligence is also associated with the slogan which reads: "The management of knowledge" because it is more and more popular to say that organizations based on knowledge are able to resist the growing competition on the global market. J.Surma in [Surma, 2009] quotes the following definition: "BI is defined as the process of gathering, exploring, interpreting and analyzing the data, focused mainly on its users, which leads to improvement and rationalizing the decision-making process." According to Howard from Gartner Group[6] BI is a group of conceptions and methods used for improving the decision making process by the use of Consulting Systems. Searchdatamanagement.bitpipe.com portal gives another definition which is: "Business intelligence (BI) is a broad category of applications and technologies for gathering, storing, analyzing, and providing access to data to help enterprise users make better business decisions. BI applications include the activities of decision support systems, query and reporting, online analytical processing (OLAP), statistical analysis, forecasting, and data mining." [1].

The origin of Business Intelligence dates back to the biblical times. Joseph, Jacob's son sold by his brothers to Egypt, was the only one who could interpret pharaoh's dream about 7 fertile and 7 infertile years that were drawing near. He could use his supernatural knowledge while interpreting the information on the basis of which pharaoh came to a decision of putting some crops aside during the fertile years as reserves of food for the infertile years. Without this information, the decision of gathering the food would have been unjustified. However, knowing the information, Egypt not only could wade through this situation but also made money from selling the food to its neighbors.

The conception of Business Intelligence is similar. In order to benefit from business, we should make strategic decisions based on analyzed information we have, which is not commonly known. The difference concerns only the data sources. For many years experience was the only source of information. Then its place was taken by mathematics, mathematical, statistical and economic models and currently also the Internet.

Along with the growth of the amount and the need for keeping and analyzing the stored data the quality of supporting and reaching decisions becomes more important. Today it is the main element in competition. It is possible to win for those who know more and as a result are able to make right decisions quickly. We can even say that, this is the end of era in which business was run by intuition. The revolution of computer systems has started a new chapter of quick decisions made on the basis of the analysis of the stored data. That correlation between the data, information and decision shows Figure 1.

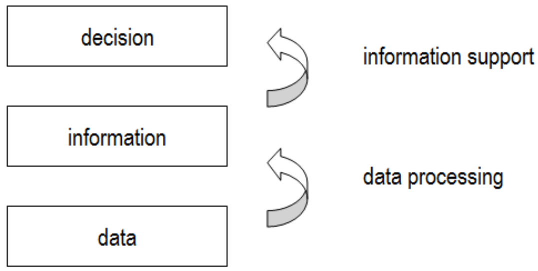

Figure 1. The correlation between the data, information and decisions. Source: Self-made research.

The main BI technologies

Business Intelligence applications aim at supporting the management of enterprise, its condition and efficiency, mainly by gathering, storing, making the data accessible managing the knowledge by using various analytical tools. In a word, they give the opportunity to look at the business as a whole and answer three main questions:

- What is the organization's situation like at the moment?
- Why is it happening so?
- What should be done to reach the goals?

The answers for these questions support the work of managers who are responsible for running the key areas of business.

Data Warehouses, Multidimensional Data, OLAP, Query and Reporting systems are basic constituents of Business Intelligence. Figure 2 shows the most common structure of BI.

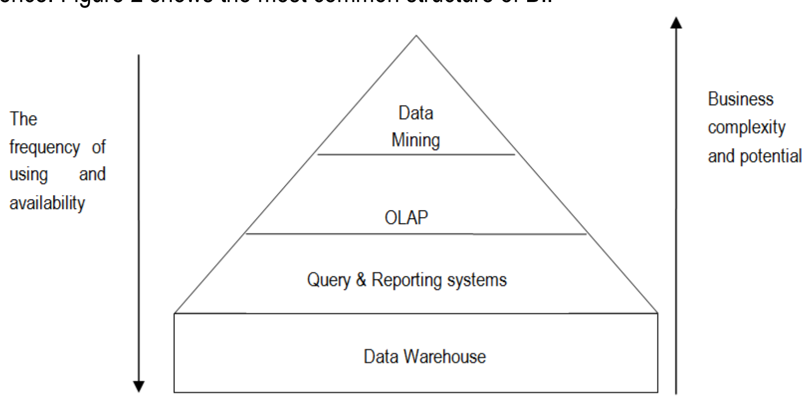

Figure 2. The structure of Business Intelligence. Source: [Januszewski, 2008, p.13]

Data Warehouse allows to sort out data gathered in the enterprise. It is the main source of information for the whole organization, the basics for analytical systems and the source of information that is necessary for reaching decisions in the organization. The data gathered in the organization is sorted out thematically, permanent, integrated and often redundant usually have time dimension.

Multidimensional databases refer to data that can be analyzed according to many criteria. For example, the size of sale can be analyzed according to the type of product, the region of sale or to a particular period of time.

The analysis of OLAP is a technology which allows to build multidimensional sets of data on the basis of information coming from data warehouse. As a result, the data help us to find the answer for some complex business questions. It is organized in such a way that makes it possible to look over and compare the data in many aspects. OLAP systems are responsible for presenting and delivering strategic information for managers.

Reporting engines are very simple and used often among others BI applications. They answer the users' questions e.g. What was the sale of a certain product in a particular period of time like, how many customers have purchased a particular product etc. Reports contain also some tables and charts.

The exploration of data is a process of discovering the correlation, models and tendencies among the vast amount of data. It is done by the means of techniques used for recognizing models, artificial intelligence (genetic algorithms, neural networks), statistical and mathematical methods. This process makes it possible to predict the future. The data is the knowledge essential for the organization [Twardowski, 2009].

The main source of data for BI systems is Online Transaction Processing (OTP) for example: ERP/MRP, CRM, SCM or call center. Sometimes the data is taken from Excel files, Access, e-mail programs or any other Internet services. The data, on the basis of which it is possible to make reports and analysis complete, has to be placed in one point (Data Warehouse).

BI systems are another generation of the computerized information systems of management, which are classified by high standards of decisions support [Gontarz, 2008]. Figure 3 shows the location of BI systems.

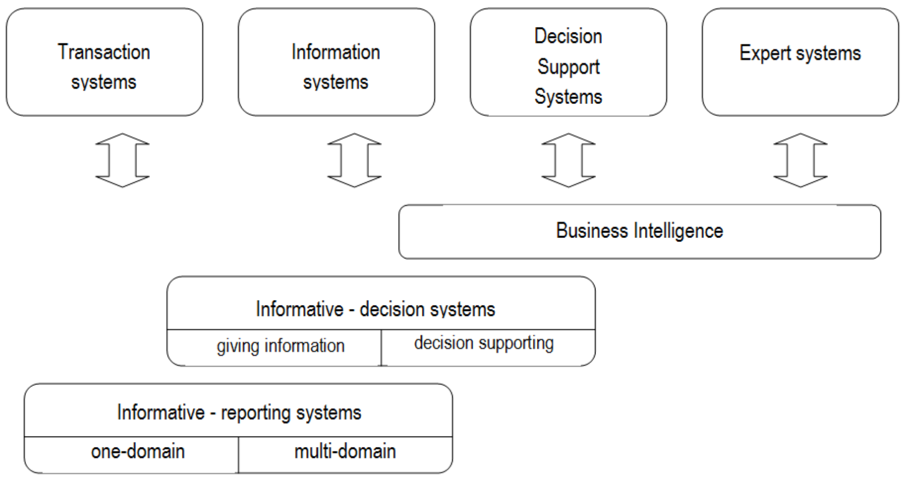

Figure 3. Management information systems. Source: [Niedzielska, 2003, p.55]

It is possible to distinguish within BI the following group of activities[6]: analytical (multidimensional-OLAP, business, geospatial), prognostic (supporting strategic decisions), monitoring and generating the knowledge, techniques used for presenting and visualizing or some more advanced techniques like preparing the balanced scorecard, managing the knowledge or implementing the enterprise's portal and others.

Business Intelligence – the manager's tool

BI systems support the decision-making process providing the access to the reliable information for the staff. The implementation of BI makes reaching the right, either operational and strategic decisions easier. It provides an easy access to necessary information for the users by means of the engines they use every day. It makes it possible to share the knowledge with other people, to cooperate on the whole enterprise scale and to increase its profits.

The effective planning, budgeting and forecasting decide about the organization's success. The planning, together with taking into consideration all elements that are being transformed, is the key and very often the most difficult process. Creating business models, compilation of budgets and plans has been a time-consuming process and it required handmade work. Computer scientists had to devote much time to try to adjust those applications to the organization's needs. Finally, the process of integrating the necessary data was completed by means of Microsoft Office Excel.

The functionality of BI application includes either scalable technological platform and some other applications supporting the decision making process designed for workers occupying all positions in the company. Apart from the main components of BI systems we should enumerate these which implement various types of indicators, help to monitor the enterprise's results and determine its current condition or trends as well as key performance indicators. These are analyses, predicting analytics, scorecards and management dashboards.

The technologies of data exploration make it possible to use predictive analysis by means of processing data by using particular algorithms and carrying out statistical analyses. They allow to discover the most important possibilities and to draw conclusions – e.g. define market sections, reach decisions about carrying out economic analysis in order to estimate the probability of the rise in the sale of hot-dogs caused by the rise of promotion of crisps.

Finding the key data, which help to draw conclusions often requires looking over a vast amount of information. The scorecards and management dashboards render it easier to monitor the efficiency of work and show the enterprise's goals, it's condition and also the trends in the form of accessible Key Performance Indicators (KPI). The management dashboard is a tool used in order to visualize the most important data clearly in the form of graphic index, charts and tables. Thanks to it, it is possible to put various data coming from different source on one screen. The management dashboard, available through a web browser constitutes an intuitive and flexible way of presenting the data. The scorecards provide rich graphic environment, in which all the Key Performance Indicators are organized according to the organization's aims and strategies. They show its current condition, plans and trends. They also help to adjust all workers to the organization's goals.

The only restriction of BI application is human's imagination, although it seems to cease to be a barrier.

The advantages of using BI depend to large extent on the skills and the possibility of using them effectively in the decision making process. We should bear in mind that BI technologies become useful while creating specialized business applications but they are not the means in itself. BI systems are most often used by mercantile firms, fuel concerns, means trade, administration, banking, telecommunication, controlling, real estates, power industry and insurances [Olszak, 2005].

The analyses offered by BI solutions in these lines of business bring significant business effects. Thanks to them it is possible to perform an analysis which supports the supplementing sale, segmentation and profiling the client, analysis of parameters validity, analysis of the length of client's survival period, analysis of the client's loyalty and joining their competitors, analysis and assessment of one's credit worthiness, detection of deceptions, logistic optimizations, prognostication of the development of strategic business processes, analysis and assessment of the functioning of the Internet services and their contents[Olszak, 2006].

According to the research made by press.teleinteractive.net, the advantages of implementing BI have been divided into two groups. The first group includes the advantages that can be measured such as: time saving (up to 60%), costs saving (38%), ROI (32%), new incomes (22%), total cost of ownership (21%) and shareholder's value (about 15%). The second group consists of the advantages that cannot be measured ant these are better strategic planning (57%), better decision making (56%), the improvement of the efficiency of the processes (55%), value of the client's/deliverer's satisfaction (37%), and the increase of the workers' gratification (35%).

The reliable and up-to-date information concerning many aspects of the business activity run by a particular company give us better access to the company's activity and improvement of the decision making process. Readable and cross-sectional data about the company's activity help the managers to decide what measures should be taken in order to reach their business goals. The costs reduction of conducting the analysis is possible thanks to the use of intuitive business areas. The system is able to answer simple questions and use the drag&drop method to make reports. BI help also to save the time by the use of subscription and delivering the reports on time. In some alarming situations the system send the report with the information which is necessary to diagnose the problem and take indispensable actions. The scorecards verify the realization of the firm strategy. It is possible to read out the extent of the strategy realization and to trace the trends for each of the key performance indicators. BI systems help to enable us to plan and budget on the integrated Data Warehouse level.

BI systems improve the company efficiency by means of data warehouses, the improvement of business processes and snatch so called "bottlenecks".

There are many BI systems existing on the market (Comarch Business Intelligence, SAS Business Intelligence, Oracle Business Intelligence Standard Edition One, Cognos 8 Business Intelligence, PROPHIX, Qlik View). These systems, apart from Qlik View, perform the same roles. Qlik View start to became the next cell evolving in BI systems.

An ideal situation is when each worker can see their decisions in the context of the whole organization's activity and when each decision is consistent with its goals and strategy.

BI is one of the elements in the process of extending availability and function of computerized systems which support decision-making process [Twardowski, 2008]. These systems are different from the past models because of the technology and the way of reaching decisions. The changes taking place in the field of technology refer mainly to Data Warehouse, advanced analytical techniques, and techniques used for data visualization. The integration of these solutions creates an intelligent environment for taking decisions.

Broader and broader use of BI application brings different point of view on the problems connected with reaching decisions, looking for new solutions and the need for new equipment and technologies. The next step in the development of BI is the improvement of prognostic engines and equipment. By means of gathering and standardizing the data from many sources, BI tools help to analyze the trends and predict the changes. They make it possible to carry out a cross-section analysis through different departments, products and clients. This analysis helps to make a statement about the level of development, condition and the direction in which a particular organization is heading for. The next move is to reach decision which can be sometimes difficult. A great volume of reports, the excess of data, a vast amount of possible answers, the complexity of decision-making process and the level of complication slow down the process. BI systems should help to reach good decisions which are connected with a particular set of features related to them. Such decision should be unambiguous, taken in the right time and based on gathered information. Each choice should be explained if the effects are consistent with the assumptions accepted at the moment of taking decision. The costs of these processes should be adequate to their consequences in case of making wrong decisions.

BI systems support the business process in its key moments and minimize the risk taken by the organization on operational and strategic level. The use of BI solutions while supporting decisions reaching process makes it possible to introduce the high level of automation of the systems in which workers' participation is very important. It should be stressed that the human indicator is the main element of creating the operational risk in the context of decisions which are taken and mistakes which are made. Getting rid of it makes it possible to increase the volume of decisions that we make use of and minimize the risk of making errors and the costs connected with the operational use of data. BI solutions make the decision making process automated. They work effectively in the environment in which the goal of the function is complex and consists of many criteria. The conclusion is that it is possible to polish the business application up in order to preserve an individual attitude towards the client while increasing the amount of the decisions that are taken and making the business system automated. Such relations with the customers help to build unique bonds that bring profits and give us advantage over our competitors.

The new generation of BI applications

At first BI systems were reserved only for supporting tactical and strategic decisions while creating and developing products, the management of finances and the processes' efficiency. The goal of new generation of BI applications is to make accessible the information which is necessary to take decisions on the operational level. They are also designed for these employees who realize the operational processes based on decisional rules and those using technology of adaptive recognition of patterns. This technology uses neural networks and the learning mechanisms which carry out the prognostic analysis. It makes it possible to personalize the current operational activity of the organization. BI application play a very important role while supporting the employees who stay in touch with the customers.

The second tendency in the development of informative and operational systems is the use of the Internet technologies and setting the BI applications in the corporate intranet, especially while presenting and making it accessible.

The basic elements of BI systems of new generation are Enterprise Information Portals. They constitute informative and application platform which is responsible for presenting the results of analyses and supporting the workers. Www website makes many data and information about the enterprise and its surrounding accessible. The goal of new generation of BI applications is to get information from the network. It requires new, ''intelligent'' mechanism of searching and selecting the information which is important for the decision making process. It is tried to be done by the means of Artificial Intelligence – intelligent agents. The assumption of BI applications is individualization of the knowledge for people making decisions, creating the electronic marketplaces and new branches in the decision making process and also the recognition of new skills important for the workers' knowledge.

Another important change takes place in the OLAP tools which have been very successful on the market. These multidimensional data bases have made it possible to analyse the data from different perspectives. For many years OLAP have seemed to be the only possible and good solution. However, we have to bear in mind that creating it is one of the most time-consuming design stage of implementing BI systems. The first stage of the implementation should predict and include all questions for which the users may want to have an answer in the future. It is a very difficult task especially when the enterprises reorganize themselves and then it may happen that implemented BI solution does not suit to the new strategy.

The current economic crisis and the necessity of getting savings have changed the way we look at BI systems. As a result many new modified BI systems have been created – analytic tools of new generation working without OLAP applications and calculating in their own operational memory. The implementation of such tools takes only few weeks and do not require proportionate lower expenditure. The most modern analytic tool existing without OLAP applications is Qlik View. It does not require complicated equipment and is able to integrate itself with other systems, such as ERP and CRM. As a result the time of implementation is shortened and the data is analysed in the operational memory.

Conclusion

The development and implementation of BI solution require the changes in the organization itself. It is difficult to differentiate between the benefits resulting from implementing analytic applications and data bases and the effects of the organizational changes accompanying the implementation of computerized solutions. The direct connection between the decision and the result of using BI systems hardly ever exists in the decision making process. It should be emphasized that the impact which BI solutions have on the quality of the decisions that are made should be considered in long-term perspective. While talking about benefits we should pay our attention to their quality rather then quantity.

BI systems give the possibility of increasing the competition on the market and taking proper and quick decisions. The solutions of a particular form help also to expand the funcional possibilities of ERP forms that have been used so far and CRM systems. BI systems help also to combine the initiative conected the entrprise's future with the branch of conducted business activity in order to understand and sort out the data in such a way that helps the managers to receive the crucial information in the due time and as a result increase the enterprise's effiency.

BI systems use regresssion analysis, decision trees, neural networks and other artificial intelligence tools for data mining.

Created prognostic analysis systems are able to learn the rules based on the existing data whose role is to look for the connection between the data and the later behaviour. The modules of knowledge mangement in organization are more often included in BI applications. It is noticeable that the knowledge and the information have been spread among the large group of employees in a readible form by the means of visual techniques. The effect is the integration of information which is not structural.

Nowadays, the attitude toward BI changes in many organizations. It is the end of era in which the business is run by intuition. The organizations which are going to be successfull are those which will be able to manage the information and use it in the decision making process.

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Major Fields of Scientific Research: Management Information Systems, Business information technology

COMPUTER MODELING FOR MODERN BUSINESS

Elena Serova

***Abstract**: Improving management systems is getting more and more important and topical, as the organizational structure of modern society consists of many features, peculiarities, relations, and is continuously getting more intricate. Although the society has been complex for a long time, it is only now that we are starting to comprehend its real complexity. It has become obvious that changing a characteristic can easily cause or require change to other parts of the system. Attempting to achieve an enterprise's highest efficiency, each modern executive should use computer modeling from time to time, as it is an efficient tool for management system research that weighs qualitatively and quantitatively characteristics of system functioning. A prerequisite of modern management is to know the principles and capabilities of modeling, be able to create research and use such models. This report considers the role of business modeling for modern management tasks. Generalizing theory development in the area along with international practices and domestic experience, the author chooses the main directions of modeling for modern management and those fields of management where applying computer modeling is more efficient.. This paper weighs perspectives of modeling used to solve business problems; considers modern modeling approaches used to describe architecture, develop operational models and carry out reengineering; briefs on existing techniques and instrumental tools used in modern business modeling.*

***Keywords**: business process, business modeling, business process modeling techniques, simulation modeling, structure-function approach, discontinuous event-driven approach, agent modeling, modeling tools.*

***ACM Classification Keywords**: I.6.5 Model development – Modeling methodology*

Introduction

Business modeling techniques and tools have proven their usefulness. Development and implementation of ERP (Enterprise Resource Planning Systems), decision making support complexes, consultancy on describing organization architecture, changing business processes, auditing and certifying operations are just a few examples of how these tools can be used. To successfully complete such projects, modern business modeling approaches and tools are indispensable.

When solving business problems, modeling tools are primarily used to ensure mutual understanding at every organizational level, bridge the gap between strategic vision and its implementation. To do that, modern business modeling tools use special software, languages and systems that help develop models and diagrams to demonstrate how business processes are built and how staff interaction is organized, and what needs to be changed to optimize the whole architecture.

Computer modeling allows for considering processes that run in a system at any level of detail. Almost any algorithm of managerial activities or system behavior can be modeled. In addition, models that can be researched with analytic methods can be analyzed with simulation methods as well. These are the reasons why computer modeling methods are becoming a principal research method for complex management systems.

Companies that actively use cutting-edge information technologies consider modeling as a stage of executive decision making [Lychkina, 2007]. They provide their managers with systems that help make strategic executive decisions. In addition, computer modeling based tools use methods and advantages such as object-oriented programming, video and multimedia supporting real-time animation.

Computer modeling allows for describing complex nonlinear business interactions, e.g., modeling economic agents' behavior in a crisis situation, weighing effects of different scenarios or forecasting further stream of events. The essence of computer modeling in business is to get quantitative and qualitative results from the existing model. By receiving from the analysis of business processes (structure-function modeling), qualitative results allow for finding previously unknown features of a complex system (e.g., management one): structure, development trends, sustainability, integrity, etc. Most quantitative results help forecast certain future values of variables characterizing the real system that is researched or explains those from the past, and can be obtained with modern simulation modeling techniques described in this paper. Naturally, all the modeling methods used to solve modern business problems are not mutually exclusive and can be applied to management system research either simultaneously or in a combination.

Goals and Objectives of Computer Modeling for Management Task

Computer models of complex management systems should show all major factors and correlations characterizing real situations, criteria and limitations. Models should be universal enough to describe objects close in application, simple enough to allow research needed at reasonable cost, and allow achieving the following objectives:

1. to abolish a series of functions and reduce the number of management levels, to disengage mid-level workers;
2. to rationalize solving management problems by implementing mathematical methods of data processing, using simulation modeling and artificial intelligence systems;
3. to create a modern, dynamic organizational structure, improve the enterprise's flexibility and manageability;
4. to reduce administrative costs;
5. to reduce time spent to plan activities and make decisions;
6. to increase competitive advantages.

To make the role of computer simulation modeling in the modern management more clear, I have to mention application of the structure-function approach to solving business problems. The essence of computer modeling in business is to get quantitative and qualitative results from the existing model. Qualitative results allow for finding previously unknown features of a complex system (e.g., management one): structure, development trends, sustainability, integrity, etc. Most quantitative results help forecast certain future values of variables characterizing the system researched or explain those from the past.

It is an essential difference of the computer simulation modeling from the structure-function one that the former gives both qualitative and quantitative results.

There is another direction of computer modeling. It solves management problems with mathematics and logic and, as a rule, uses Excel spreadsheets. The problems solved are those of stock management as well as transport, industrial or marketing logistics [Gorshkov et al., 2004]. The same is done with problems of linear and multiple regression forecasting, resource utilization review, etc. Such tools are quite popular, although specific management software, both scientific and commercial, that uses structure-function and simulation approaches, is more perspective.

Naturally, all the modeling methods listed above: simulation, mathematical logic and structure-function—are not mutually exclusive and can be applied to management system research either simultaneously or in a combination. Modeling tool Bpwin [Maklakov, 2003] can export models into a most efficient simulation modeling tool—the Arena system developed by Rockweel Automation (http://www.arenasimulation.com), and allows for optimizing business processes with simulation modeling (Fig.1). Using such an approach, various processes can be simulated and optimized: industrial technological operations, inventory control, banking, restaurant services, etc.

This is an example of how two leading directions of computer modeling can be integrated to solve modern management problems, demonstrating how simulation modeling can be applied to get quantitative results when modeling business processes.

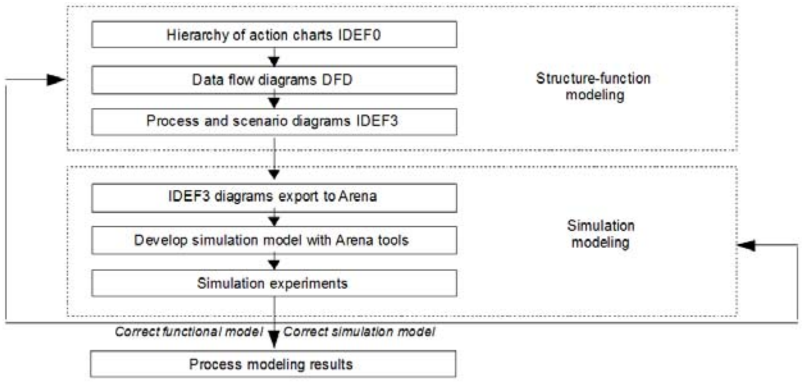

Figure 1. Integrating simulation and structure-function modeling when solving modern business problems

Structure-Function Approach to Business Modeling

The most intuitive and quite popular example of the structure-function computer modeling in modern management is the business process modeling.

The market situation modern companies operate in is quite unstable which makes them respond to change quickly and accurately. Sooner or later, businesses have to restructure, and managers have to think how to change the existing business processes in order to improve the enterprise's operations. Thus, a manufacturer may wish to reconsider purchasing, ordering or delivery. Business process reengineering is tied together with altering the architecture of information systems. The key to success of a reorganization project is close cooperation of all the groups interested in solving the problem, primarily IT specialists and experts in the business area. It is achieved by building structure-function computer models that reflect business processes which are comprehensible for all participants. Such models should simultaneously help formalize and document the current state of affairs and find room for improvement. There are several computer technologies aimed at automating structure models—the CASE (Computer Aided Software Engineering) tools. The definition of CASE involves various tools used to analyze and model, and business process analysis tools are just a small fraction of the class.

Organization and structure changes in a company, especially when they involve an ERP implementation, bring serious risks. Implications of such changes should be carefully studied and analyzed before they start. Such ERP as SAP R/3, BAAN, ROSS iRenaissance, etc. use methods and tools proven by extensive experience and allow minimize risks and resolve issues arising from reorganization of business processes, including those linked with implementation of modern IT systems.

Today's approach to business process description suggests continuous improvement and modification, analysis and prognosis, as well as timely changes to the business model. The description should adequately reflect current state of affairs to underlie an integral comprehension of business development strategy and business automation. The following series of steps is best for business development or modification [Proshin, 2006]:

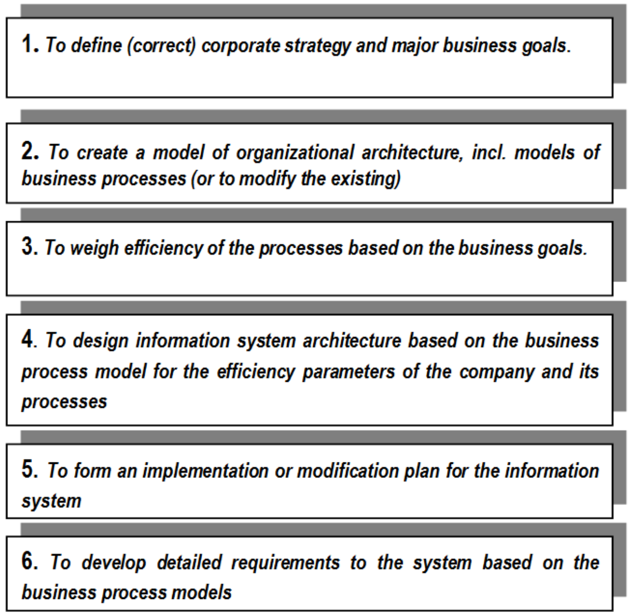

Figure 2. Business development (modification) steps

There are several techniques to describe and model business processes. The most popular are: Business Process Modeling, Work Flow Modeling and Data Flow Modeling [Repin, Yeliferov, 2008].

Suggested in the 1970s by Douglas Ross, the Structured Analysis and Design Technique (SADT) underlies the IDEF0 business process modeling standard. AllFusion Process Modeler 4.1 (BPwin 4.1) by Computer Associates (CA) is a modeling tool fully compliant with IDEF0 that allows analyzing, documenting and planning changes in complex business processes [Maklakov, 2003].

Another actively used process description methodology is the Work Flow Modeling—the IDEF3 standard to build process models as time sequences of jobs (functions, operations). The IRIS source environment by IDS Scheer AG that creates methodological and work instructions with eEPS (extend Event-driven Process Chain) models, is based on IDEF3 [Ilyin, 2006].

DFD (Data Flow Diagramming) notations allow reflecting job sequences within a process and information flows circulating between those jobs. The DFD methodology minimizes subjectivity of business process description and can be efficient when implementing process approach to organizational management.

The developing UML (Unified Modeling Language) methodology is also quite widely used. It considers a series of diagrams (e.g., the Activity Diagram) that can be used to describe business processes [Vendrov, 2000], although business modeling is not what UML is intended for.

Along with the techniques listed above, there are other ones offered by various software producers. Even such corporations as IBM and Oracle offer their own business process description and modeling tools. E.g., the Oracle Workflow technology used to automate job flows contains tools for process description and formalization. The most popular state-of-the-art business process management standard is BPEL (Business-Process Execution Language). Based on this product, an integral platform for all applications used can be created. Public and private institutions throughout the world are switching to BPEL. Certain pilot projects have been carried out in Russia as well, successfully solving IT infrastructure optimization problems [Proshin, 2006].

Simulation Modeling to Solve Business Problems

The structure-function method allows describing existing business processes, finding their drawbacks and building a model of the enterprise's operations. However, the difficulty is the optimization of particular processes, or the study of how various parameters influence a certain business process. To solve this problem, the structure-function model may be insufficient, and other modeling techniques and tools turn out to be more appropriate. An approach that solves such business problems and gives quantitative characteristics of business processes is simulation modeling. Simulation models can provide statistics of processes as if they were happening in reality. Normally, such models are built to find an optimum solution with limited resources, when other mathematical models are too complex. Owing to its simplicity, the idea of simulation modeling attracts both executives and system researchers. The simulation approach to business problems requires special software that is widely denoted with such terms as "simulation system" and "simulation modeling system". The terms refer to an aggregate of a simulation model of a complex process, a set of simpler models of the same process, algorithms and relevant software associated with the models. Some examples of such systems applied to business modeling are the Arena simulation modeling system by Rockweel Automation (http://www.arenasimulation.com), AnyLogic by XJ Technologies (http://www.xjtek.com) or GPSS (General Purpose Simulation System) by Minuteman Software (http://www.Minutemansoftware.com). To create simulation models, one should know special algorithmic languages that can express concepts which modeling specialists use. Each language is specific in:

1. how complex the concepts of simulation modeling are represented;
2. language base;
3. number of basic concepts.

An important factor to choose a simulation modeling language is if there is an efficient translator for the chosen computer hardware. A multifunctional user interface makes many language operators excessive. This is why a special simulation modeling language is ideal to build a simulation model for business problems.

The modern simulation modeling theory offers four major approaches [Borshchev, Filippov, 2006]:

- dynamic system modeling (simulation modeling systems MATLAB Simulink, VinSim, etc.),
- discontinuous event-driven modeling (GPSS, Arena, eMPlant, AutoMod, PROMODEL, Enterprise Dynamics, FlexSim, etc.) [Serova, 2007],
- system dynamics (VenSim, PowerSim, iThink, etc.), and
- agent modeling (AnyLogic [Karpov, 2005], Swarm, Repast, etc.).

Each direction develops its own tools, simulation modeling systems and languages.

System dynamics (SD) and dynamic systems are traditional, established approaches; whereas the agent modeling (AM) is comparatively new. SD and dynamic systems operate mostly with continuous processes, while the event-driven and agent modeling cover discontinuous ones.

The following two approaches are used most often to solve business problems as basic formalization and structuring conceptions in modern simulation modeling systems:

- process and transaction oriented modeling systems based on process description. In the modern IT market, they represent the discontinuous event-driven simulation modeling approach and are the most representative class of such systems. These are such systems as GPSS, Arena, Extend, AutoMod, ProModel, Witness, Taylor, eM-Plant, QUEST, SIMFACTORY II.5, SIMPLE++, etc. [Serova, 2007];
- agent modeling that uses models to study decentralized systems which dynamics and functioning is not defined by global rules, on the contrary, those rules are a result of the group members' individual activities. In Russia, such systems are represented by AnyLogic [Karpov, 2005];

Simulation modeling systems with discontinuous event-driven and agent approaches have proven most efficient in such areas of business modeling as business process and service modeling. The Arena simulation modeling system is integrated with a CASE tool, BPWin, whereas GPSS possesses tools needed to model processes relevant to such a dynamically developing area as the service-oriented economy [Serova, 2007].

Conclusion

Aiming at securing a stable economic position in a very competitive environment and attracting funding, the most forward-looking companies pay more and more attention to developing and implementing cutting-edge computer modeling systems. A principal tool to solve modern business problems related to cost cutting and restructuring, business modeling, service-oriented economy and decision-making procedures in management systems, is computer simulation modeling technologies. They include developed graphic interfaces for model construction, result presentation and output statistics filing. Moreover, simulation modeling widely uses methods and advantages of object-oriented programming, video and multimedia supporting real-time animation.

State-of-the-art simulation modeling technologies used at every level of enterprise management: strategic, tactic and operational—is a direction for development and a criterion for stable economic growth in the modern competitive environment.

Thus, an organization willing to use state-of-the-art business modeling tools can choose a methodology out of several standard options. The choice should be based on the clear understanding of the models' capabilities and drawbacks, as well as the purposes. Business modeling tools and instruments are evolving and tend to switch from a visual description of certain narrow business areas towards a holistic description of organizational architecture. The application of modeling is widening from information exchange within a small group of specialists to management of distributed organizations requiring comprehensive information of all the organization's operations. The opportunities of integration between different business modeling approaches that have appeared allow for fully implementing modeling and analysis tools into the organization's existing infrastructure. The most perspective direction seems to be the growing correlation of business modeling and analysis systems with management systems.

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ANALYSIS AND SYNTHESIS OF GOALS OF COMPLEX INDUSTRIAL SYSTEMS

Lyudmila Lukyanova

***Abstract**: A problem of incompatible and contradictory of results of making decisions in industrial organization-and-technical complexes (OTC) is outlined. A system-and-goal approach and a semiotic approach to make system of decisions satisfying requirements of logical correctness and completeness are concretized. A concept model of knowledge-based dialog system of analysis and synthesis of goals (DS ASG) to make system of goals is considered. Using the DS ASG decision-makers work out not only the system of goals but corresponding plan of goal-achieving satisfying requirements of logical correctness and completeness and in this way solve the problem of incompatible and contradictory of results of making decisions in OTC.*

***Keywords**: organization system, goal setting and achieving, goal analysis and synthesis,*

***ACM Classification Keywords**: Management, Systems analysis*

Introduction

The results of making decisions in industrial organization-and-technical complexes have to be complete, compatible and non-contradictory. On account of OTC complexity, vagueness of its environment and some other difficulties these requirements are seldom satisfied. As our study showed a problem of complete, compatible and non-contradictory results of making decisions in OTC may be reduced in two main sub-problems. The first sub-problem is caused by general character of a regulative part of making system of decisions (MSD) methodology. The second sub-problem is caused by high at the scale of good sense and intuition in MSD-process and a little formalization of its procedures.

We concretized a MSD-regulative component specifically approaches and principles. Concretizing a system-and-goal approach was carried out via constructive definition of organization-and-technical complex as a specific system and definition of its goals (a system of goals). Concretizing a semiotic approach was carried out via: 1) definition of semantic relations between goals, functions, criteria of goal-achieving; 2) work out a semiotic system (model) for reasoning about goals. Concretizing principles of MSD-methodology is carried out via: 1) unity of goal-setting and goal-achieving; 2) completeness and logical correctness of OTC goals; 3) co-ordination of good sense and intuition of decision-maker and opportunities of formal-and-logical system to discover and correct incorrectness and incompleteness in results of goal-analysis; 4) co-ordination of goal-synthesis (goal-achieving plans) results and the results of goal-analysis [Лукьянова, 2007].

We allocated nine main stages of making systems of decisions in OTC (Figure 1). The key result of making system of decisions in OTC is system of goals that is formed by work out a scheme of goal-achieving and match it with the structure of goals (titles of corresponding stages in Fig. 1 are marked out by the bold font).

Formalization of procedures of goal-analysis and goal-synthesis is carried out via semiotic (logic-and-linguistic) modeling of goals in MSD-process. The paper presents some models for further its realization in a dialog system of analysis and synthesis of goals that will secure man-machine working out a system of goals satisfying requirements of completeness and logical correctness.

Models for working out a system of goals

In Figure 2 a concept model of working out a system of goals and a corresponding plan of goal-achieving is shown. It includes two main components: models and interfaces.

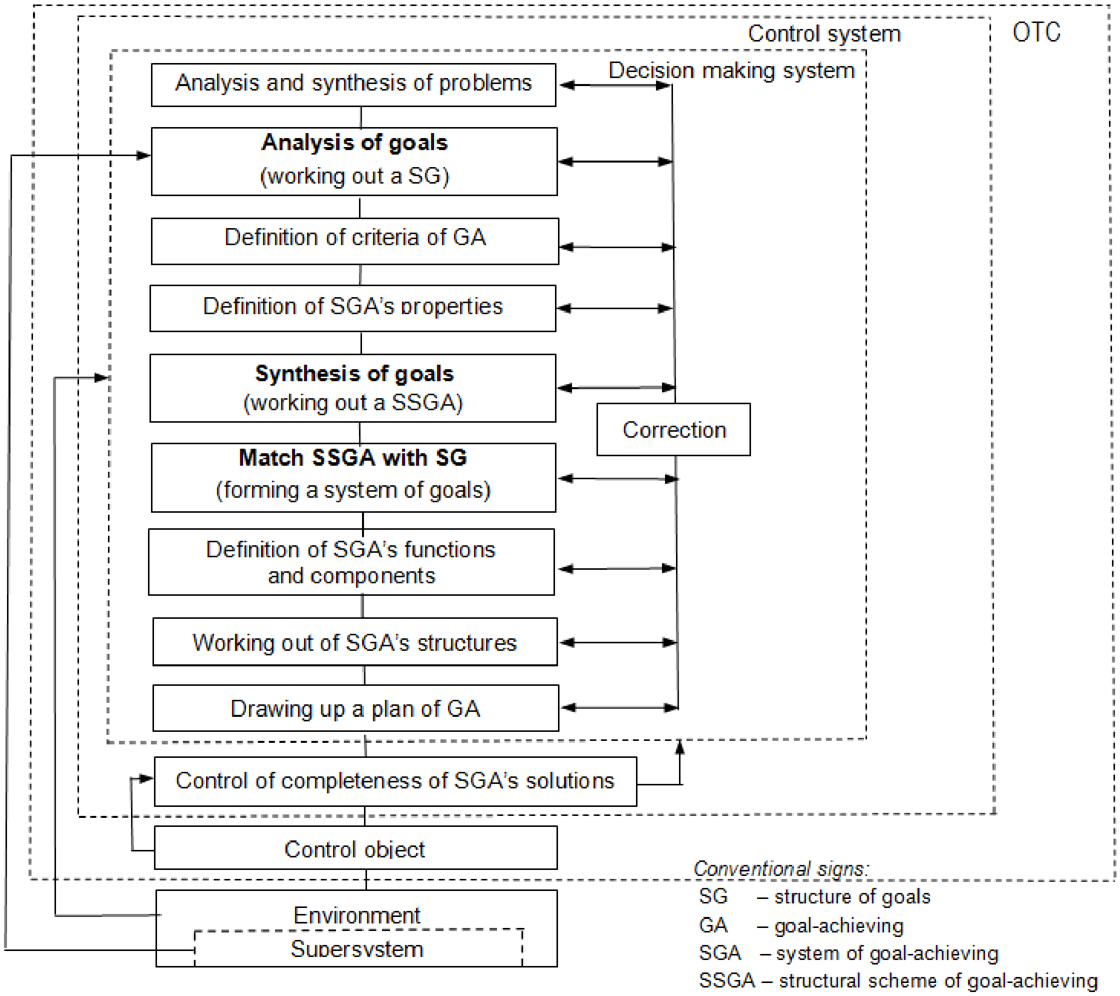

Figure 1. The main stages of making decisions in OTC

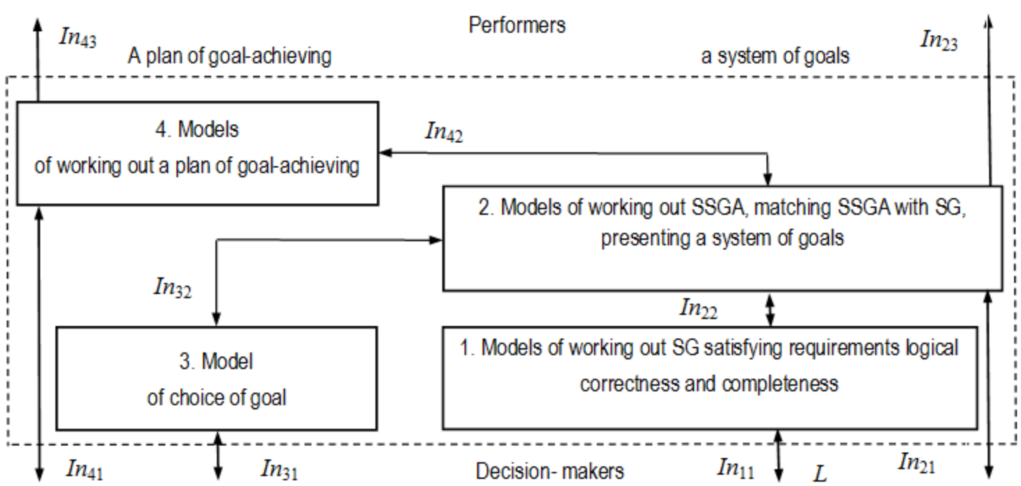

Figure 2. The concept model of working out system of goals and plan of goal-achieving

To work out a system of goals satisfying completeness and logical correctness requirements it is proposed the following models: 1) a semantic model of goal-wordings; 2) semantic graphs of goals and goal-achievement; 3) logical-and-linguistic model (semiotic system [3]) for reasoning about goals.

A semantic model of goal-wordings. As preliminary analysis is shown majority goals of industrial OTC are defined future real objects. For example one of goals of fishing industry is: ‘Increase quantity, quality, and the variety of the fish products produced from fishes of an open part of World Ocean’. Such a goal is closely related to activity of fishing industrial system (in this case activity is ‘production of fish products’). Therefore it is natural to use a model of activity for goal simulation.

Industrial goals are very complex and they should be measured to check degree of their achievement. It is possible by means of different kinds of scales and in principle on a ratio scale. It is natural to bring about syntactic, semantic, and pragmatic measurements of goals as it is required in semiotics.

Due to these considerations it seems necessary to study conception of rational formalization of goals. We base upon an idea that goal-setting is a human’s prerogative. Managers can and must compass selection of pragmatically correct goals (it means their significance in current situation). Therefore pragmatic measurement of goal as a whole must charge managers themselves. However checking and calculation of pragmatic correctness of goal it is expediently to charge to the semiotic system by means of using basic pragmatic knowledge about goals of any industrial system.

OTC’s goals (wordings of goals), as a rule, are described by infinitive (Inf) sentences. Such descriptions are realized in according of the following scheme [11]:

- Inf (e.g.: ‘to design a fish processing machine’);
- Inf <*a*> (e.g.: ‘to develop technology and design machinery *of production of varies fish food products*’).

As analysis showed goal-wordings are fixed activities either mean desired (e.g.: ‘to design a fish processing machine of production of fish food products’) or result desired (e.g.: ‘to develop smoked fish food products by the automation line based on a conveyor type furnace’). In first case goal-wording consists in a reference on the result (‘*of production of fish food products*’) produced by the mean. In second case goal-wording consists in a reference on the mean that will produce this result (‘*by the automation line based on a conveyor type furnace*’). Therefore for goal-wording partition formal describing we use a model ‘means-result’ of OTC activity. Adjusting the model ‘means-result’ on a subject region, increasing or restricting its functional components in according of pragmatic requirements of OTC and its environment we got the two-level model of goal-wording.

First level of the model is a level of functional semantic of means and a result. The corresponding base semantic structure of goal-wording is ‘agence-techniques-technology-place-object’. Increasing this structure is carried in wide and deep. In wide it is carried by left-side increasing of supporting semantic-syntactic structure, and as minimum basis structure. In deep every functional component of supporting semantic-syntactic structure may be substituted by any possible structure. So, it is defined the special role frame as a first level model of goal-wording named ‘sentence-goal’, in which the word ‘sentence’ is used in the meaning of Frege.

It is rather sufficient the following function structure of ‘goal-sentence’ for OTC:

< < *agence* (or *1*) > < t*echnology-1* (or *2*) > < t*echniques* (or *3*) > < *object-1* (or *4*) > < *technology-2* (or *5*) >
< *place* (or *6*) > < *object-2* (or *7*) > >.

Example of description of a goal-wording ‘to design machinery of production of food products from fish’ in formal language in which the model is realized looks as

<<techniques: to design machinery > <object-1: fish>< technology-2: production>< object-2: food products >>

or in a compact form:

< < *3* to design machinery > < *4* fish > < *5* production > < *7* food products > >.

For second level of the model of goal-wording named 'phenotype- phrase' we use two categories: 'thing' and 'property' and represent thing that substitute every position (role) in 'goal-sentence' by measuring space of four kinds of properties: functional (FP), characteristic (CP), inscribed (IP) and physical (PP).

Example of description of a goal-wording 'to design automation line of smoking fish based on furnace of conveyor type' in formal language in which the two-level model of goal-wording is realized looks as

< <*G 3* automation line *FP* smoking > < *3* furnace *PP* type . conveyor> < *4* fish >

< *7* products *CP1* food *CP2* smoked > >.

To more adequateness of the descriptions relations of order of role phrases were added in the model.

Semantic graphs of goals and goal-achievement. Since we needed to construct the logically correct and complete structure of goals and structural schemes of the achievement of goals, we had to: develop the models named as graphs of goals G^a and tasks G^c [Поспелов, 1981]; represent them in the form of semantic directed graphs of goals ${}^cG^a$, ${}^cGN^c$ и ${}^cGK^c$; match the goals described linguistically (the language L_1, see Fig. 2) with the vertices of these graphs and specify both structural and some non-structural relations on the indicated vertices (on the goals).

According to the principle of hierarchy of the complexes [Лукьянова, 2007], the tree order relation, which is specified in the graph G^a by the semantic relation ${}^sR^{sub}$ of subordination of goals that form it, is the structure-forming relation of the graph ${}^cG^a$. This semantic relation acts as the basis for the semantic tree order. The names of the relations ${}^sR^{sub}$ correspond to the basic strategies of analyzing the goals that do not exceed ten in number in the complexes. For instance, the structures of goals in fishing industrial complexes include the goals connected by the relation ${}^sR^{sub}$ with the following names: the result-the means (I_1), the whole-the part (I_2), the sort-the type (I_3), the rank-the subrank (I_4), the system-the system aspect (I_5), and the system-the lifestyle stage of the system (I_6), so that $I^{sub}=\{I_j\}, j=1(1)6$. The semantic graphs ${}^cGN^c$ and ${}^cGK^c$ are also formed by the relation of semantic tree order, which is inverse as compared to the graph ${}^cG^a$.

Graph of goals ${}^cG^a$ is a semantic model of SG. Graphs of goal-achievement ${}^cGN^c$ and ${}^cGK^c$ that are the initial and the last semantic models of *SSGA* matching with SG in system of OTC goals.

A semiotic system (logical-and-linguistic model) for reasoning about goals. A semiotic system W is a formal system $W=<T,B,A,P, \psi_T,\psi_B,\psi_A,\psi_P>$, given by the sets T, B, A and P of basic symbols, syntactical rules, axioms, and derivation rules (pragmatic semantic rules), respectively, and the sets ψ_T,ψ_B,ψ_A and ψ_P that give the rules of changing T, B, A, and P, respectively [Осипов, 2002]. A semiotic system S for reasoning about goals is built as a system of the class $SW1$, with its specific features mainly lying in semantics of the elements of the sets T and A. For example, the variables in different states of the system S denote either phrases f_{ij} of the goal sentences or their composing objects of different structuredness (basic and derived) and the names I_s of the semantic relations defined on them, and the axioms of the proper part of S represent the dependencies of analyzing and setting goals in OTC. The truth of propositions on the goals of a bush of goals and the correctness of the reasoning about them are the conditions, under which the system S proves the logical correctness of the bush formed by the decision maker. In the industry, the correctness of such reasoning is conventionally based on the consistency principle interpreted rather widely by the decision maker.

The semiotic system S secures working out structure of goals satisfying requirements of logical correctness and completeness and a structural scheme of goal-achieving in a system of goals matching with SG.

Model of choice of goal

Model of choice of goal secures choosing rational goal between alternative goals.

Here we use a wide-known hierarchical model [Saaty, 1991].

Models of working out a plan of goal-achieving

To work out plan of goal- achieving it is usually used a wide-known models realized in a programs of project management. Here we use models realized in a programs of project management 'Spider project Professional' [Spider project, 2009].

Interfaces

Interfaces of DS ASG includes two groups interfaces:

- external interfaces: In_{11}– an intelligent interface of man-machine interaction based on L and on a transformer from a linguistic form of goal description to logical one; In_{21} – a graphic man-machine interface based on L and semantic graphs: ${}^{c}G^{a}$, ${}^{c}GN^{c}$, ${}^{c}GK^{c}$; In_{24} – a graphic man-machine interface based on goal-wordings and semantic graphs: ${}^{c}G^{a}$, ${}^{c}GK^{c}$; In_{31} – a man-machine interface based on languages of program [http://www.expertchoice.com, 2009]; In_{41} – a man-machine interface based on languages of program [www.spiderproject.ru, 2009]; In_{43} – reducing In_{41}.
- internal interfaces: In_{22} – interface based on a transformer from a linguistic form of goal description to logical one; In_{32} – interface based on goal-wordings represented in a format of program [http://www.expertchoice.com, 2009]); In_{43} – interface based on goal-wordings represented in a text format of program [www.spiderproject.ru, 2009]).

Conclusion

Thus the knowledge-based dialog system of analysis and synthesis of goals allows decision-makers to build a system of goals and to help in solving the problem of incompatible and contradictory of results of making decisions in OTC specifically work out plan of goal-achieving satisfying requirements of logical correctness and completeness.

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Intelligent Medical and Diagnostic Systems

SYNTHESIS OF STATIC MEDICAL IMAGES WITH USING MACHINE LEARNING METHODS

Łukasz Piątek, Grzegorz Owsiany

Abstract*: A part of collection of new algorithms for synthesis of melanocytic skin lesion images is briefly described. Presented approach in the developed algorithms based on a semantic conversion of textual description of melanocytic skin lesions into hybrid (vector-raster type) digital respective images of such lesions. It is assumed, that the developed methodology could be successfully used in education of dermatology students.*

Keywords*: TDS, melanocytic skin lesion, image synthesis.*

ACM Classification Keywords*: I.3.3 Computing Methodologies – Computer Graphics – Picture/Image Generation*

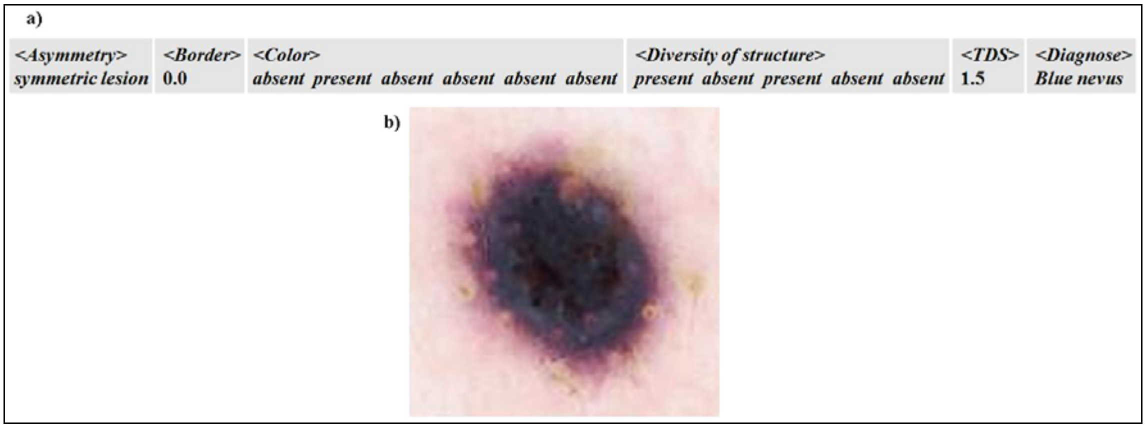
Introduction

In the past few years an increasing interest in images of melanocytic skin lesions can be clearly noticed. These images can be treated as a visual support in diagnosing of *malignant melanoma*, currently one of the most dangerous type of tumors [Topwik, 1998]. But on the other hand the lack of professional computer databases, containing images of such lesions, could be clearly noticed. This situation (at least in Poland) appears from owing the specific interpretation of the personal data protection act. Namely, the current interpretation of this law imposes the necessity for obtain patient permission not only for making in a hospital (or in clinic) a photo of a real lesion, but also approval for publishing or handing such image to any scientific research institution, i.e. specialized in image processing.

These above mentioned reasons inspired us to start the research over the development of effective algorithms for synthesis of static medical images, but generally to synthesize static images of melanocytic skin lesion. It seems, that the collection of developed algorithms – implemented in the specialized computer program (called *ImageSYNTHESIZER* [Piątek, 2010]) - allow to create large, multi-category informational database, which could be successfully used in teaching of medicine students.

Structure of the source database

In our initial research [Hippe and Piątek, 2005] we use informational (textual) database, already discussed in [Hippe, 1999], contains information about almost **550** real cases of anonymous patients lesions, confirmed by histopatological tests. At present, prepared database contains (***i***) **53** textual description of melanocytic lesions in combination with (***ii***) respective digital photographs of such lesions (Fig.1) obtained from [Triller et al., 2008]. To increase the dataset each image (Fig.2a) has been rotated by **90**, **180** and **270** degrees (Fig.2b-d) – such procedure provides a set of **212** real images of lesions.



a)

<Asymmetry>	<Border>	<Color>	<Diversity of structure>	<TDS>	<Diagnose>
symmetric lesion	0.0	absent present absent absent absent absent	present absent present absent absent	1.5	Blue nevus

Figure 1. An example ***textual data vector*** *(**a**) and* ***digital photograph*** *(**b**) of real lesion (Dermal nevus type) [Triller et al., 2008], stored in informational database of melanocytic skin lesions [Hippe, Grzymała-Busse oraz Piątek, 2009a]*

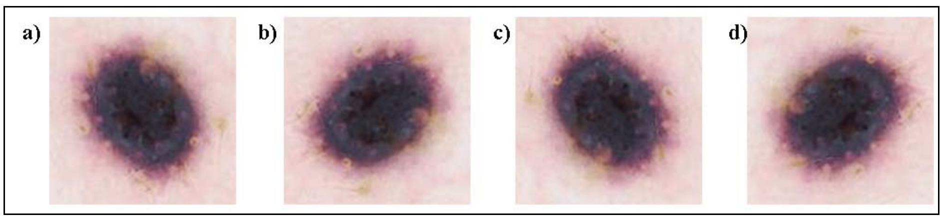


*Figure 2. Digital image (i.e. photograph) of real lesion (Dermal nevus type) (**a**) [Triller et al., 2008] and **3** additional images (**b**, **c** and **d**), obtained by applying the operation of four-fold symmetry axis, perpendicular to the plane of the image*

Each textual description of the lesion (Fig.1a) is saved in the form of 15-th component data vector, which values transmit information about presence or lack of specific symptoms of a give lesion. These symptoms – in machine learning called *descriptive attributes* – are (*i*) *asymmetry*, (*ii*) *border*, (*iii*) *color* and (*iv*) *diversity of structure*. In fact, classification of every real case formally relies on the application of the ABCD *rule* [Stolz et al., 2006], in which A (*Asymmetry*) shows a result of evaluation of lesion shape's asymmetry, B (*Border*) – estimates the character of the rim of lesion, C (*Color*) – stands for number of colors (one or more, from six allowed) and D (*Diversity of structure*) – identifies number of structures (one or more, from five allowed). Elements of ABCD *rule* enumerate four main symptoms of the mentioned lesion, and these element are used to compute value of the TDS (*Total Dermatoscopy Score*) parameter [Braun-Falco et al., 1990], according to the Eq. (1) presented below:

$$\text{TDS} = 1.3 * \textit{Asymmetry} + 0.1 * \textit{Border} + 0.5 * \Sigma\ \textit{Color} + 0.5 * \Sigma\ \textit{Diversity of structures} \quad (1)$$

For example, for a case described by a vector with values presented below:

- ***A****symmetry* equal to **symmetric change**,

- ***B****order* equal to **0**,

- ***C****olor* equal to **four** selected colors observed in a lesion, and

- ***D****iversity of structure* equal to **four** selected structures presented in a lesion

the **TDS** parameter value equals to 4.0 (Eq. (2)):

$$\mathbf{TDS} = \mathbf{1.3} * 0 + \mathbf{0.1} * 0 + \mathbf{0.5} * (0+0+1+1+1+1) + \mathbf{0.5} * (1+1+1+1+0) \quad (2)$$

Due to the **TDS** value (Table 1) the analyzed lesion can be assigned to one of four allowable categories of melanocytic skin lesion, namely: *Benign nevus, Blue nevus, Suspicious nevus* or *Malignant melanoma*.

Table 1. Classification of melanocytic lesions in dependence of ***TDS*** *value*

TDS value	Lesion classification
TDS < **4.76** and **lack** of blue color	*Bening nevus*
TDS < **4.76** and blue color is **presented**	*Blue nevus*
4.76 <= **TDS** < **5.45**	*Suspicious nevus*
TDS >= **5.45**	*Malignant melanoma*

Methodology of the research

In our initial research [Hippe and Piątek, 2005] the algorithms of transformation of a single case from the textual informational database [Hippe, 1999] allowed to obtain only one synthetic lesion image. At present, developed algorithms are improved to generate the exhaustive number of synthesized images [Kulikowski, 2005], corresponding to symptoms displayed by a given lesion. The set of new developed algorithms define the hybrid (*vector-raster* type) approach to synthesis of medical images. Precisely, developed methodology determine a connection of (***i***) *vector* type procedures applied in graphics, combined with (***ii***) *raster* graphics operations, and (***iii***) elements of *machine learning* methods. A sequence of application of the developed algorithms is divided into separate modules – i.e. (i) *learning* module and (ii) module of specify *synthesis process* (Fig.3). In this paper the attention is focused only on part related to the algorithms of mapping lesions' asymmetry (processes no. 2 and no. 5 at the Fig.3) .

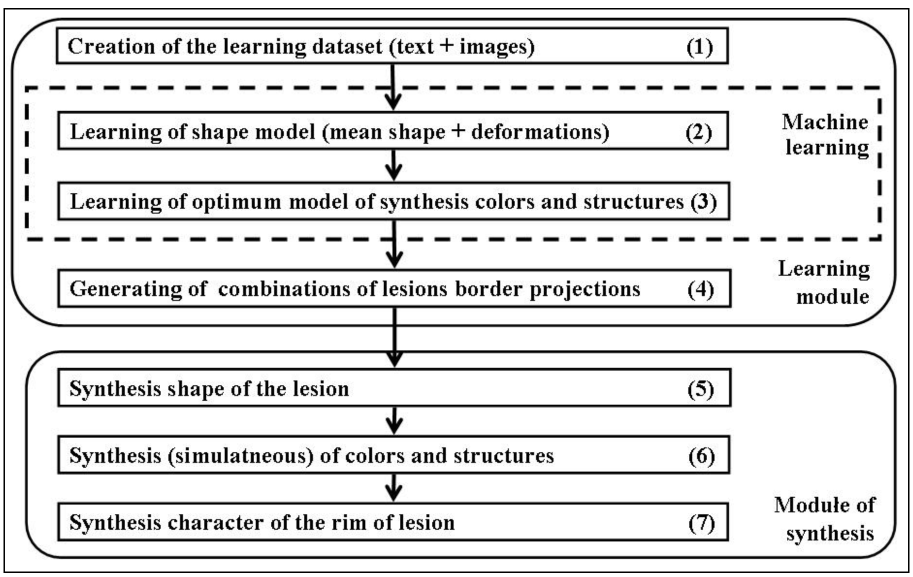


Figure 3. A sequence of application of the developed algorithms

It should be stressed, that in our research we concern on synthesis of melanocytic skin lesion images from only two most dangerous groups of such lesions, i.e. *Nevus* and *Melanoma* [Stolz et al., 2006]. Precisely, Nevus group contains five types of lesions, i.e. *Junctional nevus, Junctional and dermal nevus, Atypical/dysplastic nevus, Dermal nevus* and *Palmo-plantar nevi*. *Melanoma* group include two types of lesions – *Superficial Melanoma* and *Nodular Melanoma*.

Synthesis of the lesions' asymmetry

Mapping asymmetry of a lesion (i.e. shape of a lesion) in synthetic image is divided into separates module as follows at Fig. 4, right into (***i***) *learning* module and (***ii***) module of specify *synthesis process*.

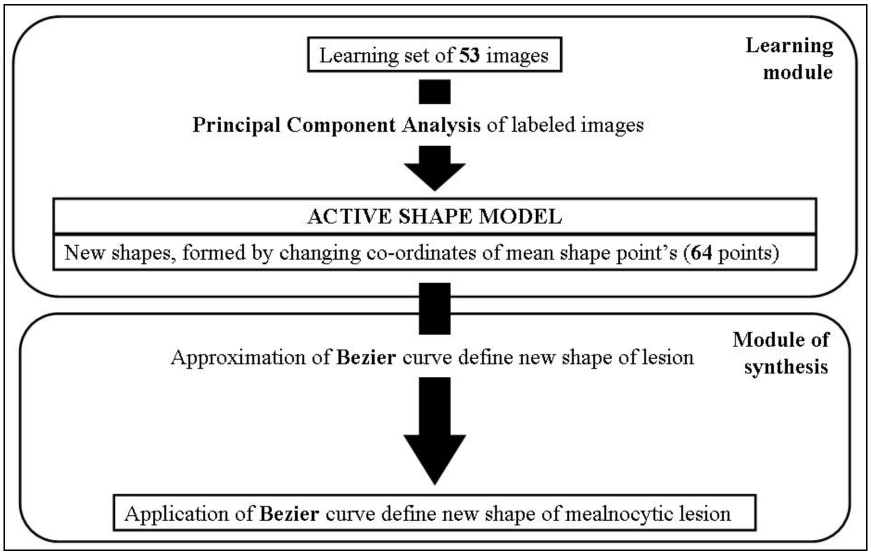


Figure 4. A sequence of selected operations in process of synthesis of an image of lesion shape's asymmetry

At the first module the literature algorithm called ***ASM*** (***A****ctive* ***S****hape* ***M****odel* [Cootes et al., 1994]) is applied. ***ASM*** could be define as a structural information about the *mean shape* of object placed onto digital images, joined with information about the permitted *deviation* from the mean shape, observed in the learning set of images. ***ASM*** models are obtain by statistical analysis of *point distribution model* ***PDM***, based on the set of points labeled manually onto the set of all learning images, with the required conditions. Such control points (so called landmarks) of each training image had to represent a required correspondence (Fig.5).

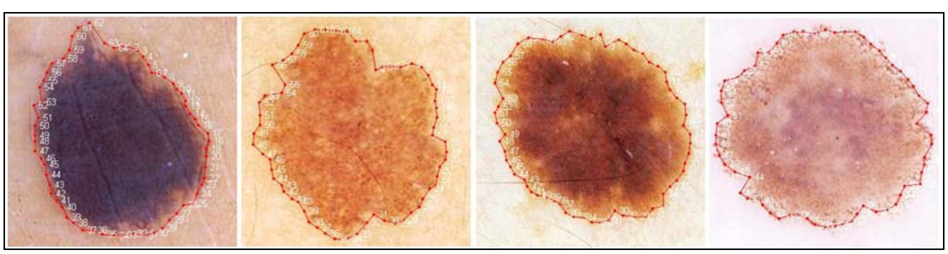


Figure 5. Selected images from the training set (for symmetric lesions) – each with marked 64 landmark points

In other words, every shape ***X*** from the training set is represent as an n-point polygon in images coordinates $\mathbf{X = (x_1,y_1,\ldots,x_n,y_n)^T}$. Every point with coordinates equal $\mathbf{(x_n,y_n)}$ for n equal form 1 to 64is defined in the place of intersections of 32-fold symmetry axis with an edge of the lesions' shape. Finally, each new shape can be obtain according to the Eq. (3):

$$X = \Gamma + P_t * b \qquad (3)$$

where:

Γ - it is a mean shape of all images from the training set,

$\mathbf{P_t = [u_1,u_2,\ldots,u_t]}$ - includes t first eigenvectors of the model covariance matrix, and

b = [b$_1$,b$_2$,…,b$_t$]^T – it is so called shape model vector, contains shape model parameters for each of the selected eigenvectors.

Components of the shape model vector **b$_i$** can be fixed according Eq. (4) within the following range:

$$-s * \sqrt{\lambda_i} \geq b_i \leq s * \sqrt{\lambda_i} \quad (4)$$

where:

λ_i – it is a selected eigenvalue correspond to eigenvector **u$_i$**, and

s – it is a constant value, in our research experimentally equal to **1**.

Active Shape Model – i.e. mean shape and permitted deformation of this shape, observed in the set of training images - for symmetric lesions are presented at Fig.6-9.

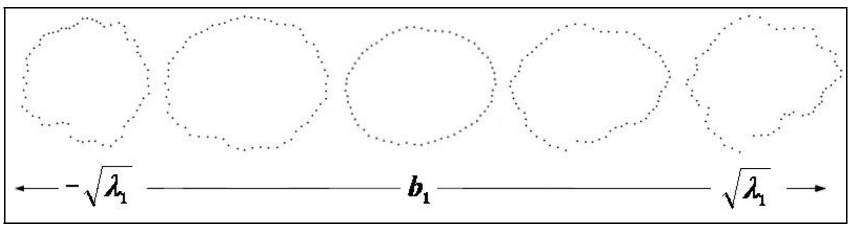


Figure 6. Changing of the mean shape for symmetric lesion, by changing value for the first eigenvector u_1 (1st eigenvector contains 47.9% information about the symmetric lesion shape)

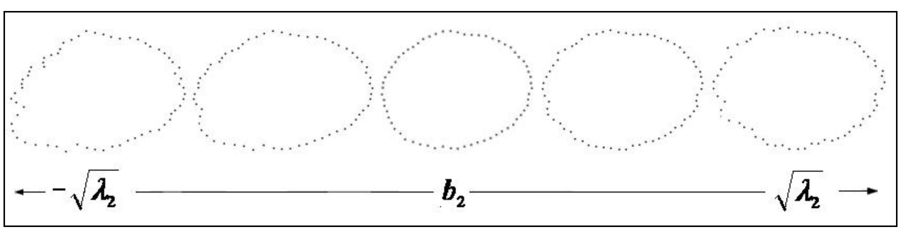


Figure 7. Changing of the mean shape for symmetric lesion, by changing value for the second eigenvector u2 (2nd eigenvector contains 16.8% information about the symmetric lesion shape)

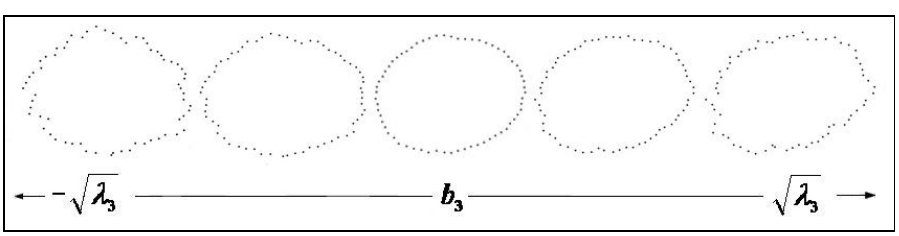


Figure 8. Changing of the mean shape for symmetric lesion, by changing value for the third eigenvector u3 (3rd eigenvector contains 10.8% information about the symmetric lesion shape)

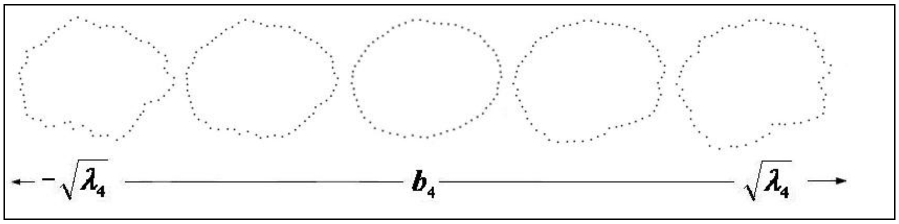


Figure. 9. Changing of the mean shape for symmetric lesion, by changing value for the fourth eigenvector u4 (4th eigenvector contains 8.8% information about the symmetric lesion shape)

Based on the connections of **64** control points of shape **X** (calculate according to the Eq. (3)) the control polygon of the curve is defined. Finally – in the process of synthesis of lesions shape – by using ***the Casteljau*** algorithm [Matusiewicz, 2008] each segment line between neighboring landmark points of the control polygon is splitted with a fixed ratio **t / (t-1)**. This process is performed until arriving at the single point of a curve, corresponding to the parameter **t**. Curve generated with this method is called as a ***Bezier*** curve. According to the developed methodology of synthesis lesion asymmetry we can achieve reliable shapes of synthetic images, similar to shapes of the real melanocytic skin lesions. Example shapes for various types of lesions' asymmetry – i.e. *symmetric lesion, one-axial asymmetry lesion* and *two-axial asymmetry lesion* – is presented below at Fig.10.

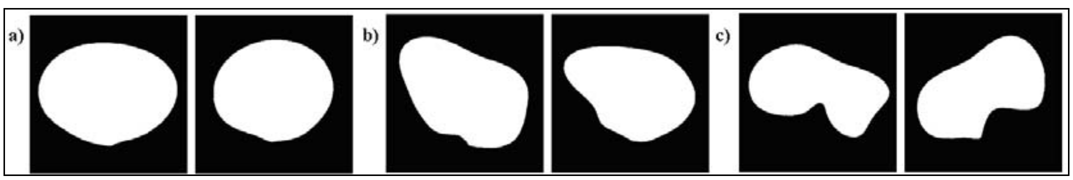


Figure 10. Examples of shapes defined with Bezier curve for symmetric lesion (a), one-axial asymmetry lesion (b) and two-axial asymmetry lesion (c)

Time complexity

Time complexity [Papadimitriou, 2002] of algorithm of mapping lesion's asymmetry for (***i***) learning module (see Eq. (5)) and for (***ii***) module of synthesis process (see Eq. (6)) is presented below:.

$$O(M^2 (M + N)) \tag{5}$$

$$O(N (M + N)) \tag{6}$$

where:

M – is a number of shapes from the set of learning images, equal 22 for *symmetric lesions*, 13 for *one-axial asymmetry lesion* and 18 for *two-axial asymmetry lesion*, whereas

N – is a number of control points, labeled onto every image (shape) from the training set. Value of N is constant and equal to 64.

It could be assumed, that those values of time complexity allow to generate synthetic images of lesion in statu nascendi, it means at the time when physician can need such images.

Conclusion

In research described here, we succeeded in obtaining random synthesis of the most important symptom of melanocytic skin lesions, namely ***A****symmetry*. Combination of algorithms described here and also discussed in [Hippe et al., 2009] follow a new approach to hybridization of synthesis of static medical images (*vector-raster* type), but in general images of melanocytic skin lesions. The set of developed algorithms – already implemented in specialized computer program (called ***Image*SYNTHESIZER** [Piątek, 2010]) – could be used to create large, multi-category informational database, which can be useful in teaching of medicine students, but also in a practice of less experienced dermatologists.

In our future research we consider two main directions. The first problem had to be solved is connected with synthesis of asymmetry. Precisely, apart from synthesis shape's asymmetry, we consider develop additional algorithms for synthesis asymmetry of location selected colors and structures, presented in a given lesion. The second improvement, based on adding the 3rd dimension of synthesize images, should allow to synthesize more reliable images of various type of melanocytic skin lesion (i.e. nipple lesions).

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Major Fields of Scientific Research: Algorithmic

A CONCEPT OF DESIGN PROCESS OF INTELLIGENT SYSTEM SUPPORTING DIABETES DIAGNOSTICS

Wioletta Szajnar, Galina Setlak

***Abstract**: The paper presents an approach to designing an intelligent system to be used in diabetes diagnostics as well as to creating a problem knowledge base for the system. The work also gives a description of constructing a decision tree for diabetes diagnostics and shows how to use it as a basis for generating knowledge base rules. Finally, the article also outlines how an intelligent diagnostic system works.*

***Keywords:** neural networks, artificial intelligence, expert systems, hybrid systems, decision tree diabetes diagnostics.*

Introduction

Diabetes is nowadays considered to be the one of the greatest health hazards of the XXI century. The number of diabetics patients has been increasing to reach 2 million in Poland and more than 200000 million worldwide. Diabetes has become a social disease, associated with the progress of civilization, that has been afflicting more and more people. It needs intensive monitoring and medical care. On account of this, scientific research to find new approaches and tools in order to support diabetes diagnostics and treatment is socially important and timely. Presently, such research is being conducted at numerous scientific research centres all over the world.

In recent years, teleinformation systems and Internet portals have been developed to both improve diabetes diagnostics and educate diabetics. A special telemedical programme has been created in EU (Telematic Management of Insulin- Dependent Diabetes Mellitus; T- IDDM) for patients with type 1 diabetes. There is, however, a shortage of advanced solutions and computer systems grounded on a knowledge base which support and facilitate medical diagnostics.

The purpose of the relevant research is to develop methods of designing and creating intelligent diagnostic systems founded on a knowledge base. The research also aims at implementing state-of-the-art methods and artificial intelligence tools to model and analyze knowledge acquired from various sources. The modelling of knowledge and processes will copy the human way of reasoning.

The basic task of the research is the development of a knowledge base as the foundation of an intelligent diagnostics supporting system which can be used in a dispersed medium, in teleinformation systems supporting the monitoring and treatment of people who have diabetes.

The paper presents an approach to the designing of an intelligent diabetes diagnostics system as well as to the creation of a problem knowledge base for the system. The work describes the construction of the decision tree for diabetes diagnostics and explains how to use it to generate knowledge base rules.

In recent years artificial intelligence tools (such as neural networks, genetic algorithms, vague logic and others) have been very popular and found their application in solving newer, more complicated problems including diagnosing and recognizing diseases. Artificial intelligence tools are the components of the expert systems that are being built to effectively support diagnostics. Many of them have already been developed and applied, among other things, to diagnose neoplastic diseases, heart and cerebrovascular diseases and many others.

The article is an introduction to developing an intelligent diagnostic system whose task is to initially find out whether the patient has diabetes and then to decide whether the illness is of type 1 or type 2. The paper also presents a decision tree which will help to tentatively determine whether a patient with clinical symptoms suggesting diabetes really has the disease or if it is only a group of symptoms indicative of his, e.g. sugar intolerance. In order to decide on the right line of further analysis we have to prepare, in the first instance, a set of data. The system is very helpful in diagnosing and can make a diabetologist's work much easier.

Basic principles of an intelligent diagnostic system designing

The proposed system of diabetes diagnostics should be a computer system of open architecture and molecular structure which will enable the application of a few methods of knowledge representation and integration of different knowledge processing schemes during the process of inference.

Intelligent diagnostic systems should integrate chosen contemporary methods and techniques of knowledge and process modelling, namely:

- artificial neuron networks - the most fascinating tool of artificial intelligence that can model complex functions and imitate (to some extent) the activities of human mind, namely the ability to learn,
- vague logic-technologies and methods of natural language formalization, linguistic and qualitative knowledge processing and vague inference,
- genetic algorithms and methods of evolutionary modelling - algorithms that can learn, based on the theoretical achievements of the theory of evolution and enriching the two aforesaid artificial intelligence techniques (as optimization algorithms they can be applied to teach neuron networks and neuron vague systems and/or to optimize the structure of networks and systems).

The combination of these tools with a traditional skeleton expert system where knowledge is symbolically represented will allow for the creation of comprehensive programme tools. They will be used to solve complex problems and tasks necessitating the processing of incomplete, fragmentary, vague or contradictory knowledge as well as in all the situations where the knowledge is difficult to formalize.

The artificial neuron networks, classified as basic tools in the paper, are indispensable for the solution of a lot of important tasks such as identification and classification of symptoms, grouping analyzed data or prediction based on historical data. An enormous asset of neuron networks is that they make it possible to look for models for only slightly familiar phenomena and processes. They also allow for controlling complex problems of multidimensionality. Another advantage of neuron networks is undoubtedly the previously mentioned ease of their application. Neuron networks, practically all by themselves, construct models the user needs. It is because they learn automatically while filling up their adaptation structure with the necessary parameters based on the user provided examples of the modelled system's behavior. To some extent, neuron networks copy the way human mind works although they are founded on a very simple model representing the very basis of the working of a biological nervous system.

An expert system is assumed to be a computer system which, as its name indicates, performs its tasks as efficiently as an expert in a particular branch of knowledge or science. The programme, using a given knowledge base as well as a rule base and facts, draws conclusions and makes decisions, just like a human being.

Expert systems can be classified in various ways. They can function as: advisory systems, i.e. they suggest the direction your activity should take; decision making systems, working without human help or interference; criticizing systems, i.e. those which, based on the specific problem and a man's predicted solution, analyze and comment on a particular way of reasoning or actions. Creating a system founded on a knowledge base means acquiring the knowledge of an expert who often finds the solution making use of relevant information and experience. The expert system that applies the written expert knowledge of a particular field can use it many times in an economical and effective way without the expert's presence. This enables the expert to avoid analogous reports and take up more creative tasks. Thus, a particular asset of such systems is the possibility of solving given tasks without the expert's participation, and also the possibility of aggregating knowledge within one system of a numerous expert team. [Kowalczuk,Wiszniewski, 2007]

Any expert system should contain a few fundamental components:

- knowledge base,
- data base,
- interference procedures - inferring engine,
- explanation procedures - explain interference strategy,
- procedures of dialogue control- input/output procedures enable the user to formulate tasks and the programme to transmit the solution,
- procedures that make it possible to enlarge and modify knowledge - its acquisition. [Kwaśnicka, 2005]

Hybrid intelligent systems are a relatively new category of systems based on artificial intelligence. They consist in the combination of the best features of such tools of artificial intelligence as: expert systems, learning systems, neural networks and genetic algorithms. Owing to this, the hybrid system is able to handle more difficult problems which a single system, which is a part of the hybrid system, could not cope with.

Structure of the expert hybrid system under construction

A hybrid system is a combination of an expert system with neural networks. This way, symbolic processing, characteristic of traditional expert systems is complementary in relation to dispersed, parallel processing typical of neural networks. In the simplest case, both ways of processing may occur independently. It is assumed that there should be a kind of superior medium. It distributes tasks between particular systems. Depending on the sort of problem the tasks are allotted to the system which guarantees the best solution. The functioning of this solution can be described briefly as follows. An expert system operates the interface, processes the data that have been entered into appropriate coefficients and searches the data base. It is accepted that in this field there are no clear and explicit rules; that is why an artificial neural network is the appropriate tool for processing this kind of vague knowledge. An expert system forms a file containing the calculated business coefficients as the input data for the neural network. After the calculation has been carried out by the neural network, the results obtained at its output are passed back to the expert system to be interpreted. In the end, the final results can be read in the displayed window. [Bubnicki, 1990]

The components of an expert system are:

- skeleton of the system consisting of:
    - user's interface - which enables asking questions, giving the system information and taking answers and explanations from the system,
    - knowledge base editor- which allows for the modification of the knowledge contained in the system enabling its growth,
    - inference mechanism - which is the main component of an expert system. It performs the whole reasoning process while solving the problem put by the user,
    - explaining mechanism - one of the components of the system-user interface which enables the user to learn why the system gave him just this answer of all answers or why just this question was asked.
- knowledge base - this is the declarative form of the expert knowledge of a particular field written by means of a chosen way of knowledge representation, most often rules or frames.
- variable data base – which is a working memory storing same facts entered during the dialogue with the user. The base enables the reconstruction of the way of inference conducted by the system and then presenting it to the user by the explaining mechanism.

The acquisition of knowledge from experts is usually the responsibility of knowledge engineers. This is usually a long and tiring process since expert knowledge is of intuitive - practical nature, often difficult to verbalize.

The reasons for building this sort of systems based on artificial intelligence may be the following:

- It is not always possible to obtain heuristic rules for knowledge bases of the expert system. However, there are data that may be used for building a neural network.
- There is not always an appropriate data set to be based as a basis for teaching neural network. On the other hand, there is a possibility of building a knowledge base (e.g. when we have an open model).
- The problem that is being solved is of complex nature, and another kind of data processing technology seems to be more effective or convenient for solving each of the problems. [Białko, 2000]

In the case when various methods can be used for solving the same problem, same features of one of them can be decisive (e.g. it may be the ability of the expert systems to explain and codify knowledge).

The building process of a hybrid system, which is the effect of the neural network and expert system integration, in the PC- Shell system consists of the following stages (the sequence of points 1 and 2 is arbitrary)

- Generating neural applications (SN_1, … , SN_m), for selected sub problems by means of the Neuronix system.
- Elaborating knowledge bases (as knowledge sources) SE_1, … ,SE_n.
- Integration of the knowledge sources elaborated at the previous stages at the level of the knowledge presentation language of the PC- Shell system.

From the point of view of practical realization, the role of the Neuronix system boils down to teaching the network and generating the definition of the neural application as a defining file (files with **npr** extension) and a file containing weighing kit (files with weight extension). [Mulawka, 1996]

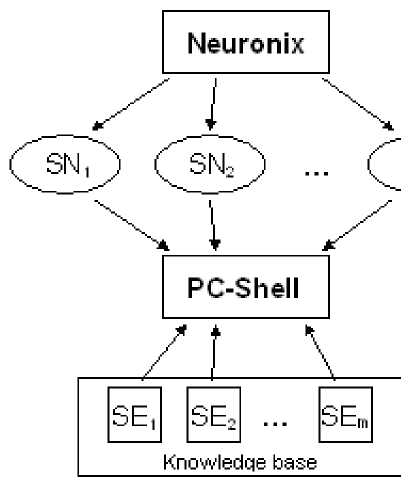

Fig.1. Structure of hybrid application (SE+SN) in the PC- Shell system

Decision tree as a model of diabetes classification

Decision tree structure

The decision tree is a flow diagram of a tree- like structure where each top means attribute testing, each edge stands for test exit (value or attribute value set), and each leaf represents a class.

To classify an unknown object the values of its attributes are tested following the information comprised in the decision tree. During the testing process, the path in the tree from the root to one of the leaves is covered - in this way the class the object is going to be classified into will be defined.

Decision trees can easily be transformed into classification rules.[5] The object to be classified is the set of objects, S, which are described by (m+1) - the dimensional vector of characteristics (x_1, x_2, … x_m, y).

Variable y is the explained variable - i.e. singled out, because of which the classification is performed. What is more, variable y, depending on the problem being solved, can be a quality variable - (linguistic, nominal or order variable) or continuous and binary variable.

The result of the classification in the decision tree induction method is the decision tree.

The main problem to face while building a decision tree is the defining of the criterion enabling the choice of the attribute applied in the development of the tree. In order to choose such an attribute it is necessary to calculate the entropy (entropy is the information contained in the teaching example set). Entropies are calculated following the formula:

$$I(E) = -\sum_{i=1}^{|E|} \frac{|E_i|}{|E|} \bullet \log_2\left(\frac{|E_i|}{|E|}\right) \tag{1}$$

Where: E – set of teaching examples,

!Ei! – number of examples which describe i-th object,

!E! – number of examples in the teaching set

In order to choose the attribute that will be ascribed to the generated node of the decision tree, the criterion of the maximum relative information increase is applied; the increase is caused by the use of a particular attribute (the attribute for which the criterion function value is the highest is applied as the successive attribute):

$$\Delta I(E,a) = I(E) - I(E,a) \tag{2}$$

Diabetes diagnostics

To start a diagnosis it is necessary to gather the proper number of data. The source of the data can be: the patient himself, his record, a primary doctor, a specialist, a biochemical lab and specialist tests. The system gathers data by means of a number of tests: subjective, objective tests, laboratory tests and extra tests.

- subjective tests - general interview: the system takes such data as: name, surname, age, occupation, place of work, living conditions (diet, smoking addiction, nicotine addiction, alcohol), general health condition, eating habits, nutritional status (obesity, emaciation), history of body mass changes, family interview (did the family members suffer/suffered from similar diseases), the beginning of the disease (how many years ago), course of the disease so far, other organ and system complaints, past diseases and operations, present or previous infections, diabetes education, course of treatment (in the case of previously treated diabetes patients) medication applied,
- objective tests: height and body mass measurement (BMI), calculating the due body mass and comparing it with the real mass, personal development phase evaluation (sexual-bodily phase, old age phase), arterial pressure evaluation in the lying and standing position (with the measurement of the orthostatic reaction), ophthalmoscopes tests of fondues (at pupillary dilation), thyroid test, heart test, taking pulse and testing all the peripheral arteries accessible when fingering and ausculating, feet test, neurological test, teeth and gums test, skin and mucosa tests,
- laboratory tests: glycaemia test on an empty stomach and daily glycaemia profile, notation of glycated haemoglobin and fructosamine, notation of the lipid profile on an empty stomach: total cholesterol and cholesterol in lipoproteins of high density (HDL- high density lipoproteins), cholesterol in lipoproteins of low density (LDL- low density lipoproteins) and triglicerydes, urine test

(apart from glucosuria) to check ketone bodies and protein presence, (macro- and micro-albuminuria) and microscope test of the sediment, bacteriological test (urine cultures and possibly antibiogram), euthyroidism test and morphological status of the thyroid (concentration evaluation of T3, T4 and TSH, scintigraphy of the thyroid), peripheral arteries tests (potency and the rush of blood), electrocardiogram, echocardiography, ergometer test, neurological tests, especially the electromyography test, ophthalmic review (general test of the organ of sight),

- Additional tests: fundus test. [World Health Organization (WHO), 1999]

The diagnosis of diabetes is based, most of all, on checking the glucose level. However, many other symptoms that may suggest diabetes are also considered.

They include: increased thirst (polidypsia), polyuria, loss of body mass, urinating during the night, increased appetite, general fatigue, dermatomycosis and mucous membrane mycosis, skin infections (mycosis, furuncles) feeling of dryness in the mouth cavity, pruritus of the vulva, cramps, vision disorders. [Czech,Tatoń, 2009]

Biochemical criteria:

hyperglycaemia (glucose concentration of above 126mg/dl in venous blood found at least twice),

- casual blood glucose level in the serum (at any time of the day) of above 200mg/dl,
- blood glucose level of above 200mg/dl, two hours after a 75g glucose oral load (oral glucose tolerance test OGTT),
- glucosuria. [cukrzyca.info]

Principles of constructing a detailed decision tree for diabetes diagnostics

There is a set of three objects:

- diabetes (object E_1),
- impaired glucose tolerance (object E_2),
- lack of the disease (object E_3).

The characteristic features of the objects are:

- occurrence of diabetes in the family: yes, no
- thirst: great, normal
- urination: frequent, normal
- body mass: great (obesity), normal
- appetite: great, normal
- fatigue: great, little
- age: over 45, under 45
- hypertension: yes, no
- cholesterol level: high, normal
- triglyceride level: high, normal
- cardiovascular diseases: yes, no
- physical exercise: little, a lot
- dermatomycosis: yes, no
- glucose tolerance test: above 200mg/dl, below 200mg/dl
- glucosuria: yes, no
- skin infections: often, rarely
- xerostomia: yes, no
- cramps: yes, no
- vision disorders
- glucose level: above 126mg/dl, below 126mg/dl

- occasional glucose content in the serum: above 200mg/dl, below 200mg/dl

Figure 2 shows a decision tree representing the algorithm of type 2 diabetes diagnosis (the most common), considering the factors increasing diabetes hazard.

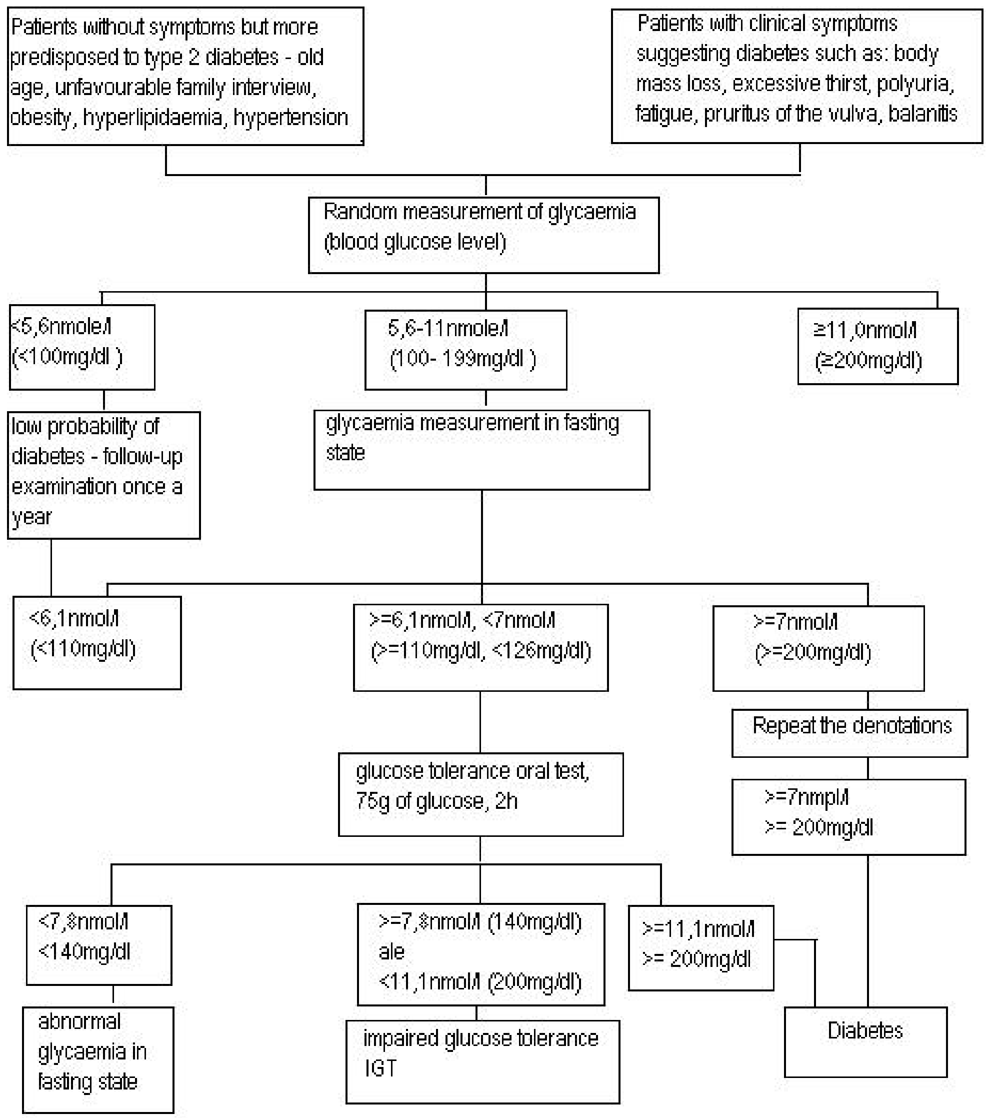

Fig. 2 Diagnostic scheme of diabetes with regard to factors increasing diabetes risk

Due to a multitude of symptoms that might suggest diabetes two groups of patients were selected:

- patients without clinical symptoms, but with more diabetes predisposition,
- patients with clinical symptoms suggesting diabetes.

The beginning of the tree consists of the alternatively presented syndromes of the patient's condition. The next component is the examination (diagnostic activity) for which the scheme predicts three possible results: the first suggest completing the procedure, the second – another examination, the third points to the specific condition of the patient (diagnosis). Two results are anticipated for the next examination. One of them- like the result of the first examination - suggests diagnosis, the other, however, insists on another examination whose possible results (given separately) somehow enhance the previously suggested diagnoses. The principle of the practical interpretation of the scheme is like that in the previous case: finding such and such initial state necessitates conducting such and such examinations whose nature and sequence depend on the results obtained and which finally lead to such and such diagnosis. [Czech,Tatoń, 2009]

Inference rules can be formulated based on the generated decision tree.

> ***If*** *(the patient's state without symptoms and more predisposed to diabetes = random glycaemia measurement <100mg/dl),* ***then*** *the probability of diabetes low.*
>
> ***If*** *(the patient's condition without clinical symptoms and more predisposed to diabetes = random glycaemia measurement>100mg/dl but ≤199mg/dl) and (glycaemia fasting state measurement=<110mg/dl),* ***then*** *the probability of diabetes low.*
>
> ***If*** *(the patient's condition without clinical symptoms,* ***and*** *more predisposed to diabetes= random glycaemia measurement from 100mg/dl to 199mg/dl) and (glycaemia fasting state measurement=≥110 but <126mg/dl and (oral glucose tolerance test=<140mg/dl),* ***then*** *abnormal fasting state glycaemia.*
>
> ***If*** *(the patient's condition without clinical symptoms, and more predisposed to diabetes= random glycaemia measurement from 100mg/dl to 199mg/dl) and (fasting state glycaemia=≥110 but <126mg/dl) and (oral glucose tolerance test=<200mg/dl),* ***then*** *impaired glucose tolerance.*
>
> ***If*** *(the patient's condition without clinical symptoms, and more predisposed to diabetes= random glycaemia measurement from 100mg/dl to 199mg/dl) and (fasting state glycaemia= ≥110 but<126mg/dl) and (oral glucose tolerance test=≥200mg/dl),* ***then*** *diabetes.*

The other rules are formulated in the same way.

Conclusions

If follows from the aforesaid consideration that each information processing technique has its advantages and disadvantages. Consequently, some complex problems may be difficult to solve if only one technique is applied, which finally leads to making use of hybrid solutions. At least three factors can be mentioned that can encourage hybrid solutions:

- reducing the drawbacks of a given technique by applying another technique,
- multiplicity of tasks fulfilled by the application requires the use of various techniques,
- it is necessary to emulate different techniques within the scope of one architecture.

To make the system work it is necessary to create a detailed base of knowledge and an inference mechanism.

The successive stages of building the expert system can be presented as follows:

- Problem identification. Its aim is to create an informal description, define the needs to be met by the expert system and the function scope of the system (the scope cannot be too wide so as not to include the problems whose solution methods are not known. The circle of users is to be determined as well.
- Defining the function principle of the system, where the way the expert works when solving similar tasks is analyzed. A few typical tasks to be solved by the system are selected together with the expert. Then the process of their solution is watched closely.

The most important criteria are:

- the system's ability to apply the knowledge base,
- the possibility of changing and completing the knowledge base,
- the possibility of giving explanation.

Describing the essence of the expert system functioning it is necessary to define: the course of the dialogue with the user (who makes a dialogue), the way the dialogue goes (determination of the menu, the questions and the

kind of language), the way the system reacts (immediately, after the inference cycle) and how answers will be formulated. Additionally, it is advisable to define the programme tools to be used, what computers will be used.
The definition of the knowledge base extent and the choice of the way of representation involves answering the following questions:

- do the demands we want the expert system to meet lead to the choice of the definite way of representation?
- is high effectiveness (speed) necessary?
- is it possible to apply the existing skeleton systems?
- is the system compatible with other systems?
- will it be necessary to change the knowledge base during the operation?
- are the tools of knowledge acquisition necessary?

The construction and verification of the prototypes on the properly selected examples.
Testing investigations and the evaluation of the applicability of the system involve the evaluation of the quality of the decisions suggested by the system, correctness of the inference techniques, the quality of the cooperation with the user, efficiency, transferability reliability, testing convenience, simplicity of modification methods.

- The expert system, which has the knowledge written by an expert in a particular field, can make use of it in an economically effective way as the expert’s presence is not necessary. This way the expert does not have to repeat the same expertise and can concentrate on more challenging tasks,
- The comparison of the results obtained by the expert system with those obtained by man shows explicitly that in many fields the expert system is not as fallible as a human,
- The expert system can precisely prove its inference process, which a man, an expert falling back on his intuition and experience, is not capable of,
- The expert system can solve a large group of problems from a particular field and each task that begins to exceed the inference rules causes steady work quality deterioration of the system. (in the case of an expert there occur irregular drops in quality or a complete lack of answer),
- Future expert systems will be able to solve tasks from various, not interrelated, fields of knowledge based only on the structural similarity of the inference rules,
- The expert system can be used even in those fields that cannot be easily described by rules, but a human can deal with them fast and in the right way. In such cases the expert system, that can substantiate the decisions taken, can be applied as a sort of help by people who are not familiar with the particular branch of knowledge well enough to start working independently,
- Future expert systems that corroborate the decisions taken in the inference process will adjust the difficulty level of their explanations to the user’s level of knowledge. An expert might get other explanations than a person not knowing a particular field,
- The expert system can contain mechanisms enhancing its working - enlarging the knowledge by new facts and inference rules. The mechanisms include: check of lack of discrepancy between the rules newly entered into the knowledge base and the rules that have already been there, check of the congruity of the rules with the newly entered facts, the mechanism of the evaluation of the application frequency of particular rules, and the mechanism of extending the existing rule base beyond the scope of the given knowledge base,
- The model of the expert system structure means a qualitative change in computer programming. It enables a simple adjustment of a computer programme elaborated for a definite field to effective use in another field,
- Expert systems can be created by means of editorial programmes which enable avoiding a lot of mistakes. The programmes have the following properties: a user- friendly communication system

and automated registration operation during information distribution, checking the spelling and syntax correctness of the entered text information, checking lack of semantic discrepancy between the present content of the data base and the newly entered facts, facilitating the creation of the data base by applying appropriate window systems and enabling the user to enter the information in the graphic medium,

- After the identification of mistakes in the expert system function it is possible to rebuild the knowledge base of the system. The process can be performed or supervised by a knowledge engineer or done automatically by the expert system,
- Some expert systems can automatically, without any supervision, create successive knowledge bases (so learn by themselves) being aided by a filter that can stop false information (information noise) based on its discrepancy with the already existing knowledge base. [Bizoń, 2008]

The hybrid system I made is to function as a medical expert diagnosing diabetes. It is supposed to replace, in a sense, the doctor in the first phase of the illness diagnostics (it allows for an interview and a detailed blood test).

The knowledge base created so far was confined to the determination of three object groups.

After getting the information about the patient, symptoms and the disease, and after completing the basic medical examinations, the moment is reached when our expert system, based on the above information, draws the relevant conclusions. Diagnosing involves moving in the decision tree. As aforesaid, the system discussed recognizes three classes of the disease: type 1 diabetes, type 2 diabetes and diabetes mellitus in pregnancy. Secondary diabetes is very difficult to recognize and of great diversity. It takes a separate interpretation and analysis. For that reason it was ignored in initial tests.

The scheme of the diagnosis is quite simple and in a way obvious. The final result may be a statement that the patient suffers from a particular kind of diabetes and the recommended remedy is simply an appropriate diet together with pharmacological treatment.

It is this way that we reach the stage of diagnosis. If we analyzed in detail one of the possible ways, we would observe that its particular stages do not differ from the proceedings adopted by the doctor. Our expert system is to come to the right conclusion behaving like an expert in a given field, that is, a doctor.

The next stage is the classification of the symptoms and the division into two types of diabetes (objects type 1 and 2), considering differential diagnostics. Training files containing verified patient data will be prepared by an expert.

Further analysis can be carried on in different ways, which will be decided after the data set is ready.

It is very important that there should be a close cooperation between the system engineer and the experts in the field in question when constructing the appropriate expert system. Nothing can replace the doctor's knowledge and his long-standing experience.

The system of diabetes diagnostics based on artificial intelligence that we constructed would be the first system of that kind made in Poland.

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Major Fields of Scientific Research: decision-making in intelligent manufacturing systems, knowledge and process modelling, artificial Intelligence, neural networks, fuzzy logic, evolutionary computing, soft computing.

Computer Engineering, Mechanical Engineering

SURFACE PROFILE ANALYSIS PACKAGE

Paweł Dobrzański, Magdalena Dobrzańska, Wiesław Żelasko

Abstract: *In the article it has been presented the Robust Gaussian regression filtering techniques. Several typical robust weight functions have been adopted and compared with each other. Next the surface profile analysis software was shown which enables for the analysis of actual and simulated surface roughness profile. The application enables to choose the filter parameters that will be determined and gives the result of filtering in the form of a graph, and values of parameters.*

Keywords: *surface profile analysis, filtering techniques, Visual C++*

ACM Classification Keywords: *J. Computer Applications, J.2 Physical Sciences And Engineering, G. Mathematics Of Computing, G.4 Mathematical Software*

Introduction

An assessment of microtopography by surface parameters is useful when long wavelength components are removed from the measured surface data. Surface characterization is based on the separation of surface components. A necessary preliminary to numerical assessment of surface profiles is to extract the frequency components representative of the roughness and to eliminate those that would be irrelevant. The unwanted elements of the surface geometry are commonly referred to the waviness, due to imperfections in the manufacturing process. The cut-off length is selected to separate roughness and waviness for a given surface. The methods of separation of profile on roughness and waviness are described in Reference [Raja, Muralikrishnan, Fu 2002]. The choice of filtering methods has an important influence on surface characterization. Recently, Gaussian filtering technique was adopted to filtration of surface profiles. This technique solved the problems of phase distortion and complex design of filters. The performance of Gaussian filtering technique is affected by certain conditions, especially for the surfaces having freak signals (outliers) such as grooves, scratches and scores. The question of finding reference lines is very difficult for multi-process texture. One finishing process of this type is called plateau honing. The problem is that control of such surface texture requires a complementary response from surface metrologists. Without adequate measurement technique the control and hence any attempt to maintain quality is lost. Although the fine texture marks fall well within the accepted bandwidth for the sample length (cut-off) the scratches do not. They are too wide. For these surfaces, the distortion after Gaussian filtering can be also big.

Gaussian filtering technique

Robust Gaussian filtering

The impulse response function of Gaussian filtering is described by its weighting function s(x).

$$s(x) = \frac{1}{\alpha\lambda_C}\exp\left[-\pi\left(\frac{x}{\alpha\lambda_C}\right)^2\right] \quad (1)$$

where:

x – distance from the center of weight function

λc –cut-off

$\alpha = \sqrt{\ln 2/\pi}$.

With the convolution operation, the original measured profile z(x) can be divided into low-frequency reference w(x) and high-frequency roughness r(x) [Li, Jiang, Li 2004].

$$w(x) = \int_{-\infty}^{\infty} z(x-\xi)\cdot s(\xi)\cdot d\xi \tag{2}$$

$$r(x) = z(x) - w(x) \tag{3}$$

where: $r(x)$ – roughness profile .

$$w(x) = \int_{-\infty}^{\infty} z(x-\xi)\cdot \rho(x) s(\xi)\cdot d\xi \tag{4}$$

Strictly speaking, we used modified Gaussian weight function in running-in and running-out lengths in order to eliminate edge effects (regression filtering).

Robust weight functions

According to M-estimation, different robust weight function can lead to various results for the same observed signal. So several typical weight function were selected and compared with each other.

Sometimes the standard deviation is used as the estimating scale. However it is less robust than a median MED or median absolution deviation MAD. So only MED or MAD robust scale parameters were used. In initial calculations we analyzed a lot of weight functions. As the result of it, several selected typical weight functions were compared [Dobrzański, Pawlus 2005]:

WLAV

$$\rho(x) = \frac{1}{|v|} \tag{5}$$

where: $v = r(x)/s$, $s = MED = |med(r(x))|$ lub $s = MAD = med(|r(x) - med(r(x))|)$.

Tukey

$$\rho(x) = \begin{cases} \left(1 - v^2\right)^2, & |v| \le 1 \\ 0, & |v| > 1 \end{cases} \tag{6}$$

where: $v = r(x)/cs$.

Huber

$$\rho(x) = \begin{cases} 1, & |v| \le c \\ \dfrac{c}{|v|}, & |v| > c \end{cases} \tag{7}$$

where: $c > 0$, $v = r(x)/s$.

$$s = \begin{cases} \sigma, & |v| \le c \\ MAD, & |v| > c \end{cases} \tag{8}$$

where: σ – standard deviation.

Hampel

$$\rho(x) = \begin{cases} 1, & |v| \le a \\ a/|v|, & |v| \in (a,b] \\ a\dfrac{c-|v|}{(c-b)|v|}, & |v| \in (b,c] \\ 0, & |v| > c \end{cases} \tag{9}$$

where: $v = r(x)/s$, $0 < a < b < c < \infty$.

Andrews

$$\rho(x)=\begin{cases}\frac{1}{\pi v}\sin(\pi v), & |v|\le 1\\ 0, & |v|>1\end{cases} \tag{10}$$

where: $v = r(x)/cs$.

ADRF

$$\rho(x)=\begin{cases}1, & |v|\le a\\ a/|v|, & |v|\in(a,b]\\ b/v^2, & |v|\in(b,c]\\ 0, & |v|>c\end{cases} \tag{11}$$

where: $v = r(x)/s$, a= 1, b= 2.5, c=3.

Fair

$$\rho(x)=\frac{2}{1+|r(x)|/k\sigma} \tag{12}$$

Denmark

$$\rho(x)=\begin{cases}1, & |x|\le k\sigma\\ \exp\left(-\frac{|r(x)|}{k\sigma}+1\right), & |x|>k\sigma\end{cases} \tag{13}$$

IGGI

$$\rho(x)=\begin{cases}1, & |x|\le a\sigma\\ k\sigma/|r(x)|, & |x|\in(a\sigma,b\sigma]\\ 0, & |x|>b\sigma\end{cases} \tag{14}$$

QC

$$\rho(x)=\begin{cases}1, & |v|\le k\\ 0, & |v|>k\end{cases} \tag{15}$$

where: $v = r(x)/\sigma$.

Surface Profile Analysis Package

On the commercial market there are many applications for the analysis of surface profiles. Unfortunately, these applications are expensive and not available educational version. Therefore, the authors made attempts to write such an application, which can be used both in scientific work and teaching. With Surface Profile Analysis Package a user can analyze data files collected from a variety of instruments from most major manufacturers.

Designed application enables for the analysis of real and simulated surface roughness profile. The application enables to choose the kind of filter and parameters that will be determined and gives the result of filtering in the form of a graph, and the selected parameters.

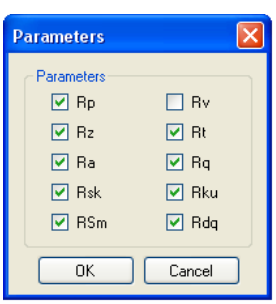

Figure 1. Determined parameters selection window

The user after loading the data (Files-> Open) can choose the parameters which undergo subsequent analysis does this in the Options menu-> Parameters (fig. 1).

The program sets the basic roughness parameters such as:

Ra Roughness Average (Ra)

Rq Root Mean Square (RMS) Roughness

Rt Maximum Height of the Profile

Rv, Rm Maximum Profile Valley Depth

Rp Maximum Profile Peak Height

Rz Average Maximum Height of the Profile

Sm, RSm Mean Spacing of Profile Irregularities

Rsk, Sk Skewness

Rku Kurtosis is a measure of the randomness of heights, and of the sharpness of a surface.

Rdq Mean absolute slope

By default, all parameters are selected, i.e. all the parameters will be determined. The next step is to choose the filter/s (from the menu Filtering) fig.2 by which will be analyzed and loaded surface profile. Therefore, some filters that can be run with different parameter values and therefore the user has the option after selecting a filter, for example, Tukey determines the value of the parameter. Another choice which the user must make is the cut-off by default is set to 0.8 mm.

a) b)

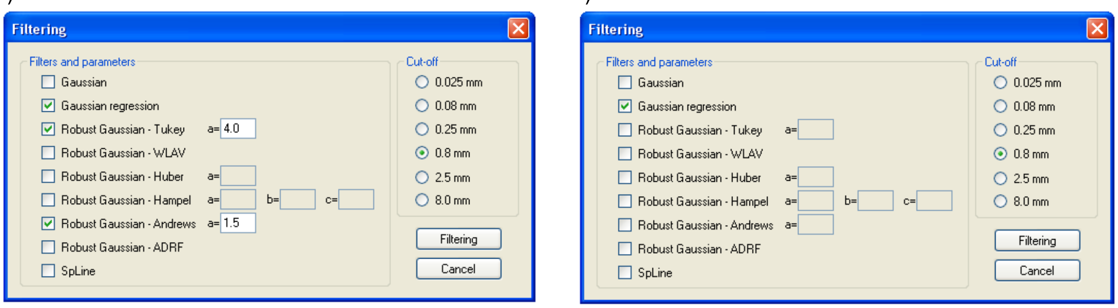

Figure 2. The selection of filters used in the analysis of surface profiles

Often the user wants to be able to compare the effects of several filters on the same surface profile analyzed. Therefore, the application gives the user to create this possibility. A surface profile can be analyzed by using several filters, then get a summary table of results (in the form of a graph and calculated values of parameters).

Figure 3. Result analysis of the surface profile as a graph (blue - measured profile, green-waviness, red - roughness) and calculated values.

What will user observe the graph depends on itself and setting what will. The choice is between a profile without filtration, waviness and roughness, and their combinations. Result of filtration (graph/s and the parameters) can be written on the example of later analysis.

Conclusion

The article presents the software written in Visual C++. The software is the part of the system which has been created for the need of the analysis of surface profiles. The software will be extended with new modules such as 3D analysis. Created application is very helpful in the analysis of surface profiles. It allows user to efficiently carry out studies designed to perform data analysis profiles of the surface.

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METHOD OF CONGLOMERATES RECOGNITION AND THEIR SEPARATION INTO THE PARTS

Volodymyr Hrytsyk, Viktor Vlakh

Abstract: *The article presents a method of identification and separation of visual objects that partially overlay each other. We also had investigated this method for example cell conglomerates division.*

Keywords: *decision support systems, pattern recognition.*

ACM Classification Keywords: *I.2.1 ARTIFICIAL INTELLIGENCE-Applications and Expert Systems*

Introduction

Today there are strong tendencies in attempts to replace the man in all of the processes where possible. Computer technology is so ingrained in our society, that today one cannot imagine any activity not related somehow to the computer [D. Forsyth, J. Ponce, J ,2004]. Increasingly there are attempts to introduce automated systems that are designed to perform routine work instead of rights, for it is during this kind of person most often mistaken. This affects many factors foremost of which is loss of concentration, i.e. inattention. This may lead to an increase in the number of erroneous decisions, and thus to distort the results.

Especially important to avoid such mistakes in areas that require precision and performance man. Among the existing lines of automation is a special place computer vision problem. This is due to the fact that the human operator about 90% of all information receives through the visual analyzer [9]. Vision allows to perceive form, color, brightness and motion of objects.

To research the subject area selected, which best shows the need of automation of all listed aspects of computer vision. That automation in microbiology [V. Hrytsyk, M. Vlakh , 2006], [V. Hrytsyk, N. Pelykh, 2009] combine high demands on the quality of their work and high responsibility for shutting errors during processing. Today, however, complete automation is impossible. This is due primarily to complexity of research in which technology is not yet able to fully replace the man.

In this article the description of the developed method, which allows to automate the solution of complex problem, which becomes an obstacle in automating many microbiological studies – the problem of separation of conglomerates. We introduce the definition of conglomerate, which may be defined as a *group of objects combined in a single structure that is difficult to separate*.

Identification and separation of conglomerates problem is currently difficult to resolve, and existing efforts do not give enough accurate results. This is due to simultaneous influence of several factors, main of them are: accidental overlay objects, natural objects (i.e. all objects are different in nature and never repeated), technology only highlights the labeling of the object (thus the whole body of object is not always visible).

The existence of conglomerates on the images makes it impossible to get accurate results, since not following the separation of objects of interest is included in the conglomerate, it is impossible to make a classification of certain formal characteristics. This in turn will affect the results. Minimal impact from such events will be in cases when objects share not taken into account in the samples is small. Usually the situation is such that not taken into account objects have a significant impact on all results. Moreover, the danger of conglomerate wrong interpretation always exists, because of possible visual similarity of conglomerate and the object of attention. This would mean that the automated system will conglomerate of some object that can also distort the results of the study.

This method is used to minimize the number of objects in the field of attention, which are included in the composition of conglomerates and can be incorrectly interpreted in this case.

Problem Statement. Aim of research

The following aims of the research have been identified:

1) To develop a method of searching for images conglomerates.

2) To develop a method that will most completely and accurately select the objects of interest, as part of the conglomerate.

3) To confirm the efficiency of the technique with tests.

Solutions of the above mentioned problems allow to computerize the system of image classification and are intended for specific types of samples, improving their reliability and accuracy with minimal cost to their modification. This approach will increase the degree of automation of processing samples in all areas of microbiological research. Therefore, feasibility and scientific importance of this research cannot be overstated.

Partitioning problem into subtasks

Considering all the features of images conglomerates research should include the following related subtasks:

- To develop a method of separating components of conglomerate formations up into objects.
- To develop a method for splitting control process.
- To define criteria for splitting.

Priority of subtasks results from their mutual bindings. The first step is to develop a method for separation of conglomerates. Having such a method elaborated, one can proceed to the development of process monitoring and automatic control. This will remove person from this process, and this is the primary motivation for this work.

Solving problems. Problem conglomerates

Fig.1. demonstrates a few examples of images that contain conglomerate formation. They can be carefully analyzed to note the fact that conglomerates are very different in structure, number of objects that form them, and so on. The simplest case is a conglomerate formed by a combination of two objects (cells) which are laying low. This conglomerate can be divided with almost no loss of information about objects that were included. This can be achieved by increasing the stiffness parameters of filtration, using a simple analysis of the shapes of objects. However, there are conglomerates, which are made up of three or more objects of significant mergers and laying them. In such cases the restoration of conglomerate becomes very challenging task. Its solution requires a better and more universal approach.

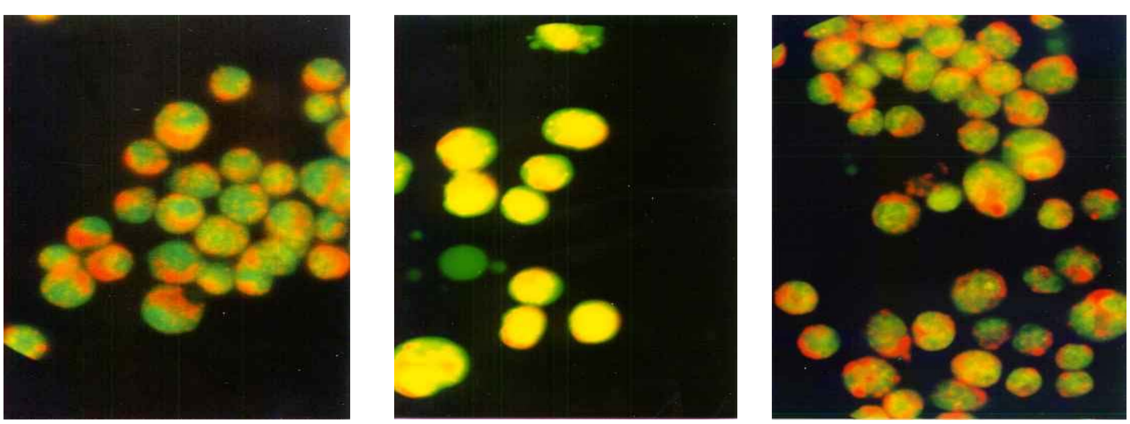


Fig. 1. Aggregation of blood cells: monocytes, lymphocytes and neyrofils

Decomposition of objects method

Note that each object (part of the conglomerate) is unique (shape, size, color, and their ratio, even density and brightness). The one that is common is a convex shape of the object. If [8] show us objects are detected by spectral analysis, we can't use this method for the conglomerate, since, as an object can be taken conglomerate.

Fig. 2 is an example of merging two objects in common conglomerate. Picture is schematic. Circles mark pixels that form the image of the object of analysis.

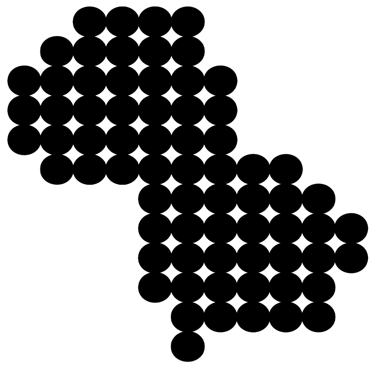
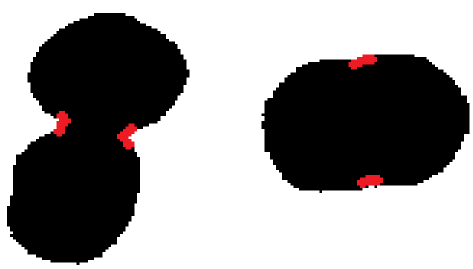


Fig. 2 Pixel based representation of conglomerate

The main characteristic of conglomerate is a sharp change of direction to follow the contour of the object (See Fig. 3 a). The exceptions are the merger objects at which levied a large part of their area. This merger is shown in Fig. 3 b. Such sharp changes in the contour course are thinner section of the local conglomerate. This phenomenon is the basis for separation of layers method.



a) b)

Fig.3 a) outline course changing at the confluence of two objects
b) No significant difference of contour course when overlap of the objects is considerable.

As thinner is present at the confluence place of the objects, then we remove layers (step by step) from the object contour, sooner or later we will get a break of the conglomerate confluence. Two parts of conglomerate which contains only pixels that belong to each object - it is split algorithm result. Two tasks are especially important for this algorithm:

- Cutting layers of the object in order to separate it into components.
- Restoring layers separately for each component of conglomerate.

Removing layers of conglomerate is actually repeating the removal operation applied to conglomerate. Contour is a set of pixels that belongs to object and touch the background pixels.

Fig. 4 b) represents conglomerate pixels, which belong to first cutting layer. Fig. 4 b) presents second cutting pixel layer. As this figure demonstrates in consequence two cut, we received two groups of pixels (A and B), which are independent pieces of objects that form this conglomerate.

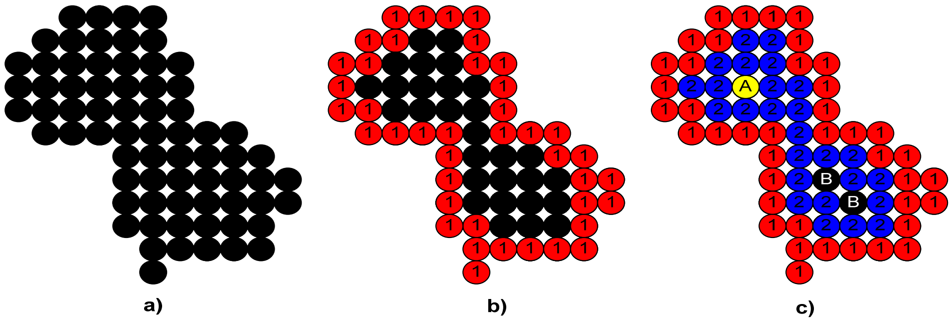


Fig.4. separation procedure.

a) input cell image; b) cut of first layer; c) cut of second layer.

The next step is to recover deleted layers. Important at this stage is to prevent the re-merging of objects. The solution of this problem is method of inverse increase of layers. Restoration of layers is performed in the order opposite to cutting process. Fig. 5 shows the input data set for the process of increasing. These are independent parts of objects (A and B) and truncated indexed pixel layers (that was cut).

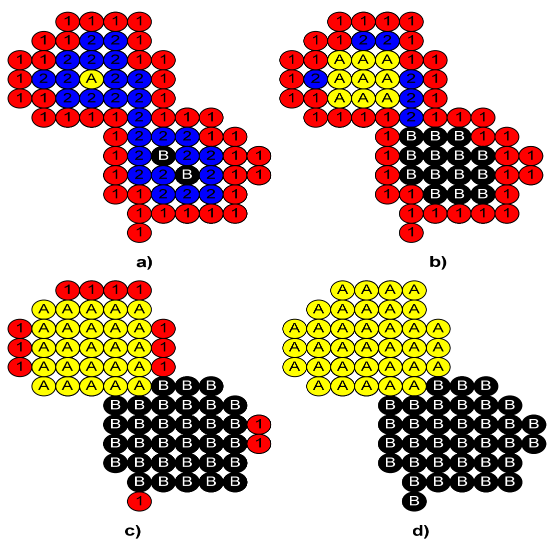


Fig. 5. Recovery of each cell. a) input image (object A and B); b) recovery of first layer; c) recovery of second layer; d) recovery of third layer.

Method of Identification of conglomerates in the image

Before the objects classification operations were defined, we introduced three major classes of objects: conglomerates, not conglomerates, objects with noise. In order to solve these following two approaches can be used.

First approach: further filtering of input images – use a series of filters and their combinations: contrasting, spectral analysis, morphological analysis and others. If an object splits into several separate units, one can assume that it is the conglomerate. The disadvantage of this approach is that the use of filters will work only on certain types of images. We have this situation because in most of cases of the structure of conglomerate is so difficult that the color characteristics within the merger did not differ from the characteristics of separate objects. So, in most of cases, when we change the settings of filter incoming information, their options will vary too.

The second approach is the analysis of geometric characteristics of objects. This algorithm is enough to conduct preliminary processing of information – to bring the image to binary form: background images contain one value "0", and other images of cells value "1".

Another possible solution is to use the method of circuit analysis. It is designed to determine whether the object is a conglomerate. The method is based on analysis of object shape. We can represent cell form as an incorrect ellipse (lack of symmetry relative radius), hence, this characteristic can be a basis for identifying the object as a conglomerate (and/or not cell). The contour of each object that is not a conglomerate satisfies the following rule:

Direction of the initial movement of analysis algorithm is the "north-east and clockwise"; the next steps will include: south-east, south-west, NW, and can't be modified and the availability of this sequence repeats in this scheme. Fig. 6 shows the changes of contour pattern direction.

If direction of outline turning does not meet this scheme, the object can be identified as a conglomerate, and program must divide an object before further analysis.

Fig. 7. represents the structure where this rule does not hold due to the fact that change in the direction "south-east" comes "north-east, this case is not typical for one object. Thus, this structure can be attributed to class of conglomerates or to class of objects which are affected by noise. To search for such changes we use the method of bypass contour.

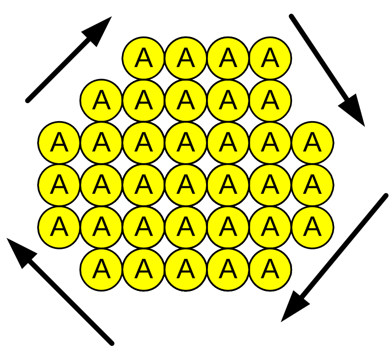


Fig. 6. Changing direction of contour characteristic for one object

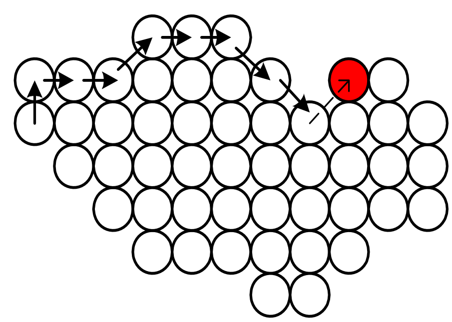


Fig. 7. Object with "broken-down" contour

Bypass object contour algorithm

To find local changes of contour directly algorithm must bypass all points that touch the background and belong to the object. Let the image is brought to binary form and recorded in the *vec array size m, n*, where values of 1 correspond to points belonging to object, and 0 belonging to the background. Then for the true contour points following condition:

$$\text{If } vec[x,y]=1 \quad \text{and}$$
$$vec[x,y-1]=0 \vee vec[x-1,y]=0 \vee vec[x+1,y]=0 \vee vec[x,y+1]=0 \Rightarrow (x,y) \in K(A) \quad (1)$$

where: $x=\overline{0,n}$; $y=\overline{0,m}$ $K(A)$ – circuit of object A.,

where: A – array of points that form the object of our image.

Simple scan the entire image to search for all points that satisfy condition (1) prevents the collection of data on the changing direction of the contour. The only approach to obtain such data is the method of bypassing contour based on the principle of the neighborhood.

The first step of this method is to capture of two contour points of an object that are "neighbors", that touch each another. You can apply a simple scan of matrix *vec* method for finding neighboring points of contour. Algorithm of finding neighboring points based on analysis of eight surrounding points principle. The next step is to establish the direction of contour movement. This parameter is determined from the ratio of coordinates of initial points.

Let Point1, Point2 – it is initial point; x1, y1, x2, y2 – it is according to the coordinates, and then the direction is calculated according to Table1.

After setting the initial direction, algorithm makes further movement on the contour of the object. All further iterating the order of important points for installing an accessory to the contour. The calculated direction is determined by one of the possible cases shown in Fig. 8. Numbered contour indicates the pixels that you want to check belonging to the object in order numbering. Contour analysis process stops, then when the current coordinates with start of which began bypassing. Changing directions, determined from Table 1 are the contour of the object characteristic, which can identify the object as a conglomerate, or nominate the statement that this circuit was subjected to noise.

Table 1

x2 - x1	y2 – y1	Direction
1	1	1
0	1	2
-1	1	3
1	0	4
-1	0	5
1	-1	6
0	-1	7
-1	-1	8

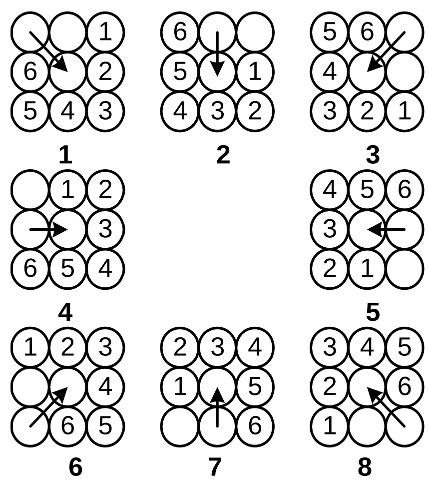


Fig. 8. Rules for establishing order of analysis of pixels for belonging to the object contour

Algorithm for automatic separation of conglomerates

The structure of this algorithm contains the following three main blocks:

1st Block - preparatory stage is to bring the image to a standard view.

Step One - finding objects and background. The main objective of this stage is to find a background pixels. You can apply algorithms that can be based on finding the background color brightness limits, methods of contour bypass and clustering

Step Two – converting image to binary form

Fig. 9 shows image which is converted to binary form

2nd Block - Phase decomposition

1. Step one – At this step, the main task is to select the objects for further analysis. You can use a method to unify all the neighboring points, which is based also on the analysis of 3x3 matrix.
2. Step Two - analysis facility for the presence of local changes in the direction of the move path. If the presence of such changes on this object is copied to the clipboard for further decomposition.
3. Step three - find the next object on the input image. In case of success finding the transition to phase 1.
4. Step Four - check presence in the buffer objects that require decomposition. In the absence of such facilities move to step 6.
5. Step Five - decomposition of objects and their indexation. Changing the input image for buffer of layers that are cut. Go to step 1.
6. 6th step - completion of decomposition

Fig. 10 presents a binary image that had processed of bringing all objects to one standard: the lack of progress towards local contour changes.

3rd Block - composition process and selection of objects contours

- step one – Recovery objects
- step two – mark contour of objects

Fig. 11. represents binary image after the process of separating conglomerates

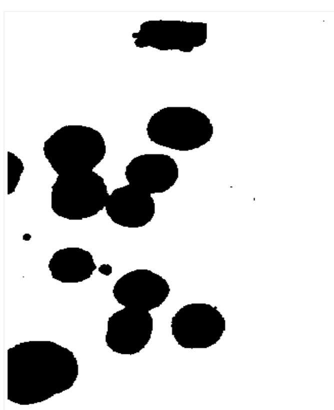


Fig. 9. Image of blood cells that are converted to binary form

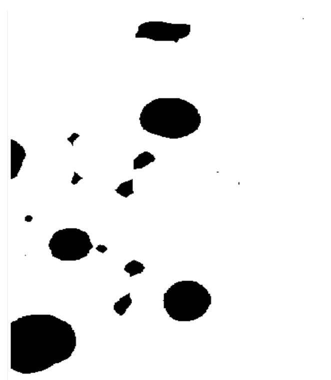


Fig. 10. Objects after decomposition process

Fig. 11. Image of objects that had passed all stages of processing

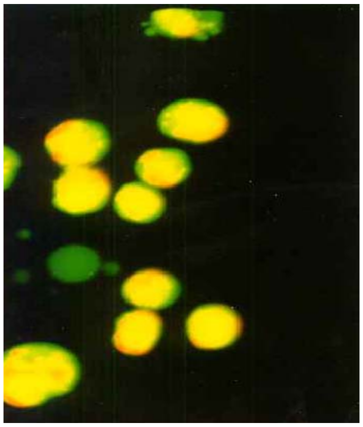
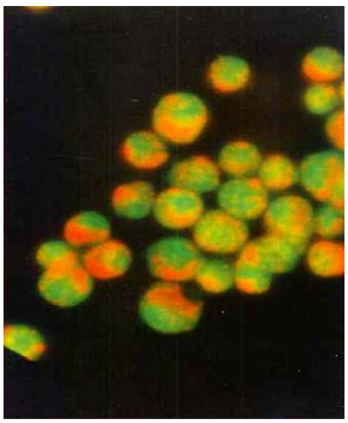
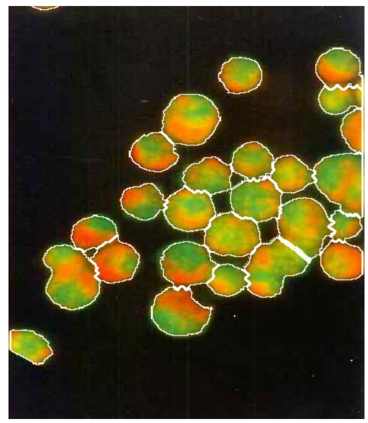
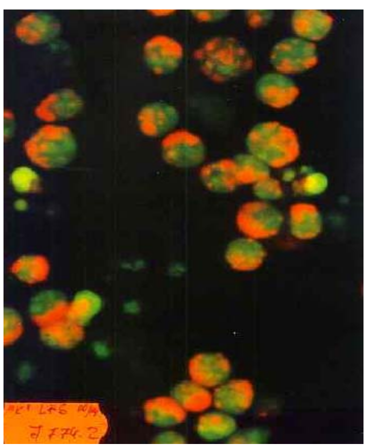
Test results

Table 2 shows the results of the separation of conglomerates in the complex background

Conclusion

Algorithm and data processing method of complex images and their recognition is effective for use. Considered test images in the real tasks. The developed method can be effectively applied to the most varied domains of knowledge in computer vision systems.

Table. 2. The results of the separation of conglomerates in the complex background

Input image	Output image
	
	
	

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FAILURE PREDICTION IN COMPLEX COMPUTER SYSTEMS

Paweł Janczarek

***Abstract**: Failure prediction has its origins at the turn of the 15th and 16th centuries. Trade companies tried to calculate what was the risk with shipping goods over the sea. Modern failure predictions start in 70's of 20th century. Naturally software prediction has its origins in failure prediction of electronic equipments. Nomenclature and definitions are very often similar to those used in electronics. Since 70's scientists have been trying to find perfect model to simulate failures in software.*

***Keywords**: system availability , failure, prediction, reliability, risk management*

***ACM Classification Keywords**: G. Mathematics of Computing, G.3 PROBABILITY AND STATISTICS, G.3 PROBABILITY AND STATISTICS, Reliability and life testing*

Introduction

Failure prediction has its origins at the turn of the 15th and 16th centuries. Trade companies tried to calculate the risk related to shipping the goods over the sea. Modern failure predictions started in 70's of 20th century. Naturally software prediction has its origins in failure prediction of electronic equipment. Nomenclature and definitions are very often similar as those used in electronics. Since 70's scientists have been trying to find perfect model to simulate failures in software.

Failure prediction in software

At first we need to answer the following questions: *What is a failure in complex information system? Is this complete system shutdown? Is this delay in response for user?* Every system is very unique so for everyone of them failure has to be defined in slightly different manner.

Second very important issue is how we define the measure of time, or more precisely what type of clock we use to measure time between the failures. Is this human-clock time (days, hours, seconds, etc.) or we use hardware-clock time (CPU, logical executions, etc). Right time measure is crucial for software failure prediction. Natural measure for people is normal human-clock, but in context of software it is very often misleading. Systems often have their own life-cycle (batch processing, night recalculations, backups, etc.) not very correlated with human-clock way of perceiving the time aspect.

We also need to know what are the origins of our failures. Are they human errors, bugs in software, hardware malfunctions or else. According to Gartner analysis 80 % of errors are those in direct cause of human mistake. In our future analysis it is good to think if we would like to divide them separately.

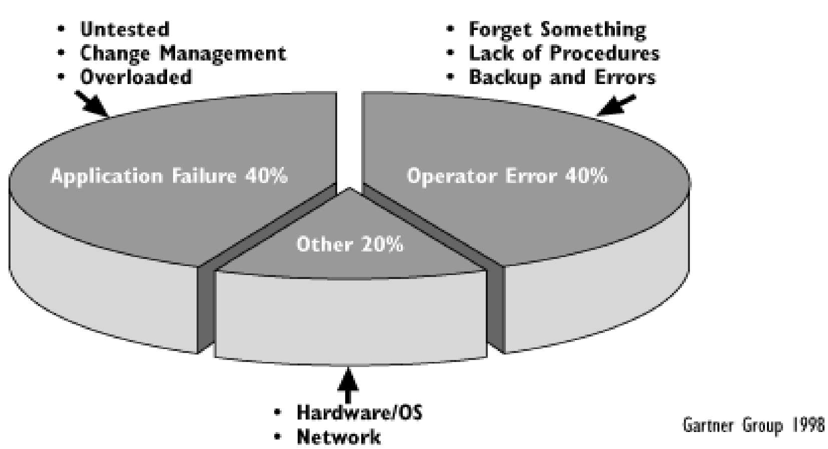

Figure 1. Origins of software errors

Basic theoretical background in failure prediction

Theory used for software failure predictions has its origins in hardware failure prediction. That's way names and formulas are very similar to those used for hardware (or sometimes even form theirs predecessor - risk calculation for shipping goods over the sea from the turn of the 15th and 16th centuries).

We can compute probability of a failure in very simple way as [Summerville]:

$$P(T \le t_0) = \int_0^{t_0} f_T(t)dt \tag{1}$$

where $f_T(t)$ – is the density function which describes distribution of failures in time. We can also calculate probability of failure in case there hasn't been any error for some time (Z(t) Δt). To do this we need to use conditional probability [Summerville]:

$$Z(t)\Delta t = P(t < T < t + \Delta t | T > t) \tag{2}$$

where T is time of failure, and Δt is time period in which failure will occur.

As we see to do all those calculations we need to have density function which describes distribution of failures in time. Without this density function identified we are unable to do any predictions of failures. Using empirical distribution functions based on history of previous failures we are able to fairly approximate distribution of failures for software. Simple example is presented in the next section.

At this moment we can calculate reliability of our system, which is telling us that it won't break down before t_0 point in time, with the following formula [Summerville]:

$$R_T(t_0) = P(T \ge t_0) = 1 - F_T(t_0) = 1 - \int_0^{t_0} f_T(t)dt = \int_{t_0}^{\infty} f_T(t)dt \tag{3}$$

The least value, the better reliability is between two systems. As one can see, the most important is the density function $f_T(t)$. Without it we can't do any predictions.

In practical cases, very often we can assume that Δt is very short so we can pass it over. Then we can simplify our conditional probability of failure to following equation [Summerville] (aka failure rate):

$$Z(t) = \frac{f_T(t)}{R_T(t)} \tag{4}$$

In almost all bibliography and electronics we can very often run across with term of MTTF (Mean Time To Failure). Using our previous calculation, we can now calculate MTTF, as:

$$MTTF = \frac{1}{Z(t)} \tag{5}$$

Failure prediction in software - example

In previous paragraph we discussed, theoretical mathematical concepts of failure predictions. The key figure in this equations is density function which describes distribution of failures in time. Earlier in previous paragraph, I also mentioned empirical distribution functions. In this paragraph, I will try to show how to calculate density function using empirical distribution function on real example from complex software system failures dataset.

Let's assume (and that is real example) that we have failures related data from complex software system (presented in the table below).

Table 1. Failures in system

Number of failures	1	2	3	4	5	6	7	8	9	10	11	12	13	15	16	17	18	19	20	22
Time of failure	1	4	49	50	52	56	69	71	73	89	96	99	119	120	126	127	128	129	135	154

Number of failures	23	24	25	27	29	31	34	35	36	37	38	40	41	42	43	46	47	49	50	52
Time of failure	170	172	174	175	176	183	185	186	188	196	197	217	219	220	222	232	233	234	237	238

Number of failures	53	55	57	58	59	60	62	63	64	65	66	67	68	70	72	73	75	77	78	79
Time of failure	241	246	248	249	251	266	268	269	271	273	280	294	295	296	300	301	302	303	305	306

Number of failures	80	82	84	86	87	88	89	91	93	94	98	99	100	101	102	103	104	105	106	110
Time of failure	323	329	330	331	332	333	334	335	345	346	347	348	349	350	351	352	371	372	374	375

Number of failures	111	112	113	114	115	116	117	118	119	120	123	125	126	130	133	136	137	138
Time of failure	377	378	381	382	384	396	399	400	401	402	403	404	405	406	407	408	410	411

As can be seen, in system there had been observed 138 failures and the last was in 411 time interval. Data are form real system used by over 30 thousands of users every day, from January of 2005 to half of March of 2006. Therefore, data are from pretty modest system. Very often, we have that kind of data from our software systems.

At first we present some diagrams that show data from the table 1. First let's see how number of failures has increased in time.

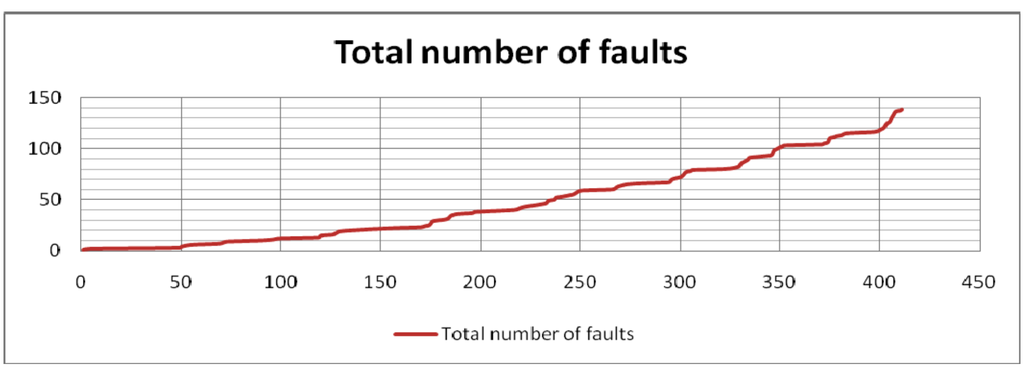

Figure 2. Total number of failures in time

Before we start computing distribution function, we can also look at faults intervals presented on figure 2.

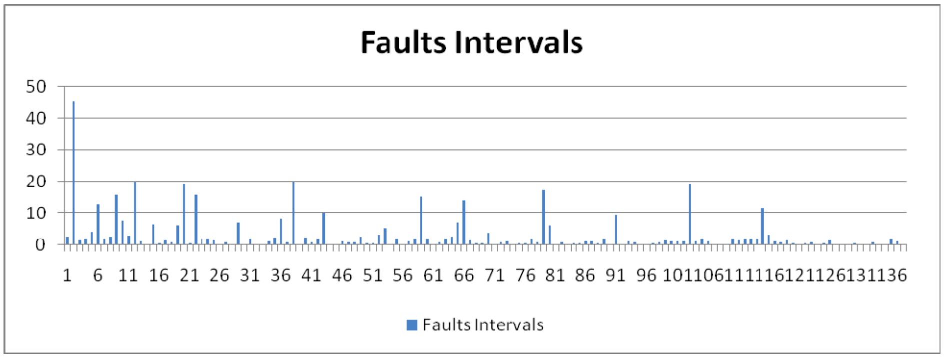

Figure 3. Faults intervals

At this moment we can start to do some calculations. Using data only from table 1, we can do some calculations which will describe quantitatively our examined software system. Calculated values are presented below.

- MTTF (average interval length)= 3 time intervals
- Median = 1
- Variance = 33,9
- Standard deviation = 5,8

As we see, on average we will have one fault every 3 days (we need to assume also, that time taking of failure is forgetful factor), but the variance of intervals is very big, so some of faults occurrences are dense and other time they are rare.

At this point, we can start with generating our density function using empirical distribution. First we need to group our fault interval into groups.

Table 2. Number of failures grouped by intervals

Interval	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**12**	**13**	**14**	**15**	**16**	**17**	**19**	**20**	**45**
Number of faults	39	48	20	7	2	1	3	3	1	1	1	1	1	1	1	2	1	2	2	1

If we will have more groups, then we would have more accurate approximation, but in our case 6 groups will be sufficient. Now we will group faults intervals into this 6 classes:

- $[0;1)$
- $[1;2)$
- $[2;3)$
- $[3;6)$
- $[6;10)$
- $[10;\infty)$

Table 3. Calculation of empirical distribution

Time interval	Number of faults	Percent of total %	Empirical distribution value
[0-1)	39	28,26%	0,28
[1-2)	48	34,78%	0,63

[2-3)	20	14,49%	0,78
[3-6)	10	7,25%	0,85
[6-10)	8	5,80%	0,91
[10-∞)	13	9,42%	1,00

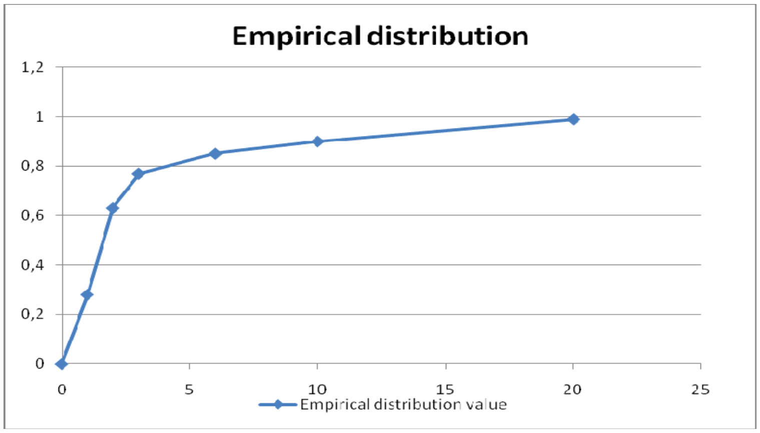

Figure 4. Empirical distribution value

Now when we have approximation of density function, we can easily go back to previous chapter and calculate probability of failures in the future. While calculating probability we need to read our values form above chart.

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THE AUTOMATION OF PARAMETER PPQ IDENTIFICATION PROCESS FOR PROFILES WITH FUNCTIONAL PROPERTIES

Wiesław Graboń

Abstract: *Methods and standards to determine Ppq parameter for profiles with periodical-random character, which are of functional importance, have not been developed yet. This article proposes a method to solve this problem. Furthermore, an equation describing this kind of profiles, and method of constructing software which uses this equation for calculating roughness parameter were described.*

Keywords: *algorithms, multi-process surfaces, roughness parameters.*

ACM Classification Keywords: *Algorithms, Measurement.*

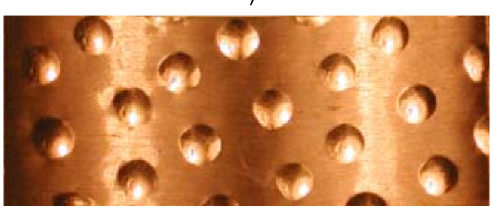
Introduction

In modern manufacturing techniques the basic goal is to obtain good quality connected with specific quality of surface layer processing machining articles. Strong connections exist between the state of surface layer and the ability of this surface layer to perform different performance requirements by machine parts.

The external surface is an integral part of surface layer. The geometrical structure of the surface has fundamental influence on operating properties such as: tribology wear resistance, stiffness of butt join, fatigue strength, thermal conductivity, flow resistance, coating density and others.

The importance of multi-process surfaces has recently increased, because every "element" of these surfaces influences particular functional and working properties of machine parts. Multi process surface textures are considered surfaces having stratified functional properties. Among these surfaces, surfaces which have periodical-random and random-periodical structures are vital. Bottom layers of these surfaces include oil pockets created in different ways for example: electrochemical etching, laser method or burnishing (fig. 1). Usually these oil pockets have periodical character.

a)



b)

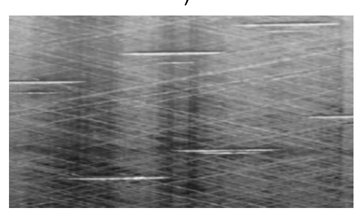


Figure 1. Examples of: a) surface bearing liner which includes oil pockets,
b) cylinder liner surface with burnished oil pockets.

For better density of date accumulation on magnetic discs, the slider should move nearby rotating disc in gaseous lubricants condition. In order to reduce the static friction and increase the life of the disc, valleys on the surface of the disc are created near fare internal edge of the disc [Talke, 1995]. Theoretical research in this area was conducted by the authors of publication [Tagawa, Hayashi, Mori, 2001]. The analysed surfaces were covered with rectangular prisms, the distance between which was 60 μm in circumferential and 40 μm in axial direction. Horizontal dimension of rectangular prisms, and the distance between them have influence on the position of the slider during its movement in relation to the disc which rotates around its axis (it should be the lowest possible position). It was found that structure showed in fig. 2. in B configuration is optimal.

Usually laser technique is used to create valley texture on the surfaces of discs. Valleys created by means of this technique have toroidal or sombrero shape. They usually have inside diameter of 10 - 15 μm and height of 15 - 25 nm. The authors of research [Cha, Lee, Han, Lee, 1999] found that creating valley on a hard disc surface cause smaller static friction force in comparison with a disc without valleys which had undergone mechanical working in start and stop zone. Another possibility is to create valleys on the surface of a slider which interacts with a smooth disc. The author of paper [Suh, Lee, Polycarpou, 2004] stated that this solution reduced the inclination to adhesion, and friction force compared with smooth surfaces.

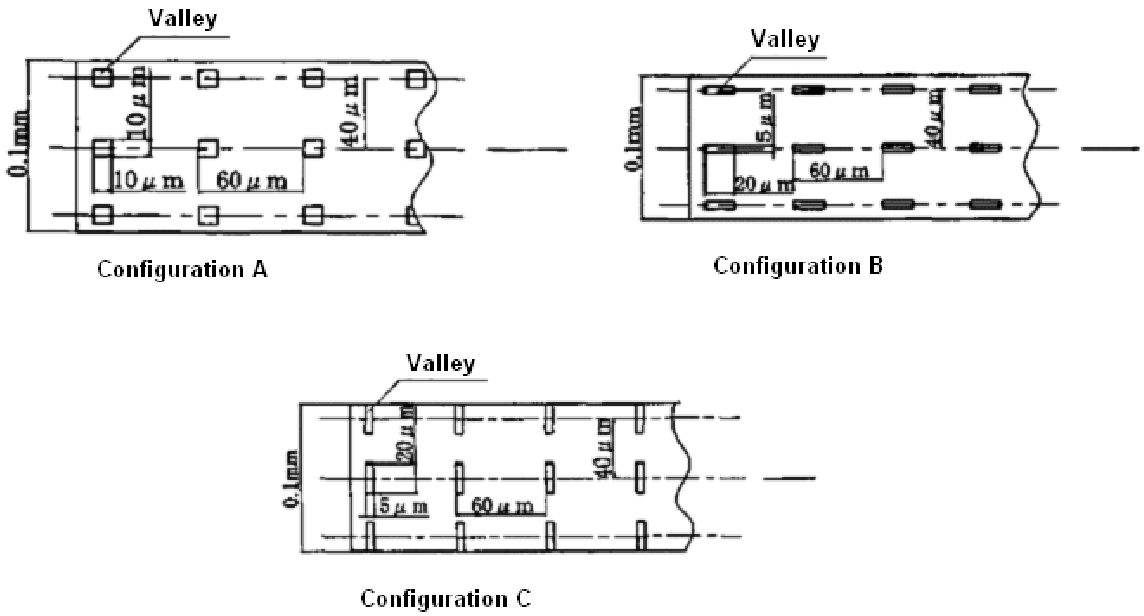
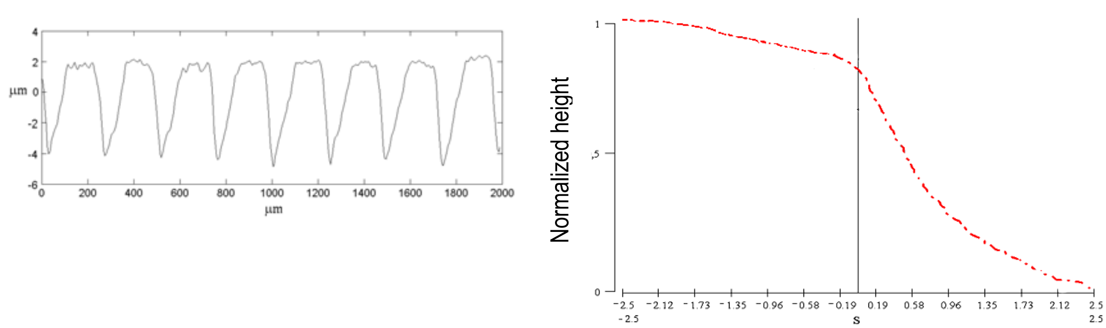


Figure 2. Configurations of surfaces analyzed in the article [Tagawa, Hayashi, Mori, 2001]

This kind of surfaces topography is usually described by giving depth, width and length of valleys, and degree of coverage with valleys. Values of parameters Ra and Rq are also given for better description of these surfaces.

Other examples of surfaces which have periodical-random character are surfaces of piston skirt before exploitation. Top part of this surface has random character while valleys have periodical character after being turned (fig. 3). Surfaces topography of piston skirt during zero wear can be described with parameters: Sq, SΔq and Sp/St. Additionally, Str, Std, Sds (or SΔq/Sq) and St are proposed. The description of axial profiles of piston skirt before working includes the following parameters: Pq, Psk (Pp/Pt), Pku i PΔq [Krzyżak, 2005]. Methods and standards to determine Ppq i Pmq parameters profiles with periodical-random character which are functionally vital haven't been developed yet. This article proposed a method to solve this problem.



a) b)

Figure 3. Axial piston skirt profile with abrasive wear of little degree, and with original shape of triangular (a), and its probability plot of cumulative distribution with normalized height (b) [Krzyżak, 2005].

Model analysis

The process of formation of periodical-random profile (for example during wear) is shown in fig. 4. Amplitude distribution of roughness profiles of surfaces which have stratified functional properties and include traces of two processes, does not have normal distribution. Nevertheless, we can make an assumption that in this case, for this type of surfaces, the surface with normal distribution and surface with rectangular distribution overlap. Therefore, the first step to describe independently these two overlapping surfaces is modeling every component as a different distribution.

The profile presented in fig. 4 a1, shows the geometrical structure of a surface before initial machining process. The probability plot of cumulative distribution of this profile is shown in a3, and fig. a2 shows the amplitude distribution for this profile. Profiles which are illustrated in fig. 4b1 and c1 present the model of periodical surface after different periods of being used. Figs b3 and c3 show probability plot of cumulative distribution of these profiles and fig b2 and c2 show amplitude distribution for these profiles.

In laboratory conditions only the final profile is measured (profiles on fig. 4 b1 and c1). On this profile there are only the deepest valleys of the initial rough surface (triangular profile) which are represented by red line in the bottom part of the chart with amplitude distribution (fig. b2 and c2) – it results from ordinate distribution of triangular profile.

The upper part of the initial roughness profile is deleted and replaced with a less rough structure of the surface (so called plateau) with random character of density distribution axis. It is illustrated in the blue part of the amplitude distribution chart (fig. 4. b2 and c2).

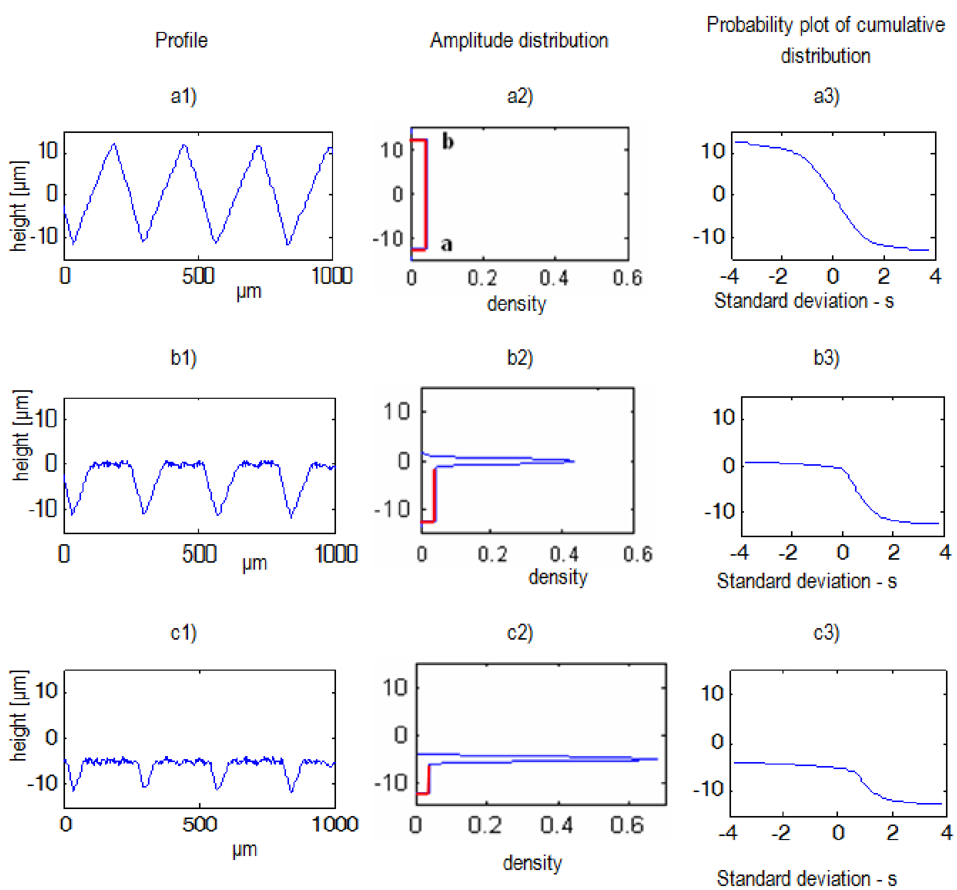


Figure 4 Profile which has a periodical character (a1), its amplitude distribution (a2) (in portions between a and b), probability plot of cumulative distribution (a3), profiles with periodical-random character (b1, c1), and their amplitude distribution (b2, c2) and probability plots of cumulative distribution (b3, c3).

Based on the research the authors of publication [Oczoś, Liubimov, 2003], who assumed rectangular distribution of axes for triangular profile (which can be concluded from amplitude distribution shown in fig. 4 a2), the methodology of assigning parameter Ppq based on amplitude distribution may be proposed. In this methodology amplitude density distribution of periodical-random profile should be approximated by the following function:

$$f(z)=f_1(z)\cdot\left(1-\int_{-\infty}^{z}f_2(\xi)d\xi\right)+f_2(z)\cdot\left(1-\int_{-\infty}^{z}f_1(\xi)d\xi\right)$$

$$f_1(z)=\begin{cases}\dfrac{1}{b-a} & \text{when} \quad a<z<b\\ 0 & \text{when} \quad z\le a \text{ or } z\ge b\end{cases} \qquad f_2(z)=\frac{1}{\sigma\sqrt{2\pi}}e^{-0.5\left(\frac{z-\mu}{\sigma}\right)^2} \quad \text{when} \quad z\in(-\infty,\infty) \qquad (1)$$

where:

z- height of roughness profile,

μ and σ – mean height and standard deviation of axis secondary profile with random character,

a, b – rectangular distribution beginning and end.

Calculated value of standard deviation (σ) constitutes value Ppq parameter.

Implementation

To automate the determination process of parameter Ppq in plateau area, a computer program was created. In this program preliminary estimation of density distribution axis of profile was done with the use of Parzen window method. In the next step density distribution obtained as a consequence of using Parzen window method was approximated with the use of function (1) in the nonlinear regression method.

The value of standard deviation, mean of normal distribution, and rectangular distribution beginning and end were obtained. According to the principles of the model, the value of standard deviation becomes the value of Ppq parameter. Figure 5 shows examples of the results of calculating the parameters.

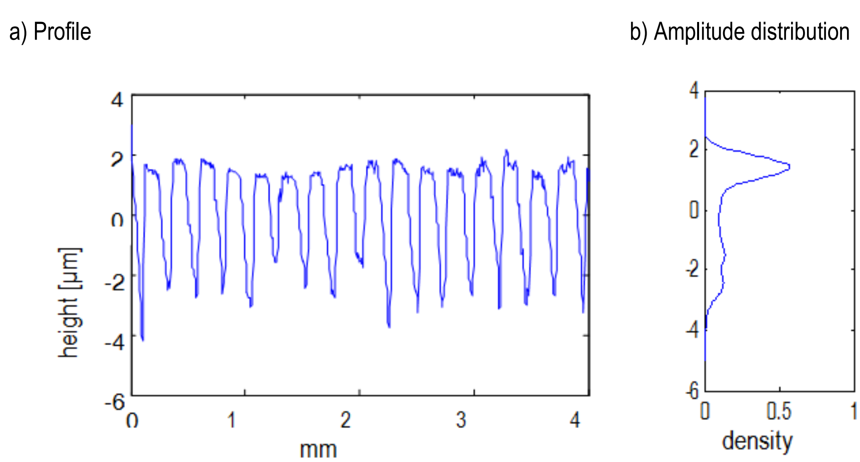


Figure 5. Profile of piston skirt surface before wearing (a), and amplitude distribution received after working program (b) for which value of parameter Ppq equals 0.35 µm.

Conclusion

During friction in the presence of lubrication, excessively smooth surfaces badly hold lubricant (which can cause seizing up interacting parts of a machine). On the other hand, too rough surfaces wear too quickly. One way of improving tribological properties of machine parts is creating oil pockets on interacting surfaces.

Oil pockets may increase aerodynamic lift with the use of cavitation mechanism or they can create tanks with leaking oil, which can decrease the contact of interacting surfaces (lower speed) [Nilsson, Rosen, Thomas, Wiklund, Xiao, 2004]. In both of these cases friction force is minimized. Oil pockets may also serve as traps for abrasive solids. One example of this kind of surfaces are periodical-random surfaces.

For better understanding of functional properties for this kind of surfaces, and for connecting these properties with functional quality, a precise description should be realized. Such description with the use of only one parameter is very difficult, because this kind of surfaces have independent components of their structure which should be characterized separately and very precisely. Independent description of particular components of these surface profiles enables us to better understand their working, but methods and standards to describe the plateau part of these profiles characterized by Ppq parameter have not been developed yet. Therefore, methodology for calculating Ppq parameter for this kind of profiles was proposed. Automatic determination of this parameter improves the process of controlling this sort of surfaces. The proposed software meets the above mentioned expectations.

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SIMULATION OF THE EFFECT OF STYLUS TIP RADIUS ON THE RESULTS OF SURFACE TOPOGRAPHY MEASUREMENT

Sławomir Górka, Paweł Pawlus

Abstract: *This paper presents the results of application of numerical methods for surface topography analysis. Surface profiles after one and two-processes were computer generated. The effect of various tip radii on distortion of surface topography measurement results was analysed.*

Keywords: *surface topography; roughness; stylus measurement; tip radius*

ACM Classification Keywords: J.2 *Physical Sciences And Engineering;* ***G.1.2*** *Approximation;* ***G.1.3*** *Numerical Linear Algebra;*

Introduction

Despite a great development of optical and other techniques a stylus profilometer is still the most common roughness measuring device in mechanical industry. The principle of a contact measurement and methods of its making was not changed for years. However development of the microelectronics and the computer technique create occasion to increase the range and the resolution of devices and to introduce facilities for operators to reduce their chances to make mistakes. It seems that it will be the trend in development of a stylus surface measurement in the next years [Mathia, (in press)].

The probe tip is characterized by its radius and flank angle. The sizes of stylus tip decide about instrument transmission characteristics. Te behaviour of tip depends of not penetrating narrow valleys or irregularities of smaller sizes than tip size. Poon and Bhushan [Poon, 1995] found that spherical tip caused profile distortion by increase of correlation length (the distance, in which autocorrelation function slowly decayed to a defined value – usually 0.1) or other similar spacing parameters and decrease of standard deviation of Gaussian profile height. Whitehouse [Whitehouse, 1974] found that after application of 10 micrometers tip radius the surface height of elements after typical machining processes decrease up to 15%. Usually the tip of smaller radius should be used to measurement of very smooth surfaces, which is connected with the fact that the main wavelengths of them is usually very small.

Some authors [Whitehouse, 1974; Chetwynd, 1979; Mendeleyev, 1997; Wu, 1999; O'Donell, 1993] tried to simulate the co-action between tip and the surface. But these effects were mainly concentrated on random surfaces after one processes. However the role of two-process surfaces still increases. The surface topography of two-process surfaces is functionally important in tribology, but it is notoriously difficult to characterize. Plateau honed cylinder surface is the typical example of two-process surfaces. It consists of smooth wear-resistant and load-bearing plateaux with intersecting deep valleys working as oil reservoirs and debris trap. Cylinder surface topography affects running-in duration, oil consumption, exhaust gases emission and engine performance. Manufacturing cylinder liner is difficult because the demands on good sealing and on optimal lubrication are antagonistic.

The measurements based on a stylus profilometers in 3D surface topography of the surface are time consuming, what is significant limitation of them. A possibility of overcoming this inconvenience is a spiral sampling [Wieczorowski, 2001]. Irrespective of the contact devices the constructions based on the optical phenomena are being developed [Mathia, (in press)].

Methods of profiles modeling and simulation of stylus tip effect on measurement results

Method of profile modeling

Cylinder profiles of Gaussian ordinate distribution were computer generated using procedure proposed by Wu [Wu, 2000]. The other similar procedures [Hu, 1992; Newland, 1984] were also taken into consideration but Wu method was found to be the best. Gaussian profiles of exponential shape of autocorrelation function were simulated. There were the following input values: correlation length CL and standard deviation of profile height Pq.

The parameters describing surface after 2 processes can be calculated from the probability plot of material ratio curve, according to ISO 13565-3 standard. The slope of each presented straight lines gives the Pq roughness of the corresponding process. Also the transition characteristic, called plateau depth Pd from one to another process can be estimated. In standard ISO 13565-3 the Pd parameter is not calculated. Instead of it Pmq is computed. But there is a connection between Ppq, Pvq, Pmq and Pd:

$$Pd = Pmq\,(Ppq-Pvq) \quad (1)$$

The following procedure should be done in order to simulate two-process profile [Pawlus, 2008; Pawlus, 2006]:

1. Creation two Gaussian profiles PP (plateau) and PV (valley) with correlation lengths and variances as parameters describing them.
2. The choice of the distance (Pd) between the mean lines of the profiles (the centre of the Gaussian distributions).
3. For all the points "i" of two distributions (profiles): If PP(i) > PV(i) then RP (i) (resulting profile after two processes) = PV(i), else RP (i) = PP(i).

Figure 1 presents example of modelling of 2-process profile [Pawlus, 2006].

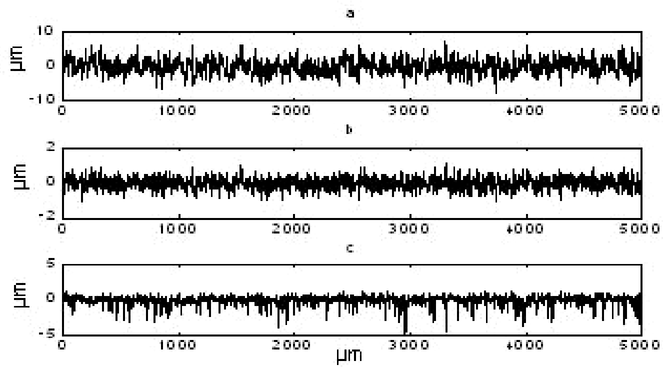

Figure 1. Computer generated profile after 2 processes: (a) valley profile, (b) plateau profile, (c) resulting profile

The special software in C language was generated to random profile after one and two-processes modeling. It was found that the Pq and CL parameters of Gaussian profiles were very cose to assumptions (input values).

Method stylus tip effect simulation on measurement results

The method presented in papers [Mendeleyev, 1997; Wu, 1999] was applied to simulate the effect of circular tip on measurement results. Figure 2 presents the idea of this method (after) [Wu, 1999].

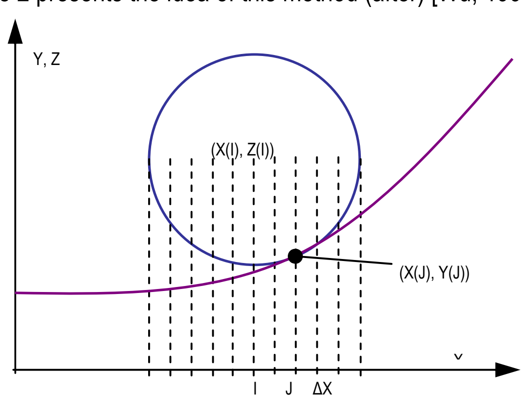

Figure 2. Method of rounded profile tip mechanical filtration simulation

It was assumed that probe tip radius was r and that plastic deformation don't occur.

Contact point has coordinates X(J) and Y(J), but middle point of tip: X(i) and Y(I). Index J of contact point is the result of discrete points searching in order to find maximum of function:

$$H(J) + Z(J) = Z(I) = \max_k (H(k) + Y(k)) \quad (2)$$

where:

$$H(k) = \sqrt{r^2 - (k - I)^2 (\Delta x)^2} \quad (3)$$

There is the following range of k index: from I – (r/Δx) to I + (r/Δx).

The problem of so-called edge effect on other profile details exists. It was solved by assumption that profile near finishing profile points is flat.

The special software in C language simulating the effect of radius of spherical tip on profile distortion was developed in C language. The results were very similar with those obtained using Villarubia's software [ftp.nist.gov/pub/spm_morph].

Results and discussion

Profiles of normal ordinate distribution

The analysis of 2D profile filtration is simplification. It can be used for highly anisotropic rough surfaces analysis. Rounded stylus tips had diameter of 2, 5 and 10 micrometers. Gaussian profiles were characterized by the Pq parameter in ranges: 0.2-10 µm, and correlation length CL in ranges 2-100 µm. Sampling interval was 1 µm. The changes of commonly used surface topography parameters [Pawlus, 2006]] caused by mechanical filtration by stylus tip were used. In addition, peak and valleys curvatures (pc and vc, respectively) and correlation lengths were also studied. Tables 1-2 show relative changes of absolute values of Pq, PSm (spatial parameter), PΔq (rms. slope), pc and vc parameters caused by stylus tip mechanical filtration of radii 5 and 10 micrometers. Only PSm values increased, other parameters decreased as the result of mechanical filtration by stylus tip. Changes of the parameters seem to be too high because some profiles look unrealistic (it is difficult to find profiles with correlation length of 20 and especially 2 micrometers, especially for high roughness height). Usually when height is higher, spacing parameters (like PSm) are larger. However the main intention of authors was only to find tendency of parameter changes. Please take into mind that the possibility of create surfaces with different profile shapes recently increased. Usually the parameters after mechanical filtration are compared with the result obtained with those of profile measured with the smallest tip radius (always 2 micrometers). In this case the parameters relative changes would be higher. Wu [Wu, 1999] proposed application of minimum sampling interval depending on parameters of measured surface and on radius tip. The correctness of Wu's calculation was confirmed by our investigations. When this sampling interval was used, changes of horizontal parameter were smaller (maximum relative changes of PSm was 10%). Changes of parameters connected with height and spacing (like slope and peak radius) were then similar to changes in the Pq parameter, not depending on sampling interval. Similar tendency of parameter changes were obtained after analysis of profiles measured with tip of 2 µm radius.

Table 1. Relative absolute changes of the Pq parameters as the result of mechanical filtration by stylus tips of radii 5 µm and 10 µm

CL, µm	r=5 µm Pq= 0.2 µm	r=5 µm Pq=1 µm	r=5 µm Pq=5 µm	r=10 µm Pq=0.2 µm	r=10 µm Pq=1 µm	r=10 µm Pq=5 µm
2	20.46%	31.07%	37.35%	25.67%	35.82%	42.56%
20	2.79%	6.69%	11.09%	4.43%	9.56%	16.33%
100	0.15%	1.06%	2.18%	0.53%	1.56%	3.37%

Table 2. Relative absolute changes of the PSm parameter as the result of mechanical filtration by stylus tips of radii 5 µm and 10 µm

CL, µm	r=5 µm Pq= 0.2 µm	r=5 µm Pq=1 µm	r=5 µm Pq=5 µm	r=10 µm Pq=0.2 µm	r=10 µm Pq=1 µm	r=10 µm Pq=5 µm
2	59.09%	184.14%	400.57%	102.16%	291.39%	663.80%
20	22.78%	101.65%	202.47%	53.67%	143.85%	322.41%
100	3.16%	52.33%	157.02%	23.01%	94.70%	229.21%

Table 3. Relative absolute changes of the PΔq parameter as the result of mechanical filtration by stylus tips of radii 5 µm and 10 µm

CL, µm	r=5 µm Pq= 0.2 µm	r=5 µm Pq=1 µm	r=5 µm Pq=5 µm	r=10 µm Pq=0.2 µm	r=10 µm Pq=1 µm	r=10 µm Pq=5 µm
2	40.24%	67.73%	79.01%	54.30%	78.02%	88.55%
20	18.64%	45.23%	60.63%	30.72%	57.88%	73.94%
100	2.95%	31.07%	52.31%	16.55%	43.01%	64.25%

Table 4. Relative absolute changes of the pc parameter as the result of mechanical filtration by stylus tips of radii 5 µm and 10 µm

CL, µm	r=5 µm Pq= 0.2 µm	r=5 µm Pq=1 µm	r=5 µm Pq=5 µm	r=10 µm Pq=0.2 µm	r=10 µm Pq=1 µm	r=10 µm Pq=5 µm
2	61.21%	91.10%	98.08%	79.19%	95.45%	98.95%
20	28.15%	80.37%	95.67%	56.29%	89.83%	97.70%
100	3.22%	60.84%	90.94%	25.32%	78.95%	95.31%

Table 5. Relative absolute changes of the vc parameter as the result of mechanical filtration by stylus tips of radii 5 µm and 10 µm

CL, µm	r=5 µm Pq= 0.2 µm	r=5 µm Pq=1 µm	r=5 µm Pq=5 µm	r=10 µm Pq=0.2 µm	r=10 µm Pq=1 µm	r=10 µm Pq=5 µm
2	164.17%	76.12%	84.04%	146.87%	84.00%	91.71%
20	28.72%	82.33%	70.38%	45.04%	86.51%	81.24%
100	4.49%	46.42%	67.50%	25.92%	57.93%	76.33%

Mechanical filtration by stylus tip causes decrease in amplitude parameters. Changes of maximum parameters are a little bigger than those of average parameters like Pa and Pq. Profile slope also decreases, its changes is bigger than of height parameters. Horizontal parameters, like PSm and correlation length increase. Changes are greater for initial smaller parameter values. Standard deviation of peak height decreases, peak density and curvature also decrease. Changes of valleys parameter are similar to those of peak; however valleys height decrease is smaller than peak amplitude change. Height of peaks and valleys usually decrease as the result of mechanical filtration.

After mechanical filtration profile became more asymmetric; the parameters Psk and Pku increase. The emptiness coefficient Pp/Pt also increases.

Generally relative changes of parameters of the same height are larger for smaller initial value of spacing parameters like PSm and CL. However the changes of profiles with the same correlation length are higher for larger initial height. It seems that initial values of spacing parameters are more important.

The tendency was found that parameter changes were higher for bigger sizes of stylus tip. The application of tip with radius of 2 µm caused small changes of profile parameters of initial value of Pq parameter 0.2 µm and correlation length of 100 µm.

Figures 3 and 4 present profiles details before and after mechanical filtration by spherical probes.

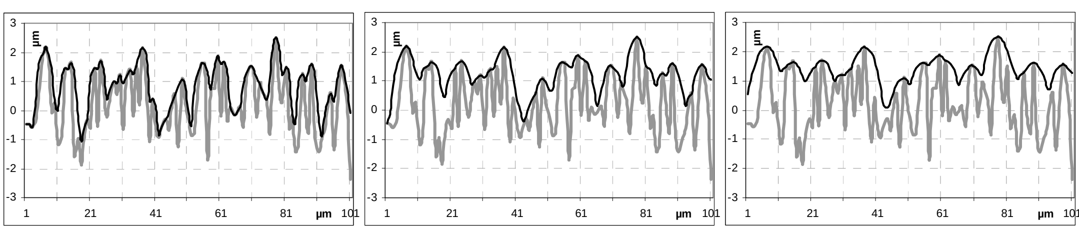

Figure 3. Detail of profile (Pq = 1 µm, CL = 2 µm) – grey line and profile after mechanical filtration by spherical tip - black line. The tip radius r = 2 µm (a), 5 µm (b) and 10 µm (c)

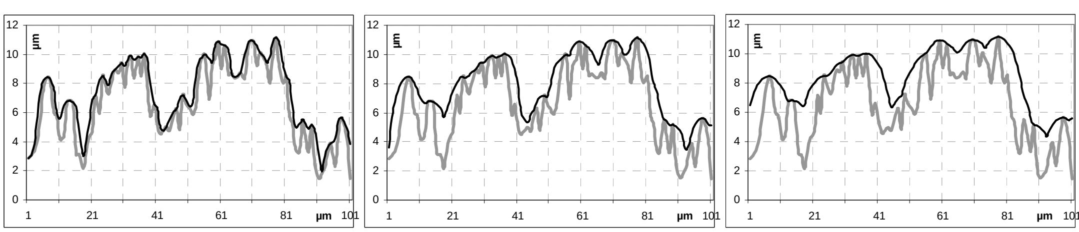

Figure 4. Detail of profile (Pq = 5 µm, CL = 100 µm) – grey line and profile after mechanical filtration by spherical tip - black line. The tip radius r = 2 µm (a), 5 µm (b) and 10 µm (c)

Two-process profiles

Profiles after 2 processes were simulated using described above procedure. The correlation length of plateau (peak) part was called CLp and of valley part CLv. Two cases were analysed: when CLp was not bigger than CLv (first case characteristic for plateau honed surfaces) and when CLp was bigger than CLv (second case characteristic for surface after a low wear process). Pmq parameter was higher than 50%. In first case horizontal parameters, like CL and PSm were larger. Table 6 presents selected parameters of 6 analysed profiles. Table 7 shows parameters of these profiles after mechanical filtration by spherical tip of radius 2 µm, Table 8 - 5 µm, but Table 9 – 10 µm.

Table 6. Parameters of two-process profiles

Parameter / Profie	Ppq µm	Pvq µm	Pmq %	PSk -	CLp µm	CLv µm	CL µm	Pq µm	PSm µm	PΔq -	pc 1/ µm	vc 1/ µm
B1	1.14	4.95	50.1	-2.127	40	300	229.59	2.80	35.31	0.49	0.91	0.92
B2	0.96	4.96	50.2	-2.142	300	40	34.27	2.74	18.33	1.12	1.62	1.81
B3	0.20	5.02	49.8	-2.251	2	20	14.95	2.84	12.55	1.54	2.14	2.51
B4	0.11	5.05	50.3	-2.266	20	2	1.29	2.87	5.04	2.93	4.75	6.44
B5	0.12	5.02	83.2	-3.461	40	300	177.01	1.13	103.70	0.25	0.24	0.25
B6	0.115	4.9	84.6	-4.081	300	40	15.96	1.14	26.77	0.63	0.52	0.66

Table 7. Parameters of two-process profiles after mechanical filtration by spherical stylus tip of radius 2 µm

Parameter / Profile	Ppq µm	Pvq µm	Pmq %	PSk -	CL µm	Pq µm	PSm µm	PΔq -	pc 1/ µm	vc 1/ µm
B1	1.10	4.16	66.8	-2.148	229.38	2.72	52.51	0.36	0.42	0.55
B2	0.71	3.99	62.3	-2.263	34.39	2.20	32.13	0.63	0.34	0.69
B3	0.16	4.17	65.0	-2.738	14.24	1.93	25.92	0.74	0.33	0.78
B4	0.09	2.5	65.2	-3.487	3.70	0.68	10.78	0.55	0.34	0.79
B5	0.10	3.41	82.1	-3.551	170.96	1.02	157.54	0.18	0.11	0.15
B6	0.08	3.40	88.8	-5.014	14.10	0.73	30.45	0.32	0.09	0.22

Table 8. Parameters of two-process profiles after mechanical filtration by spherical stylus tip of radius 5 µm

Parameter / Profile	Ppq µm	Pvq µm	Pmq %	PSk -	CL µm	Pq µm	PSm µm	PΔq -	pc 1/ µm	vc 1/ µm
B1	1.06	4.06	65.5	-2.159	230.09	2.64	70.62	0.27	0.18	0.37
B2	0.73	3.60	70.4	-2.284	35.60	1.82	41.80	0.40	0.16	0.38
B3	0.13	3.55	73.7	-3.196	13.98	1.35	33.44	0.43	0.16	0.39
B4	0.085	0.45	75.8	-4.079	4.74	0.28	9.15	0.18	0.14	0.27
B5	0.10	3.16	82.9	-3.634	167.79	0.92	199.80	0.13	0.08	0.10
B6	0.08	2.67	92.1	-5.867	13.39	0.47	32.90	0.17	0.05	0.10

Table 9. Parameters of two-process profiles after mechanical filtration by spherical stylus tip of radius 10 µm

Parameter / Profile	Ppq µm	Pvq µm	Pmq %	PSk -	CL µm	Pq µm	PSm µm	PΔq -	pc 1/ µm	vc 1/ µm
B1	1.03	4.01	66.1	-2.176	230.35	2.58	87.15	0.21	0.10	0.28
B2	0.72	3.00	74.4	-2.120	41.58	1.52	44.52	0.26	0.09	0.26
B3	0.12	2.75	78.6	-3.505	15.46	0.92	35.31	0.24	0.09	0.23
B4	0.075	0.45	89.4	-3.155	7.08	0.17	10.81	0.09	0.08	0.15
B5	0.10	2.88	83.0	-3.722	165.49	0.84	182.04	0.10	0.06	0.08
B6	0.07	2.16	83.0	-6.461	13.96	0.33	31.63	0.10	0.03	0.06

The tendencies of parameters changes caused by mechanical filtration of two-process profiles were similar to those of profiles of normal ordinate distribution. Height parameters decreased; the changes were higher for profiles from second case. Changes in maximum height parameters were smaller than those of statistical parameters. As example, in first case, the maximum change of Pq parameter was 56%, but of Pt parameter 36%, when stylus tip of radius 2 µm was used. In the second case the changes were larger.

Changes of most of horizontal and hybrid parameters were higher for the second case than in the first case and those of profiles of normal ordinate distribution. Horizontal parameters increased as the result of mechanical filtration. Increases of the PSm parameter were higher those of CL parameter; maximum change of PSm was 160%, but CL 15% for stylus tip of 5 μm radius and the first cases. For the second case, these changes were higher. Surface slope decreased; these changes were higher than those of height parameters. It is the result of the fact that slope depends on spacing and height profile features. Maximum slope decrease was 45% when stylus tip of 2 μm radius was applied (first case) and 81% (second case). Peak and valleys curvatures decreased; the changes of peak curvatures were bigger. Peak height decreased; similarly to other parameters changes were larger for the second case.

Parameters describing the shape of the profile ordinate distribution usually decreased (maximum change of Pp/Pt was 21%, but of Pku 56 for the highest analysed tip radius) for the first case. The values of the Pku parameter increased (maximum change was 90%). In the second case the possibility of Psk and Pp/Pt increase and of Pku decrease occurred. It can be explained by difficulty of stylus tip penetration to the bottoms of valleys of small width.

The changes of parameters from the standards ISO 13565-2 and ISO 13565-3 were also studied. These parameter are commonly used for two-process surface topography description. Similarly to other analysed parameters the biggest changes of profiles belonging to the second case occurred. The decrease of parameters Pvq and Pvk took place. Decrease of the Pk parameter was smaller. Usually Ppq parameter values also decreased. However parameters Pmq, Pmr1 and Pmr2 increased for most of the profiles. Similar character of changed of profiles belonging to the first group took place.

The described analysis was carried out for sampling interval equal to 1 μm. Tendency of changes in parameters describing profile height was the same for higher sampling interval used. However dependencies of frequency-dependent parameters could be changed. For example increase of the sampling interval caused similar changes of radii of peaks and valleys. Some of the tested profiles were unrealistic. However the intention of the present authors was to find the tendency of profile distortion caused by tip radius increase.

Figures 5 and 6 present details of two-process profiles belonging to the first and second cases, respectively, before and after mechanical filtration by spherical probes.

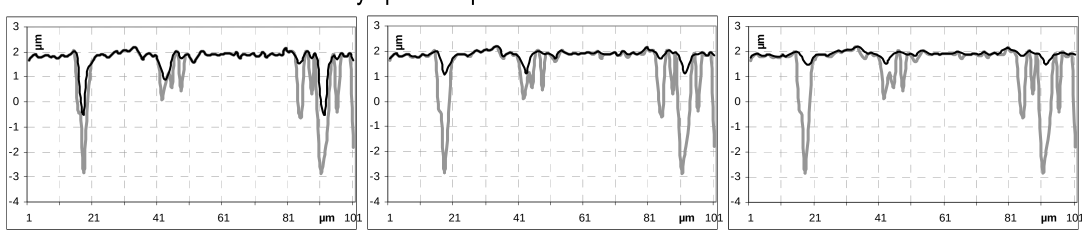

Figure 5. Detail of profile B3 – grey line and profile after mechanical filtration by spherical tip – black line. The tip radius r = 2 μm (a), 5 μm (b) and 10 μm (c)

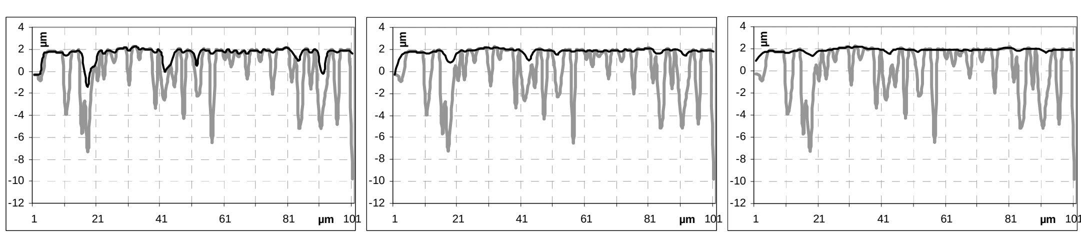

Figure 6. Detail of profile B4 – grey line and profile after mechanical filtration by spherical tip – black line. The tip radius r = 2 μm (a), 5 μm (b) and 10 μm (c)

Conclusions

Today reference data are needed to check accuracy of the algorithms and output parameters from the software. The mechanical filtration by the stylus tip can be predicted numerically. Input of surface data can be obtained either from digital input from profilometer or from numerical simulation of the rough surfaces. Randomly generating surface roughness by numerical means is simpler and offers some advantages. The hardware and software requirements can be eliminated. It also removes the need to filter out the unwanted wavelengths from the measured surface. Furthermore, surface modeling and simulation of the effect of stylus tip radius on the results of surface topography measurement ensure decrease of cost and time of experimental investigation.

Measurement of surface profiles by stylus tip of spherical radius causes changes in profile parameters. Profile height, slope and peak density decrease, main wavelength and peak radius increase. Changes of parameters are higher for higher radius of the probe tip.

Distortion of one-process profile of normal ordinate distribution depends on ratios between profile height and correlation length and between profile height and tip radius. Changes in profile shape are the highest for the highest profile height and the smallest correlation length.

Character of profile after two processes distortion is more complicated than that of one-process profile of Gaussian ordinate distribution. Changes of profile shape caused by mechanical filtration by stylus tip can be large when the main wavelength of plateau part is higher than that of valley part.

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