ITHEA

International Journal INFORMATION THEORIES & APPLICATIONS

2012 Volume 19 Number 3

International Journal
INFORMATION THEORIES & APPLICATIONS
Volume 19 / 2012, Number 3

International Journal "INFORMATION THEORIES & APPLICATIONS" (IJ ITA)
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International Journal "INFORMATION THEORIES & APPLICATIONS" Vol. 19, Number 3, 2012

Edited by the **Institute of Information Theories and Applications FOI ITHEA**, Bulgaria, in collaboration with:
V.M.Glushkov Institute of Cybernetics of NAS, Ukraine,
Institute of Mathematics and Informatics, BAS, Bulgaria,
Universidad Politécnica de Madrid, Spain.

Printed in Bulgaria

Publisher ITHEA®
Sofia, 1000, P.O.B. 775, Bulgaria. www.ithea.org, e-mail: info@foibg.com
Technical editor: **Ina Markova**

ISSN 1310-0513 (printed) **ISSN 1313-0463 (online)** **ISSN 1313-0498 (CD/DVD)**

USE PROXIES IN TREE TOPOLOGY ARCHITECTURES TO REDUCE THE COMMUNICATION TIME IN MEMBRANES SYSTEMS

Miguel Ángel Peña, Ángel Castellanos, Alberto Arteta, Francisco Gisbert

***Abstract**: There are two architectures that preserve the tree topology of the P system: peer-to-peer and hierarchical peer-to-peer. Architectures used the concept of proxy to reduce the size of messages and communication time. In this paper, we propose that the proxy no only reduces the time needed to sending messages, but also reduce the number of connections between processors. Normally, in one transition, two processors communicate three times, but with this algorithm, the communications are reducing to only one. We present the proxy algorithms for these architectures.*

***Keywords**: Distributed Communication, Membrane Computing, Membrane Dissolution, P-Systems Architectures.*

***ACM Classification Keywords**: F.1.2 Modes of Computation, I.6.1 Simulation Theory, H.1.1 Systems and Information Theory, C.2.4 Distributed Systems*

Introduction

In 1998 Gheorghe Păun introduced membrane computing [Păun, 2000] as a parallel computing model based on the biological notion of the cell. On the original model, there have been several variations in order to solve various problems, and improve computation times, in order to solve complex problems such as NP-complete, in similar times to the polynomial.

The idea behind a membrane system is based on the permeability of the same, and those internal changes whose taking place. Depending on the elements that are working, we can distinguish two main types, those which manipulate objects and those which work with strings. The behavior is similar in both cases. In parallel, each membrane performs a series of rules with its own objects or strings, resulting in other objects or strings, which, using the permeability of the membrane can move to other membrane if it was indicated in their transformation rules. The great advantage of these systems is that each membrane is run independently of the others, so the runtime does not depend on the number of membranes.

We can divide the dynamics of P System in two steps: the internal application to the membrane and communication between membranes. The first step is the allocation of objects in active rules (which imply that they are useful and applicable) and the creation of new objects. In the communication step, the membrane communicates the new items to their corresponding membrane due to the capabilities of membrane permeability and dissolution of the membranes.

To reduce the execution time of P System are used distributed implementations, such as [Syropoulos, 2004] and [Ciobanu, 2004]. In the use of these implementations has been observed network congestion. To solve these problems, several authors have proposed architectures where communication takes place without collisions. The first example is the Peer-to-Peer Architecture [Tejedor, 2008] which was introduced by Tejedor. Based on this architecture, Bravo proposed the Hierarchical Peer-to-Peer Architecture [Bravo, 2007]. Both architectures make use of the proxy concept introduced by Tejedor [Tejedor, 2008] so that "when a membrane wants to communicate with another one located at a different processor, the first one uses a proxy".

Communication between membranes is done internally in the processor and externally by proxy. Thus, for the communication of new objects will use the proxy, and for the dissolution of membranes will be used again. In addition to determining the useful rules, the membrane needs to know the existence of other membranes in the P System. According [Frutos, 2009] would be necessary to know the total context for the selection of rules. In the case of using any of the above referenced distributed architectures, it is necessary communications between distributed teams to determine the presence or absence of membranes.

Thus, there are three types of communications between processors: object communication, dissolution of membranes and knowledge of whether or not exist other relative membranes to determine the total context. All these communications can be reduced to only three (one of each type) through the use of proxy. In this paper we propose a variant of the proxy, so that the three communications that are made in each evolution of the P System can be done in just one. Because each one of the above architectures has differentiating features, the proxy implementation, even following the same idea, should be done differently. Therefore, it will be explained the behavior of this proxy for each one of the four indicated architectures.

P System definition

The first definition of a P System was published by Păun [Păun, 2000], who defined a Transition P System as:

Definition: A Transition P System is $\Pi = (V, \mu, \omega_1, \ldots, \omega_n; (R_1, \rho_1), \ldots, (R_n; \rho_n); i_0)$, where:

V is an alphabet (composed of objects).

μ is the membrane structure with n membranes.

ω_i are the multiset of symbols for the membrane i.

R_i are the evolution rules for the membrane i. A rule is a sorted pair (u,v) where u is a string over V, and $v = v'$ or $v = v'\delta$ and v' is a string over $V_{TAR} = V \times TAR$ with $TAR = \{here, out\} \cup \{in_j \mid 1 \le j \le n\}$. δ is a special symbol no include in V, and represent the dissolution of the membrane.

ρ_1 are the priority of rules for the membrane i.

i_0 indicates a membrane, which is the system output membrane or skin membrane.

Proxy: General Idea

A proxy is a program or device located in the processor that carries out an action in representation of another. [Tejedor, 2008] uses this idea to reduce the time when the membrane send objects to other membranes located in other processor. This idea is used in all architectures, but Tejedor did not specify anything about the other data pieces between processors. Figure 1 shows an example of a distributed P system in 4 processors and the relative proxies.

We propose a new proxy that solves the problem of multiple submissions of information between processors, performing a single shipment in every stage of execution. To determine useful rules, each membrane needs to know the total context, i.e. the existence of membranes that can be parents or its daughters. In the application phase, to avoid existence of communication between processors, to determine the presence or absence of membranes, the proxy must know whether a membrane exists or has been dissolved. To send objects between membranes, the proxy also must know where each membrane, with it wants communicate, is located. The membrane dissolution step is executed after the communication of objects. If a membrane is dissolved, all objects and containing membranes pass to belong to mother. This indication of dissolution also be communicated to its parent membrane and also it is conveyed to all proxies who need to know its existence to the determination of useful rules. Proxies at all times know the total context of the membranes of the processor. In addition, a membrane after the application of rules known whether it will be dissolve or not, but does not dissolve until transferring objects. If the membranes begin to dissolve and the communication with the parent is made before transmission of the new objects, information can be losing. However, with the correct order in the sending of messages it may indicate that the membrane is dissolved while sending objects, reducing the two shipping to only one. The correct order of delivery will depends on the architecture to be used, as shown in the following part.

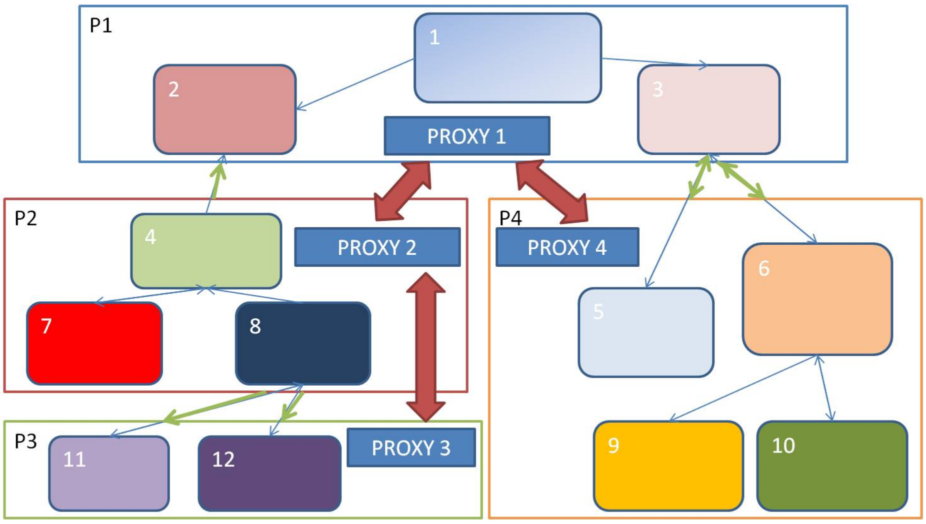

Fig. 1. Example of P system distribution and the associated proxies

Peer-to-peer architecture proxy

The architecture Peer-to-peer (P2P) was introduced by Tejedor in [Tejedor, 2008]. In this architecture the membranes are located in P processors conserving the tree topology. Then a processor only communicates with its parent or children processor, to reduce the time of communication to 2(P-1) communications. When a processor communicates with another, it waits the response.

For this architecture, the proxy must maintain the tree topology of P System (at least for the descendants or ascendants of the membranes that contained membranes, until to the membrane that cannot be dissolved). Thus, for each of these membranes, the proxy must will know where they are located; also it will know the tree processors structure, so that if it has to make a referral to a processor offspring, it knows through which of its children should do it. Finally, it keeps objects to send to other membranes (we named ObjectsToSend), and an indication of the membranes dissolved (MembranesToDissolves), and objects that are contained.

In the example in Figure 2 (based of the distribution of Figure 1), where each membrane is referenced by a circle, the processor contains the membranes 4, 7 and 8, with all its elements (objects, rules...). The proxy contains the structure of other descendants or ascendants to the membrane which cannot be dissolved, indicating only the topology. It also maintains an indication of the processors for the ascending and descending to the membranes indicated. The proxy has ObjetToSend store, where it stores the objects that should be communicated to another membrane that does not belong to processor, and an indication of the dissolved membranes, whether they are in the processor or in the proxy. In the rules application step, to know that rules are useful, the processor request information to the proxy about existence of other membranes, because it contains such information.

For each outside membrane, the proxy only contains its identifier, the indication of the daughters and parent membranes, and the corresponding proxy reference. Proxy also contains information from other proxies. For each proxy contains its identifier, its address, its parent and children proxies, and the membranes include of the proxy. Then, for *m* membranes and *p* proxies, is necessary:

$$4m + 5p \text{ numbers} \quad (1)$$

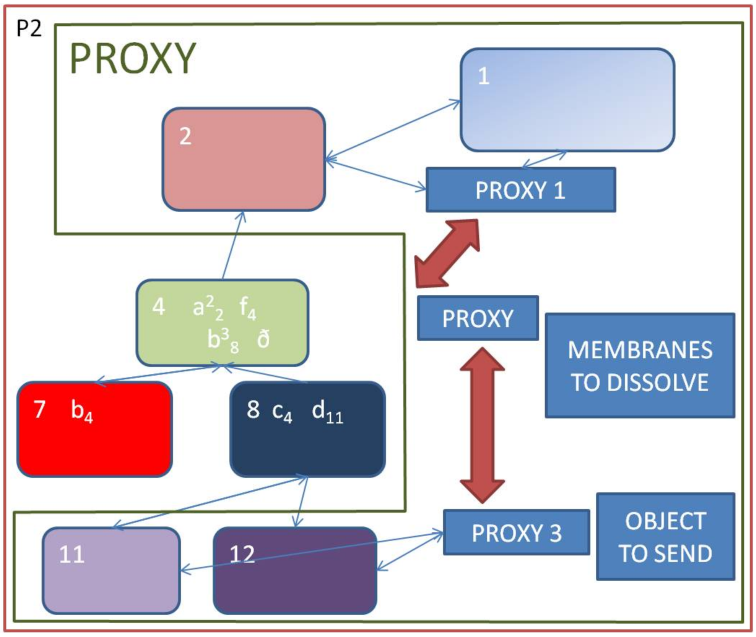

Fig. 2. Proxy of processor 2 (based of P system distribution show in Fig. 1)

The algorithm will run in parallel on each processor, and must contain six parts running sequentially which are running similarly to proxies for all architectures: Local analysis, synchronization, parent receiving message, children communication, preparing the message for the parent with dissolved membranes application, and father sending.

- The **local analysis** is cover all available membranes in the processor and analyst the new object destine. Put objects in the corresponding membrane if it is in the processor, or put it in ObjectToSend, so that later they will send to their respective destinations. In addition, if any membrane will be dissolved, this is added to MembranesToDissolve.
- To avoid collision in the communication, there must be **synchronization** between the processors, so that only one is communicating at all times. To do this, at this point which processors need to communicate with other processors, stop execution until the parent process sends the order to continue. The processor *0* or root will give the order himself, being the only begins to run. The way to give permission to report will be with a message.
- The father, also give an indication that the child should continue its execution, the message send objects and an indication of the dissolved membranes. Therefore, the child, upon **receiving the message from the father**, must process and drop the objects in the corresponding destination (the membrane itself if it

is found in the processor or objectToSend in other case). He will also receive an indication of the membranes that have been dissolved, and add them to his list of dissolved membranes (MembranesToDissolve).

- After receiving and processing information from the parent, it **communicates with the children**. Thus, sequentially, for each child prepares a message, it sends, waits for the child to respond and process the response message. In the message prepared for the child, are attaching all objects in ObjectToSend whose destine is in the child processor or any of their descendants. It adds an indication of the membranes that have been dissolved. It sends this message, telling the child to continue its execution, and waits until the child finishes and passes the order to continue. When it received this order will also receive a message from the child, indicating what membranes are dissolving and what objects are sending.
- At this point, already has all the information to be communicated to the parent. Objects found on ObjectToSend are destined for an ascending of that processor, so they are added to a **new message that is preparing to send the parent**. Also, add the indication of the membranes that are marked to dissolve. It processed all labeled membranes to dissolve and then they are dissolved. This dissolution is to move its objects to the mother membrane if it is on the same processor, or add objects (put as destine the mother membrane) to the message if it is on another processor. Completes the dissolution by removing the membrane, and adjusting the membranes tree (indicates the relationship between membrane).
- Finally **sends the message to the father**, indicating that it has finished executing, and that the parent can continue.

The algorithm is present as Algorithm 1:

```
Algorithm 1: Proxy algorithm for P2P architecture
    Local analysis (Algorithm 2)
    Synchronization (Algorithm 3)
    Parent receiving message and Process the message (Algorithm 4)
    Children communication (Algorithm 5)
    Preparing the message for the parent with dissolved membranes application (Algorithm 7)
    Father sending (Algorithm 8)
```

```
Algorithm 2: Local analysis
    for all membrane of current processor do
      for all new object do
        if current processor contain the destine of object then
          Put the object in the membrane
        else
          Put the object in objectToSend
        end if
      end for
      if execute a rule to dissolve the membrane then
        Add membrane to MembranesToDissolve
      end if
    end for
```

```
Algorithm 4: Process the message
    1:  for all object do
    2:    if CurrentProcessor contain the destine then
    3:      PUT the object in the membrane
    4:    else
    5:      PUT the object in ObjectToSend
    6:    end if
    7:  end for
    8:  for all membrane in MembraneToDissolve received in the message do
    9:    ADD to MembranesToDissolve if not exists
    10: end for
```

```
Algorithm 5: Children communication
    1: for all child processor do
    2:   Create a message (Algorithm 6)
    3:   SEND (child processor, message)
    4:   WAIT (message)
    5:   Process the message (Algorithm 4)
    6: end for
```

```
Algorithm 6: Create a message
    1: for all object in ObjectToSend do
    2:   if membrane's target is in this child processor or another descendant of this child
processor then
    3:     PUT the object in the message (and remove to the ObjectToSend)
    4:   end if
    5: end for
    6: for all membrane in MembranesToDissolve do
    7:   PUT the membrane in the message
    8: end for
```

```
Algorithm 7: Preparing the message for the parent with dissolved membranes application
    1:  for all object in ObjectToSend do
    2:   PUT the object in the message (and remove to the ObjectToSend)
    3:  end for
    4:  for all membrane in MembranesToDissolve do
    5:    PUT the membrane in the message
    6:    if parent membrane in other processor then
    7:      for all object in the membrane do
    8:        PUT the object in the message, but the target is the parent of membrane.
    9:      end for
    10:   else
    11:     for all object in the membrane do
    12:       MOVE the object to the parent membrane
    13:     end for
    14:   end if
    15:   ADJUST the tree removing this membrane
    16: end for
```

```
Algorithm 8: Father sending
    1: if currentProcessor <>0 then
    2:   SEND (parent processor, message)
    3: end if
```

Hierarchical Peer-to-Peer architecture proxy

This architecture (HP2P) proposed by Bravo [Bravo, 2007] as a variant of the previous. With the same idea, and parallelizing the communication, reduce the time. In this architecture, a processor can communicate sequentially with all its children without waiting for a response to communicate with the following. Later the communication with the children, these communicate with the processor, and finally, the processor communicates with his parent.

The proxy for this architecture has a performance similar to the Peer-to-Peer architecture. In this architecture, communication with children can be done sequentially without waiting for the response of the child. After all the children sent in sequential order, and when they are completed, send a message to the parent.

The proxy only should maintain, for all the membranes of the processor, their descendants and ascendants until the membrane that cannot be dissolved. In the event that contained more information on membranes, the knowledge of them be out of date. This knowledge does not influence the total context of a membrane during the process.

The operation of the proxy presents only this variant, as seen in the algorithm 9:

```
Algorithm 9: Proxy algorithm for HP2P architecture
    1: Local analysis (Algorithm 2)
    2: Synchronization (Algorithm 3)
    3: Parent receiving message and Process the message (Algorithm 4)
    4: Children communication (HP2P) (Algorithm 10)
    5: Preparing the message for the parent with dissolved membranes application
(Algorithm 7)
    6: Father sending (Algorithm 8)
```

```
Algorithm 10: Children communication in HP2P architecture
    1: for all child processor do
    2:   Create a message (Algorithm 6)
    3:   SEND (child processor, message);
    4: end for
    5: for all child processor do
    6:   WAIT (message)
    7:   Process the message (Algorithm 4)
    8: end for
```

Conclusion

The use of proxies in the communication of the membranes is extended regardless of the architecture used. This article has proposed a variant of the proxy introduced by Tejedor. With this new proxy, at each step of evolution, at least three communications between processors are reduced to just one.

The operation of the proxy, which satisfies a general idea, has a small difference if the parallelism of the Hierarchical Peer-to-Peer Architecture is used. Using this proxy, which connects the dissolved phase with the objects shipping, allowing the membranes begin the rules application phase but not all membranes have completed their communication phase, reducing wait times and improving global times in the evolution of the system.

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SEMANTIC CONSTRUCTION OF UNIVOCAL LANGUAGE

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Abstract: *In this paper a solution is propose to organize the space of words that exist in a specific language in their different semantic categories. By taking a natural language, we're going to define a unique meaning for each word, as a construction made (d,C) of pairs of words and contexts. On the other hand, let us consider the space of meanings. All the words that share meaning (synonymous words) can be associated with one meaning. This permitus to make a partition of the space of words in groups of synonyms. Finally, a classification of the space of words will be obtained in the different groups of words that share meaning. This allow to choose the useful word that represent a meaning, and reduce the number of words selecting one representative from each group of synonyms. It will be very useful for calculating distances between words.*

Keywords: *Natural Language, Semantic, Context.*

ACM Classification Keywords: *C.2.1 Network Architecture and Design; D.2.1 Requirements Specifications (D.3.1) Languages; D.3.2 Language Classifications Applicative (functional) languages; E.1 [Data Structures] Graphs and networks; H.5.2 [User Interfaces] Natural language.*

Introduction

Let A' be a natural language. We built $D = (A',*)$, with a free semigroup structure, treated as a set, regardless of its algebraic properties [Dieter, 2004]. Can be built the pair (d, C) made of one word and one context that select one of the possible meanings of the word. So, a solution to the problem of poly semy is proposed. Now, is necessary to consider the space Δ of all the possible meanings that built a language. Over the pair (d, C) the meaning mapping $\psi: (d, C) \longrightarrow \Delta$ is defined (we're going to include programming abstractions such as procedures, functions [Miguel, 2011]) ψ assigns to each pair (d, C) only one meaning. Finally, an equivalency relation over (d, C) is defined in order to build a quotient space inducing a classification in the different semantic classes [Ito, 1977], [Angelova, 1988], wherein each equivalence class is formed by all the words associated with a determinate meaning (synonymous words) [Ito, 1981].

Space of Words

$\boldsymbol{Definition}$ **1.** Let $\mathbf{A} = \{a, b, c \ldots\}$ be an alphabet, such that $A \neq \emptyset$.
We can define a word as a finite succession of elements of $\boldsymbol{A}$, where repetitions are allowed.
For example **aaa**, **aabcc**, **b** are different words.
Let $\boldsymbol{A}'$ be the set composed by words.
$\boldsymbol{Definition}$ **2.** Let $\boldsymbol{D} = (\boldsymbol{A}',*)$ be a free semigroup with a associative law (*) juxtaposition, and an identity element $1 \in G$.

We can multiply two words **aaabbb*abccc=aaabbbabccc**, where the identity element '1' is defined as the empty succession of words.

The grammatical rules are defined as restrictions on this free semigroup.

$\boldsymbol{Definition\ 3}$. Let the inclusion mapping be $\boldsymbol{i_{|\Theta}}: \boldsymbol{D} \longrightarrow \boldsymbol{\Theta}$,Θ the space of concepts which belongs to a given lexicon $\mathcal{L}$. The inclusion mapping $\boldsymbol{i_{|\Theta}}$ saves the words that belong to $\boldsymbol{\mathcal{L}}$.

Let $d \in D$ then $\boldsymbol{i_{|\Theta}}(d) = \{d/d \in \Theta\}$ and $\boldsymbol{i_{|\Theta}}(d) = \{\emptyset/d \in D\backslash\Theta\}$.

For example $\boldsymbol{i_{|\Theta}}(\boldsymbol{aabbacc}) = \emptyset$ such that $\boldsymbol{aabbacc} \notin \boldsymbol{\mathcal{L}}$ and $\boldsymbol{i_{|\Theta}}(\boldsymbol{dog}) = \boldsymbol{dog}$ such that $\boldsymbol{dog} \in \boldsymbol{\mathcal{L}}$.

In the next point the space of context is building as a simple generation rule so as we will see how to calculate the shortest path between two contexts.

Space of Contexts

Let $\boldsymbol{C}$ be a context, a list of words that define an ambient where to locate a word belonging to $\boldsymbol{\mathcal{L}}$.

$\boldsymbol{Definition\ 4}$. Let $\boldsymbol{C}$ a graph made of $\{\boldsymbol{C_1}, \boldsymbol{C_2}, \dots \boldsymbol{C_n}\}$ a countable set of contexts, such that $\boldsymbol{C_i} \in \boldsymbol{\Omega}$ and $\boldsymbol{\Omega}$ is the space of contexts inspired by [Dieter, 2004].

We're going to build C with a simple $\boldsymbol{formation\ rule}$. Let $\boldsymbol{C_i} \in \boldsymbol{\Omega}$ be a determined context composed by more specific disjoint contexts $\boldsymbol{C_{i+1}} \in \boldsymbol{\Omega}$.

$$C_i = \bigcup_{\boldsymbol{i=1}}^{\boldsymbol{n}} \boldsymbol{C_{i+1}^{j}} \quad such\ as \cap_{\boldsymbol{j=1}}^{\boldsymbol{n}} \boldsymbol{C_{i+1}^{j}} = \emptyset \equiv [4.1]$$

$\boldsymbol{Definition\ 5}$.Let the $\boldsymbol{generation\ rule}$ be the process of division of a context $\boldsymbol{C_i} \in \boldsymbol{\Omega}$ in their constituents subcontexts $\boldsymbol{C_{i+1}} \in \boldsymbol{\Omega}$ in $[4.1]$. The number of generation rules must be countable to avoid problems of computability.

We consider $\boldsymbol{C_i}$ as a vertex of the graph and all the contexts in which $\boldsymbol{C_i}$ is subdivided as a set $\{\boldsymbol{C_{i+1}^1}, \boldsymbol{C_{i+1}^2}, \dots \boldsymbol{C_{i+1}^n}\}$ of new vertex's connected with $\boldsymbol{C_i}$ by edges.

If we are applying the rule generation to $\boldsymbol{C_i}$ and one of the subcontext generated $\boldsymbol{C_{i+1}^3}$ is the same as another $\boldsymbol{C_{j+2}^5}$ belonging to another division $\boldsymbol{C_{j+2}^5} = \boldsymbol{C_{i+1}^3}$, then this two subcontexts are considered the same and we can see it in the graph using the edges from the previous settings $\boldsymbol{C_i}, \boldsymbol{C_{j+1}}$ to it.

This breaks the tree structure of the graph, creating closed paths and cycles.

Let $\|\boldsymbol{\alpha}(C_i, C_j)\|$ be the $\boldsymbol{lenght\ of\ a\ path}$ between two contexts [Dieter, 2004].

$\boldsymbol{Definition\ 6}$. The $\boldsymbol{shortest\ lenght\ of\ a\ path\ between\ two\ contexts}$ is:

$$\|\boldsymbol{\alpha_{min}}(C_i, C_j)\| = \{\|\boldsymbol{\alpha}(C_i, C_j)\|\ such\ that \forall\ \|\boldsymbol{\alpha}'(C_i, C_j)\|, \|\boldsymbol{\alpha}'(C_i, C_j)\| \geq \|\boldsymbol{\alpha}(C_i, C_j)\|\}$$

It will be useful to calculate in the future, the minimum distance between two contexts.

In the next point we're going to build the relationship between the space of words $\boldsymbol{\Theta}$ and space of contexts $\boldsymbol{\Omega}$ in the pair $(\boldsymbol{d}, \boldsymbol{C}) \in (\boldsymbol{\Theta}, \boldsymbol{\Omega})$.

Once this is achieved, we will assign one meaning to each pair through a well defined mapping.

The Meaning Mapping

$\boldsymbol{Lemma\ 1}$. Let $(\boldsymbol{d}, \boldsymbol{C}) \in (\boldsymbol{\Theta}, \boldsymbol{\Omega})$ be the pair made of one word and one context. $\boldsymbol{\Theta}$ is the space of concepts which belongs to a given lexicon, and $\boldsymbol{\Omega}$ is the space of contexts.

It is important to realize that most of the words of a given lexicon $\mathcal{L}$ are polysemous.
Is selected one of the possible meanings of the word through the context where to locate the word.
Let $\boldsymbol{\Delta}$ be meanings space of a given lexicon $\mathcal{L}$.
$\boldsymbol{Lemma\ 2.}$ Let $\boldsymbol{\psi}: (\boldsymbol{\Theta}, \boldsymbol{\Omega}) \longrightarrow \boldsymbol{\Delta}$ a mapping. $\boldsymbol{\Delta}$ is the meanings space, $\boldsymbol{\Theta}$ is the space of words that belong to $\mathcal{L}$, and $\boldsymbol{\Omega}$ the space of contexts.
Once we have selected a word and a context by the pair, we assign one meaning to the pair through the mapping $\boldsymbol{\psi}$.
For example, the word "paint", choose different meanings for different contexts through the mapping $\boldsymbol{\psi}$.
$\boldsymbol{\psi}(\boldsymbol{paint}, \boldsymbol{decoration})$ =a coloured substance which is spread over a surface and dries to leave a thin decorative or protective coating.
$\boldsymbol{\psi}(\boldsymbol{paint}, \boldsymbol{basketball})$ =a rectangular area marked near the basket at each end of a court.
$\boldsymbol{Proposition\ 1.}\ \boldsymbol{\psi}$ is a well-defined mapping.
$\boldsymbol{Proof.}$ By making $\boldsymbol{\psi}$ a mapping, we have found a way to avoid the polysemy problem and assign one only meaning to each pair (**word, context**) [Kazimierz, 2010].
Let $\boldsymbol{d} \in \boldsymbol{\Theta}$ be a word.
Let $\boldsymbol{C_1}, \boldsymbol{C_2}, \dots \boldsymbol{C_n}$ be a list of contexts associated to the word d.

$$\forall\ (\boldsymbol{d}, \boldsymbol{C_i})\ \exists!\ h\ \in \Delta /\ \boldsymbol{\psi}(\boldsymbol{d}, \boldsymbol{C_i}) = h \text{ with } i \in \{1,2, \dots n\}.$$

We can consider a pair $(\boldsymbol{d}, \boldsymbol{C}) \in (\boldsymbol{\Theta}, \boldsymbol{\Omega})$, the support of $\boldsymbol{\psi}$, that allow to define $\boldsymbol{\psi}$ as a mapping.
$\boldsymbol{\psi}: (\boldsymbol{\Theta}, \boldsymbol{\Omega}) \longrightarrow \boldsymbol{\Delta}$ defines only one meaning for each pair.
In the last point we will organize the pairs $(\boldsymbol{d}, \boldsymbol{C}) \in (\boldsymbol{\Theta}, \boldsymbol{\Omega})$ by groups that share meaning (synonymous words) through an equivalence relation $\sim$. This allow to choose the word that represents a meaning that suits us, and reduce the number of words by choosing one representative from each group of synonyms. It will also be very useful for calculating distances between words.

The space of semantic meanings

$\boldsymbol{Lemma\ 3.}$ Let $\sim$ be an equivalence relation. Two words in one of their concrete contexts are related: $(\boldsymbol{d}, \boldsymbol{C}) \sim (\boldsymbol{d'}, \boldsymbol{C'})$ if and only if $\boldsymbol{\psi}(\boldsymbol{d}, \boldsymbol{C}) = \boldsymbol{\psi}(\boldsymbol{d'}, \boldsymbol{C'})$.
For example:
$\boldsymbol{\psi}(\boldsymbol{late}, \boldsymbol{time})$ = after the expected or usual time.
$\boldsymbol{\psi}(\boldsymbol{delayed}, \boldsymbol{person})$ = retarded, incapacitated.
$\boldsymbol{\psi}(\boldsymbol{delayed}, \boldsymbol{traffic})$ = after the expected or usual time.
Where $\boldsymbol{\psi}(\boldsymbol{late}, \boldsymbol{time}) = \boldsymbol{\psi}(\boldsymbol{delayed}, \boldsymbol{traffic})$.
$\boldsymbol{Teorem\ 1.}$ $\sim$ is a **equivalence relation**.
$\boldsymbol{Proof.}$
$\sim$ is a **reflexive relation**: One word in one of its meanings is related with himself
$(\boldsymbol{d}, \boldsymbol{C}) \sim (\boldsymbol{d'}, \boldsymbol{C'}) \leftrightarrow \boldsymbol{\psi}(\boldsymbol{d}, \boldsymbol{C}) = \boldsymbol{\psi}(\boldsymbol{d'}, \boldsymbol{C'})$
Obviously: $(\boldsymbol{late}, \boldsymbol{time}) \sim (\boldsymbol{late}, \boldsymbol{time}) \leftrightarrow \boldsymbol{\psi}(\boldsymbol{late}, \boldsymbol{time}) = \boldsymbol{\psi}(\boldsymbol{late}, \boldsymbol{time})$ =after the expected or usual time.

$\sim$ is a **symmetric relation**: If one word, in one of their meanings, is related with another one (in one of its meanings). This involves that the another word is related with the first word, each one, in one of its meanings.
$(\boldsymbol{d}, \boldsymbol{C}) \sim (\boldsymbol{d}', \boldsymbol{C}') \leftrightarrow \boldsymbol{\psi}(\boldsymbol{d}, \boldsymbol{C}) = \boldsymbol{\psi}(\boldsymbol{d}', \boldsymbol{C}') \equiv \boldsymbol{\psi}(\boldsymbol{d}', \boldsymbol{C}') = \boldsymbol{\psi}(\boldsymbol{d}, \boldsymbol{C}) \leftrightarrow (\boldsymbol{d}', \boldsymbol{C}') \sim (\boldsymbol{d}, \boldsymbol{C})$
Is not difficult to see:
$(\boldsymbol{late}, \boldsymbol{time}) \sim (d\boldsymbol{elayed}, \boldsymbol{traffic}) \leftrightarrow \boldsymbol{\psi}(l\boldsymbol{ate}, \boldsymbol{time}) \sim \boldsymbol{\psi}(\boldsymbol{delayed}, \boldsymbol{traffic}) =$ after the expected or usual time$= \boldsymbol{\psi}(\boldsymbol{delayed}, \boldsymbol{traffic}) = \boldsymbol{\psi}(l\boldsymbol{ate}, \boldsymbol{time}) \leftrightarrow (\boldsymbol{delayed}, \boldsymbol{traffic}) \sim (\boldsymbol{late}, \boldsymbol{time})$.
$\sim$ is a **transitive relation**: When one word(always in one of their meanings) is related with another and the third word is related with another one, this implies that the firs and the last word are related.

$$(\boldsymbol{d}, \boldsymbol{C}) \sim (\boldsymbol{d}', \boldsymbol{C}') \text{ and } (\boldsymbol{d}', \boldsymbol{C}') \sim (\boldsymbol{d}'', \boldsymbol{C}'') \leftrightarrow \boldsymbol{\psi}(\boldsymbol{d}, \boldsymbol{C}) = \boldsymbol{\psi}(\boldsymbol{d}', \boldsymbol{C}') = \boldsymbol{\psi}(\boldsymbol{d}'', \boldsymbol{C}'')$$

In this case:
$(\boldsymbol{late}, \boldsymbol{time}) \sim (\boldsymbol{delayed}, \boldsymbol{traffic})$
and $(\boldsymbol{delayed}, \boldsymbol{traffic}) \sim (\boldsymbol{overdue}, \boldsymbol{born}) \leftrightarrow \boldsymbol{\psi}(\boldsymbol{late}, \boldsymbol{time}) = \boldsymbol{\psi}(\boldsymbol{delayed}, \boldsymbol{traffic}) = \psi(\boldsymbol{overdue}, \boldsymbol{born})$that means as we know: after the expected or usual time.

This **equivalence relation** $\sim$ allow to organize the different pairs in their classes:

$[(\boldsymbol{d}, \boldsymbol{C})] = \{(d', C') \in (\Theta, \Omega)/(\boldsymbol{d}', \boldsymbol{C}') \sim (\boldsymbol{d}, \boldsymbol{C})\} \equiv \{(d', C') \in (\Theta \times \Omega)/\boldsymbol{\psi}(\boldsymbol{d}', \boldsymbol{C}') = \boldsymbol{\psi}(\boldsymbol{d}, \boldsymbol{C})\}$
consisting of all possible pairs, formed by words and their contexts that share the same meaning.

This **equivalence relation** $\sim$ induces in $(\boldsymbol{\Theta} \times \boldsymbol{\Omega})$ the classification of their elements in the different semantic classes, building the quotient space $(\boldsymbol{\Theta}, \boldsymbol{\Omega})/\sim = \{[(\boldsymbol{d}, \boldsymbol{C})]/(\boldsymbol{d}, \boldsymbol{C}) \in (\boldsymbol{\Theta} \times \boldsymbol{\Omega})\}$ wherein each element is one of the classes that share meaning.
For example:
$[(\boldsymbol{late}, \boldsymbol{time})] = \{(\boldsymbol{delayed}, \boldsymbol{traffic}) \in (\Theta, \Omega)/(\boldsymbol{late}, \boldsymbol{time}) \sim (\boldsymbol{delayed}, \boldsymbol{traffic})\}$.
We can see that:

$$\cup_{\forall\, i,j}\left[\left(\boldsymbol{d_i}, \boldsymbol{C_j}\right)\right] = (\Theta \times \Omega)/\sim \text{ such that } \mathrm{j} \in \{1{,}2 \ldots \mathrm{n}\}, \mathrm{i} \in \{1{,}2 \ldots \mathrm{m}\}$$

$$\cap_{\forall\, i,j}\left[\left(\boldsymbol{d_i}, \boldsymbol{C_j}\right)\right] = \emptyset \text{ such that } \mathrm{j} \in \{1{,}2 \ldots \mathrm{n}\}, \mathrm{i} \in \{1{,}2 \ldots \mathrm{m}\}$$

Lemma4. Let $\boldsymbol{\psi}*$ be the meaning mapping defined on the quotient space$\boldsymbol{\psi}*: (\boldsymbol{\Theta}, \boldsymbol{\Omega})/\sim \longrightarrow \boldsymbol{\Delta}$
$\boldsymbol{\psi}*$ is a mapping from the classes to the meanings

$$\boldsymbol{\psi}*[(\boldsymbol{late}, \boldsymbol{time})] = \boldsymbol{\psi}(l\boldsymbol{ate}, \boldsymbol{time}) = \boldsymbol{\psi}(\boldsymbol{delayed}, \boldsymbol{traffic}) = \boldsymbol{\psi}(\boldsymbol{overdue}, \boldsymbol{born})$$

that means as we know: after the expected or usual time.

Theorem2. The equivalent relation$\sim$makes be$\boldsymbol{\psi}*$a injective mapping.

Proof. $\boldsymbol{\psi}*[(\boldsymbol{d}, \boldsymbol{C})] = \boldsymbol{\psi}*[(\boldsymbol{d}', \boldsymbol{C}')] \leftrightarrow [(\boldsymbol{d}, \boldsymbol{C})] = [(\boldsymbol{d}', \boldsymbol{C}')] \equiv (\boldsymbol{d}, \boldsymbol{C}) \sim (\boldsymbol{d}', \boldsymbol{C}')$
Two classes have the same meaning if they are the same class.
Finally the injective mapping $\boldsymbol{\psi}$ allows us to choose only one word that represents a meaning that suits us from each group of synonyms, simplifying the process.
We can see that:
$\boldsymbol{\psi}*[(\boldsymbol{late}, \boldsymbol{time})] = \boldsymbol{\psi}*(\boldsymbol{delayed}, \boldsymbol{traffic}) =$ after the expected or usual time.

Conclusion

We approach a solution to the problem of polysemy, building the different pairs $(\boldsymbol{d}, \boldsymbol{C})$**,** choosing an unique meaning for each word. Acting on this pairs $\boldsymbol{\psi}(\boldsymbol{d}, \boldsymbol{C})$, the meaning mapping $\boldsymbol{\psi}$, assigns one meaning to each pair. Finally, we have solved the synonymy problem, organizing all the words in their different semantic classes, through the quotient $(\boldsymbol{\Theta}, \boldsymbol{\Omega})/\sim$, where two pairs $(\boldsymbol{d}, \boldsymbol{C}) \sim (\boldsymbol{d}', \boldsymbol{C}')$ are related if and only if they share the meaning $\boldsymbol{\psi}(\boldsymbol{d}, \boldsymbol{C}) = \boldsymbol{\psi}(\boldsymbol{d}', \boldsymbol{C}')$. With this action, we reduce the number of words by choosing one representative from each group of synonyms, allowing the selection of the word that represents the useful meaning.

Acknowledgements

This work is supported by AXON Ingeniería y Desarrollo de Software, S.L. (Spain); Buaala.TV Project, Avanza 2 TSI-090302-2011-19; Ministerio de Industria, Turismo y Comercio (Spain) and FEDER (European Union)

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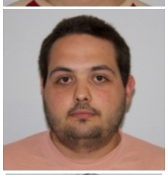

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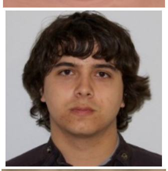

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MODELING AND CONTROL OF LYAPUNOV EXPONENTS IN A COUPLED MAP LATTICE

Vitaliy Yatsenko, Olexandr Kochkodan

***Abstract**: We describe a control method based on optimization techniques to control of spatiotemporal chaos in a globally coupled map lattice (CML) system. We have developed a method for updating a CML model emulating complex spatial dynamics in an epileptic brain that exhibits characteristic spatiotemporal changes seen during transitions into a seizure susceptible state. Our updating algorithm uses metaheuristic techniques for obtaining feedback control parameters for controlling spatiotemporal chaos (local and global Lyapunov exponents). This methodology can be used in systems with hidden variables, i.e. where not all variables can be observed, such as the human brain, to reconstruct evolution maps and complex spatial patterns. Results from numerical simulations show that this algorithm is robust and effective in achieving controllability of the lattice model. We discuss the computational aspects of this learning methodology and its potential application in epileptic seizure control.*

***Keywords:** modeling, optimization, Lyapunov exponent, control, chaos, oscillator*

***ACM Classification Keywords:** 1.6. Simulation and modeling, H.1 Models and principles, Optimization*

Introduction

The presence of chaos has been extensively demonstrated in natural and technical systems. Recently, controlling chaos has attracted increased attention over the past few decades due to its broad applications in physical, chemical and biological systems. One of the important and challenging areas for the application of chaos control techniques is the problem of treatment of neurological disorders such as epilepsy. Characterization of the electroencephalogram (EEG) using measures of chaos has been very useful in providing information about the dynamical state of the epileptic brain. Studies in humans [Iasemidis, 1990; Iasemidis,1991; Iasemidis,, 2004; Yatsenko, 2004] and animal models [Nair, 2004] of epilepsy suggest that occurrence of spontaneous seizures correlates with the evolution of the brain to a more temporally ordered state. This has been demonstrated by changes in gross system properties such as Lyapunov exponents calculated from EEG recorded from multiple brain regions. It has been postulated that such spatiotemporal transitions occur due to self organizing transitions in the epileptic brain that drives it from chaos to order. Furthermore, seizures have been considered to be inherent resetting mechanisms of the brain to revert it back from order to the chaotic regime [Iasemidis, 1996]. It is hence obvious as to why the maintenance of chaos in such biological systems is extremely desirable because of its implications from a therapeutic or control point of view. More recently the concept of “anticontrol” schemes, where the goal is the maintenance of chaos, has been the topic of much investigation and several algorithms have been devised to realize this objective [Ramaswamy, 1998; Wang, 2000; Morgu,I 2003]. The design and adaptation of such chaos control algorithms to dynamical systems that exhibit exceedingly complex dynamics, such as the brain, is not a trivial challenge.

Biological systems are inherently adaptive in nature and therefore require adaptive control techniques [Glass,1988]. Recent investigations in human epilepsy have suggested that effective modulation of brain dynamics needs new control techniques that rely on robust prediction and adaptive optimization methods [Iasemidis, 2000; Yatsenko, 2004; Pardalos, 2004; Iasemidis, 2003]. In this paper we will mainly concentrate on the theoretical problem of controllability of a system property that has shown to reflect state changes in neural systems, namely the Lyapunov exponent. Possible real world implications of controlling the Lyapunov spectrum include being able to control the convergence and divergence of this entity as quantified by the statistical measure T-index among different regions in an epileptic brain, which has been shown to be predictive of a seizure susceptible state [Yatsenko, 2004; Kaneko, 1984]. We reformulate the problem of controllability of the Lyapunov exponent as an optimization problem in which we try to estimate the control parameters by minimizing the error function calculated from the global Lyapunov exponents of a system.

The paper is organized as follows. We start by introducing the problem of control of a dynamical system and the need for optimization based techniques for choosing the optimal feedback parameters. In the next section, we introduce the problem of calculation of Lyapunov exponents and present some general feedback schemes for controlling the mean Lyapunov exponent from a system of globally coupled nonlinear maps. We also describe a constrained optimization technique to solve for the optimal feedback parameters. We then present some numerical and experimental results and finally propose a learning scheme based on optimized feedback parameter selection to simulate dynamics of an epileptic brain using a globally coupled map lattice system.

Control Of Chaos In Coupled Lattice Systems

Coupled Map Lattice. A coupled map lattice is a *N*-dimensional network of interconnected units where each unit evolves in time through a map (or recurrence equation) of the discrete form:

$$X^{k+1} = F(X^k), \quad (1)$$

where X^k denotes the field value (*N*-dimensional vector) at the indicated time *k*. In the case of a globally coupled map, with a global (mean field) coupling factor ε, the dynamics can be rewritten as:

$$x_n^{k+1} = (1-\varepsilon) f_n\left[x_n^k\right] + \frac{\varepsilon}{L}\sum_{j=1}^{L} f_j\left[x_j^k\right], \quad (2)$$

where n and j are the labels of lattice sites (j ≠ n). The term L indicates over how many neighbors we are averaging and it is sometimes referred to as coordination number. The local N-dimensional map is assumed to be chaotic. Completely synchronous chaotic states are possible with this model when corresponding N-dimensional manifolds are attracting or stable. The criterion for stability of this synchronization manifold has been derived in [Ding, 1997]. Further stability analysis of synchronized periodic orbits in coupled map lattices can be found in [Amritkar, 1991]. Varying ε and L we can change the extent of spatial correlations, from systems with local interactions to systems with long-range interactions. These systems typically exhibit spatially and/or temporally chaotic behavior, the control of which is very desirable because of its potential real-life applications. Several strategies have been proposed to control the collective spatiotemporal dynamics of such systems. In this paper we first describe adaptive feedback control strategies for coupled map lattice systems and then describe an optimization technique for choosing optimal feedback parameters.

Model Updating. The main idea behind controlling dynamical systems is to control apparently abrupt and intermittent transitions between dynamical modes of operation that are the mainstay of nonlinear chaotic systems. Some of the goals to be met while controlling spatiotemporal systems include formation of specific spatiotemporal patterns, stabilization of behavior, synchronization/desynchronization, suppression/enhancement of chaos, etc. The goal behind this adaptive feedback strategy is to control some specific property of the system. The controllers are applied in the feedback loops associated with every cell in the lattice structure, based on the internal states of the system. The control input U* to the system can be defined as follows:

$$U^{*k} = G(\psi^{*k} - \psi^k), \tag{3}$$

where G is the stiffness of control and ψ^* and ψ are the desired and estimated values of the system property respectively. The target value of the system property can either be a constant or a time varying function. In the case of a multidimensional system, ψ could be a global property of the system or some property of individual subsystems.

Optimization of Feedback Parameters. Next we introduce a performance function that can also be termed as an error function given below by equation (4) that calculates the error between the target value of the system property and the computed value at each time step. The goal of optimization is to minimize this error by choosing the most optimal feedback parameter for the system. If we choose the mean Lyapunov exponent $\bar{\lambda}$ as the monitored system property, then the function to be minimized is as follows:

$$\xi = \lambda^* - \bar{\lambda}^k, \tag{4}$$

where λ^* is the target value of the Lyapunov exponent and for a coupled map lattice we can define the mean Lyapunov exponent as

$$\bar{\lambda}^k = \frac{1}{L}\sum_{n=1}^{L} \lambda_n^k \tag{5}$$

Control Algorithms

Calculation of Lyapunov Exponents. When the objective is to maintain a desired level of chaoticity, a natural choice for the monitored property of the controlled system is the Lyapunov exponent. The global Lyapunov exponent for a discrete one dimensional system $x^{k+1} = f(x^k)$ can be defined by:

$$\lambda = \lim_{N\to\infty}\frac{1}{N}\sum_{k=0}^{N-1}\ln\left|f'(x^k)\right| \tag{6}$$

In order to study the evolution of Lyapunov exponents of a coupled map lattice system as described by equation (2), we first introduce the Jacobian matrix as follows:

$$\wp^k = \begin{bmatrix} \frac{\partial x_1^{k+1}}{\partial x_1^k} & \frac{\partial x_1^{k+1}}{\partial x_2^k} & \frac{\partial x_1^{k+1}}{\partial x_3^k} & \cdots & \frac{\partial x_1^{k+1}}{\partial x_L^k} \\ \frac{\partial x_2^{k+1}}{\partial x_1^k} & \frac{\partial x_2^{k+1}}{\partial x_2^k} & \frac{\partial x_2^{k+1}}{\partial x_3^k} & \cdots & \frac{\partial x_2^{k+1}}{\partial x_L^k} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ \frac{\partial x_L^{k+1}}{\partial x_1^k} & \frac{\partial x_L^{k+1}}{\partial x_2^k} & \frac{\partial x_L^{k+1}}{\partial x_3^k} & \cdots & \frac{\partial x_L^{k+1}}{\partial x_L^k} \end{bmatrix}$$

The Lyapunov exponents of the system are calculated from the eigenvalues of the above matrix. If the eigenvalues of the $\wp^k$ are {Λ_1^k, Λ_2^k, Λ_3^k, ..., Λ_L^k} then the local Lyapunov exponents are given by

$$\lambda_n^k = \log|\Lambda_n^k|; (n = 1,2,...,L) \tag{8}$$

Theorem 1. Consider a system described by equation (1). Let $\wp$ denote the Jacobian of F at X, and Λi denote the ith eigenvalue of the matrix $\phi_m = \wp(X_{m-1})..\wp(X_1)\wp(X_0)$, where X = X_0 at time step t = 0. Suppose that $\|\wp'(X)\| \le M$, where M is a positive constant and that the smallest eigenvalue of $[\wp'(X)]^T \wp'(X)$ satisfies $\Lambda_{\min}([\wp'(X)]^T \wp'(X)) \ge \beta > 0$, where $\beta \le M^2$ and $X \in \Omega$. Then for any $X_0 \in \Omega$, all the Lyapunov exponents at X0 are located inside the interval [0.5 lnβ, lnN].

Additive Control. For the system described by equation (1), this control strategy is implemented by the following general dynamical equations:

$$X^{k+1} = F(X^k) + U^k, \tag{9a}$$

$$U^k = G(\lambda^* - \lambda^k). \tag{9b}$$

Let us consider the logistic map, given by equation as an example:

$$x^{k+1} = \alpha^k x^k (1 - x^k) \tag{10}$$

Using equations (9) we can rewrite equation (10) as:

$$x^{k+1} = \alpha\, x^k (1 - x^k) + g(\lambda^* - \lambda^k)\,, \tag{11}$$

where g specifies the control stiffness for a single oscillator. Here the target value of the global Lyapunov exponent is a constant as opposed to a time varying function. The optimal value of the control parameter g needs to be worked out in any practical implementation of this strategy. For a coupled map lattice we use the mean global Lyapunov exponent as described by equation (5).

Multiplicative Control. Consider the system described by equation (1) with an additional controlled variable V. Here the control is implemented by changing this variable using a feedback method. Let us consider a lattice with controlled maps

$$X^{k+1} = F(X^k, U^k)\,, \tag{12}$$

where V^k is a multiplicative control. For multiplicative control of the lattice it is necessary to study a controllability problem. Suppose that the lattice includes only a single map with a scalar multiplicative control that can be described by the following equation:

$$X^k = F(X^{k-1}, U^{k-1}) = [A + BU^{k-1}]X^{k-1}, \quad k = 1,2,3,..., \tag{13}$$

where X^k is the state vector, U^{k-1} is the scalar control, and A, B are real constant matrices of appropriate dimensions.

If $\hat{\Re}^n = \Re^n - \{0\}$ is the punctured n-space, then

$$X^k = \prod_{i=1}^{k} \left[A + U^i B\right] X^0 \equiv \gamma(X^0, U_k) \tag{14}$$

$U_k = [U^1, ..., U^k] \in \Re^k$.

Definition 1. A lattice is said to be controllable on $\hat{\Re}^n$ if for any $X^1, X^2 \in \hat{\Re}^n$, there exists a positive integer *s* and finite control sequence U^s such that $X^2 = \gamma(X^1, U^s)$, where *γ* is a mapping factor.

The main result is stated in the following theorem.

Theorem 2. The lattice system given by (13) is controllable on $\hat{\Re}^n$ if there exist positive integers *P*, *Q* such that for all $X \in \hat{\Re}^n$ we have:

(a) $\|A^P X\| = \|X\|$,

(b) rank $H_Q(X) = n$,

where $H_Q(X) = [BA^{Q-1}X, ABA^{Q-2}X,..., A^{Q-1}BX]$.

The feedback control algorithm can be described by the following equations:

$$X^{k+1} = F(X^k, U^k), \tag{15a}$$

$$U^{k+1} = U^k + R(\lambda^* - \lambda). \tag{15b}$$

where *R* specifies the control stiffness in this case. This scheme as with the previous one is adaptive in nature in that the parameters that determine the nature of dynamics adapt themselves to yield the desired dynamics. This type of feedback has also been termed as “dynamic feedback control” in literature [6]. We demonstrate the implementation of this control strategy in both single and coupled logistic maps, the monitored property being the mean Lyapunov exponent in the latter case.

Additive and Multiplicative Control. The third and final control strategy described in this paper is a combination of both additive and multiplicative control. The implementation of control in this case follows naturally from the above two schemes and can be described by the following dynamics:

$$\begin{aligned} X^{k+1} &= F(X^k, V^k) + G(\lambda^* - \lambda^k), \\ V^{k+1} &= V^k + R(\lambda^* - \lambda^k). \end{aligned} \tag{16a}$$

Heuristic Optimization Technique. The application of optimization techniques in control of dynamical systems involves minimizing the error function described in equation (4). The objective of the optimization technique in our examples is to find the optimal stiffness parameter that gives a constrained minimum of the error function. Consider the multiplicative control strategy as described in section 3.3. We define the linear inequality Rmin≤***R***≤***R***max and proceed to find iteratively, the value of ***R*** that gives the minimum of equation (4).The problem is formulated as follows:

$$\min_R \xi(R) \text{ subject to: } R_{\min} \le R \le R_{\max}, \tag{17}$$

We have used the Matlab ® optimization toolbox to solve this optimization problem. A sequential quadratic programming (SQP) method is used to solve this minimization problem. In this method, the function solves a quadratic programming (QP) sub-problem at each iteration. An estimate of the Hessian of the Lagrangian is updated at each iteration. A line search is performed using a merit function similar to that proposed by [22-23]. For a more detailed explanation of the optimization function refer to Matlab® optimization toolbox documentation. multiplicative control strategies respectively.

Numerical And Experimentsl Results

Experimental studies in rodent models of epilepsy [Nair, 2004] have used EEG recordings from four to six electrodes placed in frontal and temporal regions of the animal brain. We have therefore chosen a CML model with five non-identical logistic maps. The system parameters $\alpha_1 \ldots \alpha_5$ were chosen randomly as 3.9, 3.97, 3.95, 3.965 and 3.96. The coupling term ε was varied from a value of 0.10 to 0.14 to study the dynamical behavior in both the spatial and temporal regimes. Figure 1 shows the changes in spatiotemporal patterns as we increase the value of the parameter ε. For illustration purposes we have only shown the amplitude and Lyapunov exponent profiles of the single cell (cell 1). The remaining cells exhibit a similar pattern. As we increase the value of ε gradually as shown in Figure 1D, the amplitude plot, shown in Figure 1A becomes more ordered and we can also see a drop in the Lyapunov exponents (calculated as a running mean) from the same time series, suggesting a more ordered state as illustrated in Figure 1B. Figure 1C shows the mean Lyapunov exponent profile calculated over all 5 cells in the CML. We can observe a gradual fall in the values of this global measure with increasing values of coupling.

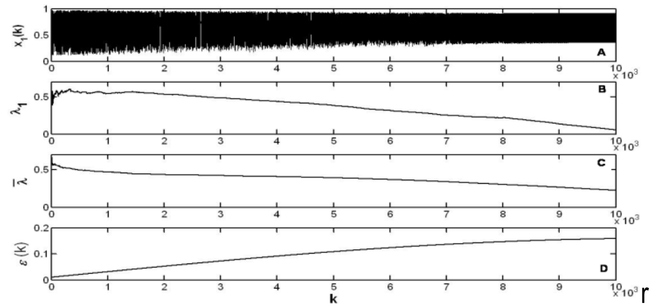

Fig. 1. (A) Amplitude spectrum as a function of time; (B) Lyapunov exponent profile of the single cell; (C) Mean Lyapunov exponent profile (L=5) estimated from a five cell CML; (D) parameter ε as a function of time.

Figure 2 illustrates the feedback control strategy also referred to as 'dynamic feedback control' in literature [Nair, 2004] described, for a target $\lambda^* = 0.3$. Since there can be several values of the controlled parameter α (corresponding to several different attractors) which gives the desired value of the Lyapunov exponent, the actual value of the controlled parameter takes depends on the stiffness of control, and initial conditions. The fluctuations in the controlled parameter are proportional to the value of the stiffness, converging to a single value for small stiffness while exhibiting large variations for higher values of stiffness.

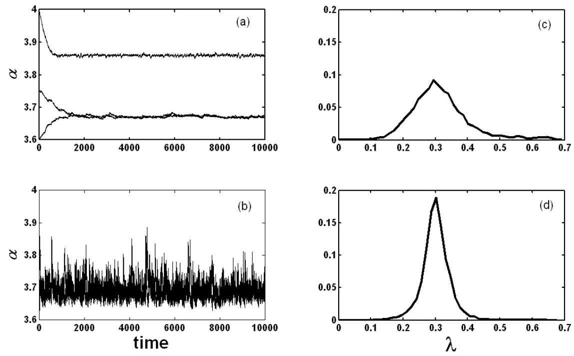

Fig. 2. Multiplicative control: of the parameter α as a function of iteration step for $\lambda^* = 0.3$, and stiffness a) g = 0.001, and b) g = 0.02. The different curves correspond to different initial α. Probability distributions of finite step Lyapunov exponents for α0 = 4.0 and stiffness (c) g = 0.001, and d) g = 0.01.

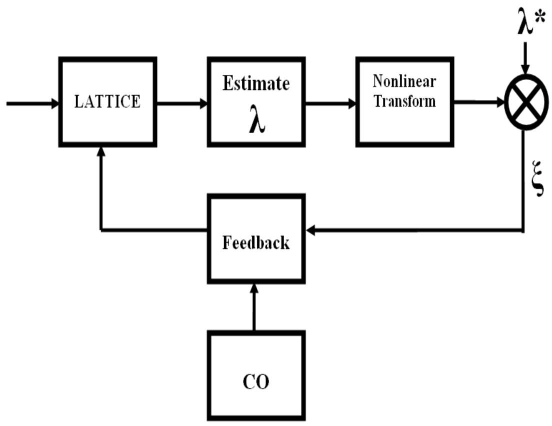

Fig.3. Proposed adaptive learning algorithm for a coupled map lattice via optimized feedback control to emulate the target dynamics of any complex network. CO refers to the constrained optimization block. ξ refers to error generated from nonlinearly transformed estimates of local Lyapunov exponents and target Lyapunov exponents.

Conclusions

In this paper, we have proposed an optimization method to control of spatiotemporal dynamic in coupled map lattice systems. We showed that a constrained optimization technique can be used for minimization of an error function to select optimal control parameters. It is also shown that feedback control can be applied to systems with hidden variables and hence may be plausible in control design for a highly complex system such as the epileptic brain where not all variables are known.

This paper presents a method to calculate finite-time Lyapunov exponents for experimental time series using numerical simulation to approximate the local Jacobian of the system at each time step. This combined numerical–experimental approach to the calculation of Lyapunov exponents is applicable to any physical system which can be numerically approximated.

Successful applications of control techniques to the brain dynamics must address in a comprehensive fashion at least the following items: (i) selection of variables for inputs, outputs and desired behaviors, (ii) construction of dynamical models of brain sites and its interactions, (iii) appropriate simplifying hypothesis to establish performance bounds.

We propose a learning algorithm in which a coupled map lattice system can be used to model the dynamical evolution of Lyapunov exponents in a complex system (Figure 3). The algorithm involves generating an error function between the target Lyapunov exponent profile of the complex system and some nonlinear transformation of estimated lattice Lyapunov exponent values. The error is used to generate an optimized feedback input to the lattice. Such a learning algorithm can be used in developing realistic model of complex system dynamics and hence make the models more useful in the study and control of such complex systems.

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Area of research: modeling**,** control of chas, optimization

SOME ASPECTS OF CHOICE OF SWITCHING SCHEME FOR CONSTRUCTION OF OPTICAL SIGNALS' SWITCHING SYSTEM

Yuri Grinkov

Abstract: *Some aspects of choice of switching scheme for optical signals' square switching system's construction of big capacity are considered in the work. Variant based on scalar criteria of choice is offered and multicriteria optimization which allowed to receive results which can be applied at designing of optical signals' switching systems is made.*

Keywords: *optical switching, optical signals' switching systems, switching schemes, scalar criteria of choice.*

ACM classification keywords: *B.6 LOGIC DESIGN – B.6.3 Design Aids, B.4 INPUT/OUTPUT AND DATA COMMUNICATIONS - B.4.3 Interconnections (subsystems)*

Introduction

At present time it is impossible to imagine modern computer technologies, communications, management's and signals' processing's facilities without use of optical components. This is consequence of prompt development of fiber and integrated optical technologies on the one hand and with another – consequence of constantly growing requirements of channels' information capacity, information processing speed and telecommunication networks' (TN) reliability increase. Nevertheless till now switching schemes basically are realized on electronic elements that not only limits TN's operating speed as a whole but also demands additional engineering study of questions connected with optical and electronic elements' correct interaction's maintenance.

New problems which are directed on increase of information processing's speed demand revision of approaches not only to designing of telecommunication objects but also physical principles on the base of which these objects' components are constructed.

Graphic evidence of these problems' urgency is all-optical networks' (AON) concept based on application of exclusively optical technologies. Research of AON's concept has shown its application's efficiency first of all at transport level during creation of branched out network architecture. However at the same time creation of branched out optical networks demands decision of major problem – optical signals' switching systems (OSSS) realization. Analysis of problem's status in sphere of optical networks' creation [1-5] has shown that at present time fiber-optical transfer's systems' functioning's principles are studied well enough. At the same time questions of OSSS's realization are considered superficially and demand carrying out of further researches. Now there are only general conceptual approaches to OSSS's construction demanding development and careful analysis.

Statement of the problem

Existing optical signals' switching methods [6] provide necessity of preliminary transformation of optical radiation bearing the information in the electronic form (O/E), electric signal's switching and electrooptical reconversion (E/O) with the subsequent strengthening of optical radiation's power (fig. 1).

Such approach to optical signals' switching imposes restrictions on switching system's (SSt) bandwidth and its capacity. Realization of information signal's double transformation firstly essentially limits SSt's bandwidth (to 2,5 Gb/s) and secondly it is characterized by excessive power consumption that raises cost of device's operation.

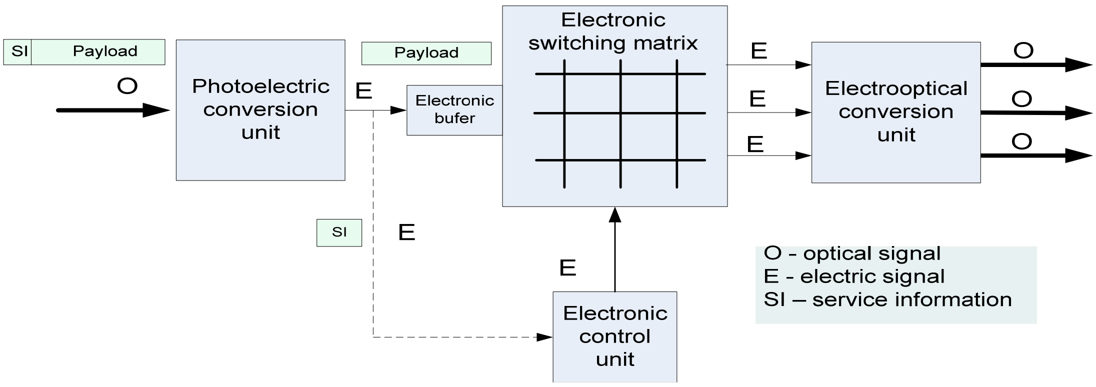

Figure 1 – O/E/O switching system's block diagram

Moreover raised power consumption and presence of cross-fire leads to restriction of similar switching systems' capacity which does not exceed 32x32. [7,8]

So electron-optical switching systems become TN's bottleneck and are deterrent at escalating of its bandwidth. To eliminate this phenomenon it is necessary to develop OSSS's model which will not only switch signals in the optical form but will also provide management of switching process by means of optical radiation. Here under the optical management of switching process it is understood management of information's carrying over between optical channels which is realized exclusively with use of optical technologies and allow to make transition to penta-bit speeds of information transfer in TN.

In all-optical switching system's model (fig. 2) information optical signal bearing some block of information and which is simultaneously being remembered by optical buffer (OB) arrives on entrance of optical management's module (OMM) which provides analysis of information block, allocates address information and generates optical signal of optical switching matrix's (OSM) management after its processing. Then optical signal is being taken from OB and following switching way arrives on exit of SSt. After increasing of power signal is being transferred by optical waveguide to the following switching node.

Despite advantages of all-optical approach to switches' construction its application meanwhile causes number of complexities. First of all it concerns OMM's realization using optical processors applied in war industry and nuclear power engineering cost of which exceeds cost of their electronic analogues in ten times [9].

One more obstacle in a way OSSS's development is complexity of optical buffer's with direct access (Optical RAM) working out. Fiber delay lines (FDL) existing for today are capable to accumulate optical signal only during limited time interval that is caused by extremely fast attenuation of optical radiation in tiny delay's loops [10].

In this connection actual problem is creation of hybrid OSSS's model for transition period which realizes "cut through" concept without buffering that will allow to raise efficiency of optical networks' functioning. Such OSSS's model should be deprived electron-optical transformation of information signal and switching management can be realized in electronic way. It will allow to solve problem of high power consumption and complexities of big capacity's switching systems' construction by use of microelectromechanical systems' (MEMS) technology [11] using high-efficiency's electronic processors accessible under the price for management of optical switching sphere.

Thus one of actual problems at OSSS's designing with capacity higher than 1024 ports is definition of the optimum switching scheme. This work is devoted to the decision of problem of choice of optimum switching scheme for square multicascade OSSS's development.

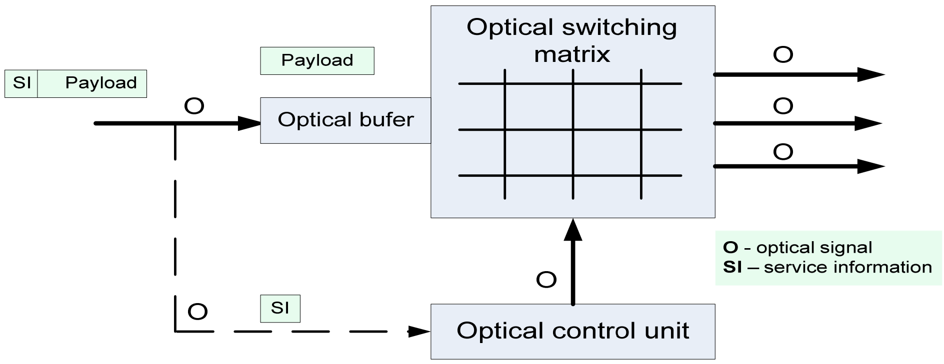

Figure 2 – O-O-O switching system's block diagram

Basic principles of optical signals' switching systems' development

At the construction of spatial optical signals' switching systems functional suitability and effectiveness of OSSS are being estimated using the following features [12,13]:

– blocking characteristics;

– number of basic elements;

– homogeneity of switching;

– crossing of waveguides.

Possibility of connection between any pair of free ports on the input and output (X_{in}, Y_{out}) is understood as blocking's characteristics of switching system. Depending on this characteristic there are non-blocking and blocking switching schemes [14].

Non-blocking of switching scheme is a key requirement for spatial optical signals' switching systems. Meanwhile non-blocking switching schemes in turn are divided into:

– non-blocking in the strict sense;

– non-blocking in the wide sense;

– non-blocking with rerouting.

Non-blocking switching schemes in the strict sense is a type of schemes that does not require rerouting of any connection when using any handshake.

Non-blocking switching schemes in the wide sense characterizing by the lack of appropriate rerouting of existing connections only in case of use of specific connection's establishment's procedure.

These first two types of non-blocking switching schemes today can be effectively used for the construction of OSSS. This is because the non-blocking schemes require tunable rerouting of existing connections which is problematic because of the need in optical signal's buffering.

Under the basic element (BE) multistage switching scheme it is understood the switching device 2x2 or 1x2. Consequently at the stage of switching system's design it is necessary to minimize the number of basic used elements which allows reducing of the developed device's elements. Crossing of waveguides is necessary to minimize or eliminate altogether since it determines the appearance of optical power loss and transition loss as a result of the interaction of light beams.

Under the homogeneity of the switching it is meant equality of minimum and maximum number of primitives that will be an optical signal before it reaches the output switching system. Given the fact that each basic optical element introduces attenuation the design of OSSS should strive to ensure that firstly the number of basic elements through which the optical signal has been minimal and secondly, the minimum and maximum losses signals must be identical. Among the existing schemes of switching devices' combining satisfying non-blocking it can be distinguished: matrix, scheme of Benesh, scheme of Shpanke and scheme of Shpanke-Benesh [12]. The main characteristics of non-blocking switching schemes are shown in table 1

Table 1 – Features of non-blocking switching schemes *NxN*

Scheme / Features	**Matrix**	**Benesh**	**Shpanke-Benesh**	**Shpanke**
Non-blocking	In the wide sense	With rerouting	With rerouting	In the strict sense
Number of BE	N^2	*N(2log2N-1)/2*	*N(N-1)/2*	*2N(N-1)*
Maximum losses	*2N-1*	*2log2N-1*	*N*	$2\log_2 N$
Minimum losses	*1*	*2log2N-1*	*N/2*	$2\log_2 N$
Homogeneity of switching	No	Yes	No	Yes
Crossing of waveguides	No	Yes	No	Yes

The solving of the task of switching scheme's selection

There is a set of switching schemes Ω consisted of certain variants ω_i so that each certain variant $\omega_i \in \Omega$ is considered to be a point in a space of quality's indexes and a set of possible variants Ω is defined as an existence domain: $\Omega = \{\omega_i\}$, $i = \overline{1, N}$.

Alternative variants of homogeneous set Ω are presented by minimum final descriptions corresponded to parametric of switching scheme $P = \{p_j\}$, $j = \overline{1, J}$ that describes adequately of each variant of homogeneous set Ω. The set of characteristics $\{p_j\}$ for switching schemes $\Omega = \{\omega_i\}$ consists of subset of quality's indexes $\{k_l\}$ and subset of conditions $\{У_z\}$. The set of alternatives that satisfies combination of circumstances C_∂, that is acceptability requirement is an acceptable set Ω_∂.

Taking into consideration that a key condition of realization of OSSS is a requirement of non-blocking switching scheme the set Ω_∂ composes from the following switching schemes: matrix scheme W_1, scheme of Benesh W_2, scheme of Shpanke-Benesh W_3 and scheme Shpanke W_4.

The problem of choice is to choose a variant from a set of possible switching schemes $\Omega_д$ that has the best meaning k_l in terms of accepted criterion formulation.

Before creating criterion formulation $K=\{k_1,\ldots,k_M\}$, it's necessary to display switching schemes' characteristics on number scale. An ordinal scale is used to describe qualitative characteristics such as type of non-blocking and switching homogeneity. Quantitative characteristics such as number of basic elements, minimum and maximum loss are displayed on absolute scale.

Let k_1 is type of non-blocking switching scheme, k_2 – number of basis elements, k_3 – maximum loss, k_4 – minimum loss, k_5 – homogeneity of switching, k_6 – crossing of waveguides. So criterion formulation K has the following form:

$$K = \{k_1 \to \max, k_2 \to \min, k_3 \to \min, k_4 \to \min, k_5 \to \max, k_6 \to \max\} \quad (1)$$

In consideration of the fact that switching schemes' characteristics have different physical dimensions, it's necessary to do normalization of datum value. Meanwhile influence of every normalized index on efficient feature will be comparable, if a range of possible changes of each index is common. There to the following formula (3.5) is used:

$$k_1 = \frac{(k_l - k_l^{*})}{(k_l^{**} - k_l^{*})} \quad (2)$$

where $k_l^* = \min k_l \in \{k_l\}$, $k_l^{**} = \max k_l \in \{k_l\}$.

Applying the formula (2), characteristics of non-blocking of switching schemes after normalization is received for every characteristic k_l.

Determination of used selection criterion is an important step of task's solving. Vector criteria (Pareto and Slater criteria) permit to reject the worst variants and to reveal not bad but effective by Pareto and Slater. The main feature of vector criteria is objectivity because quality's indexes in such criteria are independent [15].

Taking into consideration the fact that formulated problem in this work provides for presence of independent quality's indexes (particularly homogeneity of switching depends on number of minimum and maximum loss), the use of vector criteria is unreasonable.

More over one of the main demand to use Pareto and Slater criteria is comparability of variants. Variants are comparable, if all quality indexes' meanings of a variant are more (or less) then the other variant. If it's not, the variants are incomparable. Preliminary analysis of initial set of permissible variants shows a small number of comparable variants that helps to make a conclusion about inefficiency of use of vector criteria for solving assigned problem.

Distinctive feature of scalar criteria is a possibility to receive the only variant of solution. However, a scalar criterion has a great part of subjectivity of a person who makes decision. In the case of solving a problem of choice of switching schemes, a function of a selection becomes a functional that is a complex quality index which reflects cumulative target effect. So it's reasonable to use an integral test of comparison of alternatives.

A ranking method is used for fixing peer reviews of weighting factor, because this method provides for the possibility of accurate estimation of importance of each index of selected variant. The essence of the method is estimation of quality indexes on relative scale (for example, over the range from 1 to 10). According to this method, weighting factor for M indexes are calculated with the help of the formula (3)

$$a_l = \lambda_l / \sum_{l=1}^{M} \lambda_l, \qquad (3)$$

where λ_l – value index of *l* factor.

Meanwhile, the following formula (4) is used for M weighting factors.

$$\sum_{i=1}^{M} a_l = 1, \qquad a_l \geq 0, \qquad \overline{l = 1, M}, \qquad (4)$$

Estimation of quality indexes on 10 point scale is seen in a table 2.

Table 2 - Estimation of quality indexes on scale of importance.

Quality indexes	Mark
Type of non-blocking, a_1	10
Number of basic elements, a_2	3,51
Minimum loss, a_3	1
Maximum loss, a_4	1,49
Homogeneity of switching, a_5	2
Crossing of waveguides, a_6	1,8

Weighting factor of every quality index is defined with the help of equation (3) that permitted to solve the task of selection of switching schemes by means of integral criterion of additive type (5).

$$W' = \sum_{l=1}^{M} a_l k_l, \qquad l = \overline{1, M} \qquad (5)$$

Calculation results of integral criterion of selection for every switching scheme (SS) W_i are given in figure 3.

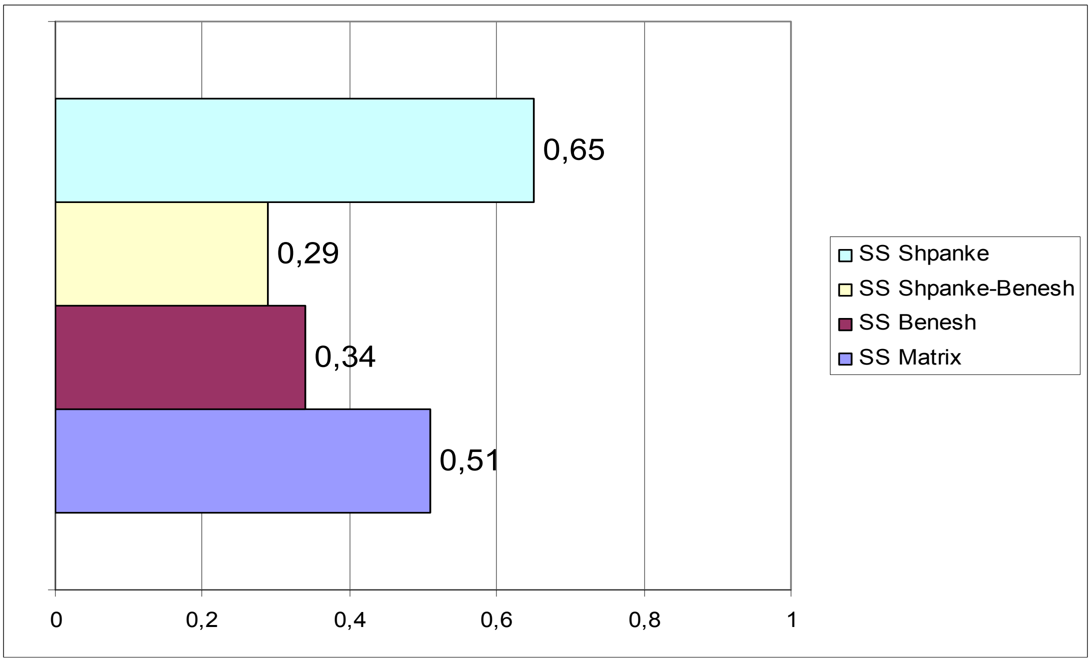

Figure 3 – Indexes of integral criterion of selection for non-blocking switching schemes.

Thereby calculation results shows that alternative W_4 (switching scheme of Shpanke) is optimal, because it's an only scheme among all the schemes satisfies strict non-blocking condition.

Conclusion

Introduced in the work approach for the selection of optimum switching scheme for switching system's development permits to confirm the explicitly that conducting of multiobjective optimization is characterized by the great subjectivism of a person who makes a decision. Adequacy of such optimization depends on person's qualification and professionalism.

Problem's solving with use of integral criterion permitted to define optimality of switching scheme Shpanke usage for construction of square high capacity's optical signals' switching systems. Indubitable advantage of Shpanke's switching scheme is a characteristic of strict nonblocking. But great amount of 1x2 devices are needed for its realization. Another switching schemes considered at the problem's solving can be used to construct multistage switching systems of optical signals only when problems of optical realization of existing connects' rerouting is solved.

Acknowledgements

The paper is published with financial support by the project ITHEA XXI of the Institute of Information Theories and Applications FOI ITHEA (www.ithea.org) and the Association of Developers and Users of Intelligent Systems ADUIS Ukraine (www.aduis.com.ua).

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The main areas of research: all-optical networks, switching of optical signals

MODELING AND OPTIMIZATION OF CRYOGENIC – OPTICAL GRAVIMETERS

Vitaliy Yatsenko, Nikolay Nalyvaychuk

Abstract: *This paper considers the problem of designing and developing optical-cryogenic devices using optimization techniques, modeling, and new materials. We have shown how to produce reliable YBCO thin films with controllable surfaces and physical properties and how to integrate them in a ring form into the optical-cryogenic gravimeter so as to reduce its size and render it convenient for future space applications. Its function is based on the magnetic levitation phenomenon of the probe and on the measurement of its displacement with subsequent data processing.*

Keywords: *gravimeter, modeling, optimization, HTSC, YBCO, thin films, superconducting ring*

ACM Classification Keywords: *1.6. Simulation and modeling, H.1 Models and principles. Optimization*

Introduction

Since their discovery, the high temperature superconducting (HTSC) materials have always been a very promising technology for integration in electronic multilayered assemblies, such as antennae, filters, SQUID-s etc. due to their exotic properties.

YBa2Cu3O7-x (YBCO) has attracted a lot of research interest since it is still superconducting at temperatures above that of liquid nitrogen (70 K) and exhibits the highest currents recorded in the literature, of the order of 10^8 A/cm^2 [Vassiloyannis, 1999], enabling the construction of experimental devices highly sensitive in magnetic field changes. In this paper we concentrate in an attempt to integrate YBCO thin films in a ring form into the gravimeter described in [Yatsenko, 2003] in order to reduce its size and make it convenient for future space applications.

Highly monocrystalline good quality YBCO thin films can be reliably deposited onto SrTiO3 substrates by Pulsed Laser Deposition (PLD) with Tc values ranging from 89 up to 91 K [Wellhofer, 1998]. Films grown on nominal [001] substrates exhibit, however, non-controllable surface morphologies [Vassiloyannis, 1997], with island growth and deep trenches in between which render the material unreliable for further integrations, since these features tend to create undesired holes and joins between adjacent deposit layers. It has been shown [1] that offcutting the STO substrate by 1.69^o off the (001) towards the (100) plane allows the growth of smoother YBCO films with a controllable surface morphology (with average surface roughness Ra ~ 1.05 nm, even less than the YBCO unit-cell height) and with improved physical properties, i.e. an average current density Jc measured up to 108 A/cm^2 for B = 0.2 T and T = 4.2 K. In this report we propose the integration of 130-230 nm thick YBCO films grown on 1.69^o miscut STO substrates with single offcut direction [5] for the construction of a gravimeter.

The concept of the cryogenic-optical sensor

The sensor is based on a new type of free suspension of the probe of the superconducting gravimeter. Its functioning is based on the magnetic levitation phenomenon of the probe and on the measurement of its displacement with subsequent data processing. A free suspension of a probe can be realized using the Braunbeck-Meisner phenomenon due to the ideal diamagnetism of a superconductor solid sphere. Our conception is based on the zero electrical resistance of a closed coil, for example, a ring which, due to levitation, may have a free equilibrium position. As a consequence of the superconducting phenomenon, the ring achieves zero electrical resistance. At the same time, modern methods of signal processing are used for estimation of a small perturbation (against a background of significant noise) which corresponds to parameters of the measured gravitational field.

The newly developed superconducting gravimeter is represented by a spring type suspension. An analogue of the mechanical spring of our device accomplishes the magnetic returning force acting on a superconducting probe in a non-uniform magnetic field of superconducting rings or in a permanent magnet (in another variant). Due to the high stability of the superconducting currents of the rings, a highly stable non-dissipative spring is created.

The gravimeter is based on the following principle. In balance a probe is levitated in the position where the gravitational force is compensated by the magnetic force which acts in the opposite direction. At a gravitation change of the probe, it is moving from its zero position and an optical sensor measures an error signal. Due to current change in a control ring, a self-tuning system creates an additional magnetic field that is proportional to the signal which keeps the probe in zero position. Since the returning force is a linear function of the current, its measurement in a control ring provides linear estimation of the gravitation force changes.

This suspension needs a high precision optical registration system for the probe displacement. It is proposed to estimate the position of the probe by a laser sensor that allows to exclude the electric and magnetic fields which affected the probe. For detection of supersmall displacements it is proposed to use a modern interferometry method and dynamical effects of a laser signal constrained that correlates with mechanical displacement of the probe. An interferometric method can provide a precision of coordinate measurement of the probe at most 0.1 nanomenter.

An experimental scheme with a laser displacement sensor has been selected and realized. This sensor provides a conversion of a signal into the digital form for signal processing. Recently it has been shown that the optical sensor based on a laser diode with an external resonator as a source of monochromatic radiation, and a single mode optical fibers as a channel for light transportation to the probe preserving the coherence of an optical radiation) satisfiy all the necessary requirements.

Several stages are used for signal processing in a cryogenic-optical gravimeter. The first stage consists of noise compensation which influences the mechanical part of the device. The second stage is focused on the use of an inverse dynamical model of the sensor. An adaptive digital filter is used at the third stage of signal processing. A combination of a free probe suspension, the use of an optical registration system, and new tools of signal processing provide new dynamic properties to our device.

Modeling and Optimization

A fundamentally new optic-cryogenic sensor based on superconductive nanofilms has been grounded and mathematically modeled. Also the problem of optimal supersmall acceleration estimation has been investigated. The new principles of such sensor construction, has been proposed. We analyze the problem of the sensor resistance using modern theoretical and experimental approaches. Also a model of a quantum device for optimal information processing has been consodered. Solving of these problems requires further development of the bilinear dynamical systems theory and investigation of chaotic regimes of the "10^{-10} g" dynamics. Taking into account the sensor competitiveness and high sensitivity to gravitational perturbations, we plan to cover the device by a patent. Also mathematical modeling of separate sensor components (superconductive suspension, laser sensor and software) has been conducted. The modeling of the satellite sensor for micro-gravitational perturbation estimations has been grounded. Moreover, nanomaterials suitable for constructing such accelerometers have been determined. This will allow creation of adaptive micrometer-size gravimeter sensors for microsatellites. In this chapter, we describe a superconducting gravity meter, its mathematical state. We have also presented a mathematical model of the superconducting uspension which is based on a magnetic levitation. A nonlinear control algorithm has been implemented for the purpose of maintaining chaotic behavior in the sensor.

Nonlinear properties of a magnetic levitation system and an algorithm of a probe stability are studied. The phenomenon, in which a macroscopic superconducting ring chaotically and magnetically levitates, is considered. A nonlinear control scheme of a dynamic type is proposed for the control of a magnetic levitation system. The proposed controller guarantees the asymptotic regulation of the system states to their desired values. We found that if a non-linear feedback is used then the probe chaotically moves near an equilibrium state. An optimization approach for selection of optimum parameters is discussed

The new recurrent RBF network architecture have been introduced as practical solutions to the noise cancellation problem. It has been shown that the properties of the signals involved induce biased estimates of the filter parameters in many practical cases. Although these effects can be eliminated by estimating a disturbance model, it has been demonstrated that this additional

New filter realizations based on both the traditional and a new recurrent RBF network architecture have been introduced as practical solutions to the noise cancellation problem. It has been shown that the properties of the signals involved induce biased estimates of the filter parameters in many practical cases. Although these effects can be eliminated by estimating a disturbance model, it has been demonstrated that this additional complexity can be avoided by employing a new approach that mitigates the problem of bias without introducing excessive computational complexity. Incorporating the ideas into a new RBF architecture provides an alternative structure to traditional polynomial nonlinear filter design by combining the approximation capacity of the network with unsupervised/supervised learning scheme comprising two separate consecutive stages, a k-means clustering procedure and a suboptimal least-squares-based network updating strategy.

In contrast to the conventional recursive schemes, the latter can be implemented by performing a sequence of Givens rotations in a highly efficient manner with numerical robustness. In addition, the inclusion of linear dynamic link connections has been shown to enhance convergence. Finally, simulation examples have been described to demonstrate the potential of the new RBF noise cancellation filter design. These results, coupled with the on-line monitoring capabilities of the model validity tests, suggest that the new RBF filter provides an appropriate structure for noise cancellation filter design. A comparison with earlier results given in Billings and El-Hitmy (1990), which employed various simpler linear and nonlinear polynomial models with the present design, indicates that the new design framework based on the recurrent RBF network structure coupled with the hybrid training algorithm exhibits excellent complexity can be avoided by employing a new approach that mitigates the problem of bias without introducing excessive computational complexity.

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Experiments

The superconducting gravimeter is a spring type gravimeter in which the mechanical spring is replaced by a magnetic levitation of a superconducting sphere in the field of superconducting, persistent current coils. The object is to utilize the perfect stability of supercurrents to create a perfectly stable spring. The magnetic levitation is designed to provide independent adjustment of the total levitating force and the force gradient so that it can support the full weight of the sphere and still yield a large displacement for a small change in gravity. The gravimeters provide unequaled long term stability so that instrumental noise can be either below geophysical and cultural noise or indistinguishable from it over periods ranging from years to minutes. This article reviews the construction and operating characteristics of the instruments, and the range of research problems to which it has been and can be applied. Support for operation of the instruments in the United States has been limited so that operation of multiple instruments for periods much longer than a year has not been possible. However, some of the most appropriate applications of the instrument will require records of several years from arrays of instruments. Commercial versions of the instruments have now been purchased in sufficient numbers elsewhere in the world so that a world-wide array has been organized to maintain instruments and share data over a period of six years.

A $YBa_2Cu_3O_{7-x}$ thin film of 130-230 nm in thickness was grown onto a $SrTiO_3$ substrates vicinally offcut at 1.69^o off the (001) towards the (100) plane. The substrate was firstly pre-annealed at 900^{o}C for two (2) hours and then studied using a Digital Instruments Nanoscope II AFM in air with the cantilever force at 8 nN in order to evaluate its surface stepped structure. The YBCO film was subsequently deposited onto the substrate by Pulsed Laser Ablation (PLD) with the specimen being heated during the whole process at a temperature of 820^o C in an oxygen atmosphere at a dynamical pressure of 0.4 Torr [3]. The film orientation with respect to the substrate c-axis was examined by conventional θ-2θ scans using a Siemens D5000HR high resolution, four circle, six axis diffractometer, with a CuKa source. Rocking curve experiments enabled measurement of the film full width at half maximum (FWHM), whilst φ-scans through the (018) YBCO peaks were conducted to evaluate the film in plane alignment. The film surface was characterized using a Digital Instruments Nanoscope II STM (scanning tunneling microscope) operating in constant current mode at a bias of 800 mV and a tunneling current of 50 pA. Average magnetization measurements have been performed at temperatures of 4.2, 25, 50 and 77 K using an Oxford Instruments Vibrating Sample Magnetometer (VSM).

The specimens firstly reached the required temperatures in zero field cooling mode and data were collected with the field being increased up to 12 T at a sweep rate of 10 mTs^{-1} and then decreased down to 0 T. M-O images were received of the specimen using a typical ferromagnetic iron garnet (Bi_x $Lu_{3-x}Ga_yFe_{5-y}O_{12}$) grown on a GGG garnet ($Gd_3Ga_3O_{12}$) ([1] and references therein) in combination with a mercury arc light source and filter. The polarizer/analyzer system maintained stable at all processing times at an extinction angle of 6o off their crossed position. A CCD camera with various shutter speeds (from 1/120 up to 1/40000 s^{-1} of a Nikon Optiphot 100S optical microscope with a x5 objective lens and a 60 W white light was used to capture the M-O images.

Results

X-ray Characterisation: A sharp superconducting transition at ~ 90 K has verified the good superconducting character of the specimen under study [Vassiloyannis, 1999]. A full width at half maximum (FWHM) value of 0.3212^o for the (005)YBCO reflection confirmed the onocrystalline nature of the film. θ-2θ diffractograms with only (001) peaks of the film and the substrate verified only one crystalline phase of the film with its c-axis aligned along the substrate c-axis[Vassiloyannis, 1999]. The -scan diagrams captured evidenced the absence of impurity phases or of grains of different orientation on the film [Vassiloyannis, 1999].

AFM-STM Evaluation: The data received during the AFM study on the STO substrate after the preanneling treatment revealed a uniformly shaped substrate surface. An image received of a representative area 1×1 m^2 of the substrate surface is shown in Fig. 1 as a “top view” plot with the color scale representing the height above the lowest point of the AFM scan: steps uniformly shaped with a width of 114 nm and a height of 2.93 nm were visible along the (100) direction demonstrating the sample offcut direction, while some rare steps smaller in width were also seen along the (010) and (110) directions. The steps consist of several STO unit cells in height (STO unit cell height ~ 0.389 nm ([Vassiloyannis, 1999], and references therein)), while they are also larger in width than the STO unit cell as expected by the specimen offcut angle. The stepped structure of the substrate influenced the structure of the film deposited, the surface structure of which also followed a well consistent stepped morphology. In that case, as can be seen in the 0.5×0.5 μm^2 image shown in Fig. 2., the YBCO film surface also consists of almost single oriented steps, with an average surface roughness R_a=1.05 nm (even smaller that the YBCO unit cell height, 1.12 nm [Vassiloyannis, 1999], , while some smaller steps are also distinguished along the (110) direction.

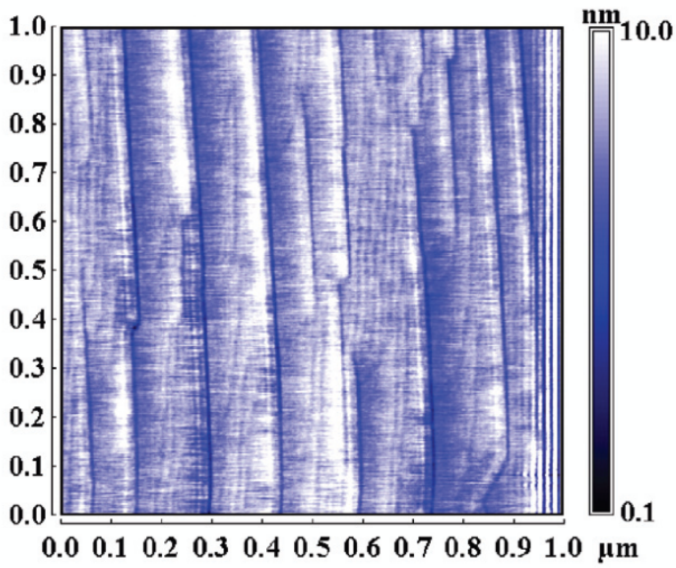

Figure 1 – AFM-image of the 1.69° off cut STO substrate

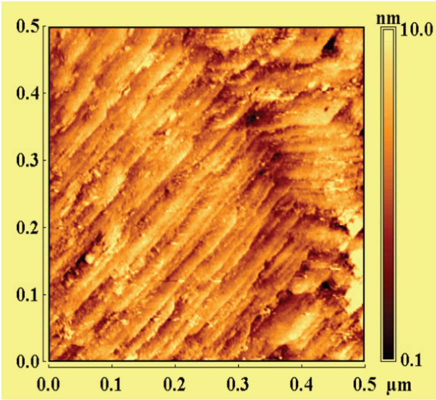

Figure 2 – Corresponding STM-image of the YBCO film grown

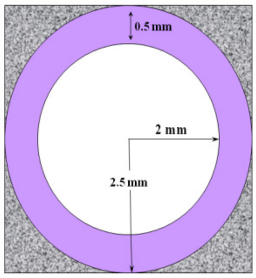

Figure 3 – Schematic representation of a superconducting ring 0.5 mm in diameter (purple area) on a 5.5 mm2 YBCO thin film platelet with outer radius 2.5 mm and inner radius 2mm

VSM Measurements: The magnetic hysteresis half-loops received by the VSM measurements are symmetrical for fields above 0.2 T for all temperatures [Wellhofer, 1998]. Therefore, the average current density flowing within the film can be extracted according to the Bean model and references therein) using the following formula:

$$J_c = 240(\nabla M/t) \tag{1}$$

where ∇ M is in emu, t in cm and J_c in A/cm^2. The average current density dependence over field increase for the four (4) different temperatures studied for the 1.69^0 sample are illustrated in figure 4. A top value of $6x10^{11}$ Am^{-2} is captured for B=0.2 T and T=4.2 K.

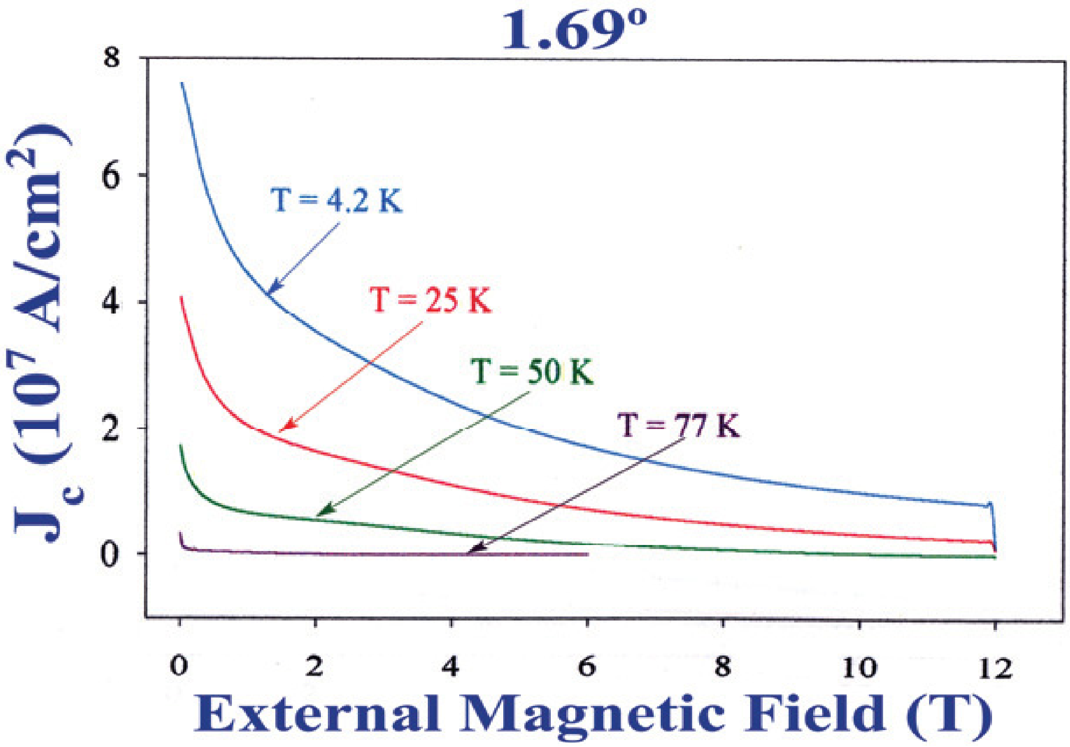

Figure 4 – Average current density Jc for the 1.69° specimen extracted by VSM hysteresis loop measurements

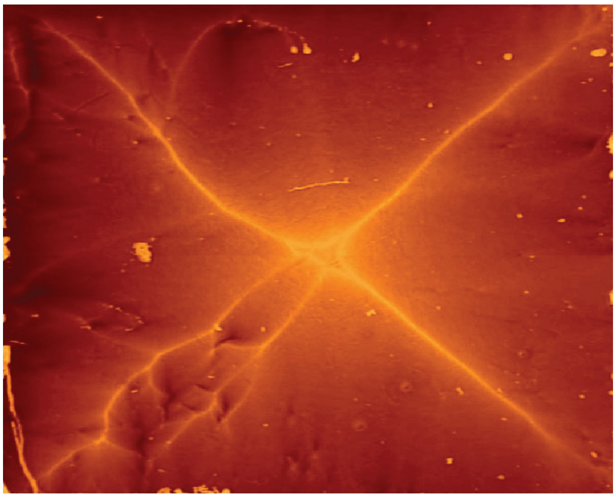

Figure 5 – Top-view M-O image of the 1.69° film for full penetration of the external field at T=25 K and B=103.8 mT

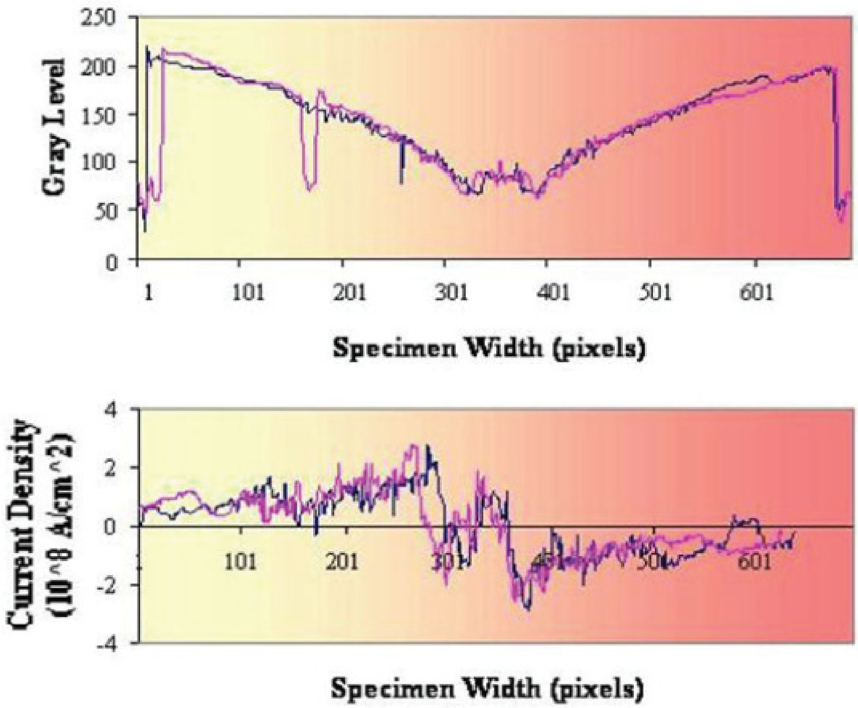

Figure 6 –J_c current densities in the parallel (blue) and perpendicular (pink) direction of the specimen [100] direction. J_c current densities in the parallel (blue) and perpendicular (pink) direction of the specimen [100] direction

M-O Analysis: A M-O image captured of the 1.69o sample at T=25 K and B=103.8 mT (full field penetration into the sample) is illustrated in Fig.5. as top-view image, with the color gradient representing the field gradient within the platelet [Vassiloyannis, 2006]. The color gradient corresponds to field numerical values and, thus, the current density within the sample can be extracted inverting the Maxwell equation: $\nabla B = \mu_0 J$ (for E = 0). To achieve the inversion a Pascal program is used [Vassiloyannis, 1997], based on the formula:

$$H_Z(\vec{\rho}, d) = \frac{1}{4\pi} \int_s g(\vec{\sigma}) \int_0^t \frac{2(d+\xi)^2 - |\vec{\rho} - \vec{\sigma}|}{[|\vec{\rho} - \vec{\sigma}|^2 + (d+\xi)^2]^{5/2}} d\xi d^2\sigma \quad (2)$$

The grey profile of the image in Fig. 6 corresponds to the 3-D field distribution within the film. Two crossed lines have therefore been selected, which passed from the specimen center, shown in Fig.6. top plot. After the inversion process the corresponding crossed lines which passed from the current distribution profile center (the "inverted" surface) were depicted and are illustrated in Fig. 6 bottom plot. The currents along the crossed lines ("blue" [100] and "pink" [010] specimen directions) are equal, thus no discernible anisotropy is detected rendering the 1.69o specimen reliable for the gravimeter rings.

HTSC Ring Construction: The YBCO film grown can be used for integration into the gravimeter proposed in [Yatsenko, 2003]. The main measurement device is based in 2 rings of a conventional low temperature superconductor (niobium-titanic) of a 2.38 cm inner diameter and 2.5 cm outer radius. The top plane of the probe is polished in order to be used as a reflecting plane for the laser registration system. The gap for levitation, depending on the weight of the probe, is selected from 7 mm up to 15 mm. Such working models have been investigated theoretically and experimentally in the frame of the system suspension registration sensor. In particular, the presence of an additional ferromagnetic mass on the probe has been analyzed. The influence of the passive filter on the accuracy of the measurements has also been studied.

We propose the replacement of the conventional superconductor rings by rings patterned on HTSC platelets of the type of the 1.69^o specimen developed. The proposed HTSC ring is schematically illustrated in Fig. 6: the surface of the film platelet is 5 ×5 mm^2, while its thickness is ~200 nm (dark rectangular "marble area"). A HTSC ring of 2.5 mm outer radius and 2 mm inner radius ("purple" area), with a thickness of ~ 200 nm can be patterned by either optical (UV) or electron beam patterning. For the rings replacement it is also necessary to reduce the dimensions of the gravimeter of [2] to 1/10 of the current device.

Conclusions

We describe a new gravimeter, which is suitable for long-term continuous observations. It uses laser interferometry to measure the acceleration of a falling corner cube with reference to atomic standards. Between drops, the corner cube is lifted to the top by rotating the vacuum pipe around a horizontal axis with an angular velocity high enough to keep the cube fixed by centrifugal force. This method has an enormous advantage for making a large number of measurements since there is no complicated mechanism inside the vacuum pipe. This absolute gravimeter seems to have no source of systematic error which will exceed one part in 109 if we can reduce the amplitude of the mechanical vibration to less than about 1.5 nm. We describe here the principle and the results of the experiments that we have made to date.

In this paper, we have shown how to integrate YBCO thin film rings into the optical-cryogenic gravimeter in order to reduce its size and make it convenient for future space applications. Its function is based on the magnetic levitation phenomenon of the probe and on the measurement of its displacement with subsequent data processing. A free suspension of the probe is realized using the magnetic potential well effect. Preliminary experimental investigations have shown that the developed sensor can provide a displacement measurement precision for the probe of ~ 0.1 nanometer, which corresponds to a measurement precision for the Earth's gravity field acceleration at a level of ~ 10^{-10} g.

We report in this paper the results of a measurement of the gravitational constant *G* obtained in a laboratory at distances of about 1 m, using a superconducting gravimeter. The instrument measured the gravitational effect due to an annular mass of about 330 kg moving up and down around the gravimeter. The experiment yielded for the gravitational constant the value *G* _=_(6:679 - 0:008) $10^{-11}Nm^2/kg^2$ which agrees, within its uncertainty, with the last CODATA valu anometer, which corresponds to a measurement precision for the Earth's gravity field acceleration at a level of ~ 10^{-10} g.

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Area of research: remote sensing, space instrumentation

MULTICRITERION CHOICE PROBLEM FOR ENTERPRISES TO CREDITING

M. M. Malyar, V. V. Polischuk

Abstract: *Observing an approach for multicriterion choice problem by means fuzzy sets. The brought model over determination problem of borrower for crediting banks.*

Keywords: *multicriterion choice, fuzzy sets, crediting, decision making.*

ACM Classification Keywords: *H.1.1.Systems and Information Theory*

Introduction

After crisis time the Ukrainian banks very diligently and carefully go near the choice of borrowers. In the conditions of large demand on resources and by small suggestion, the task of correct choice of client for a grant to the credit and in the end its timely returning appears very actual. The decision takes place on two, and sometimes and on more the stages. On the first stage analysts estimate indexes, interests and consequences that characterize the variants of decisions. On the second stage person who makes decision (PMD), collects the estimations of analysts, and on the basis of which deduces a conclusion for a final decision making (DM).

In-process was taken approach, that was based on the theory of fuzzy sets, which gave an opportunity to pass to the only scale of evaluation of many different criteria. DM about the choice of borrowers is conducted on the basis of belonging function values, that is convolution of belonging functions of fuzzy sets, that answer criteria after that they are estimated. Application of methods is considered on the real example from six alternative clients.

Mathematical model

For realization of researches above the task of choice we shall describe it by means of - the next mathematical vehicle. The great number of alternatives we shall mark through *X*, this great number can be as complete, that is possible alternatives can be enumerated $X = \{x_1, x_2, ..., x_n\}$, and continuous set by terms-limitations. We shall mark $K = \{K_i, i = 1,2,...,m\}$ multitude of the criteria of effectiveness, by means of that the estimation of every alternative is conducted out of multitude *X.* The great number of criteria is set in a ball scale. Thus, the task of choice can be set forth as follows: to choose the best alternative from the great number of *X*, when the estimations are known on this great number $K_i, i = 1,2,...,m$, where *m* – is an amount of estimations. Farther we will examine the tasks of choice, in that the great number of possible alternatives is discreted and completed, then the model of such task can be presented in the form charts:

	x_1	x_2	x_3	...	x_n
K_1	O_{11}	O_{12}	O_{13}	...	O_{1n}
K_2.	O_{21}	O_{22}	O_{23}	...	O_{2n}
………					
K_m	O_{m1}	O_{m2}	O_{m3}	...	O_{mn}

or the matrixes decisions :

$$O = (O_{ij}),\ i = 1, \ldots, m;\ j = 1, \ldots, n; \tag{1}$$

where O_{ij} – it is an estimation j-alternatives i's- criterion.

We shall introduce into consideration point $T=(t_1, \ldots, t_m)$ from space R^m_{++} and we shall try to describe the fuzzy set of points.

We shall take the great number of alternatives of X, - for the great number of points, and the function of belonging we shall mark through $\mu_A(x)$ [Zadeh, 1965]. Then the task of choice can be described by means of the washed out model, and alternative to arrange in relation to the function of belonging :

$A_T = \{x, \mu_A(x)\},\ \forall\ x \in X \subset R^m_{++}$,

where A_T – the multitude of points, close to given point T, $\mu_A(x)$ characterises « degree of belonging" of elements to the $x \in X$ point of $T \in R^m_{++}$, that is this the function the appurtenances of affirmation "point x close to point T.

Determination. The point of pleasure" is named an imaginary alternative, at what estimation PMD would satisfy on all criteria [Malyar, 2006].

Coordinates of $T=(t_1, \ldots, t_m)$ are estimations for to the corresponding criteria the value of that satisfies PMD . Such estimations we will examine as points $t_i \in R_+$ from an inalienable set.

A question of construction function of belonging is one of major questions in the theory of the washed out sets. We shall describe approach of construction of function of belonging $\mu_A(x)$ [Malyar, 2006]. Imagine that we know matrix of decisions (1) and set point "of satisfaction" of T We shall define the great number of sizes as follows:

$$z_{ij} = 1 - \left|t_i - O_{ij}\right| \Big/ \max\left\{t_i - \min_j O_{ij}; \max_j O_{ij} - t_i\right\}, i = 1, \ldots, m, j = 1, \ldots, n \tag{2}$$

Each such size is the relative estimation of closeness of element of matrix (1) to the corresponding element of point of «satisfaction». As every alternative of $x \in X$ is the point of space of R^m_{++}, then the matrix of $Z = \{z_{ij}\}$ characterizes column-wise the relative estimations of closeness of alternative x_j to the point" of satisfaction" of T on every concrete criterion and takes off the question of different scales of evaluation.

Following step is an arranging of alternatives. For this purpose we will build the function belonging, as some convolution of numerical estimations. Let PMD knows or can set weighty coefficients to every criterion of efficiency $\{p_1, p_2, \ldots, p_m\}$ from an interval [0,a] (for consideration of expert and as it comfortably him for example, from 0 to 10, or from 0 to 100). Then it is possible to define the rationed weighty coefficients for every criterion:

$$\alpha_i = \frac{p_i}{\sum_{i=1}^{m} p_i},\ i = 1, \ldots, m;\ \alpha_i \in [0,1], \tag{3}$$

which correspond to condition $\sum_{i=1}^{m} \alpha_i = 1$.

Farther we build the function of belonging, as one of offered convolution, depending on the psychosomatic mood of PMD:

$$\mu_A^2(x_j) = \frac{1}{\sum_{i=1}^{m} \frac{\alpha_i}{z_{ij}}} \text{ - pessimistic;} \tag{4}$$

$$\mu_A^3(x_j) = \prod_{i=1}^{m} \left(z_{ij}\right)^{\alpha_i} \text{ - careful;} \tag{5}$$

$$\mu_A^4(x_j) = \sum_{i=1}^{m} \alpha_i z_{ij} \text{ - middle;} \tag{6}$$

$$\mu_A^5(x_j) = \sqrt{\sum_{i=1}^{m} \alpha_i (z_{ij})^2} \text{ - optimistic} \tag{7}$$

Between them there exists next subordination, [Osipova, 1968]: $\mu_A^2(x) \le \mu_A^3(x) \le \mu_A^4(x) \le \mu_A^5(x), \forall x \in X$.

Clients' choice problem

Let an aim - choice of borrower and great number of alternatives, which we will examine as enterprises with economic indexes is set. PMD necessary to choose enterprises that work stably have good economic indexes and better in all befit for the receipt of loan in a bank. We will consider that an aim is described by some great number of criteria for that ball estimations can be certain. We shall uncover the content of criteria, meanings and scale according to points of scale. Criteria $\{K_1, K_2, ..., K_{10}\}$ of effectiveness are following:

Criterion	Name of criterion
K_1	The index of immediate liquidity
K_2	The index of current liquidity
K_3	The index of general liquidity
K_4	The index of financial independence
K_5	The index of manoeuvrability of the personal funds
K_6	The index of financial leveriju
K_7	The Gain dynamics from products realization
K_8	The analysis of incomes and damages
K_9	Profitability of production
K_{10}	Credit history

We shall expose maintenance and gradations of criteria in accordance with a ball scale [NBU 2000]

1. An instantaneous liquidity ratio will calculate by means of formula:

K_1 = (*Current financial investments* + *the Monetary resources in national currency* + *Equivalents of monetary resources in foreign currency)/Current liabilities.*

Accounts and the gradations of scale criterion K_1:

- – if meaning K_1 less than 0,2;
- 10 – if meaning K_1 0,2-0,25;
- 20 – K_1 more 0,25.

2. The index of current liquidity is calculated in accordance to equality :

K_2 =(*Account receivable for commodities, works, services them net realization cost* + *account receivable after calculations* + *Other floating debtor debt* + *the Current financial investments* + *the Monetary resources in national currency* + *Equivalents of monetary resources in foreign currency)/Current liabilities.*

Accounts and the gradations of scale criterion K_2:

- 0 – if meaning K_2 less than 0,5;
- 10 – if meaning K_2 0,5-1,0;
- 20 – K_2 more 1,0.

3. A general liquidity ratio is determined as circulating assets are divided into current liabilities.

Estimations and gradations of scale of criterion K_3:

- 0 – if value K_3 less than 1,0;
- 15 – 1,0-1,9;
- 20 – 2,0-2,5;
- 0 – K_3 more than 2,5.

4. The coefficient of financial independence is calculated by means of formula:

K_4 =(Providing of next charges and single-sourcing + is the Long-term debt + Current liabilities)/ Property asset.

Estimations and gradations of scale of criterion:

- 25 – K_4 less than 1,0;
- 15 – 1,0;
- 5 – K_4 more than 1,0;
- 0 – if value of property asset less than " 0".

5. The coefficient of manoeuvrability of the personal funds is determined, as a difference between a property asset and inconvertible assets is divided into a property asset.

Estimations and gradations of scale of criterion K_5:

- 5 – less then 0,5;
- 15 – 0,5;
- 25 – more then 0,5;
- 0 - if value of property asset less than " 0".

6. The coefficient of financial leveriju is calculated in accordance with equality :

K_6 = (A long-term debt + the Short-term credits of banks + the Floating debt after a long-term debt)/Property asset.

Estimations and gradations of scale of criterion K_6 :

- 5 - less than 0,7;
- 15 - 0,7;
- 25 - more than 0,7;
- 0 - if value of property asset less than " 0".

7. Dynamics of profit yield from realization of products (commodities, works, services) will define in a percentage ratio in comparing to the corresponding period of the last year.

Estimations and gradations of scale of criterion K_7 :

- 30 is an increase in comparing to the corresponding period last year (increase anymore 20%);
- 25 is an increase in comparing to the corresponding period last year (increase of 10-20%);
- 20 is an increase in comparing to the corresponding period last year (increase less than 10%) or absence of changes;
- 0 is reduction in comparing to the corresponding period last year (a decline of volume is more than on 20%);
- 5 is reduction in comparing to the corresponding period last year (decline of volume of 10-20%);
- 15 is reduction in comparing to the corresponding period last year (a decline of volume is less than on 10%).

8. We shall write down estimations and gradations of scale of criterion K_8 :

- 120 - activities profitable for the previous year;
- 140 - profitable activity for the last two years;
- 20 - losing activity over the past year;
- 0 - unprofitable activity for the last two years;
- 70 - activities in the absence of gains and losses or lack of activity;
- 0 - a report for the previous financial year not given.

9. Profitability of production is calculated in obedience to equality:

K_9 = (Net income* of 100%)/(Material expenses + of Expense on the remuneration of labour + of Contribution on social measures + Depreciation + Other operating charges).

Estimations and gradations of scale of criterion K_9 :

- 0 - less than 5%;
- 10 - 5%-10%;
- 15 -more than 10%.

10. We shall write down estimations and gradations of scale of criterion K_{10} :

- 80 - paid off a credit in good time;
- 60 - paid off a credit with violation of term 1-30 days, but in good time paid percents;
- 30 - paid off a credit with violation of term 31 - 90 days;
- 10 - paid off a credit with violation of term 91 - 180 days;
- 0 - paid off a credit with violation of term more than 180 days;
- 50 is redemption in a period covered unforeseen.

Practical realization of model

Let bank six requests entered from enterprises for the receipt of loan. Enterprises will examine as alternatives, among what PMD must choose one for delivery of credit.

Their criterion estimations are given as a table:

	x_1	x_2	x_3	x_4	x_5	x_6
K_1	10	20	20	20	10	10
K_2	0	10	10	20	10	20
K_3	15	0	20	15	15	15
K_4	25	15	5	5	5	15
K_5	15	5	15	25	25	0
K_6	15	25	5	15	25	15
K_7	30	25	20	15	5	30
K_8	140	120	120	70	20	120
K_9	10	15	10	0	15	10
K_{10}	80	60	30	50	30	80

Let the great number of points "of pleasure", for example, PMD has defined as follows - *T*={20; 20; 15; 20; 15; 15; 25; 120; 10; 60}. Weight of criteria an expert estimated in numbers from an interval [0,10] accordingly: {8, 10, 9, 8, 7, 6, 7, 5, 8, 9}. Then the rationed weighty coefficients we shall calculate on a formula (3) and we shall write down as a great number: {0,10; 0,13; 0,12; 0,10; 0,09; 0,08; 0,09; 0,06; 0,10; 0,12}.

Let's arrange the alternatives in relation to the point "of satisfaction" of *T*. Calculate sizes by means of formula (2) and result we shall write down as a matrix of *Z*:

$$Z = \begin{pmatrix} 0,0000 & 1,0000 & 1,0000 & 1,0000 & 0,0000 & 0,0000 \\ 0,0000 & 0,5000 & 0,5000 & 1,0000 & 0,5000 & 1,0000 \\ 1,0000 & 0,0000 & 0,6667 & 1,0000 & 1,0000 & 1,0000 \\ 0,6667 & 0,6667 & 0,0000 & 0,0000 & 0,0000 & 0,6667 \\ 1,0000 & 0,3333 & 1,0000 & 0,3333 & 0,3333 & 0,0000 \\ 1,0000 & 0,0000 & 0,0000 & 1,0000 & 0,0000 & 1,0000 \\ 0,7500 & 1,0000 & 0,7500 & 0,5000 & 0,0000 & 0,7500 \\ 0,8000 & 1,0000 & 1,0000 & 0,5000 & 0,0000 & 1,0000 \\ 1,0000 & 0,5000 & 1,0000 & 0,0000 & 0,5000 & 1,0000 \\ 0,3333 & 1,0000 & 0,0000 & 0,6667 & 0,0000 & 0,3333 \end{pmatrix}.$$

For the choice of the best alternative we shall calculate middle and optimistic convolution with help of formulas (6) - (7) and we shall write down them as a table:

	$\mu_A^4(x_j)$ Middle	Ranging	$\mu_A^5(x_j)$ Optimistic	Ranging
x_1	0,6180	2	0,7358	2
x_2	0,5931	4	0,7010	5
x_3	0,5747	5	0,7065	4
x_4	0,6147	3	0,7277	3
x_5	0,2641	6	0,4306	6
x_6	0,6699	1	0,7770	1

From a previous table evidently, that for middle and optimistic convolution the best alternative will be x_6. Calculation of alternatives is impossible for careful and pessimistic convolution, so as a matrix of Z has zero values. Thus, the choice of the best alternative generally speaking depends on the psychosomatic mood of PMD.

Conclusion

Choice problem model of depends on the "point of pleasure" and determination of fuzzy set that can be formulated in different ways. The considered approach of designing of multicriterion task of choice allows to build arranging row for alternatives using their comparing to the "point of pleasure" and using the different types of convolution. It differs from the known approaches because it does not need pair comparison of alternatives.

Acknowledgements

The paper is partially financed by the project ITHEA XXIII of the Institute of Information Theories and Applications FOI ITHEA and the Consortium FOI Bulgaria (www.itea.org, www.foibg.com).

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DECISION MAKING PROBLEM WITH FUZZY SET OF GOAL SETS

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Abstract: *The problem of alternatives rational choice, in which goal of person who makes decision, is defined with the fuzzy set of fuzzy goal (aim) sets. The concept of intersection of fuzzy set of fuzzy sets is introduces and in it also investigated its properties.*

Keywords: *fuzzy set, fuzzy goal, membership function, fuzzy set of type 2, decision making, rational choice.*

ACM Classification Keywords*: H.4.2 Information Systems Applications: Types of Systems: Decision Support.*

Introduction

One of the most important problems, which arise in decision making practice, is the problem of making multi-goal decisions under fuzzy information.

In this paper we consider the problem of alternatives rational choice in an environment where goal of person who makes decision (PMD) is defined with fuzzy set of fuzzy goal sets. These models generalize well-known decision making problems, in which the PMD aim is characterized by a clear set of fuzzy sets (Bellman-Lotfi Zadeh approach, [Bellman, 1970]). On the one hand, such a generalization allows to analyze the situation in the cases when it is impossible to clearly specify which sets are characterizing the PMD aim, on the other - helps deeply and more accurately understand the decision making process, ways of finding and selecting reasonable alternatives under fuzzy information.

Decision making problem with fuzzy aim

Let be X – universal set of alternatives in which defined fuzzy set of alternatives D by the membership function $\mu_D : X \to [0,1]$. The fussy subset (let be marked G) of the universal set X is named as fussy goal (aim) [Bellman, 1970]. The fussy set G will be defined by the membership function $\mu_G : X \to [0,1]$.

According to Bellman - Lotfi-Zadeh approach the decision making problem with fuzzy defined aim is to reach the goal G within a fuzzy set of alternatives D. And, in this fuzzy formulation it is not simply taking about achieving goal, sand its achievement of one or another degree, taking into account also the membership degree to fuzzy set of alternatives.

Suppose, for example, that some alternative x provides a $\mu_G(x)$ degree of achievement of goals, and it belongs to fuzzy set of alternatives with degree $\mu_D(x)$. Then by [Bellman, 1970] it considered that the degree of membership of this alternative to the fuzzy set of problem solutions is equal to the minimum of these values. In other words, the alternative with the degree of membership, such as 0.3, with the same degree belongs to fuzzy set of solutions, despite the fact that it provides to achieve goal with a degree equal to, for example, 0.8.

So, the fuzzy solution of achievement of fuzzy goal problem on fuzzy set of alternatives by the Bellman – Lotfi-Zadeh approach – is called intersection of fuzzy sets of goal and alternatives. Membership function of fuzzy set of solutions to this problem has the form: $\mu(x) = \min\{\mu_G(x), \mu_D(x)\}$. If there are few goals, then fuzzy set of solutions is described by membership function as follows: $\mu(x) = \min\left\{\mu_{G_1}(x), ..., \mu_{G_n}(x), \mu_D(x)\right\}$.

Let be $G = \bigcap_{i \in N} G_i$, where $N = \{1,...,n\}$ - PMD's set of fuzzy goals. Then the fuzzy set G, that is characterized by the membership function $\mu_G(x) = \min_{i \in N} \mu_{G_i}(x)$, will be the PMD's fuzzy goal set. The fuzzy set of solutions $X^* = G \bigcap D$ will be described by membership function $\mu(x) = \min\{\mu_G(x), \mu_D(x)\}$. If PMD interested in any particular alternative, then the rational choice is the so-called maximizing alternative [Bellman, 1970], which satisfies the condition $x^* = \arg\max_{x \in X} \mu(x)$.

Definition of the decision making problem with fuzzy set of goals

Sometimes PMD can't clearly specify which fuzzy sets G_i, $i \in N$, characterizing its goal, but may ask some fuzzy subset $\tilde{N} \subseteq N$ of these sets. Note, that the set N should be called, down in this article, like universal set of goals indexes.

For example, if the buyer chooses a product that should belong to certain goal sets, which define: price, calorie content, quality, freshness, prestige - that all these sets are not necessarily characterize his goal with the degree of membership equal to one. Therefore, the buyer may ask some fuzzy subset of universal set of goals that will adequately characterize the true goal.

Denote $\eta : N \to [0,1]$ like the membership function of fuzzy set $\tilde{N}$ of fuzzy sets G_i that characterize the PMD goal. Then the whole goal may be defined by the intersection $\tilde{G} = \bigcap_{i \in \tilde{N}} G_i$ of fuzzy set $\tilde{N}$ of fuzzy sets G_i, $i \in N$.

Define the concept according to the approach that was proposed in [Mashchenko, 2010].

Let be $\mu_{G_j} : X \to [0,1]$ - membership function of fuzzy set G_j, $j \in N$. For the first let's consider the set $G = \bigcap_{i \in N} G_i$, which is the intersection of a clear set N of fuzzy sets G_i, $i \in N$. According to the classical theory [Zadeh, 1973] $G = \bigcap_{i \in N} G_i$ - is a fuzzy set, which is given by the membership function $\mu_G(x) = \min_{j \in N} \mu_{G_j}(x)$, $x \in X$. It is easy to see, that the value of membership function $\mu_G(x)$ for each fixed alternative $x \in X$ is actually defined as the value of objective function of trivial problem "clear" mathematical programming $\mu_G = \min_{j \in N} \mu_{G_j}$ (in this record for the visual perception is not specified a fixed value $x \in X$).

Let consider the intersection $\tilde{G} = \bigcap_{i \in \tilde{N}} G_i$ of fuzzy set $\tilde{N}$ of fuzzy sets G_i, $i \in N$. Generalization of classical operation of intersection clear set N of fuzzy sets naturally leads to the fact that the set $\tilde{G}$ is defined by the membership function:

$$\mu_{\tilde{G}}(x) = \min_{j \in \tilde{N}} \mu_{G_j}(x), \; x \in X. \tag{1}$$

It is clear that the value of this membership function $\mu_{\tilde{G}}$ for each alternative $x \in X$ will be defined as the value of the objective function for the fuzzy mathematical programming problem:

$$\mu_{\tilde{G}} = \min_{j \in \tilde{N}} \mu_{G_j} \quad (2)$$

(in this record, as in the previous case, also not specified a fixed $x \in X$).

Fuzzy mathematical programming problems are sufficiently well studied. According [Orlovsky, 1981], the solution of problem (2) is fuzzy set $\tilde{N}^{\cap}$, a carrier which is the set of Pareto optimal solutions (denote it by $N^{\cap}$) next two-criteria problem:

$$\mu_{G_i} \to \min, \ \eta(i) \to \max, \ i \in N. \quad (3)$$

Membership function $\eta^{\cap}$ of fuzzy set $\tilde{N}^{\cap}$ is a narrowing of the membership function $\eta(i)$, $i \in N$ from universal set of criteria indexes on the set $N^{\cap}$.

In other words, this membership function is as follows: $\eta^{\cap}(i) = \begin{cases} \eta(i), & i \in N^{\cap}, \\ 0, & i \notin N^{\cap}. \end{cases}$

According to the solution of problem (2), which is a fuzzy set $\tilde{N}^{\cap}$, by [Orlovsky, 1981] defined fuzzy set $\Re$ of optimal values of objective function of this problem. It is defined by the membership function $\rho : [0,1] \to [0,1]$, $\rho(z) = \max_{\mu_{G_j} = z} \eta^{\cap}(j)$, $z \in [0,1]$. It should be noted that the membership function $\rho(z)$, $z \in [0,1]$, of fuzzy set $\Re$ of optimal values of objective function of problem (2) defined on the interval $[0,1]$. This explained by the fact that this segment is a strongly possible set of values of membership function $\mu_{\tilde{G}}(x) = \min_{j \in \tilde{N}} \mu_{G_j}(x)$ of fuzzy set $\tilde{G} = \bigcap_{i \in \tilde{N}} G_i$ in any fixed alternative $x \in X$.

Thus, for each fixed alternative $x \in X$ value of membership function (1) of fuzzy set $\tilde{G} = \bigcap_{i \in \tilde{N}} G_i$ also forms fuzzy set. Hence we can conclude that the fuzzy set $\tilde{G}$ is the so-called [Zadeh, 1973], fuzzy set of type 2.

So, our research can now formalize the notion of intersection $\tilde{G} = \bigcap_{i \in \tilde{N}} G_i$ of fuzzy set $\tilde{N}$ of fuzzy sets G_i, $i \in N$.

For any alternative $x \in X$ lets have a look at the ratio of dominance, which is generated by the goal sets of the problem (3) in a universal set of goals N.

We say that the goal with index $i \in N$ dominated by the goal with index $j \in N$ for alternative $x \in X$ and mark it $i \overset{(x,y)}{\succ} j$, if there are such inequalities taking true: $\mu_{G_i}(x) \le \mu_{G_j}(x)$, $\eta(i) \ge \eta(j)$, and at least one of them is strict.

This concept allows to define a set of Pareto optimal solutions for two-criteria problem (3), which will be the carrier of fuzzy set of solutions of problem (2). For any $x \in X$ let denote this carrier like this:

$$N^{\cap}(x) = \left\{ i \in N \mid j \overset{(x)}{\not\succ} i, \ \forall j \in N \right\} \quad (4)$$

For all $x \in X$, $i \in N$, let make a definition of the membership function of fuzzy set of solutions of problem (2):

$$\eta^{\bigcap}(x,i)=\begin{cases}\eta(i), & i\in N^{\bigcap}(x),\\ 0, & i\notin N^{\bigcap}(x),\end{cases} \tag{5}$$

Then the intersection of fuzzy set $\tilde{N}$ of fuzzy sets G_i, $i\in N$, will be called $\tilde{G}=\bigcap_{i\in\tilde{N}} G_i$ - fuzzy set of type 2, which is given by pairs $(x,\mu_{\tilde{G}}(x,z))$, where x - the element of the set of alternatives X, and $\mu_{\tilde{G}}(x,z)$ - fuzzy image $\mu_{\tilde{G}}: X\times[0,1]\to[0,1]$, which serves as its fuzzy membership function and defined as follows:

$$\mu_{\tilde{G}}(x,z)=\max_{i\in N}\{\eta^{\bigcap}(x,i)\mid \mu_{G_i}(x)=z\}\text{, if } \exists i\in N,\ \mu_{G_i}(x)=z,\ z\in[0,1]; \tag{6}$$

$$\mu_{\tilde{G}}(x,z)=0\text{, if } \mu_{G_i}(x)\neq z, \forall i\in N,\ z\in[0,1] \tag{7}$$

Calculation of the membership function $\mu_{\tilde{G}}(x,z)$ by (4) - (7) can be simplified if you use the following theorem.

Theorem 1. Let G_i, $i\in N$, - some fuzzy sets defined on the set of alternatives X, which are set by membership functions $\mu_{G_i}(x)$, $x\in X$, $i\in N$; $\tilde{N}$ - fuzzy subset of N with the membership function $\eta(i)$, $i\in N$. Then the membership function of fuzzy set $\tilde{G}=\bigcap_{i\in\tilde{N}} G_i$ of type 2 is given by the following formula:

$$\mu(x,z)=\begin{cases}\max\limits_{i\in N^{\bigcap}(x,z)}\eta(i), & N^{\bigcap}(x,z)\neq\varnothing,\\ 0, & N^{\bigcap}(x,z)=\varnothing,\end{cases} \tag{8}$$

and $N^{\bigcap}(x,y,z)=\left\{i\in N\mid \mu_{G_i}(x)=z,\ z=\min_{j\in N}\{\mu_{G_j}(x)\big|\eta(j)\geq\eta(i)\},\eta(i)=\max_{j\in N}\{\eta(j)\big|\mu_{G_j}(x)\leq z\}\right\}$, (9)

$\forall x,y\in X$, $z\in[0,1]$.

Proof. To prove the theorem we should show that $\mu(x,z)=\mu_{\tilde{G}}(x,z)$ for $\forall x\in X$, $z\in[0,1]$.

Suppose that for some $x\in X$, $z\in[0,1]$ $N^{\bigcap}(x,z)=\varnothing$, than from (8) $\mu(x,z)=0$, and by (9) for $\forall i\in N$ should be implemented at least one of the following conditions:

$$\mu_{G_i}(x)\neq z, \tag{10}$$

$$\exists j\in N: \mu_{G_i}(x)>\mu_{G_j}(x),\ \eta(j)\geq\eta(i) \tag{11}$$

$$\exists j\in N: \eta(i)<\eta(j),\ \mu_{G_j}(x)\leq\mu_{G_i}(x) \tag{12}$$

If condition (10) became true, then by (7) we obtain $\mu_{\tilde{G}}(x,z)=0$. If condition (11) or (12) became true, then $j\overset{(x)}{\succ}i$. Then according (4) $i\notin N^{\bigcap}(x)$. Hence by (5) $\eta^{\bigcap}(x,i)=0$. Therefore by (6) we get also $\mu_{\tilde{G}}(x,z)=0$. Thus, $\mu(x,z)=\mu_{\tilde{G}}(x,z)=0$.

Suppose that for some $x\in X$, $z\in[0,1]$ $N^{\bigcap}(x,z)\neq\varnothing$. Hence by (8) we get $\mu(x,z)=\max_{i\in N^{\bigcap}(x,z)}\eta(i)$. Denote $i^*=\arg\max_{i\in N^{\bigcap}(x,z)}\eta(i)$. Then from (9) it follows next:

$$r_{i^*}(x) = z\ ,\ j \overset{(x,y)}{\not\succ} i^*,\ \forall j \in N\ . \tag{13}$$

So according to (4) $i^* \in N^{\cap}(x) \neq \varnothing$, $\eta^{\cap}(x,i^*) = \eta(i^*)$. Hence $\mu_{\tilde{G}}(x,z) \geq \eta(i^*)$.

Let show that $\mu_{\tilde{G}}(x,z) = \eta(i^*)$. Assume contrary that $\mu_{\tilde{G}}(x,z) > \eta(i^*)$. Denote $j^* = \arg\max_{i \in N}\{\eta^{\cap}(x,i) \mid r_i(x) = z\}$.

Then $\eta(j^*) > \eta(i^*)$, $\mu_{G_{j^*}}(x) = z$ and by (5) $j^* \in N^{\cap}(x)$. As for (13) $\mu_{G_{i^*}}(x) = z$, then $\mu_{G_{i^*}}(x) = \mu_{G_{j^*}}(x)$. So $j^* \overset{(x,y)}{\not\succ} i^*$. Hence $j^* \notin N^{\cap}(x)$. We obtained contradiction. So, $\mu_{\tilde{G}}(x,z) = \eta(i^*) = \mu(x,z)$. Theorem is proved.

To illustrate the intersection of fuzzy set of fuzzy sets let take a look on an example.

Example 1. Let be the set of alternatives X which consists four alternatives: *a*, *b*, *c*, *d*. The set of fuzzy alternatives D is defined by the membership function $\mu_D(x)$ (Tab.1). On the set X also defined two fuzzy sets G_1, G_2 with membership functions respectively $\mu_{G_1}(x)$ and $\mu_{G_2}(x)$, and whose values are listed in Tab.1. Let also define fuzzy subset $\tilde{N}$ from indexes set of these relations $N = \{1,2\}$ with membership function $\eta(i)$, $i \in N$, which takes the values: $\eta(1) = 0.5$, $\eta(2) = 0.8$. So, lets find the intersection $\tilde{G} = \bigcap_{i \in \tilde{N}} G_i$ of fuzzy set $\tilde{N}$ of fuzzy relations G_1, G_2 .

In Tab.1 also indicated the sets $N^{\cap}(x)$, $x \in X$, and membership function $\eta^{\cap}(x,i)$, $x \in X$, $i \in N$. The values of membership function $\mu_{\tilde{G}}(x,z)$ of fuzzy set $\tilde{G}$ of type 2 are listed in Tab.2.

Table 1 Function and sets

x	a	b	c	d
$\mu_D(x)$	0.1	0.2	0.3	0.5
$\mu_{G_1}(x)$	0	0.5	0.3	0
$\mu_{G_2}(x)$	0	0.3	1	0
$N^{\cap}(x)$	{2}	{2}	{1,2}	{2}
$\eta^{\cap}(x,1)$	0	0	0.5	0
$\eta^{\cap}(x,2)$	0.8	0.8	0.8	0.8

Table 2 Membership function $\mu_{\tilde{G}}(x,z)$

z	x			
	a	b	c	d
0	0.8	0	0	0.8
0.3	0	0.8	0.5	0
0.5	0	0	0	0
1	0	0	0.8	0

Note that in Tab.2 recorded only those values of variable $z \in [0,1]$ that meet a priori non-zero value of membership function $\mu_{\tilde{G}}(x,z)$.

The solution of decision making problem with fuzzy set goals

Proceed to the construction of solution of the problem of rational choice of alternatives for the fuzzy goal, which is defined by the fuzzy set $\tilde{G} = \bigcap_{i \in \tilde{N}} G_i$ of type 2.

To do this it firstly need to construct the general solution, which is fuzzy set $X^* = \tilde{G} \bigcap D$ of type 2, and then must determine the approach to the selection of specific alternatives in this set.

According to [Zadeh, 1973] the intersection of two fuzzy sets A and B of type 2, which are defined by fuzzy reflection (they act as their fuzzy membership functions), respectively, $\mu_A(x,z)$ and $\mu_B(x,z)$, $x \in X$, $z \in [0,1]$ - is fuzzy set of type 2, which is given by membership function

$$\mu_{A \cap B}(x,z) = \max_{\substack{z_A, z_B \in [0,1], \\ z = \min\{z_A, z_B\}}} \min\{\mu_A(x,z_A), \mu_B(x,z_B)\} \quad (14)$$

Table 3 Membership function $\mu_D(x,z)$

z	x			
	a	b	c	d
0	0	0	0	0
0.1	1	0	0	0
0.2	0	0	1	0
0.3	0	0	0	1
0.5	0	1	0	0
1	0	0	0	0

Table 4 Membership function $\mu(x,z)$

z	x			
	a	b	c	d
0	0.8	0	0	0.8
0.1	0	0	0	0
0.2	0	0	0.8	0
0.3	0	0.8	0	0
0.5	0	0	0	0
1	0	0	0	0

Therefore, fuzzy reflection, which define the fuzzy membership function of fuzzy set of solutions $X^* = \tilde{G} \bigcap D$ of type 2 will look like $\mu(x,z) = \max_{\substack{z_D, z_G \in [0,1], \\ z = \min\{z_D, z_G\}}} \min\{\mu_D(x,z_D), \mu_{\tilde{G}}(x,z_G)\}$, where $\mu_D(x,z_D)$ - reflection, which define the fuzzy set of alternatives D and determined to $\forall x \in X$, $\forall z \in [0,1]$, as follows: $\mu_D(x,z) = \begin{cases} 1, & z = \mu_D(x), \\ 0, & z \neq \mu_D(x). \end{cases}$

For example 1, a membership function of fuzzy sets of type 2 $\mu_D(x,z)$ and $\mu(x,z)$ are respectively defined in the Tab. 3 and 4.

Since PMD can interest a specific alternative, then there is the problem of rational choice from fuzzy set X^* of type 2. It is clear that for PMD is important to choose the alternative that from one side will maximize the fuzzy value $z \in [0,1]$ of dominates degree, and, on the other hand, maximize the fuzzy value μ, which is characterizing the degree of membership the z value to the fuzzy set of its values.

Thus, we can formulate the following 2-criteria problem:

$$z \to \max,\ \mu(x,z) \to \max,\ x \in X,\ z \in [0,1].$$

Let be $x^* \in X$, $z^* \in [0,1]$ - a solution to this problem, then the value z^* characterizes the dominates degree of alternative x^*, and the value $\mu(x^*,z^*)$ - the membership degree of z^* to fuzzy set with membership function $\mu(x^*,z)$, $z \in [0,1]$. To distinguish between these concepts, then the value $\mu(x^*,z^*)$ will be called the degree of certainty dominates z^* of alternative x^*.

Depending to the comparing methods of alternatives [Podinovsky, 1982] by the criteria of 2-criteria problem (14) consider two definitions.

Alternative $x^* \in X$, which is strongly no-dominates with degree z^* of credibility $\mu(x^*,z^*)$ will be called fuzzy weakly-effective alternative (it set we denote $S(X)$), if $\nexists x \in X\ \nexists z \in [0,1]$, for which: $z > z^*$, $\mu_{ND}(x,z) > \mu_{ND}(x^*,z^*)$.

Alternative $x^* \in X$, which is no-dominates with degree z^* of credibility $\mu(x^*,z^*)$ will be called fuzzy effective alternative (it set we denote $P(X)$), if $\nexists x \in X\ \nexists z \in [0,1]$, for which the condition or $\mu_{ND}(x,z) \geq \mu_{ND}(x^*,z^*)$, $z > z^*$, or $\mu_{ND}(x,z) > \mu_{ND}(x^*,z^*)$, $z \geq z^*$.

It is clear, that $S(X) \supseteq P(X)$.

For example 1 according to the Tab.4 it is easy to verify that alternative *b* is only one fuzzy effective alternative with the membership degree 0.3 and with reliability 0.8.

In general, those alternatives which have a maximum no-dominates degree may have a low degree of reliability and vice versa.

From the famous theorem [Podinovsky, 1982] as a consequence follows the criterion of efficiency alternatives.

Corollary. The alternative $x^* \in X$, which is no-dominates with degree z^* of credibility $\mu(x^*,z^*)$, is effective if and only if it is the best solution of pair of optimizations problems:

$$\begin{aligned} &\mu(x,z) \to \max, \\ &z \in [z^*,1],\ x \in X; \end{aligned} \tag{15}$$

$$\begin{aligned} & z \to \max, \\ & \mu(x,z) \ge \mu(x^*,z^*), \\ & z \in [0,1], \;\; x \in X. \end{aligned} \tag{16}$$

Construction of all fuzzy sets of effective alternatives is a difficult task, but as often PMD interesting choice of specific alternative, then this is not necessary.

One of the possible variants of rational choice alternatives can be considered using one of problems (15), (16).

First consider the searching problem of fuzzy alternative x^* that maximizes the degree of credibility μ of no-dominates degree *z*, not less than a value $\tilde{z} \in [0,1]$, ie:

$$\begin{aligned} & \mu(x,z) \to \max, \\ & z \in [\tilde{z},1], \; x \in X; \end{aligned} \tag{17}$$

Fair such a statement.

Proposition 1. Let the pair (x^*, z^*) is a solution of problem (17) for some value $\tilde{z} \in [0,1]$. Then there is x^* which is weakly-efficient alternative that is no-dominates with degree z^* and with degree of credibility $\mu(x^*, z^*)$.

Proof. Denote μ^* the maximum value of the objective function of problem (17). Suppose contrary to that $x^* \notin S(X)$. Then, by definition, $\exists \hat{x} \in X \; \exists \hat{z} \in [0,1]$ for which are performed next inequalities: $\mu(\hat{x}, \hat{z}) > \mu(x^*, z^*)$, $\hat{z} > z^*$. According to (17) $\tilde{z} \le z^* \le 1$, then $\tilde{z} \le z^* < \hat{z} \le 1$. Therefore a pair $(\hat{x}, \hat{z})$ satisfies to the conditions of problem (17), and $\mu(\hat{x}, \hat{z}) > \mu^*$. Obtained contradiction. The claim is proved.

Lets consider the searching problem of fuzzy alternative x^* with maximum no-dominates degree *z* that has degree of credibility μ_{ND}, not less than a value $\tilde{\mu} \in [0,1]$, ie:

$$\begin{aligned} & z \to \max, \\ & \mu(x,z) \ge \tilde{\mu}, \\ & z \in [0,1], \;\; x \in X. \end{aligned} \tag{18}$$

Fair such a statement.

Proposition 2. Let the pair (x^*, z^*) is a solution of problem (18) for some value $\tilde{\mu} \in [0,1]$. Then there is x^* which is weakly-efficient alternative that is no-dominates with degree z^* and with degree of credibility $\mu(x^*, z^*)$.

Proof. Note that z^* is the maximum value of the objective function of problem (18). Suppose contrary to that $x^* \notin S(X)$. Then, by definition, $\exists \hat{x} \in X \; \exists \hat{z} \in [0,1]$ for which are performed next inequalities: $\mu(\hat{x}, \hat{z}) > \mu(x^*, z^*)$, $\hat{z} > z^*$. According to (18) $\mu(x^*, z^*) \ge \tilde{\mu}$ then $\mu(\hat{x}, \hat{z}) > \mu(x^*, z^*) \ge \tilde{\mu}$. Therefore a pair $(\hat{x}, \hat{z})$ satisfies to the conditions of problem (18), and $\hat{z} > z^*$. Obtained contradiction. The claim is proved.

Conclusion

In the end it should be noted that considered in this paper an approach to "rational" choice of alternatives in decision-making problem with the goal set, which is defined by the fuzzy set of fuzzy goal sets is another view to this problem than the method that was developed in the works of Zadeh in particular in [Bellman, 1970], using weights coefficients that characterize PMD advantage on the set of goal sets.

It should also be noted that the new operation of intersection of fuzzy set of fuzzy relations, which is formalized in this paper presents an independent interest and can be used in various productions of new decision making problems. The concept of fuzzy effective alternatives will be correct and has some interest for the decision making problem with goal of which will be defined by fuzzy set of clear goal sets.

Acknowledgments

The paper is partially financed by the project ITHEA XXIII of the Institute of Information Theories and Applications FOI ITHEA and the Consortium FOI Bulgaria (www.itea.org, www.foibg.com).

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METHODS AND TOOLS OF KNOWLEDGE MANAGEMENT AT THE SEMANTIC WEB ENVIROMENT

Julia Rogushina

Annotation: *the main problems of ontological knowledge management for Web are analyzed, e.g. the problem of integration of knowledge from different sources, knowledge acquisition and knowledge retrieval for specific task. Methods of automated generation of metadata described the semantics of informational resources and for personalized search on base of thesauri and ontologies of user subject domain are proposed. These methods are realized in design of informational retrieval system MAIPS where the retrieval procedure is personified on multiagent paradigm and ontological analysis. MAIPS uses technologies and standards of Semantic Web and Web 2.0 (e.g. OWL – for interoperable ontology and thesauri representation, RDF – for metadata representation of informational resources, tag clouds – for visualization of search thesauri, social services – for user interaction), some set-theoretic operations on thesauri and creation of thesauri by natural language texts are realized. Text readability criteria are used for retrieval of information pertinent to personal informational needs of user.*

Key words: *Semantic Web, knowledge management, ontology.*

ACM Classification Keywords: *I.2.4 Knowledge Representation Formalisms and Methods*

Introduction

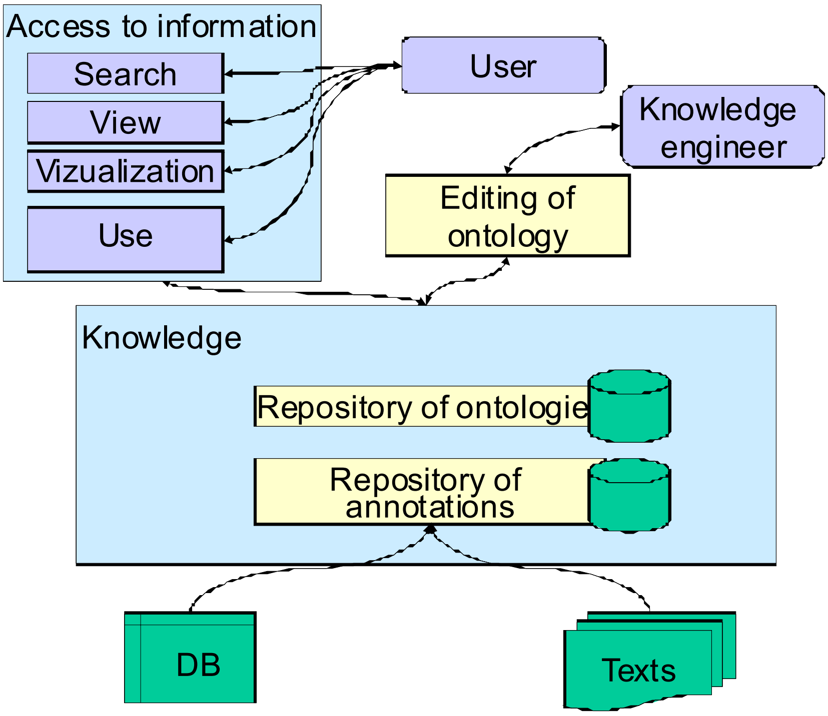
Now a lot of Web applications are intelligent and use knowledge about some subject domain or produce some new knowledge. In such applications knowledge is represented in interoperable form and can be reusable. For such representation ontological approach is widely used because ontologies have a fundamental theoretical foundation (descriptive logic).

Ontologies typically provide some general vocabularies that describe different domains of user interest or specialization of informational resource and define the meanings of terms used in the vocabulary. The ontology representation contains data and conceptual models, for example, sets of terms, classifications or theories.

Problems of knowledge management for Web

Main problems of knowledge management for Web deal with (pic.1):

- Integration of knowledge from different informational resources (e.g. integration of ontologies built on base of different texts from one subject domain);
- Search of inconsistency of knowledge acquired from content of different informational resources and rating of their adequacy and security;
- Knowledge acquisition from accessible information and it’s representation at form understandable to user;
- Search of knowledge that user needs for solution of some specific tasks;
- Automation of metadata creation and improvement that correctly describes the content of informational resources (textual or multimedia) on semantic level, and efficient search of such metadata.



Pic.1. Main elements of ontological knowledge management

A lot of other examples of similar exists bat all of them come to the following ones:

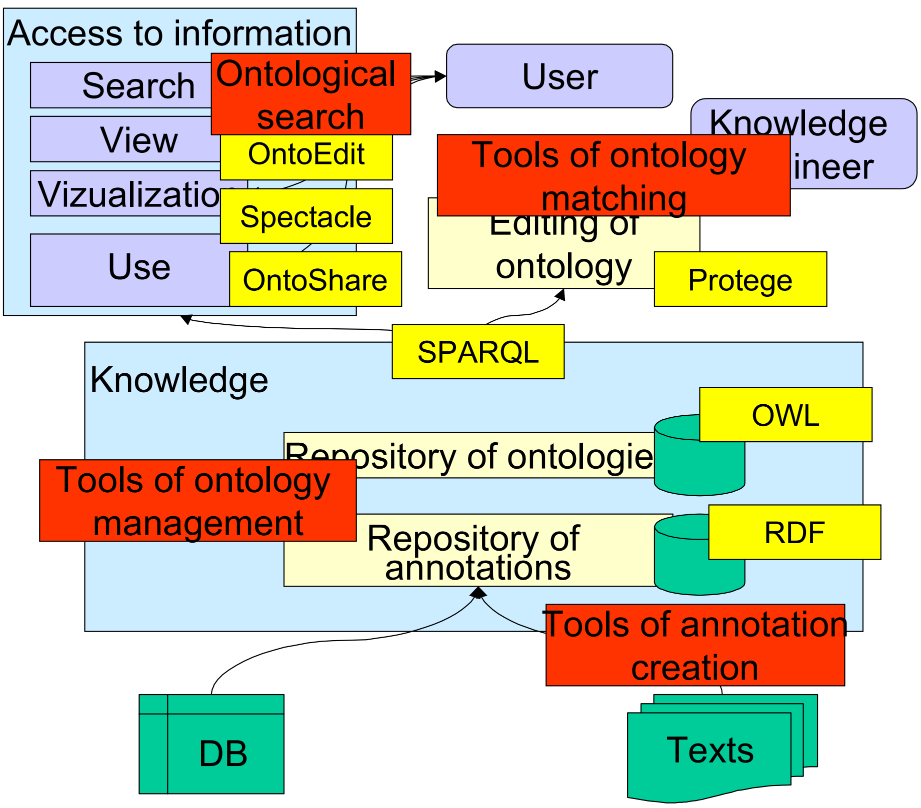
1. Selection of means for knowledge representation (sufficiently powerful to satisfy the different requirements of users but available to rapid processing and understandable for human): Now for these goals ontologies are widely used but the problem deals with selection of ontology representation language version (OWL 1.0 versus OWL.2.0, OWL Lite, OWL DL, OWL Full, RDF, RDF Schema etc.) [1]. Domain ontology is the certain part of knowledge that describe important concepts and relations that can be used for solution of problems at this domain.
2. Methods of acquisition of new knowledge on base of some informational resources (for example, creation of metadescriptions of informational resources, inductive and traductive inference): new knowledge can be acquired from implicit, uncertain, contradictory textual representations but large capacity of such information necessitates some automated methods of their processing. Availability of RDF – language for metadata representation – is a necessary but not sufficient condition for it. For example, automated creation of metadata that describes the natural language document on semantic level requires to use: 1) methods of linguistic analysis; 2) knowledge of subject domain (e.g. domain ontology); 3) application-dependent methods of inductive, deductive or traductive inference oriented on processing of specific structures of knowledge (e.g. RDF triplets).
3. Methods of matching of different informational objects on semantic level (e.g. integration of two ontologies or detection of differences between them, matching of informational query and informational resource relevant to this query, discovery of subject domain of informational resource by analysis of it's content): these problems are not trivial and don't reduce to traditional search because they have to analyze rules and knowledge of subject domain and their formal

representations by special matching algorithms. The matching operations deal with following challenges: large-scale evaluation, performance of ontology-matching techniques, discovering missing background knowledge, uncertainty in ontology matching, matcher selection and self-configuration, user involvement into the process of matching, explanation to user of matching results, collaborative ontology matching, alignment management and reasoning with alignments [2].

4. Quality rating of new knowledge (veracity, consistency, actuality, completeness). It needs to develop the different models of knowledge representation, to use the appropriate mathematical apparatus (e.g. first-order sentence theory, descriptive logics) and to evaluate the quality of ontologies concerning to real world and informal knowledge about real world.

At the present stage of IT in the majority of cases Web applications use standards and technologies of knowledge management developed by Semantic Web project. Knowledge management in Semantic Web environment needs in creation of adequate tools for retrieval, acquisition, store and use of knowledge subject to such properties of up-to-date Web as dynamics, heterogeneity, very large capacity and orientation on semantics.

The main component of Semantic Web conception is an ontology use that allows to formalize knowledge about subject domain. Ontology in contrast to XML Schema is a knowledge representation not a message format. Different instrumental tools provide following possibilities: ontology creation and their linking with different informational resources, checking of ontology’s consistency, refinement of ontology and executed of inference operations on ontologies (pic.2).



Pic.2. Knowledge management architecture on base of Semantic Web

Ontologies as a knowledge representation means

Analysis of publications shows that ontologies are the adequate and effective means for knowledge modeling about different subject domains, informational resources and other objects. Different authors represent various formal models of ontology but all these models include [3]:

- the set of concepts that can be subdivided into the set of classes and the set of individuals;
- the set of relations between concepts where the some subclasses of relations («class-subclass», hierarchical, synonymy etc.) and functions (as special relation where the n-th element of relation is uniquely defines by other n-1 elements) can be separated;
- axioms and interpretation functions of concepts and relations.

Formal model of ontology is a triple O=<X, R, F>, where X is a set of concepts, R – a set of relations between concepts from X and F – interpretation functions for concepts from X and relations from R. This is a general model, and in practice more precise models are used. For example, in [4] ontology is defined as a structure that includes identifiers of concepts, identifiers of relations, identifiers of attributes, data types and hierarchies of concepts and relations. In [5] ontology is defined as a tuple that, in addition to sets of classes, individuals, relations and data types, contains a set of values and some special relations (specialization, exception, creation of individual and assignment).

Existing technologies of the Semantic Web propose various means of ontology representation that differ one from others by their expressiveness and their complexity: RDF Schema is the simplest representation and OWL Full is the most powerful. Decision of ontology representation depends of problem specifics.

Languages for ontology representation can be viewed as syntacsic variants of Description Logic (DL). The fundamental modeling concept of a DL is the *axiom* - a logical statement relating roles and/or concepts. There are many varieties of Description Logic and there is an informal naming convention, roughly describing the operators allowed: F – Functional properties; E – Full existential qualification (Existential restrictions that have fillers other than owl: Thing); U – Concept union; C – Complex concept negation; S – An abbreviation for ALC with transitive roles; H – Role hierarchy (subproperties - rdfs:subPropertyOf); R – Limited complex role inclusion axioms; reflexivity and irreflexivity; role disjointness; O – Nominals. (Enumerated classes of object value restrictions - owl:oneOf, owl:hasValue); I – Inverse properties; N – Cardinality restrictions (owl:cardinality, owl:maxCardinality); Q – Qualified cardinality restrictions (available in OWL 2.0, cardinality restrictions that have fillers other than owl:Thing); (D) – Use of datatype properties, data values or data types. The prototypical DL Attributive Concept Language with Complements (ALS) is a simply AL with complement of any concept allowed, not just atomic concepts. The description logic SHIQ is the logic ALC plus extended cardinality restrictions, and transitive and inverse roles. The naming conventions aren't purely systematic so that the logic ALCNIO might be referred to as ALCNIO and abbreviations are made where possible ALS used instead of the equivalent ALUE. The design of OWL is based on the family of DL. The Protégé ontology editor supports SHOIN(D). OWL 2.0 provides the expressiveness of SHOIQ(D), OWL-DL is based on SHOIN (D), and for OWL-Lite it is SHIF(D).

Semantic search as an important component of Web knowledge management

We think that one of the most important tasks in knowledge management for Web deals with semantic informational search – in a lot of intelligent Web application informational retrieval is a part of a system or is called as an external service. Semantic search is a superstructure on traditional retrieval procedure where (i.e. more efficient satisfaction of user's informational needs) processing of knowledge (about user, his/her personal informational needs and interests; about informational resources accessible for retrieval mechanism) is used for the purpose of increasing of search pertinence [6]. The result of semantic search can be not only the concrete Web document or fragment of such document but some more complex informational object:

1. interesting to user information acquired from accessible informational resource (textual or multimedia) where this information contains implicitly;
2. a list of informational resources with some semantic annotations deal with user's query and user's personal preferences;
3. integration of knowledge contained in different informational resources;
4. informational object of specific for subject domain class (corresponding to some concept of domain ontology) – for example, organization, geographical object, human or scientific article;
5. composition of classified informational objects (e.g. human with some characteristics that work in organization of specific type and live in some concrete city).

On base of analysis of current state of work in sphere of informational content representation and methods of programming for Semantic Web we can mark out some main problems that we have to solve in process of design of intelligent Web application realized the semantic search procedure (i.e. the questions that have not now some universal standardized methods of solving and for which open software products are not realized):

- automated creation of meta-descriptions of informational resources that reflect not only formal characteristics of documents but their semantics that deals with some subject domain;
- generation of semantic markup of natural language documents by ontological concepts;
- automated creation and enhancement of ontology (at initial stage and for existing ontologies) on base of informational resources processing and by use of expert knowledge, particularly:

- formation of thesaurus of natural language informational resource;
- formation of initial ontology of subject domain by the set of natural language documents selected by user;
- enhancement of ontology of subject domain by the set of natural language documents;
- acquisition of ontological information from meta-descriptions of informational resources;
- use of inductive inference for discovery of relations between the ontological concepts;

- operations on ontologies (the most necessary operations are consistency valuation of ontology, matching of pair of ontologies and integration of terminological base of different ontologies);
- semantic search that take into consideration ontological knowledge about subject domain, user and task that user try to solve.

It is not easy for user to formalize the query for semantic search that reflects his/her informational need (as a user we consider either human or agent – software entity with some goals and intentions) because this formalization has to reflect:

1) the description of problem that needs some information for it's solving;

2) what information user has before this query;

3) what level of complexity and form of knowledge representation user can understand;

4) how to acquire the necessary knowledge from accessible documents.

Semantic sears has some important differences from traditional one realized in usual information retrieval systems (IRS) that operate at Web environment:

	Traditional IRC	Semantic IRC
Query	The set of keywords	Informational need deal with some subject domain and problem
Information for search personification	History of user queries	Models of user and his informational needs
Search results	Document with keywords	Knowledge acquires from relevant to query documents that describe some interesting for user object (document, human, organization etc.)
Source of information about accessible IR	Index DB of IRS	Index DB of IRS and their metadata
Description of subject domain interesting for user	-	Domain ontology

Linguistic methods in creation of ontologies of natural language informational resources

The algorithm of semantic markup of natural language texts is proposed. This algorithm factors into morphological and syntactical properties of natural language and knowledge about subject domain. As a result of this algorithm we receive the text where some fragments are linked with concepts and relations of domain ontology. The other result of this step is a set of rules that provide links between ontological entities and word forms of natural language. The input of first stage are: O_0 – initial ontology of subject domain containing the most obvious for user concepts and relations; T_0 – the set of natural language texts that describe interesting for user domain (texts from glossaries, manuals, textbooks, Wikipedia articles, other well structured definitions of domain terminology). O_0 and T_0 can be empty.

On the next step the rules of markup are used for new texts. If in one sentence two or more fragments are marked up by ontological concepts but no fragments are marked by ontological relations then we can add (if necessary) new relation to domain ontology. If in one sentence one fragment is marked up by ontological concepts and other one – by ontological relations then we can add (if necessary) new concept to domain ontology.

This algorithm can mark up not only classes bat individuals as well. In natural language the equivalents of individuals are named entities (names, titles etc.).

The results of such semantic markup can be used for development and improvement of ontologies together with linguistic approach. If some text paragraph contains two fragments linked with ontological concepts and a fragment linked with ontological relation and if linguistic analysis of the sentence shows that in this sentence these fragments are associated but the domain ontology don't contains such relation of these concepts then the ontology can be enriched by this relation. Ontology is enriched by the new concept: if one fragment of the text paragraph is linked with some other concept and other fragment – with some ontological relation and linguistic analysis helps to search the fragment that is semanialally associated with these fragments than user can determ a new ontological concept associated with this frafment.

In prosess of linguistical analysis we propose to create and devlope a lexical ontology of domain that contains information about natural text fragments that are associates with concepts and relations of domain onntology. This ontology is created in process of semanic markap of domain texts and then enreached in dialog with user durin the analysis of other texts.

Use of thesauri in semantic search

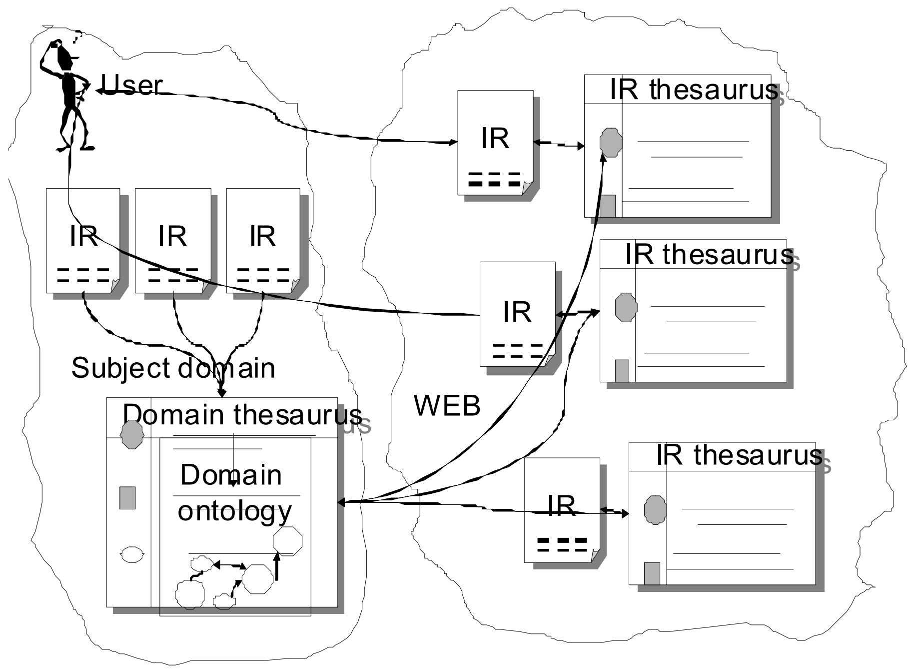
Thesaurus is a special case of ontology T=<X, R, ∅>. In some situations we can match in processof semantic search the thesaurus of domain that is interesting for user with thesauri of avaluable informational resources. The replacement of the ontologies by the thesauri reduces the problem of their generation because we can create thesaurus of natural language document much easier (by lexical analysis) then ontology.

The thesaurus of domain is created as a union of sets that represent thesauri of natural language documents selected by user to describe the sphere of his/her interests. Then user can refine this thesaurus according to IDEF5 methodology for development of ontological models (www.idef.com/IDEF5.html).

If we have an ontology of some domain or informational resource than we can reduce it into the thesaurus. In some situations for retrieval procedure we can take into account only the set X (concepts) and then matching of ontologies can be reduced to comparison of these sets (there is not a deep semantic analysis but this procedure can help to reject informational resources without corresponding terms.

For modeling of ontological relations mereological apparatus can be used. Mereology as a formal theory about parts marks out seven types of relation «the part of», for example, component-object, part-mass, material-object. This classification helps in refining of ontologies if user in process of adding of new relation to ontology explicitly states the mereological type of this relation.

For analysis of the lot of IR an algorithm of thesauri building is proposed: term vocabulary is building by the general list of document words, and then words from user list are thrown away from that vocabulary. User list can contain stop-words for soma subject domain or natural language. If IR has some metadata describing it's semantics (for example, in RDF) then words for vocabulary can be acquired from this metadata. Then this vocabulary is matched with user thesaurus. User thesaurus can be built by extraction of concept names from domain ontology in OWL, as a union of vocabularies of IRs selected by user, manually by user or by combination of these methods (pic.3).



Pic.3. Informational retrieval on base of thesauri

Realization of semantic search in IRS MAIPS

The results of described above research work were used in realization of semantic search system MAIPS. This IRC is oriented on users that have stable informational interests into the Web and needs in regular acquisition of corresponding information. At this system ontologies and thesauri are used for formalized definition of subject domain that is interesting for user, and inductive inference methods provide acquisition of additional information about users by analysis of their permanent query history (e.g., preferences in informational sources, language and size of the text). In addition, the search is personified with a help of individual indexes of natural language text readability that provides the most understandable and valuable information to user.

MAIPS integrates ontological representation of knowledge, multi-agent paradigm and Semantic Web technologies for the purpose of semantic search. The main features of MAIPS:

- use of OWL language for domain ontologies and thesauri interoperable representation;
- realization of set-theoretic operations on thesauri;
- automated thesauri generation by natural language documents;
- use of Web 2.0 technologies (tag clouds – for search thesauri visualization, social services – for user cooperation;
- original sequencing algorithms for searched IRs with account of ontological concepts;
- use of natural language texts readability criteria for informational retrieval with account of personalized user needs;

- original inductive inference methods for generalization of MAIPS operation experience;
- use of multiagent paradigm for modeling of intelligent IRS behavior on base of BDI architecture;
- use of intelligent Semantic Web services paradigm for interoperable description of MAIPS functions.

Inductive inference in MAIPS

IID3M Algorithm. A significant drawback of the well-known algorithm of inductive generalization ID3 [7] consist in the fact that it builds a classification rule only for the two classes. The IID3M algorithm [8] generalizes ID3 to an arbitrary number of classes and takes into account the level of accessibility of attribute values. This algorithm also detects the situation attributes that which carry the most information about the result and thus help in constructing of the smallest decision tree. At the each step the algorithm searches an attribute Ai

$$C(A_m) = \sum_i \sum_j \frac{C(A_m = a_{mi}, R = R_j)}{T(A_m)} = \\ = \max_s C(A_s) = \max_s \sum_i \sum_j \frac{C(A_s = a_{si}, R = R_j)}{T(A_m)} \quad (1)$$

where C (X, Y) - the amount of information $C(X,Y) = \sum_i \sum_j p(X = x, Y = y) * \log p(X = x, Y = y),$ where p (X = x, Y = y) is a probability of combined occurrence of the events X = x and Y = y, and T (Am) is the cost of obtaining the value of Am.

The time for classification of the object by classification rule built IID3M upon the average is not exceed the classification of the object in any other classification rule built on the learning sample. This follows from (1).

MID3 Algorithm. Attribute selection criterion (1) usually gives a good result but the decision tree branching at every step for all possible attribute values causes a number of problems: the specialized rules are built and the number of examples in the nodes is reduced. Separation of the attribute values into two subsets increases the computational complexity by the choice of these subsets. In this regard, we propose an algorithm MID3 - pseudo-binary generalization of IID3M that avoid complex calculations bat allows to remedy these deficiencies. Instead of branching for each value of attribute chosen by (1) it can branch some individual attribute value and other values in the form of a common branch and at each node of the decision tree attribute is a conditionally binary and accepts only two values – "X" and "not X".

For the same attribute these X may be different at different nodes of decision tree. The choice of attribute values that is allocated to the separate branch is doing on base of information entropy measure (2). We choose the value of an attribute that carries the most information about the result:

$$a_{ki} : \sum_p C\left(A_k = a_{kp}, R = r_j\right) = \max_m \sum_j C\left(A_k = a_{ki}, R = r_j\right) \quad (2)$$

Procesing of incomplete data. IID3M and MID3 algorithms are designed for processing of complete data during the consultation. But often it is necessary to classify objects where a full investigation is impossible (because of the complexity, cost and other reasons). Data are incomplete (Maybe-data) if their values is currently unknown but although they can be determed later. On base of these data it is not always possible to unambiguously classify the object but we can select a subset of classes that object can belong on various methods of completions of incomplete data. We propose a method for constructing of such subsets - a method of yellow-green branches [8].

The most adequate way of formalizing and processing of incomplete data is proposed by Codd method "Null Values" [9] according to which data is incomplete if the property value for this object is currently unknown, although the property is inherent to the object and can be determed later. This unknown value can be defined by special constant, and any occurrence of such value may be substituted by the concrete value from the set of acceptable ones. The work with unknown values requires a special three-valued logic with the epistemic truth values (T-yes, F-no, W-maybe) and the corresponding truth table for all logical operations. The application of this logic to incomplete data sorts them into two classes: True-data that values are always accessible, and Maybe-data that values can be not available.

The following technology for inductive generalization of incomplete data is proposed:

Step 1: all n attributes are sortes by two classes according to a priori knowledge about their incompleteness: m attributes whose values are always available in the process of consultation, $m \le n$, and k attributes whose values during the consultation can be unknown,$n = k + m$; then from the training set matrix X' obtained from the matrix X by reordering the columns so that the first m columns of X' is formed by True-data;

Step 2: matrix X' is divided into a set of matrixs – matrix A containing m columns and matrixs B [h] containing k columns that the matrix A consists of such rows that for any row of the matrix A there a row of the matrix X ' exists where substring of the matrix A is a substring containing the first m attributes, and there is non another row of A where the first m values of which coincide with the values of this row, and each of the matrixes B[i], $0 < i \le h$, consists of such lines that for any row of the matrix B[i] there a row of X' exists that is a substring of it and the first m values of it a substring of the i-th row of the matrix A.

Step 3*:* decision trees building by the inductive inference algorithms for each of the obtained matrixes wher another meaning - "unknown" (the attribute value is missing, can not be obtained, not known precisely, and so on - the data type Maybe) – is added to the list of possible values for each attribute of B[i] matrix. This value during the consultation is interpreted in a special way and is not considered in decision tree constructing because the situation with an attribute value "unknown" is possible only in the consultation process.

Such indictive methods can be used for Semantic Web knowledge management in two ways: 1) for ontological knowledge acqisition from natural language documents (where the rows of learning sample are the occurrences of ontological concepts into some text and the results are the correlations of text with some domain); 2) for ontology enhancement by new relations and concepts. In MAIPS inductive inference is used also for acquisition of personal preferences of users (by generalization of system experience) and for clusterization of users with similar informational needs.

Summary

A method of use of user subject domain ontologies and thesauri is proposed to increase the pertinence of semantic informational retrieval as an important component of knowledge management. An algorithm of the automated acquicition of ontological knowledge from subject domain natural texts is developed. These methods are realised in intelligent IRS MAIPS oriented on users with permanent informational needs. MAIPS allows to personify the informational retrieval by inductive generailasation of search expirience and by taking into account of personal readability of informational resources.

All proposed technologies can be used for task of competence identification of scientific researchers or learning cources [10] as a part of research planning. This task is an example of a problem that needs an integrated use of different methods of Web knowledge management because knowledge about potential researchers and subject domain has to be acquised from the available Web resources: structured descriptions of individuals (e.g., FOAF) and institutions (organizational ontologies) and their posibilities (for example, in form of Web services) with account of their confidence level (with the help of Web 2.0 technologies and social networks) and from natural language and multimedia documents (and metadata that describe their content) that fix the results of researsh work (articles, monographis, reports, presentations etc.) and then methods of srmantic matchmaking have to be applied to founded information.

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A MODEL FOR VISUAL LEARNING IN AUTISM

Ekaterina Detcheva

Abstract: *The paper describes a nearly new learning and teaching model referred to as visual learning. The definitions of "visual learning" and "concept map" are given. The use of concept mapping is described together with a number of semple applications. The advanages of concept maping are explained. A comparsion is made between visual learning model based on cocept maps and a concrete practical model used by the autor in education of 10 years old autistic boy. The possibilities of appying of such kind of visual learning models in education of autistic children are described Ideas for the extension of this model and its application are given.*

Keywords: *mental models, cognitive psychology, visual learning, concept map, autism.*

ACM Classification Keywords: *J.1 ADMINISTRATIVE DATA PROCESSING – Education; J.4 SOCIAL AND BEHAVIORAL SCIENCES - Psychology; K.3 COMPUTERS AND EDUCATION - K.3.2 Computer and Information Science Education*

Introduction

Visual learning is a powerful method for representing information in a graphical way as a tree diagram or organizational chart. Each "node" of the chart contains an idea, concept or question linked together by branches to show their relationship to each other. Visual learning techniques teach students to clarify their thinking, and to process, organize and prioritize new information. Visual diagrams reveal patterns, interrelationships and interdependencies. They also stimulate creative thinking.

Visual Representation of Information

The basic elements of human thinking are the **cncepts** (ideas) and i**mages** (visual, hearing, smelling, sensory). This dualism of the theory of mind is initially presented by Paivio [Paivio, 1986]. According to Ehlberg [Ehlberg, 2002] it stands the critical assestmant and corresponds all the rest theories and facts about human thinking.

Human beings all the time build "schemes" about the world with or without intention to do this. They construct both perceptual (sensory) schemes based on world images, and coceptual (ideal) schemes based on concepts (ideas) [Ehlberg, 2002]. Perceptual and conceptual schemes are internal representation of the world [Bunge, 1983; Bunge, 1983-a]; Ehlberg, 2002]. In the past Tolman [Tolman, 1948] called these schemes **cognitive shemes.** Elsewere they are known as **mental schemes** [Ehlberg, 2002]. These internal cognitive strustures can be represented in the form of graphs wich are external representation of these structures Ehlberg, 2002], [Novak, 1984].

In the 1960s, Joseph D. Novak [Novak, 1993] at Cornell University began to study the concept mapping technique. His work was based on the theories of David Ausubel [Ausubel, 1968],, who stressed the importance of prior knowledge in being able to learn about new concepts. Novak concluded that "Meaningful learning involves the assimilation of new concepts and propositions into existing cognitive structures."

According to Jonassen et al. [Jonassen, 1990], concept maps are "**representations of concepts and their interrelationship that are intended to represent the knowledge structures that humans store in their minds.**" Usually, concept maps are defined as **semantic representations of declarative memory presented graphically** [Jacobi, 1991].

A **concept map** is a visual representation of information in **graphical mode** where **nodes** (points or vertices) represent concepts, and **links** (arcs or lines) represent the relationships between concepts. The concepts, and sometimes the links, are labeled on the concept map. The links between the concepts can be one-way, two-way, or non-directional. The concepts and the links may be categorized, and the concept map may show temporal or causal relationships between concepts [Plotnick, 1997].

A simpler view of cognitive cartography has also been proposed under the term of **mind maps** [Buzan, 1995], where only concepts and their proximity are represented, without any particular meaning imposed on the relationships.

Purpose of Concept Mapping.

Concept mapping is a type of knowledge representation. Jonassen & Grabowski [Jonassen, 1993-a] state that structural knowledge may be seen as a separate type of knowledge. "Structural knowledge provides the conceptual basis for why. It describes how prior knowledge is interconnected. … Structural knowledge is most often depicted in terms of some sort of concept map that visually describes the relationships between ideas in a knowledge domain." Representing knowledge in the visual format of a concept map allows one to gain an overview of a domain of knowledge.

Visual representation has several advantages [Plotnick, 1997]:

- Visual symbols are quickly and easily recognized;
- Minimum use of text makes it easy to scan for a word, phrase, or the general idea; and
- Visual representation allows for development of a holistic understanding that words alone cannot convey.

Concept mapping can be used for several purposes [Plotnick, 1997]:

- **Creativity Tool -** Drawing a concept map can be compared to participating in a brainstorming session. As one puts ideas down on paper without criticism, the ideas become clearer and the mind becomes free to receive new ideas. These new ideas may be linked to ideas already on the paper, and they may also trigger new associations leading to new ideas.
- **Hypertext Design Tool -** As the World Wide Web becomes an increasingly powerful and ubiquitous medium for disseminating information, writers must move from writing text in linear fashion to creating hypertext documents with links to other documents. The structural correspondence between hypertext design and concept maps makes concept mapping a suitable tool for designing the conceptual structure of hypertext. The structure of both a hypertext document and a concept map can be seen as a directed graph or a knowledge graph [Conklin, 1987]. A concept map placed on the Web in hypertext may also serve as a Web navigational tool if there are clickable areas on the concept map that take the user immediately to indicated parts of the hypertext document.

Designing hypertext is an activity with inherent problems. Botafogo, Rivlin & Schneiderman [Botafogo, 1992] describe a dilemma faced by designers of hypertext authoring systems. In order to stimulate authors to write clearly structured hypertext (usually hierarchical), they have to decide when to force authors to reflect upon the structure of their work. Imposing a hierarchical structure from the beginning may result in too many restrictions for the author, while any effort to stimulate hierarchy afterwards is too late, and it may even be impossible for authors to restructure the jungle of nodes and relationships. Concept mapping may be a good intermediate step for authors to use to reflect upon their work when developing hypermedia.

- **Communication Tool -** A concept map produced by one person represents one possible way to structure information or ideas. This is something that can be shared with others. A concept map produced by a group of people represents the ideas of the group. In either case, concept mapping can be used as a communication tool for people to use to discuss concepts and the relationships between the concepts. They may try to agree on a common structure to use as a basis for further action.
- **Learning Tool -** Novak's original work with concept mapping dealt with learning. Constructivist learning theory argues that new knowledge should be integrated into existing structures in order to be remembered and receive meaning. Concept mapping stimulates this process by making it explicit and requiring the learner to pay attention to the relationship between concepts. Jonassen ([Jonassen, 1993] argues that students show some of their best thinking when they try to represent something graphically, and thinking is a necessary condition for learning. Experiments have shown that subjects using concept mapping outperform non-concept mappers in longer term retention tests [Novak , 1983].

  Concept mapping is also gaining inroads as a tool for problem-solving in education. Concept mapping may be used to enhance the problem-solving phases of generating alternative solutions and options. Since problem-solving in education is usually done in small groups, learning should also benefit from the communication enhancing properties of concept mapping.
- **Assessment Tool**-Concept maps can also be used as assessment tools. The research team around Joseph Novak at Cornell found that an important by-product of concept mapping is its ability to detect or illustrate the imisconceptionsl learners may have as explanations of content matter. The conceptions students may have are often incomplete and deficient leading to misunderstanding of instruction. Concept maps drawn by students express their conceptions (or their misconceptions) and can help the instructor diagnose the misconceptions that make the instruction ineffective [Ross, 1991].

Some Applications of Concept Mapping.

According to Kay Hawes [Hawes, 1998] concept maps can be devided to three basic groups:

- process maps
- problem soution maps
- characteristic maps

Next figure shows a concept map about the cocept maps:

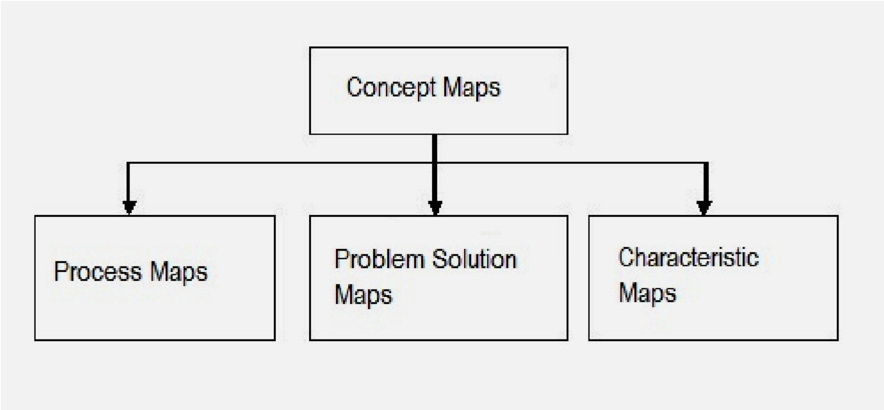


Figure 1: A concept map about the cocept maps

The samples below show some of the kinds of maps

- ***Process Maps***

Process maps show a process for accomplishing a task. There is a beginning and an end, with multiple steps and alternatives at each step.

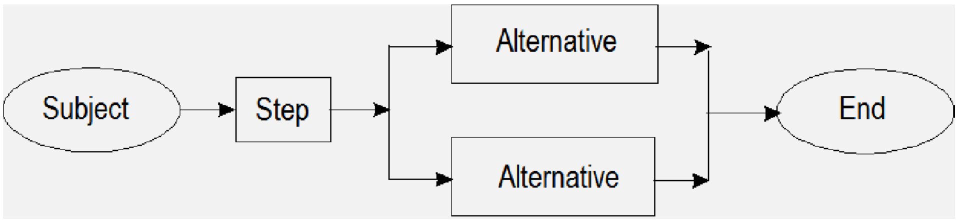


Figure 2. A process map

- ***Problem Solving Maps***

A fairly straightforward map is a problem-solution map. In this, there is problem statement, definition, causes, and effects, leading to a possible solution.

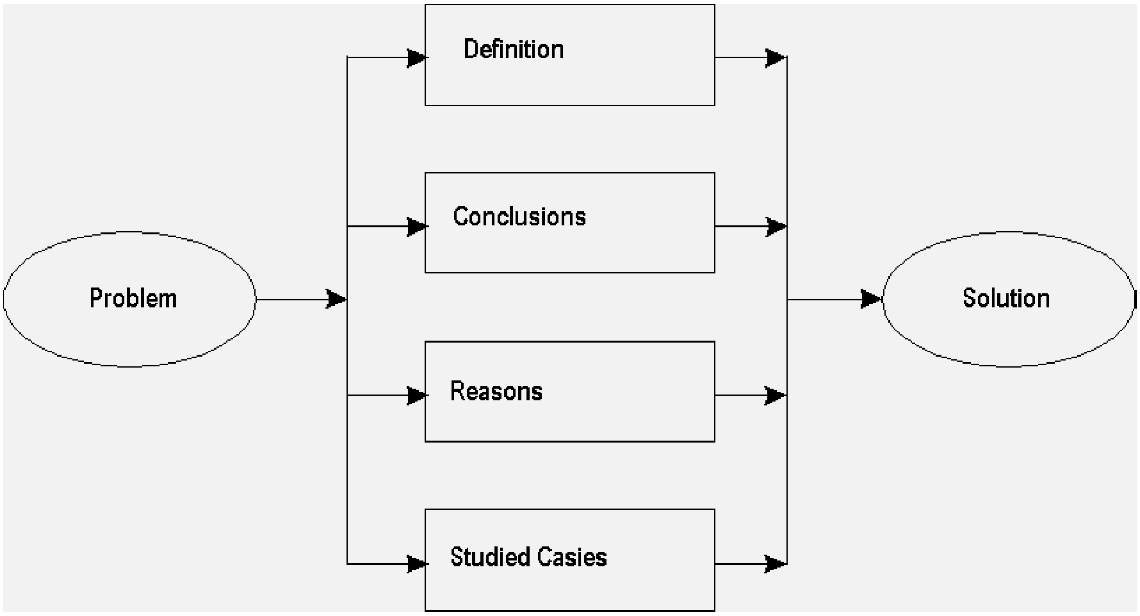


Figure 3. A problem solving map.

This scheme leads to narrative story line maps and persuasive argument maps:

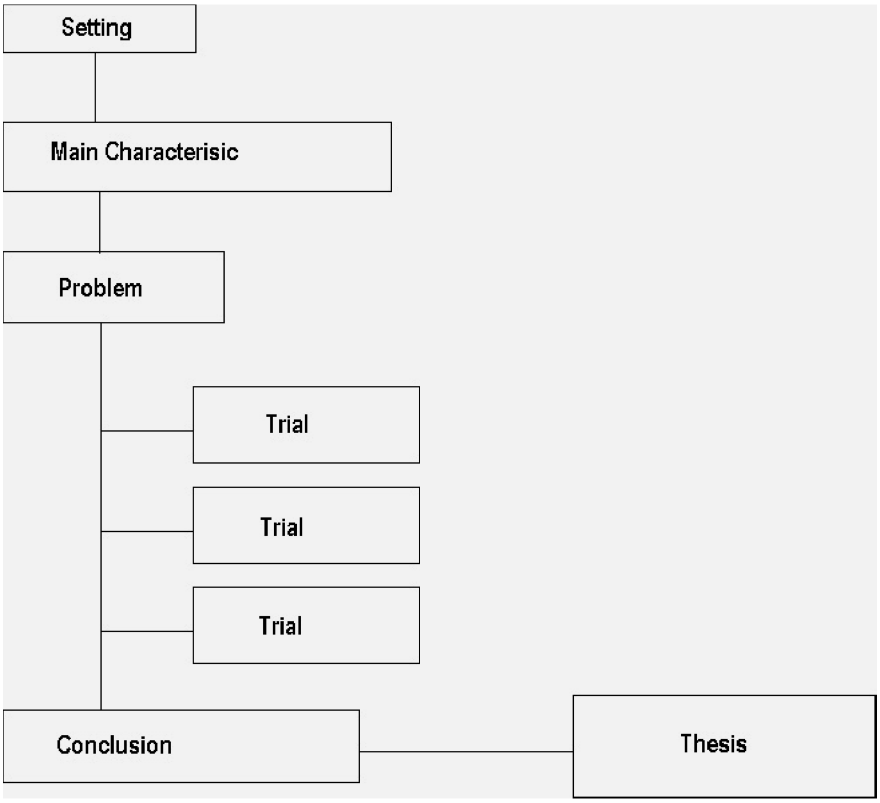


Figure 4. A story line map.

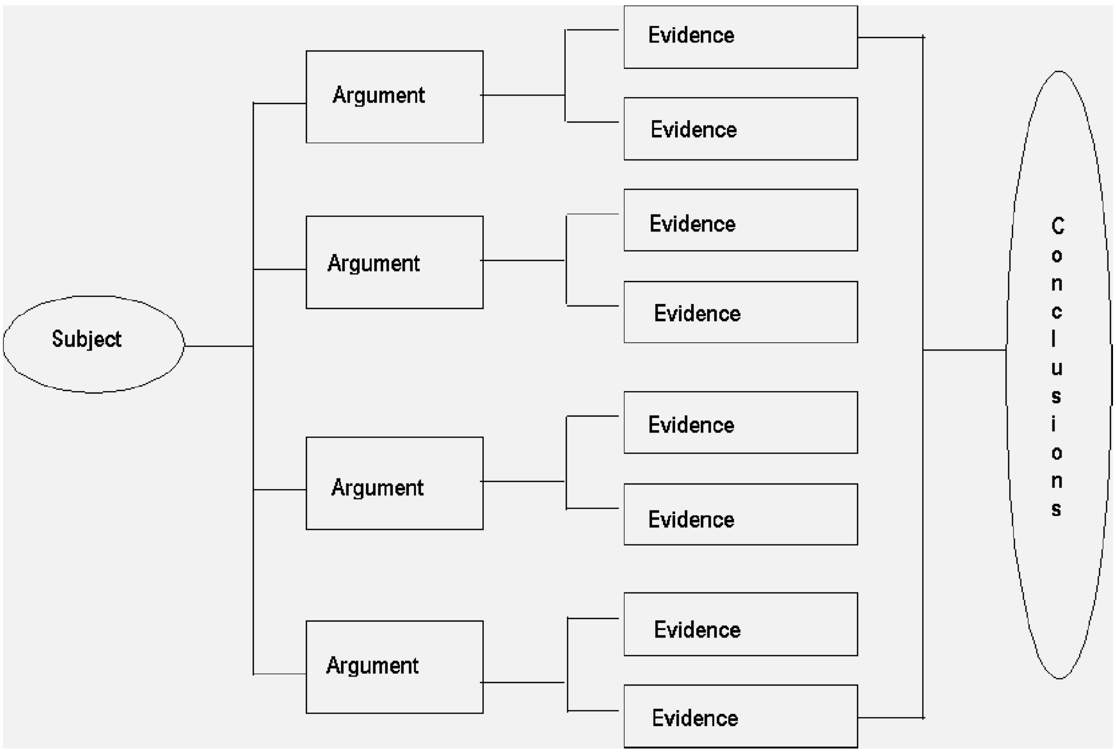


Figure 5. A persuasive argument map.

- ***Characteristic Maps***

These maps show characteristics or atributes which describe the given object or person. They may include object specification, list of some of its chracteristics and functions, studied events and its importance.

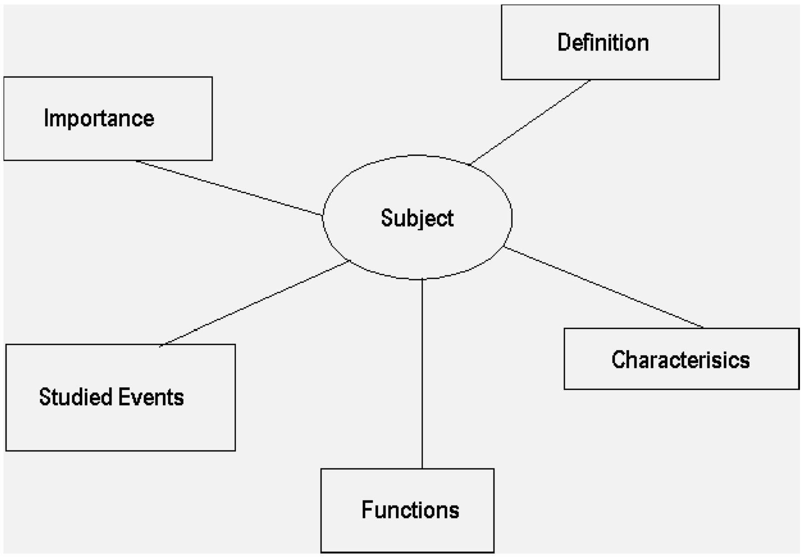


Figure 6. A characteristic map

What is Autism?

Clinically autism is barely fifty years old. Although with the benefit of hindsight it is possible to identify likely cases of autism throughout the century and, in specific isolated incidents, throughout history, the initial identification of the condition was presented to the world towards the end of the second world war. In a fantastic coincidence, possible only as a result of the global conflict, two completely independent studies and publications identified and discussed a 'new' severe condition effecting social interaction, communication, behaviour and development. What is more remarkable is that the authors of both studies, Leo Kanner and Hans Asperger, chose to describe the condition as 'autism'. The word autism itself is derived from the Greek 'autos', meaning self. The world was used earlier in the century to describe an element of schizophrenia where the sufferer becomes detached, unresponsive and unaware of the outside world. In many ways it is a very apt and profound use of medical nomenclature.

Autism as defined in Hans Asperger's paper (published in German in 1944) has developed into what is now described as Asperger's Syndrome. In many ways this is seen as a form of High Functioning Autism and is discussed in depth elsewhere. Of greater relevance to current diagnostic criteria for autism is Leo Kanner's paper (published in 1943) and the 'classical autism' which he described is still very much the typical standard by which autism is understood today [Kanner, 1943].

Following five years of observation and study in Baltimore Leo Kanner published his paper 'Autistic disturbances of affective contact' in 19436. He illustrated the condition with 11 case studies. He provided a vivid and enduringly perceptive insight to autism and many of his observations survive as the foundation for current identification and diagnosis. A number of these observations related to behaviour and ability as presented by the children in his case study. These included a profound lack of affective contact with other individuals, an inability to form reciprocal social relationships and interactions; a reliance and desire for sameness which included stereotypical behaviour, elaborate routines with a high degree of repetitiveness and seeming compulsion, and an obsession with manipulating and relating to objects (as opposed to other individuals); severe deficits or difficulties in the use of speech and communication (including literalness, echolalia and failure to use the first-person pronoun) as well as muteness in three cases; generally severe learning disabilities in most areas; the existence and presentation of the disorder from birth or by the age of 30 months. In addition to these elements of Kanner's autism he also observed that his subjects demonstrated high level skills in some areas (such as rote memory learning and visuo-spatial skills) in comparison to their general learning disabilities. Kanner also described his children as presenting an attractive appearance with the suggestion of an inner alertness or intelligence. This theme is often repeated throughout the history of autism and although it demonstrates a desire to look at the autistic child as an individual with an identity of their own it also raises the risk of false assumptions and unrealistic goals and aims in intervention and interpersonal relationships (the effect of these perspectives are considered elsewhere in this section).

Contemporary to Kanner and as enduring and relevant to understanding of autism today was the work of Hans Asperger. Working in Vienna during the second world war Asperger's insight into the condition which he was studying was equalled by the compassion, understanding and devotion he extended towards the children he was involved with. Both are important in terms of current day theory and practice. The condition that Asperger described received little attention outside of the German speaking world at the time in which he published his paper 'autistic psychopathy in children' [Asperger, 1944]. More recently however appreciation and use of the observations and inferences that he made are widely recognised and accepted. Today Asperger's syndrome is commonly used to describe an 'autistic' condition associated with higher levels of functioning. A raised IQ often within the bounds of normality is not rare, social interaction impairments are present but masked or compensated for in a number of cases and there is often regarded as being a greater acquisition of language although deficits in the use of language may be starkly evident.

Autism (sometimes called "classical autism") is the most common condition in a group of developmental disorders known as the autism spectrum disorders (ASDs). Autism is characterized by impaired social interaction, problems with verbal and nonverbal communication, and unusual, repetitive, or severely limited activities and interests. Other ASDs include Asperger syndrome, Rett syndrome, childhood disintegrative disorder, and pervasive developmental disorder not otherwise specified (usually referred to as PDD-NOS).

There are three distinctive behaviors that characterize autism. Autistic children have difficulties with social interaction, problems with verbal and nonverbal communication, and repetitive behaviors or narrow, obsessive interests. These behaviors can range in impact from mild to disabling.

The hallmark feature of autism is impaired social interaction. Parents are usually the first to notice symptoms of autism in their child. As early as infancy, a baby with autism may be unresponsive to people or focus intently on one item to the exclusion of others for long periods of time. A child with autism may appear to develop normally and then withdraw and become indifferent to social engagement.

Children with autism may fail to respond to their name and often avoid eye contact with other people. They have difficulty interpreting what others are thinking or feeling because they can't understand social cues, such as tone of voice or facial expressions, and don't watch other people's faces for clues about appropriate behavior. They lack empathy.

Many children with autism engage in repetitive movements such as rocking and twirling, or in self-abusive behavior such as biting or head-banging. They also tend to start speaking later than other children and may refer to themselves by name instead of "I" or "me." Children with autism don't know how to play interactively with other children. Some speak in a sing-song voice about a narrow range of favorite topics, with little regard for the interests of the person to whom they are speaking.

Many children with autism have a reduced sensitivity to pain, but are abnormally sensitive to sound, touch, or other sensory stimulation. These unusual reactions may contribute to behavioral symptoms such as a resistance to being cuddled or hugged.

There is no cure for autism. Therapies and behavioral interventions are designed to remedy specific symptoms and can bring about substantial improvement. The ideal treatment plan coordinates therapies and interventions that target the core symptoms of autism: impaired social interaction, problems with verbal and nonverbal communication, and obsessive or repetitive routines and interests. Most professionals agree that the earlier the intervention, the better.

- Educational/behavioral interventions;
- Medications;
- Other therapies;

One of the most damaging side in autism is the lack of generalizing skills. This leads to the lack of ability to think in abstract ideas and to deduce new knowledge from the existing one, namely to learn from his or her own experience. On the other side autistic children have many other talants like a good memory and a visual thinking (thinking in pictures).

As is mentioned in previous part, in visual learning with concept maps the structure of the knowledge can be graphivally presented which makes them easy to understand and mastered, and sutable for education of autistic children.

Let see some examples from the autor`s practice in education of 10 years old autistic boy.

Next scheme has been usd for the representation of the Bilgarian sentence structure:

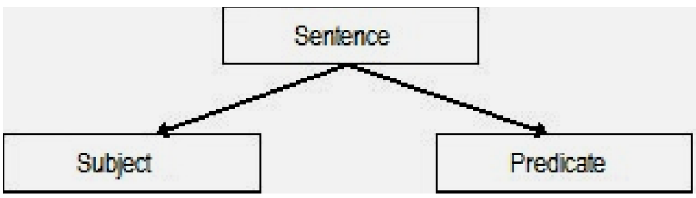


Figure 8. A scheme of the sentence structure.

It shows that the Bulgarian sentence consists of a subject and a predicate. Here is an example of a sentence:

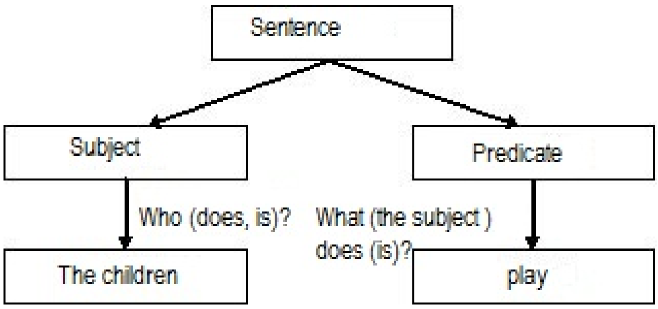


Figure 9. A scheme with an example of a sentence.

The questions about the subject and the predicate are presented.

This scheme can be extended to subject and predicate group respectively:

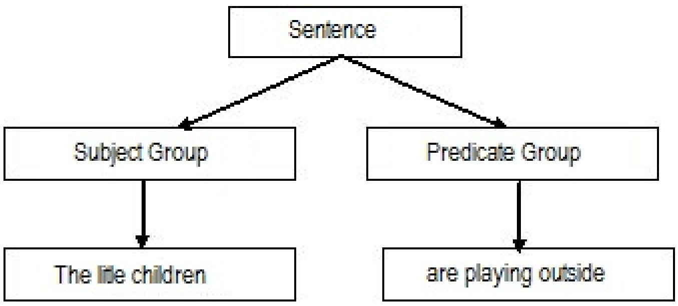


Figure 10. Extended sheme of the sentence structure.

These schemes are similar to the map representing concept maps in previous part (Fig. 1).

Using these schemes the boy learned to make sintactical analysis of different kind of sentences. Furthermore he overcame step by step the difficulty to distinguish the sentences in written text wich helped him later to understand simple texts and to perform different tasks upon the written instructions as recipes and software users guides.

One of the main difficulties of autistic children is the lack of narrative skills and verbal communication of the information. They much easly can learn the hole text by heart then to explain it by his or her on words. Again in this case cane be used some kind of concept maps.

A simmilar approach is applied in the tutoring of the same boy to make him able to tell a reading story. The instructions started with fairy-tales. Initially the story is devided into logically independent parts. Then each part of the story is expressed in one or two simpleand easy to understand phrases. The boy writes the phrases down and drows s picture about the matter they are expressing. In this way a numbered list of such kind of phrases is made and in the and the moral is written. Here is the example of the Bulgarian story “The fishman and the golden fish” (in Bulgarian):

Приказка за рибаря и рибката

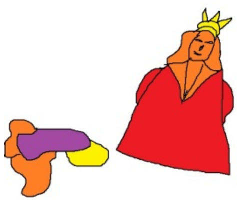
1. Живял дядо със своята баба край брега на морето в схлупена къщурка. Старецът ловял с мрежа риба. Веднъж хванал в мрежата златна рибка. Златната рибка се помолила на дядото да я пусне срещу откуп.

2. Дядото се върнал вкъщи и разказал на бабата за златната рибка и за откупа. Бабата се скарала на дядото, че не е поискал едно ново корито. Дядото се върнал на брега и поискал от златната рибка ново корито. Тя му го дала.

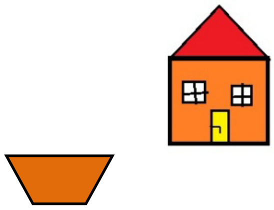
3. Бабата отново била недоволна и поискала нова къща. Рибката изпълнила и това желание.

4. Бабата се разлютила, че дядото не е поискал още повече. Поискала да стане дворянка. Дядото се примолил на рибката и тя изпълнила за последен път желанието на бабата.

5. Вбесена, бабата поискала да стане царица, а дядото и рибката да й бъдат слуги.



6. Златната рибка се ядосала на ненаситността на бабата и си взела всичко обратно. Бабата се оказала пред старата къща и пробитото корито.



7. Извод: Човек не трябва да е ненаситен. Той трябва да е скромен, да работи и да не чака да получава богатства и титли наготово.

After this the boy learns the text from the points by heart. The instructor yhen asks him questions about each point. Step by step the boy beins to answer the questions and later he becomes able to tell the hole story as it is written before.

This scheme with points illustrated with corresponding pictures is the simple version of the story line map from the previous part (Fig. 4) and is applied in learnig process during the whole school time. Each point fro the list is simmilar to the nodes in the concept maps and the pictures illustrate the matter of the point. The numbers of the points represent the sequence of the story parts like the arrows in the context maps.

In the course of study this scheme has become more complicated and extended. Gradually the pictures dropped out and this scheme turned to learning outlines of the other subjects like history, geography and science. To the main points the subtopics and charts and illustrations are added to them.

It is important to mention that these schemes and outlines are made in cooperation between the boy and his instructor and the meaning of the text is cleared.

The need of visual representation of information arrised in the course of work with psychologist when it was found that he easily copes with the description of subjects and events and with the comparsion between them when he uses som visuale cures. In this case a extention of the described above educational model can be implemented with the use of the two versions of the characteristic maps (fig. 6 and Fig. 7) both in description and camparsion between studied subjects and events. This is a possible way for extension and improvment of the visual learning model described here.

Results

In the first sight the model explained here looks like text memorizing and repeating over and over again without any sence of its content. Actually, in addition to the acquisition of the elementdy knowledge from the text the following results are obtained:

- The text of each topic can be presented in the form of question;
- A lot of language patterns are coleected;
- Gradually begins to answer questions
- Acquisition of conversation skills;
- Acquisition of skills for sharing experiences;
- Illustrating of thegeneraliztinq can be done.

The model has some disadvanages,as follows:

- The lessons preparation takes too much time;
- As this model is applied to assist the homework mastering, it does not include the answer “I don`t know”;
- A model is not applied to the text generation, i.e. to the writing of stories and articles.

Nevertheless, the application of this simple model for visual learnig with the use of concept maps aids speech development, thinking in more abstract ideas and generalization skills. This enabled to reduce some of autism deficites and to achieve better development end a good life in future.

Conclusion

Concept maps are toeels for representing the structure of informetion. Ther are several ways of concept maps application: idea generation, design support,increasin of the information exchange, facilitation of the learnig and estimation. Concept maping application in education allows autisic students and their teachers easily to costruct visual structure of the knowledge from the lessons. This knowledge can be shared and extended and thus to help children with autism to deduct new knowledge from the existing one.

Acknowledgement

The paper is published with financial support by the project ITHEA XXI of the Institute of Information Theories and Applications FOI ITHEA (www.ithea.org) and the Association of Developers and Users of Intelligent Systems ADUIS Ukraine (www.aduis.com.ua).

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Информация за автора

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OPTIMIZATION OF CONNECTION’S STRUCTURE OF REMOTELY-OPERATED PORTABLES TO INFORMATION NETWORKS' BASIC EQUIPMENT

Galyna Gayvoronska

Abstract: *The abstract model of information network's evolution's process is considered. Three classes of equipment's types on the network are specified. Classification of information network's structure's optimization problems by a time sign is offered and proved. Possibilities of the further research of modernized network's development's general problem according to the offered classes of problems are defined.*

Keywords: *information network, basic equipment, portable, station, structure of connection.*

ACM classification keywords: *H. Information Systems - H.1 MODELS AND PRINCIPLES.*

Introduction

Information networks' (IN) designing includes various problems from mathematical and technical to economic and political. Recently so-called portable or remotely-operated equipment which is connected to the equipment named basic and functionally interconnected with it is more widely used on information networks. Information networks' basic equipment can work as stand-alone, and together with the considered portable equipment. There is great number of systems working in such way: digital switching systems with portable remote modules connected to them - digital concentrators or subscriber's multiplexers, computer systems using the «Client - server» connection principle and control systems co-operating on the «control device - operated object» principle. Base stations' controllers connected to mobile communication's cellular networks' switching centers work by such principle.

Earlier network development's process was planned for each station independently. Occurrence of portable equipment which is usually named portable modules (PM) creates additional logic connection between stations and brings about necessity of integrated approach for planning. Taking into account entered equipment's features at definition of network's modernization strategy it is important to consider a way of connection between PM and basic equipment. This work is devoted to one of possible approaches for the decision of this problem.

Problem statement

Let's consider IN's development model at introduction of the new equipment differing by a number of governing modernized networks' structure parameters. The general formulation of a research's problem is given in [1,2], some private problems' decision's aspects within the formulated problem's limits in works [3-5]. For a considered problem network development's strategy is defined by type, site and placing time of anew entered equipment.

Superposition method at which existing equipment keeping in network's stations and development is carried out by the new one and a replacement method at which existing equipment is replaced with the new are considered. At the same time network's development model considers network's interrelations in space and in time.

According to the problem put by let's allocate three classes of equipment's types (fig. 1) used on the network:

- existing technology's equipment;
- new technology's basic equipment;
- new technology's portable equipment.

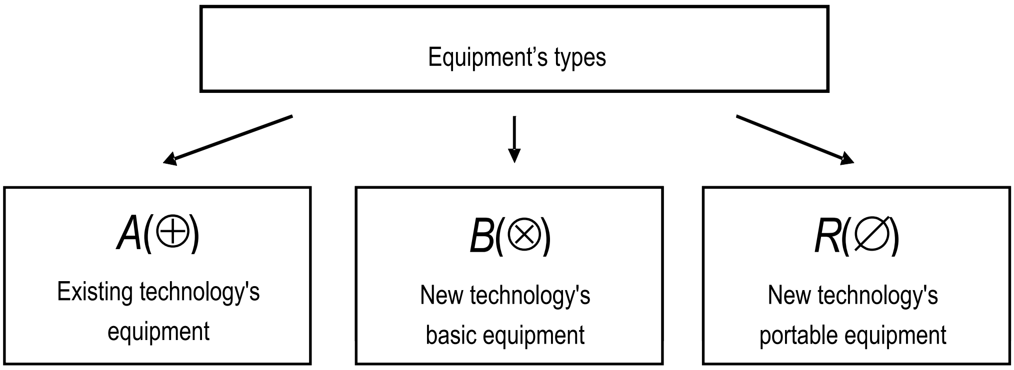

Fig. 1 Classification of equipment's types

Let's designate these equipment's classes in the form of the sets A, B and R. It is natural to consider these sets final which each element a_i, b_i or r_i represents equipment's type of corresponding class.

Definition of information network's evolution's strategy

Let's consider IN's development model at new equipment's introduction differing in parameters influencing modernized network's structure. Network's evolution strategy is defined by type, site and placing time of the new equipment.

With use of works' [1-5] results decision of considered problem can be examined in a kind of pair (X,Y), where $X: I \times T \to 2^{A \cup B \cup R}$ defines used equipment's types on stations. Such task X means that there can be some types of equipment $X(i,t) \subseteq A \cup B \cup R$ simultaneously established on some station i during each moment of time t.

Let's put additional designations of this characteristic for what we will fix some station i and define $x_i : T \to 2^{A \cup B \cup R}$, $x_i(t) = x(i,t)$.

Let's name set of equipment's types used at present on station and accordingly functions which are carried out in station - station's condition. Then $\Psi = 2^{A \cup B \cup R}$ - set of station's conditions.

For stations with established portable modules let's define basic station to which concrete PM is connected at present time. For this purpose let's set representation

$$Y : E_R \to I_B ,$$

where $E_R = \{< i,t >| i \in I, t \in T : X(i,t) \cap R \neq \varnothing\}$ - set of spatio-temporal system's points demanding the basic equipment that is ordered pairs from time's moment and station on which PM is located.

$I_B = \{i \mid i \in I : \exists t \in T \; X(i,t) \cap B \neq \varnothing\}$ - set of potentially basic spatial points that is stations on which at replacement basic equipment is entered during the investigated period.

This representation in its range of definition sets basic station $Y(i,t) \in I$ to which station i is connected at the moment of t .

Then the decision of a problem of a choice of IN's evolution strategy can be considered in a kind of pair (X,Y) where $Y : I \to I_0$ defines connection's structure of the portable equipment. Let's formulate this statement in the form of a lemma.

Lemma 1. *It is always possible to define network's evolution strategy on the basis of pair* (X,Y) *and thus only one.*

The proof. Admissible network evolution strategies are only that one which allow either full replacement of previous type's equipment with new type's equipment, or preservation of previous type's equipment and usage of new type's equipment only for expansion of station's capacity, during the introduction of new type of the equipment. During the concrete moment of time introduction only of one equipment's type on one station is supposed.

From the foregoing follows that if there is a change of a set of used equipment's types at the moment of time t at station i

$$X(i,t) \neq X(i,t-1),$$

only two variants are possible

$$X(i,t) = X(i,t-1) \cup \{\chi_2\}$$

or

$$X(i,t) = \left(X(i,t-1) \setminus \{\chi_1\}\right) \cup \{\chi_2\},$$

where $\chi_2 \in B \cup R$ - the equipment's type entered during moment t ;

$\chi_1 \in B \cup R$ - the equipment's type entered directly ahead of χ_2 .

The first variant corresponds to imposing of the type χ_2 equipment on the existing equipment and the second - full replacement of the type χ_1 equipment by the type χ_2 equipment. These variants for each station i and time moment t are defined unequivocally and in their turn unequivocally define development's strategy as was to be proved. ■

Let's carry out classification of IN's evolution problem by complexity level. For this purpose let's enter several definitions [3].

Let's name station's j on which PM is established work remote control by station i supplied with the basic equipment as **portable's** j **connection** to basic station i during some moment t .

$$y_j(t) = i$$

$$x_j(t) \cap R \neq \varnothing$$

$$x_i(t) \cap B \neq \varnothing$$

Let's name basic station's change for PM on station j as **portable's j connection change**

$$\exists t \in T,\ i,k \in I, i \neq k, t > 0: \quad y_j(t-1) = i \wedge y_j(t) = k\ .$$

Let's name set of each network station's connections as network's **portables' connection structure**.

Let's name invariant throughout all period of research connection as **station's j strictly stationary connection**. It means that basic station for this PM j stays invariable within all considered time area $y_j(t) \equiv \text{const}$.

Let's name invariant on segment $[\theta_j, h]$, where θ_j - the portable equipment's introduction moment on station j, connection as **station's j generalized stationary connection**.

$$\forall t \in T: \theta_j < t \leq h \quad y_j(t) = y_j(t-1)\ .$$

Let's name connections' structure on all network as **network's strictly (generalized) stationary connections' structure** if each of station's connections are strictly (generalized) permanently.

Directly from the entered definitions follow statements.

Lemma 2. *Any strictly stationary connection is generalized stationary.*

Lemma 3. *Any strictly stationary connections' structure is generalized stationary.*

Let's allocate problems' classes (fig. 2) corresponding to assumptions:

- class K_1: the connections' structure of network is strictly stationary;

$$\forall j \in I \quad y_j(t) \equiv \text{const} \tag{1}$$

- class K_2: the connections' structure of network is generalized stationary;

$$\forall j \in I, t_1, t_2 \in T: \theta_j < t_1, t_2 \leq h \quad y_j(t_1) = y_j(t_2) \tag{2}$$

- class K_3: any connections' structure in which there are no connections' changes is possible;

$$\forall j \in I, t_1, t_2 \in T: t > 0 \quad \begin{cases} y_j(t_1) \in I \\ y_j(t_2) \in I \end{cases} \Rightarrow y_j(t_1) = y_j(t_2) \tag{3}$$

- class K_4: arbitrary connections' structure is admissible.

Construction of problems' classes indicates that they make a chain of inclusions, namely $K_1 \subset K_2 \subset: K_3 \subset: K_4$ where the first class problems actually exclude possibility of the portable equipment's introduction.

Lemma 4. *Let* (X, Y) *the decision of the first class problem. Then*

$$f(t) = \text{sgn card}\, x_i(t) \cap R = \text{const} \quad \forall i \in I \tag{4}$$

The proof. Let's carry out the proof by contradiction method. Let's assume that the condition (4) is not executed, that is

$$\exists i^* \in I, t^* \in T, t^* > 0: \ \text{sgn card}\, x_{i^*}(t^*) \cap R \neq \text{sgn card}\, x_{i^*}(t^*-1) \cap R \tag{5}$$

Considering the set's cardinal number's properties it is possible only in the event that $\text{sgn card}\, x_{i^*}(t^*-1) \cap R = 0 \wedge \text{sgn card}\, x_{i^*}(t^*) \cap R = 1$, that is $x_{i^*}(t^*-1) \cap R = \varnothing \wedge x_{i^*}(t^*) \cap R \neq \varnothing$.

But then by definition $y_i(t)$ $y_{i^*}(t^*-1) = 0 \wedge y_{i^*}(t^*) \neq 0$. That is $\exists i^* \in I, t^* \in T : y_{i^*}(t^*-1) \neq y_{i^*}(t^*)$.

However it means that portable's connection for some station is not strictly stationary, that is the network's portables' connection's structure as a whole cannot be strictly stationary that contradicts a condition.

Thus the assumption (4) is incorrect. The lemma is proved. ■

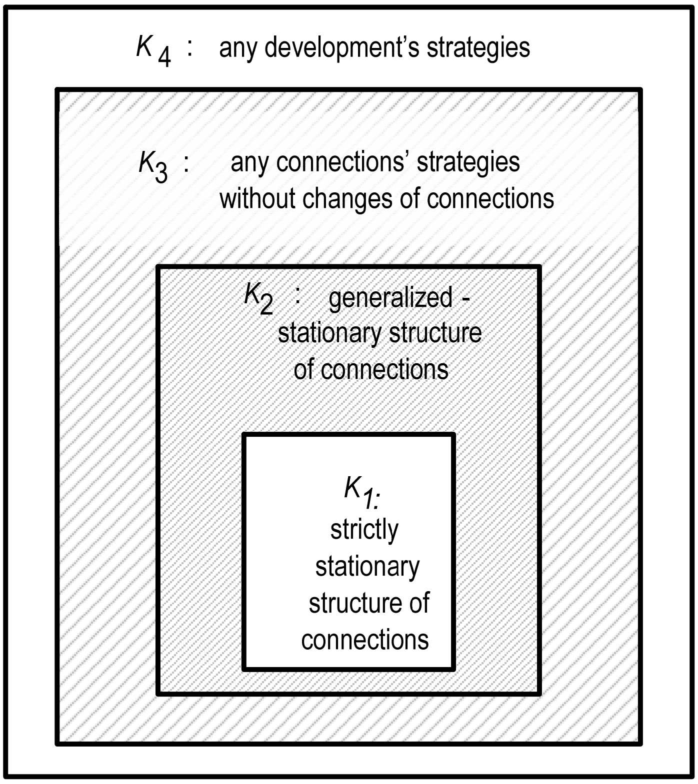

Fig. 2 Classes of problems on complexity

If thus during the initial time moment the portable equipment has not been established it is possible to formulate more essential conclusion.

Consequence. If in the lemma's 4 conditions moreover the condition of portable equipment's absence on all network's stations during the initial time moment $\forall i \in I \ x_i(0) \cap R = \varnothing$ is satisfied, *the statement that this equipment will not be established during the investigated period and not one station will not be served by another as basic is fair*

$$\begin{gathered} \forall i \in I, t \in T \ \ X(i,t) \cup R = \varnothing \\ Y(i,t) = 0 \end{gathered} \tag{6}$$

The proof. Let's prove the statement by time t induction.

Induction's base: at $t = 0$ (6) is true on the condition.

Let's assume that the lemma's statement is fair $\forall t \le k, k \ge 0$. Let's show that it is true for $t = k + 1$ too.

According to the lemma 4 $\operatorname{sgn} \operatorname{card} x_i(k+1) \cap R = \operatorname{sgn} \operatorname{card} x_i(k) \cap R$.

But under the induction's assumption $x_i(k) \cap R = \varnothing$,

that is

$$\operatorname{sgn} \operatorname{card} x_i(k) \cap R = 0.$$

And it attracts equality

$$\operatorname{sgn} \operatorname{card} x_i(k+1) \cap R = 0,$$

in other words

$$x_i(k+1) \cap R = \varnothing.$$

And from this follows

$$y_i(k+1) = 0.$$

That is the lemma's statement is true for $t = k + 1$ too.

The step is executed. The lemma is proved. ■

The proved one indicates that the class 1 problems are too narrow and uninteresting.

Class K_4 though is more general and does not produce any restrictions to problem's condition insignificantly differs from class K_3. The difference consists only in admissibility or inadmissibility of serving station's change for some portable.

Lemma 5. (X,Y) *is the decision of class* $K_4 \setminus K_3$ *problem in only case when*

$$\exists j^* \in I, t_1^*, t_2^* \in T : t_1^*, t_2^* > 0 \quad y_{j^*}(t_1^*), y_{j^*}(t_2^*) \in I, \text{but } y_{j^*}(t_1^*) \ne y_{j^*}(t_2^*).$$

The proof evidently follows from classes K_3 and K_4 definition.

Let's consider the general aspects of the classes K_2 and K_3 problems' decision. The basic distinction between these classes consists that K_3 supposes replacement of the portable equipment on basic, and class K_2 - no.

Lemma 6. *If* (X,Y) *is the decision of class* $K_3 \setminus K_2$ *problem following* $\exists j^* \in I, t_1^*, t_2^* \in T : t_1^*, t_2^* > 0 \quad x_{j^*}(t_1^*) \cap R \ne \varnothing \wedge x_{j^*}(t_2^*) \cap R = \varnothing$ *is true.*

The proof. If (X,Y) simultaneously is the class K_3 problem's decision and is not the class K_2 problem's decision by definition for (X,Y) it is carried out (2) and it is not carried out (3). That is

$$\exists j^* \in I, t_1^{**}, t_2^{**} \in T : \theta_{j^*} < t_1^{**}, t_2^{**} \le h \quad y_j(t_1^{**}) \ne y_j(t_2^{**})$$

besides, that

$$\begin{cases} y_{j^*}(t_1^{**}) \in I \\ y_{j^*}(t_2^{**}) \in I \end{cases} \Rightarrow y_{j^*}(t_1^{**}) = y_{j^*}(t_2^{**}).$$

It means one of condition's fulfillment

$$\left[\begin{array}{l} y_{j^*}(t_1^{**}) \notin I, \\ y_{j^*}(t_2^{**}) \notin I. \end{array}\right.$$

Really if it was not so owing to (3) $y_{j^*}(t_1^*)$ it would be equal $y_{j^*}(t_2^*)$. From definition of function $y_j(t)$ expansion,

$$\left[\begin{array}{l} x_{j^*}(t_1^{**}) \cap R = \varnothing, \\ x_{j^*}(t_2^{**}) \cap R = \varnothing. \end{array}\right. \tag{7}$$

But also t_1^{**} and t_2^{**} are strictly more then the first imposing θ_{j^*} time for which by definition it is carried out $x_{j^*}(\theta_{j^*}) \cap R \neq \varnothing$.

Let's designate t_2^* that one from variables t_1^{**} and t_2^{**} which provides fulfillment of set (7), $x_{j^*}(t_2^*) \cap R = \varnothing$.

Let also $t_1^* = \theta_{j^*}$. We have received

$$\exists j^* \in I, t_1^*, t_2^* \in T : t_1^*, t_2^* > 0 \quad x_{j^*}(t_1^*) \cap R \neq \varnothing \wedge x_{j^*}(t_2^*) \cap R = \varnothing .$$

Which was to be proved.

This classification is convenient because it allows concretizing station's evolution's strategies. In particular for a case with one type of the existing equipment, one type of new portable and one type of new basic it is possible to assert that there are strategies only on one type of station's evolution in each of classes K_1, $K_2 \setminus K_1$ and $K_3 \setminus (K_2 \cup K_1)$.

These station evolution's types are on fig. 3 and defined as follows:

- imposing of the new basic equipment and the subsequent replacement of the existing equipment by it;
- imposing of the new portable module and the subsequent replacement of the existing equipment by it;
- imposing of the new portable module and the subsequent replacement of all equipment by the new basic.

The listed types of station's evolution assume only potential possibility of imposition's and replacement's events, that is, this or that event can not occur at all. For example, strategies of the second and third type include preservation's possibility of the imposed portable equipment on the station till the end of the investigated period. Also it is necessary to notice that all three strategy's types include strategy of proceeding growth. Similar classification's ambiguity can be eliminated easily enough if we agree to carry the strategy belonging simultaneously to several station's evolution's types only to type with minimum number. Then for each station it will be possible to define unequivocally one of three strategies of its evolution.

It is necessary to notice that information which gives that the station develops by the second or third type strategy is insufficient it demands specifications. Namely it is necessary to specify also what station is basic for the given portable.

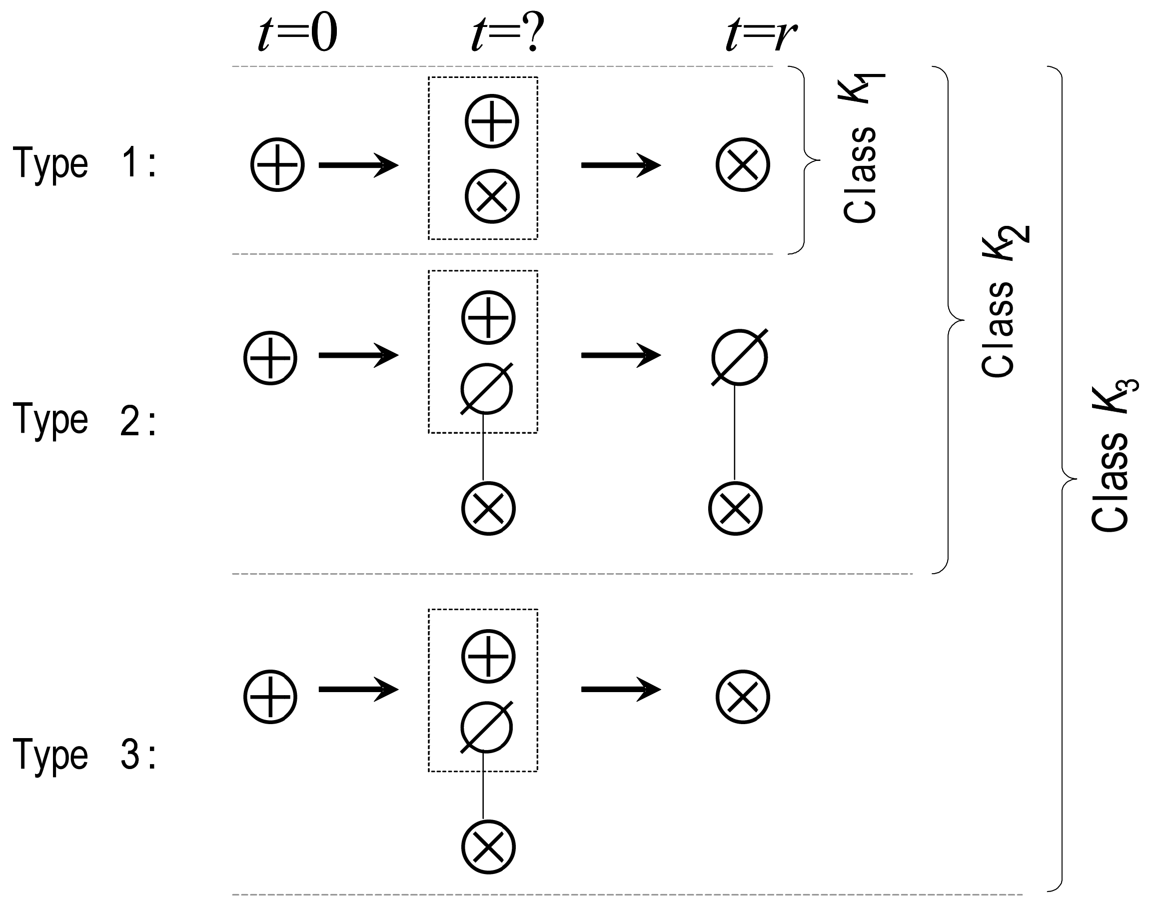

Fig . 3 Three types of station evolution's strategy

According to this let's define binary variables χ_{ij} and divide them into three groups corresponding to types of station evolution's strategies $\forall i, j \in I$

$$\chi_j^1 = \begin{cases} 1, & \text{if station } j \text{ develops by type 1 strategy;} \\ 0, & \text{otherwise.} \end{cases}$$

$$\chi_{ij}^2 = \begin{cases} 1, & \text{if station } j \text{ develops by type 2 strategy and connects to station } i; \\ 0, & \text{otherwise.} \end{cases}$$

$$\chi_{ij}^3 = \begin{cases} 1, & \text{if station } j \text{ develops by type 3 strategy and connects to station } i; \\ 0, & \text{otherwise.} \end{cases}$$

Let's define sets X^1, X^2 and X^3 as sets of the binary variables corresponding to each type of strategies

$$X^1 = \{x_j^1 \mid j \in I\},$$

$$X^2 = \{x_{ij}^2 \mid i, j \in I, i \neq j\},$$

$$X^3 = \{x_{ij}^3 \mid i, j \in I, i \neq j\}.$$

As the new equipment's imposition's moment is defined by value $\theta_j \in T$ and the replacement moment - $r_j \in T$ for any station j pair $\theta_j - r_j$ should satisfy to following parity $0 \le \theta_j \le r_j \le h$.

Let's define sets P_θ and P_r as set of the imposition's or replacement's moments accordingly

$$P_\theta = \{\theta_j \mid j \in I\},$$

$$P_r = \{\theta_r \mid j \in I\}.$$

Then it is possible to present network evolution's strategy in the form of system P

$$P = (P_\theta, P_r, X).$$

To finish the description of network evolution's strategy let's define connections' structure X as follows

$$\mathrm{X} = \{\chi_{ij} \mid i, j \in I\},$$

where $\chi_{ij} = \begin{cases} 1, & \text{if station } j \text{ connects to the basic station } i, \\ 0, & \text{otherwise.} \end{cases}$

Let's notice also that $\chi_{jj} = 1$ means installation of the new basic equipment on station j. If $\chi_{ij} = 1$ station j is the portable connected to station i only if $\theta_j < h$. Otherwise the existing equipment remains on station j.

Thus it is proved that the further researches of the modernized network's development's general problem can be carried out only for set of the second and third classes' problems. Naturally rejection of the portable equipment's replacement's possibility on basic essentially constricts decision's generality however consideration of stationary connections' structure considerably simplifies it. Therefore it is expediently to reduce problems where replacement of portable by basic station is seldom to the second class problem and to use methods of the decision for such problems.

Conclusion

In work it is proved that the abstract model of network evolution's process can be presented in a kind of pair functions (X, Y) describing types of the equipment established on each station at each time moment and structure of portable modules' connection. Classification of IN's structure optimization’s problems by a time sign is offered and proved. It is shown that problems of the first class are too narrow and mismatch difficult real problems of IN's planning and designing. Therefore at the further researches these problems can be considered as special cases of wider classes' problems.

In the subsequent works the generalized model of network's evolution's spatio-temporal structure's optimization by criterion of the minimum size of the future expenses' valid cost for network's evolution with which use the research of IN's evolution's strategies is executed.

Acknowledgments

The paper is published with financial support by the project ITHEA XXI of the Institute of Information Theories and Applications FOI ITHEA (www.ithea.org) and the Association of Developers and Users of Intelligent Systems ADUIS Ukraine (www.aduis.com.ua).

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PROGRAM MODEL FOR AUTOMATED DESIGN OF TELECOMMUNICATION NETWORKS

Galyna Gayvoronska

***Abstract**: The example of usage of the program complex developed by the author for automated design of telecommunication networks at the introduction of two types of interconnected equipment realizing essentially new technologies.*

***Keywords**: Telecommunication network, network's development, network node, remote unit, basic equipment.*

***ACM Classification Keywords**: H. Information Systems - H.1 MODELS AND PRINCIPLES.*

Statement of problem

Modern tendencies of infocommunications' development demand development of new methods of telecommunication networks' (TN) synthesis for the purpose of convenient automated tool's creation for networks' planning, which is answering not only the present situation, but also considering directions of further development [1]. Such tool is necessary, as at the present stage of telecommunications' development traditional planning has become outdated, because it is based on planning of separate nodes or networks' separate fragments, and does not consider their interrelation and interaction in time and space [2].

Rendering of data processing services is information networks' feature which distinguishes them from the networks, rendering only information transfer services, that is telecommunication networks. Therefore, TN is a subsystem of information network. Telecommunication networks belong to the class of the big systems that predetermines complexity of their development and maintenance. From this follows, that they cannot be created for the short time, therefore one fragments of TN can be already worked, others - to be projected, and the third - only to be researched. Features of TN as big system are [3]:

- the big number of terminal equipments and nodes and their heterogeneity;
- small connectivity, that is the presence of peer-to-peer communication of each node only with a small number of adjacent nodes;
- existence duration with step-by-step escalating of capacities and extension of rendering services;
- the big variety of requirements to delivery of various messages;
- bandwidth heterogeneity of links (channels);
- territorial heterogeneity and heterogeneity of inclinations between separate terminal equipments.

As TN is the big system, for its analysis and synthesis it is necessary to apply a number of various models mirroring certain aspects of system's functioning. At TN's planning it is especially important to consider simultaneous change of network both in time and in space. The common statement of the problem of TN's synthesis as big system is resulted in [4]. Paper [5] is devoted to development of TN's spatio-temporal mathematical model. Various aspects of TN's synthesis in the conditions of the model presented in [5] are considered in papers [6-14]. On the basis of completed researches it is drawn a conclusion that simulation modeling method is possibility for the most completely considering of all factors influencing development of TN. According to this, algorithmic solution of the problem of developing TN's synthesis is resulted in papers [15, 16], and its program implementation is considered in [17,18]. Model's basic purpose is definition of the optimal evolution scenario at minimization of cost indexes. The researched model of network upgrade can be used for matching of various network evolution scenarios and choice of most expedient of them, by economic criterion, taking into account technical requirements and the limitations applied by administration of the researched network.

One example of the created simulation model's usage is considered lower. Optimization of development of fragment of big city TN is made in this example.

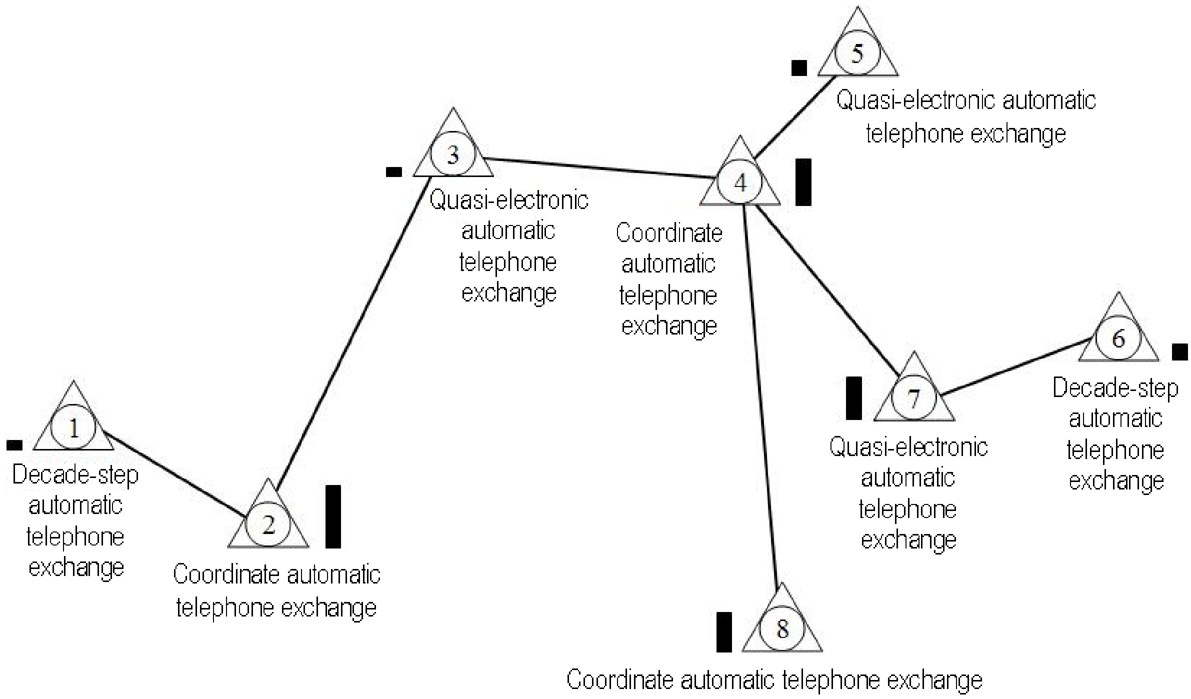


Fig. 1 Initial state of researched network

Description of researched network

The considered fragment of a network consists of eight switching nodes and services territory of typical rapidly developing area on big city suburb. There is the natural barrier between considered territory and other part of a city. It is limiting link between the considered fragment of network and city centre. The configuration of considered fragment of network is shown on fig. 1, statistical data about it is resulted in tab. 1.

Parameters of considered analogue and digital switching systems are resulted in tab. 2.

Real expenses of typical [7] operator are used in the model as cost parameters for analogue and digital switching nodes and transmission equipment. No specific limitations on node's development were applied.

The perspective equipment can be entered by method of overlaying or method of replacement existing [6]. Network's development combining methods of overlaying and replacement for the equipment of new technologies is considered in this paper. For this purpose it is necessary to define nodes to be installed with basic equipment, nodes to be installed with portables and nodes to be not upgraded at all.

Table 1. Parameters of network and research

<table>
<tr><td colspan="2">Parameters of network and research</td><td>Value</td></tr>
<tr><td colspan="2">Duration of researched time (years)</td><td>20</td></tr>
<tr><td colspan="2">Number of nodes</td><td>8</td></tr>
<tr><td colspan="2">Switching nodes of different types (units)</td><td>9</td></tr>
<tr><td rowspan="5">Capacity of existing switching nodes at beginning of research</td><td>Decade-step (per cents from common value)</td><td>16</td></tr>
<tr><td>Coordinate (per cents from common value)</td><td>57</td></tr>
<tr><td>Quasi-electronic (per cents from common value)</td><td>26</td></tr>
<tr><td>Average tempo of network increase (link/node/year)</td><td>565</td></tr>
<tr><td>Average internodes distance (km)</td><td>47</td></tr>
</table>

Table 2. Parameters of switching equipment

Type of switching equipment	Format of signals (A – analogue, D – digital)	**Capacity, thousand. №№**
Decade-step	A	10
Coordinate	A	10
Quasi-electronic	A	2,5
Digital, basic	D	100
Remote subscriber unit	D	1

Research results

Research results are presented on steps of algorithm used for solution of problem in view:

Step 1. Calculation of standard cost. Cost of network development settles up preliminary like if there is no implantations of new equipment at all (strategy of continuous increase). It can be made by means of the formulas introduced in [13]. This cost will be used as measurement standard for definition of economic feasibility of accepted solutions and makes $C^A = 47067$ (All expenses are resulted in thousand US dollars).

Step 2. Calculation of expenses for nodes development. The structure of expenses for each network node's development is mirrored in fig. 2. There are eight plots (one plot per each node of optimized network) in the figure. Following denotations are used:

C_i^A - cost of node’s i development by existing equipment;

$C_i^{\theta B}(t)$ - cost of basic node’s i development at the moment t of overlaying;

$C_i^{rB}(t)$ - cost of basic node’s i development at the moment t of replacement;

$C_i^{\theta R}(t)$ - cost of remote node’s i development at the moment t of overlaying;

$C_i^{rR}(t)$ - cost of basic node’s i development at the moment t of replacement.

Step 3. Allocation of basic nodes. Problem of basic equipment's layout's definition providing the minimum cost of network development with holding of limitations on equipment availability is reduced to the classical task of linear programming - the transportation problem formulated in [16] and designated as $P1$.

Solution of optimization procedure $P1$ is sets $X = \{x_{it}^*\}$, $Y = \{y_i^*\}$ and $Z = \{z_{it}^*\}$, corresponding to the minimum value of goal function where logical variables x_{it}, y_i and z_{it} are defined as:

$$x_{it} = \begin{cases} 1, & \text{if there is installation of remote on node } i \text{ at the moment } t; \\ 0, & \text{otherwise.} \end{cases}$$

$$y_i = \begin{cases} 1, & \text{if existing equipment remains on node } i; \\ 0, & \text{otherwise.} \end{cases}$$

$$z_{it} = \begin{cases} 1, & \text{if there is installation of basic equipment on node } i \text{ at the moment } t; \\ 0, & \text{otherwise.} \end{cases}$$

According to solution techniques of problem of optimal resource allocation $P1$ (often named transportation problem) [19] set of all network nodes is divided into three mutually disjoint classes:

$I_A = \left\{ i \in I \mid y_i^* = 1 \right\}$ – nodes on which existing equipment remains;

$I_B = \left\{ i \in I \;\middle|\; \sum_{t \in T} z_{it}^* = 1 \right\}$ – nodes which are to be installed with new basic equipment;

$I_R = \left\{ i \in I \;\middle|\; \sum_{t \in T} x_{it}^* = 1 \right\}$ – nodes which are to be installed with new remote units.

Following solution for the problem $P1$ has been got:

$x_{16}{}^* = x_{22}{}^* = x_{36}{}^* = x_{58}{}^* = x_{64}{}^* = x_{74}{}^* = x_{82} = 1 \qquad z_{42}{}^* = 1$.

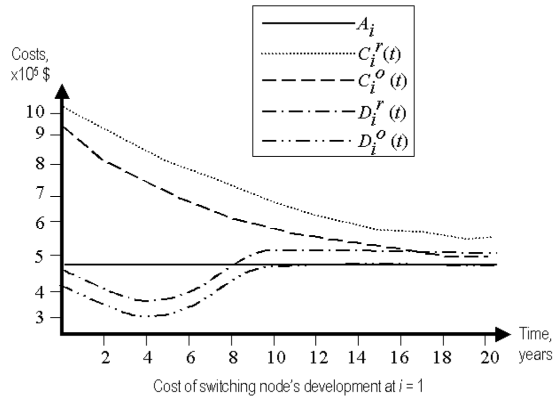
$$I_A = \varnothing$$
$$I_R = \{1,2,3,5,6,7,8\}$$
$$I_B = \{4\}$$
$$C^B = 40\,238.$$

Step 4. Allocation of portables. There is only one defined potential basic node on the step 3: $I_s^o = \{4\}$, $I_r^o = \{1,2,3,5,6,7,8\}$. There is allowed set of portables P_β defined for each potential basic node $\beta \in I_S^m$ as intersection of set of allowed portables with set of potential nodes remained on given iteration $\forall \beta \in I_S^m \quad P_\beta = R_\beta \cap I_r^m$ if $P_\beta = \varnothing$ transfer to the next basic node. Otherwise it is possible to formulate discrete knapsack problem $P2(\beta)$ for node β that is done in [16].

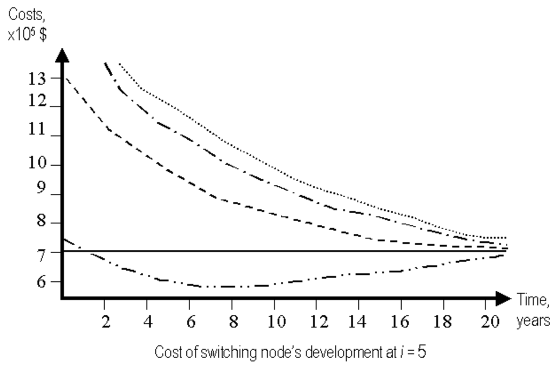
Problem solution in this case gives following set of allowed remote units $P_4 = \{\sigma_1^1, \ldots\ldots \sigma_5^1\} = \{1,\ 2,\ 3,\ 5,\ 7\}$. On the given iteration we receive solution of problem $P2(4)$ $\overline{\sigma}_4 = \{1,\ 2,\ 3,\ 5\}$, $C^0(4) = C^0 = 33\,560$. There is only one carried out iteration on step 4 and the algorithm passes to step 5 for selection of new basic nodes. It caused by the fact that set of potential basic nodes is empty $I_s^1 = \varnothing$ at the next iteration and set of potential portables $I_r^1 = \{6, 7, 8\}$.

Step 5. Introduction of additional basic nodes. Installation of new basic nodes starts with the definition of initial sets of potential basic nodes and portables $J_r^o = J_s^o = \{6, 7, 8\}$. Consecutive solution of problem $P2(4)$ leads to following expenses for network's development:

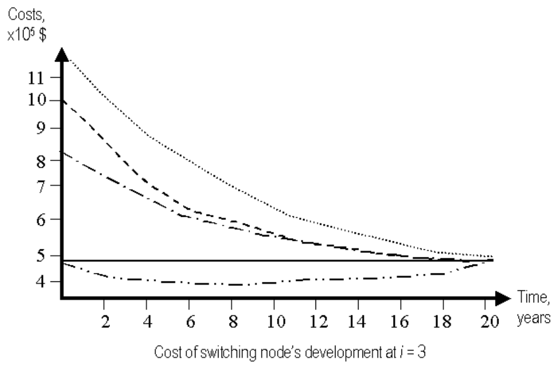
$$\left.\begin{array}{l} C^1(6) = 33560 \\ C^1(7) = 33673 \\ C^1(8) = 34162 \end{array}\right\} C^1 = C^1(6) \text{ and } \sigma^1 = \{7,8\}.$$



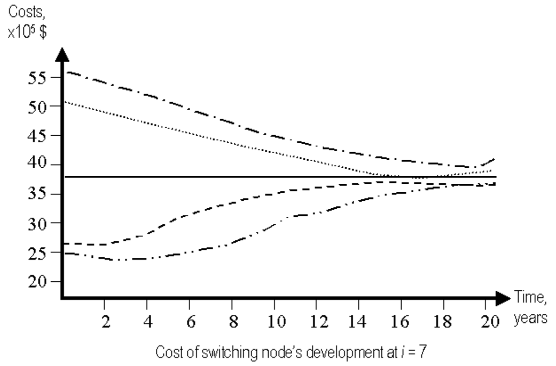
a)



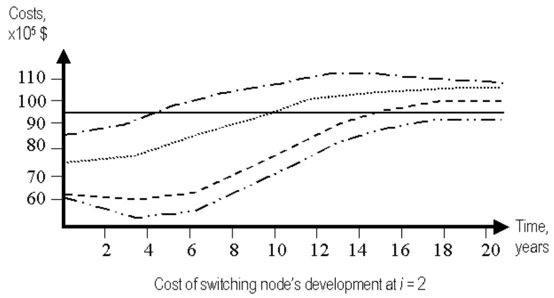
e)



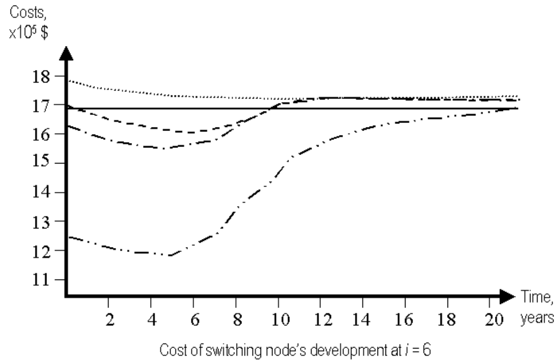
c)



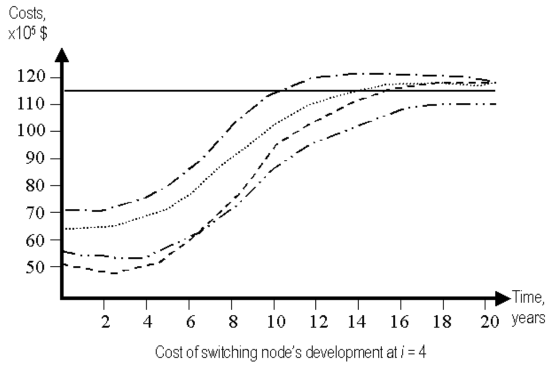
g)



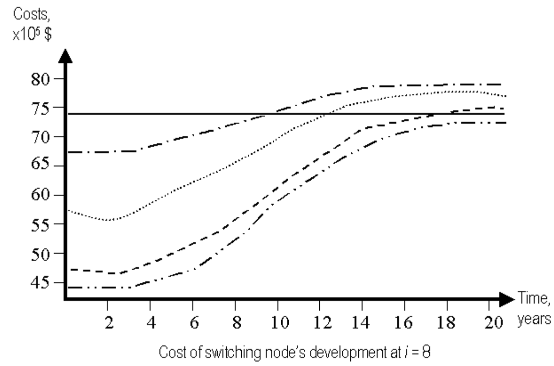
b)



f)



d)



h)

Fig. 2 Expenses for development of each node of the researched fragment of network

Set of potential portables is settled at this stage. This leads to algorithm termination. Optimal network's design shown on fig. 3 is generated as a result. Cost of network's development received thus way is on 29 % lower than cost of base variant at analogue development C^A.

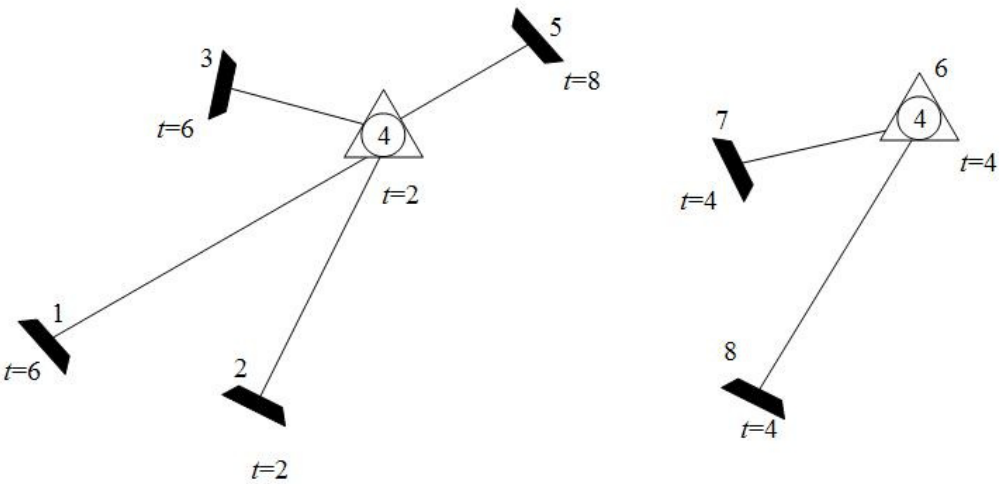


Fig. 3 Optimal variant of network’s development

Though switching component of expenses of this solution is on 0,8 % above than in the next by optimality solution where node 7 services portables 6 and 8, transmission component of expenses in the selected solution is on 2,1 % lower. This leads to the total better result.

There is range of limitations on equipment availability to the first 5 years of the 20-year-old research period used in the example. Though this is the simplest method allowing considering short-term financial limitations, its usage demands selection of network investments to be known before it will be transferred in limitations on equipment availability. According to this approach considering short-term investment limitations at long-term research is developed. This method is based on two consistently executable optimization procedures:

- first one minimizes short-term capital expenses;

- second one uses results of the first as limitations and minimizes economic criterion during all research period.

Conclusion

Minimum level of short-term investments can be received as a result of the considered algorithm functioning. Then appropriate network configuration can be used as basic, defining initial budgetary limitation for reception of optimal network structure at long-term research.

Acknowledgments

The paper is published with financial support by the project ITHEA XXI of the Institute of Information Theories and Applications FOI ITHEA (www.ithea.org) and the Association of Developers and Users of Intelligent Systems ADUIS Ukraine (www.aduis.com.ua).

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