COMPUTER-BASED BUSINESS GAMES' RESULT ANALYSIS

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***Abstract**: Given research considers the Business Intelligence analysis of computer based business games. A tool environment, called Competence-based Business Game Studio (CBGS), is applied for business games' design and development. An approach is proposed that allows designing and conducting business games based on enterprises business processes. Consequently, CBGS may be considered as a universal product with respect to domain. Competence-based Business Game Studio consists of several subsystems. The Analysis Subsystem makes possible to exclude human factor from the process of player skills and knowledge assessment, the latter are scored employing an automated approach based on formal parameters. This paper defines the source data for Analysis Subsystem as well. Data warehouse containing multidimensional data marts was designed for the evaluation of player's competency. Two info-cubes were developed: the first info-cube is proposed to assess players' actions, the second one - to identify bottlenecks within business processes using efficiency assessment of Decision Making Points. In order to collect information about players Complex Analysis methods are proposed for implementation: such as aggregation, navigation and filtering. To evaluate business game quality three types of Decision Making Points should be distinguished. Decision Making Points completed by players are allocated to the aforementioned types using cluster analysis (PAM-algorithm) and supervised classification.*

***Keywords**: business intelligence methods, data warehouse, competencies, active learning methods, business-game.*

***ACM Classification Keywords:** K.3 Computers and Education: K.3.2 Computer and Information Science Education – Information systems education. I. Computing Methodologies: I.2 Artificial Intelligence: I.2.1 Applications and Expert Systems – Games.*

Introduction

The implementation of game mechanics implies an increase of a player's involvement into the learning process by simulation of real-life conditions. Moreover, player's actions are evaluated in accordance with the set of competencies and criteria. There are a lot of researches in the business games area. For instance, one of the most popular and complex business games products are SimulTrain, Innov8, BrandPro. However, most of such systems focus on a certain domain.

The proposed approach to the creation of competence-based educational environment consists of the development of design, technical, organizational and methodological tools for implementing one of the active methods of forming competencies that is named competence-based business games [Vikentyeva, 2013]. The approach is multi-model and is based on the development of domain-specific models applied in design and execution stages [Vikentyeva, 2015].

Competence-based educational system (CBGS – Competence-based Business Games Studio) should consist of several subsystems. The CBGS structure is presented in Figure 1. [Vikentyeva, 2013].

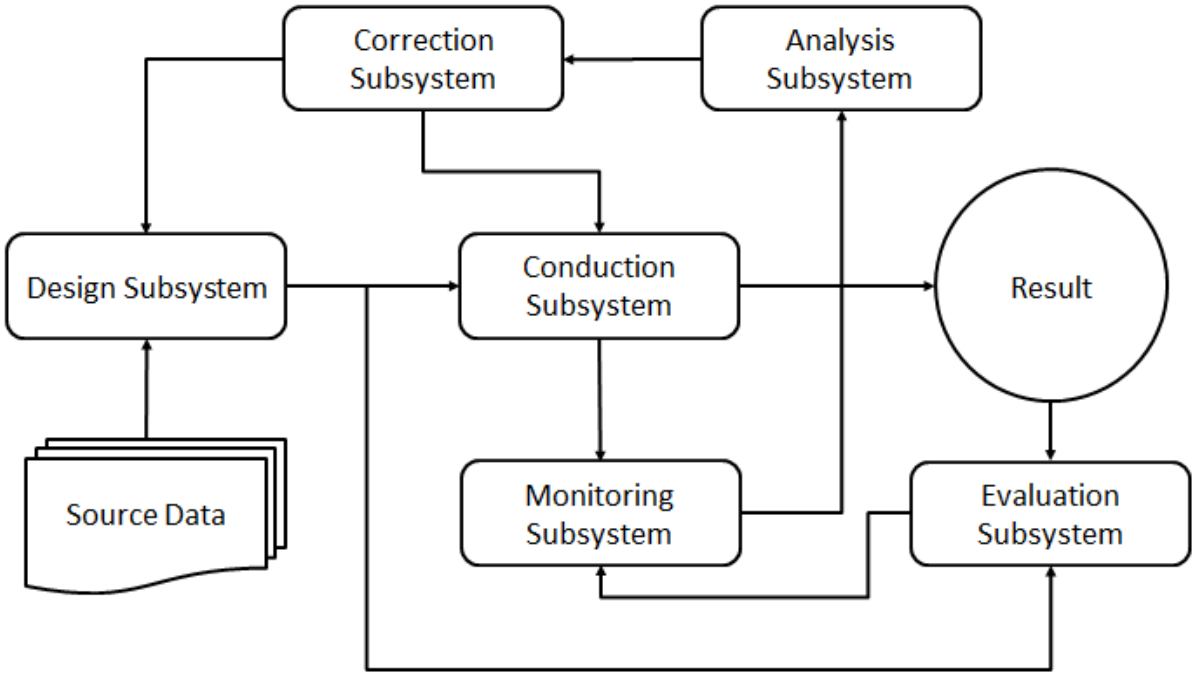

Figure 1. Structure of CBGS

Nowadays prototypes of following subsystems are developed:

- Design Subsystem. Business Processes Models are building within the Design Subsystem. These models are transformed from weakly formalized format based on real business processes models into formalized form with the use of graphical models editor.
- Conduction Subsystem. Source data for the subsystem are game plan and information about resources used during the game. The mechanism testing users is named Decision Making Point (DMP). DMP determines the course of game when a user has chosen resources.
- Evaluation Subsystem. It allows evaluating player's actions based on tests.

– Monitoring Subsystem. The subsystem implements two modules for working with databases: one is design to work with the database of operational data obtained during the game, the second works with a database of the results of players' testing.

This research issues related to business games results analysis using Business Intelligence methods are considered.

The process of human resources knowledge evaluation is subjective since it implies the influence of human factor. The CBGS's Analysis Subsystem allows excluding human factor due to automated approach to assess the trainee competency based on formal parameters. Nowadays there is a lot of research in the field of Educational Data Mining (EDM). EDM aims to apply Data Mining methods to extract information related to the learning process [Hung, 2012], [Jeong, 2013], [Sahedani, 2013].

The Analysis Subsystem should assess player's competences (knowledge, skills, experiences) based on his choice of resources within DMPs. DMPs allow the player to choose the sequence of operations of a business process. Data of passed games have to be compared with the reference model developed within the Design Subsystem.

It is important to take into account that the reason of a trainee inability to complete the game with 100% success might be the Game bottlenecks. Some algorithms may be not trivial even for experts of a corresponding business process as model of unified educational business process (UEBP) including DMP is automatically generated. Business game scenario is being built based on UEBP.

Analysis Subsystem should perform two major analysis procedures [Vikentyeva, 2016]:

– Player's actions analysis that allows providing player's characterization based on all business games, which the player participated.
– Game analysis to its correction in the case of bottlenecks identification. Such analysis has to be conducted for all DMPs.

Data Sources for Analysis Subsystem

The reference model of business process is created within the Design Subsystem. Business Process Design database stores the correct sequence of operations for each business process as well as a set a set of resources for every operation. Data for tables «Business Process», «Operation», «Resources» have to be loaded from this database [Vikentyeva et al., 2015].

Competence is a set of knowledge, skills, experience and personal characteristics, that are needed for successful performance of tasks [Kozodaev, 2015].

The concept of competence is considered in the learning process. It is important to understand that personal characteristics and experience of players are not considered within the project, because it is extremely difficult to evaluate experience level in a short time. Therefore, competence will be defined as a set of knowledge, skills necessary for successful passage of a business game.

Process of competences planning implies creation of matrix defining the dependence between operations of business processes and competences [Vikentyeva et al., 2013]. Within different business processes the same operations can be characterized by different competences.

It is possible to identify the relationship between operations and set of competences. In order to determine to what extend is competence formed and what knowledge and skills a player has, the resources that the player chooses to perform operations should also be included in the multidimensional array of competencies, since they are the ones that determine whether the player possesses the necessary set of knowledge and skills to perform the operation (the player knows which resources to choose and can apply them).

This structure can easily be formed in a multidimensional data warehouse, developed within the framework of the analysis subsystem [Vikentyeva, 2016]. The schema of database storing the results of passing games is also considered in the research [Vikentyeva, 2016].

Based on the data that can be extracted from the Design Subsystem and the Conduction Subsystem, it can be determined that the evaluation of the players' actions should be carried out according to three criteria:

- Correspondence of the sequence of operations performed by the learner during the game to the reference model.
- Competence of the player (within a single game).
- Satisfactory time of passing the game.

Data Warehouse Info-objects

Data warehouse info-objects are divided into two types [Kolb, 2012]:

- A characteristic is a sequence of values of one of analyzed parameters. Characteristics may include master data, texts and hierarchies;
- A key figure is a data quantitatively characterizing the set of characteristics.

Table 1 presents characteristics that are created within the designing data warehouse.

Table 1. Characteristics Developed in the Data Warehouse

Characteristic Name	Type	Amount of Symbols
Time of a Game	Time	–
Game Number for the Player	Integer	–
Player	String	5
Business Process	String	255
Operation	String	255
Resource Type	String	255
Resource	String	255
Competence	String	255
Competence Type (Knowledge/Skill)	String	6
Knowledge/Skill Name	String	255
Operation Number in the Reference Model	Integer	–
Actual Operation Number	Integer	–

Table 2 presents key figures that are created within the designing data warehouse.

Table 2. Key Figures Developed in the Data Warehouse

Key Figure Name	Type	Unit of Measurement
The Deviation in Operations Sequence	Integer	–
Operation Performance Indicator	Integer (0 or 1)	–
Resource Selection Indicator	Integer (0 or 1)	–
Formed Percentage of Knowledge/Skill	Number	Percentage
Maximum Percentage of Knowledge/Skill	Number	Percentage

Data Warehouse Info-Providers

Within the developed data warehouse multidimensional data marts (info-cubes) are used.

In accordance with the functional requirements for the Analysis Subsystem it is necessary to design two info-cubes:

- Evaluation of Players' Actions.
- Search of Business Game Bottlenecks.

Table 3 represents the set of info-objects that are included into the info-cube designed for evaluation of players' actions [Vikentyeva, 2016].

Table 3. Structure of Info-cube Designed for Evaluation of Players' Actions

Dimension	Characteristics
Time	Time of a Game
Game	Player
	Game Number for the Player
	Business Process
	Operation
	Resource
Competence	Competence
	Competence Type (Knowledge/Skill)
	Knowledge/Skill Name
Key Figures	
	The Deviation in Operations Sequence
	Operation Performance Indicator
	Formed Percentage of Knowledge/Skill

With the use of this set of data, the following reports can be obtained:

- The percentage of each competence formation for the player. The report will show aggregated data on competences.
- List of knowledge and skills that a player possesses or does not possess.
- Correspondence of actual operation sequence of a game to the reference model.

Table 4 represents the set of info-objects that are included into the info-cube designed for searching business game bottlenecks [Vikentyeva, 2016].

Table 4. Structure of Info-cube Designed for Searching Business Game Bottlenecks

Dimension	Characteristic
Game	Player
	Business Process
	Game Number for the Player
Decision Making Point	Operation
	Resource Type
	Resource
Key Figures	
	Resource Selection Indicator
	Maximum Percentage of Knowledge/Skill

By applying clustering to the data bottlenecks in decision making point (DMP) can be detected.

The Process of Loading Data into Data Warehouse Info-providers

Into the info-cubes data is loaded from the following databases:

- Database for business processes' modeling.
- Database for competence planning.
- Database of actual results of game.

The algorithms for loading data into the info-cube designed for evaluation of players' actions are presented in Table 5.

Table 5. The Algorithms for Loading Data into the Info-cube Designed for Evaluation of Players' Actions

Dimension	Characteristics	Algorithm of Data Loading	Source Database
Time	Time of a Game	Formula: End Time-Start Time of a Game	Database of actual results of game
Game	Player	Direct assignment	Database of actual results of game
	Game Number for the Player	Count distinct Business Process ID with the actual Business Process ID, Player ID and Start Time less or equal the Game Start Time	Database of actual results of game
	Business Process	Direct assignment	Database for business processes' modeling
	Operation	Direct assignment	Database for business processes' modeling
	Resource	Direct assignment	Database for business processes' modeling
Competence	Competence	Direct assignment	Database for competence planning
	Competence Type (Knowledge/Skill)	Defined by table type	Database for competence planning
	Knowledge/Skill Name	Direct assignment	Database for competence planning

Key Figures			
Dimension	Characteristics	Algorithm of Data Loading	Source Database
	The Deviation in Operations Sequence	Formula: Operation Number within the Reference Model for the Game – Actual Operation Number	Database for business processes' modeling Database of actual results of game
	Operation Performance Indicator	If the operation is present in the database of the actual results of games for a particular game and for a specific player, then 1, otherwise 0	Database of actual results of game
	Formed Percentage of Knowledge/Skill	If the resource characterizing knowledge/skill is selected within the specified business process and operation, then the percentage of knowledge/skill within the competence is assigned, otherwise 0	Database for competence planning Database of actual results of game

Table 6. The Algorithms for Loading Data into the Info-cube Designed for Searching Business Game Bottlenecks

Dimension	Characteristics	Algorithm of Data Loading	Source Database
Game	Player	Direct assignment	Database of actual results of game
	Game Number for the Player	Count distinct Business Process ID with the actual Business Process ID, Player ID and Start Time less or equal the Game Start Time	Database of actual results of game
	Business Process	Direct assignment	Database for business processes' modeling
Decision Making Point	Operation	Direct assignment	Database for business processes' modeling
	Resource	Direct assignment	Database for business processes' modeling
	Resource Type	Direct assignment	Database for business processes' modeling
Key Figure			
	Resource Selection Indicator	Direct assignment (if resource was selected, then 1, otherwise 0)	Database of actual results of game
	Maximum Percentage of Knowledge/Skill	Direct assignment	Database for competence planning

Data Analysis Algorithms for the Info-cube Designed for Evaluation of Players' Actions

Complex Analysis method is applied for Evaluation of Players' Actions. The player's competence within a single business process may be defined by several ways:

- The total competence of player based on actual results of game. Aggregation on Business Process and calculation of average percentage of competence are necessary for this analysis. Other characteristics are not considered. Sample of data includes Game Number, Player, Business Process, Competence, Formed Percentage of Knowledge/Skill.
- The percentage of competence obtained by a player within a single game. Such a sample will determine the degree of competence obtained by the player within the operation. Sample of data includes Game Number, Player, Business Process, Operation, Competence, Formed Percentage of Knowledge/Skill.
- Possession of certain knowledge and skills. For this type of analysis, the data should be fully detailed. Sample of data includes Game Number, Player, Business Process, Operation, Resource, Competence, Competence Type (Knowledge or Skill), Knowledge/Skill Name, Formed Percentage of Knowledge/Skill (the key figure is restricted by condition «>0»).
- Unformed knowledge and skills of the player. For this type of analysis, all the data within a single game must be aggregated by Operations and Knowledge/Skills. Sample of data includes Game Number, Player, Business Process, Operation, Competence, Competence Type (Knowledge or Skill), Knowledge/Skill Name, Formed Percentage of Knowledge/Skill (the key figure is restricted by condition «==0»).
- In addition to the degree of the player's competence, the data set of the Info-cube also allows to determine the deviation of actual operations' sequence from the reference model. Sample of data includes Game Number, Player, Business Process, Operation, The Deviation in Operations Sequence (the key figure is restricted by condition «<>0»).
- In addition, it is possible to identify which operations from the reference model were not performed. Sample of data includes Game Number, Player, Business Process, Operation, Operation Performance Indicator (the key figure is restricted by condition «==0»).
- A player progress. This type of analysis is performed by comparison of all results of passing a particular game if the player participates in the game not for the first time.

Data Analysis Algorithms for the Info-cube Designed for Searching Business Game Bottlenecks

Models of real business processes performed at enterprises can't be used in the design of business games, therefore the concept of a model of a unified educational business process (UEBP) is introduced [Vikentyeva, 2015]. UEBP reflects the essential invariant characteristics of business processes of enterprises. UEBP can be quite complex and include not only consistent actions, but also various business conditions, repetitive operations. UEBP must contain operations that simulate the learning situation in the Business Game. The learning situation is understood as the situation in which decisions are made in the process of selecting resources for performing operations and/or the next operation of business process, etc. The learning situation allows to form or verify the player's competencies.

The Business Game is an interactive test for each player, and, as it is known, the tests should include questions, the correctness of the answers to which has a normal distribution. Therefore, there are two types of Decision Making Points taking a role of bottlenecks in Business Game or UEBP. Types of such points are the following:

- Simple DMPs are DMPs in which almost nobody makes mistakes even passing a game for the first time.
- DMPs of increased complexity are DMPs in which even the most competent players make the same mistakes.

The data analysis for the search for "bottlenecks" in Business Game should be implemented using one of the Data Mining methods - clustering. At this stage of the design, we are looking for clusters of three types of DMPs:

- Simple DMPs.
- DMPs of normal complexity.
- DMPs of increased complexity.

Set of characteristics of the same type is used for each combination of Business Process and Decision Making Point. Training sample is formed for all Business Processes.

The following characteristics must be used for DMPs' clustering:

- Amount of mistakes made when selecting mandatory resources.
- Amount of mistakes made when selecting optional resources.
- Formed percentage of the player's competence within each game.

During factor analysis it was revealed that the characteristics must be normalized in order to reduce the amount of data. Normalization of data is performed by calculating the following values for each DMP:

- Average rate of mistakes made when selecting mandatory resources.
- Average rate of mistakes made when selecting optional resources.
- Average rate of the player's competence within each game.

These average values represent three dimensions in the characteristic set for clustering.

After that it was necessary to identify the most appropriate clustering algorithm for finding bottlenecks in Business Game.

It is important to understand that the search for problem Decision Making Points needs to be done in two stages, that is, clustering is performed two times. Simple Decision Making Points need to be identified in a sample that includes the results of absolutely all games, including games of players with low level of competencies. Decision Making Points of increased complexity should be identified only among those games for which users have received high assessment, that is, the average player's competence within a business process is at least 75%. The second sample allows clearing the data from the unsuccessful traineeship due to a lack of knowledge of business processes.

The paper [Barsegian, 2004] provides a description of the clustering algorithms that is later is used for algorithms' comparison.

Comparison of clustering algorithms will be performed according to the following criteria:

- The total number of clusters is known (three clusters: simple DMPs, DMPs of normal complexity and DMPs of increased complexity).
- The volume of data sets may vary.
- The form of the clusters is arbitrary.
- Ease of work with multidimensional objects.
- The distance between clusters is small.

These criteria were singled out on the basis of the initial data (data in info-cube for searching bottlenecks in Business Game), requirements for the result of data analysis and analysis of clustering methods.

The comparison is made by the method "from the inverse", that is, it is determined which algorithms do not satisfy the criteria in question. A comparison of clustering algorithms is presented in Table 7.

Table 7. Clustering Algorithms Comparison

Algorithm Name	Known Total Number of Clusters	Variable Volume of Data Sets	Arbitrary Form of Clusters	Ease of Work With Multidimensional Objects	Small Distance Between Clusters
AGNES (Agglomerative Nesting)	No	Yes	Yes	Yes	Yes
CURE	Yes	No	Yes	Yes	Yes
DIANA (Divisive Analysis)	No	Yes	Yes	Yes	Yes
BIRCH	No	Yes	No	Yes	Yes
MST	No	Yes	Yes	No	Yes
K-means	Yes	Yes	Yes	Yes	No
Maximin	No	Yes	Yes	Yes	Yes
PAM	Yes	No	Yes	Yes	Yes
CLOPE	No	No	Yes	Yes	Yes
Self-organizing Map	Yes	No	Yes	Yes	Yes
HCM	Yes	No	Yes	Yes	Yes
Fuzzy C-means	Yes	No	Yes	Yes	Yes

The results of the comparison show that no algorithm fully meets all the criteria. However, it is important to take into account that under large volumes of data, databases with a multimillion-number transactions and a large set of characteristics are understood. As factor analysis allowed reducing characteristic set to three dimensions and OLAP technology allows getting aggregated data, it is assumed that actually the volume of data is not large in the general sense. Thus, evaluating the characteristics of the algorithms, it was decided to use the PAM algorithm for DMPs' clustering, since the training sample will not include a huge number of objects, the number of clusters is set and equal to three, the algorithm is less sensitive to emissions, the occurrence of which cannot be predicted in advance. Clusters will be classified in remoteness from the reference model.

In order to exclude of possible clustering mistakes related to fixed numbers of clusters two technical DMPs should be added into training sample. For instance all DMPs might be of normalized complexity, but PAM algorithm will distribute them into three sets anyway as this condition is set initially. Technical DMPs with following parameters {0; 0; 100} and {100; 100; 0} representing simple DMP and DMP of increased complexity properly allows getting rid of this problem. Here the first parameter is average rate of mistakes made when selecting mandatory resources, the second - average rate of mistakes made when selecting optional resources and the third - average rate of the player's competence gained during the DMP performance. Such technical DMPs should not be displayed to the player as an output, but allow avoiding errors associated with a fixed set of clusters.

In addition to clustering, supervised classification should also be applied to evaluate the quality of DMPs' design. Since DMPs distributed in clusters «Simple DMP» and «DMP of increased complexity» might be simple or complex but have not worthless id their parameters are not equal to {0; 0; 100} or {100; 100; 0}. The decision about such points redesign has to be made by the developer of UEBP, however DMPs having parameters equal to {0; 0; 100} or {100; 100; 0} should be highlighted singularly since they require redesign doubtlessly.

Conclusion

Since each resource is related with knowledge or skill analysis of player's competency is possible.

To conduct analysis of player's competency corresponding info-cube was designed. Applying Complex Analysis methods such as aggregation, navigation and filtering following reports regarding player's competency can be obtained:

– Player's competency within a business process.

- The percentage of different player's competences.
- Bottlenecks in player's knowledge and skills.
- The reasons of the lack of player's competency.
- The list of the most qualified participants.
- Weaknesses of players.
- Knowledge and skills not acquired by players previously.
- The average time taken to complete a single iteration of the business process.
- The progress of players in time.

To conduct analysis of Business Game another info-cube was designed. The analysis of the Business Game includes an assessment of the degree of successful DMPs performance in order to determine if DMPs were designed correctly. To assess the quality of the business game, it is proposed to distinguish three types of Decision Making Points:

- Simple DMPs.
- DMPs of normal complexity.
- DMPs of increased complexity.

Clustering is used to distribute all DMPs to these types. To determine the most appropriate clustering algorithm, a characteristic set was determined:

- Amount of mistakes made when selecting mandatory resources.
- Amount of mistakes made when selecting optional resources.
- Formed percentage of the player's competence within each game.

In order to increase operating speed of clustering algorithm, it was necessary to reduce the number of analyzed transactions. Therefore, it was decided to normalize the analyzed indicators and characteristic set was reformulated as follows:

- Average rate of mistakes made when selecting mandatory resources.
- Average rate of mistakes made when selecting optional resources.
- Average rate of the player's competence within each game.

Since the number of clusters is knows and the volume of training sample is not large due to normalization of analytic set it was decided to use the PAM in order to assess DMPs. In addition to clustering supervised classification should be applied.

Based on implementation of clustering and supervised classification algorithms the UEBP developer is able to identify DMPs that are recommended to revision as well as DMPs that must be revised as they distort the results of player's competence assessment.

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