Software for the computational experiment "Synthesis of the topological structure of the cognitive model"

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Abstract. There is a great number of applications used today to support decision-making in socio-economic sphere. Various approaches and tools are used to implement the applications. The article provides the overview of scientific publications developing software algorithms based on cognitive modeling and fuzzy logic. The authors develop the software tool to conduct simulation experiments to synthesize the topological structure of a cognitive model for socio-economic facilities and objects. The results from the simulation experiment aimed to study the structure of the cognitive model taken as an example, are presented as a digraph "Impact of the Media on Mass Audience". The software uses the programming language Java, JavaFX.

1. Introduction

To study semi-structured and decision-making support systems, fuzzy logic and cognitive modelling are applied based on the subjective views of experts to the situation. Cognitive modeling is implemented with the software applying FCM-algorithms, neural networks, genetic algorithms, and others.

The article by S.M. Weisberg, N.S. Newcombe discusses the process of individual decision making about behavioral patterns using virtual environment. The work aims to study the cognitive mechanism of human navigation. The participants of the experiment are to recreate a spatial layout of routes after their one-time viewing the video. Visualization of the route is performed by building the cognitive maps using software «Navigator» with the help of FCM algorithm.

The second part of the experiment concerns the identification of routes while their cognitive maps are appearing on the screen. At first, the individual routes are presented, and then they are integrated. It is necessary to identify and select the individual routes, which constitute the integrated route. The results have discovered that the exact identifications of the routes are possible if the participants of the experiment remember the sequence of objects observed along the route. As a result, the participants are divided into groups according to the criterion of space orientation in virtual environment.

W. Stach, L Kurgan, W. Pedrycz write that development of fuzzy cognitive maps (FCM) for description of dynamic systems is a complex task, which in many cases could not be fully implemented on the basis of human experience. Fuzzy cognitive maps are powerful mechanisms to model dynamic systems consisting of the aggregate of interrelated factors and they can be formalized using graph theory. FCM graph edges represent causal relationship between factors and corresponding quantification. Most existing FCM are developed using expert evaluation. The architectural process initially corresponds to building the matrices which elements are presented by experimental data. FCM include feedback loops and non-trivial data conversion functions. The FCM-method is exemplified in the process of control for draining fluid from the tank. There are two types of liquid and two valves in the tank. When blending liquids a chemical reaction starts. The experiment aims to maintain the desired level of the fluid and its specific weight. The control system is based on the FCM model and includes information about the amount of liquid in the tank and valve conditions [2].

T. Sammut-Bonnici, J. Mcgee describe Fuzzy Cognitive Map (FCM) as soft computer modeling of complex systems, which originate from a combination of logic FKQ and neural networks. The authors examine cognitive maps as mental images, mind maps, diagrams and reports created for visualization and assimilation of information. Visualizing as the act of organizing the information in visual spaces is used to solve various tasks, such as memorizing speeches, face recognition, designing objects, clustering, etc. [3].

V. Mpelogianni, P.P. Groumpos state that the world is facing a severe energy crisis nowadays, so rational use of electrical energy and its effective control with various automated tools are of great necessity. The authors consider the FCM-method for fixing the cost of energy consumption and energy monitoring systems in housing taken as an example. Indicators for automation of the processes providing life-cycle functions, include such components as building ventilation, lighting, air-conditioning, maintaining the optimum temperature, etc. The data is presented as the input fuzzy sets to calculate the output characteristics of ‘consumption’. The input data is converted into the output data as shown on the example of energy processes with the use of fuzzy logic [4].

The article by D. Liu, M. Cong, Q. Zou, Y. Du. devoted to the self-learning method suggests the episodic cognitive maps to be used to navigate the robot under the conditions of uncertainty. Markov process can be applied to model the episodic memory organization. The authors use the EM-MDP pattern that could teach a robot in real time. The predicted trajectory is calculated through activating the author’s neural network based on episodic cognitive map. The robot with EM-MDP pattern evaluates the past events, predicts the current state and plans the desired sequence of behavior. The experimental results show the effectiveness of teaching the mobile robot navigation using EM-MDP pattern in real office environments [5].

P. Prabhu writes that in business environment, there are varied sets of information to support decision-making, for example the approval of a bank loan, e-commerce systems, recommendations for goods etc. Decision-making in this area is based on two kinds of Big Data: OnLine analytical processing OLAP and OnLine transaction processing OLTP. The author suggests that FI-FCM algorithm is necessary for business intelligence to analyze the frequent sets of goods and their additional clustering. The goal is to increase efficiency of the decision-making process. The copyright software is necessary to help clients in finding relevant goods. For the experiment, electronic commerce is selected. Various indicators of electronic commerce are used for testing labor productivity. The results show that the suggested FI-FCM method is effective to identify clusters, gain knowledge from data analysis and improve business analytics [6].

In the article by R. Suganya and R. Shanthi describes the fuzzy algorithms to cluster data. In general, such algorithms can be divided into two categories. One of them is hard clustering; the other is soft (fuzzy) clustering. In hard clustering data is concentrated in separate clusters, where each data element belongs to one cluster only. In soft clustering, data elements can belong not only to one cluster. Their availability in clusters is distributed into levels. The FCM algorithm is used for data visualization of a broad spectrum of engineering and scientific disciplines. The author's algorithm is based on detecting similarities between normative data-prototypes and real data obtained through experimentation. The survey obtained from specialists dealing with programming based on FCM, has shown that its use reduces the time required to search for relevant information from great sets of data [7].

B.N. Prasad, M. Rathore, G.Gupta, T. Singh develop a method of multivariate data analysis using FCM-algorithms. The purpose of the method is to group data in sets with multiple attributes, the similarity between them being maximized within the same cluster and minimized between the data belonging to different clusters. Deficiency of FCM algorithm is its inaccuracy with the results when applying to the analysis of a large number of clusters of different sizes. The paper analyzes the application of the algorithm using k-means (Euclidean norm) and fuzzy c-means (new metric norm). The authors show that the new metric is more reliable than the Euclidean norm. Thus, there are two algorithms: AHCM-hard with c-medium and AFCM-soft with c-average. The numerical results have proven that AHCM algorithm has better performance than the AFCM, as well as a better indicator of temporary AFCM [8].

The authors V. Ng-Thow-Hing, K.R. Thórisson, S.R.K. Sarvadevabhatla, J.A. Wormer develop the architecture of the cognitive map algorithm that minimizes the scope of rewriting obsolete software for its integration with other software tools. The cognitive map for these purposes is considered as information space of related components including the diagnosis of internal and external environment. The application of cognitive maps as a software interaction diagrams allows the components to share information quickly. The authors use a flexible architecture characterized by increased availability, failsoft and mobility, implementing the concept of threefold “meaning-plan-action”. The authors’ multicomponent distributed software system has a modular structure, for example, the module “Development of scripts”, “Components”, etc. The communication between the components is realized via the transfer of messages or data flows. The architecture is implemented in the Robot ASIMO made by Honda Motor Com, Ltd. The application uses several sources of information to create new knowledge. The authors will proceed to the monitoring module, which acts as an independent component. It will perform a visual examination of the relationships between the components of the cognitive maps to identify the original source of incorrect information. The proposed architecture of software performs learning objectives with various interaction mechanisms [9].

The article by J.E. Sutton, M. Buset, and M. Keller presents the results of the study of the relationship between training of pilots and their ability to develop virtual cognitive local maps. Automation of experimental data processing performs fuzzy algorithms. The experiment involve two groups of students who are selected because they play video games with the function of building virtual objects. The participants play video games defined by the category “Action” on average twice a week. These games require human brain to process big spatial data. The participants build virtual cognitive maps after their real stay on the local grounds. The pilots are significantly more accurate than the students in the control group are, when assessing directions, but they do not differ when doing the test “Object prospects”. The authors speculate that the pilots thanks to their navigation experience are better in developing cognitive maps for new environment, than non-pilots. It is also possible that after many hours of flights the pilots appear to have positive relationship between flights and spatial orientation in nonflying conditions. The experiment is a perfect way to explore the links between spatial orientation and human experience. The studies designed to investigate the structure of visual intelligence of pilots help determine how flight experience changes spatial cognitive processes [10].

J.R. Cole, K.A. Persichitte write that there is a lot of research on the application of the FCM method in the educational environment. The concept of FCM is actively used for traditional disciplines to form models of the collection and presentation of knowledge. Nowadays understanding of complexities connected with human learning increases, so it is necessary to create new ways to support learning. Fuzzy cognitive maps are possible steps in this direction. FCM-structure has enormous potential to develop cognitive tools in combination with dynamic fuzzy logic modeling. Most modern mapping systems use discrete values, but they do not accurately describe human understanding. Most human reasoning is of an imprecise nature; therefore combining fuzzy logic with cognitive mapping gives good results. Fuzzy logic enables to present values of various indicators in continuous scale. Their combining is realized with the FCM-method, which is easily modeled on computers. The purpose of using the FCM-method is to make implicit knowledge available for the students through automated structuring of knowledge retrieval tasks. Cognitive mapping is a tool for the development of such structured environment [11].

D.N. Cassenti, V.D. Veksler develop MLCC-automated approach for multilevel cognitive cybernetics. The approach announces adaptive helpers that should work when there is a need to increase productivity of the user. Automation uses cognitive modeling and MLCC approach developing a software tool to recreate the necessary process simplistically. MLCC approach has some features such as touch output, visual interface, alert sounds. The copyright software tool functions as a modular structure in accordance with the individual capabilities of the user and his or her physiological indicators that can be modified under stressful situations or reduced productivity. The physiological indicators include heart rate variability, electro-derma activity and pupil diameter. If they exceed threshold values, the adaptive technology is activated, and the work will be done, taking into account the mental state of the user. The modules operate in parallel, so as not to interfere with each other. The copyright software creates situations plausible to real world. Its use is exemplified in the work of Airbus pilot [12].

F. Chame, P. Martinet describe the software to control robots-manipulators as general-purpose mechanisms. Bots must ensure adaptability of the cognitive robots to learn and take action. The methods of control in the form of visual management are used. This article describes the CRR platform through which the cognitive robotic systems to perform tasks are realized. They combine decision-making and learning with the help of visual control technique. The advantage of the CRR is the ability to adapt to changing conditions. The platform is of modular organization. The cognitive module is responsible for decision-making and learning. The auditory-module is responsible for speech recognition processes. The visualization module is responsible for monitoring. In the experiment, the object is placed before the robot. The robot signals to choose certain actions in accordance with the rules and reinforcing incentives. To ensure coordination of the robot the methodology IBVS and library ViSP are used. There are the following tools and hardware components used: AVT MARLIN F-131C camera, DELL Vostro 1500 laptop (Intel Core 2 Duo 1.8 GHz, 800 Mhz FSB, 4.0 GB DDR2 667 MHz RAM, 256 MB NVIDIA GeForce 8600 m GT), TX-40 robot manipulator [13].

M.I. Ann Arbor, F.L. Pensacola, V.A Arlington develop the software for users, which supports the synthetic Cyber-tools (software simulation), as well as the real Cyber-tools such as NMAP. Learning with the use of automated programs DARPA Cyber-Genome and Cyber Grand Challenge, which mostly rely on machine learning technology and pattern matching is presented. The copyright software provides parallel processing of human reasoning in the form of models to assess situations using fuzzy cognitive maps. The analogy between gaining knowledge by the user and a combat mission, in which the ability of the trainees is matched with the creative potential of cyber-thriller. In the authors' program, cognitive processes play the key role. There is a possibility to combine different offensive elements of military strategies to achieve learning objectives. The program generates space offensive and defensive tactics, simulates learning mechanisms as analogues of cyberwars. Automation of user behaviors is based on cognitive architecture Soar, which has proven its ability to provide realistic human behavior when solving complex tasks. These tasks include piloting a fighter jet or creating a virtual world with different characters. Learning models are designed as online tools for application in real time. User experience serves as a connection in model networks to integrate and deploy the learning process as an analogue to the fighting. The authors use standards Lincoln Lab CCER (MIT/LL) and IHMC for continuous operation in real time [14].

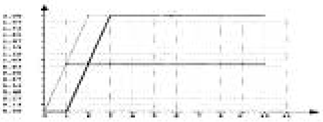
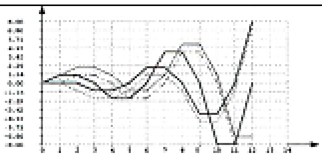
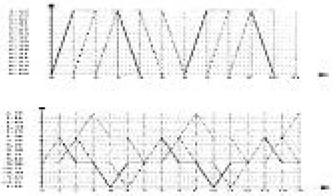
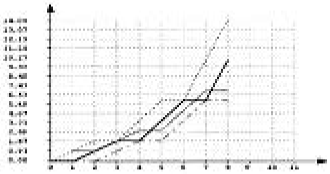
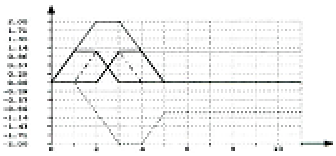
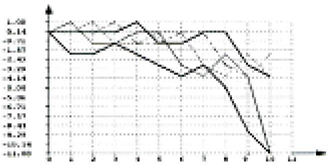
2. Authors' software

We have developed the software tool that allows creating versions of topological structure of an investigated object in the form of a cognitive dynamic model. Formalization necessary to build it is executed with application of graph theory and numerical methods. Many peaks of the developed digraph are considered as a set of basic factors. Edges or arcs of the graph represent the relationship between the factors, and feature the expert estimations that vary when implementing a computational procedure to solve a system of finite-difference equations. The software uses the programming language Java, JavaFX.

The stages of the preparation and performing the computations are as follows. First the adjacency matrix of cognitive models is formed as a digraph in accordance with the scheme of interaction of the factors proposed by the experts. If numerical experiment shows the presence of unstable version, that is linear or exponential resonance (Fig. 1), then the generating of sustainable structures is carried out automatically when pressing the corresponding button. An acceptable variant of the structure is set by the nature of changes in the values of pulse process factors proposed by G.V. Gorelova (Table).

Table 1. Impulse Process Types.

Steady pulse process	
Steady pulse process	**Intermittent pulse process**

$A_G = \begin{array}{c} V_1 \\ V_2 \\ V_3 \\ V_4 \end{array} \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$ 	$A_G = \begin{array}{c} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{array} \begin{bmatrix} 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 \end{bmatrix}$ 
$A_G = \begin{array}{c} V_1 \\ V_2 \\ V_3 \end{array} \begin{bmatrix} 0 & 0 & 1 \\ -1 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix}$ 	$A_G = \begin{array}{c} V_1 \\ V_2 \\ V_3 \\ V_4 \end{array} \begin{bmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 \end{bmatrix}$ 
$A_G = \begin{array}{c} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{array} \begin{bmatrix} 0 & -1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 \end{bmatrix}$ 	$A_G = \begin{array}{c} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{array} \begin{bmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 & 0 \end{bmatrix}$ 

In the table boxes to the left, the incidence matrices of the studied cognitive model are presented. The results of the pulse simulation that enable to determine visually whether the pulse process is sustainable or not, are given on the right. As a result of numerous experiments, G.V. Gorelova and her colleagues have found that "the increase of complexity of the simple cognitive structure, reflected in the number and the ways of combining elementary structures, does not result in large variety of pulse processes" [15]. To verify the developed software the simulation experiments are conducted with the cognitive model "The Impact of MEDIA on the Public Consciousness" [16]. Figures 1 and 2 show the results of computations.

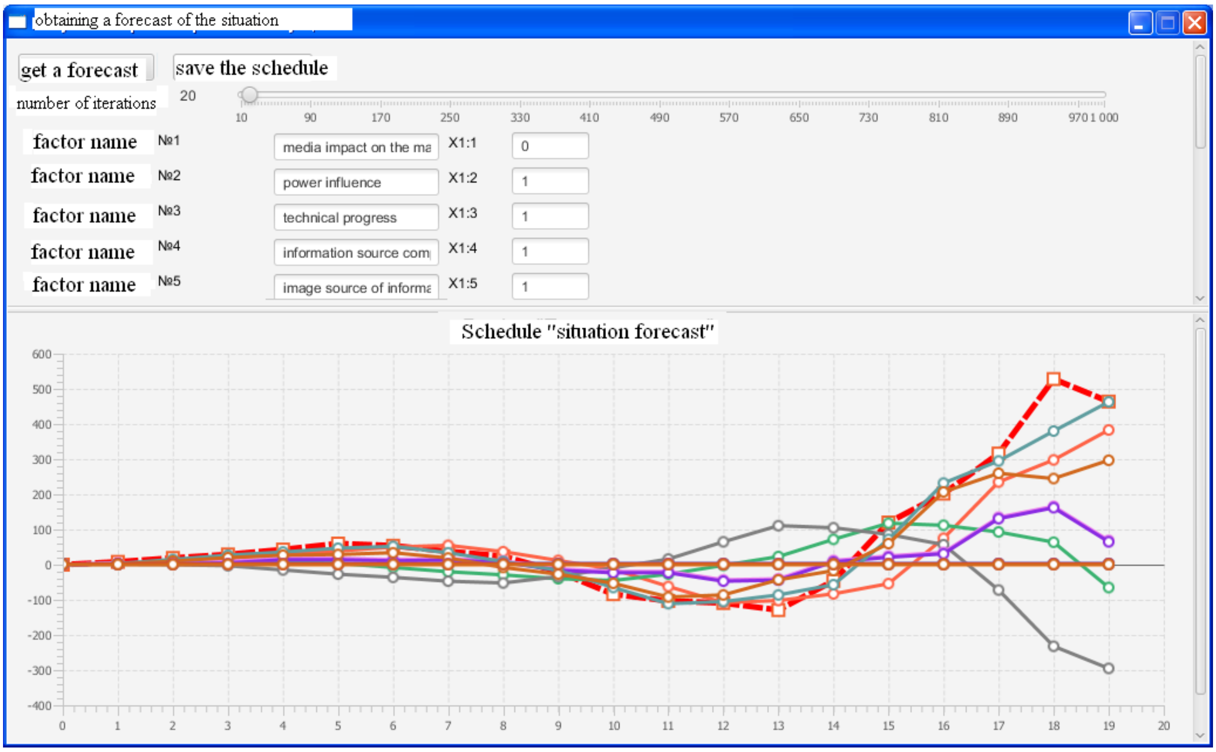


Figure 1. Unstable structure of cognitive model.

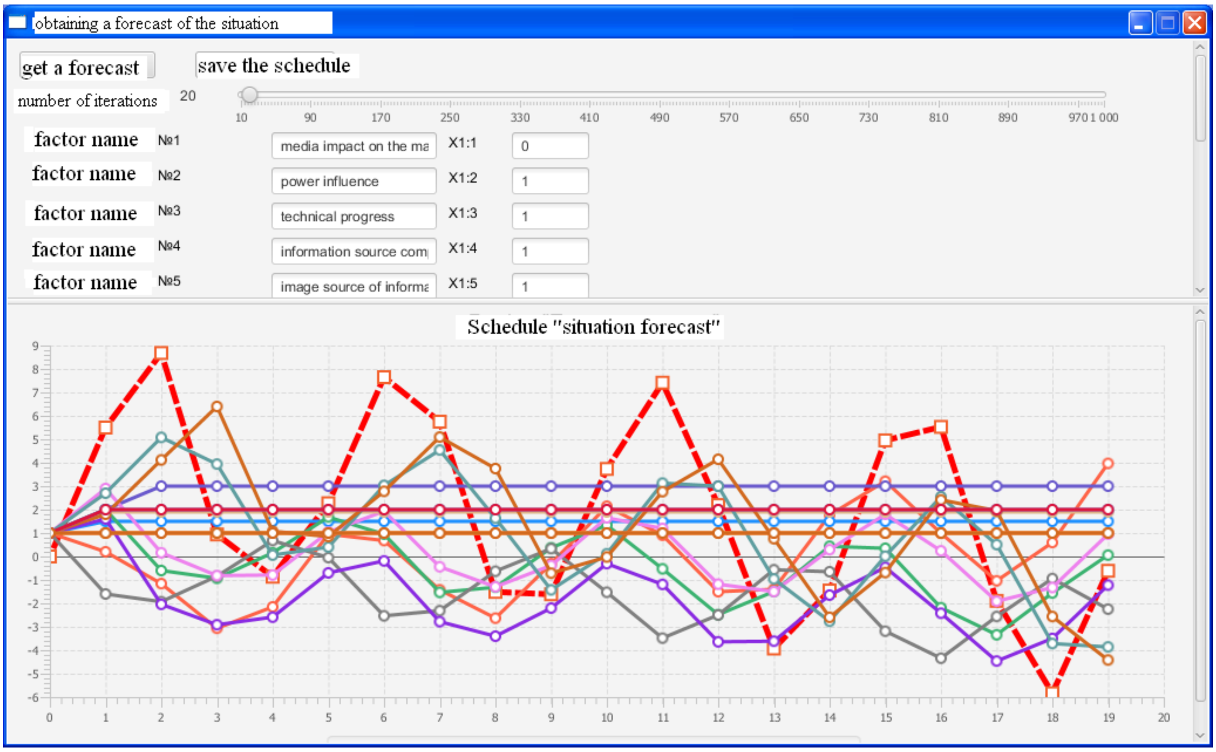


Figure 2. Stable structure of cognitive model.

Unstable structure is received at the initial stage of cognitive modeling using the expert methods. The decision maker has estimated the initial option as unacceptable. Stable structure of the cognitive model is automatically developed when you push the corresponding button or click the program “window”.

Conclusion

With the theoretical developments of F.S. Roberts as well as the practical interpretations of the cognitive structures by the expert team under G.V. Gorelova, we have developed a software tool “Synthesis of topological structure of cognitive models” using the Java and JavaFH programming languages, which allow automatically generating the stable structure of cognitive models of the object studied.

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