Information technology applications

Aplikácie informačných technológií

2 2019

PANEURÓPSKA VYSOKÁ ŠKOLA
FAKULTA INFORMATIKY

PAN-EUROPEAN UNIVERSITY
Faculty of Informatics

VZDELÁVANIE VEDA VÝSKUM
EDUCATION SCIENCE RESEARCH

International Journal of Information Technology Applications (ITA)

Volume 8, Number 2, December 2019

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International Journal of Information Technology Applications (ITA)

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Deadlines of two standard issues per year

paper submission deadline	– end of May/end of October
review deadline	– continuous process
camera ready deadline	– end of June/end of November
release date	– July/December

Editorial office address

Faculty of Informatics, Pan-European University, Tematínska 10, 851 05 Bratislava, Slovakia
juraj.stefanovic@paneurouni.com

Published by

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Paneurópska vysoká škola, n.o., Tomášikova 20, 821 02 Bratislava, IČO 36 077 429
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Multigrafika s.r.o., Rajecká 13, 821 07 Bratislava

Subscription

Contact the editorial office for details.
Older print issues are available until they are in stock.

ISSN: 2453-7497 (online)
ISSN: 1338-6468 (print version)

Registration No.: EV 4528/12

Contents

Editorial

Dear authors, dear readers,

Let me please express my gratitude for your publication activities in 2019. The second issue of our journal is focused on presentation of theoretical and practical results obtained in your project solutions and research activities at Slovak and Russian universities.

Papers in this issue are oriented on development of advanced methods and algorithms based on artificial neural networks, fuzzy logic and virtual reality, and their applications in different fields. The proposed modern methods have been verified and implemented in decision support systems, automotive, and smart home processes modelling and control.

I would like to thank to all concerned people for collaborating, preparing articles and reviewing the submitted papers. Your forthcoming papers and contributions are welcomed throughout 2020. I wish you a pleasant reading of the published contributions.

Juraj Štefanovič
ITA Editor-in-Chief

International Journal
Information Technology Applications (ITA)

Volume 8, Number 2, December 2019

COMPARISON OF REGULARIZATION AND OPTIMIZATION METHODS FOR PROCESS RECOGNITION WITH USE OF DEEP NEURAL NETWORK

Zuzana Képešiová, Štefan Kozák

Abstract:

This paper brings the topic of comparison of optimization techniques using gradient descent, gradient descent with momentum, Adam and learning rate decay in combination with previous optimization algorithms for face recognition using deep neural network. This paper compares several settings of these techniques as well as techniques among themselves with combination of regularization techniques varying in using no regularization, L2 regularization and dropout to successfully recognize the sex of a person captured. The result of the evaluation is taken in a matter of successfully recognized face rate for training data and test data, cost and deep neural network learning time.

Keywords:

Regularization, optimization, gradient descent, learning rate decay, machine learning.

ACM Computing Classification System:

Computer vision, machine learning, artificial intelligence, neural networks.

Introduction

Currently humanity relies on computers in more extent than ever before and this trend is still on its arise. One of abilities of computers is also image processing called computer vision. Computer vision could be used in wide range of application as object detection, situation development prediction, object identification, object recognition and many more.

In this paper we will analyze the topic of success of different optimization algorithms with different learning rates and regularization techniques used in the context of person´s sex recognition based on the given facial photo as a subject of face recognition. As a dataset the UTKFace library is used. Original dataset consists of over 20 000 face images with annotation of age, sex and ethnicity. The images cover large variation in pose, facial expression, illumination, occlusion, resolution, etc. [1].

1 Regularization Techniques

Regularization presents one of methods used for reducing the overfitting of data. One of the options is to increase training data, but another are regularization methods such as *L2 regularization* or *dropout*.

A. L2 Regularization

L2 regularization technique has many synonyms and it is known also as weight decay or Tikhonov regularization and as ridge regression in statistics. *L2 regularization* is most used method of regularization. The principle of *L2 regularization* is to add extra term to the cost function and regularize the cost function. A modified cost function is expressed by formula:

$$J(\theta) = J(\theta) + \frac{\lambda}{2n}\sum_W W^2 \tag{1}$$

Where $J(\theta)$ is a cost function, λ is a regularization parameter, n is size of a training set and W is a weight in network [4].

B. Dropout

Not only overfitting, but also the neural network size could be solved by regularization. In case of large neural network, we could focus on a technique called dropout to reduce the size of neural network and to speed up the learning process of the algorithm. The idea of *dropout* is based on dropping out units, in this case neurons, in a neural network. These units are chosen randomly with a probability of $q=1-p$. If the unit is chosen to be dropped out, then all incoming and outcoming connections are abandoned. Randomly dropping neurons ensure each neuron to learn something useful on its own instead of relying on other neurons [5].

With consideration of a neural network of a size of L layers, where index of neural network layer l is $l \in \{0, \cdots, L-1\}$, $l = 0$ is an input layer and $l = L - 1$ is output layer. Input and output vectors in hidden layers are computed according to relation:

$$x^{(l+1)} = W^{(l+1)}y^{(l)} + b^{(l+1)} \tag{2}$$

$$y^{(l+1)} = a(x^{(l+1)}) \tag{3}$$

where $x^{(l)}$ refers to input vector of layer l, $W^{(l)}$ is weight parameter, $y^{(l)}$ refers to output layer vector to layer l, $b^{(l)}$ is bias parameter at layer l and $a(x^{(l)})$ is an activation function. Previous equations (2) and (3) change to:

$$\delta_i^{(l)} \sim Bernoulli(p) \tag{4}$$

$$\bar{y}^{(l)} = \delta^{(l)} \otimes y^{(l)} \tag{5}$$

$$x^{(l+1)} = W^{(l+1)}\bar{y}^{(l)} + b^{(l+1)} \tag{6}$$

$$y^{(l+1)} = a(x^{(l+1)}) \tag{7}$$

by applying *dropout*, where $\otimes$ is element by element multiplication, $\delta_i^{(l)}$ is a Bernoulli random value of neuron i at layer l [5].

2 Optimization Techniques

In the experiment of recognizing sex of a subject by provided face photography, optimization methods such as *gradient descent*, *gradient descent with momentum* and *Adam* were used. As the algorithms provide different approaches to the problem, they also generate different results for settings provided.

A. Gradient Descent

Gradient descent is considered as one of the most popular method to optimize neural network. The main technique is performance of minimizing cost function $J(\theta)$ with the parameter θ updating parameters in reverse direction of the gradient of the cost function $\nabla_\theta J(\theta)$ with respect to the parameters [2].

Gradient descent varies in volume of data processed to compute the gradient of the objective function. *Gradient descent* could be a *batch gradient descent*, *stochastic gradient descent* and *mini-batch gradient descent*. The difference is, that *batch gradient descent* computes the gradient of the cost function for the whole dataset, while *mini-batch gradient descent* computes gradient respectively to data divided into small datasets and *stochastic gradient descent* computes gradient for each training example. In this paper we will consider a *gradient descent* as *batch gradient descent*. For computing the gradient of the cost function with respect to the parameters we will use the following:

$$\theta = \theta - \eta \cdot \nabla_\theta J(\theta) \tag{8}$$

where θ is standing for parameters, that are updated by gradient $\nabla_\theta J(\theta)$ multiplied by parameter η, a learning rate [2], [6].

B. Gradient Descent with Momentum

As we could see in the previous part, there are some oscillations across epochs. These oscillations slow down the convergence to minimum. *Gradient descent with momentum* is an optimization algorithm which relies on exponentially weighted averages. This method smoothens the oscillations by adding a fraction γ of the update vector of the past time step to the current update vector v and update parameters θ by:

$$v_t = \gamma v_{t-1} + \eta \cdot \nabla_\theta J(\theta) \tag{9}$$

$$\theta = \theta - v_t \tag{10}$$

The momentum term γ is usually set to 0.9 or a similar value [3].

C. Adam

Adaptive Moment Estimation or also so-called *Adam* is an optimization technique computing adaptive learning rates for each parameter. *Adam*, just as *Adadelta* or *RMSprop*, stores exponentially decaying average of past squared gradient s_t, but on the other hand, also keeps an exponentially decaying average of past gradients v_t, like momentum:

$$v_t = \beta_1 v_{t-1} + (1-\beta_1)\nabla_\theta J(\theta) \tag{11}$$

$$s_t = \beta_2 s_{t-1} + (1-\beta_2)\nabla_\theta J(\theta)^2 \tag{12}$$

v_t and s_t are estimates of the mean and uncentered variance of the gradients respectively. Both variables are initialized as vectors of zeros. Problem is, they tend to bias towards zero and therefore they must be bias corrected first. The bias-correcting looks like:

$$v_t^{corrected} = \frac{v_t}{1-\beta_1^t} \tag{13}$$

$$s_t^{corrected} = \frac{s_t}{1-\beta_2^t} \tag{14}$$

With corrected mean and variance, the Adam update parameters rule is as follows:

$$\theta_{t+1} = \theta_t - \frac{\eta}{\sqrt{s_t^{corrected}+\varepsilon}} v_t^{corrected} \tag{15}$$

As the authors [12] of the algorithm propose default values of $\beta_1 = 0.9$, $\beta_2 = 0.999$ and $\varepsilon = 10^{-8}$ [2][3][7], this experiment adopt these values as well.

D. Learning Rate Decay

Learning rate decay is a form of learning rate scheduling, which if done well, can result in significantly faster convergence and convergence to a better minimum. Initial large steps enable a rapid increase in the objective function, but later smaller steps are needed to descend into finer features of the loss landscape.

Some of the learning rate scheduling methods include exponential scheduling, where learning rate decays as:

$$\eta_t = \eta_0 * 10^{\frac{-t}{r}} \tag{16}$$

Another learning rate decay as a power scheduling is used by Bottou [8] or Xu [9] as follows:

$$\eta_t = \eta_0 (1 + \frac{t}{r})^{-c} \tag{17}$$

where *c* is a “problem independent constant” [10].

A learning rate decay used for this experiment is inspired by one used by Andrew Ng [11]:

$$\eta_t = \frac{1}{1+\eta_0 i} \tag{18}$$

3 Case Study

Deep neural network models applied on this experiment were built, trained and tested on a laptop consisting of Intel® Core™ i5-7200U 2.50GHz – 2.71GHz Processor and 8GB GeForce 940MX RAM.

For this experiment the original dataset was cut in the numbers and age scale. Used dataset consists of 454 face images of people ranged in age of 18 to 60 included. The composition of dataset was a composition of 185 male and 269 female face images, which were selected randomly.

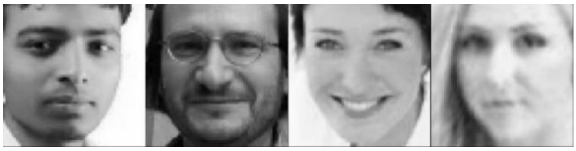

Fig.1. Example of training data.

As a training set and test set face images were preprocessed to size of 64x64 pixels and the rgb color palette was shrank into greyscale and standardized to divide the number representing a pixel by 255 for faster data processing.

There we 81 different deep neural network models created to test the accuracy of reading and recognizing the sex of a person by face. Models were a combination of *no regularization technique*, *L2 regularization* and *dropout* method with optimization algorithms such as *gradient descent*, *gradient descent with momentum* and *Adam.* Afterwards, *learning rate decay* optimization method with different values was used in a combination with all mentioned regularization and optimization methods to support wider range of models and their settings. Initial *learning rate* varies in value in 0.05, 0.005 and 0.0005. A general model setting is a 3NN layer model containing 4096 input nodes in input layer representing each pixel of a photo, 20 nodes in first hidden layer, 5 nodes in second hidden layer and 1 node in output layer resolving in 0 for a male and 1 for female.

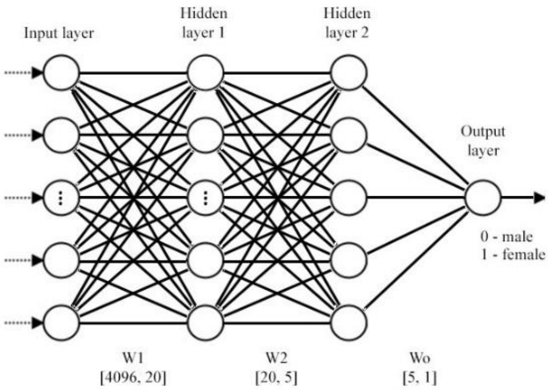

Fig.2. 3NN Deep neural network architecture.

As an evaluation tool, a successful sex recognition of provided face image from training set and test set, cost function and learning time of a model was used to ensure a selection of a model that would not be only accurate in the results of face recognition, but also it would be the fastest one to guarantee the recognition in real time. The total value of a model is computed by the following relation:

$$V = 0.8 \cdot train\_A + test\_A + \frac{max\_tt - tt}{max\_tt} \tag{19}$$

where V is a value of network, *train_A* is accuracy of training data, *test_A* is accuracy of test data, *max_tt* is maximum total time of model training out of all created models and *tt* is total time of current model training. By increasing the value V we obtain better mathematical model. The best and the worst results will be provided to not overload with unnecessary data.

A. Models Compared by Regularization Method

a) *No regularization* method in proposed main model setting and with provided data varied in results of value of network from 1.06 to 2.35.

Table 1. Models with no regularization.

Total value	Description			
	Settings	***Training set accuracy [%]***	***Test set accuracy [%]***	***Total training time [s]***
2.35	Gradient descent, lr = 0.005, lrd = 0	99.74	84.05	86.7958
1.06	Adam, lr = 0.005, lrd = 0.5	59.22	59.42	301.3619

As we could see in the Table 1., without use of any regularization method, the best results provides model with gradient descent using learning rate 0.005 with use of no learning decay.

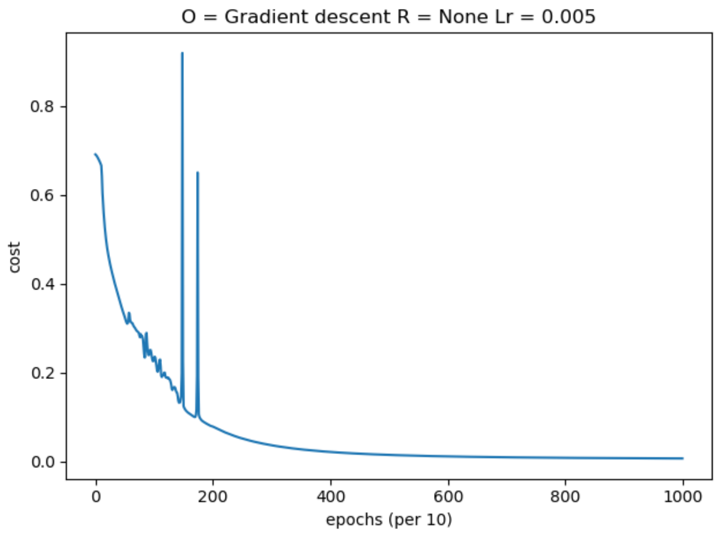

Fig.3. Cost function of model using gradient descent, no regularization and learning rate 0.005.

b) *L2 regularization* vary in value of network from 1.22 to 2.33. The bottom line is better than with use of *no regularization*, but the upper line is a bit worse, what favors *no regularization* at all in a comparison of *L2 regularization* and *no regularization* in this case.

Table 2. Models with L2 regularization.

Total value	Description			
	Settings	***Training set accuracy [%]***	***Test set accuracy [%]***	***Total training time [s]***
2.33	Gradient descent with momentum, lr = 0.005, lrd = 0	2.33	85.50	2.33
1.22	Adam, lr = 0.005, lrd = 0.5	1.22	59.42	1.22

By comparison of *no regularization* method and *L2*, we could conclude in poor results for *Adam* algorithm, but with *L2 regularization* in better total training time.

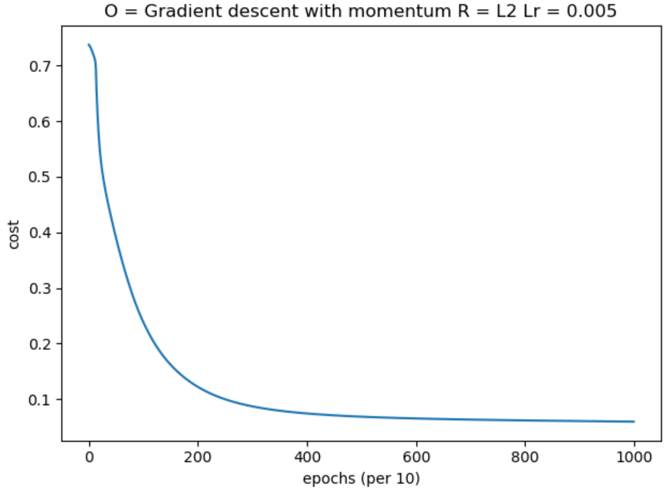

Fig.4. Cost function of model using gradient descent with momentum,
L2 regularization and learning rate 0.005.

c) *Dropout regularization* results are the worst out of all regularization methods. As in other cases, in this time *Adam* has the worst results and on the other hand, *gradient descent* leads the regularization in this case too, but with overall poor results. The cost function of the best model using dropout shows us, that the algorithm can provide better results, but in cost of more epochs and so longer training time.

Table 3. Models with dropout.

Total value	**Description**			
	Settings	***Training set accuracy [%]***	***Test set accuracy [%]***	***Total training time [s]***
2.01	Gradient descent, lr = 0.005, lrd = 0	72.46	75.36	96.7259
1.13	Adam, lr = 0.005, lrd = 0	59.22	59.42	280.5022

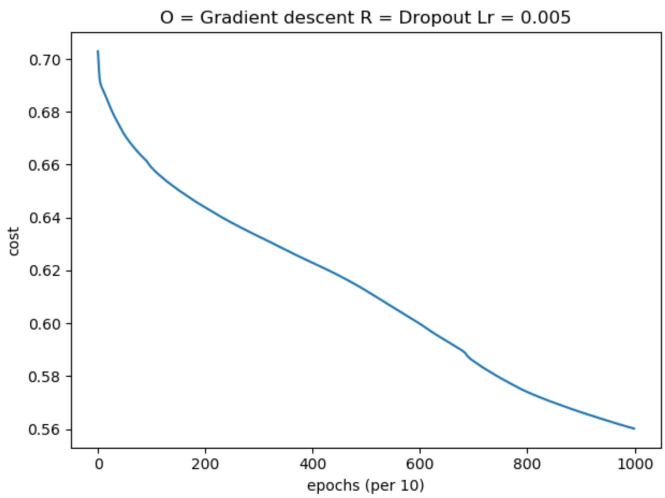

Fig.5. Cost function of a model using gradient descent, dropout regularization and learning rate 0.005.

B. Models Compared by Optimization Method

a) *Gradient Descent* is taking the all data at once and therefore it may appear slower than the other solutions, but in this case of data it was necessary to use the whole batch instead of mini-batches, because mini-batches of size of 64 or 128 samples created noise around one certain value without any sign of improvement as we can see below:

Fig.6. Use of mini-batch in experiment creating oscillations and fluctuations.

Changing the optimization or regularization technique did not get rid of the noise around one certain point and therefore the idea of using *mini-batch* in a case of this experiment was not considered, but instead a batch *gradient descent* was used. The Table 4. depicts the same settings for *no regularization* method and for *gradient descent* optimization as the best combination so far. As for *gradient descent*, the worse thing to do is pick *L2 regularization*, high learning rate and too fast *learning rate decay*.

Table 4. Models with gradient descent.

Total value	**Description**			
	Settings	***Training set accuracy [%]***	***Test set accuracy [%]***	***Total training time [s]***
2.35	No regularization, lr = 0.005, lrd = 0	99.74	84.05	86.7958
1.69	L2, lr = 0.05, lrd = 1	59.22	59.42	112.4739

b) *Gradient Descent with momentum* method in proposed main model setting and with provided data varied in results of value of network from 1.06 to 2.35.

Table 5. Models with gradient descent with momentum.

Total value	**Description**			
	Settings	***Training set accuracy [%]***	***Test set accuracy [%]***	***Total training time [s]***
2.34	No regularization, lr = 0.005, lrd = 0	99.74	84.05	87.7204
1.73	Dropout, lr = 0.0005, lrd = 1	63.63	60.86	114.5733

Gradient descent with momentum compared to *gradient descent* with same parameters gives the same result, but in a bit longer time, while the worst results are an improvement in training set accuracy as in test set accuracy.

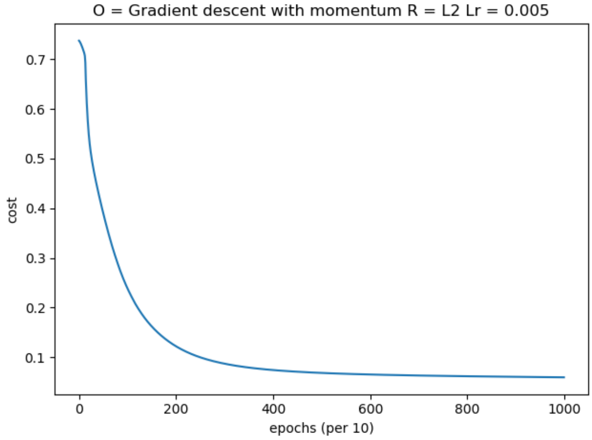

Fig.7. Cost function of model using gradient descent with momentum, L2 regularization and learning rate 0.005.

c) *Adam* optimization method brings comparable results when it comes to training and test accuracy, but the total training time is almost double of *gradient descent*, what lowers a total value of the model used with this optimization algorithm for selected problem.

Table 6. Models with Adam.

Total value	**Description**			
	Settings	***Training set accuracy [%]***	***Test set accuracy [%]***	***Total training time [s]***
2.08	No regularization, lr = 0.0005, lrd = 1	99.74	84.05	167.1711
1.06	No regularization, lr = 0.005, lrd = 0.5	59.22	59.42	301.3619

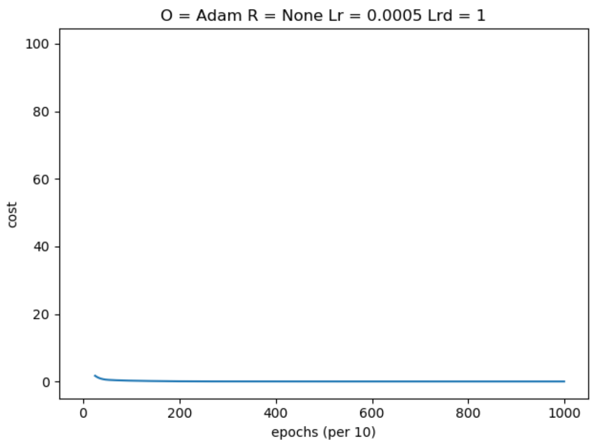

Fig.8. Cost function of a model using Adam, no regularization, learning rate 0.005 and learning decay 1.

Curve of cost function of the best Adam model was incomputable at the early stages for its high value.

d) *Learning rate decay* during experimental process acquired several values: 0, 0.5 and 1, which significantly influenced the whole learning process.

Table 7. Models with Adam.

Total value	**Description**			
	Settings	***Training set accuracy [%]***	***Test set accuracy [%]***	***Total training time [s]***
2.35	Gradient descent, No regularization, lr = 0.005, lrd = 0	99.74	84.05	86.7958
1.06	Adam, No regularization, lr = 0.005, lrd = 0.5	59.22	59.42	301.3619

Conclusion

The evaluation of several models with different regularization techniques such as models with no regularization technique at all, L2 regularization also called weight decay and dropout regularization was done. In this case, considering training set accuracy, test set accuracy and total training time, a best option would be skip the regularization completely.

Out of all optimization method, the one that works best with this kind of a problem and provided data set, a gradient descent would be the best resulting option, while Adam would be the least option. From another point of view, learning rate decay in this case has no place here and it would be the best to omit it.

If we would look at the results solely by test set accuracy, we would receive different results, a L2 regulated model with use of gradient descent with momentum optimizer, learning rate of 0.0005 and learning rate decay of 1, but in cost of total training time. Sometimes it is better to have a little bit less accurate system than have one too slow.

Acknowledgement

This paper was partially supported by the Slovak Research and Development Agency (VEGA 1/0819/17), by the Cultural and Educational Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic (KEGA 030STU-4/2017), and by the Scientific Grants SEMOD-79-2/2019 and Semod-80-7/2019.

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Authors

Ing. Zuzana Képešiová
Faculty of Electrical Engineering and Information Technology,
Slovak University of Technology in Bratislava, Slovakia
zuzana.kepesiova@stuba.sk
Currently a student of doctoral studies at Slovak University of Technology in Bratislava. The main focus of her studies is oriented to development of a remote laboratory to monitor and control of mechatronic systems using digital twin and mixed reality.

prof. Ing. Štefan Kozák, Phd.
Faculty of Informatics, Pan-European University, Bratislava, Slovakia
stefan.kozak@paneurouni.eu
Currently at the Institute of Applied Informatics at the Faculty of Informatics, Pan-European University in Bratislava. His research interests include system theory, linear and nonlinear control methods, numerical methods and software for modeling, control, signal processing, IoT, IIoT and embedded intelligent systems for digital factory in automotive industry.

ICT/CI ASSISTED COMPLEX ECONOMIC NETWORK IN VIRTUAL REALITY

A Contribution to Emerging Theory of Virtual Complex Networks - Part I

Ladislav Andrášik

Abstract:

In the contemporary mainstream economics there is a persisting reckoning on mathematical apparatus of Newtonian Mechanics or in better case on the first (of Clausius) Thermodynamics. However the economy in objective reality isn´t existing as a mechanical system but as such they are living in the form of complexly evolving social organism creating a complex network. De facto it is a spontaneous product of great population of Homo sapiens in a very long historical evolution. Problems and difficulties for economics scholar are consist in fact that such entities in objective reality are not directly observable and the less they are such ones as a wholeness effectively controlled from separate sole centre. Fortunately the progress in ICT and mainly in computational intelligence (CI) is bringing new possibilities for insight if not directly into objective economies thereabout at least into virtual ones. For such purposes we are constructed within relatively simple software called STELLA the primordial virtual economy which allows for the user directly in computer to observe the behaviour in it. Fever explanatory however is only a slide showing of snapshots passed from STELLA. For that reasons we must to expend the exposition by voluminous verbal commentaries. On the other hand we must emphasize that "reading" of snapshots from computer simulation is new very efficient modus of mining knowledge from complex economic process. In the Part II of this essay (in the next issue of ITA journal) *we are bringing results of simulations and deep commentary to behaviour in virtual economy.*

Keywords:

Complex systems, computational experimentations, constructive approach, complexity, decentralized market process, economies as artificial (computational) worlds, economics, economy, emergent organization, endogenous interactions, experiment, graph theory, idiosyncrasies, network, interaction structure, mainstream economics, ontological and methodical mistakes, STELLA software, virtual environment, virtual laboratories.

ACM Computing Classification System:

Network economics, network performance evaluation, network modelling, network simulation, network experimentation, network properties.

Introduction

The theory and application of advanced field of complex networks is promising approach, with devices and tools for building mental models on complex worlds and further resume applications in those bases certain virtual world in computers with suitable software. Our motives in this essay are to use these new possibilities for better understanding the behaviour of complex socio-economic organisms at least in using metaphors with virtual economies created in software environment of STELLA. Actually this is need because in the contemporary mainstream economics there is a persisting reckoning on mathematical apparatus of Newtonian Mechanics or in better case on first (of Clausius) Thermodynamics. However the economies in objective reality do not exist as a mechanical system but they are living as complexly evolving social organism in the form of complex network. Unfortunately for economics scholar such entities in objective reality are not directly observable and the less they are such ones as a wholeness effectively controlled from separate sole centre. In this introduction we begin with concise explanation on complex network approach to economies.

1 Types of Complex Networks

From the point of view of purposes of this essay it is interesting to show certain types of complex networks. One of them is a *Scale-free network*. It is, as it is written in expertly sources a such network whose degree distribution follows a *Power Law*, at least asymptotically.

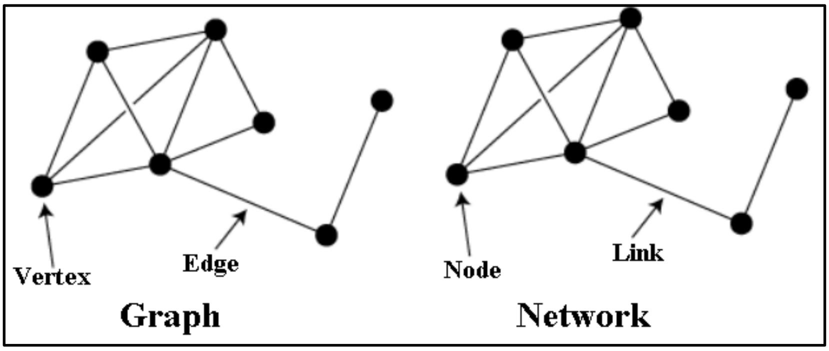

Fig.1. The different terminology between Graph and Network theories.

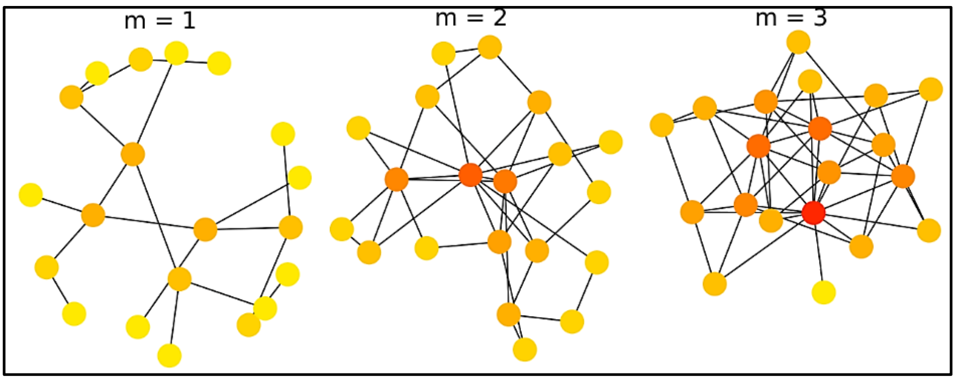

Fig.2. The insight of three Barabási-Albert models of scale-free networks.

That is, the fraction *P(k)* of nodes in the network having *k* connections to other nodes goes for large values of *k* as $P(k) \sim k^{-\gamma}$ where γ is a parameter whose value is typically in the range $2 < \gamma < 3$ (wherein the second moment of $k^{-\gamma}$ is infinite but the first moment is finite), although occasionally it may lie outside these bounds. We are bringing typical examples of *Scale-free network*, which is descending from A-L. Barabási, [2]. The snapshot of (Fig.2) displays three graphs of his and Albert model.

Each has 20 nodes and a parameter of attachment m as specified. The colour of each node is depending upon its degree (the same scale for each graph). The second type of complex network which is interested for us is so called *Small-world network*. It is a type of mathematical graph/network in which most nodes are not neighbours of one another, but the neighbours of any given node are likely to be neighbours of each other and most nodes can be reached from every other node by a small number of hops or steps. We are bringing very simple example of such graph/network, (Fig.3).

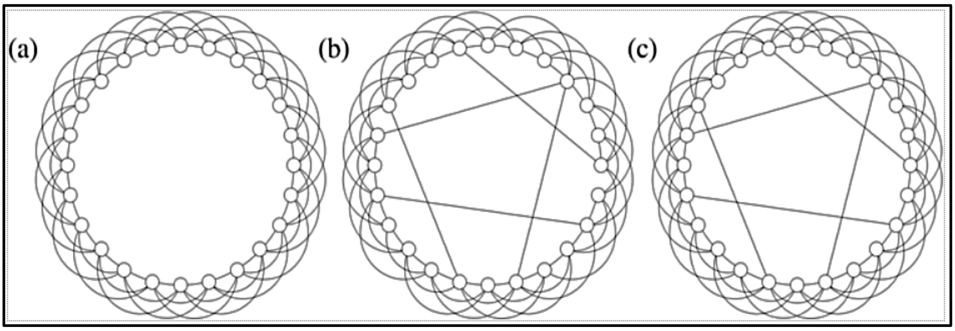

Fig.3. The type of network called Small world – three distinct graphs.

In the (Fig.3) there are three models: (a) A ring network in which each node is connected to the same number l=3 nearest neighbours on each side[1]. (b) A Watts–Strogatz network [24] is created by removing each edge with uniform, independent probability *p* and rewiring it to yield an edge between a pair of nodes that are chosen uniformly at random. (c) The Newman–Watts [17] variant of a Watts–Strogatz network, in which one adds "shortcut" edges between pairs of nodes in the same way as in a WS network but without removing edges from the underlying lattice. This figure was appeared in Newman work, [7, (2003)]. In this essay we are using terminology due to software STELLA because it is very suitable for creating economic networks. In (Fig.4) we are showing a simple but abstract networks created by using STELLA building blocks.

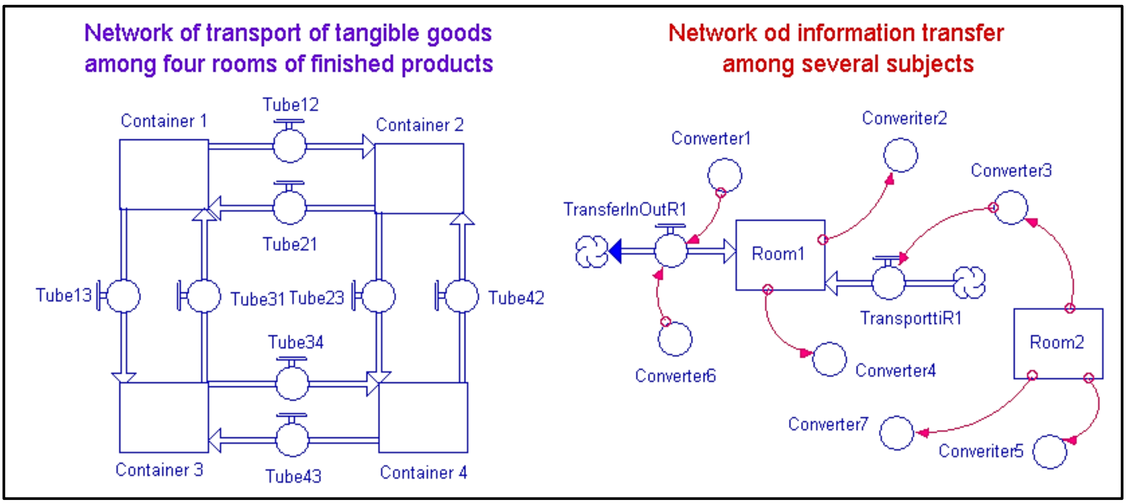

Fig.4. The snapshot of two different simple network scheme created in STELLA.

[1] This network resembles a one-dimensional lattice with periodic boundary conditions.

In recent thirty years there is a rising set of studies of networks from an economics perspective (Kirman (1997), Ioannidis (1997, 2002, 2004), Tesfatsion (1997), Weisbuch and Kirman and Herreiner (2000), Kranton and Minehart (2001), Corominas-Bosch [6, (2005)], Wang and Watts [14, (2002)]) and others. Actually recent surveillances are shoving that there are several attitudes to focus attentions on complications with economies in objective reality from different side than in the mainstream economics namely from the side of theory of graphs and networks ones. The first approach to capture the global properties of such systems as complex network is to model them as graphs whose nodes represent the dynamical units, and whose links stand for the interactions between them.

The author O. Gomes in his essay on *Complex Networks in Macroeconomics* [9] published in 2014 is informing on using this new approach in different branches of contemporary science and he puts main focus on economics. He shows that even on first sight the socio-economic entities are looking like a *Complex Networks*. He has written that socio-economic phenomena might be approached, in many different contexts, through the construction of networks that highlight the local interaction among heterogeneous agents. We must to add onto this assertion that every agent is authentic and inherently heterogeneous so in his roles, functions and activities too. Real-world networks concerning human relations in the society or in the economy involve a large number of nodes, and large numbers and qualitative varieties of links connecting them and an evolving structure where both nodes and links may be generated or may disappear at each time period. He emphasizes that the economies are behaving as a *Scale-Free Complex Network*[2]. A market for a given good, the financial system or the world economy, all display characteristics that allow to classify them as the complex network structures and, more specifically, as having property of *Scale-Free Networks*.

In other important example A. Kirman discusses resourceful problems, which are from the subject of our virtual economy, certain economic models in which agents interact directly with each other rather than through the price system as in the standard general equilibrium model. Actually in his chapter *Economies with Interacting Agents* [10] among others as contributor to the book *The Economics of Networks* [4] He is suggested that the relationship between micro and macro behaviour is very different from that in the standard model and that the aggregate phenomena and process too that can arise are rich. The models considered by A. Kirman include ones with global interaction in which all agents can interact with each other which is by our opinion an overambitious strong assumption and the one in which agents can only interact with their immediate neighbours which is more realistic approach. The author is considering both static and dynamic models and the latter includes the class of evolutionary economic models. In the last part of his chapter A. Kirman is discussing models in which communication networks evolve. Among others we are known that A. Kirman together with Oddou and Weber (1986) applied stochastic graphs to simple decentralized pure-exchange economies. The Kirman´s contribution into *introductory theory and methodology of complex networking economies* is very significant and useful.

Other interesting for our investigation is a chapter in cited book: *Spatial Interactions in Dynamic Decentralized Economies: a Review*, due to the author G. Fagiolo [4], pp.53-91. He describes in his chapter dynamic models of decentralized economies with imagination that agents in economies are spatially distributed and interact directly and locally. He put more exactly that this means: (a) agents are located in a space as some graph or integer lattice that is seen in our essay perspective as a network; (b) the current choice of each agent is influenced by past choices of their neighbour.

[2] In recent literature the *Scale-free Networks* are described as a connected graph or network with the property that the number of links originating from a given node exhibit a *power law distribution*. A scale-free network can be constructed by progressively adding nodes to an existing network and introducing links to existing nodes with preferential attachment so that the probability of linking to a given node $\boldsymbol{i}$ is proportional to the number of existing links $\boldsymbol{k_i}$ that node has.

In this way we are obtaining belief that this approach is very congenial with economic evolution in objective reality and it is also a good inspiration for our work. We are owing oneself in this contexts to vigorously emphasize that it is a cardinal difference between if in one hand it is an economics of such sectors of economies as the networks are: networks of oil and other products pipelines, electrical networks, etc., that is sectorial economics, and the other side it is a general economics of fullness economy as a complex network.

Authors Newman, M. E. J., Watts, D. J. and Strogatz, S. H., describe in theirs essay with name *Random graph models of social networks* [12] some new exactly solvable models of the structure of social networks, based on random graphs with arbitrary degree distributions. They give models both for simple unipartite networks, such as acquaintance networks, and bipartite networks, such as affiliation networks. Authors compare the predictions of their models to data for a number of real-world social networks and find that in some cases, the models are in remarkable agreement with the data, whereas in others the agreement is poorer, perhaps indicating the presence of additional social structure in the network that is not captured by the random graph. Their works are also very inspirational in our endeavour to constructing virtual laboratories in STELLA in the form of complex networks.

Among others we want to focuses attention of readers to *Agent-based computational economics* (ACE) which is important further way, in the study of economies different from neoclassical approach. This approach is very congenial with our approach in this essay. ACE branch of economics is using agent-based modelling and simulation, in which an agent based model, is a one that comprising autonomous agents placed in an interactive social environment or network of socio-economic interaction among its nodes. Simulating these and similar models using appropriate software in common computers is very useful and most practical way to understand evolution of economies by visualizing the process running in virtual environment, see for example [13] or [15]. In these contexts worth mentioning the impact of theory and functional *computational neural networks* on reasoning in economics in direction to go to complex networks including such ones as *Multilayer Perceptron Neural Networks* and/or *Auto-associative Neural Networks*, [13]. In contemporary era the crucial role of development of socio-economic complex networks are playing the entirety of the Networks based on advanced ICT, and mainly the Internet among them, (Fig.5).

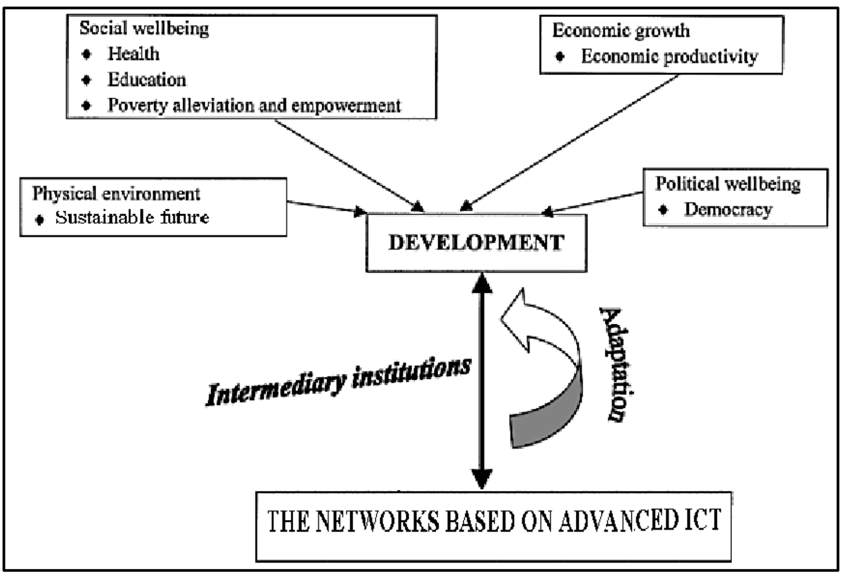

Fig.5. The schema of complex development influenced by ICT networks.

The construction of this schema was inspired by Shirin Madon, LSE Research Online London) The authors of *Job Information Networks, Neighbourhood Effects, and Inequality* [7] are focused their attention on the fact that considerable interest has emerged recently in the economic literature about social interactions and the ways in which social norms and structures are the conditions of individual behaviour. They emphasized that treatment of labour-market transactions being very different from trading in goods reflects the importance of *Idiosyncrasies* due to social effects, outcomes within social groups. One of typical example of where such idiosyncrasies play a prominent role is job-market search. Their research has already used network analysis to elucidate the origins of previous unexplained similarities in outcomes by qualitative differences such as race, ethnicity, and gender. Furthermore, they identify the source of some neighbourhood correlations in labour-market outcomes.

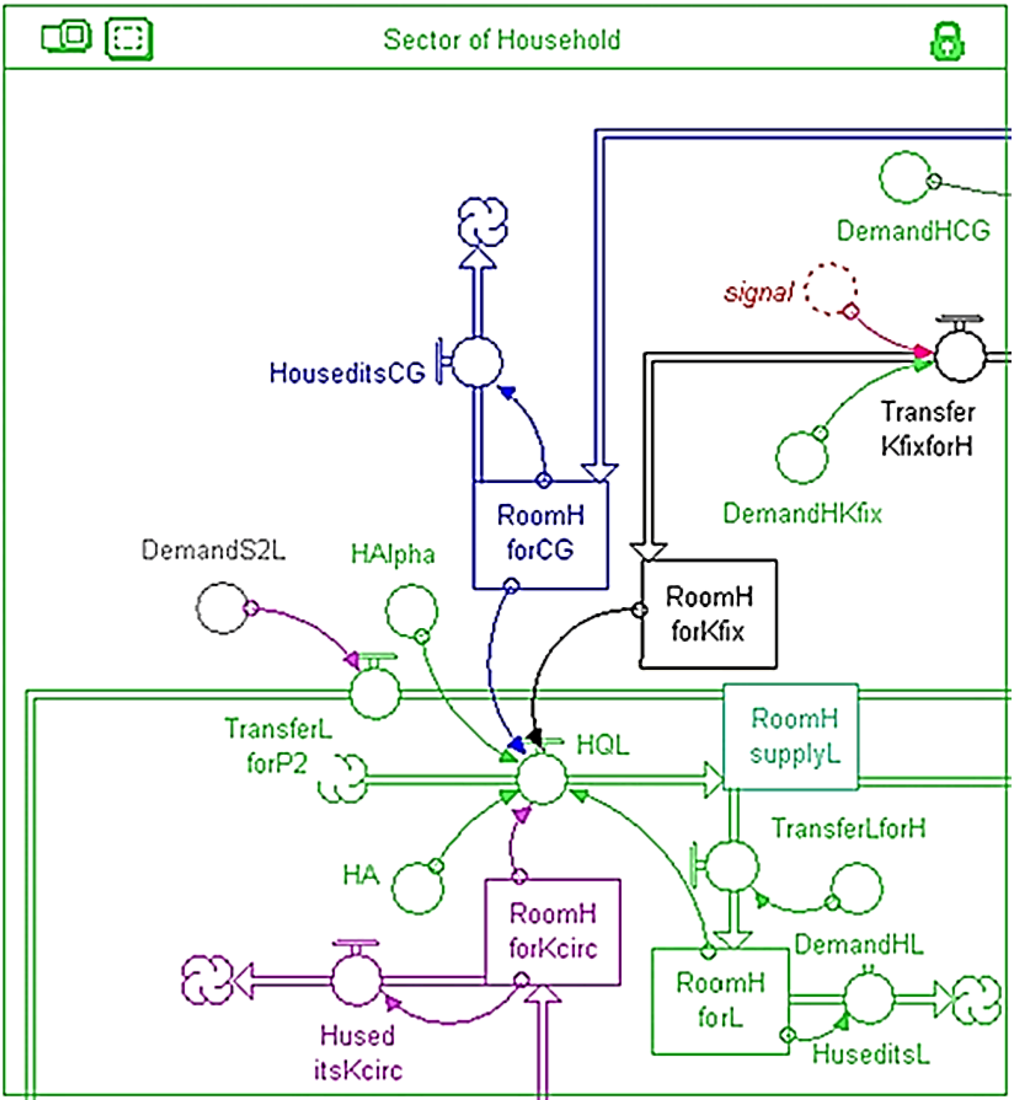

Fig.6. The snapshot of Households scheme created in STELLA.

At the same time they note that, there are a number of promising areas where research is needed. In particular, the importance of employer characteristics and the role of the internet in altering the role of informal contacts in the future are topics that deserve special attention[3].

Among others scholars Margarida Corominas-Bosch with two co-workers [6] is considered a bargaining in a bipartite network of buyers and sellers, who can only trade with the limited number of people with whom they are connected. Such networks could arise due to proximity issues or restricted communication flows, as with information transmission of job openings, business opportunities, and transactions *not easily regulated by external authorities*. They are beginning with two separate simple networks, which are then joined by an additional link. Participants appear to quickly grasp important characteristics of the networks.

The results diverge sharply depending on how this connection is made, typically conforming to the theoretical directional predictions. Payoffs can be systematically affected even for agents who are not connected by the new link. They find evidence of a form of social learning - the shares (publicly) allocated to others in the past affect what one is willing to accept. They are performing an experimental test of a graph-theoretic model that allows them to decompose any two-sided network into simple networks of three types, with unique predictions about equilibrium prices for the networks in their works. These (noted above) contributions to subjects in question are from our view the most important and obvious applications of networks to approach in virtual economic models in economics where so many markets are not centralized, but rather consisting of a complex structure of bilateral trades and relationships.

However our approaches to build economies as complex network economies in virtual environment are differing from those they are cited in earlier passage in a good deal richer tools of STELLA building boxes and much brighter in discriminating qualitative and quantitative variability among nodes/stocks and interaction/flows of some created graphs. The snapshot of (Fig.6) is showing the Households part of Economic Network entirety created in STELLA environment. The vertices, converters and edges are coloured for better distinguishing the one sector from the others ones. For *Households* are chosen green colour. The primeval vertex of *Households* is a *Container* called *RoomHsupplyL*, which is supply of disposable *Labour Forces L* for all sectors of virtual economy; it departures as flows of performance the *Live Works* via four pipelines called *TransferLforH*, *TransferLforP1*, *TransferLforP2* and *TransferLforP3*. The intimately need for household is the supply of consumer goods and services called *RoomCGforH* for feeding the persons of *Population* living in *Households*. Some part of all *Population* is a supply charge of all *L*. The filling of *RoomCGforH* is coming as flow thru pipeline called *TransferCGforH*, blue colour, which however isn´t shown as full in the snapshot of (Fig.6) (it is set to the snapshot of (Fig.7)). More details of links and values flowing among blocks of sectors are shown in (Tab.1a) and (Tab.1b).

There are certain differences between sector *S1* and of households *H* (and sectors *S2* and *S3* too), because of different character of theirs supplied and demanded products. The product of *S1* is investment goods, which is traded per years whereas with labour forces *L* and *Kcirc* and *CG* are traded per month. These time instance discrepancies are doing in network entirety some perturbations, which are introduced into flows fluctuations in one year frequencies. In Part 2 of this essay (next issue of this journal) we will bring snapshots with detail graphs of such *saw tooth waveform*.

[3] For our research in economic problems of complex network and for this essay too the other two works of Ioannides are important [12] and [13].

Tab.1a. The fillings of building blocks of Household scheme – upper part.

Sector of Household

RoomH_forCG(t) = RoomH_forCG(t - dt) + (TransferCG - HouseditsCG) * dt
INIT RoomH_forCG = 10
INFLOWS:
TransferCG (IN SECTOR: Sector of Kfix Producers P1)
OUTFLOWS:
HouseditsCG = IF(TIME=0) THEN 0 ELSE RoomH_forCG

RoomH_forKcirc(t) = RoomH_forKcirc(t - dt) + (TransferKcirc_forH - Hused_itsKcirc) * dt
INIT RoomH_forKcirc = 10
INFLOWS:
TransferKcirc_forH (IN SECTOR: Sector of Kcirc Producers P2)
OUTFLOWS:
Hused_itsKcirc = IF(TIME=0) THEN 0 ELSE RoomH_forKcirc

RoomH_forKfix(t) = RoomH_forKfix(t - dt) + (Transfer_KfixforH) * dt
INIT RoomH_forKfix = 10
INFLOWS:
Transfer_KfixforH = signal_2*DemandHKfix

RoomH_forL(t) = RoomH_forL(t - dt) + (TransferLforH - HuseditsL) * dt
INIT RoomH_forL = 10
INFLOWS:
TransferLforH = IF(TIME=0) THEN 0 ELSE HdemandL
OUTFLOWS:
HuseditsL = IF(TIME=0) THEN 0 ELSE RoomH_forL

Tab.1b. The fillings of building blocks of Household scheme – lower part.

RoomH_supplyL(t) = RoomH_supplyL(t - dt) + (HQL - TransferL_forP3 - TransferLforH - TransferL_forP1 - TransferL_forP2) * dt
INIT RoomH_supplyL = 0
INFLOWS:
HQL = HA*((RoomH_forKfix+RoomH_forKcirc)^HAlpha)*(RoomH_forCG+RoomH_forL)^(1-HAlpha)
OUTFLOWS:
TransferL_forP3 (IN SECTOR: Sector of Kfix Producers P1)
TransferLforH = IF(TIME=0) THEN 0 ELSE DemandHL
TransferL_forP1 (IN SECTOR: Sector of Kfix Producers P1)
TransferL_forP2 = IF(TIME=0) THEN 0 ELSE DemandS2L

DemandHCG = 10
DemandHKfix = 2
DemandHL = 10
DemandS2L = 10
HA = 2
HAlpha = 0.5

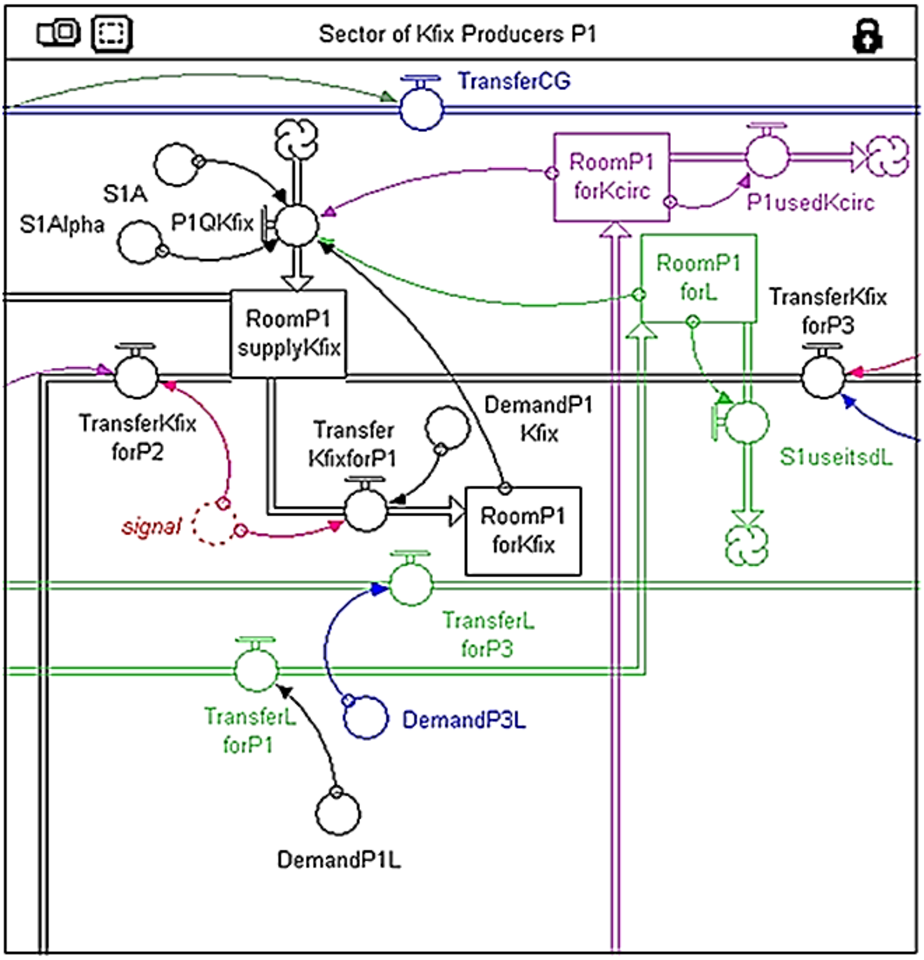

Fig.7. The snapshot of sector P1 scheme created in STELLA.

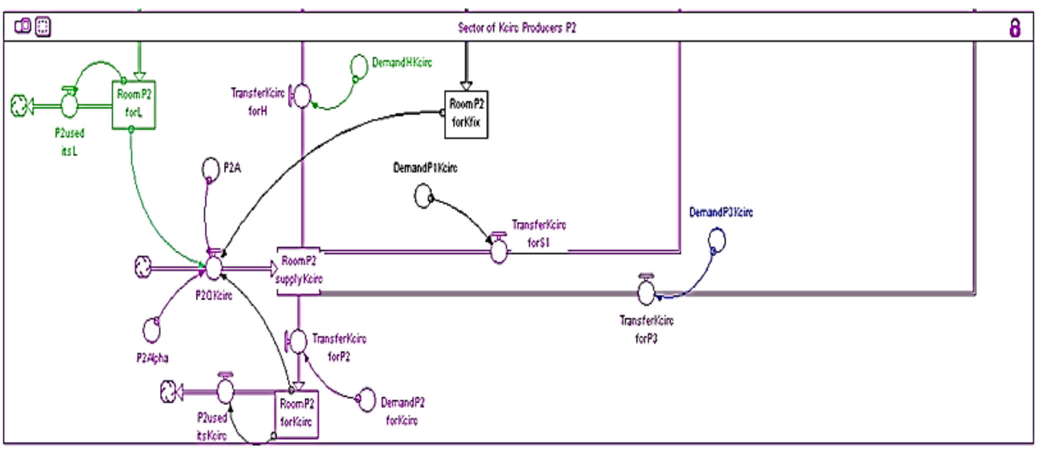

Fig.8. The snapshot of sector P2 scheme created in STELLA.

Tab.2. The fillings of building boxes of sector P1.

```
Sector of Kfix Producers P1
RoomP1_forKcirc(t) = RoomP1_forKcirc(t - dt) + (TransferKcirc_forS1 - P1usedKcirc) * dt
    INIT RoomP1_forKcirc = 10
    INFLOWS:
        TransferKcirc_forS1 (IN SECTOR: Sector of Kcirc Producers P2)
    OUTFLOWS:
        P1usedKcirc = IF(TIME=0) THEN 0 ELSE RoomP1_forKcirc
RoomP1_forKfix(t) = RoomP1_forKfix(t - dt) + (Transfer_KfixforP1) * dt
    INIT RoomP1_forKfix = 10
    INFLOWS:
        Transfer_KfixforP1 = DemandP1_Kfix*signal_2
RoomP1_forL(t) = RoomP1_forL(t - dt) + (TransferL_forP1 - S1useitsdL) * dt
    INIT RoomP1_forL = 10
    INFLOWS:
        TransferL_forP1 = IF(TIME=0) THEN 0 ELSE P1demandL
    OUTFLOWS:
        S1useitsdL = IF(TIME=0) THEN 0 ELSE RoomP1_forL
RoomP1_supplyKfix(t) = RoomP1_supplyKfix(t - dt) + (P1QKfix - Transfer_KfixforH -
    TransferKfix_forP2 - Transfer_KfixforP1 - TransferKfix_forP3) * dt
    INIT RoomP1_supplyKfix = 14
    INFLOWS:
        P1QKfix =
        signal_2*(S1A*((RoomP1_forKfix+RoomP1_forKcirc)^S1Alpha)*RoomP1_forL^(1-S1Alph
        a))
    OUTFLOWS:
        Transfer_KfixforH (IN SECTOR: Sector of Household)
        TransferKfix_forP2 = DemandP2_Kfix*signal_2
        Transfer_KfixforP1 = DemandP1_Kfix*signal_2
        TransferKfix_forP3 = DemandP3_Kfix*signal_2
TransferCG = IF(TIME=0) THEN 0 ELSE DemandHCG
    OUTFLOW FROM: RoomP3_supplyCG (IN SECTOR: Sector of CG Producers P3)
    INFLOW TO: RoomH_forCG (IN SECTOR: Sector of Household)
TransferL_forP3 = IF(TIME=0) THEN 0 ELSE DemandP3L
    OUTFLOW FROM: RoomH_supplyL (IN SECTOR: Sector of Household)
    INFLOW TO: RoomP3_forL (IN SECTOR: Sector of CG Producers P3)
DemandP1_Kfix = 6
DemandP3L = 10
P1demandL = 10
S1A = 0.99
S1Alpha = 0.5
```

In production process in the sectors there can be emerging several other perturbations. Let we preserve simplicity of understanding: we were chosen only one of them namely in production process of investment goods where we have embedded perturbation into parameter *AP1*, in the form of $\Delta AP1 = +\text{small value}$, but only in one time instance. This sole perturbation is caused increasing of investment goods production without change of other inputs and in container called *RoomP1supply Kfix*, begins to raise inventories of investment goods. This new situation force the CEO´s of sector *P1* to lowering the price of investment goods called *PriceKfix*. The lower *PriceKfix* enables for sectors *H*, *P2* and *P3* to buy more investment goods and by these decisions of those sectors CEO´s the emerging problem for *P1* is excided.

The scheme of Bank accounts network is seemingly parallel and independent from the four sectors of goods. However the networks are connected by several information links, which are carrying values of prices and goods. The software STELLA allows this via tool called *Ghost* . Because of emerged perturbation of values of investment goods we must introduced into model the so called *built in regulators.*

Tab.3. The fillings of building boxes of sector P2.

```
Sector of Kcirc Producers P2
RoomP2_forKcirc(t) = RoomP2_forKcirc(t - dt) + (TransferKcirc_forP2 - P2used_itsKcirc) * dt
INIT RoomP2_forKcirc = 10
 INFLOWS:
   TransferKcirc_forP2 = IF(TIME=0) THEN 0 ELSE DemandP2_forKcirc
 OUTFLOWS:
   P2used_itsKcirc = IF(TIME=0) THEN 0 ELSE  RoomP2_forKcirc
RoomP2_forKfix(t) = RoomP2_forKfix(t - dt) + (TransferKfix_forP2) * dt
INIT RoomP2_forKfix = 10
 INFLOWS:
   TransferKfix_forP2 (IN SECTOR:  Sector of Kfix Producers P1)
RoomP2_forL(t) = RoomP2_forL(t - dt) + (TransferL_forP2 - P2used_itsL) * dt
INIT RoomP2_forL = 10
 INFLOWS:
   TransferL_forP2 (IN SECTOR:  Sector of Household)
 OUTFLOWS:
   P2used_itsL = IF(TIME=0) THEN 0 ELSE RoomP2_forL
RoomP2_supplyKcirc(t) = RoomP2_supplyKcirc(t - dt) + (P2QKcirc - TransferKcirc_forH -
TransferKcirc_forS1 - TransferKcirc_forP3 - TransferKcirc_forP2) * dt
INIT RoomP2_supplyKcirc = 0
 INFLOWS:
   P2QKcirc =
     P2A*((RoomP2_forKfix+RoomP2_forKcirc)^P2Alpha)*RoomP2_forL^(1-P2Alpha)
 OUTFLOWS:
   TransferKcirc_forH = IF(TIME=0) THEN 0 ELSE DemandHKcirc
   TransferKcirc_forS1 = IF(TIME=0) THEN 0 ELSE DemandP1Kcirc
   TransferKcirc_forP3 = IF(TIME=0) THEN 0 ELSE DemandP3Kcirc
   TransferKcirc_forP2 = IF(TIME=0) THEN 0 ELSE DemandP2_forKcirc
DemandHKcirc = 10
DemandP1Kcirc = 10
DemandP2_forKcirc = 10
DemandP3Kcirc = 10
P2A = 2.829
P2Alpha = 0.5
```

Tab.4. The fillings of building blocks of the sector P3.

```
Sector of CG Producers P3
RoomP3_forkcirc(t) = RoomP3_forkcirc(t - dt) + (TransferKcirc_forP3 - P3used_itsKcirc) * dt
INIT RoomP3_forkcirc = 10
 INFLOWS:
   TransferKcirc_forP3 (IN SECTOR:  Sector of Kcirc Producers P2)
 OUTFLOWS:
   P3used_itsKcirc = IF(TIME=0) THEN 0 ELSE RoomP3_forkcirc
RoomP3_forKfix(t) = RoomP3_forKfix(t - dt) + (TransferKfix_forP3) * dt
INIT RoomP3_forKfix = 10
 INFLOWS:
   TransferKfix_forP3 (IN SECTOR:  Sector of Kfix Producers P1)
RoomP3_forL(t) = RoomP3_forL(t - dt) + (TransferL_forP3 - P3useditsL) * dt
INIT RoomP3_forL = 10
 INFLOWS:
   TransferL_forP3 (IN SECTOR:  Sector of Kfix Producers P1)
 OUTFLOWS:
   P3useditsL = IF(TIME=0) THEN 0 ELSE RoomP3_forL
RoomP3_supplyCG(t) = RoomP3_supplyCG(t - dt) + (P3QCG - TransferCG) * dt
INIT RoomP3_supplyCG = 0
 INFLOWS:
   P3QCG =
     P3A*((RoomP3_forKfix+RoomP3_forkcirc)^P3Alpha)*RoomP3_forL^(1-P3Alpha)
 OUTFLOWS:
   TransferCG (IN SECTOR:  Sector of Kfix Producers P1)
DemandP3_Kfix = 3*CorrDemKfix
P3A = 1
P3Alpha = 0.5
```

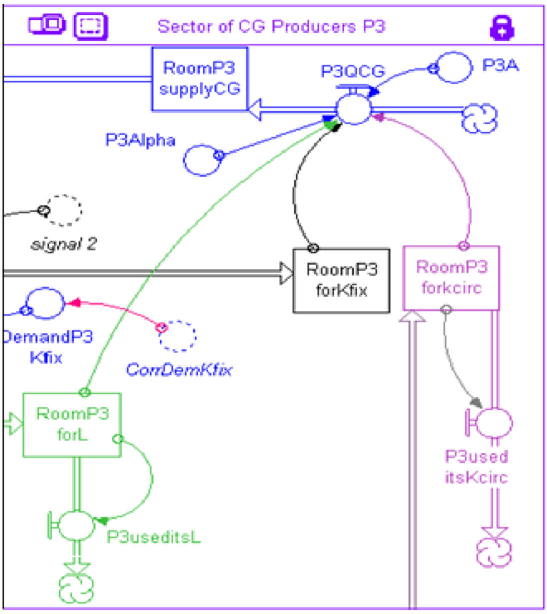

Fig.9. The snapshot of P3 scheme created in STELLA.

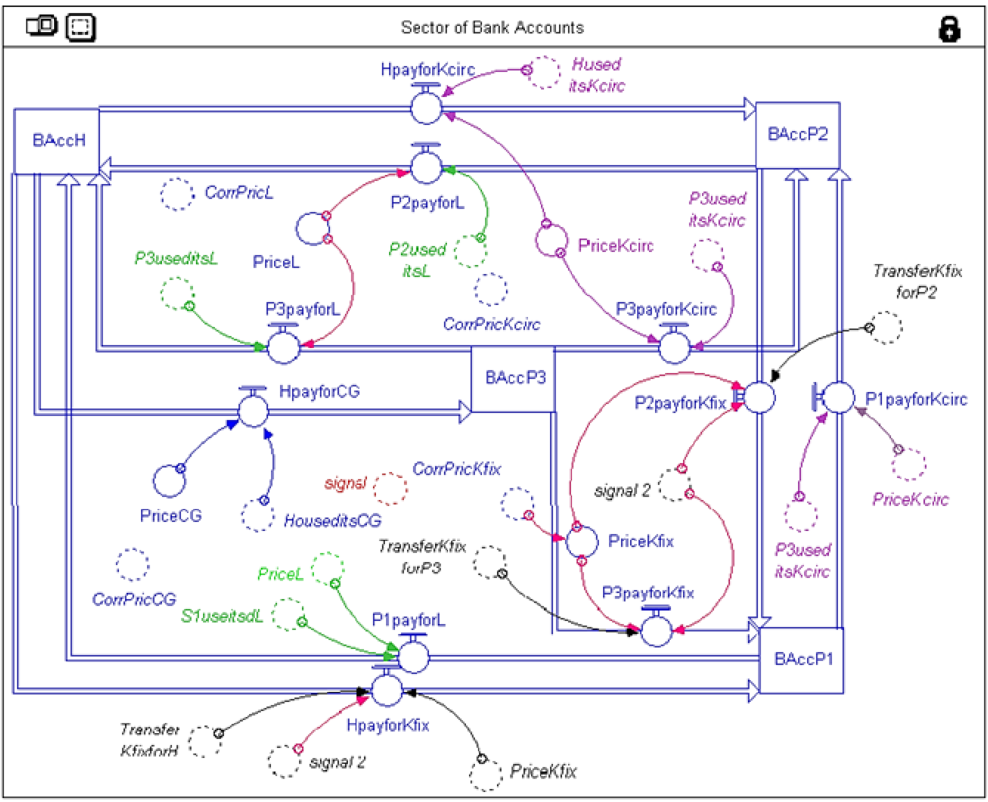

Fig.10.The snapshot of Bank accounts scheme created in STELLA.

Tab.5. The fillings of building boxes of sector of Bank accounts.

```
Sector of Bank Accounts
BAccH(t) = BAccH(t - dt) + (P3payforL + P2payforL + P1payforL - HpayforKcirc - HpayforCG -
HpayforKfix) * dt
INIT BAccH = 500
 INFLOWS:
   P3payforL = PriceL*P3useditsL
   P2payforL = PriceL*P2used_itsL
   P1payforL = PriceL*S1useitsdL
 OUTFLOWS:
   HpayforKcirc = PriceKcirc*Hused_itsKcirc
   HpayforCG = PriceCG*HouseditsCG
   HpayforKfix = PriceKfix*signal_2*Transfer_KfixforH
BAccP1(t) = BAccP1(t - dt) + (P3payforKfix + P2payforKfix + HpayforKfix - P1payforKcirc - P1payforL)
* dt
INIT BAccP1 = 500
 INFLOWS:
   P3payforKfix = PriceKfix*signal_2*TransferKfix_forP3
   P2payforKfix = PriceKfix*signal_2*TransferKfix_forP2
   HpayforKfix = PriceKfix*signal_2*Transfer_KfixforH
 OUTFLOWS:
   P1payforKcirc = PriceKcirc*P3used_itsKcirc
   P1payforL = PriceL*S1useitsdL
BAccP2(t) = BAccP2(t - dt) + (HpayforKcirc + P1payforKcirc + P3payforKcirc - P2payforL -
P2payforKfix) * dt
INIT BAccP2 = 500
 INFLOWS:
   HpayforKcirc = PriceKcirc*Hused_itsKcirc
   P1payforKcirc = PriceKcirc*P3used_itsKcirc
   P3payforKcirc = PriceKcirc*P3used_itsKcirc
 OUTFLOWS:
   P2payforL = PriceL*P2used_itsL
   P2payforKfix = PriceKfix*signal_2*TransferKfix_forP2
BAccP3(t) = BAccP3(t - dt) + (HpayforCG - P3payforKfix - P3payforL - P3payforKcirc) * dt
INIT BAccP3 = 500
 INFLOWS:
   HpayforCG = PriceCG*HouseditsCG
 OUTFLOWS:
   P3payforKfix = PriceKfix*signal_2*TransferKfix_forP3
   P3payforL = PriceL*P3useditsL
   P3payforKcirc = PriceKcirc*P3used_itsKcirc
PriceCG = 4.15
PriceKcirc = 1.04
PriceKfix = 49*CorrPricKfix
PriceL = 2
```

Tab.6. The fillings of building units of regulators.

```
Sector of  calculations for built in regulators
CorrDemCG = IF(TIME>0) THEN IF(P3QCG>14.14) THEN (SupplyKfix_3/P3Qnul) ELSE 1 ELSE 1
CorrDemKcirc = IF(TIME>0) THEN IF(P2QKcirc>40.01) THEN (SupplyKcirc)/P2Qnul ELSE 1 ELSE 1
CorrDemKfix = (SupplyKfix/P1Qnul)/1.2
CorrDemL = IF(TIME>0) THEN IF(HQL>40) THEN (SupplyL)/HQnul ELSE 1 ELSE 1
CorrPricCG = IF(TIME>0) THEN IF(P3QCG>10) THEN P3Qnul/SupplyKfix_3 ELSE 1 ELSE 1
CorrPricKcirc = IF(TIME>0) THEN IF(P2QKcirc>40.01) THEN P2Qnul/SupplyKcirc ELSE 1 ELSE 1
CorrPricKfix = (P1Qnul/SupplyKfix)*1.2
CorrPricL = IF(TIME>0) THEN IF(HQL>40) THEN HQnul/SupplyL ELSE 1 ELSE 1
HQnul = 38
P1Qnul = 14
P2Qnul = 38.01
P3Qnul = 13.14
SupplyKcirc = IF(RoomP2_supplyKcirc>0) THEN RoomP2_supplyKcirc ELSE 1
SupplyKfix = IF(RoomP1_supplyKfix>0) THEN RoomP1_supplyKfix ELSE 1
SupplyKfix_3 = IF(RoomP3_supplyCG>0) THEN RoomP3_supplyCG ELSE 1
SupplyL = IF(RoomH_supplyL>0) THEN RoomH_supplyL ELSE 1
```

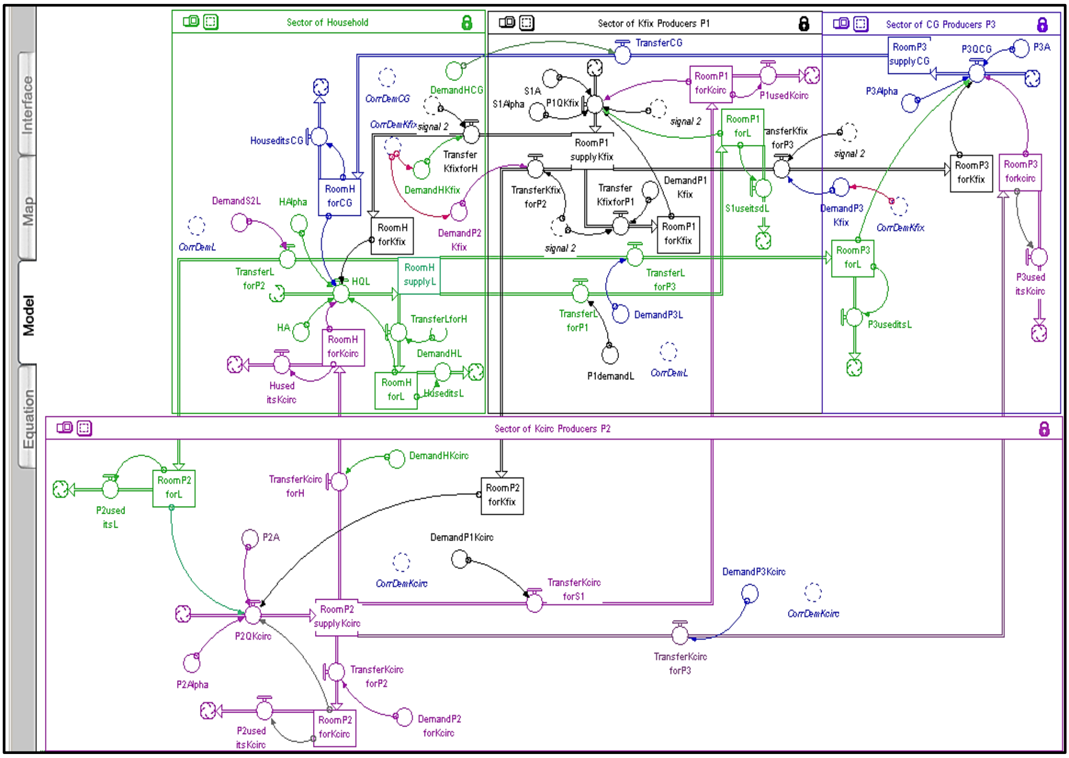

Fig.11. The snapshot of entirety scheme of Virtual Economy created in STELLA.

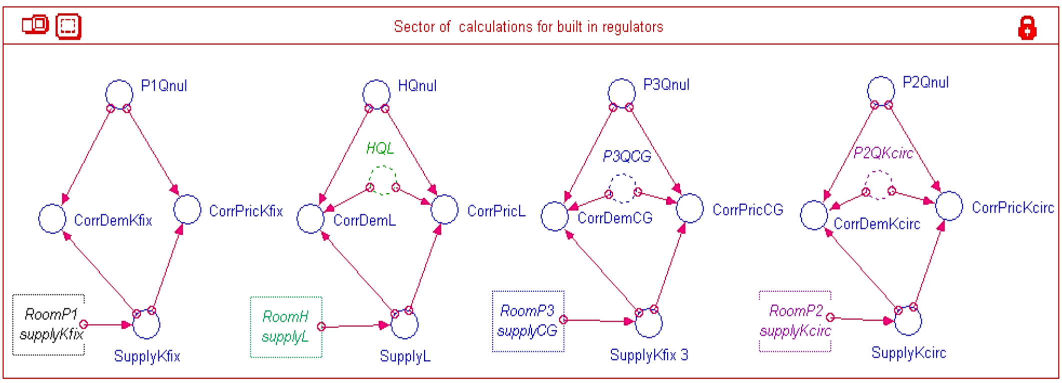

Fig.12. Sector of calculations from outside of model.

Conclusion

In this essay we are trying to focus attentions on imperfections in mainstream economics by the use for attestation of unconformity the objective reality example of economic growth. For those purposes we are using construction of virtual economy in environment of software STELLA in the form of complex economic network. Although we have choose relatively simple models for construction in STELLA, the simulation runs show clearly that the emergence of complexities in these constructed network don´t allow to describe economic growth with simple abstract formulas as it is in neoclassical theory. This is because economy is not a mechanical system similar to Newtonian mechanics not to thermodynamics due to R. Clausius, but complex in network evolving social organism. We are attempting to deeper permeate to spontaneous human construction of economies in objective realities using metaphors of virtual economies constructed in STELLA environment.

Our primeval endeavour was to remark on inconsistent approaches of mainstream economics to economies in objective realities based on immoderate simplifications, abstractions and to use not suitable mathematical formalism for such complex evolutionary social organism the economy essentially is. We are emphasizing that economies in objective reality are evolving not only as a whole but unforeseeable they are discretely changing theirs values and qualities of all participants in network. For the purpose of understanding these complexities in economies we are in traducing several not only verbal but first of all graphical informations. Mainly the graphical "language" is the newest mode of better understanding such complex phenomena as economy is. This unconventional approach is needed from concerned readers to have a great patience for "reading" scheme of STELLA networks and the snapshots from realised runs in computer.

Among other within the contexts between network metaphor and real economies the basic impulse and driving engine of economic growth in present global dimension is still the natural seminal instinct of Homo sapiens, formalized as a difference between birth rate and dead one for simplicity. However in matured societies where the birth and death rates are equal to null or are a little lower they govern on economic growth with scientific advances and technologic progress. We have included into STELLA virtual economy the event of positive population growth. For that reason the growth of labour forces L in the model is caused by two driving forces: the first one is natural seminal instinct (extensity) and the second one is the growth of consumed with them goods and services (intensity). We have not embedded into model all three usually used neutral technological progresses but only one of type of Hicks (a progress which raises the marginal productivity of labour and capital in the same proportion that is in our model called by symbols Ai). The random change of the value in random time instance of Ai is the only perturbation force in our STELLA models of virtual economy. On the overall conclusion we are need to emphasize that models presented in this essay are no more than a rough metaphor of economy in objective reality but they are a little nearer than pure neoclassical formulas ones.

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Authors

Prof. Ladislav Andrášik, DrSc. (DSc.), PhD., MSc.
Professor emeritus of Slovak University of Technology
ladislav.andrasik@gmail.com

The author is specialist in application of Information Technologies into antiaircraft missiles/guidance systems and scholar in introducing ICT/CI into theory and methodology of socio-economic sciences. He is graduated of different military schools and alumni of Economic University. Its brown jobs in Army persist 35 years (ten years he occupied roles in anti-aircraft brigade and 25 years in Military Academies an in General Staffs of Army). After he reached statutory retirement age in army he works in Academy of Science as chief scientific worker and as a department chief in Faculty of Electrical Engineering and Information Technology of Slovak University of Technology. He is author, editor and contributor of several monographs, textbooks for Military Academy and for Slovak University of Technology and for Economic University. He published more than 100 scientific essays, articles and papers for scientific conferences organized in several European countries.

DEVELOPMENT OF A DECISION SUPPORT SYSTEM IN PROJECT MANAGEMENT

Andrey Preobrazhenskiy, Emma Lvovich, Eugen Ružický, Artyom Lvovich

Abstract:

In a number of scientific works, the authors consider the problems of development of the various sectors of the industry and suggests methods of solution in the framework of the theory of managing projects and portfolios of projects. It should be noted that in the project management process many different solutions are adopted. All of these solutions can be divided into two groups. The first group is solutions that are associated with current issues and not related to the implementation of the project (for example, with the personal interests of staff of the project). The second group of decisions influences significantly the effective implementation of the project. These decisions are made by the head of projects, and they directly affect the achievement of the goals of the project. Moreover, the project manager has to make decisions constantly, at every phase of the life cycle of the project requires the adoption of certain managerial decisions. Decision-making is practically difficult because of the diversity and complexity which requires the consideration of the business processes of investment, production, financial, managerial, as well as numerous characteristics of external and internal market environment of a business project. It is incumbent on decision-makers to face complex problems, an effective solution of which is impossible without the use of a systematic approach. The paper identifies the levels in the system of support of decision-making. The analysis of the solution process of the activities of the project tasks is carried out to develop a conceptual model of information support of decision-making. The simulation system is for decision support and shows how information is stored in the internal database. The features of the architectural approach to implementing a decision support software product are demonstrated, as well as testing such a system is illustrated by examples. Using this information system provides the advantages as e.g. are receiving different types of messages quickly; increasing the speed of decision-making; rapid detection of trends using predictive methods.

Keywords:

Project management, reporting module, forecasting module, decision support.

ACM Computing Classification System:

Real-time system specification, interaction design, human computer interaction.

Introduction

Changing the managing style in the middle of a project cycle is a highly debatable topic. Most business enterprises consider it a risky process and therefore resist it. Change can mean a shift to agile management, but this is usually possible for smaller projects or partial subprojects (see [1]). One of the major problems of the modern enterprise is the problem of decision-making and its affect on project management, which is common because of the rapid life cycle of the project or change the composition of the participants. To solve this problem, you need a tool, which has in its functional mechanism the data collection and analysis as well as reporting and the conclusion of proposed solutions to address the current problems in the project [2].

The relevance of research due to the need to solve problems of increasing of project management quality, which is caused by the need for a visual representation of information on the problems of employees and obtaining the prediction of possible decision options.

The results of the analysis of the existing information system make it possible to support goal of decision-making in project management tasks so as to address the contradiction between the need to improve the quality of management of processes based on objective review and the lack of software products that enable this control to be effectively implemented [3].

Based on this improved project management it is possible through the introduction of a new tool that provides support for decision-making and project management solving quality problems evaluation of design decisions. For this purpose, as a tool, you can use the information decision support system for data collection, analysis, problem identification and forecasting of project management options in view of the possible alternatives.

The aim of this paper is the theoretical basis and practical implementation of information provision to support decision making in problems of project management to improve their quality.

1 Analysis of the Problems and Possible Solutions of the Problems in the Management Decision Support

Features of hardware and software are continuously improved, while their prices does not increase or increase only slightly. Corporations develop distributed systems that provide easy access to information held in various places and combining them with other information and control systems. In any corporate system, there are reports that are generated for controlling grass-roots level, mid-level and senior managers.

The decision is practically difficult because of the diversity and complexity of requiring registration of business processes - investment, industrial, financial, administrative, as well as the numerous characteristics of internal and external market environment of the business project.

It confronts decision-makers face (DMF) challenges, where an effective solution is impossible without the use of a systematic approach for the implementation of which in this case will be understood that the following tools:

1. the mathematical models that adequately reflect the content side of the business processes;
2. methods and algorithms for the analysis of these mathematical models that allow automated processing of information extracted from them;
3. software packages, numerically implementing the above methods and algorithms for analyzing and enabling DMF process and present this information in an automated mode.

Typically, large corporations have a separation of departments, which can be viewed as a set of projects, over each of which has a control - decision maker.

An increasing number of transactions within a company, however, the external transaction savings are obtained. Corporation has a wide range of possibilities to work with projects and tasks, so delegating one of the elements forming the organizational management structures. It is necessary to find an acceptable balance of centralization and decentralization, depending on factors such as the size of the organization, production technology, and the external environment. The decision process at the lowest levels must complement high control system and being part of the daily decision-making processes. Every project has its own level of difficulty. This complexity is made up of a variety of factors such as: a goal that will be of value to the business, completed with certain specifications; specific start date and end date; to have a certain limit of financing; to have a certain human and non-human resources.

If the project manager has many different resources available, then it is necessary to decide whether for some individual resources only the senior official will decide. The control system, on the basis of information about the state of information coming from the external environment, determines the target decision object and generates a directive activity acting for the management team.

The necessary information of process control is recorded, transmitted, stored, accumulated and processed. The complex of these procedures is an information management process. Project management systems are toolboxes, methodologies, techniques and resources used in the control process, include means for scheduling tasks, scheduling, budget management, resource allocation, documenting, reporting, collaboration performers.

These circumstances forced to use the currently available advanced software and hardware. Widespread and effective use of these funds was one of the factors of survival and success of the enterprise in the conditions of intense competition. In recent years, this widespread automated information system has often been referred to as an information system that cannot be imagined without automation [4].

Usually, these are corporate information systems (Enterprise Resource Planning, ERP). For discrete manufacturing it is an important aspect, which has a significant impact on the planning model inherent in the system, as a serial production and available for stock management. The current trend in almost all industries is characterized by the gradual expansion of the range of products and the reduction of seriality. From a planning perspective this feature complicates the task and increases the initial data sets, both in number and nomenclature. However, the implementation of corporate information systems is a complex process, due to the fact that the management of the enterprise is not a process of collecting and analyzing data for decision-making on project objectives and emerging issues. Therefore, into an existing system it can be integrated a decision support system (DSS). This will improve the speed of data processing and analysis, as well as to identify ways of decisions and their impact on the project. Decision support system can be divided into several levels.

1. **User level.**
   1.1. Passive decision support system - a system that helps the decision-making process, but can not make a proposal, what decision to take.
   1.2. The active system - can make an offer which solution to choose.
   1.3. Cooperative system - allows the decision-maker, modify, add or improve the solutions offered by the system, then sending these changes to the system to check. System changes, adds or enhances these solutions, and sends them back to the user. The process continues until an agreed solution is found.

2. **The conceptual level.**
   2.1. Control posts support a group of users working on a common goal.
   2.2. Control data oriented to access and manipulate data.
   2.3. Control documents are searched to manipulate unstructured information defined in different formats.
   2.4. Control of knowledge to provide a solution to problems in the form of facts, rules and procedures at divided data levels.
   2.4.1 Operational decision support system designed to respond immediately to changes in the current situation in the management of financial and economic processes of the company.
   2.4.2 Strategic systems are focused on the analysis of significant amounts of various information collected from various sources.
   2.5. Control models are based on mathematical models. For their construction, you can use OLAP-systems that make the complex data analysis, and then a system of decision support can be attributed to hybrid systems that provide modeling, search and processing.

There are three main problems in decision support systems: data entry, data storage and data analysis. Similarly, the system does not make the right decision just to give an idea of the possible solutions and their consequences. The main characteristics of decision support systems are these:

1. DSS is flexible, adaptable and quick reaction,
2. DSS is designed so that the user can control the input and output data,
3. DSS from the user does not require special knowledge and specific skills,
4. DSS applies modeling tools and complicated analysis,
5. DSS includes user-friendly software,
6. DSS is interactive, that is subject to change and include the new data.

We can confidently say, that with proper project management of resources it is achieved maximal efficiency. In many ways, human re-sources are exactly what the decision-maker has to work with [5].

Proper allocation of the project tasks to participants is a difficult task, in which there is necessary to make data collection and analysis, and further to develop of the project development strategy and finally to make a decision. Particular attention is required in the initial stages of the project - the initiation and planning of resources.

2 Analysing the Process Solutions Activities of Project Tasks

The existing process of the design is targeted to the following features. Firstly, every interaction with the search engine of a specific project or person is complicated due to lack of a common list of activities. And secondly, to search for and collect all the necessary information the user should own search engine API, which is described by the similarity of SQL queries. Third, a comparison of the activities is possible only through autographic collection of all the materials and a subsequent analysis of materials at hand.

Thus, the user has to make calculations on the possible increase in the pace of work on activities. The first feature of the system is an important issue in the event of critical situations within the company, where the response time can be the most critical factor that allows to solve the situation in a positive or negative direction. In solving such problems, the user will be easier to see possible solutions to problems and ways of preventing them in the future, rather than the use of other internal resources and combining them through the tools available. Thus, the development of the interaction element, taking into account the preservation and display activities is a prerequisite for the information system decision support.

Each time the user is required to perform these operations to obtain relevant information, for editing and shaping of the result set. The use of two external systems, as well as two software products complicates the logic operations and thus there are risks of errors that will affect the final result of the decision [6].

When optimizing this process, we get a lot of time and does not take advantage of any user of the machine resources in view of the fact that all the work is done on the side of the information system.

The second feature of forcing the user to learn the basics of SQL queries, when to obtain information from an external system, is leading to loss of time or to need professionals who could write a valid request. This point is related to a feature of the external system, which focuses more on the technical specialists, however, to find any information to non-technical user it performs only a minimal functionality, where most of the work has to be done manually.

3 Development of a Conceptual Model of Information Support of Decision-Making Support

The conceptual model of the information system is created on the basis of characteristic features of the solution design for IS users. The model describes the full range of all the tasks necessary to address the issues associated with the project activity.

The conceptual model includes the following tasks and functions: reports on the construction projects and the projected scenarios under a specific set of input parameters; a creation of a virtual project with the existing resources; configuration of the virtual project and help in decision-making resource changes; building the assessments and identification of specific resources and capabilities; support for redistribution to the most appropriate position, taking into account the future growth of activities and a possible increase in the progress of a particular human resource.

It should be also taken into account the possibility of an authorization in view of the fact that the project objectives are not open data and the information is accessible to users with accounts that have customized lists (see activities).

This integration with external systems makes possible in the future to set up working more closely with all external resources. And for this it will be necessary to develop an external API, which allows other systems to integrate this solution to fit the needs. In general, the model of decision support system is shown in (Fig.1) - The support system for decision-making model. (Fig.2) shows a conceptual model of information system (data flow).

System model is built from components that will continue to be joined together:

1. the user interaction component for input parameters;
2. the logic component describing basic functions and tasks of the system;
3. the reaction of the component with the data store.

Logic component contains the following components and it is implemented in the server portion of the application:

1. the module working with projects;
2. the reporting module;
3. the prediction unit.

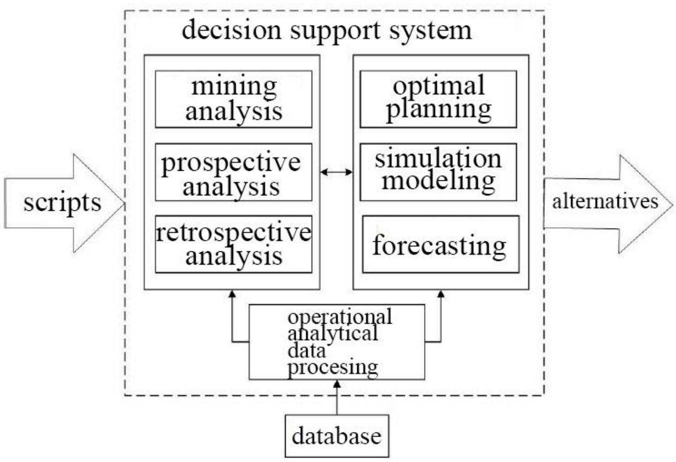

Fig.1. The support system for decision-making model.

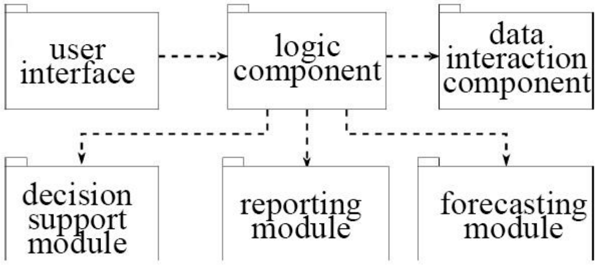

Fig.2. Data flow for conceptional model.

For reception of the input parameters and to display information to the user using a web interface (see Fig.2), these components of this update will not affect the other parts of the next information model. The component includes a visualization of all the parameters describing problems and provides system interoperability through a standard set of web components.

4 Support System Modeling of Decision

After logging the user can select the system module to obtain the necessary information. Realization of movement between subsystems is routed to the user interface level. The major transitions of the main page are: prediction unit; support decision module; reporting module.

Finding the optimal design, it is based on the history of completed tasks, and comparing them with the project objectives. Search optimization problems also use already existing statistics to identify strengths and weaknesses, which will point to the possibility of working with a particular type of task to choose the candidate as resource. The user may refer to the records system for references and records of the company's existing activities. This will avoid the occurrence of any error in the system and make the job even easier. Reports are available to the following entities in the system: companies; staff projects. Reports can be shared or have their own specifics. Prediction of the system is based on a survey method using extrapolation.

This extrapolation method uses the principle in which the predicted level taken as equal to the mean value of a number of levels in the past. The result of using this method is the point estimate that is suitable for the task because it is more effectively used for short-term forecasting.

5 Storing Information in an Internal Database

The current model of information support means to make a local storage for quick access. Such a decision is based on the fact that the local information will have a consistent look, thereby reducing the time of issuance of system output to the user. Updating and addition of data will be carried out at the user's request for a specific activity. If the data has been updated in external systems, it will be made with data synchronization with the local copy. For data storage, it is used an object-oriented database.

The main entities that are present in the system are: the staff; project; task; a comment. Using the Object storage allows you to avoid the decomposition of objects and attributes in reverse action.

This is a common approach for decision-making system, to be used for modeling situations, given that the objects are displayed in diagrams and their actions are better understood by man as object attributes.

It is also an object-oriented approach allows us to use all of features and programming approaches which is used to support decision-making: it contains aggregated and atomic data. It occurs combining data from a plurality of external resources.

Internal database comprises current and historical data: users can not change the data (minimal storage costs). Loading data in the storage occurs with a certain frequency (combining data from a plurality of external resources).

6 The Architectural Approach to the Implementation of a Software Product

Based on the identified requirements, the client-server architecture should be used to implemented solutions for decision support. This approach will allow the system to decompose entity, thereby guaranteeing the simplest design and support of the individual components. The decision support system is implemented in the form of an information system. Following (Fig.3) shows a model of a software product: Support system of decision-making.

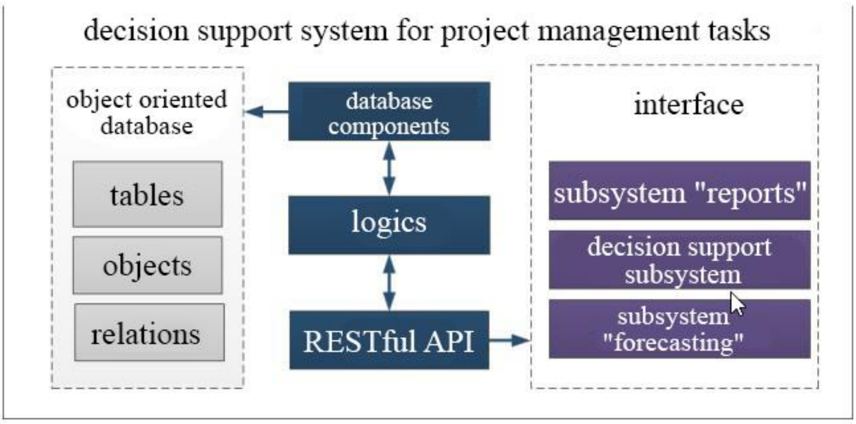

Fig.3. Model of support system of decision-making.

Following the architecture, implementation should be divided into two main parts, the first of which is responsible for interaction with the user, and the second one implements the logic of business processes and the interaction with the data. The user interface has a four individual modules that allow correctly generate a re-quest for the server side.

Business logic and data management are in close interaction with each other and work on one environment. Business logic responds to all requests of the user, a direct request to read data is not present, all is regulated within the business processes. Data Management includes, in addition to work with the already loaded data, the work with remote application servers to swap data in an internal database. The results will be used to model a proposed system that simulates a simple artificial intelligence system to support project decision-making.

Next (Fig.4) shows the user interface components. This set of components allows users to effectively use the software to solve business problems and automate processes that were previously handled manually.

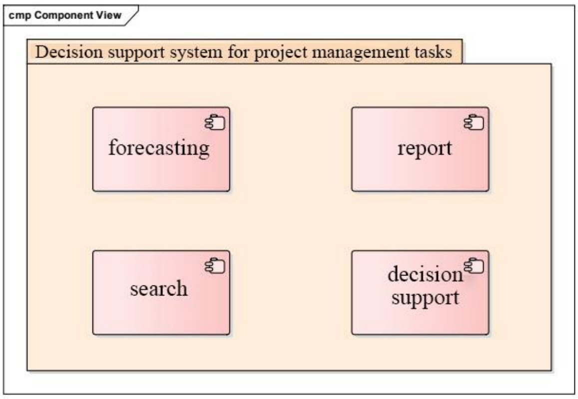

Fig.4. User Interface Components.

7 Implementation of an Information System to Support Decision Making

To implement the tool, following technologies were used: Java Spring Boot; Angular 2. To implement the server-side framework it was used an open Java Spring Boot, which implements REST API architecture interaction with the user of the application. Also, the server part is responsible for interaction with the database. However, implementation has not any graphical user interface and operates autonomously via downloaded and installed assembled packet to the application server.

In this case, we used Apache Tomcat. The implementation of the user interface used by Angular 2. The platform is built on the JavaScript language and has its own Typescript language and a compiler that converts all code written in JavaScript. Typescript provides greater flexibility in writing code and its support because every web page can work with an object. Thereby maintaining the integrity of data stored on the server side, since no permanent serialization and de-serialization of objects is transferred.

8 The Results of Some Product Data

Once the software has been implemented, the system was filled with sham-generated data to provide complete testing. Testing was started with the reporting module. Tables show a scenario was used to test the performance of the module. Following (Tab.1) shows Generation of scenario employee report and (Tab.2) shows a scenario of generating a draft report.

Table 1. Generating script employee report.

Number 1	**Create employee report**
Characters	User system
The initial state	The user is on a Report Page
The final state	System generated reports about the employee
Scenario	1. The user selects the type of report; 2. The system displays the field attributes for the detail of the staff report; 3. The user fills in the attributes and presses the button «Start»; 4. The system generates and displays a report in the next step.
Error messages, warnings	All fields must be filled.

Table 2. Generation of scenario projects report.

Number 1	Create project report
Characters	User system
The initial state	The user is on a Report Page
The final state	System generated reports about the project
Scenario	1. The user selects the type of report; 2. The system displays the field attributes for detail project report; 3. The user fills in the attributes and presses the button «Start»; 4. The system generates and displays a report in the next step.
Error messages, warnings	All fields must be filled.

Prioritization of tasks in a set can be a system, however, in the test data, we have the following set:

- Blocker: High importance of the tasks they affect the operation of the customer as a whole;
- Critical: Critical challenges that impede the customer, but not blocking his work as a whole;
- Major: Medium priority tasks, the problem which arises from the customer several times per week;
- Normal: the lowest priority.

Further testing was performed according to the scenario forecasting module displayed in (Tab.3).

Table 3.- Creation script on the employee prognosis.

Number 1	Creating a prediction about the employee
Characters	User system
The initial state	The user is on the prediction page
The final state	The system has generated a forecast about the employee
Scenario	1. The user selects the type of prediction; 2. The system displays the field attributes for detailed forecasting of staff; 3. The user fills in the attributes and presses the button «Next»; 4. The system generates and displays a prediction in the next step.
Error messages, warnings	All fields must be filled.

The system analyzes the existing problem and the employees in a list of projects with a similar set of challenges. Searching for the best candidate for the job based on the task of applicants using trend generated by the prediction unit. The module also includes employees who are represented in the system only for a certain period of time and will be able to become as mentors for newcomers.

The obtained results of testing modules very accurately show the performance of the developed solutions and meet the requirements of the final product.

Conclusion

The proposed method analyzes and introduces a new way to support project management based on previously examined the issue of information systems ERP large enterprises. The proposed new module of decision support in project management allows to increase the quality of project and this decision support is a promising direction in project management.

Literature analyses show that the implementation of decision-making in the management of projects by the decision maker poorly uses information technology. The analysis identified the main processes in which decision support is needed, as well as their positive impact on the final decision making a more accurate estimate of the project solution.

We developed a model information system based on the allocated requirements and algorithms. A software solution to support decision-making in project management problems was implemented.

Testing of the support system developed by these results proved that the use of decision support system leads to improvement of quality indicators of decision-making.

Using this information system provides the following advantages:

1. increasing the speed of decision-making;
2. receiving different types of messages quickly;
3. possibility to work remotely;
4. automated interaction with external systems for timely updating of information in the local database;
5. rapid detection of trends using predictive methods.

Therefore, establishing a company with a large number of employees and a large number of tasks, supporting the decision-making of the information system in project management problems is effective and appropriate.

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Authors

Prof. Andrey Preobrazhenskiy
Doctor of Sciences (Engineering), associate professor,
Voronezh Institute of High Technologies
app@vivtl.ru

Ass. Prof. Emma Lvovich, PhD.
Candidate of Sciences, associate professor
Voronezh Institute of High Technologies, Russia
office@vivt.ru

Assoc. Prof. Eugen Ružický, PhD.
Faculty of Informatics, Pan-European University, Bratislava, Slovakia
eugen.ruzicky@paneurouni.com

Artyom Lvovich
Student
Comenius University in Bratislava, Slovakia
artemlv2000@mail.ru

DETECTING AWARENESS STATE OF A DRIVER DURING DRIVING

Zuzana Képešiová, Ján Cigánek, Štefan Kozák

Abstract:

The presented paper deals with automatic detection of driver drowsiness. Detecting the driver's drowsiness behind the steering wheel and then alerting him may reduce road accidents. Drowsiness in this case is captured using a car camera, whereby, based on the captured image, the neural network recognizes whether the driver is awake or tired. The convolutional neural network (CNN) technology has been used as a component of a neural network, where each frame is evaluated separately and the average of the last 20 frames is evaluated, which corresponds to approximately one second in the training and test dataset. First, we analyze methods of image segmentation, and develop a model based on convolutional neural networks. Using an annotated dataset of more than 2000 image slices we train and test the segmentation network to extract the driver emotional status from the images.

Keywords:

Image segmentation, artificial neural networks, convolutional neural networks, Python, deep learning.

ACM Computing Classification System:

Computer vision, machine learning, artificial intelligence, neural networks.

Introduction

Over the past ten years there has been an unprecedented development of digital information, communication and intelligent technologies that affects the quality and lifestyle at our planet in a revolutionary way. World-wide innovation trends in complex embedded computerization and digitization processes in smart cars are now leading to the need for research, development and implementation of new system solutions and changes, introduction of new intelligent methods for diagnosing critical processes in modern cars and in many other areas.

The degree of up-to-date use of soft computing methods in modern car architectures is very high, as it is a dominant and indispensable part of modern smart car production. Smart car architecture and intelligent platforms represents the realization and naming of large-scale changes in the automotive industry. These changes include, in particular, digitization, automation and ICT integration at all levels process of the car control and diagnosis.

The proposed paper is based on the development of effective soft computing methods using convolution neural networks and deep-learning techniques to solve the problem of monitoring, detecting and modelling critical situations and emotional stress of a smart car driver. Fast detection and monitoring of the selected car parameters the attentive and emotional status of the driver are critical for safety and comfort of driving.

Face recognition as a typical biometric identification technology is recognized as an essential technology to establish secure control in many areas. Face recognition has attracted much attention from researchers and engineers over the past decades owing to its wide range of applications in many fields including information security, identity authentication, law enforcement, smart cards, access control systems and so forth. The entire face recognition procedure consists primarily of two operations: feature extraction and classifier design. These two steps have a substantial influence on effectiveness and reliability of various recognition approaches.

The paper is organized as follows. Section 2 introduces a deep lerning methods for classification. Section 3 shows case study results.

1 Deep-Learning Methods

The methodology of the presented paper corresponds to the latest global trends in research and development of advanced soft computing methods based on machine and deep-learning methods for classification, pattern and image recognition with possible use in the various fields (robotics, smart cars, health processes, biotechnology, etc.).

Deep learning is making major advances in solving problems that have resisted the best attempts of the artificial intelligence community for many years. Deep-learning methods are representation-learning methods with multiple levels of representation obtained by composing simple but non-linear modules that each transforms the representation at one level (starting with the raw input) into a representation at a higher, slightly more abstract level. With the composition of enough such transformations, very complex functions for large-scale applications can be learned.

A. Artificial Neural Networks (ANNs)

ANNs are widely used not only for segmentation, but also for preprocessing, compression, feature extraction, enhancement, reconstruction or restoration of images.

As with biological neural networks, the basic ANN calculation unit is the neuron (Fig.1). Each neuron has one or more inputs (called dendrites) and just one output (an axon). Axon is linked by synaptic connections to dendrites of other neurons. The power of these synaptic connections is referred as weight w and is changed during training. In the basic model, dendrite carries a signal to the body of the neuron, where signals from all dendrites add to each other with the addition of bias b. This sum is the input of the activation function f of the neuron; a common activation function is sigmoid function:

$$\sigma(x) = \frac{1}{1+e^{-x}} \tag{1}$$

or ReLU, out = *max(0, in)*. The result of the activation function goes to the output of the neuron, the axon.

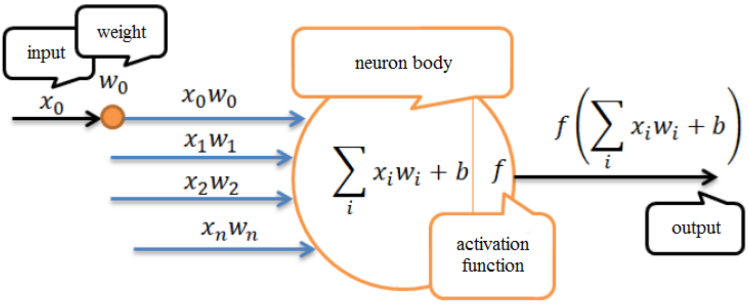

Fig.1. Artificial neuron.

Generally, the ANN consists of neurons grouped in three basic layers: input, hidden and output layer, with a different number of neurons. Principally, it is not allowed to connect neurons from the same layer, only from different ones (Fig.2) [1].

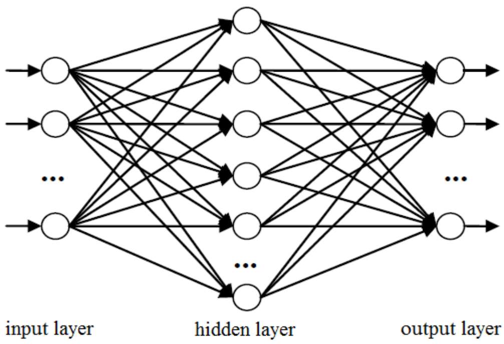

Fig.2. Artificial neural network scheme with 3 basic layers.

One type of ANNs is also forward neural networks. They comprise a plurality of layered neurons such that each neuron of the preceding layer is connected with each neuron of the next layer. The first layer of neurons is called the input layer (there are no calculations in the input layer), the last one is output layer and the layers between them are called hidden layers. The Single Layer Perceptron is a forward neural network without a hidden layer, and the Multi-Layer Perceptron (MLP) contains at least one hidden layer.

For MLP training we need data with assigned values of required outputs for a given sample of inputs. MLP is trained using a back-propagation algorithm in iterations. In each iteration, weights are adjusted using new training data. In this way they pass through all the layers up to the output layer. Subsequently, the MLP result is compared with the desired result from the training data.

A large neural network may take a lot of time to train and therefore a technique called dropout may be used. This method is used to reduce the size of neural network and to speed up the learning process of the algorithm. The idea of dropout is based on dropping out units, in this case neurons, in a neural network. These units are chosen randomly with a probability of q=1-p. If the unit is chosen to be dropped out, then all incoming and outcoming connections are discarded. Randomly discarded neurons guarantee each neuron to learn something useful on its own instead of being dependent on other neurons [3].

With consideration of a neural network of a size of L layers, where index of neural network layer l is $l \in \{0, \cdots, L-1\}$, $l = 0$ is an input layer and $l = L - 1$ is output layer. Input and output vectors in hidden layers are computed according to relation:

$$x^{(l+1)} = W^{(l+1)} y^{(l)} + b^{(l+1)} \tag{2}$$

$$y^{(l+1)} = a(x^{(l+1)}) \tag{3}$$

where $x^{(l)}$ refers to input vector of layer l, $W^{(l)}$ is weight parameter, $y^{(l)}$ refers to output layer vector to layer l, $b^{(l)}$ is bias parameter at layer l and $a(x^{(l)})$ is an activation function. Previous equations (2) and (3) change to:

$$\delta_i^{(l)} \sim Bernoulli(p) \tag{4}$$

$$\bar{y}^{(l)} = \delta^{(l)} \otimes y^{(l)} \tag{5}$$

$$x^{(l+1)} = W^{(l+1)} \bar{y}^{(l)} + b^{(l+1)} \tag{6}$$

$$y^{(l+1)} = a(x^{(l+1)}) \tag{7}$$

by applying *dropout*, where $\otimes$ is element by element multiplication, $\delta_i^{(l)}$ is a Bernoulli random value of neuron i at layer l [3].

B. Convolutional Neural Networks (CNNs)

CNNs are a type of ANNs, but they are modified to be more efficient in processing images as inputs. They use four operations: convolution, pooling, ReLU and MLP as their basic building unit. Each of these operations has a 3D image for both input and output.

Each image can be represented as a matrix of pixel values. 3D image consists of width, height and depth. The depth in this case is the number of channels. For example, a standard color image consists of three channels - red, green and blue. MRI or CT medical images are a black and white images that have only one channel.

The role of **convolution** in CNNs is to select the main properties from the input image. The convolution preserves the relationships of individual pixels in space to learn these properties from smaller squares of the image. It contains several learning filters to process the image. These filters (called kernels) have a small size (e.g. 5 pixels in width and height, and several pixels in depth). When processing an image, the filters move across its entire width and height. For example, if the image is 5x5 pixels in grayscale and the filter is a matrix of 3x3x1 elements, then the convolution results in a 3x3 matrix, as the 3x3x1 matrix can be shifted 3 times in width and 3 times in height. The convolution output matrix (called an activation map, a property map or a tensor) is the result of matrices multiplication (image and filter) by elements on all channels. (Fig.3) shows an example of convolution with a 3x3 size filter, with one input and one output channel.

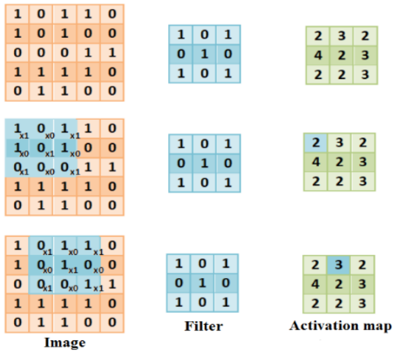

Fig.3. Convolution with a 3x3 size filter, with 1 input and 1 output channel.

The size of the convolution property map is affected by three parameters: depth, filter step, and zeros. Depending on the number of filters used in the convolution, the depth (number of channels) of the output increases. The filter step tells how many pixels the filter is to be shifted by the next matrices multiplication. Sometimes the image is supplemented with zeros to the edge so that the resulting property map has the same width and height as the original image.

The transposed convolution, or deconvolution, has the same operations as the convolution, but in the opposite direction. This means that instead of diminishing the image dimension, it expands the image. It is used to adjust the image to its original size, after convolution, so that CNN input has the same dimensions as the output (i.e., the indicated output pixels correspond to the same input pixels).

The 3x3 filter convolution, with one input and one output channel, can also be represented in a different way than in (Fig.3). First, the filter (3x3 from the previous example) becomes a convolution matrix (9x25), where each line represents a convolution operation with other window position. The input image values are stored in a column vector. Subsequently, the value of the activation map is calculated as a multiplication of the filter and image matrices. In this case, the output is a column vector whose values represent the activation map. The whole process is shown in (Fig.4).

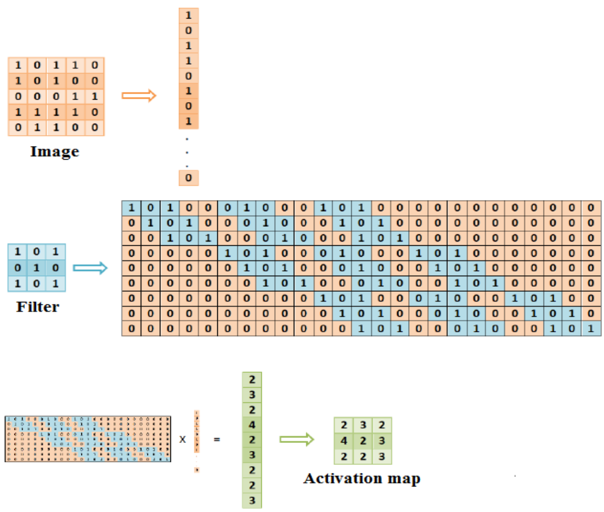

Fig.4. Convolution shown by matrix multiplication.

The transposed convolution uses the transposed convolution matrix (25x9), otherwise the procedure is the same. The transposed convolution matrix is multiplied with the input image converted into a column vector. The result is an activation map (5x5). The transposed convolution process is shown in (Fig.5). The output of the transposed convolution, using the same filter as in the previous example, is different from the initial image used at the beginning in (Fig.4).

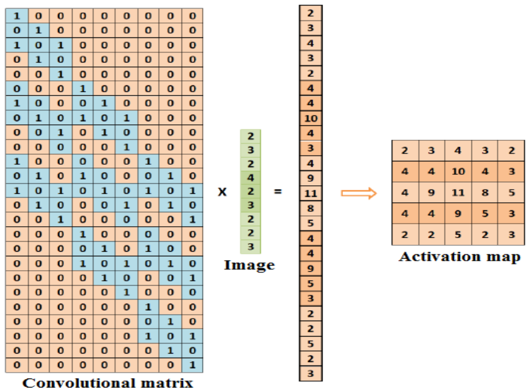

Fig.5. Transposed convolution with a 3x3 size filter.

ReLU is a nonlinear operation. The output value is calculated according to function out = max (0, in), where in is the input and max is a function that returns the maximum value of two or more elements. ReLU is an operation by elements (applied in pixels). If ReLU input is a negative number, then the output is zero, otherwise the input remains unchanged. Its role is to bring nonlinearity to the convolutional network. In contrast to sigmoid functions, ReLU has the advantage of suppressing the problem of vanishing gradients [2].

Pooling reduces the dimension of activation maps while keeping a clear signal throughput. There are several types of pooling: maximum, average, sum and others. In the case of maximum pooling (Max Pooling), the window size is first defined, the window is scrolled through the image as a filter in convolution, with the difference that the next window does not overlap with any previous one and the output from the window is the largest element. In the case of average pooling, the output is the average of all window elements. (Fig.6) shows an example of Max Pooling with a 2x2 window size.

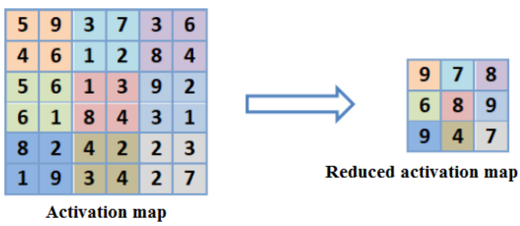

Fig.6. Max Pooling with a 2x2 window size.

After using several convolutions and poolings, the image is processed by MLP. The role of MLP is to use image properties obtained from previous operations to divide CNN inputs into multiple classes (segments).

As well as ANNs, CNNs also consist of layers (convolutional, pooling, ReLU and MLP). Most often, when creating a CNN, several convolutional and pooling layers are stacked. This pattern is repeated until the input image is divided into small pieces. There may also be parallel branches between the layers. Finally, the MLP layer follows.

It is good to know that the only difference between MLP and convolution layer is that neurons in convolution layer are connected only with the local part of the input image. But the neurons in both networks calculate the output in the same way, so it is possible to convert MLP to a convolution layer and vice versa.

2 Case Study

The aim of this study is to successfully detect driver drowsiness based on fascial expression recorder by car camera.

A. Hardware Characteristics and Software Environments

As it comes to hardware, a laptop consisting of Intel® Core™ i5-7200U 2.50GHz – 2.71GHz Processor and 8GB GeForce 940MX RAM was used for making computations.

As a software environment PyCharm development environment was used. PyCharm is one of software applications from JetBrains company used for developing python scripts and applications. One of these applications is also neural networks and machine learning area. As a help for a developer, many frameworks were created for making scripting faster and easier. Tensorflow and Keras, were used in this project.

TensorFlow is an end-to-end open source platform for machine learning. It has a comprehensive, flexible ecosystem of tools, libraries and community resources that lets researchers push the state-of-the-art in ML and developers easily build and deploy ML powered applications. [4]

Keras is a high-level neural networks API, written in Python and capable of running on top of TensorFlow, CNTK, or Theano. It was developed with a focus on enabling fast experimentation [5].

B. Dataset and Data Processing

Collected data consists of 20 different subjects. Each subject has 8 different behavioral patterns recorded on approximately 5 seconds long image sequence. These behavioral patterns are divided to two different states:

- **Aware (0)** – High concentration (1), looking around (2), happiness (3), usual face expression (4)
- **Sleepy (1)** – Slow eyelid movement (5), yawning (6), falling head (7), lethargy (8)

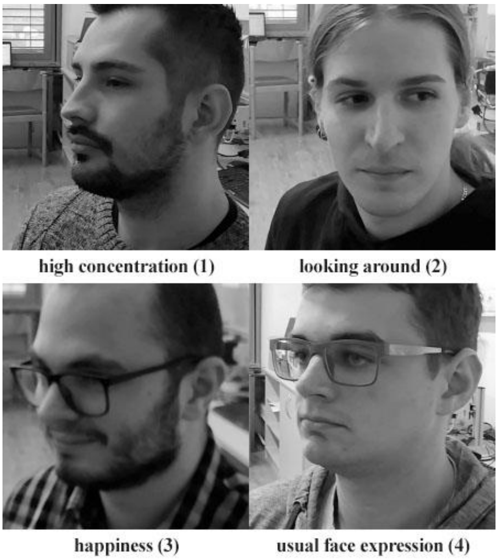

Fig.7. Example of dataset frames expressing states of awareness –
high concentration, looking around, happiness, usual face expression.

Fig.8. Example of dataset frames expressing states of sleepiness –
slow eyelid movement, yawning, falling head, lethargy.

Each video consists of one of these behavioral patterns in rate 28.16 frames per second. Each frame has dimensions of 1920 pixels wide and 1080 pixels high. Videos are recorder as color videos; therefore, they are referred as RGB videos. Each video was cut frame by frame and every fifth frame was taken to an image dataset, that created dataset of size 5258 frames divided into two categories: sleepy, that consists of 2619 frames and aware, that consists of 2639 frames.

Fig.9. Unpreprocessed video frame.

As we can see on (Fig.9), a camera is capturing a lot of junk data, that are telling us nothing about driver’s state. Therefore, image preprocessing in inevitable. At first, color of frame is not needed, and a frame was converted from RGB color spectrum to greyscale. After obtaining greyscale version of a frame, the face area is cut out and picture’s dimensions are changed to 224px per 224px. After obtaining small image cut from the frame, the image is also flipped horizontally.

Fig.10. Preprocessed video frame.

After collecting and preprocessing data, a model design follows.

C. Developed Model

Convolutional neural networks take a lot of computational power and a great amount of time to train, especially deeper these networks are. The idea of convolutional neural networks is not new, and many models were already created. There are models such as DenseNet [6], ResNet [7], Iception [8], VGG [9] any many others. These models also offer pretrained weights available online as part of Keras framework or as h5py file containing the model [10]. In first stages DenseNet and ResNet were tried out, but without much of success and therefore were not selected. For these problematics a model VGG Face was chosen, since it was trained on human faces, a dataset like dataset of this project. VGG Face is a CNN divided into 11 blocks, were 8 blocks are convolutional blocks, where each block containers one or more convolution layers followed by ReLu activation layer and/or max pooling layer. A structure of VGG Face is available on (Fig.11).

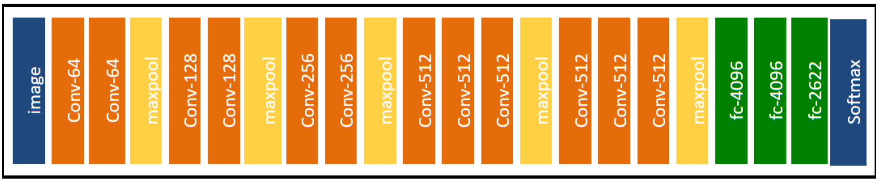

Fig.11. VGG Face structure [9].

VGG Face was trained over 2.6 million of visual inputs and can categorize them into 2622 different categories. A required input is an 224x244 big image in RGB channel. Our data are in greyscale channel, since the color doesn't matter in this case, therefore data were converted to RGB channel but visually remain as greyscale, what makes them more universal and not color dependent.

The final model uses pretrained VGG Face as a base, but to fit our needs, the last layer of VGG Face is removed and on top of that a small head model is added. This head model consists of fully connected layers, followed by batch normalization, tanh activation function and dropout.

D. Model Training, Testing and Results

Developed model was trained with custom dataset divided into batches sized of 32 during 50 epochs long process and with nadam optimizer and categorical crossentrophy loss function. VGG Face layers were not retrained, but frost and a head model was tuned only. The whole training process on mentioned hardware took about 15 hours of training, while the results of the model were 90.77% training data accuracy, 98.02% validation data accuracy.

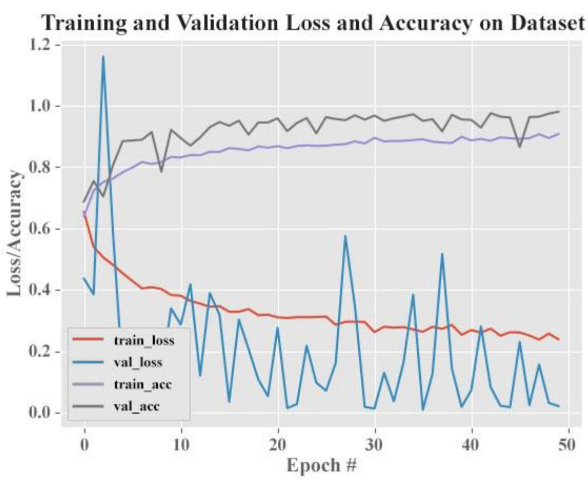

Fig.12. Training and validation loss and accuracy on dataset.

Despite good results, when the model is tested on a completely new person, that was not included in dataset, a neural network struggles to identify drowsiness in a person's fascial expression and suggesting a person is aware most of the time. Efficient gesture that is recognized in other people is slight head falling. On the other hand, all the videos of captured subjects, even ones recorded later, were recognized successfully.

Conclusion

We decided to create an application that could help drivers with detecting their mental state of drowsiness and we achieved to create a model, that works almost perfectly for separate frames and for sequence of 14 frames, what displays a 0.5s sequence, without fail. For every new person a network must be retrained to obtain satisfactory results for the subject. As the dataset consists of only 20 different subjects, there is a high probability of improvement of the algorithm by achieving dataset wider in its variety.

Outputs from the created model can then be used for sound, respectively. Light signaling to ensure reliable driving of the vehicle. Ensuring reliable vehicle operation is critical in the case of health problems such as cerebral defeat or heart attack. The proposed model approach of sensing and recognizing changes in the face of the car driver will reliably predict the occurrence of a dangerous situation.

Acknowledgement

This paper was supported by the Slovak Grant Agencies VEGA 1/0819/17, KEGA 030STU-4/2017, and by the Scientific Grants APVV-17-0190, SEMOD-79-2/2019 and Semod-80-7/2019.

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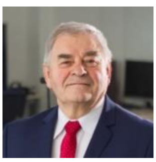
Authors

Ing. Zuzana Képešiová
Faculty of Electrical Engineering and Information Technology,
Slovak University of Technology in Bratislava, Slovakia
zuzana.kepesiova@stuba.sk

Currently a student of doctoral studies at Slovak University of Technology in Bratislava. The main focus of her studies is oriented to development of a remote laboratory to monitor and control of mechatronic systems using digital twin and mixed reality.

Ing. Ján Cigánek, PhD.
Faculty of Electrical Engineering and Information Technology,
Slovak University of Technology in Bratislava, Slovakia
jan.ciganek@stuba.sk

He was born in 1981 in Malacky, Slovakia. He received the diploma and PhD. degree in Automatic Control from the Faculty of Electrical Engineering and Information Technology, Slovak University of Technology (FEI STU) in Bratislava, in 2005 and 2010, respectively. He is now Assistant Professor at Institute of Automotive Mechatronics FEI STU in Bratislava. His research interests include optimization, robust control design, computational tools, SCADA systems, big data, and hybrid systems.



prof. Ing. Štefan Kozák, Phd.
Faculty of Informatics, Pan-European University, Bratislava, Slovakia
stefan.kozak@paneurouni.eu

Currently at the Institute of Applied Informatics at the Faculty of Informatics, Pan-European University in Bratislava. His research interests include system theory, linear and nonlinear control methods, numerical methods and software for modeling, control, signal processing, IoT, IIoT and embedded intelligent systems for digital factory in automotive industry.

DEVELOPMENT OF A SMART HOME CONTROL SUBSYSTEM

Igor Lvovich, Oleg Choporov, Yuriy Preobrazhenskiy, Juraj Štefanovič

Abstract:

The concept of smart home appeared more than 40 years ago. In the definition of such a concept, the basic concept is associated with a complex system having a single control panel. The modern concept that describes a smart home is defined as a set of control systems that can respond to the presence of a person and the environment with a subsequent solution, which is aimed at creating favorable and comfortable living conditions. With this approach, to implement remote control of a smart home, one has to face a number of problems: it is necessary to be able to access the system from the outside. Almost all devices inside a smart home are connected to the Internet, from which it is easy to view their status, and also causes any action by sending a user command. The evolution and access of high speed internet has allowed humanity to bring comfort and security to their lives. In this paper the main results of research on the management of smart home are given. Under socio-technical system we refer to an organized collection of hardware, software and hardware, as well as individuals, in which each of these components has a strictly defined framework and limit of its activity. The factors of influence on the condition of the building are analyzed. The diagram of channels and the impact on the control object is shown. Data collection and storage can be divided into a number of relatively independent stages. To improve the efficiency of collecting the process control data it is advisable to divide all sensors into groups and each group of sensors is connected to the microprocessor.

Keywords:

Computer network, traffic loading, protocol.

ACM Computing Classification System:

Network protocols, network algorithms, network types.

Introduction

Currently there are varieties of active developed Smart Home Control Systems (SHCS). The overwhelming majority of the population in urban areas spends most of the time in buildings and other premises in the protected areas. Setting the right conditions in such objects significantly affects the quality of life of the population.

During business hours, the people are in offices, manufacturing facilities, classrooms, area organizations, etc. During off-hours they are in homes, sports facilities, construction of cultural-mass assignment, clubs, etc. There is a trend of consolidation and formation of these office, residential, commercial, recreational, educational, therapeutic, diagnostic and other spaces with the use of engineered systems for management of air temperature and humidity, physical and criminal security.

The growth of the number of storeys in city buildings leads to a complicated system engineering for support of their activities; It reinforces the importance of solving problems for tracking deformations of building structures; It requires the implementation of preventive measures against potential terrorist threats to individuals and organizations in buildings.

Therefore, the task of creating maximum comfort, safety and convenience of people staying in / on these sites is urgent. In particular, the working areas need to ensure conditions for effective work of the personnel; in the classroom the temperature and humidity conditions and other parameters should contribute to the effective conduct of the educational process; in a building the people must have the opportunity to relax, to have a good time and to be feeling safe [1].

The most effective way to address these problems at the moment is to develop and implement SHCS, including to provide full and continuous monitoring of all aspects of their operation to get current status of all components.

In addition, SHCS can provide and increase the energy efficiency of buildings. Monitoring systems of buildings and areas, including their protection, have existed since time immemorial. However, such systems were very expensive and therefore rare in the past. Scientific and technological progress (especially in the field of microelectronics and information technology) will automate many of the functions that have to be addressed within the framework of SHCS buildings.

This, in turn, led to a significant reduction in the cost of such systems. As a result, at least some elements of SHCS are becoming more common in the practice of building design, to control their operation. For example, a video surveillance system in large cities has become widespread. It is used not only in industrial and office buildings, but also in a number of residential buildings - including video surveillance of the surrounding area [2]. This significantly increased security in the building for all stakeholders, as well as the comfort of stay or residence in the building.

However, as the analysis of all the available sources shows, there is currently no overall concept and operation of technology SHCS, ie existing SHCS are loosely coupled sets of separate subsystems: water, gas and others.

To ensure a comfortable stay in the area of SHCS control, it is impossible without taking into account all internal and external natural, man-made, technological and social factors. The zone of SHCS control has a significant impact on the comfort of living (for residential buildings) or stay (for office and industrial buildings) in.

Thus, the need to consider a number of factors affecting the condition of comfort and safety, as well as a large number of control parameters, covering all aspects of the functioning of SHCS generate the need for an integrated system approach to formation SHCS based on a single concept and operation of the technology, a unified algorithmic and information programming environment.

The purpose of the paper is to build a smart home control system based on a single concept and technology of functioning and integrated information and algorithmic support. In accordance with the purpose of the set and the following tasks:

1. To form the overall concept and the functioning of the SHCS technology.
2. To construct a general algorithm for decision-making in SHCS.
3. To undertake a systematic analysis of the factors that may influence the condition of the building and its components and to form a subsystem of data collection and recording.
4. To develop a central functioning algorithm for building automation with intelligent control system.
5. To develop the algorithms of individual functional subsystems of SHCS.

1 The Main Results of Research on the Management of Smart Home

Note that the smart home is a term widely used in the scientific literature for the isolation of buildings with a developed system of automation of various processes associated with the operation of the building, above all, the various functional subsystems of the building, with the active use of modern information technologies.

Usually the word "intellectual" in relation to a system refers to the existence of a system of rational behavior of opportunities for any admissible conditions of system function.

It may be noted one important requirement that must be fulfilled for the full achievement of intellectualization of the building - it is necessary to cover the intellectualization procedures of all the processes occurring in the building, since all of these processes are interrelated and interdependent. All objects associated with the building and all subjects related to building can only be treated through a systematic approach to the problem of intellectualization of modern residential and office building.

Analysis of intelligent home control systems revealed that the building management system, previously developed on different principles is focused on management of various individual subsystems of an intelligent building. In this case, all of the studies have focused only on the technical issues, and the review of an intelligent building as a socio-technical object of attention is not paid. There is an identified need for scientific research to form technology and smart home control algorithms [3]. Currently, in many leading countries there are actively developing projects for new types of buildings, in which all communication facilities and other lines are managed by an automated system in a building.

This system also takes control and other functions for management of the house, in particular the control of living conditions, security system, information and notification system, together with the automation of many other functions.

When you automate multiple subsystems together, this can lead to a synergic effect for the entire complex.

Technology based smart house is formed and organized differently than a conventional building. Firstly, the intelligent building technologies are characterized by system integration process in layers.

One of the most important procedures is the construction of performance evaluation, to get a dynamic feedback within all subsystems of the building in order to ensure conditions for further improvement and development of building control systems.

Various models have been developed to estimate the performance analysis of intelligent buildings. Preiser and Schramm have built a model for evaluating the performance of building systems based on the evaluation of "integrative capacity building", which covers all the main phases of construction of the building, by proceeding various external resources and all stages of the life cycle management, including "planning, programming, design, construction, placement and processing." Many of these studies were related to the building of the level of intelligence assessment.

Preiser and Schramm developed a Building Performance Evaluation (BPE) model which was evolved from Post-Occupancy Evaluation (POE) model [8]. The post-occupancy evaluation model determines the level of intelligence of the building process. It is usually done in three steps. First step is a formation of procedures to collect data at a conceptual level, the second step is an application and testing assessment of tools in field studies by evaluating the level of intelligence of the building. The third step is a comparative analysis of the collected data and the development of recommendations and proposals for the use of data collection instruments.

Preiser and Schramm used their process model for the evaluation of intelligent building in cross-cultural context, and their model provides "improving the quality of performance evaluation in the intelligent building, especially in the long term." This evaluation system allows you to "monitor the performance of the new high-tech systems and their impact on the building, as well as the effectiveness of these systems as a whole." Without evaluation system it is difficult to classify and validate the level of intelligence buildings. Thus, a large number of studies is done on the problem of developing methods for constructing various estimates for the intelligent building.

One of the important methods of performance assessment of buildings is developed in 1995 DEGW method based on the "method of valuation of buildings IQ" and "evaluation of the quality of the building." The method uses five categories of factors that combined to produce overall estimates of the initial suitability of the information provided by the actors of the building.

On the other hand, Arkin and Patsiuk developed a measure of "systems integration value" and the method of its evaluation to characterize the degree of integration in the building, depending on the degree of integration of the building subsystems, the integration between the systems and structures of the building.

This evaluation methodology can be used to evaluate and compare the different options of intellectualization of the building and create an unified index for evaluating the degree of integration of the system in intelligent buildings. This model was adapted for Research on performance evaluations intelligent building construction and improving the structure building, Yang Pan 2001.

In 2012, the Asian Institute of Intelligent Buildings constructed a quantitative method of assessing the intelligent building an index. According to this methodology, the individual index is based on nine separate indices relating to individual modules, intelligent building, as well as the environment and the various aspects of quality. Index number is lying in the range 1 - 100. Depending on the grade level of general intellectual performance of building, it has rank in alphabetical order from A to E. However, some of the performance evaluation models have been criticized for inadequate result estimates of certain aspects of construction and operation of buildings, as well as for the use of partly subjective assessments.

2 The Concept of Building a Smart Home Control System

As noted above, the existing approaches to building SHCS despite presenting them as integrated systems have a number of existing shortcomings. First, they cover only the most important fields of activity SHCS; First of all, the sphere of life support and safety and its commitment do not affect the scope of relations between the various legal and physical entities in the control zone. Second, as part of the subsystem SHCS is regarded as virtually independent and this creates problems in the implementation of many activities. At the end, there is a separate dedicated subsystem or service responsible for the strategic development of intelligent building.

Thus, the most serious drawback of existing concepts of building SHCS is ignoring the subjects and, above all people. Complete controlled intelligent building must necessarily be based on a consideration of the building as a socio-technical system, harmoniously combines the building and all other technical services and LAN.

Under socio-technical scope of view, the system refers to an organized collection of hardware, software and hardware, as well as individuals, in which each of mentioned components has a strictly defined framework and limit of its activity.

Intelligent building as a socio-technical system is a set of controlled building spaces, combined in a single system based on a single concept of construction and operation of the technology - we call this as a symbiosis controlled area, the people and SHCS socio - intelligent buildings.

We highlight some of the principles of construction of socio-technical systems:

1. Technical equipment as part of SHCS should not cause problems for people to live and inconvenience of travel or stay in the control area.
2. Technical equipment must not disturb or cause problems for the realization of the rights of the people, and, above all, the right to privacy and personal privacy. We highlight from this standpoint the surveillance system, which is the source of collecting a variety of information of a confidential nature. Therefore, enforcement of this principle in SHCS is quite a challenge.
3. Information concerning the private life of individuals and other legal entities and individuals, should be treated SHCS in full compliance with the law.

3 Technology Operation Subsystem of the Strategic Management and Development

The subsystem of the strategic management and development is one of the most important, being responsible for all the problems associated with the development of promising SHCS, improving comfort of stay (residence) of people in it, increasing the efficiency of all its subsystems and services. Below is the general function of the technology strategic management and development system.

The principal difference between the strategic management of operational dispatch, which is realized in the dispatch center (one of the important pillars of management) is the use of forward-looking information on future states of all components of the operation process SHCS: of buildings, premises and control zone as a whole, the external environment, legal and regulatory base composition, people, financial and economic conditions of SHCS.

As a consequence, strategic management implies the existence of subsystems they predict future parameters of the functioning of the environment and planning, which generates and mostly forms action plans based on the projected state of the system, develops technologies of selection and decision, to generate specific plans to implement the actions and taken measures [4].

4 The Technology of Electricity Service Operation

As indicated above, the detailed description of the above SHCS technology and all its components in this paper is not possible. Therefore, to describe common technology in detail procedures for individual subsystems, in this paragraph we show an operation of a technology standard functional SHCS services: the services of power. As a general technology of SHCS operation, the power center operates continuously in cycles.

Key-controlled power system parameters are the voltage of the electric current and its frequency. Therefore, at the beginning of the algorithm values of these parameters are monitored. In case of deviations of at least one of the power parameters the supply facility must immediately take steps to solve these problems. In this case, all possible measures are divided into two groups. First group - measures taken immediately to eliminate deviations (faults in the devices, circuits and line breaks, etc.), when the sources of the problem are known or they can be quickly found on the site by an electrician expert. The second group - those deviations, the causes of which are unknown, or are not able to be eliminated by expert help immediately.

When the causes of deviations could not be determined or allocated (the complexity of the accident, the presence of interfering factors in the form of fire, confined spaces, etc.) more serious action must be taken. That is, if the situation is an emergency (for example, a fire in the place of occurrence of deviations), then first of all actions are taken to prevent the safety of people and property (eg, power off in the accident zone, the restriction of movement in this area), and process control runs for the elimination of accident [5].

5 Information Technology Used in the Composition SHCS

As follows from the algorithm of SHCS operation and its components, the processes associated with control have the most diverse nature, and therefore information technologies (IT), which were designed to support these processes comprise a wide variety of different software and information means.

Let us consider in more detail what information technology demands in SHCS. The initial phase of technology is related to the collection and data logging from a variety of internal and external (database) sources: from sensors, video surveillance, internet sources of clients and staff, web browsing history, as well as from a variety of document repositories and databases (for current situations, regulatory and legal documents from past situations and events in the building, etc.).

In addition, to make data processing from the sensors the microcontrollers may be used. Finally, the necessary means too, to control the correctness, completeness and adequacy. Thus, in the first step of collection and preparation of source data you need the following IT technologies:

1. IT data accumulation and processing from primary sensors, continuous measurement of various physical parameters that can interact with microcontrollers. The set of systems providing received data from sensors and issue commands to the actuators, based on wired and wireless technologies.
2. IT applied on the basis of embedded data acquisition board with a standard system interface.
3. IT on permanent, i.e. systematically in accordance with the regulations how to specify and search data in the global network [6] (internet).
4. IT support surveillance systems. Real-time monitoring and management software is used to manage the video surveillance system and the organization of the workstation operator to monitor and work with the archive.
5. The processing systems and storing documents.
6. Database storage of different types.
7. Information system to control qualitative characteristics [7] of different types of data.

6 Development of a Subsystem of Decision-Making in SHCS

SHCS - a key component is the process of implementing measures, actions and procedures related to the solution of various problems and management tasks, i.e. the system management process. SHCS management process is divided into two kinds of management - operational management and strategic management. Each of these types of control, in turn, is divided into a series of management steps that are common to both types of management, including the following steps:

1. Collection and preparation of raw data.
2. Procedure for making decisions.
3. Adoption.
4. Implementation.
5. Control of the process and results of implementation.
6. Analysis of the implementation of the results.
7. If necessary, adjust solutions and then repeat the entire cycle of described control.

This strategic management adds another initial (second-order) phase - SHCS prediction parameters.

7 Factors of Influence on the Condition of the Building

It is required to solve the formation of the data collection system. To do this, first of all we need to form part of the collected data which is necessary for the efficient operation of SHCS.

For this, we first conduct a systematic classification of all the factors that may affect the building manager or entities that are in it legally - we call the specified set of object management. Then, based on results of classification factors we form relatively complete composition of required sensors.

By analyzing the composition of all the possible types of impacts, there are allocated groups of factors associated with the following components and SHCS management objects shown in (Fig.1):

1. Direct constructions and their individual elements which form the house itself.
2. Infrastructure systems and their elements related to human life support systems (electricity, heat, water and gas supply, lighting), and standard public services (communications, internet, ventilation, and air conditioning).
3. Infrastructure systems that support the building in a state to satisfy all regulatory requirements, as well as to provide control over the state of all the elements, systems, structures, house and home management.

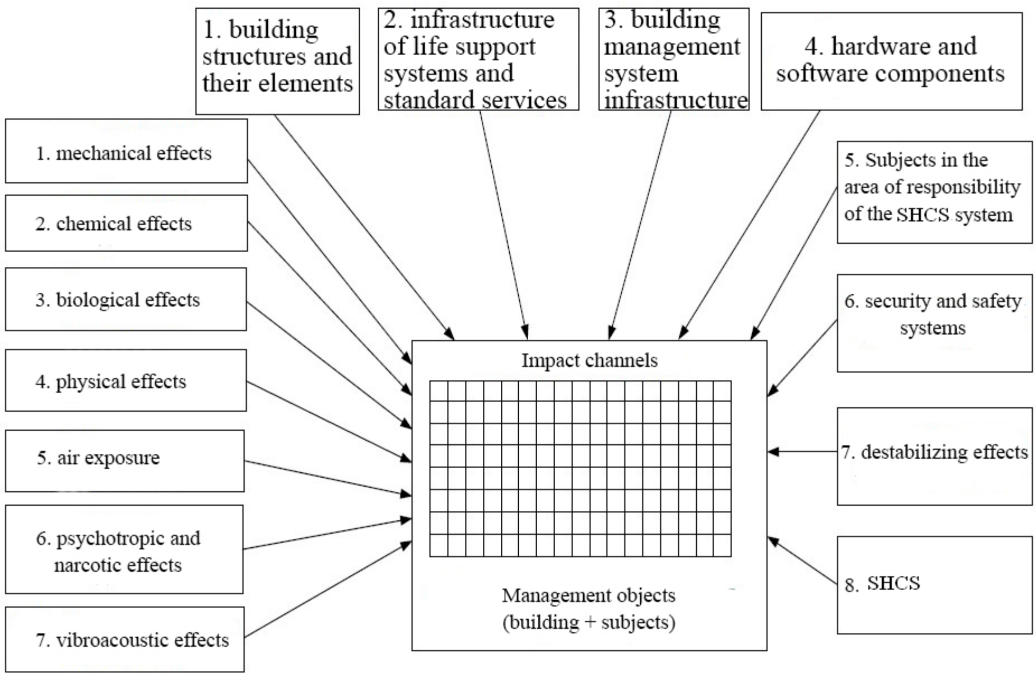


Fig.1. Diagram of channels and their impact to the controlled object.

4. Specifications and software and hardware components that make up the whole.
5. Entities that are in spaces, premises and areas of intelligent building legally or illegally.
6. Security systems and intelligent building security.
7. The various internal and external destabilizing effects of natural, man-made and subjective nature, they can upset the normal operation of intelligent building with its subsystems, and even destroy some of them.
8. SHCS directly as part of the controlled object.

Detailed view on these factors at the next level, it takes into account that a substantial part of each of these components is allowed to allocate more than 56 possible sources of influence on the controlled object.

Building and subjects located therein are exposed to various factors, both internal and external. Analysis of possible ways to influence the impact of the following classes of methods can distinguish:

1. Mechanical impact - the collapse or destruction of elements and structures of buildings and facilities, the fall of other objects in the area of displacement and finding subjects, slippery surfaces (such as ice), falling objects from a height (such as snow and heavy ice from the roof), suspensions, dusts, including carcinogenic and not deducible containing additives.
2. Chemical exposure - a substance harmful to human health or to the health of personnel, substances explosive, flammable, strong smelling, unpleasant, or dangerous for technical devices and allergens too.
3. Biological effects - microorganisms (bacteria, viruses, etc.) and macro organisms (plants and animals).
4. Physical impact (nonmechanical nature) - effect of physical fields and radiation: electromagnetic fields, X-rays, radioactive, ionizing and ultraviolet radiation, etc.
5. Smoke, dust and similar obstructions, gas leakage, a strong turbulent movement.
6. The psychotropic and narcotic effects.
7. Accustic impact - strong sound signals, a mechanical vibration feedback.

The combination of exposure to each source with each of the possible specific ways to influence one of the channels generates impacts on the control object as shown in (Fig.1).

The analysis shows that the total number of such channels is greater than the impact of several hundred influences. Each of channels requires ideally its specific used data collection devices at the appropriate exposure. Therefore, a complete analysis of the possible types of sensors required for the control object is a rather time-consuming and difficult task.

8 The Input Acquisition Subsystem

Data collection and storage can be divided into a number of relatively independent stages:

a) directly collect data using a variety of technical, software and hardware, as well as subjective sources
b) the registration of data on storage media
c) analysis of the data on criteria full notes, the adequacy, consistency, relevance, timeliness, no-rebound, trust, etc.
d) the adoption of adequate solutions for identifying violations of at least one of the following criteria and the implementation of decisions
e) transfer of received and analyzed data to the central control unit and the corresponding functional subsystems for performing their duties

From these data processing steps the most important one is the stage of collecting data directly. The general scheme of the input data stream is shown in (Fig.2). The diagram shows seven possible allocated input sources.

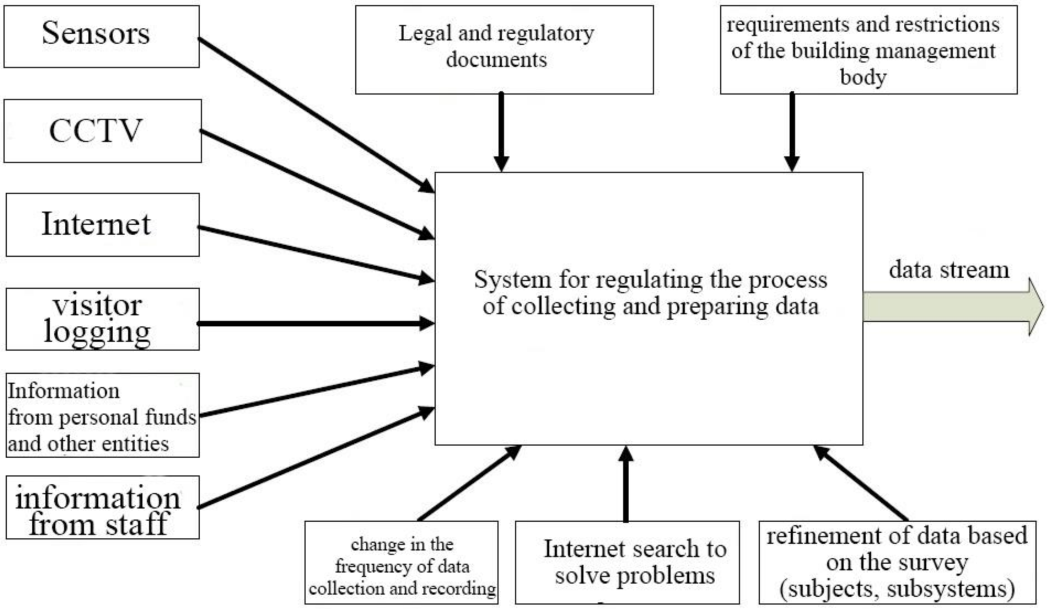


Fig.2. Diagram of inputs to building management systems.

1. The sensors and sensor devices, which are complexes comprising more than one sensor. On the basis of the sensor data collected on all technical elements of home life-support systems (such as water and energy, public services), many elements of the security system can work. This is the primary source of data for the effective functioning SHCS.
2. The video surveillance system, which is one of the main sources of information for security. This system also allows you to monitor many of the elements of smart home life support, the state of which can be identified on the basis of visual observation.
3. The Internet as a source of information that allows you to help, first of all, to find possible solutions to the various problems, as well as to obtain information about various natural persons who are or have fallen within the scope of professional tasks within SHCS security subsystem.
4. Event log, which should record all and any significant event in SHCS control zone, which allows on the basis of his analysis to identify possible problems, troubles, threats, trends, and to predict the next possible states of the entire system, including the building itself with the whole area control and SHCS.
5. Information about the people they are in the control zone SHCS legally - tenants, visitors, staff, employees, etc.), which can be supported with the help of a survey by the SHCS staff. This information can contribute to a more adequate and operational work of system.
6. Information from SHCS personnel, including the subjective nature relating to all aspects of the functioning of SHCS. This information allows you to identify potential and real problems that are still outside of the bounds with other data sources.
7. Legislative and normative documents regulating activity of SHCS in general and the activity of its subsystems, including the subsystem of data collection and preparation.

9 Technology of Data-Gathering and Processing Subsystem

The primary (center) block in (Fig.2) designed for system management of collection and preparation raw process data is described here - its function and technology.

Since this system should also implement a control function for input acquisition process, it is necessary to use sensors to get responses to control actions, that is, at a minimum they should be targeted. Furthermore, it is proposed (to the extent of available funding) to use "smart sensors" that have a large set of control parameters inside.

To improve the efficiency of collecting process control data it is advisable to divide all sensors into groups (according to the territorial location, by functional purposes, etc.) and each group of sensors connected to the microprocessor. It should carry out certain control and management functions for the respective group of sensors - in particular, control of the state of the sensors (the entire set of operating characteristics, and user).

In addition, in the case of event where sensor data are deviated from its normal procedural status, the software and microprocessor must immediately inform the dispatch center SHCS. The control actions of SHCS control center for the particular sensor or set of sensors are also advisable to pass through the respective channels. In the control center the complete information about the delivery and current implementation of the control action must be observed. Note that to enhance the exchange rate, all MK data are transmitted via a common bus.

The process of data acquisition and processing is performed continuously (cyclic) and may be partly or entirely blocked only by the direct impact from the control center or when the SHCS system is destructed.

Data collection and preparation of parallel generated control signals for the control of other systems belonging to it, is made according to the following algorithm:

1. The video surveillance system turns the nearest video cameras onto the heat source, and assigns the highest priority to these cameras, thus providing a continuous supply of video data from ignition zone. On the monitor, surveillance system forms enlarged image from these cameras. The priority mode for recording images is higher from fire zone.
2. The climate control system deactivates the supply air ventilation system in the zone of fire - to prevent the flow of fresh air (containing more oxygen) to the site with fire. To remove the smoke the corridors, hallways and stairs (along the evacuation routes) includes an appropriate subsystem of exhaust ventilators.
3. Automatic fire extinguishing system is activated - if the separate room or the whole building is equipped with such a system.
4. The power supply control system switches off the power circuit of the equipment and lighting devices in the fire area.
5. The lighting control system activates emergency lights.
6. Access system unlocks the controlled doors (for example, equipped with combination locks) for smooth evacuation.
7. The voice alarm system talks announcements in the relevant parts of the building.
8. Elevators go down on the first floor and, if necessary, they are turned off, etc.

Thus, the inclusion of all building systems into a single management system creates a new quality - integration. The system with a single platform (the concept and technology) management acquires new properties that are absent in the constituent subsystems (a synergic effect).

The technology described here with its operation of the data collection and preparation of the subsystem allows to solve many important problems relating to the function of the building and ensures a comfortable and safe stay for all the people in it at the higher level of quality.

Conclusion

1. The classification of factors they impact on intelligent building: seven groups of impact factors are identified. A procedure for the classification of systemic effects channels on two classification criteria: impact factors and the impact of the classes of objects.

2. A general algorithm of data acquisition and of the data preparation subsystem allows to increase the efficiency of operation due to more complete control of these channels in accordance with their large quantity.

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Authors

Prof. Igor Lvovich
Doctor of Sciences (Engineering), professor
Voronezh Institute of High Technologies
E-mail: office@vivtl.ru

Prof. Oleg Choporov
Doctor of Sciences (Engineering), professor
Voronezh state technical university
choporov_oleg@mail.ru

Dr. Yuriy Preobrazhenskiy, PhD.
Voronezh Institute of High Technologies, Voronezh, Russia
petrovich@vivt.ru

Ing. Juraj Štefanovič, PhD.
Faculty of Informatics, Pan-European University, Bratislava, Slovakia
juraj.stefanovic@paneurouni.com

International Journal
Information Technology Applications (ITA)

Volume 8, Number 2, December 2019

FUZZY CONTROLLER DESIGN AND CO-SIMULATION OF AUTOMATIC PARKING SYSTEM

Ján Cigánek

Abstract:

The aim of the paper is to propose a methodology control of parking process using fuzzy logic. The simplified vehicle, in which the design will be realized, is made in MSC Adams environment. This created vehicle model is afterwards exported to Matlab Simulink. In this environment a design is realized of the vehicle motion control through co-simulation using fuzzy controller. The design is tested and implemented for the control of the parking process in different parking situations, specifically for perpendicular and parallel parking.

Keywords:

Co-simulation, fuzzy controller, Matlab Simulink, MSC Adams, parking.

ACM Computing Classification System:

Computing methodologies, modeling and simulation, model development and analysis, modeling methodologies.

Introduction

Presently, the car is one of the most widespread transport vehicles. The automotive industry produces an incredible amount of cars every year. Their number is growing not only on public roads, but also in places reserved for car parking. Therefore, it is often the case that parking in places that are almost full is difficult and in many cases impossible for a person.

Parking assistant or automatic parking is no longer a novelty. Many car producers have this system and install it in their vehicles, either as an option or as part of the basic equipment of the car. It is a good help by parking in confined conditions.

The parking assistant is a system that facilitates parking of cars in both lateral (perpendicular, transverse) and longitudinal (parallel) parking. There are two types of parking assistants: those that allow manual steering of the vehicle by parking, or those that offer automatic parking.

The parking assist system consists of a set of ultrasonic sensors that are evenly distributed in both the front and rear part of the vehicle. The total number of sensors can be six or eight to twelve. Sensor data are processed in the control unit, which contains an algorithm for evaluating this data, and in the case of an automatic parking system, the algorithm is also extended to control action. The processed and evaluated data from the control unit can be presented to the driver on the display or other display units, along with an acoustic warning. The closer the vehicle is to the obstacle, the repetition frequency of the acoustic signal increases until it reaches a continuous tone, which indicates a very small distance from the obstacle.

The systems can also use a camera system to display the exact situation around the rear of the vehicle.

In automatic parking, the car itself has to make many intelligent decisions in a short time. Sensors have to find a suitable parking place. They can determine the length of free space, evaluate whether the vehicle can fit there, and send information to the control unit to calculate the correct trajectory of the parking maneuver. The best system needs sufficient parking space 80 cm larger than the length of the vehicle [1].

The first types of parking assist supported only the possibility of a longitudinal parking maneuver and allowed parking on the right side only. Presently, the systems also support cross parking and also allow parking on the left. Therefore, before starting to look for a parking space, the driver has a choice of what kind of parking and on which side of the vehicle he is interested. The maximum vehicle speed when searching for a parking space is up to 35 km / h. All data are processed, evaluated and displayed.

When searching for a parking space, it is necessary to activate the Park Assist system with the button and turn on the turn signal to the side where the driver wants to park. After finding a suitable parking space, the driver stops and engages reverse gear as instructed on the display. The driver only controls the vehicle speed when parking. The system evaluates the situation in front of and behind the vehicle and automatically rotates the steering wheel. When properly parked, the system shuts down automatically.

1 Vehicle Control

The defined movement of the vehicle model will be represented by the trajectory of the sensed point located in the center of the rear track of the vehicle model. At this point, the beginning of the XY coordinate system will also be here.

The vehicle model will move at a constant speed of $v = 0.277\ ms^{-1}$ throughout the parking maneuver. The generated reference trajectory will be compared to the actual trajectory that the vehicle model is currently executing.

Based on the deviation between these two trajectories, the steering intervention will be evaluated - representing the moment of force that will act on the steering mechanism of the vehicle model. This moment causes changes in the steering wheel angles of the vehicle model. In this way, it will be possible to control and correct the direction of movement of the vehicle model according to the reference trajectory of the sensed point.

The most widespread way to steer the direction of cars is Ackerman's steering. It is used the trapezoidal steering (Fig.1) to meet Ackerman's condition, wherein the steering arms together with the connecting rod are trapezoidal in shape [3].

After extending the front axle steering arms (*d* in Fig.1), the two arms are joined at one point - in the middle of the rear axle track. The angle between the arm and the wheel is called the Ackerman angle (β in Fig.1).

For the calculation of the Ackerman angle β is used the following equation:

$$\beta = arctg\left(\frac{A}{2\,L}\right) \tag{1}$$

where A is is front track gauge (mm) and L is wheelbase (mm).

The Ackerman steering condition: the center of rotation has to lie on the extended axle of the rear axle, as shown in (Fig.2). Fulfillment of this condition is an essential prerequisite for the proper rolling of steered wheels [3].

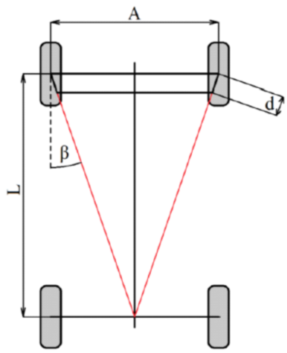


Fig.1. Creating a trapezoidal steering.

The relation between the angle alignment of the outer wheel δ_{OUT} and the angle alignment of the inner wheel δ_{IN} is:

$$cotg\ \delta_{OUT} - cotg\ \delta_{IN} = \frac{A}{L} \tag{2}$$

The equations to calculate the angle alignment of the inner wheel δ_{IN} and the angle of the outer wheel δ_{OUT}:

$$\delta_{IN} = arccotg\left(\frac{R-\frac{A}{2}}{L}\right) \tag{3}$$

$$\delta_{OUT} = arccotg\left(\frac{R+\frac{A}{2}}{L}\right) \tag{4}$$

where R is the turning radius (mm).

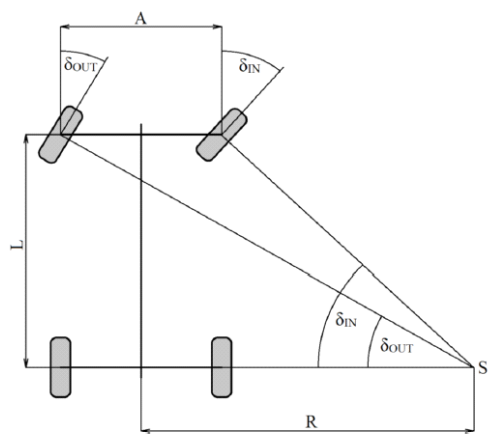


Fig.2. Angles of the wheels alignment at Ackerman steering.

Using the Pythagorean theorem, it is possible to derive the formula for calculating the turning radius of the vehicle R from the triangle in (Fig.3):

$$(L+B)^2 + \left(R + \frac{A}{2}\right)^2 = R_0^2 \tag{5}$$

leading to:

$$R = \sqrt{R_0^2 - (L+B)^2} - \frac{A}{2} \tag{6}$$

where B is distance (mm) between the front axle and the point where turning vehicle describes the circle with the largest radius with the maximum possible front-wheel turning. R_0 is contour turning radius of the vehicle.

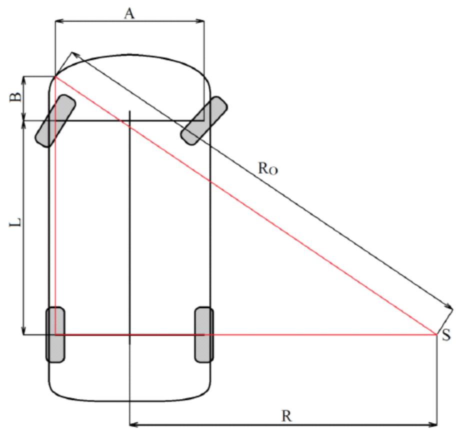


Fig.3. Angles of the wheels alignment at Ackerman steering.

2 Vehicle Modeling

To design a simplified vehicle model in the MSC Adams environment, the BMW 3 Series 320i has been selected. In order to realize the vehicle model, it was necessary to look for the dimensional and technical parameters of this vehicle, which are further used in the design of the steering wheels and trajectory control of the vehicle model. (Tab.1) shows the technical parameters necessary when designing a vehicle model [2].

Using equations (1 – 6) it is possible to calculate values of the Ackerman angle β, the turning radius R, the angle alignment of the inner wheel δ_{IN} and the angle of the outer wheel δ_{OUT}: β=15.36°;R=3 802.3 mm; δ_{IN}=42.84°;δ_{OUT}=31.56°.

The calculated angle alignments of both wheels are maximal and are based on the geometrical and driving characteristics of the vehicle. Their values are important when designing the steering wheels of the vehicle's front axle to avoid inaccurate steering caused by exceeding the maximum feasible steering angles of the front wheels. BMW models have a 50:50 front and rear axle load, it means the center of gravity is located in the center of the wheelbase of the vehicle.

Table 1. Technical parameters of the vehicle.

Length	4 633 mm
Width	2 031 mm
Height	1 429 mm
Curb weight	1 475 kg
Wheelbase *L*	2 810 mm
Front track gauge *A*	1 544 mm
Rear track gauge	1 583 mm
Contour turning diameter $2.R_0$	11 300 mm
Distance *B*	506.35 mm
Tire size	205/60 R16 92 H

Using the vehicle parameters (Tab.1) with the proposed front wheel steering control and the identified center of gravity, the vehicle model was built in MSC Adams (Fig.4).

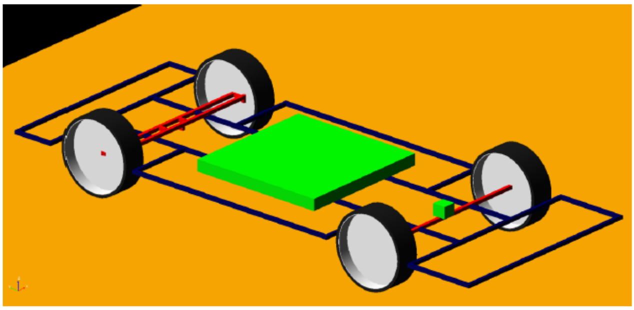


Fig.4. Vehicle model.

The vehicle model consists of several elements with major landmarks. One such point is called *Marker*. Individual elements of the vehicle model are its three basic parts: vehicle frame, wheels with its mountings and two additional weight bodies. These elements are interconnected by fixed or rotary coupling. Each coupling is defined between two elements.

The front wheel mounting elements also form the trapezoidal steering of the front axle and its individual elements are interconnected by rotary couplings to each other, allowing the front wheels to turn. The wheel mounting elements are fixed to the frame by fixed couplings. All wheels are attached to the wheel mounting elements by rotary couplings, allowing the wheels to rotate about their axis.

The vehicle model is located on a solid pad (dark yellow in Fig.4). A contact-type coupling is defined between the pad and each wheel, which ensures that all wheels roll on this pad.

In order to prevent possible exceeding of the maximum permissible angle alignments of the front, a mechanical fuse is also included in the steering mechanism of the front axle. The body marked PART_32 is fixedly attached to the trapezoid arm of the front wheel mount (PART_4), and which is fixed to the frame. The body marked PART_31 is fixedly mounted on the movable trapezoid arm of the front wheel mount (PART_7). A contact is formed between the PART_31 and PART_32 bodies. After the deflection of the arm PART_7, the body PART_31 is also deflected with it. After an ever-increasing deflection angle, it encounters an obstacle in the form of a body PART_32. The principle of the mechanism is shown in (Fig.5).

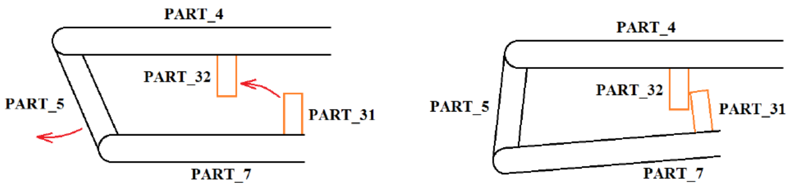


Fig.5. Mechanical safety device against exceeding the maximum steering angles.

The third part of the vehicle model consists of two bodies (green in Fig.4). They serve as an additional weight so that the mass of the vehicle model matches the curb weight $m = 1475\ kg$. The second function is to balance the vehicle model so that the center of gravity is located in the center of the wheelbase.

3 Co-Simulation

The first important step is the definition of sensed and controlled variables in MSC Adams. Sensed variables are outputs that can be either informative or directly affect the movement control of the vehicle model. Controlled variables influence the vehicle model control and represent inputs.

The output variables of the system are:

- the position of the point in the X-axis direction,
- the position of the point in the Y-axis direction,
- the angle alignment of the left wheel and
- the angle alignment of the right wheel.

The first two output variables are used to control the movement of the vehicle model. The left wheel angle and the right wheel angle are used for informative monitoring and to control the maximum angle values while driving. The input variable is the moment of force applied to the left movable steering arm of the vehicle, the magnitude of the moment affects the angle alignment.

To export a vehicle model from MSC Adams to Matlab Simulink, it is necessary to create corresponding system state variables for all input and output variables that will be used to control the movement of the vehicle model. The individual variables used to control the movement of the vehicle model, together with their corresponding system state variables, are shown in (Tab.2).

Since the output variables do not directly affect the left and right angle alignment of the vehicle model, system state variables will not be created for these variables. However, their value can be monitored on the created meters in the MSC Adams environment.

Table 2. System state variables.

Moment	M
Position in the X-axis	X
Position in the Y-axis	Y

After defining all system status variables and all input and output variables, the assembled vehicle model is exported from the MSC Adams environment to the Matlab Simulink environment, in which the motion control of the vehicle model will be implemented using the fuzzy controller.

An important step by creating the control scheme is the design of a methodology for evaluating and comparing the reference trajectory with the actual trajectory. For the evaluation of the relationship between the position of the sensing point in the X-axis direction and the position of the sensing point in the Y-axis direction, the conversion to the angle φ is used. This angle is defined between the time changes in the position of the sensing point in both directions of the XY coordinate system, as shown in (Fig.6).

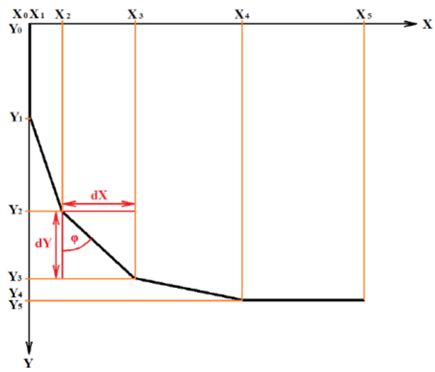


Fig.6. Conversion of XY coordinates to angle φ.

The calculation of the angle φ between changes in the position of the sensing point in the XY coordinate system is given by equation (7):

$$\varphi = arctg\left(\frac{dX}{dY}\right) \tag{7}$$

where *dX* is the time change of position in the X-axis direction and *dY* is the time change of position in the Y-axis direction. The calculation of *dX* and *dY* are given by the relations:

$$dX = X_A - X_P;\ dY = Y_A - Y_P \tag{8}$$

where X_A, Y_A are the current position values in the X-axis and Y-axis direction, X_P and Y_P are previous position values in the X-axis and Y-axis direction.

The angle φ between the time changes of the position of the sensed point in the XY coordinate system is calculated from the reference trajectory data as well as from the actual trajectory data. A simplified block diagram used for co-simulation and motion control of the vehicle model in the Matlab Simulink environment is shown in (Fig.7).

Two *Lookup Table* blocks contain time series of reference trajectory data in X-axis and Y-axis separately. The function, which is located in *Interpreted MATLAB Function* block, recalculates the time changes in the position of a point in the XY coordinate system from the reference trajectory to the angle φ using equations (7) and (8). The output values from the *adams_sub* block are the actual measured position data in the X-axis and Y-axis directions. This data enters the *Interpreted MATLAB Function1* block to calculate the angle φ for the current position change of the vehicle model. The calculated angles from both blocks are compared in the sum block with the output variable representing a control deviation *e*. The *Derivative* block calculates the derivative of the control deviation.

The control deviation between the angles and its derivative enter the *Fuzzy Logic Controller* block, where they are processed and evaluated. The output of this block is the moment *M* which controls the wheels steering of the vehicle model and corrects its movement according to the reference trajectory.

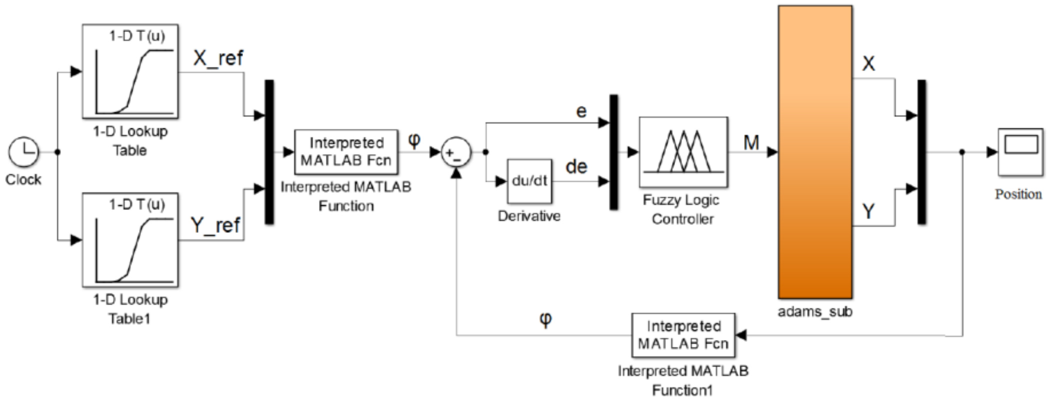


Fig.7. Simplified block diagram for co-simulation.

Design of fuzzy controller in Matlab Simulink environment is realized by *Fuzzy Logic Toolbox*. Typing the command "fuzzy" in the *Command Window* opens *FIS Editor* for fuzzy controller design. In this editor, it is possible to choose the type of fuzzy controller (Mamdani or Sugeno); to add controller inputs, controller outputs; to specify boundaries of individual input and output variables; to change numbers and types of membership functions; to set methods for implication, aggregation and defuzzification; to create rules; and to save the proposed fuzzy controller.

The proposed fuzzy controller of Mamdani type will enter two input variables: *e* represents the control deviation of angle φ with 5 membership functions (MFs) of triangular shape in range <-3°; 3°>; *de* represents the derivative of the control deviation with 3 MFs in range <-3°/sec; 3°/sec>. This fuzzy controller contains only 1 output variable *M* representing the moment with 7 MFs in range <-15 Nm; 15 Nm>.

The relations between the output variable *M* and the input variables *e* and *de* are determined by the rules. The most common way to create fuzzy rules is by IF - THEN. A fuzzy rule consists of two parts: the first is the conditional part of the rule (antecedent – consists of a combination of input variables) and the second one is the conclusion part of the rule (consequent – is made up of an output variable) [4]. All rules of proposed fuzzy controller are shown in (Tab.3).

Table 3. Rules of proposed fuzzy controller.

e / de	**Z**	**N**	**K**
ZV	KV	K	KM
ZM	K	KM	N
N	KM	N	ZM
KM	N	ZM	Z
KV	ZM	Z	ZV

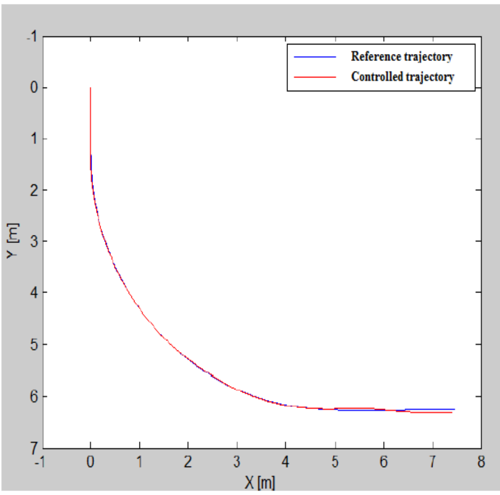
Two parking situations were created based on the parameters of the designed vehicle model. Specifically, this concerns the situation of lateral (perpendicular, transverse) and longitudinal (parallel) parking. In both parking situations, vehicle model control was applied using the designed fuzzy controller.

In both parking situations, foreign bodies are added to the vehicle model to define a parking space for a particular parking situation. Subsequently, trajectories for movement of the sensing point of the vehicle model were created for both situations.

Due to the constant rearward movement of the vehicle model, both parking situations are designed and adapted so that the vehicle model can park reversely in a defined parking space based on one trajectory of the sensing point.

For the transverse (perpendicular) parking situation, the corresponding reference trajectory for vehicle movement is used (blue in Fig.8a). The length of the co-simulation was 23 seconds. After simulation, the trajectory of movement was recorded by the sensing point of the vehicle model. A comparison of the reference trajectory and the measured controlled trajectory of the vehicle model is shown in (Fig.8a).

Similarly, for the longitudinal (parallel) parking situation, the corresponding reference trajectory for vehicle movement is used (blue in Fig. 8b). The length of the co-simulation was 30 seconds. A comparison of the reference trajectory and the controlled trajectory of the vehicle model is shown in (Fig.8b).



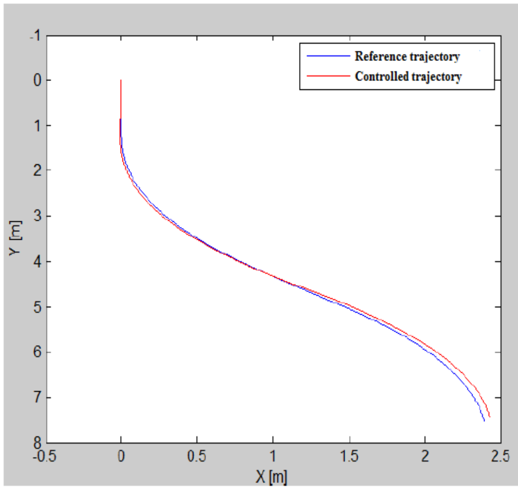


Fig.8. Comparison of reference and controlled trajectory: a) Transverse, b) Longitudinal.

It can be observed that in a transverse parking situation, the controlled trajectory of the vehicle model is almost identical to the reference trajectory. Vehicle model position during transverse parking maneuver is shown in (Fig.9a). Red bodies define a 2.5 x 5 meter parking space between them.

Similarly, in a longitudinal parking situation, the controlled trajectory of the vehicle model is very similar to the reference trajectory. Vehicle model position during longitudinal parking maneuver is shown in (Fig.9b). Red bodies define a 2.5 x 6.5 meter parking space.

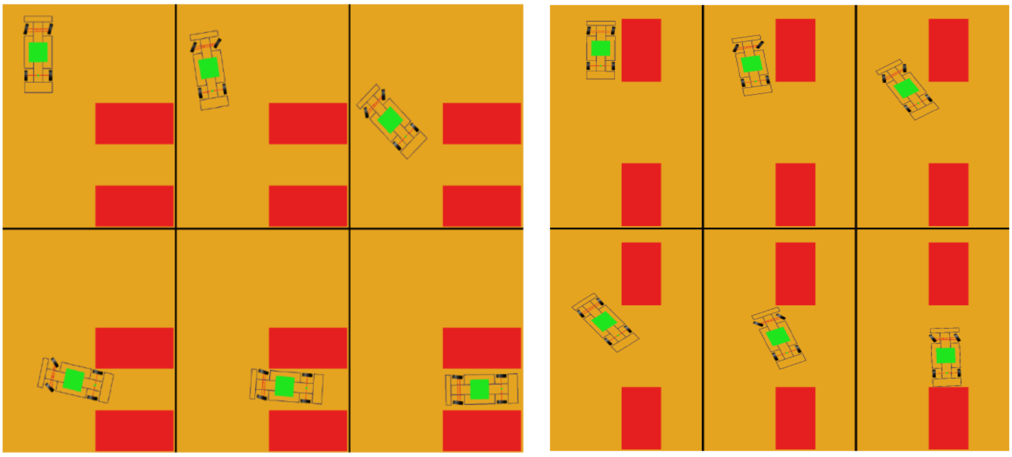


Fig.9. Positions during parking maneuver: a) Transverse, b) Longitudinal.

Conclusion

The aim of this work was to propose a methodology of vehicle parking process control using fuzzy logic and subsequently to verify it for different spatial situations. The method used to control the movement of the virtual vehicle model, which was designed in the MSC Adams environment, was based on the transformation of the X and Y coordinates of the sensed point of the vehicle model to an angle between the time changes of this point in the XY coordinate system. The motion control model was implemented in Matlab Simulink.

The proposed control was applied to two spatial parking situations in the form of transverse and longitudinal parking maneuver. From the achieved results, as well as from the graphical interpretation, it can be concluded that the proposed fuzzy controller is suitable for given parking situations.

Acknowledgement

This paper was supported by the Slovak Grant Agencies VEGA 1/0819/17, and by the Scientific Grants APVV-17-0190 and SEMOD-79-2/2019.

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Authors

Ing. Ján Cigánek, PhD.
Faculty of Electrical Engineering and Information Technology,
Slovak University of Technology in Bratislava, Slovakia
jan.ciganek@stuba.sk
He was born in 1981 in Malacky, Slovakia. He received the diploma and PhD. degree in Automatic Control from the Faculty of Electrical Engineering and Information Technology, Slovak University of Technology (FEI STU) in Bratislava, in 2005 and 2010, respectively. He is now Assistant Professor at Institute of Automotive Mechatronics FEI STU in Bratislava. His research interests include optimization, robust control design, computational tools, SCADA systems, big data, and hybrid systems.

International Journal
Information Technology Applications (ITA)
Volume 8, Number 2, December 2019

DEVELOPMENT AND SOFTWARE IMPLEMENTATION OF COMPUTER NETWORK ALGORITHM

Yakov Lvovich, Andrey Preobrazhenskiy, Juraj Štefanovič

Abstract:

In this paper, we consider the problem of modeling computer networks. The description of the basics of computer modeling is given. We have demonstrated the development of the structure of the program. Information model of the computer network is shown, a detailed description of its components is given. The algorithm of the constructed model is given. A generic algorithm for implementation of transfer processes messages in the simulation model on the basis of constructed and marked out a joint venture is shown. The structure of the program is demonstrated. The developed environment for simulation of computer networks allows us to study in detail the processes that occur in computer networks during their creation and subsequent operation. To build models in this environment, the presence of related groups of objects representing certain elements of a real network is provided. The simulation of information exchange processes between model objects is carried out by sequential processing of events, each of which reflects the manifestation of certain processes in the elements of the network under study. The main windows of the software product interface are described. When choosing the right type of equipment in the right drop-down list on the left displays all the devices of the selected category. When you select a device from the left drop-down list it will be an icon of the device. We can combine these virtual devices into a fully fledged network routers, workstations, servers and others. The device can change or display its properties. In the properties window the information can be seen about the device, its parameters and characteristics. Each device we can set according to four points of network activity. During simulation of computer network, the user can do real-time monitoring of network activity. The results can be widely used for modeling various classes of computer networks.

Keywords:

Computer network, traffic loading, protocol.

ACM Computing Classification System:

Network protocols, network algorithms, network types.

Introduction

In today's world there is an active development of both - networks, and the services provided by these networks. This process requires not only the development of new technological equipment, software products and standards, but also the right and effective design of these networks [1].

Computer modeling has been shown to play an essential role in solving both of those, and other tasks. In the process of developing a model that approximates the properties and behavior of the network it makes possible to solve problems of optimization and management. Testing of certain decisions on the models is incomparably cheaper than the real system, and eliminates potential errors.

The aim of the paper was: study of simulation and possibilities of its application. Objectives of the paper were:

- study of the term "simulation" and its basic concepts;
- research capabilities of simulation application to build a computer network model;
- development of a computer program that simulates the operation of a computer network.

1 Basic Concepts of Computer Modeling

At present, the efficiency of construction and use of corporate information systems has become a very urgent task, especially in conditions of insufficient financing of information technology in enterprises.

The criteria for evaluating the effectiveness may reduce implementation costs of information systems and reach the better compliance with the current requirements and the requirements of the near future, with the possibility of further development and transition to new technologies.

The basis of the network is a computer system, which includes components such as a wired network and the active network equipment, computer and peripheral equipment, data storage equipment, system software (OS, DBMS), special software, and in some cases the application software [2].

Using expert evaluations – it is currently the most common approach to information systems. In accordance with this approach, experts in the field of computer technology, active network equipment and cable networks on the basis of their experience and expertise carry out the design of computer systems, providing solution to a specific problem or class of problems. This approach helps to minimize the cost of the design stages and to quickly evaluate the cost of the implementation of the information system. However, obtained expert estimates of the solution, as a rule, are subjective, as well as hardware and software requirements. An assessment of performance only guarantees the effectiveness of the proposed project and computer system under development.

Instead of using expert evaluations may be employed an approach involving the development of the model and simulation (simulation works) behavior of the computing system [3].

2 Development of Own Simulation Program Structure

Based on approaches and techniques of analysis and simulation of networks considered in the first chapter, the creation of prototype information system has main tasks:

Creation of adequate models of computer networks based on three types of data:
- data about the network topology;
- the routes and the characteristics of the traffic flows;
- data processing power of network devices.

Analytical calculation of network parameters for the models.

Carrying out simulation experiment of traffic transmitted within the constructed network model.

Analysis of the results in order to identify "critical" sections of the network with low or unstable processing / transmission speed of messages.

The system will allow to evaluate the computer network at the stage of designing or upgrading, but will also be useful for evaluating the effectiveness of already functioning networks and make recommendations for their optimization [4].

3 Information Model of the Computer Network

We consider a computer network consisting of devices of various types in which data packets circulate. Computational model of the network, in general, can be represented as shown in (Fig.1). Here are the basic data objects and relations between them:

Object "network" describes the real computer network
and may include subnet as other objects of this type.

Object "network device" is modeling devices that make up the network.
This is an abstract object, the function of which is to process packets, i.e, their device retention for a time and possible modification of the packet (e.g., change its type). Each instance of the object is characterized primarily by the value of its parameter "type". The types of the network device may include: workstations, communication, peripheral equipment, data transmission channels. Type identifies a particular structure of "network device".

Object "packet processing unit" describes a basic element of the network device responsible for the speed and processing discipline of network packets.

For network devices uniprocessor "processing unit" is modeling CPU work and comprises on its output data (transactions per second).

In multiprocessor devices, each "processing unit" describes a single processor. Data "processing unit" for network transmission channel is a virtual object and characterizes the data rate (bytes (bits) / second).

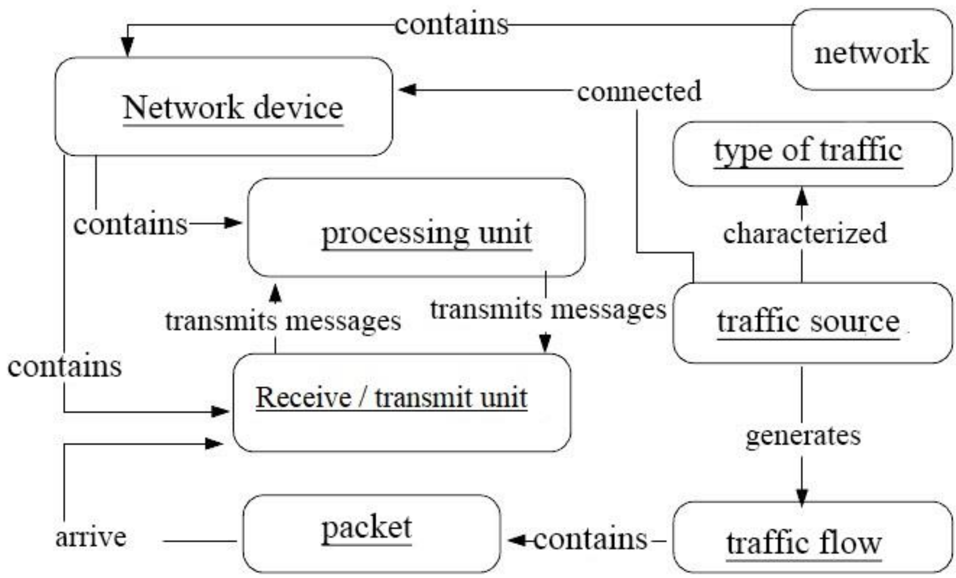


Fig.1. Information network model.

The object "transmission-reception unit" included in the "Network Device" serves to describe the network traffic flow input and output. The unit for reception and transmission network nodes is connected to their network interfaces.

Actually the analyzed network traffic is described by objects "Traffic type", "Source traffic", "Stream" and "Package." Object "Traffic type" contains information about the group of message flows in a network with common parameters. These parameters include:

- used protocols;
- services or applications that generate this traffic (for example, official, video, //p-traffic);
- priority of the traffic type;
- the delay coefficient associated with servicing this traffic type
  (e.g., queries may be served longer than the service traffic even with the same packet size);
- distribution law, characterizing the number of packets generated per unit of time;
- distribution law, characterizing the size of the packets generated per unit of time;

The object "Traffic Source" is the starting point of the same type of multiple traffic flows from one device to multiple. Traffic Source is characterized by "Transmission-reception unit" device with which it is associated "The type of traffic" and the timing of the start message generation, which may be set statically or determined at the time of operation of the device.

All messages are generated by "Traffic sources" in the general case with a different probability to enter multiple recipients (if one destination, then the probability of receipt a message equals to 1).

The object "Flow" is used for a general description of all messages generated by one "Traffic source" and directed to a single "Transfer-receiving unit" node on the same route, i.e., through some uniquely determined "Network device" at a certain time sequence.

Object "Package" describes one network flow package. Detailing to this level is only required for simulation, since its launch is associated with tracking the path of each packet. The result is a traffic statistics as a whole [5].

4 The Algorithm of the Constructed Model

The following is a generic algorithm for implementation of transfer processes for messages in the simulation model on the basis of constructed and marked out a joint venture. An event refers to the movement of the label from one position to another, ie, a plurality of kinds of S = <P1, P2, T, tr, t>, where P1, P2 - respectively are the inlet and outlet positions; T - crossing; tr - the type of traffic; t - the time at which an event occurs. A general algorithm:

```
Determination of the size of the time step for the model.
Determination of number of steps N (simulation time).
Loop through all traffic sources
            All streams cycle
                      Calculating routes
            End of Cycle
End of the Cycle;
Getting a list of events for the step.
If the step is zero
            then Formation of the list of events:
                      Loop through all the traffic on all source streams
                                Cycle
                                          Calculation of events S (P1):
                                          Choosing the next hop and the next position (of the route),
                                          the time the calculation of t;
                                          Adding to the list of S
                                End of the Cycle;
                      End of the Cycle;
```

Otherwise, if the list is empty and the step is not zero: Go to the next step;
Otherwise:
The cycle of events from the list
Checking on allowed events (corresponding transition)
If the event is allowed - Execution:
Formation of the next event S_{next}
Choosing the next hop and the next position (of the route), the calculation of the moment S_{next}.
Adding to the list
End If
End Cycle; S_{next}
End If;
End of Cycle on i.

The structure of the program is as follows (Fig.2).

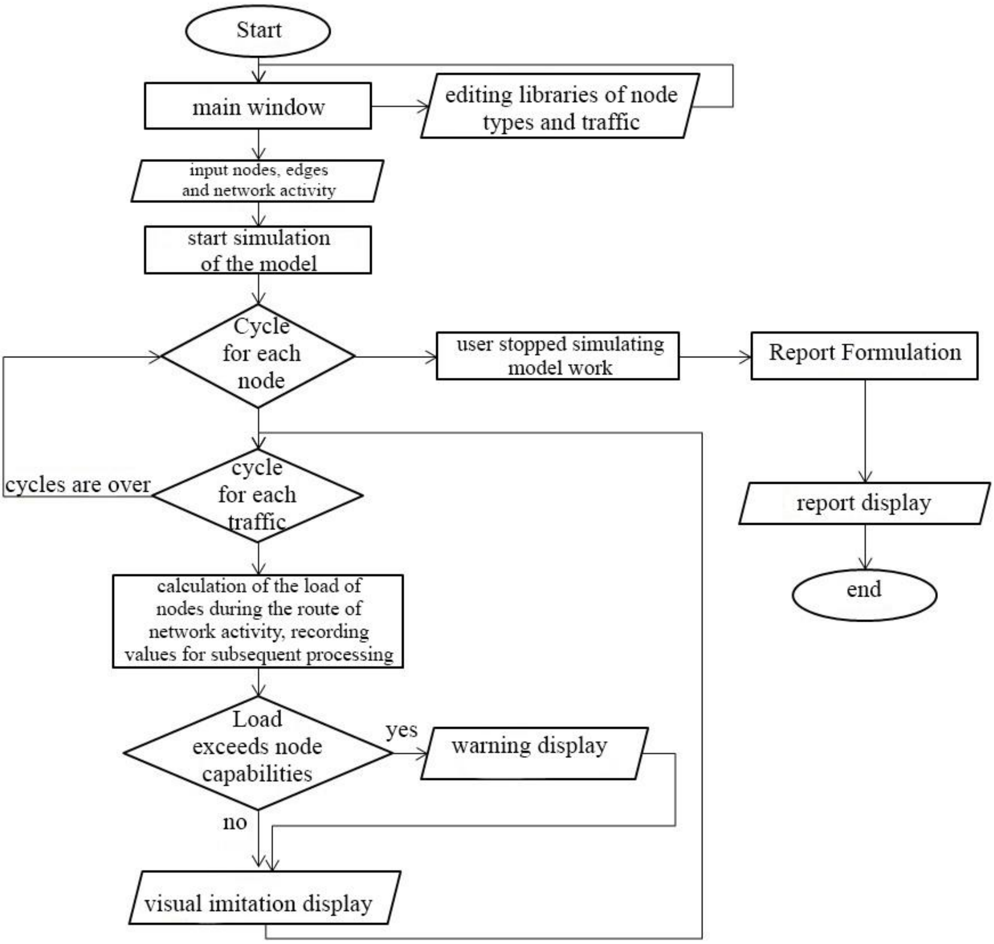


Fig.2. Structure of the program.

5 Process Network Model

(Fig.3) shows the working area of the program «Simulation Analysis». It is located at the top of the simulation tools, being necessary to: selection of equipment, statistics simulation, simulation of control [6].

When choosing the right type of equipment in the right drop-down list on the left, it displays all the devices of the selected category. When you select a device from the left drop-down list, there will be an icon of the device.

Now that we have selected the desired device, we can place it on our field by double-clicking the left mouse button (Fig.4).

Once the right devices are placed, we can connect them. To do this, just click on the selected device with left mouse button - in this case a line appears from the device to the mouse pointer, and then click the left mouse button on the second device with which we want to connect the first. Thus, we can combine devices into a fully fledged network routers, workstations, servers and other devices (Fig.5).

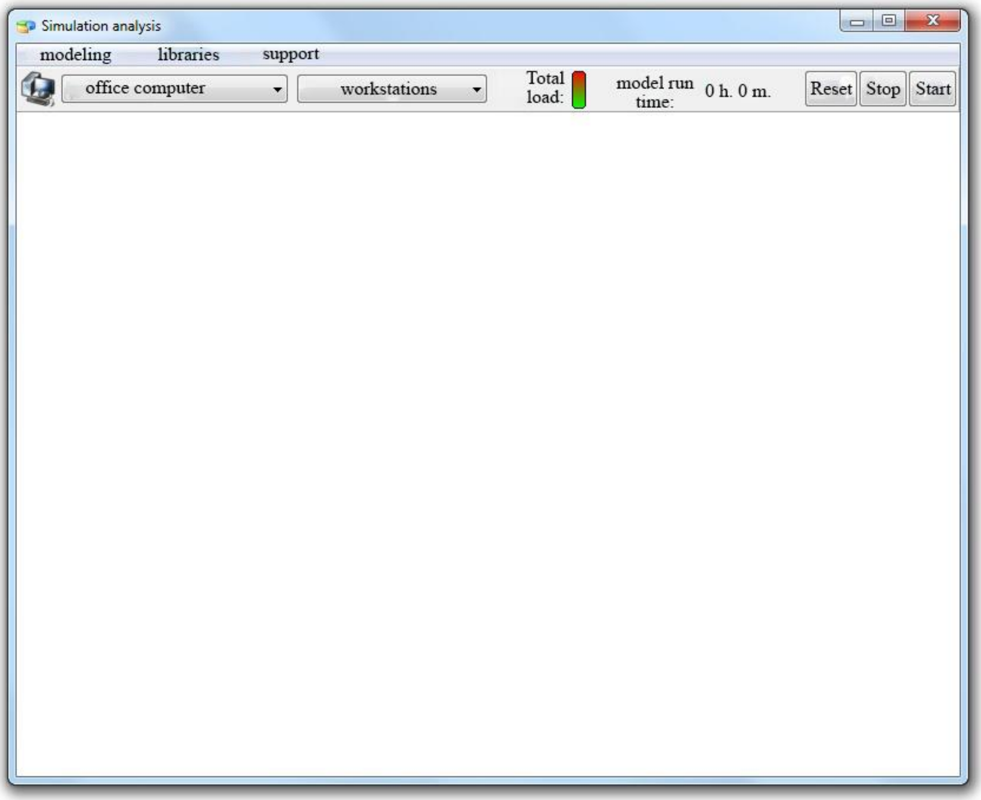


Fig.3. Working field of program.

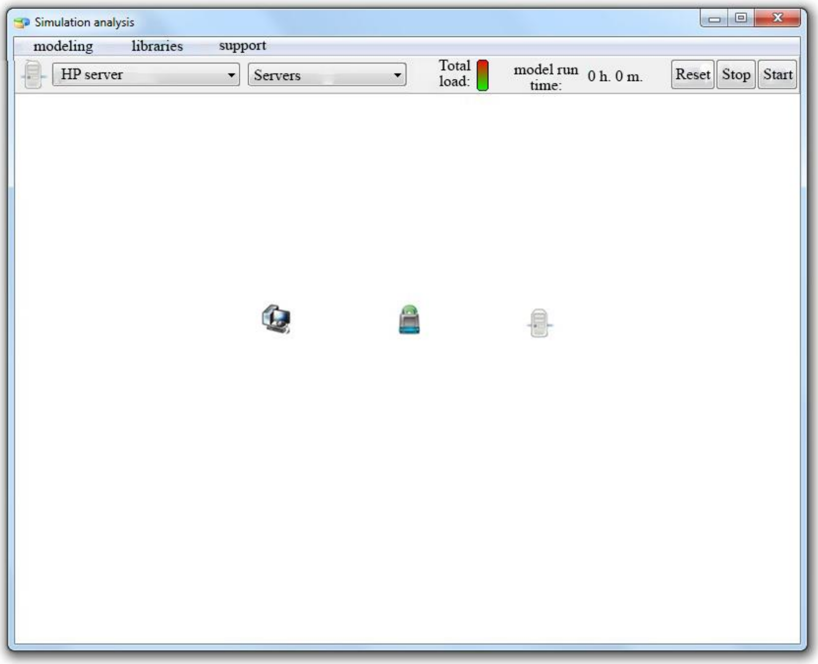


Fig.4. Devices taken on the working area.

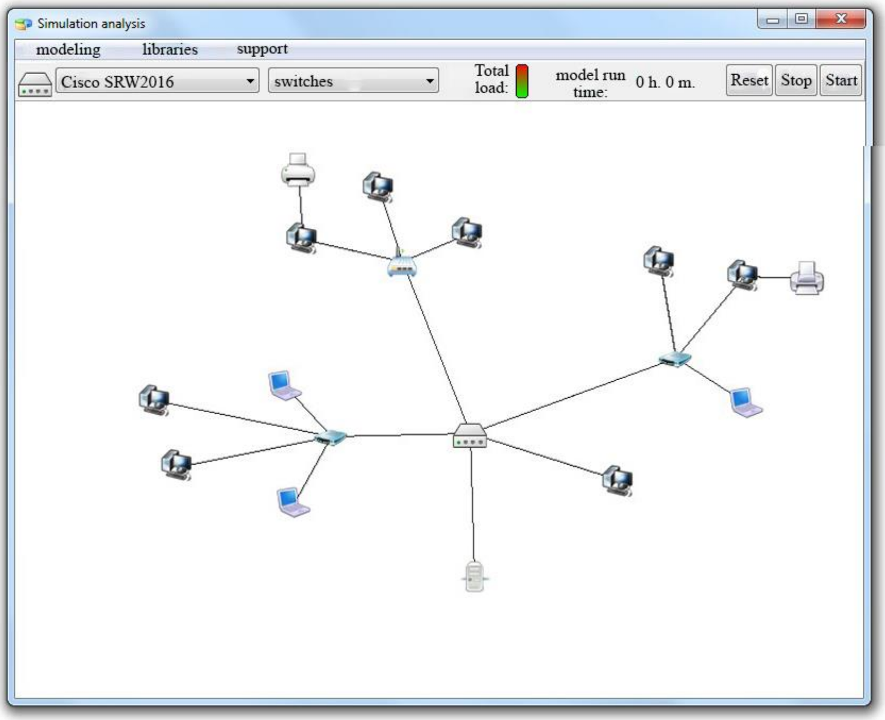


Fig.5.Example of simulated network.

Now we need to push all the necessary devices into the network activity. If we click on the device with the right mouse button, the context menu appears (Fig.6). This can move, delete, or display device properties.

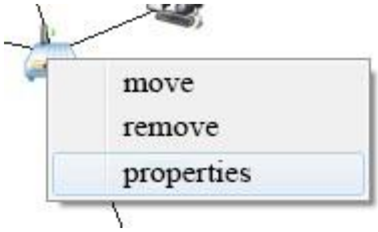


Fig.6. The context menu of the device.

The Properties window displays information about the device, its parameters and characteristics. We can also inspect here the network activity (Fig.7).

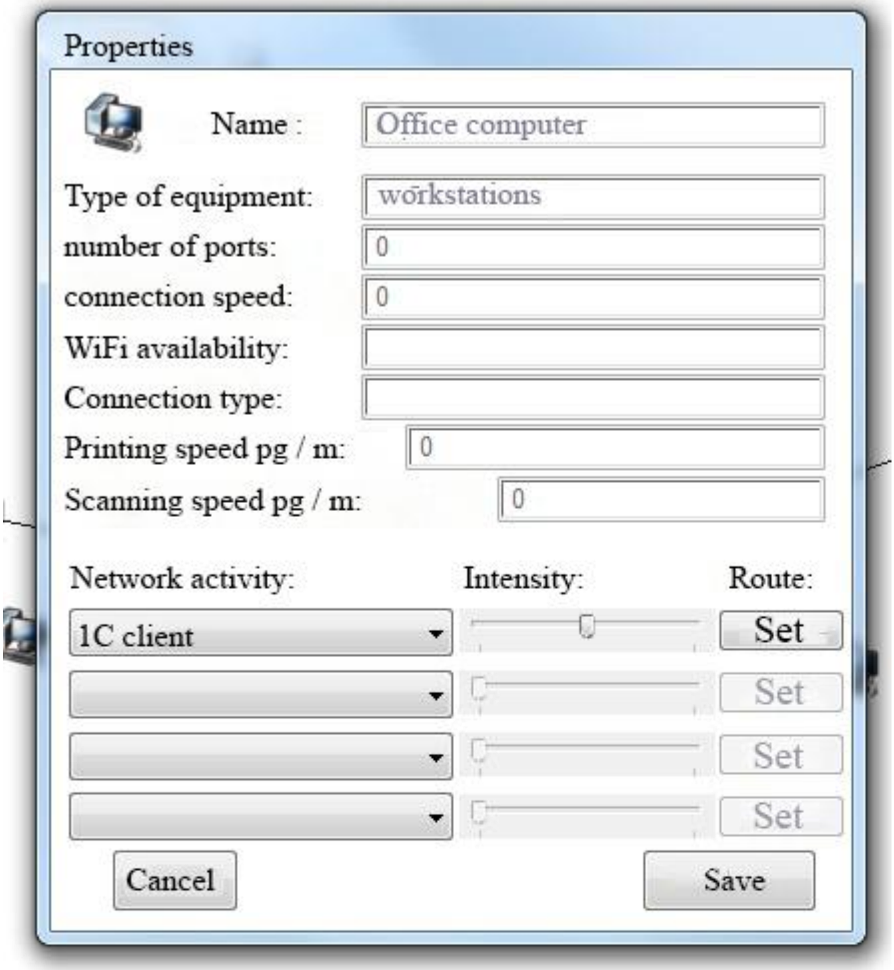


Fig.7. Window with properties of the device.

Each device can be set up to four modes of network activity. To do this, click on the desired drop-down list and select the desired network activity. This may be a client or a server 1C, file sharing, connecting to a remote desktop - in short, everything that is in the library of network activity. Selecting the network activity, we can set the intensity - if it is assumed that the work, for example, in a network 1C will be carried out without interruption, then choose a higher intensity. Here you can set the end point of the route of the package - for more detailed simulation (Fig.8).

Once all the necessary devices are assigned to network activity, we can proceed to the process of operating a computer network simulation in this model. At the right side of the top toolbar, users have access to the control buttons. We can start, pause and reset the simulation.On the left side of the buttons, a statistics is shown (overall network load) and simulation time [7].

During simulation of computer network, the user can make a real-time monitoring of network activity - it is expressed in packets that devices send each other. All this creates a burden on network equipment. In real time you can also look at the current level of load of a device (Fig.9).

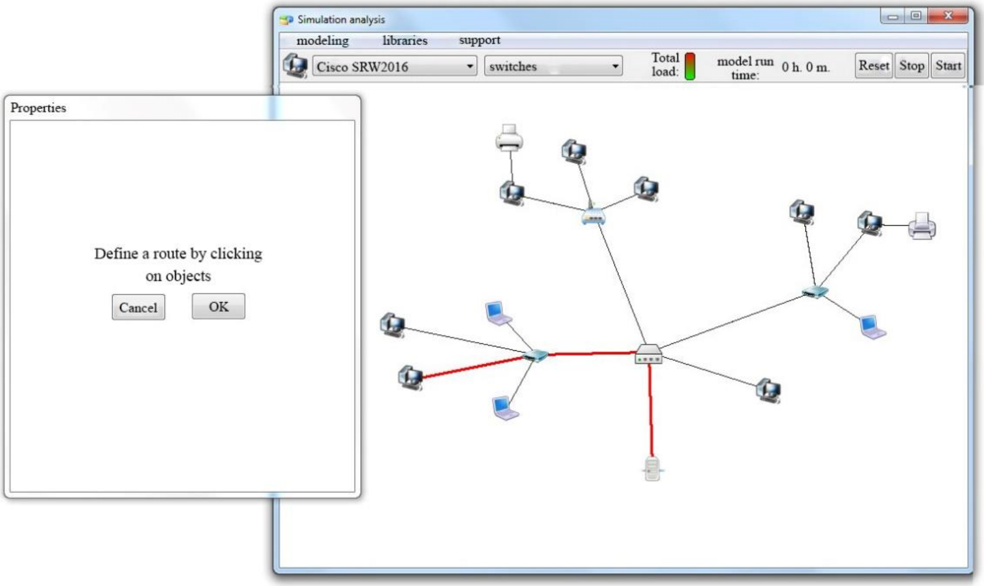


Fig.8. Route of chosen network activity.

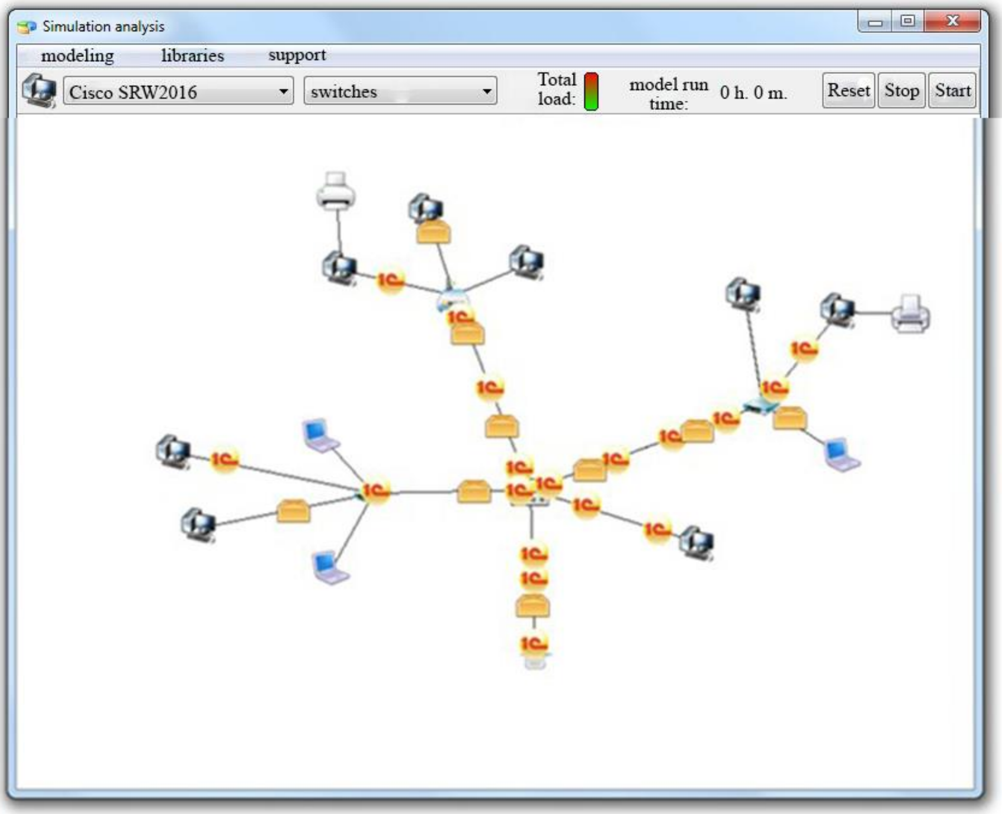
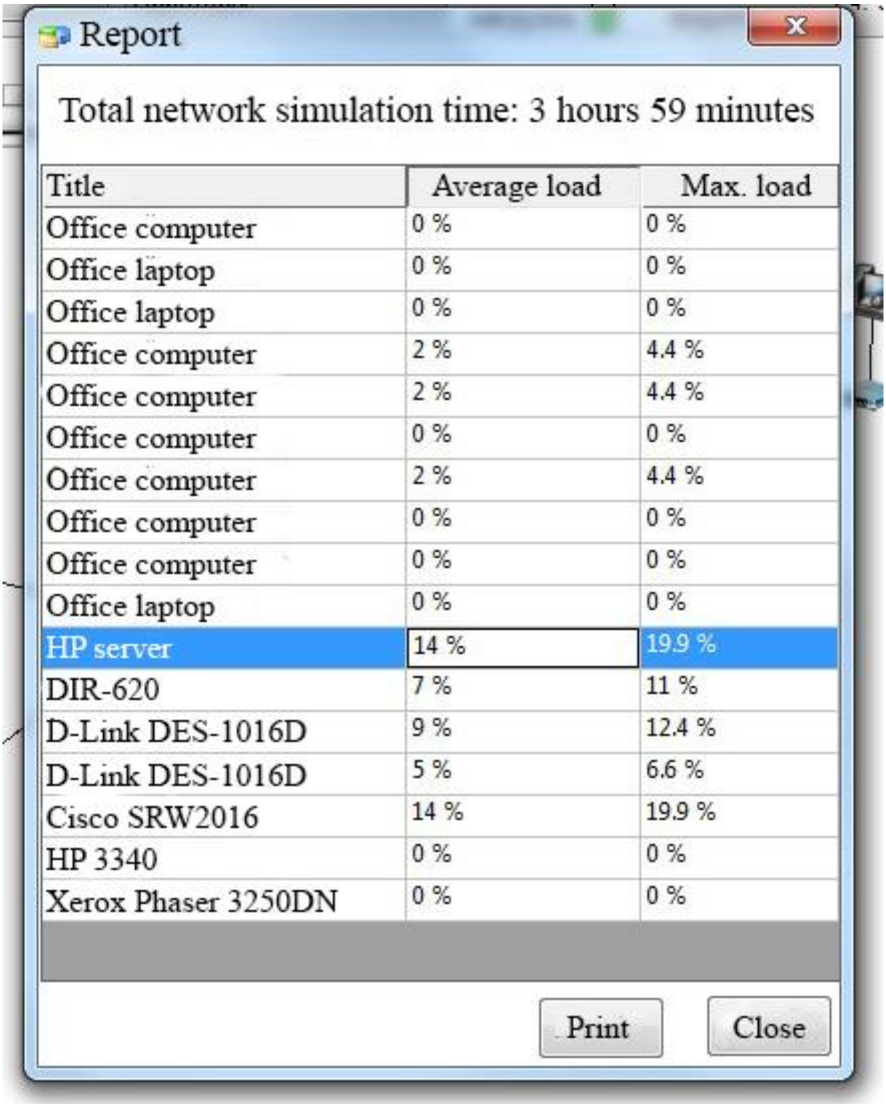


Fig.9. Simulation of network operation in action.

To view a consolidated report on the results of the simulation operation of the computer network, click "Stop". After that, a window appears asking to see the report. Click on "Yes". We will see a summary report with the results of the simulation (Fig.10).



Report

Total network simulation time: 3 hours 59 minutes

Title	Average load	Max. load
Office computer	0 %	0 %
Office laptop	0 %	0 %
Office laptop	0 %	0 %
Office computer	2 %	4.4 %
Office computer	2 %	4.4 %
Office computer	0 %	0 %
Office computer	2 %	4.4 %
Office computer	0 %	0 %
Office computer	0 %	0 %
Office laptop	0 %	0 %
HP server	14 %	19.9 %
DIR-620	7 %	11 %
D-Link DES-1016D	9 %	12.4 %
D-Link DES-1016D	5 %	6.6 %
Cisco SRW2016	14 %	19.9 %
HP 3340	0 %	0 %
Xerox Phaser 3250DN	0 %	0 %

Print Close

Fig.10. Results of the simulation of the network.

Conclusion

Based on the developed approach, there are opportunities for modeling computer networks. The created approach is implemented and the results of simulation are shown.

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Authors

Prof. Yakov Lvovich
Doctor of Sciences (Engineering), professor
Voronezh Institute of High Technologies
office@vivt.ru

Prof. Andrey Preobrazhenskiy
Doctor of Sciences (Engineering), associate professor,
Voronezh Institute of High Technologies
app@vivtl.ru

Ing. Juraj Štefanovič, PhD.
Faculty of Informatics, Pan-European University, Bratislava, Slovakia
juraj.stefanovic@paneurouni.com

ISSN: 2453-7497 (online)
ISSN 1338-6468