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A METHODOLOGY FOR THE DETERMINATION OF THE MODELS OF SOFT SYSTEMS BY MEANS OF INTELLIGENT AGENTS[1]

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Abstract

A methodology for determining models of a soft and ill-defined system is dealt with. The approach outlined is based on the model reconstruction by intelligent agents monitoring the trajectory of model behavior and reconstructing it to obtain models describing the real systems to be simulated. The methodology that has already proven its value by solving problems in various fields by applying it using a simulation system where it was implemented is dealt with. It is shown how effects among the various model elements can be tuned. This methodology may be of significant value in the field of micro- and macro-economy. The application of the procedure is illustrated on a small example utilizing high level Petri nets in an unconventional way.

Keywords: ill-defined systems, Petri nets, simulation, intelligent agents.

1. Introduction

In a wide range of fields, financial, marketing problems, environmental protection, micro-, and macro-economy, simulation can be used to investigate systems. Before starting the investigation it is a great problem very often to determine the model representing the real system adequately. In order to determine the appropriate model a methodology is applied which – starting from behavioral information – determines the internal description of the model. This can be undertaken by using historical data of the system behavior and comparing it to the trajectory of the simulation results.

In our approach the model consists of a network of interconnected model elements where the elements have parameters, functionalities and interact with each other. During the search for the adequate model:

- model element parameters and algorithms;

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- model structure (i.e. interconnection of the elements);
- interactions among the model elements

are to be changed.

The procedure based on the methodology applied for reconstructing the models is the application of intelligent agents (demons) monitoring the trajectory of the model behavior and modifying it until the adequate model is found [1]. The methodology with regard to the search of model structure and parameters has already been applied for solving practical problems in various fields [2] [3] [4]. The application of changing interaction among model elements has been elaborated recently [5] and its refinement is in progress.

The determination of adequate models is undertaken by a search in a multi-dimensional space in which the cardinality of the individual sets to be searched is very high in case of models with great complexity. However, it can be stated that in case of real problems the complexity of the models is usually very high so the heuristic search is practically always necessary.

2. Some Previous Investigations

In our previous investigations we have used AI controlled simulation to determine optimal solutions for problem solving in case of highly complex systems. A problem like that was to try to find strategies for the reduction of air pollution caused by urban traffic [3]. In *Fig. 1* the scheme of the simulation approach is illustrated, where the intelligent demon controlled CASSANDRA (Cognizant Adaptive Simulation System for Applications in Numerous Different Relevant Areas) 3.0 simulation system was applied. Here the traffic control conditions have been changed in order to obtain better results. This problem has been dealt with in the framework of a European Union project where the complexity of the model was extremely high, however, the model itself was not ill-defined.

Another previous investigation has been a preliminary study of traffic conditions influence interconnecting various regions [4]. Here the interdisciplinary nature of the problem and also the ill-defined character of the model had to be dealt with. In this case only the general or global parameters have been considered but also other social, macroeconomic parameters as capital, human resources, unemployment, number of enterprises, market conditions were taken into consideration.

3. Determination of the Model Structure

In the following the search for determining a model is shown. Here we do not aim either to show a real or artificially created model to be investigated but rather show the approach used on a simple example. The model structure is represented by a Knowledge Attributed Petri Net [6] where – among other properties – the tokens have attributes (which are observed in the input places and created in the

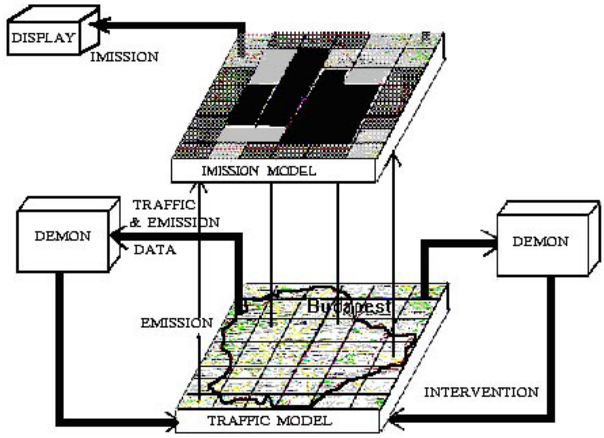


Fig. 1. Combined demon controlled traffic-air pollution model

output places by the transitions firing). There are also delays associated with the places. Thus it is possible to realize various functions with different – and even stochastic – delays thereby realistic mapping of practical problems can be performed conveniently. An unconventional approach presented here is that the token play in the model is used only as a vehicle for information transfer, i.e. the functions are realized in a way that the attributes of the created tokens are derived by using the attributes of the tokens in the input places of the respective transitions. This way the structure of the model corresponds to the functions realized.

The transition operations [6] [7] realize the effects among the model objects that can also be changed by the intelligent demon monitoring the model behavior during simulation, evaluating it and consequently changing the simulation model. In the following the methodology is illustrated on a simple example.

4. Small Example Illustrating the Methodology

Mainly model parameter and structure have been modified [2], [3] formerly in a number of problem solving applications of the methodology. In the following example the effects described by functions are modified until the adequate model is reached.

In the model there are some variables, which determine its behavior. Let some variables be inputs (x) and one variable output (y). The inner structure is unknown and the demon has the task to find the relationship between the inputs and output. The range in which the input-output relationship is searched is assumed to consist of a linear combination of three variables whose output can depend linearly, quadratically and as a square root function. The general formula for the relationship between the variables is the following:

$$y = \sum_{i=1}^{n} b_{\text{lin}_i} x_i + \sum_{i=1}^{n} b_{\text{quad}_i} x_i^2 + \sum_{i=1}^{n} b_{\text{root}_i} \sqrt{x_i} + b_0. \quad (1)$$

This means that the functional relationship is to be searched in this anticipated space.

The behavior of the system is shown in *Figs. 2a, 2b, 2c*. As the available dimensions for depicting the dependence of the output variable on three inputs do not enable to show it in a single picture, the input-output relationships are shown in three graphical representations.

The demon finds the relationship in 3 steps, it deals with only one variable in each step. In the first step the demon investigates the connection between the first input and the output. While the demon tries to find relationship between the input and the output, the connection remains between them.

5. Demon Structure for Determining the Adequate Model

In the following the structure of the demon reconstructing the model is briefly outlined. It tries to determine the structure, parameters and interrelations within the model to obtain one the behavior of which corresponds to the expected one.

As it is mentioned above both interrelations within the model and also parameters are changed. The block scheme of the demon architecture is shown in *Fig. 3*.

The demon algorithm is based on the modular structure, where the modules have special tasks and they are communicating with each other by messages. This structure is more advantageous than a monolithic one, because the modules can easily be changed, and the process of constructing is more flexible in case of a modular system. The first step to solve the problem is data collection from the model in order to find the appropriate model built from Petri Nets.

The structure can be built from different types of modules. There is an information collecting module, for monitoring the trajectory of the model behavior and providing a possibility for data postprocessing. There are some intervention modules, which can change both model parameters and/or structure, and the demon has inference engines with different search strategies and possibilities.

Fig. 3 shows the main aspects of the demon modules. The *Timer* module triggers the demon regularly, *CondOper* modules examine certain behavioral parameters, *CalcX* modules calculate the expected parameters and *AllConnect* module connects or disconnects the parts of the model objects.

During data collection the demon tries some values for the inputs and the model provides the corresponding output based on the model behavior. These outputs are stored and the demon calculates the parameters of the model to approximate those of the unknown one. The *Condition Operations (CondOper)* module helps

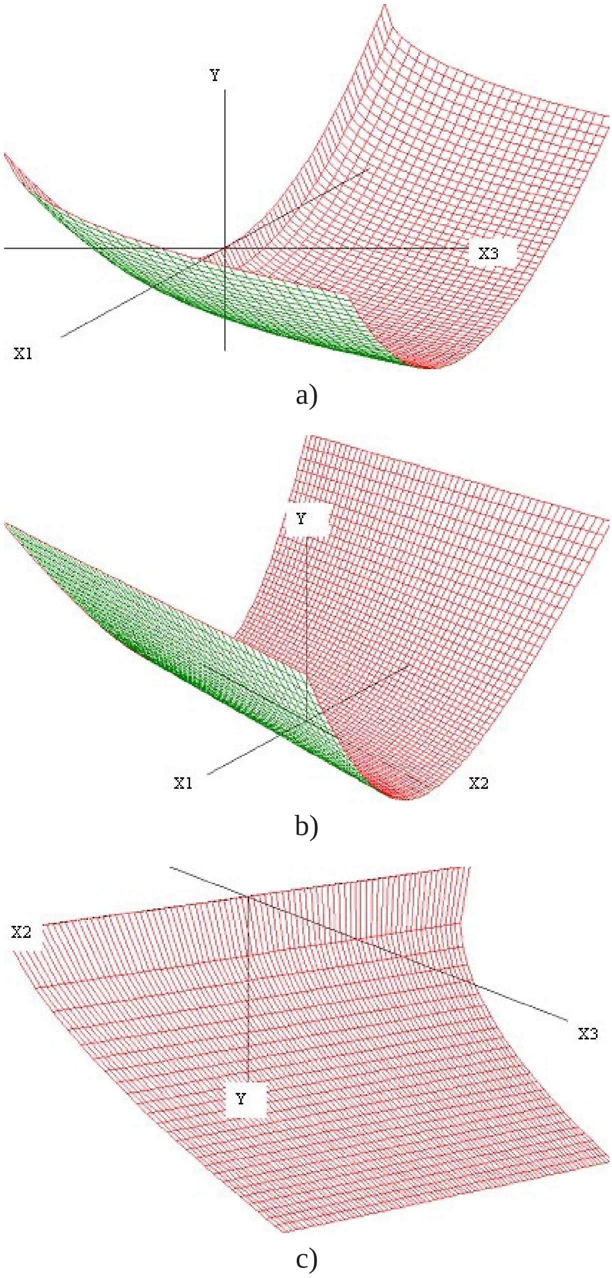


Fig. 2. Input-output relationships

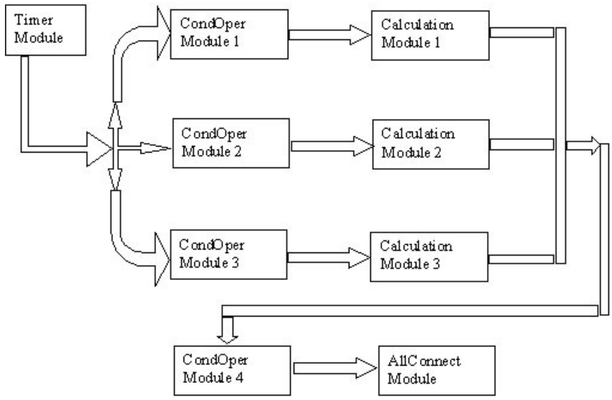


Fig. 3. Internal architecture of the demon applied

the demon to decide to connect or disconnect places and transitions, as different parts of the model. The decision of connection or disconnection is an intervention into the model to be taken before executing the simulation using the updated model version.

At the end of each decision step the demon executes the interventions using its action part. This action part can consist of more action modules. Some of them deal with system variable interventions, also these can overwrite the values of the system variables. Some of them deal with parameter interventions, also these execute the parametrical changes, and other modules execute the structural changes.

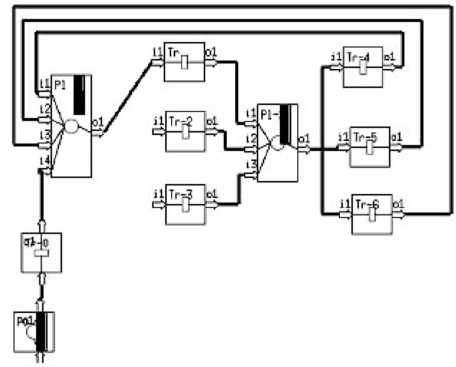
The *All Connection* module can modify the model structure. The possibility of changing the connection between different parts of the model is a very important feature of our approach. This provides a possibility for investigating various model structures. The demon may connect the output of a model element to several model element inputs or may interconnect an arbitrary model element output to another arbitrary model element input.

6. Searching the Model Structure Corresponding to the Function Describing the Operation of the Model

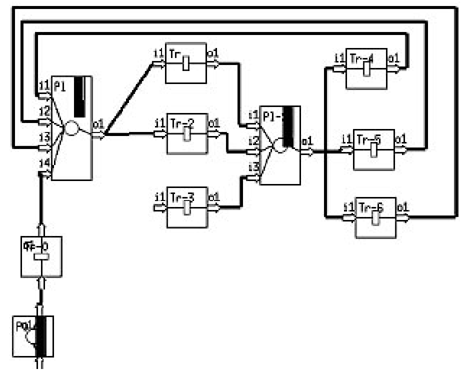
In *Figs. 4a, 4b, 4c* the structural changes during the search for finding the model corresponding to the system to be described adequately is shown. The model network is shown using the graphic representation of the model element objects of the CASSANDRA 3.0 simulation system.

The relationship between the first input and output is quadratic, and the coefficient of this function is 1.5. There are no other functional effects between them, also the relationship is clearly quadratic.

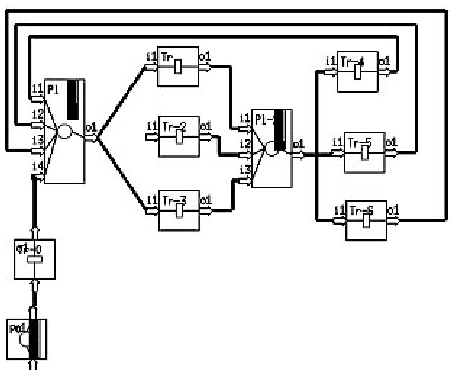
After the demon has found the relationship between the first input variable



a)



b)



c)

Fig. 4. Steps of the search procedure for determining the adequate model

and model output, it tries to find the relationship between the second input variable and output variable, as it can be seen in *Fig. 4b*.

There is no relationship between the second input and output, also the demon disconnects the connection between the second input variable and model output, and tries to find the relationship between the third input variable and output variable, as it can be seen in *Fig. 4c* and tries to create the connection with the third one. This provides the final version. After the search procedure has found the inner structure the demon connects and disconnects the output and input objects corresponding to the relationship between output and input variables. As it can be seen 2 connections: a line between the output object and the object representing the first input; and another line between the output and third input object have been chosen. This means that there is no relationship between the second input and the output variable.

The first relationship is a quadratic function and the parameters of the function can be seen in the following formula:

$$y = 1.5 \cdot x_1^2 + b_{0a}. \tag{2}$$

The second relationship is a root function by the following formula:

$$y = -2 \cdot \sqrt{x_3} + b_{0b}. \tag{3}$$

The sum of 2 constants is the following:

$$b_{0a} + b_{0b} = -3. \tag{4}$$

At the end of the simulation the demon found by the relationship described by the following formula

$$y = 1.5 \cdot x_1^2 - 2 \cdot \sqrt{x_3} - 3. \tag{5}$$

Finally, it should be mentioned that although in our small example the anticipated dependences of the output from the input variables are described in a polynomial form, but the methodology enables an arbitrary combination of functions – even empirically described ones – and in many practical problems this is the case.

7. Summary

The investigation of highly complex and ill-defined soft systems is becoming more and more significant in a large number of fields. This applies in particular to problems of economy and related social sciences. It is increasingly acknowledged that as a heuristic approach the tool for problem solving is simulation. In these cases the problem starts, however, already before the simulation experiment is started; with the determination of the model describing adequately the system to be investigated.

The solution proposed and applied in this contribution starts with an anticipated model or set of possible model structures based on certain information available already in advance and the model corresponding adequately to the real system to be investigated is to be investigated by reconstructing the model using intelligent agents. One crucial element of the method chosen and mentioned here is the object oriented nature of the models representing the target of the investigation. The network of objects – represented by a high level Petri net – provides a wide variety of possibilities which can be utilized in various fields of applications. The work presented here is a part of investigations based on a scientific philosophy of inductive-deductive view. By this we mean that specific problems from various areas are collected and it is intended to find solutions which can be applied in a large class of problems. The results achieved up to now are promising. That means that beyond solving problems in concrete areas further results in various fields are to be anticipated.

Many systems may be investigated by simulation in a wide range of fields, e.g. financial, marketing problems, micro-, and macroeconomy [8] [9] [10]. It is highly advantageous to use behavior oriented simulation model descriptions which can be applied in system synthesis [11] [12]. The difficulty of determining the optimal solution is caused not only by the high complexity of the models but also by the facts that the systems are ill-defined. In such cases before investigating the operation and performance of the model by simulation it is a necessary and also difficult problem to determine the adequate model itself before starting the investigation.

In our approach the demons execute their task by changing model structure, parameters and functionalities characterizing the cause effect interrelations among the objects of the model structure. This approach can be applied in a wide variety of fields including informatics and telecommunication networks, human conflicts concerned with peace and/or war as well.

References

[1] JÁVOR, A., Demon Controlled Simulation, *Mathematics and Computers in Simulation*, **34** (1992), pp. 283–296.

[2] SZŰCS, G. – VIGH, Á., Simulation of a Quality Controlled Manufacturing and Assembly System, *Systems Analysis Modelling Simulation*, **18–19** (1995), pp. 279–282.

[3] JÁVOR, A. – SZŰCS, G., Simulation and Optimization of Urban Traffic Using AI, *Mathematics and Computers in Simulation*, **46** (1998), pp. 13–21.

[4] JÁVOR, A. – MÉSZÁROS–KOMÁROMY, G., Investigation of the Influence of the Road Traffic Network Conditions on the Development of Regions by Means of AI Controlled Simulation, *AIS'2002, Simulation and Planning in High Autonomy Systems*, April 7–10, 2002, Lisbon, Portugal, pp. 86–90.

[5] SZŰCS, G., Szimulációs modell struktúra felépítés intelligens démon segítségével, Intelligens rendszerek, hatékony alkalmazások, Budapesti Műszaki és Gazdaságtudományi Egyetem, Információmenedzsment Tanszék, Budapest, 2001, pp. 251–260.

[6] JÁVOR, A., Knowledge Attributed Petri Nets, *System Analysis, Modelling, Simulation*, **13** (1993) 1/2, pp. 5–12.

[7] BILLINGTON, J. – WHEELER, G. R. – WILBURHAM, M. C., PROTEAN: A High-level Petri Net Tool for the Specification and Verification of Protocols, *IEEE Trans. Software Eng.*, **14** (1988), pp. 301–316.

[8] MEIER, R. C. – NEWELL, W. T. – PAZER, H. L., *Szimuláció a vállalati gazdálkodásban és a közgazdaságtanban*, Közgazdasági és Jogi Kiadó, Budapest, 1973.
[9] IVACHENKO, A. G. – KOZUBOVSKI, S. F. – KOSTENKO, YU. V., Objective System Analysis of Macroeconomic System, *System Analysis Modelling Simulation*, **7**, (1990), No. 3., pp. 201–206.
[10] CAMPISI, D. – GASTALDI, M. – LUDOVICI, B. – BELLA, A. – SCHACHTER, G., Structural Change and Regional Development: An Analysis of the Italian Economy, *System Analysis Modelling Simulation*, **16** (1994), No. 2., pp. 141–152.
[11] KERESZTES, P., Value Trace VHDL Blocks and their Application in High Level Synthesis, *Proc. of 2nd Workshop on Libraries, Component Modeling and Quality Assurance*, Toledo, Spain, April 1997, pp. 225–232.
[12] KERESZTES, P. – ÁGOTAI, I., The Concept of Superprocesses for High Level Synthesis and VHDL Modelling, *Proc. of EURO-VHDL Conference*, Hamburg, 1993.