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The introduction to the modeling and simulation of a virtual company

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Abstract The motivation of this paper is to introduce basic concepts of the modeling and simulation concerning simple business processes of a generic business company. The novel method described in this paper is the basis for further research at Silesian University in Opava, School of Business Administration in Karvina, Department of Informatics supported by grant SGS/06/2013 during 2013-14 periods. The subject of the presented research direction is the selling part of the whole company structure. JADE framework was used to include multi-agent technology into the simulation. Multi-agent system was developed in order to serve as a simulation framework and to ensure a basic platform for simulation experiments. The aim of the paper is to research a possible way of modeling and simulation of business processes using intelligent agents. The results obtained show that agent-based modeling and simulation methods could be successfully used for the efficient running control of business processes and for predictive purposes. This allows supporting the decision making processes of company's management. The results obtained could be seen as a first step of a management support tool development.

Keywords modeling and simulation, business process, business company, prediction, agents, JADE, multi-agent, framework, implementation

1. INTRODUCTION

The importance of business systems modeling has been rapidly growing recently because of globalization. The managements of business companies have to increase flexibility and the decision speed in order to keep pace with the development on the markets. The complexity of business operations often does not allow for taking measures without known impacts of such decisions. This is where the modeling and simulations find their place (e.g. Suchanek 2011). While analytical modeling approaches are based mostly on the mathematical theories (Gries et al. 2011, Liu and Trivedi 2011) our approach is based on experimental simulations.

The simulations we experiment with could be described as agent-based simulations (Macal and North 2005, Yan et al. 2001) of business processes. Usual business process simulation approaches are based on the statistical calculation (e.g. Scheer and Nuttgens 2000). In our opinion only several problems can be identified while using this method. As shown in Sierhuis (2001) there is a lot of other influences that cannot be captured by using typical business process models (e.g. the effects of the collaboration of business process participants or their communication, experience level, cultural or social factors). Statistical methods have also limited capabilities of visual presentation while running simulation. Finally, we do not actually see the participants of business process dealing with each other.

Agent-based simulations and their usage in a simulation of a company can bring several crucial advantages (Sierhuis 2001, DeSnoo 2005, Jennings et al. 2000, Moreno et al. 2003), and can overcome some of the problems identified in the previous paragraph. Software agents representing business process participants are more accordant with people and can model issues like communication, coordination or cooperation. These are the basic characteristics of a multi-agent system (MAS). Intelligent software agents can also be specialized (e.g. adaptability in a new environment or in life experience). They are able to plan the assigned tasks or to assign the work to other agents. They are suitable for the modeling of interruptions or human behavior (e.g. basic needs, personal characteristics). In an agent-based simulation, which is set in a virtual environment, possible non-modeled behaviors can emerge (e.g. an agent carrying apples can be affected by other agents that are blocking the way). Interesting MAS feature often causing unexpected results of the overall system is the emergency. Intelligence of MAS is created emergently during the interaction both among the agents themselves, with their environment, and its components.

We used the control loop paradigm (Barnett 2003, Vymetal and Sperka 2011, Wolf 2006) of generic business company for the simulations. The control loop consists of controlled units like sales, purchase, production and others managed by a regulator unit (the management of the company). The outputs of the controlled units are measured by the measuring unit and compared with the key performance indicators (KPIs). The differences found are sent to the regulator unit, which takes the necessary measures in order to keep the system in the closeness to the KPI values. However, it was shown that a business company must be looked upon as a system with social functions and responsibilities, where individuals besides the company KPIs also follow their personal aims and preferences (e.g. the paper from Sharma et al. 2009, summarizing the Corporate Social Responsibility research of many other authors). The same can be observed in the market, where the customers and the suppliers follow their own targets. Further influences of the environment, like government decisions, global market fluctuations and others also influence the modeled system. Thus, as a result we have to work with rather stochastic system.

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The previous research results of our approach to this challenge using software agents were presented in the Vymetal and Sperka (2011). We reported on more issues dealing with the business process and financial market simulations (Vymetal et al. 2012, Vymetal 2011, Spisak and Sperka 2011). Business process simulation framework called MAREA was implemented and described recently in the Vymetal and Scheller (2012). This software application uses before mentioned control loop as a core principle. The architecture is based on the intelligent agent paradigm in order to simulate the human behavior and the market disturbances.

The motivation of this paper was to use the agent technology for the modeling and simulation of simple selling business process in order to obtain KPIs values. This could be used to improve decision making processes of the company's management. For our research work, a multi-agent system was implemented, which is able to deal with unpredictable phenomena surrounding every company nowadays. To achieve this goal, we use various types of agent's behavior. The structure of the paper is as follows. In the second section the business process simulation, mathematical model, and JADE framework are described. In the third section the agent's implementation is presented. Finally, the simulation results are discussed.

2. SIMULATION FRAMEWORK DESCRIPTION

Business Process Simulation Model (BPSM) described in this section is based on the aforementioned control loop paradigm. Market conditions as well as the customers' behavior are seen as an external part of the modeled system while the internal company behavior is subject to the simulation. We simulate core business processes of a business company like selling the goods to the customers as a part of the whole control loop (Fig. 1). Multi-agent system is implemented in order to serve as a BPM simulation framework. The subject of the simulation presented in this paper consists of the seller agents, customer agent types, the informative agent, and the manager agent. It represents the sales controlled component of the generic model. Seller agent interacts with the customer agent according to the standardized FIPA contract-net protocol (FIPA, 2002). This simplified system was extended by the disturbances influencing the agents' behavior. The disturbances occurrence is random and the number of customer agents is significantly higher than the number of seller agents. Under these circumstances the whole system can be described as a stochastic system.

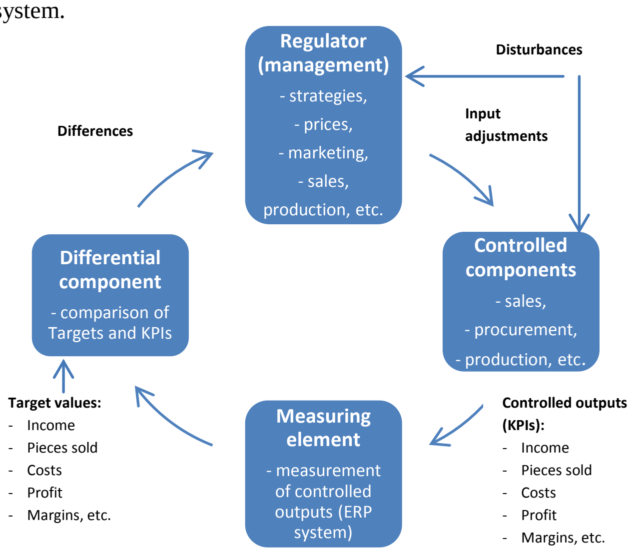

Fig. 1. Generic model of a business company (source: own)

The behavior of agents in the simulation framework is influenced by two randomly generated parameters using normal distribution. The influence of randomly generated parameters on the simulation outputs while using different kinds of distributions is presented in our previous works e.g. Vymetal et al. (2012). The normal distribution seems to be optimal for modeling real business processes.

The overall workflow of the system proposed can be described as follows. The customer agents randomly generate the requests to buy some random pieces of goods. Seller agents react to these requests according to their own internal decision functions and follow the contracting. The purpose of the manager agent is to manage the requests exchange. The contracting results in the sales events to the customers. More attributes of sales like costs, pieces sold, revenue, and gross profit are analysed. These KPI attributes results could be used for further analysis. Especially in a situation, when real business data are not available.

2.1 Mathematical model

The simplified model used to illustrate our assertions takes only one kind of stock item into consideration depicted by simulation experiments. The amount of stock items is not limited. As many pieces the customer wants to buy, so many he gets. The sellers-to-customers ratio was chosen as 1:10 - one seller serves for 10 customers. The customers were joined into groups. Each group is being served by a certain seller. None of the agents can change its counterpart. In each period turn (here we assume a week) the customer agent randomly decides whether to start buying process or not. If the customer decides not to buy anything, his turn is over. Otherwise he creates a sales request and sends it to his seller. The seller agent answers with the proposal message (a quote starting with his maximal price using limit price parameter such as – *limit_price * 1.25*). This quote can be accepted by the customer or not. An acceptation is decided due to the valuation of a customer production function, which can be formalized like in the Vymetal et al. (2012) as follows:

$$c_n^m = \frac{\tau_n T_n \gamma \rho_m}{O v_n} \qquad (1)$$

c_n^m - price of *n*-th product offered by *m*-th seller,

τ_n - market share of the company for *n*-th product $0 < \tau_n < 1$,

T_n - market volume for *n*-th product in local currency,

γ - competition coefficient, lowering the success of the sale $0 < \gamma \leq 1$,

ρ_m - *m*-th sales representative ability to sell, $0.5 \leq \rho_m \leq 2$,

O – number of sales orders for the simulated time,

v_n - average quantity of the *n*-th product, ordered by *i*-th customer from *m*-th seller.

The proposed price must be less or equal the calculated price (on behalf of the customer production function). If the price is acceptable, the contract is awarded, otherwise not. If the price or the quantity is not accepted by the customer, a rejection message is send to the seller. In such case, the seller decreases the price to the average of the limit price and the current price (in every iteration is getting effectively closer and closer to the limit price) and resends the quote back to the customer. The message exchange repeats until there is an agreement or a reserved time elapses.

The seller is responsible to the manager agent. The manager agent gathers data from all sellers each turn and evaluates the state of the company situation. These data are the result of the simulation experiment. The BPM simulation outputs serve to understand the company behavior in a time. Different simulation outputs depending on the agents' decisions, parameters, and behavior can be obtained. The customer agents need to know some information about the market (e.g. company's market share). This information is provided by the informative agent. This agent is also responsible for the turn management.

When simulating the unpredictable phenomena, the multi-agent system framework uses randomly (or pseudo randomly) generated data from the normal distribution. They provide the critical aspect of the uncertainty in a deterministic world. We have chosen two important agents attributes to be generated by the pseudorandom generator. These are sellers' agent ability and customers' agent decided quantity for purchase.

2.2 JADE

The agent platform JADE (Bellifemine et al. 2007) was chosen for the implementation, because it is a real tool for rapid agent development. There is not only communication language involved in JADE, but the whole platform for agents' deployment is present. This includes the runtime environment, where agents exist, libraries to write the source code, and also graphical tools to administrate them and to monitor their state.

JADE was developed by Telecom Italia in 1998, and it is still in development progress. Current version used, is the 4th. The agents' communication language is FIPA ACL. The runtime environment running instance is called a container. It is possible that more than one container is running at the same time. All active containers are called the platform. Every platform has always active one special "Main container" and all other containers know where to find it. Agents are located in containers (Fig. 2). There are two special types of agents – AMS (Agent Management System) agent provides the naming service and represents the authority in the platform. AMS also acts as the DF (Directory Facilitator) providing the Yellow Pages. Yellow Pages enable agents to seek the other ones and to provide the services they need to be able to achieve their goals.

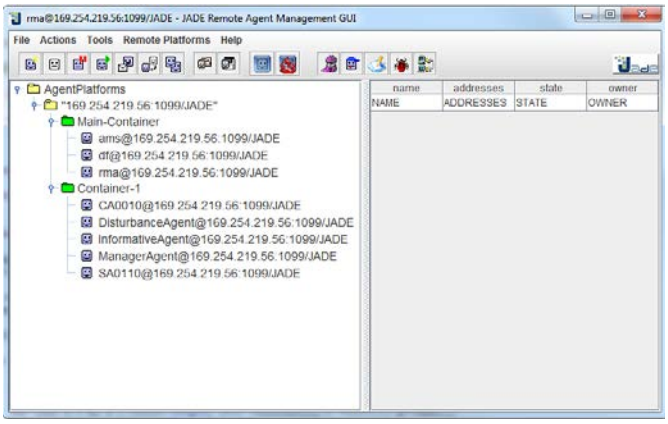

Fig. 2. JADE running environment with two containers (source: own)

Every agent is a Java class – descendant of base JADE class "Agent". Its behavior is implemented in private subclasses of the concrete "Agent" class extension. This behavior extends JADE class "Behaviour". Every agent in JADE is implemented as single Java thread. The thread depends on its encapsulation. Behaviors are private subclasses of the thread. This eliminates all synchronization issues between concurrent behaviors accessing same resources and between behavior and its agent. Thus, behavior scheduling is not pre-emptive (as for Java class) but cooperative. When one behavior is in execution, it runs until returns. Programmer must define when agent switches from one behavior to another one. On the other hand the switch from one behavior to next one is very much faster than the Java thread switch. In the next section is the agents' implementation presented in detail.

3. MULTI-AGENT SYSTEM

Agents in the multi-agent system are situated in two levels. Base agent, ancestor of all BPM agents is the "BaseBpmAgent". It has implemented base functionality, such as registering to the Yellow Pages, searching for other agents, clean-up and more. All the existing agents in the system are descendants of this class.

Detailed BPM workflow is described in the form of the sequence diagram (Fig. 3) as follows. Customer agent, as in the real market, is the engine of the process. Each turn (week) it decides whether he will buy something. If so, he decides the quantity and sends the request to his seller (in JADE called CFP = call for proposal). After this the above mentioned negotiation with the seller takes place and the result is a rejection or a selling transaction. Once this negotiation was done, the turn for the specific agent finishes. When all the customer agents finish their negotiations, the turn (week) is over.

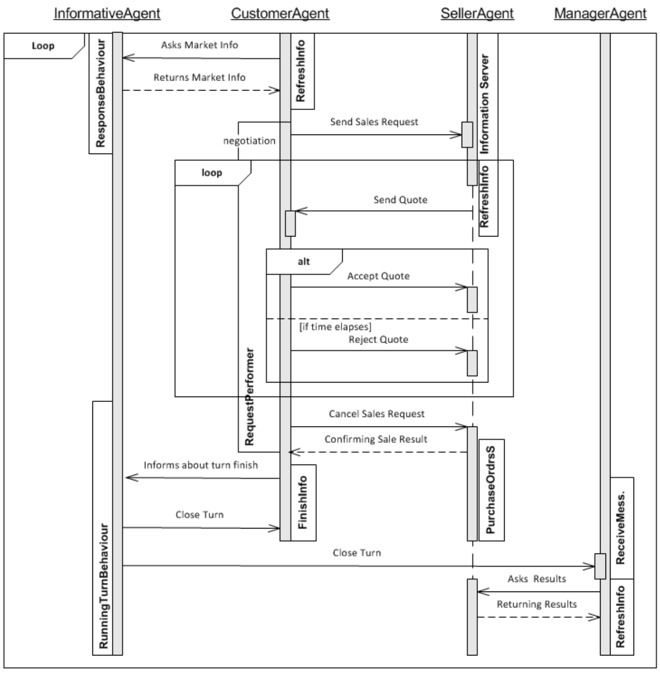

Fig. 3. BPM workflow sequence diagram (source: own)

To make its decision, customer agent needs information about the market – here the information agent comes. This information agent is responsible for giving information about the market to the customer agent (using behavior "ResponseBehavior"), but also for the timing. This agent decides when the turn (week) finishes and gives the information to all agents to prepare for another turn. Also it keeps in mind that the running model period is one year (52 weeks, using behavior "RunningTurnBehavior"). After this period it sends the info about "GameOver" (implemented in "BaseBpmAgent") and agents finish their functionality.

The customer agent has defined 4 types of behavior:

1. **RefreshInfo** – this behavior gets the current information about the market. After informing the agent following behavior is started.
2. **RequestPerformer** – the negotiation with the seller agent.
3. **ReceiveMessages** – used to obtain the information from the information agent.

4. **FinishInfo** – informs the information agent that the turn is over for this customer agent.

On the other hand the seller agent is in semi-sleep state and waiting. Once it has a request, immediately replies to the customer agent with the appropriate price and then waits again till the communication finishes. Actually, this agent is not aware of the turn (week) itself. It is informed by the manager agent asking for the report of the week work summary. This agent implements 3 server behaviors:

1. **OfferRequestsServer** – reads CFP messages from the customers and negotiates with them.
2. **PurchaseOrdersServer** – sells the goods (we don't have the limitation of the goods amount on the stock at this stage).
3. **InformationServer** – informs the manager agent about its success in the selling each week.

Once per turn manager agent asks all the sellers about their success. After this, it values the company situation and makes the report about the state.

4. SIMULATION RESULTS

One year of trading processes (52 weeks) was simulated in several simulation experiments. For each experiment the same parameterization was used. The obtained BPM simulation KPI values were different from case to case. We can see the results in the aggregated form in Table 1. Three types of final results in the three rows are presented. Four types of KPIs were counted at the end of the year (Pieces sold, Revenue, Costs and Gross Profit values). In the first row of Table 1 the sum values of KPIs are recorded. In the second row the average and in the third row the standard deviation values are listed. Similar KPI values achieve real companies on the real markets.

Tab. 1. Aggregated KPI values in 52 weeks (source: own)

	Pieces sold	Revenue (CZK)	Costs (CZK)	Gross Profit (CZK)
SUM	1969	12306,25	7876	4430,25
AVG	37,87	236,66	151,46	85,2
Std. dev.	14,68	91,73	58,7	33,02

Typical KPI functions are presented in Figure 4. More important than absolute numbers is the course of KPI functions. The one year curves show similar trends. Sharp fluctuations are typical for the current situation on the markets. They represent disturbances. The companies have to deal with these disturbances in order to survive. Therefore the agent-based BPM simulation shows fluctuating trend in KPI functions.

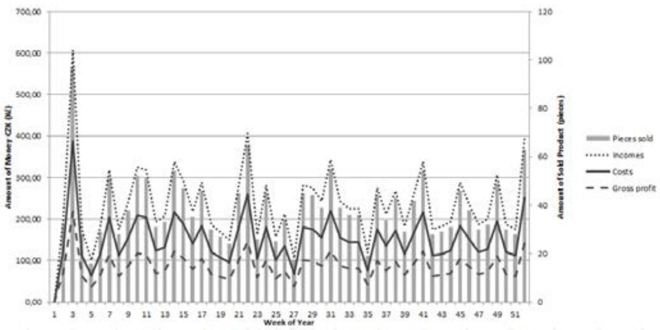

Fig. 4. KPI values. One year of trading is presented (source: own)

Practical usability of the simulation framework proposed can provide predictive possibilities in decision making process. Any business company can use it to predict KPI values at a certain time. The accuracy of such simulation depends on the parameterization. The main user task when setting up the framework is to accurately define the number of agents and behavior attributes according to Equation 1. The lack of some parameters can be replaced by random values generation. It is not necessary to dispose with all parameters.

5. CONCLUSION

This paper presents agent-based modeling and simulation of business processes. Multi-agent system was developed to support several simulation experiments dealing with selling part of a generic business company. The motivation was to simulate simple selling business processes in order to obtain key performance indicators (income, costs, revenue, sold pieces) in one year of trading behavior. The simulations were examined in JADE simulation framework. The idea is based on the precise parameterization of the framework. The results obtained show that using such framework can lead to real outputs. The outputs can be used for improving the decision making process, and to predictive purposes in business companies.

Our future research will extend the covered area to the buying processes, verification and validation of proposed approach.

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