TOWARDS A JAVA SIMULATION EXPERIMENT WITH AGENT-BASED TRADING PROCESSES

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ABSTRACT

The motivation of the paper is to introduce an agent-based business process model in the Java simulation experiment. A virtual company trading processes are simulated in order to use proposed methods as a part of a decision support tool. As in other cases, such simulation needs sufficient input parameters. However, in the case of business systems, real business parameters are not always available. Therefore, multi-agent system as a simulation framework, often operates with randomly (resp. pseudo randomly) generated data. Some of the business process simulation inputs are randomly generated in this paper. This method can also represent unpredictable phenomena. The core of the paper is to introduce the business process simulation implementation (simulation framework) and the simulation results. Finally, obtained results after the validation show that using business process model and the implementation proposed can lead to the correct output data and therefore can be used to simulate real business processes.

INTRODUCTION

Simulations used in the experiments in the paper could be described as agent-based simulations (Macal and North 2005) of Business Process Management (BPM). Business process is an activity adding the value to the company. Usual business process simulation approaches are based on the statistical calculation (e.g. Scheer and Nuttgens 2000). But only a few problems can be identified while using the statistical methods. There are a lot of other influences which are not able to be captured by using any business process model (e.g. the effects of the collaboration of business process participants or their communication, experience level, cultural or social factors). This method has only limited capabilities of visual presentation while running the simulation. Finally, an observer does not actually see the participants of business process dealing with each other.

Agent-based simulations dealing with a company simulation can bring several crucial advantages (De Snoo 2005), (Jennings et al. 2000). They can overcome some of the problems identified herein above. It is possible to involve unpredictable disturbance of the environment into the simulation with the agents. All of the mentioned issues are the characteristics of a multi-agent system (MAS).

One of the problems the simulations of business processes tackle with is the lack of real business data. Many researchers (Hillston 2003), (Yuan and Madsen 2010) use randomly generated data instead. On the basis of our previous research, we use a normal distribution in our simulation experiments. We reported on more issues dealing with the business process and financial market simulations (Sperka and Spisak 2011), (Vymetal and Sperka 2011). The simulation approach described in this paper uses a generic structure model of a company (Vymetal and Sperka 2011), (Barnett 2003) as a core principle. The influence of randomly generated parameters on the simulation outputs while using different kinds of distributions is presented in (Vymetal et al. 2012).

The novel methodology and the workflow described in this paper are implemented in the form of MAS (Wooldridge 2009). JADE (Bellifemine et al. 2010) development platform was chosen for the realization. JADE provides robust running and simulation environment allowing the distribution of thousands of software agents. Multi-agent system is used as a BPM framework in this paper. When finished, it shall cover the whole company structure from the supply of the material, through the production process, up to the selling and shipment. The overall idea of the proposed methodology is to simulate real business processes and to provide predictive results concerning the management impact. This should lead to the improved and effective business process realization. For the validation of simulation results real business data are used.

This paper is structured as follows. Section 2 briefly informs about the simulation framework. Multi-agent system implementation and the description of the production function are presented in Section 3. In Section 4 the simulation parameters and the results are introduced. In Section 5 the validation of the simulation

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results is presented. At the end, the conclusion and future research steps find their places.

SIMULATION FRAMEWORK

To ensure the outputs of the simulations a simulation framework was implemented and used to trigger the simulation experiments. The framework covers business processes supporting the selling of goods by company sales representatives to the customers (Fig. 1). It consists of the following types of agents: sales representative agents (representing sellers, sales reps), customer agents, an informative agent (provides information about the company market share, and company volume), and manager agent (manages the communication between seller and customer). All the agent types are developed according to the multi-agent approach. The interaction between agents is based on the FIPA contract-net protocol (FIPA 2002).

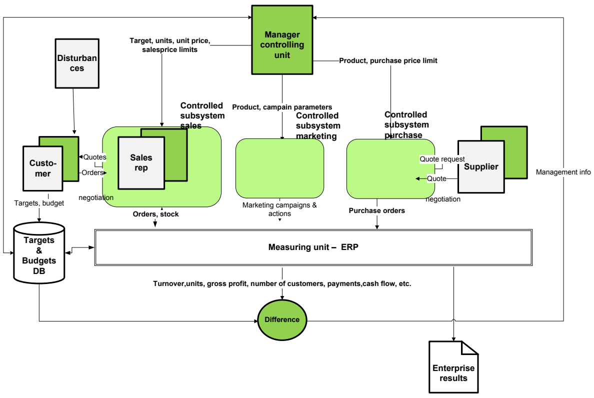

Figure 1: Generic model of a business company (Source: adapted from Šperka et al. 2013).

The number of customer agents is significantly higher than the number of sales representative agents in the model because the reality on the market is the same. The behavior of agents is influenced by two randomly generated parameters using the normal distribution (an amount of requested goods and a sellers' ability to sell the goods). In the lack of real information about the business company, there is a possibility to randomly generate different parameters (e.g. company market share for the product, market volume for the product in local currency, or a quality parameter of the seller). The influence of randomly generated parameters on the simulation outputs while using different types of distributions was presented in (Vymetal et al. 2012).

PRODUCTION FUNCTION DESCRIPTION

In this section, the mathematical definition of a production function is proposed. Production function is used during the contracting phase of agents' interaction. It serves to set up the limit price of the customer agent as an internal private parameter.

Only one part of the company's generic structure, defined earlier, was implemented. This part consists of the sales reps and the customers trading with stock items (e.g. tables, chairs). One stock item simplification is used in the implementation. Participants of the contracting business process in our system are represented by the software agents - the seller and customer agents interacting in course of the quotation, negotiation and contracting. There is an interaction between them. The behavior of the customer agent is characterized in our case by proposed customer production function (Equation 1).

Each period turn (here we assume a week), the customer agent decides whether to buy something. His decision is defined randomly. If the customer agent decides not to buy anything, his turn is over; otherwise he creates a sales request and sends it to his seller agent. The seller agent answers with a proposal message (a certain quote starting with his maximal price - limit price * 1.25). This quote can be accepted by the customer agent or not. The customer agents evaluate the quotes according to the production function. The production function was proposed to reflect the enterprise market share for the product quoted (a market share parameter), sales reps' ability to negotiate, total market volume for the product quoted etc. (in e.g. Vymetal and Sperka 2011). If the price quoted is lower than the customer's price obtained as a result of the production function, the quote is accepted. In the opposite case, the customer rejects the quote and a negotiation is started. The seller agent decreases the price to the average of the minimal limit price and the current price (in every iteration is getting effectively closer and closer to the minimal limit price), and resends the quote back to the customer. The message exchange repeats until there is an agreement or a reserved time passes.

The sales production function for the *m*-th sales representative pertaining to the *i*-th customer determines the price that the *i*-th customer accepts (adjusted according to Vymetal et al. 2012).

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

Where:

c_n^m - a price of the *n-th* product quoted by the *m-th* sales representative,

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

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

γ - a competition coefficient lowering the sales success $0 < \gamma \leq 1$,

ρ_m - a quality parameter of the *m-th* sales representative, $0.5 \leq \rho_m \leq 2$,

Z - a number of customers,

I - a number of iterations,

P - a mean probability for the request in 1 iteration,
O - a number of orders (O=ZIP),
ν - a requested number of the n-th product by the i-th customer at the m-th sales rep.

Customer agents are organized in groups and each group is being served by concrete seller agent. Their relationship is given; none of them can change the counterpart. Seller agent is responsible to the manager agent. Each turn, the manager agent gathers data from all seller agents and stores key performance indicators (KPIs) of the company. The data is the result of the simulation and serves to understand the company behavior in a time – depending on the agents' decisions and behavior. The customer agents need to know some information about the market. This information is given by the informative agent. This agent is also responsible for the turn management and represents outside or controllable phenomena from the agents' perspective.

SIMULATION PARAMETERS AND RESULTS

The parameterization of the model and the obtained simulation results are analyzed in this section. Production function (Equation 1) is the engine of the simulation. Based on it, the customer agents decide to buy or not to do so. One year of sales and purchasing processes was simulated. Each turn represents one week. Five simulation experiments were done. Each purchase of the product type was registered. In order to include randomly generated inputs, two important agents' attributes were chosen to be generated by pseudo random generator. Firstly, the seller agent's ability, and secondly the customer agent's decision about the quantity for the purchase.

For the generating of random numbers from a normal distribution (Gaussian) the Java library called Uncommon Maths written by (Dan Dyer 2010) was used. For the values generation random MerseneTwisterRNG class was implemented. The class is a pure Java port of Makoto Matsumoto and Takuji Nishimura's proven and ultra-fast Mersenne Twister Pseudo Random Number Generator for C.

The parameterization of the MAS is listed in Table 1. The table represents the parameters listed by the name and the value for each type of an agent (customer, sales representative). It also shows the number of agent type instances (how many of a particular agent types is present in the system).

Table 1: List of agents' parameters

AGENT TYPE	AGENT COUNT	PARAMETER NAME	PARAMETER VALUE
Customer Agent	500	Maximum Discussion Turns	10
		Mean Quantity	5m
		Quantity Standard Deviation	4
Seller Agent	25	Mean Ability	0.7
		Ability Standard Deviation	0.03
		Minimal Price	EUR 0.3
Manager Agent	1	Purchase Price	EUR 0.17
Market Info	1	Item Market Share	0.25
		Item Market Volume	EUR 1 950 000
		Competition coefficient	0.8

The results of the simulation are the number of product units sold (amount, pieces), income (amount x item price, EUR), costs (EUR), and revenues (EUR) obtained for the selling these products. We name these results categories as the KPIs. The parameters of the simulation were set up according to the real company trading with the UTP cable. Therefore, the units traded are the meters (m).

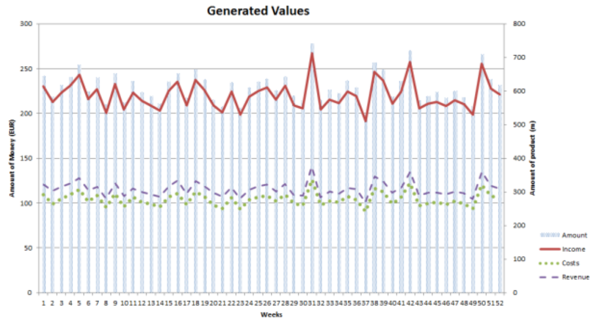

Figure 2: The generation values graph – weekly (source: own)

In Figure 2 the generated KPIs per week are depicted. The volatility of the curves shows a stable position of the company on the UTP cable market. The trends of KPIs point to the balanced selling during the whole year.

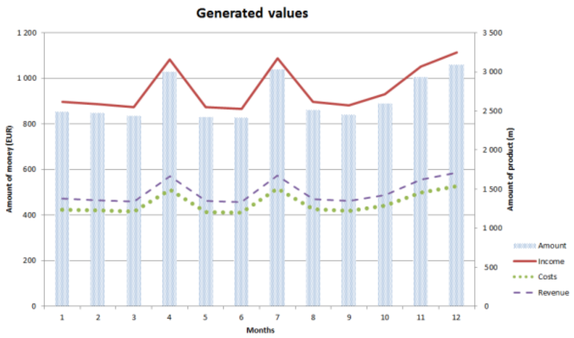

Figure 3: The generation values graph – monthly (source: own)

In Figure 3 the monthly KPIs are presented. The difference between the Figure 2 and 3 is the time step. The values resulted from the 53 weeks of the company trading. Implemented MAS provides necessary results in the form of KPIs every week (or months) during one year of trading. Obtained KPIs could be compared from one simulation experiment to the another. This could be used to analyze different simulation parameterizations and the impact on the company performance.

In the next section, real data will be used to validate the proposed model. If the validation confirms correct simulation results, the used model generates correct results.

VALIDATION OF SIMULATION RESULTS

Simulation results were compared with the real data from an anonymous computer selling company with 30 employees (from Slovakia). The real data were taken from the company's accounting information system. For the comparison of simulated and real data, monthly averages were used.

The results of the simulation are represented by the item price (Fig. 4). The graph shows monthly averages of simulated and real price. The real price trend is stabile – not growing and not falling. Generated price is quite constant. However, when we depict on the axis with generated data the values with 3 decimal places, slightly falling trend is visible. Nevertheless, the real and the generated time series have similar development in the time. All curves are located in the range from EUR 0.355 up to EUR 0.38. This evidently shows that the simulation model is valid and we are able to simulate real business processes properly.

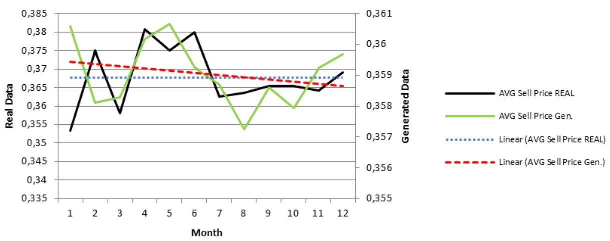

Figure 4: Prices – month averages (Source: Own).

From the statistical data listed in the following table is obvious that the dispersion and the standard deviation are higher in the real data time series. Real data are more distributed in opposite to the generated values. These points to our idea to use the disturbance agent in our simulation framework in order to bring more of the unpredictable impacts to the model. The generated values tend to be smoother with lower dispersion. We could bring more randomness into the time series development with the disturbances.

Table 2: Statistical data (Source: Own).

	value	average	dispersion	std. dev.
GENER.	Price	0,359	0,000	0,002
REAL	Price	0,367	0,003	0,055

To sum up, the results presented herein above visualise the real possibilities of the method proposed to be used for the real business processes simulation.

CONCLUSION AND FUTURE RESEARCH

The BPM simulation experiment in the form of MAS was introduced in this paper. Proposed simulation model was implemented in order to simulate the business process participants in a virtual company. Overall methodology is based on the company's generic structure. The simulation provides useful information about the core business processes. The comparison of the generated results with real data proofs the validity of the simulation model.

The next steps of our research concentrate on the statistical test of the validation, and the formal definition of the algorithm implemented. To conclude, using of a MAS implemented as a decision support tool for the management of a company will be the leading idea in the future.

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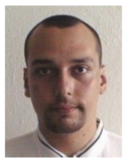

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