Phenomenal Trust Model

Arnostka Netrvalova
Jiri Safarik
Department of Computer Science and Engineering, Faculty of Applied Sciences
University of West Bohemia
Univerzitni 22, 30614 Plzen, Czech Republic
E-mail: netrvalo@kiv.zcu.cz

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ABSTRACT

The paper deals with the phenomenal trust modelling. Required terms as trust, trust types, trust values and representation are mentioned. Fundamental description of phenomenal trust formation is presented as a form of impersonal trust which is complementary to interpersonal trust. Phenomenon is defined by the set of its possible exclusive values. The model describes the trust of a subject to particular value of a phenomenon. Proposed formula for phenomenal trust formation covers the factors as product reputation, number of recommendations of product, initial trust value of products and trusting disposition of the subject. The behaviour of trust evolution depending on particular factors is studied.

INTRODUCTION

Trust is a unique phenomenon and plays an important role in the relationships among subjects in the communities. In the internet age, the trust among the machines, servers, and network nodes gains more and more on importance. Widening of e-service (Liu et al. 2008), e-commerce (Wang and Zhang. 2008), e-banking, etc., arises the question of human machine trust. Further, trust plays an important role in peer-to-peer networks (Wu et al. 2008), ad hoc networks, grid computing, semantic web (Wang and Zhang 2008), and multi agent systems, where humans and/or machines have to collaborate.

What is it trust and how it can be described? The acceptance of trust is wide and various explanations are offered (Fetzer 1988); from honesty, truthfulness, confident expectation or hope, something managed for the benefit of another, confidence in ability or intention to pay for goods or services in the future, till business credit.

The universal trust definition does not exist. Bulk of definitions comes out from Gambetta's definition (Gambetta 2000). We will understand trust as a given credit, hope, confidence in ability or intention of some subject to perform to benefit of other subject at some future time. Trust is created not only among the subjects (persons, nodes), but the subject can be perceived as a phenomenon, i.e. another type of trust – impersonal trust (Alfares and Hailes 2000; Alfares 2005) complementary to interpersonal trust; trust is formed towards a phenomenon, e. g. to certain product from a set of products of some kind.

Interpersonal trust models used for decision on selection of partners can be formed in several ways. The random selection can be the first choice, e.g. (Fort 2003). Further, probability can be applied (Yu et al. 2001), (Winsborough and Li 2002), (Yu and Winslett 2003) and (Rettinger et al. 2007). The game theoretic approach to modeling trust based decisions is proposed in (Baras and Jiang 2004), and (Sankaranarayanan et al. 2007). Next important concept used in decision support is risk (Josang and Lo Presti 2004).

Trust models, e.g. (Wu et al. 2008), (Lifen 2008), (Ryutov et al. 2007) usually deploy merely one or two of the factors which determine trust. Present models cover more factors e.g. (Wang and Zhang. 2008). Each of these factors (e.g. reputation, recommendations, and initial trust) can be modelled as an individual component.

We propose a model that tries to integrate more of trust affecting factors, i.e. initial trust, reputation, recommendations, and trusting disposition to form a probability based phenomenal trust model.

PHENOMENAL TRUST REPRESENTATION

Trust has to be measured for applying in society models of trust. However, some simplifications and limiting presumptions must be done. For examining the trust as a behavioural pattern, some ways of representing and possibly visualizing it must be known.

Generally, trust can be quantified by a value from the interval $\langle a, b\rangle$, where a, b ($a < b$) are integer or real numbers. Value a represents complete distrust and value b means blind trust. Other verbal trust levels are represented by values from this interval. Without loss of generality, we will use real values from the interval $\langle 0, 1\rangle$ as is shown in Figure 1.

Generally, mapping function which transforms verbal trust values to values from the interval $\langle 0, 1\rangle$ is neither linear nor symmetrical.

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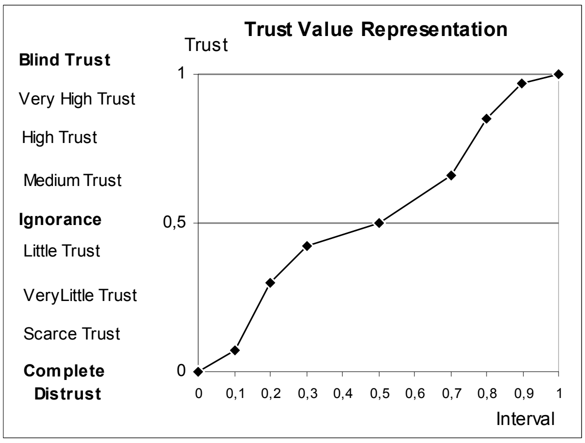

Figure 1: Trust Value Representation

Next, we specify a phenomenal trust representation, i.e. the type of trust that the subject trusts to the phenomenon. Consider a group of n subjects represented as the set $S = \{s_1, s_2, \ldots, s_n\}$ and a group of m exclusive products of some kind represented as a set $P = \{p_1, p_2, \ldots, p_m\}$, that constitutes the phenomenon. Trust of subject x_i to product p_k is denoted as follows:

$$t_i^{\mathrm{k}} = t(s_i, p_k),\ t_i^{\mathrm{k}} \in \langle 0, 1\rangle,$$

where: $i = 1, \ldots n$, and $k = 1, \ldots, m$.

We use a matrix, called phenomenal trust matrix, for representation of phenomenal trust. The matrix row represents trust values of the subject to the products. The column represents trust values of subjects to the chosen product. Matrix entry -1 denotes that the subject does not know the product.

For example, phenomenal trust matrix T

$$T = \begin{pmatrix} 0.1 & 0.9 & -1 \\ 0.6 & 0 & 0.4 \\ 0.8 & 0.1 & 0.05 \end{pmatrix} \tag{1}$$

represents trust values of three subjects to three products. The first subject does not know the third product and the second subject completely distrusts to the second product. The total of trust values of known products Tp for single subject must hold

$$Tp = \sum_{k=1,\, t_i^{\mathrm{k}} \neq -1}^{m} t_i^{\mathrm{k}} \leq 1 \tag{2}$$

Generally, phenomenal trust T_i^{k} of subject s_i to product p_k is function of trust forming factors

$$T_i^{\mathrm{k}} = F\left(t_i^{\mathrm{k}}, t_{0_i}^{\mathrm{k}}, d_i^{\mathrm{k}}, r_i^{\mathrm{k}}, G_{i(\alpha,\beta)}\right),$$

where t_i^{k} is trust value of i-th subject to k-th product, $t_{0_i}^{\mathrm{k}}$ is initial trust of i-th subject to k-th product, d_i^{k} is number of recommendations for k-th product to i-th subject, and r_i^{k} is reputation of k-th product by i-th subject considered constant over long period of time.

Following must hold for reputation

$$r_i^{\mathrm{k}} \in \langle 0,\ 1\rangle \ \text{ and } \sum_{k=1,\, t_i^{\mathrm{k}} \neq -1}^{m} r_i^{\mathrm{k}} = 1 \tag{3}$$

$G_{i(\alpha,\beta)}$, $0 \leq \alpha < \beta \leq 1$ is trusting disposition of subjects expressed by the probability distribution function reflecting the possible non rational aspects of trust forming.

Trust variation of i-th subject to k-th product can be expressed

$$T_i^{\mathrm{k}} = t_i^{\mathrm{k}} + \Delta t_i^{\mathrm{k}},$$

where Δt_i^{k} is gain (loss) of phenomenal trust of i-th subject to k-th product. We propose following formula for this gain (loss)

$$\Delta t_i^{\mathrm{k}} = \sqrt{t_{0_i}^{\mathrm{k}} t_i^{\mathrm{k}}}\ \frac{\Delta d_i^{\mathrm{k}}}{w_{d\mathrm{i}}}\ \frac{r_i^{\mathrm{k}}}{w_{r\mathrm{i}}}\ \frac{G_{i(\alpha,\,\beta)}}{w_{g\mathrm{i}}}, \tag{4}$$

where: $\sqrt{t_{0_i}^{\mathrm{k}} t_i^{\mathrm{k}}}$ is trend of trust evolution of k-th product by i-th subject with respect to initial value, Δd_i^{k} is relative gain (loss) of recommendations number of k-th product to i-th subject, i.e. $\left(\frac{d_i^{\mathrm{k}[l]} - d_i^{\mathrm{k}[l\text{-}1]}}{m}\right)$, where l represents l-th step of trust forming process and m is number of products, w_{d_i} is weight coefficient of recommendations number of k-th product to i-th subject, w_{r_i} is weight coefficient of effect of reputation of k-th product by i-th subject, and w_{g_i} is weight coefficient of trusting disposition.

Thus, trust preference of i-th subject to k-th product can be now expressed

$$T_i^{\mathrm{k}} = t_i^{\mathrm{k}} + \sqrt{t_{0_i}^{\mathrm{k}} t_i^{\mathrm{k}}}\ \frac{\Delta d_i^{\mathrm{k}}}{w_{d\mathrm{i}}}\ \frac{r_i^{\mathrm{k}}}{w_{r\mathrm{i}}}\ \frac{G_{i(\alpha,\,\beta)}}{w_{g\mathrm{i}}}$$

Trust gain (loss) to one product is the cause of change of trust to other products to keep total of trust values Tp constant. Splitting of gain (loss), expressed in (4), to other products may be accomplished, e.g. equally, proportionally or randomly.

EXPERIMENTS

To pursue trust model behaviour we carried out series of experiments. The groups of individuals of various sizes and the groups of chosen products have been generated. The trust distribution, the initial trust matrix and reputation matrix has been chosen with uniform distribution from the interval ⟨0, 1⟩. Number of product recommendations was stepwise set up and trust forming was pursued. Next we describe the studies using five subjects and five products.

Trust Forming Study

We present the behaviour of the model on variation of phenomenal trust for six couples (subject, product), namely t_1^4, t_2^5, t_3^2, t_3^3, t_3^4, and t_5^4. Number of recommendation to constituent subjects, reputation values and initial trust value were generated to represent situations in everyday life. Three following tables show initial trust values (Table 1), number of recommendations in subsequent steps for selected couples (Table 2), and reputation values of products by the subjects (Table 3).

Table 1: Initial Trust Values

Initial Trust					
to_1^4	to_2^5	to_3^2	to_3^3	to_3^4	to_5^4
0,05	0,01	0,15	0,59	0,04	0,01

Table 2: Number of Recommendations - Stepwise

	Recommendation					
Step	d_1^4	d_2^5	d_3^2	d_3^3	d_3^4	d_5^4
0	0	0	0	0	0	0
1	3	1	2	0	1	1
2	2	1	0	0	0	1
3	3	1	0	0	0	2
4	2	1	2	0	0	3
5	4	0	0	0	3	2

Table 3: Reputation Values of Products

Reputation					
r_1^4	r_2^5	r_3^2	r_3^3	r_3^4	r_5^4
0,62	0,55	0,53	0,25	0,04	0,93

Initial trusts of subjects to chosen products (for six couples) are depicted in Figure 2. The numbers of product recommendations in each step are shown in Figure 3 and product reputations in Figure 4.
Trusts evolution in subsequent steps is shown in Figure 5.

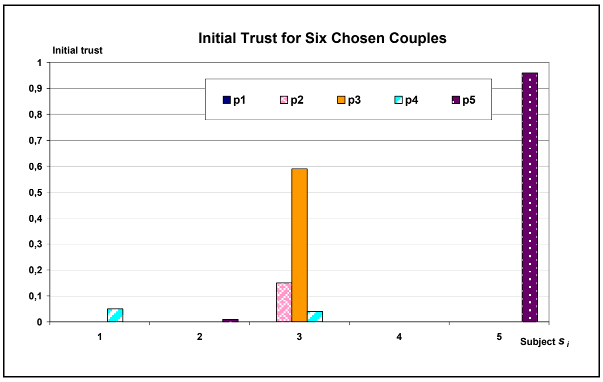

Figure 2: Initial Trust for Six Chosen Couples

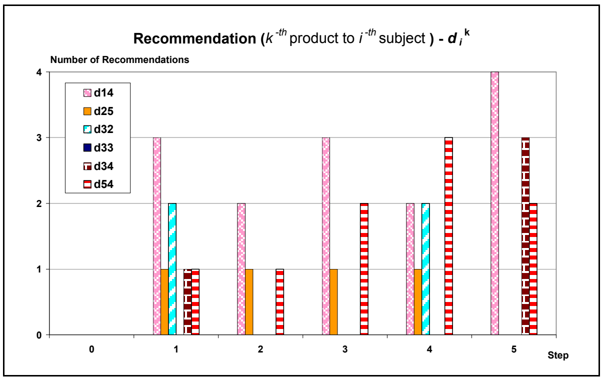

Figure 3: Number of Product Recommendations

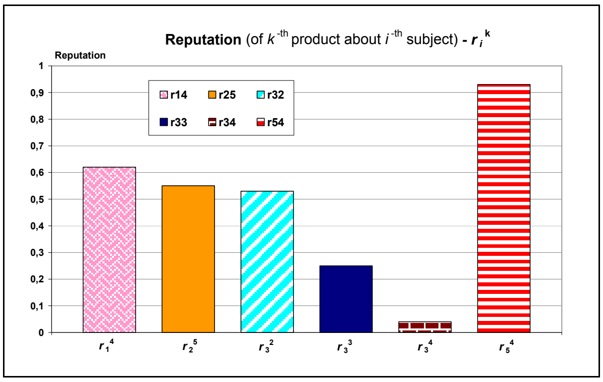

Figure 4: Product Reputations for Six Couples

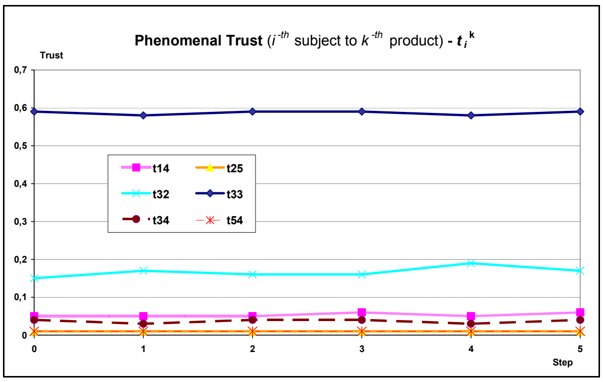

Figure 5: Trust Evolution

Trust t_1^4 of subject s_1 to product p_4 changed according to the number of recommendations. Similar changes were proved in trusts t_2^5 and t_3^2.
Trust of t_3^4 decreased in forth step, because subject s_3 got the same number of recommendations for product p_4 and product p_5 in this step and the reputation of product p_5 is very high (0,93) over poor reputation of product p_4 (0,04), so trust gain to product p_5 caused decrease of trust to product p_2.
Similarly, trust t_3^3 depends on trust loss or gain to other products, even subject s_3 got no recommendation for this product. Product p_2 showed trust gain by subject s_3 in forth steps at expense of products p_3 and p_4.
Likewise, the trust study of each subject to each product was completed. The results were in good accordance with expected behaviour.

Reputation Value Study

Next, we performed the study of reputation value influence on changes of trust to products. Five distributions of reputation values of products by subject s_1 are indicated in Table 4. Trust t_1^2 variation depending on varying reputation r_1^2 is shown in Figure 6.

Table 4: Reputation of Products by Subject s_1

Case	Reputation				
	r_1^1	r_1^2	r_1^3	r_1^4	r_1^5
1	0,2	0,2	0,2	0,2	0,2
2	0,16	0,35	0,17	0,16	0,16
3	0,125	0,5	0,125	0,125	0,125
4	0,09	0,65	0,08	0,09	0,09
5	0,05	0,8	0,05	0,05	0,05

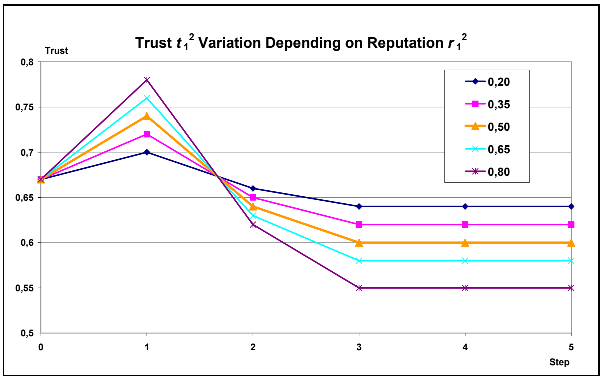

Figure 6: Trust t_1^2 Variation Depending on Reputation r_1^2

High trust value is influenced by reputation strongly. On the contrary, low trust values in products fluctuate very little as shown in Figure 7.
The sensitivity of subject to a trust affecting factor is reflected by its weight coefficient. The influence of reputation weight factor on course of trust is shown in Figure 8. We can observe the possibility to reflect the subject sensitivity by the weight coefficient.

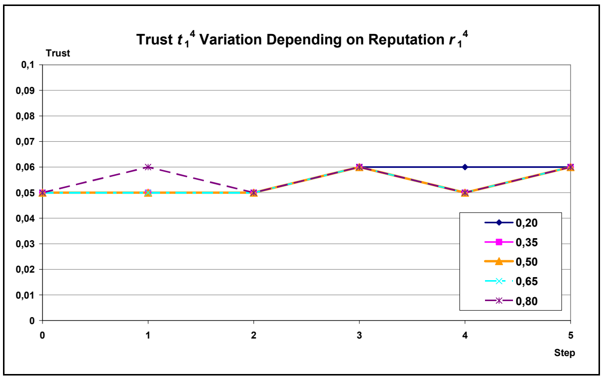

Figure 7: Trust t_1^4 Variation Depending on Reputation r_1^4

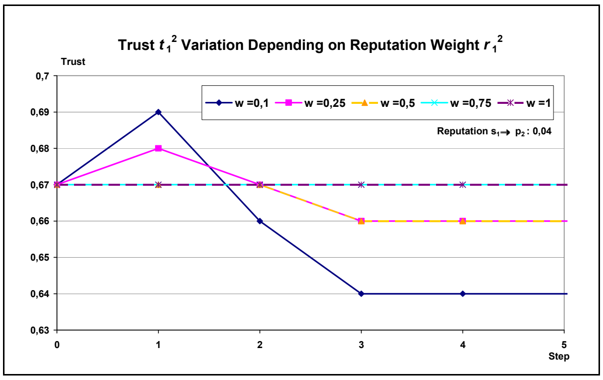

Figure 8: Trust t_1^2 Variation Depending on Reputation Weight r_1^2

Initial Trust Study

This study examines how trust to products will evolve starting with various initial values indicated in Table 5. Reputation values of products by subject s_1 are in Table 6, and Number of recommendations for subject s_1 in subsequent steps is in Table 7.

Table 5: Initial Trust values of Products

Case	Initial Trust				
	to_1^1	to_1^2	to_2^3	to_1^4	to_1^5
1	0,01	0,01	0,01	0,95	0,01
2	0,05	0,05	0,05	0,80	0,05
3	0,08	0,08	0,08	0,65	0,09
4	0,12	0,12	0,12	0,50	0,13
5	0,16	0,16	0,16	0,35	0,16

Table 6: Reputation of Products by Subject s_1

Reputation				
r_1^1	r_1^2	r_1^3	r_1^4	r_1^5
0,01	0,04	0,05	0,62	0,28

Table 7: Recommendations for Products to Subject s_1

	Recommendation				
Step	d_1^1	d_1^2	d_1^3	d_1^4	d_1^5
0	0	0	0	0	0
1	0	3	0	3	0
2	0	1	0	2	0
3	0	0	0	3	0
4	0	0	0	2	0
5	0	0	1	4	0

Phenomenal trust of subject s_1 to product p_4 was chosen as the example of trust forming. Trust evolution for initial trust values of subject s_1 to product p_4 is shown in Figure 9.

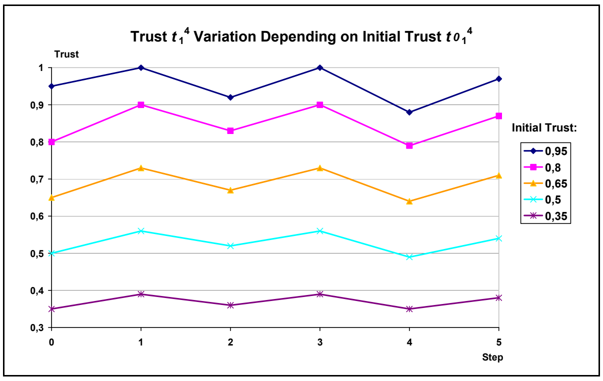

Figure 9: Trust t_1^4 Variation Depending on Initial Trust to_1^4

We can observe that trust changes are proportional to initial value. Further, the course of trust follows the increase and decrease of number of recommendations. To keep the total trust *Tp* to all known products constant, trust to other products was changed evenly.

Trusting Disposition Study

Disposition factor models the non rational aspects of a human using probability distribution function on an interval ⟨α, β⟩. Its value was generated for each subject randomly and used for each product. Values α= 0,3 and β = 0,8 were used in the study. Total ten runs were performed. Generated trusting dispositions g_i (i=1,...,5) of chosen subjects are shown in Table 8.

The reputation values and number of recommendations for products were the same as in the study of trust forming (Figure 4 and Figure 5).

Trust values after fifth step for selected couples are shown in Figure 10.

Table 9 and Table 10 present three experiment statistics – the arithmetic mean (AM) of trust value, the mean deviation (MD) and the standard deviation (SD) from initial trust value.

Table 8: Trusting Disposition of Subjects in Ten Runs

	Trusting Disposition				
Run	g_1	g_2	g_3	g_4	g_5
1	0,49	0,72	0,63	0,31	0,49
2	0,40	0,51	0,77	0,79	0,40
3	0,39	0,38	0,65	0,59	0,39
4	0,35	0,35	0,33	0,39	0,35
5	0,44	0,78	0,61	0,38	0,44
6	0,41	0,53	0,77	0,54	0,41
7	0,59	0,53	0,32	0,30	0,59
8	0,47	0,31	0,71	0,42	0,47
9	0,39	0,43	0,34	0,64	0,39
10	0,69	0,42	0,41	0,33	0,69

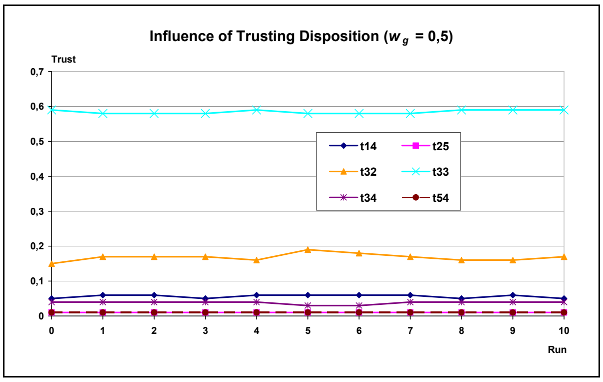

Figure 10: Influence of Trusting Disposition

Table 9: Statistics of Trusting Disposition Influence 1

	Trust		
Statistic	t_1^4	t_2^5	t_3^2
AM	0,06	0,01	0,17
MD	0,0002	0,0000	0,0008
SD	0,01	0,00	0,04

Table 10: Statistics of Trusting Disposition Influence 2

	Trust		
Statistic	t_3^3	t_3^4	t_5^4
AM	0,58	0,04	0,01
MD	0,0002	0,0002	0,0000
SD	0,01	0,01	0,00

The effect of trusting disposition, i.e. dispersion of final trust values, grows with reputation and trust value. This is in good accordance with expected human behaviour.

CONCLUSION AND FUTURE WORK

We developed a phenomenal trust model integrating factors influencing phenomenal trust evolution. The experiments proved its behaviour to be in accordance with models considering particular factor or subset of factors in our model.

Next, we intend to pursue the collaboration with sociologist to apply the model to real cases. The model itself will be deployed in an agent based trust management model under development. Specifically we plan to study the processes of intervention, e.g. advertisement, in favour of some product.

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AUTHOR BIOGRAPHIES

ARNOSTKA NETRVALOVA was born in Plzen, Czech Republic. She is senior lecturer in Department of Computer Science and Engineering at Faculty of Applied Sciences of University of West Bohemia. She holds a M.Sc. in Computer Science from University of West Bohemia in 1977. Her research in modelling and simulation covered simulation of temperature processes in man, and trust modelling. E-mail address is `netrvalo@kiv.zcu.cz`, web-page is `http://www.kiv.zcu.cz/~netrvalo`.

JIRI SAFARIK was born in Kromeriz, Czech Republic. He received his Ph.D. degree from Slovak University of Technology in 1984. Currently, he is professor in Department of Computer Science and Engineering at Faculty of Applied Sciences of University of West Bohemia. His research covers distributed systems, distributed and parallel simulation. E-mail address is `safarikj@kiv.zcu.cz` and his Web-page can be found at `http://www.kiv.zcu.cz/~staff`.