MODELLING OF INTERVENTION EFFECT ON TRUST

Arnostka Netrvalova
Jiri Safarik
Department of Computer Science and Engineering, Faculty of Applied Sciences
University of West Bohemia
30614 Plzen, Univerzitni 8, Czech Republic
E-mail: netrvalo@kiv.zcu.cz

KEYWORDS
Trust, interpersonal trust, trust modelling, trust intervention.

ABSTRACT

The paper deals with interpersonal trust modelling taking the focus on intervention effect. Terms as trust, trust factors and trust representation are introduced. Brief description of interpersonal trust forming is presented. Intervention model is introduced. The proposed trust formula formation and intervention model enable to cover trust intervention. The study of the behaviour of trust evolution is extended in this way. The comparison of trust model with and without intervention effect is discussed. The parameter values of trust intervention, i.e. intervention power, and intervention distribution are modified and the effect of these modifications on trust is studied.

INTRODUCTION

Trust is a unique phenomenon and plays an important role in the relationships among subjects in the communities. These subjects need not be only humans. In the internet age, the trust among humans and the machines, e.g. servers, network nodes or various software utilities, gains more and more on importance. Widening of e-service (Liu et al., 2008), e-commerce (Zhang et al., 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 (Mejia et al. 2009), grid computing, semantic web (Wang and Zhang, 2008), and multi agent systems, where humans and/or machines have to collaborate. Trust models are used in those uncertain environments (Wang and Varadharajan, 2008), (Camp et al., 2008), (Velloso et al., 2006). The role of trust is very important in e-service, e-banking and e-commerce particularly, e.g. (Chen and Yeager, 2008).
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 FORMING FACTORS

Trust models, and interpersonal trust models particularly, e.g. (Wu et al., 2008), (Lifen, 2008), (Ryutov et al., 2007), (Chen and Yeager, 2008) are usually focused on one of factors determining trust, but no more than two were considered. The reputation, recommendation and initial trust are basic factors determining trust. Initial trust is the trust value in other person on the start. The reputation represents the knowledge about trusted person. The information obtained by communication with others is called recommendation. Each of the factors (initial trust, reputation, and recommendations) can be modelled as an individual component.
Firstly, for examining trust as a behavioural pattern, some way of representing trust is needed. 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. Without loss of generality, we will use real values from the interval $\langle 0, 1\rangle$.
Next, we specify an interpersonal trust representation, i.e. trust between two subjects. Consider a group of n subjects represented as the set $S = \{s_1, s_2, \ldots, s_n\}$. The measure of interpersonal trust between the subject s_i and s_j is introduced by:

$$t_{ij} = t(s_i, s_j),\ t_{ij} \in \langle 0, 1\rangle, \tag{1}$$

where: $i, j = 1, \ldots, n$ and $i \neq j$.
We use a matrix, called interpersonal trust matrix, for representation of interpersonal trust in a group, where t_{ij} are matrix entries. Matrix entry -1 denotes that the subject does not know this one or self-trust (self-trust is not considered).

INTERVENTION EFFECT MODEL

We will use a general model of information intervention effect depicted in Figure 1 (Vavra F., University of West Bohemia, personal communication).
The probability distribution P on the input represents the state before intervention, the probability distribution Q on the output describes the state after intervention activity and the intervention is modelled by probability distribution R, where x ($x \in X$) is event observed from finite set of events X. These events can be products preference and the probability distribution represents their relative sale frequencies.

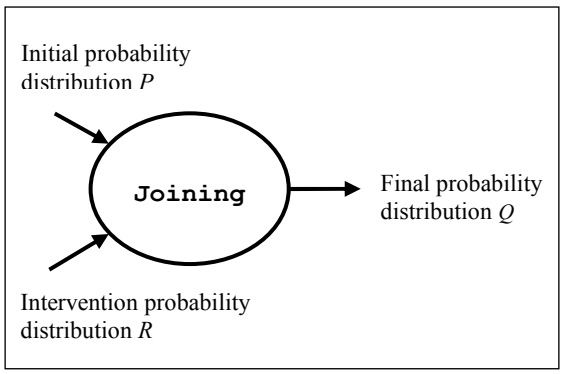

Figure 1: Model of Information Intervention Effect.

The uncertainty of preference in a single observation can be measured by entropy:

$$H(X) = -\sum_{x \in X} P(x) \cdot \lg P(x) \tag{2}$$

where $P(x)$ is the value of probability mass function. The entropy is increasing if the effect of the intervention uniforms probability distribution, whereas it is decreasing in opposite case.

The difference between initial probability distribution P and final probability distribution Q can be measured by relative entropy:

$$D(P \,||\, Q) = \sum_{x \in X} P(x) \lg \frac{P(x)}{Q(x)} \tag{3}$$

While relative entropy is not a metric, we will take symmetric relative entropy:

$$d(p,q) = D(P \,||\, Q) + D(Q \,||\, P) \tag{4}$$

For joining initial probability and intervention probability we use their mixture (Rényi, 1961):

$$Q(x) = (1-\lambda) P(x) + \lambda\, R(x), \tag{5}$$

where $0 < \lambda \leq 1$, represents intensity of the intervention.

Given probability mass functions $P(x)$, $R(x)$, $Q(x)$ the intensity λ can be found by

$$\lambda = \frac{\sum_{x \in X} \big(Q(x) - P(x)\big)\big(R(x) - P(x)\big)}{\sum_{x \in X} \big(R(x) - P(x)\big)^2}, \tag{6}$$

if exists.

The conditions of existence are

$$\sum_{x \in X} \big(R(x) - P(x)\big)\big(Q(x) - R(x)\big) \leq 0$$

and

$$\sum_{x \in X} \big(R(x) - P(x)\big)\big(Q(x) - P(x)\big) \geq 0 \cdot$$

The mixture of distributions may be used for negative λ if following holds:

$$0 \leq (1-\lambda)\, p(x) + \lambda\, r(x) \leq 1\,; \;\; \forall x \in X. \tag{7}$$

TRUST EVOLUTION MODEL

Trust between subjects evolves under changing factors determining trust. We have proposed trust model determining new value of interpersonal trust T_{ij} of subject s_i to subject s_j as function of trust forming factors, i.e. previous trust each to other, subject reputation, number of subject recommendations, number of reciprocal contacts and trusting disposition (Netrvalova and Safarik, 2009). Initial trust between subjects is got on the start. The reputation of the subject comes after individual experience and by some information dissemination about subject in its neighbourhood and influences trust formation considerable. Trust depends also on the frequency of mutual contacts of subjects. Next, trust is formed by information about another subject that other subjects have passed on. This information is called recommendation. Trusting disposition representing a degree of non rational behaviour of a subject is modelled by a random factor.

Trust forming of i-th subject (trustor) to j-th subject (trustee) is described by

$$T_{ij} = t_{ij} + \sqrt{t_{ij}\, t_{ji}} \left(\frac{\Delta c_{ij}}{w_{ci}} + \frac{\Delta d_{ij}}{w_{di}} \right) \frac{r_{ij}}{w_{ri}} \frac{g_{ij(\alpha,\beta)}}{w_{gi}} \tag{8}$$

where T_{ij} ($0 \leq T_{ij} \leq 1$) is new trust value of i-th subject in j-th one, t_{ij} is previous trust (trust starting value is t_{0ij}) of i-th subject in j-th one, t_{ji} is previous trust of j-th subject in i-th one, Δc_{ij} is relative gain (loss) of the number of contacts between i-th and j-th subject, Δd_{ij} is relative gain (loss) of the number of recommendations of j-th subject to i-th subject, r_{ij} is reputation of i-th subject about j-th one, $g_{ij(\alpha,\beta)}$, $0 < \alpha < \beta \leq 1$ is trusting disposition probability distribution, w_{ci} is weight coefficient of the number of contacts of i-th subject, w_{di} is weight coefficient of the number of recommendation of j-th subject to i-th subject, w_{ri} is weight coefficient of effect of reputation of i-th subject about j-th one, and w_{gi} is weight coefficient of trusting disposition.

The model reflects usual factors influencing interpersonal trust in standard real life situations. On the other hand, there are situation when there is a massive intervention in order to increase trust to some subject(s), e.g. election campaign.

To model trust intervention, we use described intervention effect model.

Initial probability distribution is given by initial trust values T_{ij} of a subject s_i to all other subjects. The intention to increase trust value to some subject is described by intervention probability distribution I. Expressing the intensity of intervention by λ, $0 < \lambda \leq 1$, the new trust probability distribution is given by values T'_{ij}

$$T'_{ij} = (1 - \lambda)\, T_{ij} + \lambda\, I_{ij}, \tag{9}$$

EXPERIMENTS AND RESULTS

To pursue trust intervention model behaviour we carried out series of experiments. Here, we present following scenario. The group of five subjects was considered. Relations of subject s_1 to other subjects, i.e. s_2, s_3, s_4, and s_5, from this group were chosen. Parameters of experiments are presented in Table 1 (initial trust), Table 2 (reputation), Table 3 (number of mutual contacts), Table 4 (number of recommendation), Table 5 (trusting disposition) and Table 6 (intervention distribution).

Table 1: Initial Trust of Subject s_1 to Other Subjects

$s_1 \rightarrow s_2$	$s_1 \rightarrow s_3$	$s_1 \rightarrow s_4$	$s_1 \rightarrow s_5$
0,75	0,04	0,2	0,01

Table 2: Subject s_1 - Partner's Reputation of Other Subjects

$r_2 \rightarrow s1$	$r_3 \rightarrow s_1$	$r_4 \rightarrow s_1$	$r_5 \rightarrow s_1$
0,25	0,23	0,3	0,14

Table 3: Number of Contacts of Subject s_1 with Partners

Step	$s_1 \rightarrow s_2$	$s_1 \rightarrow s_3$	$s_1 \rightarrow s_4$	$s_1 \rightarrow s_5$
0	0	0	0	0
1	0	0	0	0
2	1	0	1	0
3	1	0	2	0
4	0	0	2	0
5	0	0	3	0

Table 4: Partner's Recommendation to Subject s_1

Step	$d_2 \rightarrow s_1$	$d_3 \rightarrow s_1$	$d_4 \rightarrow s_1$	$d_5 \rightarrow s_1$
0	0	0	0	0
1	1	0	1	0
2	1	0	2	0
3	0	0	3	0
4	0	0	2	0
5	0	1	4	3

Table 5: Trusting Disposition (Subject s_1 to Others) Stepwise

Step	$s_1 \rightarrow s_2$	$s_1 \rightarrow s_3$	$s_1 \rightarrow s_4$	$s_1 \rightarrow s_5$
0	0,50	0,50	0,50	0,50
1	0,55	0,88	0,85	0,34
2	0,74	0,92	0,67	0,65
3	0,82	0,62	0,67	0,65
4	0,71	0,56	0,76	0,35
5	0,76	0,78	0,56	0,91

Trust formation of subject s_1 in other subjects without intervention effect is presented in Figure 2. Trust changes were relatively small adequately to reputation values, number of contacts and recommendations. This behaviour enables us to observe changes in trust evolution caused by intervention. Intervention distribution values used in the experiment are in Table 6.

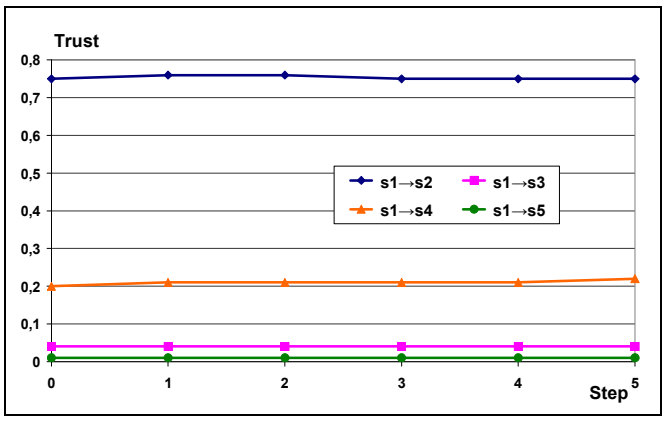

Figure 2: Trust of Subjects without Intervention Effect.

Table 6: Intervention Distribution (Subject s_1)

$s_1 \rightarrow s_2$	$s_1 \rightarrow s_3$	$s_1 \rightarrow s_4$	$s_1 \rightarrow s_5$
0,03	0,10	0,75	0,12

Values of λ parameter were set to 0,05; 0,1; 0,5 successively. Subject s_1 and its partners were observed.

Stepwise trust forming is shown in Figure 3, Figure 5 and Figure 7. The influence of the intervention intensity represented by the parameter λ can be visually observed. Moreover, the intervention effect can be measured using the terms of information theory, that were introduced previously, i.e. entropy (2), relative entropy (3) and symmetric relative entropy (4). Trust intervention effect, i.e. initial trust distribution before intervention (T_0), final trust distribution after first step (T_1), and trust intervention distribution, are depicted in Figure 4, Figure 6, and Figure 8. Entropy relative entropy and symmetric relative entropy values are presented in Table 7, Table 8 and Table 9.

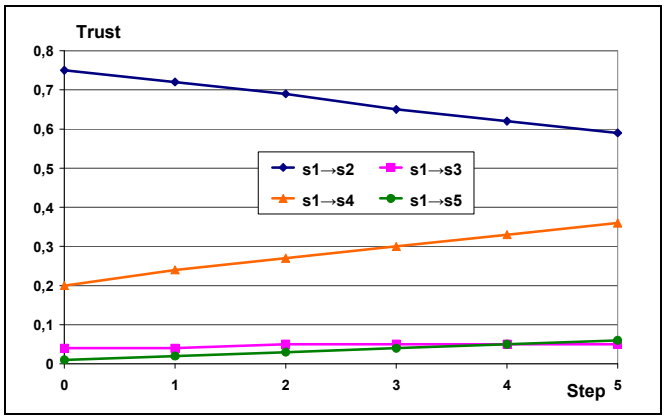

Figure 3: Trust Formation for λ =0,05 Stepwise.

Table 7: Entropy and Relative Entropy for λ =0,05 after the 1st Step

Subject	$H(T_0)$	$H(I)$	$H(T_1)$	$D(T_0 \| T_1)$	$D(T_1 \| T_0)$
$s_1 \rightarrow s_2$	0,311	0,151	0,341	0,044	-0,042
$s_1 \rightarrow s_3$	0,186	0,332	0,185	0,000	0,000
$s_1 \rightarrow s_4$	0,464	0,311	0,494	-0,052	0,063
$s_1 \rightarrow s_5$	0,066	0,367	0,112	-0,010	0,020
Sum	1,027	1,161	1,132	-0,018	0,041
$\lambda comp$=	0,053			$d(p, r)$ =	0,023

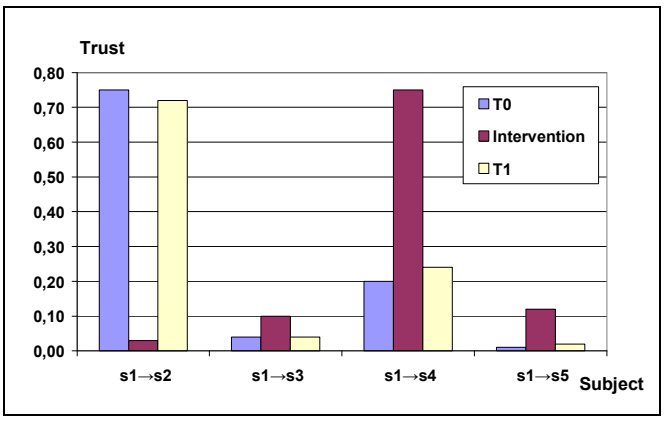

Figure 4: Trust Intervention Effect for λ =0,05 after the First Step.

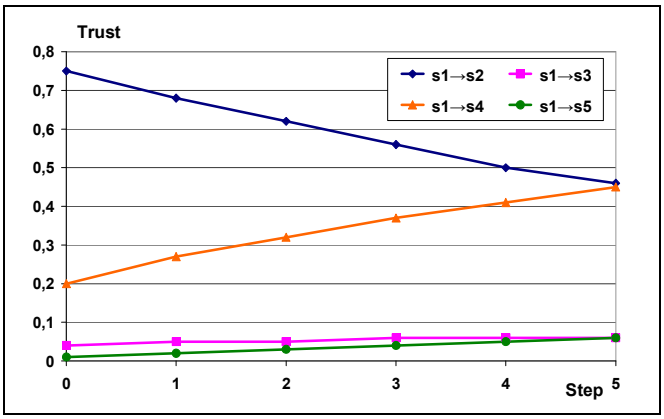

Figure 5: Trust Formation for λ =0,1 Stepwise.

Table 8: Entropy and Relative Entropy for λ =0,1 after the 1st Step

Subject	$H(T_0)$	$H(I)$	$H(T_1)$	$D(T_0\|\|T_1)$	$D(T_1\|\|T_0)$
$s_1 \rightarrow s_2$	0,311	0,151	0,378	0,106	-0,096
$s_1 \rightarrow s_3$	0,186	0,332	0,216	-0,013	0,016
$s_1 \rightarrow s_4$	0,464	0,311	0,510	-0,087	0,117
$s_1 \rightarrow s_5$	0,066	0,367	0,113	-0,010	0,020
Sum	1,027	1,161	1,217	-0,004	0,057
$\lambda comp=$	0,108			$d(p, r)=$	0,053

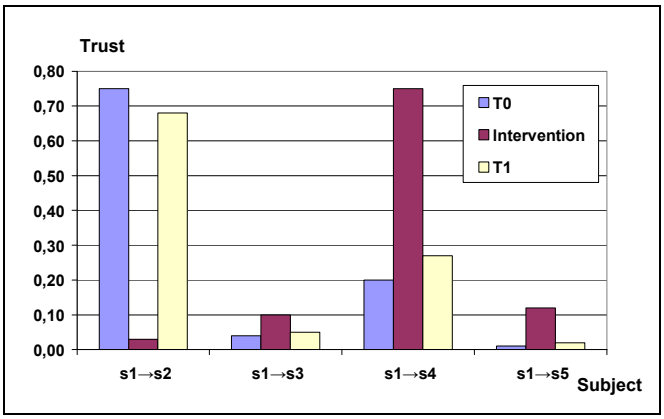

Figure 6: Trust Intervention Effect for λ=0,1 after the First Step.

The initial trust of subject s_1 is highest to subject s_2 (Table 1). The intervention is in favour of subject s_4 (Table 6). Clearly, the trust distribution has to become more even. This is proved by higher entropy $H(T_1)$ of new trust distribution (Table 7, Table 8, and Table 9) and the entropy increases when the intervention is stronger. Also, the new trust distribution has to have greater distance to the initial one, what is proved by higher symmetric relative entropy (Table 7, Table 8, and Table 9) and the distance grows when the intervention is stronger.

Achieving a trust distribution in some steps, we can ask on the intervention intensity λ which would cause the same trust distribution in one step. This value is given by Equation (6).

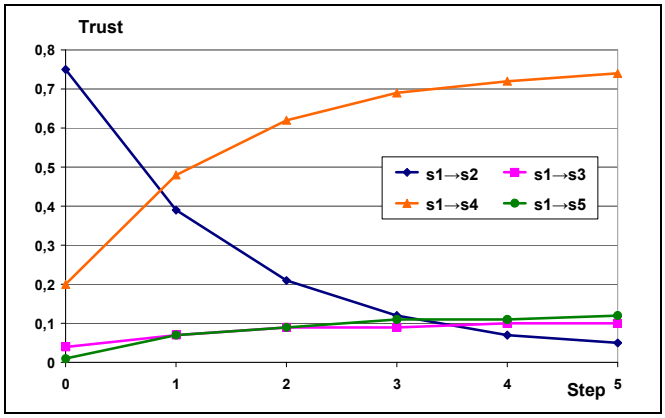

Figure 7: Trust Formation for λ =0,5 Stepwise.

Table 9: Entropy and Relative Entropy for λ =0,5 after the 1st Step

Subject	$H(T_0)$	$H(I)$	$H(T_1)$	$D(T_0\|\|T_1)$	$D(T_1\|\|T_0)$
$s_1 \rightarrow s_2$	0,311	0,151	0,530	0,708	-0,368
$s_1 \rightarrow s_3$	0,186	0,332	0,269	-0,032	0,057
$s_1 \rightarrow s_4$	0,464	0,311	0,508	-0,253	0,606
$s_1 \rightarrow s_5$	0,066	0,367	0,267	-0,028	0,197
Sum	1,027	1,161	1,574	0,395	0,492
$\lambda comp=$	0,503			$d(p, r)=$	0,887

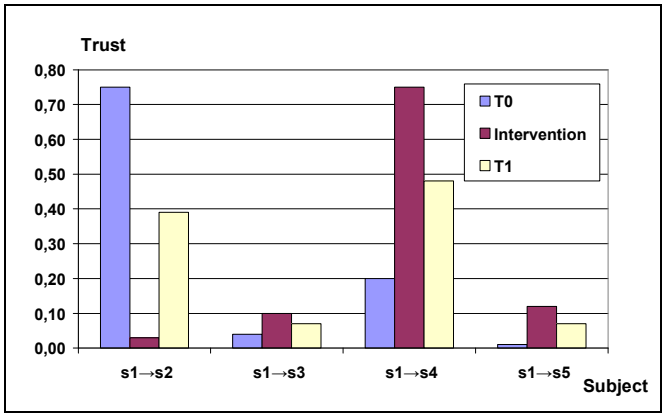

Figure 8: Trust Intervention Effect for λ =0,5 after the First Step.

Trust values achieved for λ=0,5 after five steps would be reached by λ_{comp}=0,976 in one step. Entropy relative entropy and symmetric relative entropy values are displayed in Table 10. We can observe expected decrease of the entropy $H(T_1)$ for λ_{comp}=0,976 compared to $H(T_1)$ for λ=0,5 as the distribution values became more uneven, now on benefit of subject s_4. The enormous increase of symmetric relative entropy indicates a grandiose intervention power.

Table 10: Entropy and Relative Entropy for λ_{comp} =0,976

Subject	$H(T_0)$	$H(I)$	$H(T_1)$	$D(T_0\|\|T_1)$	$D(T_1\|\|T_0)$
$s_1 \rightarrow s_2$	0,311	0,151	0,216	2,930	-0,195
$s_1 \rightarrow s_3$	0,186	0,332	0,332	-0,052	0,132
$s_1 \rightarrow s_4$	0,464	0,311	0,321	-0,377	1,397
$s_1 \rightarrow s_5$	0,066	0,367	0,367	-0,035	0,430
Sum	1,027	1,161	1,236	2,464	1,764
λ_{comp}=	0,976			$d(p, r)$ =	4,228

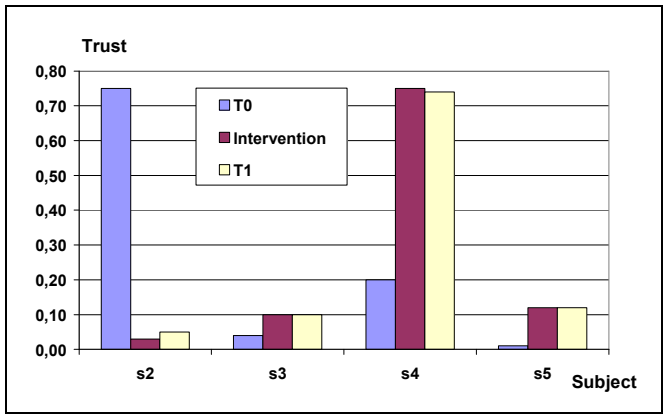

Figure 9: Trust Intervention Effect for λ =0,976.

CONCLUSION

We developed trust model integrating intervention effect for trust evolution. The experiments proved behaviour of the model to be in accordance with expectations.
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.

ACKNOWLEDGEMENTS

The work was granted by the Ministry of Education, Youth and Sport of the Czech Republic - University spec. research - 1311.

REFERENCES

Camp L., Friedman A., and Genkina A., 2008. *Embedding Trust via Social Context in Virtual Spa-ces*. Available: `http://www.ljean.com/files/NetTrust.pdf`, cit. 2008-09-12.

Chen R., Yeager W., 2008. *A Distributed Trust Model for Peer-to-Peer Networks*, Sun Microsystems. Available: `http://gnunet.org/papers/jxtatrust.pdf`, cit. 2008-09-25.

Fetzer S., 1988. "The World Book Dictionary." World Book Inc., The World Book Encyclopaedia, Chicago, USA.

Gambetta D., 2000. "*Can We Trust Trust?*" In Gambetta, Diego (ed.) Trust: Making and Breaking Cooperative Relations, electronic edition. Department of Sociology, University of Oxford, chapter 13, 213-237.

Lifen L., 2008. "Trust Derivation and Recommendation Management in a Trust Model." In *Proceedings of International Conference on Intelligent Information Hiding and Multimedia Signal Processing* (Harbin, China), 219-222.

Liu Y., Yau S., Peng D., and Yin Y., 2008. "A Flexible Trust Model for Distributed Service Infrastructures." In *Proceedings of the 2008 11th IEEE Symposium on Object Oriented Real-Time Distributed Computing* (Orlando, USA), 108-115.

Mejia M., Pena N., Munoz J., and Esparza O., 2009. "A Review of Trust Modeling in Ad Hoc Networks." *In journal: Internet Research*, vol. 19, Issue 1, 88-104.

Netrvalova A., and Safarik J., 2009. "Interpersonal Trust Model." *In Proceedings of 6th Vienna International Conference on Mathematical Modelling* (Vienna, Austria), pp. 530-537.

Rényi, A., 1961. "On Measures of Entropy and Information." In *Proceedings Fourth Berkeley Symposium Math. Stat. and Probability*, Berkeley, University of California Press, Vol. 1., pp. 547-561.

Ryutov T., Neuman C., and Zhou L., 2007. "Initial Trust Formation in Virtual Organizations." In *International Journal of Internet Technology and Secured Transactions*, vol.1, no. 1-2, 81-94.

Velloso P., Laufer R., Duarte O., and Pujolle G., 2006. HIT: *A Human-inspired Trust Model*. In: IFIP International Federation for Information Processing, Volume 211, ed. G. Pujolle, Mobile and Wireless Communication Network, (Boston Springer), pp. 35-46.

Wang X., Zhang F., 2008. *A New Trust Model Based on Social Characteristic and Reputation Mechanism for the Semantic Web*. International Workshop on Knowledge Discovery and Data Mining. The University of Adelaide, Australia, pp. 414-417.

Wang Y., Varadharajan V., 2007. *Role-based Recommendation and Trust Evaluation*. In: Proceedings 9th IEEE International Conference on E-Commerce Technology and the 4th IEEE International Conference on Enterprise Computing, E-Commerce and E-Services, Tokyo.

Wu X., He J., and Xu F., 2008. "An Enhanced Trust Model Based on Reputation for P2P Networks." In I*EEE International Conference on Sensor Networks, Ubiquitous and Trustworthy Computing* (Taichung, Taiwan), 67-73.

Zhang Z., Zhou M., and Wang P., 2008. "An Improved Trust in Agent-mediated e-commerce." *International Journal of Intelligent Systems Technologies and Applications*, vol. 4, 271-284.

BIOGRAPHY

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`, web page available at `http://www.kiv.zcu.cz/~staff`.