PHENOMENAL TRUST INTERVENTION MODEL

Arnostka Netrvalova, Jiri Safarik

University of West Bohemia, Faculty of Applied Sciences,
306 14 Plzen, Univerzitni 22, Czech Republic

netrvalo@kiv.zcu.cz (Arnostka Netrvalova)

Abstract

The paper deals with impersonal trust modeling focusing on intervention effect. Terms as trust, trust representation, phenomenal trust as a modification of impersonal trust, and trust representation are introduced. Brief description of extended trust model covering several factors effecting phenomenal trust forming is presented. Proposed model covers following basic factors: initial trust, product reputation, number of product recommendations, and trusting disposition as a representation of non rational part of human factor. With respect to trust forming, the method of intentional intervention on trust modeling is proposed. The model of trust evolution is extended in this way. The comparison of trust model with and without using 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 demonstrated. Evaluation of intervention effect by entropy, relative entropy, and symmetric relative entropy is proposed. The model of intentional intervention on trust is applied to real data. The data deal with social trust in Czech Republic acquired by the Institute of Sociology of the Academy of Sciences of the Czech Republic. Results of this study are presented too.

Keywords: Trust, Trust modeling, Impersonal trust.

Presenting Author's biography

Arnoštka Netrvalová. She 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 and a Ph.D. in Computer Science from the same university in 2010. Her research in modeling and simulation covered simulation of temperature homeostasis in an environment with increased temperature, and trust modeling.

1 Introduction

Trust is a unique phenomenon and plays an important role in social relationships. Each of us makes decisions based on or influenced by trust, most of us every day in our lives, and even many times per day. In the internet age, the trust to information acquired from web gains more and more on importance. Widening of e-service [1], e-commerce [2], e-banking, etc., arises the question of human machine trust. Further, trust plays an important role in ad hoc networks [3], grid computing, semantic web [4], and multi agent systems [5], where humans and/or machines have to collaborate.

The acceptation of the term trust is wide [6]. Based on [Gambetta], we interpret trust as a confidence in the ability or intention of a person to be of benefit to trustworthy something or someone at sometime in future. Trust is represented by a value from continuous interval $\langle a, b \rangle$, where a, b ($a < b$) are integer or real numbers [7]. Value a represents complete distrust and value b means blind trust. Usually, the interval is quantized to a few discrete verbal levels. An example for $a = 0$ and $b = 1$ is shown in Fig. 1.

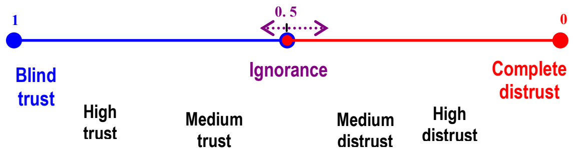


Fig. 1 Trust value representation

2 Phenomenal trust

Trust is created not only among the subjects (persons, nodes), where the term personal trust is used but the subject can be perceived as a phenomenon, i.e. another type of trust – impersonal trust. In this case, trust is formed towards a phenomenon, e. g. to certain product from a set of products of some kind, extent of crisis impact on an individual, political party etc.

Consider a group of n subjects represented as set S, $S = \{s_1, s_2, \ldots, s_n\}$ and a group of m exclusive products of some kind represented as set $P = \{p_1, p_2, \ldots, p_m\}$ that constitutes the phenomenon. Trust of subject x_i to product p_k is described by Eq. (1)

$$t_i^k = t(s_i, p_k), \quad \sum_{k=1}^{m} t_i^k = 1, \quad t_i^k \in \langle 0, 1 \rangle, \tag{1}$$

where: $i = 1, \ldots n$, and $k = 1, \ldots, m$. The directed weighted graph can be applied to phenomenal trust representation. The example for two persons and three products is in Fig. 2.

Phenomenal trust matrix T is used for the graph implementation. The matrix row represents trust distribution of the subject to the products. The column represents trust values of the subjects to the chosen product. Matrix entry -1 denotes that the subject does not know the product.

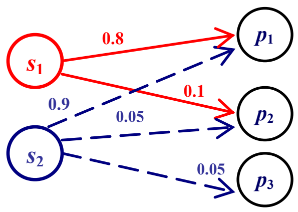


Fig. 2 Phenomenal trust representation

Trust matrix representation of the graph from Fig. 2 is given by Eq. (2)

$$T = \begin{bmatrix} 0.8 & 0.1 & -1 \\ 0.9 & 0.05 & 0.05 \end{bmatrix} \tag{2}$$

3 Model of information intervention

We will use a general model of information intervention shown in Fig. 3 (Vavra F., University of West Bohemia, personal communication).

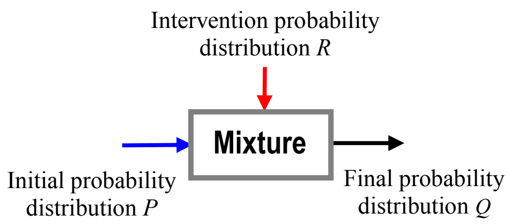


Fig. 3 Model of information intervention effect

The probability distribution P on the input represents the state before the intervention, the probability distribution Q on the output describes the state after intervention activity, and the intervention is modeled by probability distribution R.

The proper method for mixture of initial probability and intervention probability is given by Eq. (3)

$$Q(x) = (1-\lambda)P(x) + \lambda\, R(x), \tag{3}$$

where x ($x \in X$) is event observed from finite set of events X and parameter $0 < \lambda \leq 1$ represents intensity of the intervention.

For given probability mass functions $P(x)$, $R(x)$, $Q(x)$ the intervention intensity λ can be computed by least squares method.

4 Intervention model

We applied the model of information to phenomenal trust model described in [8]. Trust of the subjects to given products evolves under changing trust forming factors in this model. We have proposed trust model determining new value of phenomenal trust T_i^k of subject s_i to product p_k as the function of following trust forming factors: previous trust t_i^k to product, initial trust t_0^k to product, number of product recommendations d_i^k, product reputation r_i^k, and trusting disposition g_i^k, defined by Eq. (4)

$$T_i^k = F\left(t_i^k, t_{0_i}^k, d_i^k, r_i^k, g_i^k\right) \quad (4)$$

Initial trust of subjects to products is got on the start. The reputation comes after individual experience and by some information dissemination about product in its neighborhood. Further, trust is formed by information about another product that other subjects have passed on. This information is called recommendation. Subject trusting disposition to products represents the degree of non rational behavior of a subject modeled randomly.

Trust evolution T_i^k considering intervention effect according to Eq. (3) is

$$T_i^k = (1 - \lambda_i^k)\, t_i^k + \lambda_i^k\, I_i^k \quad (5)$$

Initial probability distribution is given by previous trust values t_i^k of the subject s_i to considered products. The intention to increase trust value to some product is described by intervention probability distribution values I_i^k. Expressing the intensity of intervention by λ_i^k, $0 < \lambda_i^k \le 1$, the new trust probability distribution is given by values T_i^k. If intervention distribution I and targeted trust distribution T are known, the intervention power values λ can be computed. On the other hand, if intervention distribution I and intervention power values λ are known, trust distribution T can be predicted.

Next, we ask how to measure the effect of the intervention. Entropy $H(X)$ is a measure of the uncertainty associated with a random variable X

$$H(X) = -\sum_{x \in X} P(x) \cdot \lg P(x), \quad (6)$$

where $P(x)$ are the values of probability mass function. Then, the entropy is increasing if the effect of the intervention uniforms probability distribution, whereas it is decreasing in opposite case and can be used for measurement of intervention effect in this sense.

The difference between initial probability distribution P and final probability distribution Q can be measured by relative entropy, i.e. divergence defined by Eq. (7)

$$D(P \,\|\, Q) = \sum_{x \in X} P(x) \lg \frac{P(x)}{Q(x)} \quad (7)$$

As the relative may be not symmetric, as a measure we apply symmetric relative entropy, i.e. symmetric divergence $d\,(p, q)$ defined by Eq. (8)

$$d(p,q) = D(P \,\|\, Q) + D(Q \,\|\, P) \quad (8)$$

5 Studies and experiments

To pursue trust model behavior, we carried out series of simulation experiments. Further, the method of intervention effect on phenomenal trust was applied to real data.

5.1 Intervention model behavior studies

The groups of individuals of various size, and initial trust distribution to products were generated. Values of trust forming factors were stepwise set up, and trust evolution without intervention was observed. Next, we introduced the intervention in order to achieve intended changes in trust distribution. Intervention effect on phenomenal trust was evaluated using proposed measures. The results are presented in graphs, in which connecting line highlights.

Trust evolution of a chosen subject s_1 into each product without intervention effect is shown in Fig. 4. Experiment covers the effects of product reputations (r_1^1=0.01, r_1^2=0.04, r_1^3=0.05, r_1^4=0.62, r_1^5=0.28), and evolving product recommendations (for 1st step: d_1^2=3, d_1^4=3, for 2nd step: d_1^2=1, d_1^4=2, for 3rd step: d_1^4=3, for 4th step: d_1^4=2, for 5th step: d_1^3=1, d_1^4=4), and trusting disposition about 0.75 for each of products. Trust changed only a little in this case.

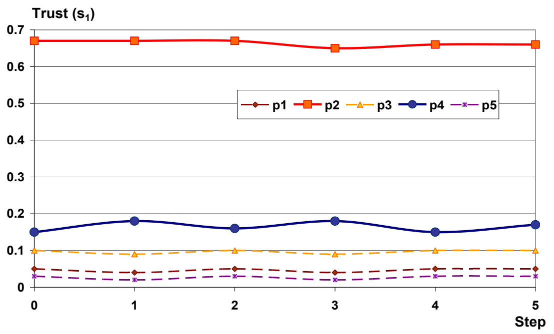


Fig. 4 Trust without intervention effect (λ=0)

The same factors were covered in next where the intervention effect was examined. Intervention intensity was set to λ=0.05 and intervention distribution (I_1^1=0.06, I_1^2=0.03 I_1^3=0.1, I_1^4=0.75, I_1^5=0.12) aimed at profit of product p_4 and to harm product p_2. The results are shown in Fig. 5. We can observe the trust increase of about 0.15 to product p_4.

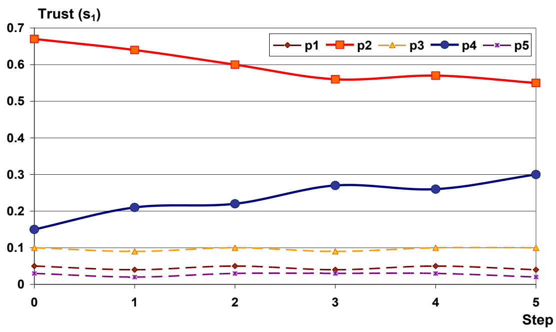


Fig. 5 Trust intervention effect (λ=0.05)

Afterwards trust intervention was raised with intensity λ=0.5, in order to explore the influence of λ. Trust values p_2 and p_4 swapped over after five steps (profit to product p_4 and harm to product p_2) as we can see in Fig. 6. So, the intervention intensity plays a substantial role.

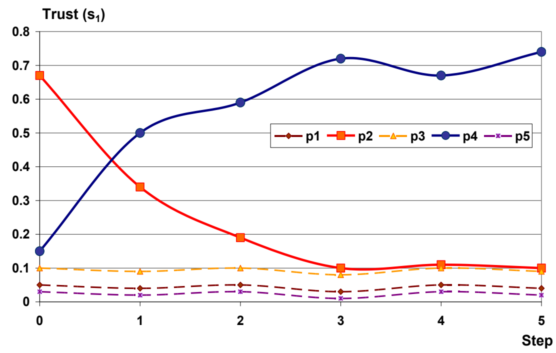


Fig. 6 Trust intervention effect (λ=0.5)

The impact of intervention after the 1st step is visualized in Fig. 7. Initial probability distribution values are in first columns, intervention probability distribution values are in middle columns, and final probability distribution values are in third columns.

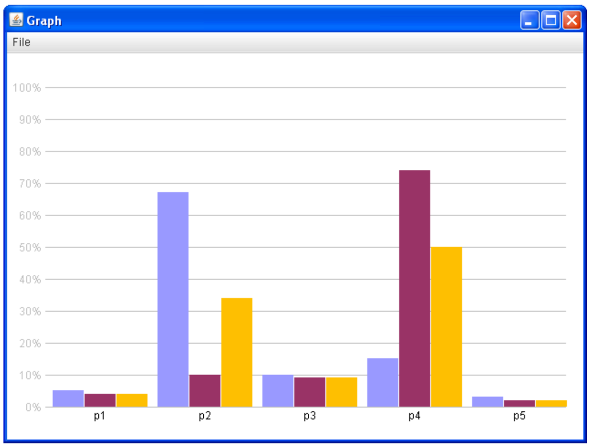


Fig. 7 Initial, intervention, and final trust distribution for the first step

Moreover, the intervention effect can be evaluated using measures proposed above. The 1st step of previous experiment is enlarged in Fig. 8.

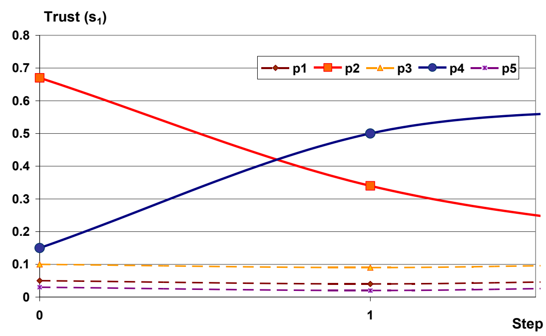
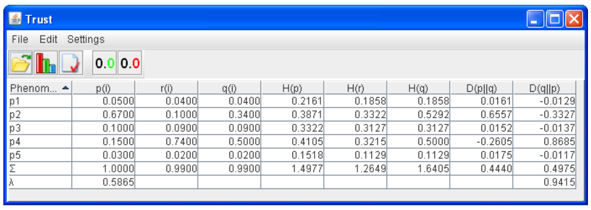


Fig. 8 Trust intervention effect (λ=0.5, after 1st step)

The parameters and measures of intervention effect for λ=0.5 after the 1st step are shown in Fig. 9.



Trust

File Edit Settings

Phenom...	p(i)	r(i)	q(i)	H(p)	H(r)	H(q)	D(p‖q)	D(q‖p)
p1	0.0500	0.0400	0.0400	0.2161	0.1858	0.1858	0.0161	-0.0129
p2	0.6700	0.1000	0.3400	0.3871	0.3322	0.5292	0.6557	-0.3327
p3	0.1000	0.0900	0.0900	0.3322	0.3127	0.3127	0.0152	-0.0137
p4	0.1500	0.7400	0.5000	0.4105	0.3215	0.5000	-0.2605	0.8685
p5	0.0300	0.0200	0.0200	0.1518	0.1129	0.1129	0.0175	-0.0117
Σ	1.0000	0.9900	0.9900	1.4977	1.2649	1.6405	0.4440	0.4975
λ	0.5865							0.9415

Fig. 9 Parameters and measures of intervention effect (for λ=0.5 after 1st step)

The initial probability distribution $p(i)$, where i represents index of product is given as the initial trust values p_i, intervention probability distribution $r(i)$ (i.e. $I_1^{\,i}$, where i =1,2,...,5) are required trust values after five steps and final probability distributions are trust values after 1st step of intervention.

Entropy of final trust $q(i)$, $H(q)$=1.6405, compared to entropy of initial trust $p(i)$, $H(p)$=1.4977, increased. This means more uniform distribution, trust values to products p_2 and p_4 are closer than after the intervention.

Symmetric relative entropy expresses the impact of trust intervention measuring the dissimilarity of initial and final trust distribution. This enables to compare the effect of alternative interventions.

For example, in Fig. 10 is enlarged the first step from Fig. 5 for smaller intervention intensity λ=0.05 only. The parameters and measures of intervention effect in this case are shown in Fig. 11.

Symmetric relative entropy for λ=0.05 decreased by factor higher then 20 compared to λ=0.5.

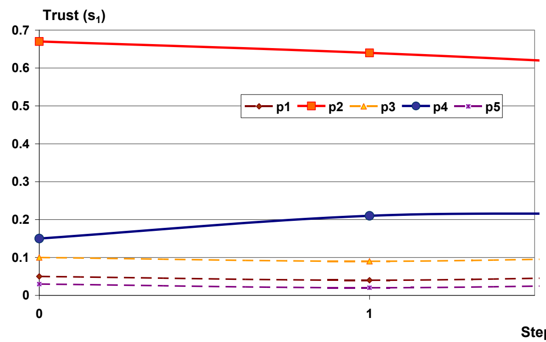
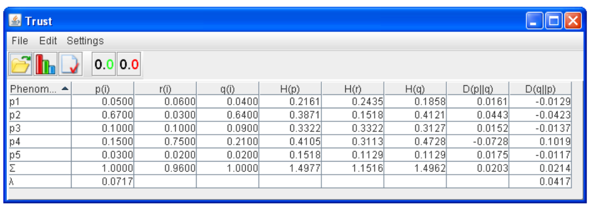


Fig. 10 Trust intervention effect (λ=0.05, after 1st step)



Trust

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Phenom...	p(i)	r(i)	q(i)	H(p)	H(r)	H(q)	D(p‖q)	D(q‖p)
p1	0.0500	0.0600	0.0400	0.2161	0.2435	0.1858	0.0161	-0.0129
p2	0.6700	0.0300	0.6400	0.3871	0.1518	0.4121	0.0443	-0.0423
p3	0.1000	0.1000	0.0900	0.3322	0.3322	0.3127	0.0152	-0.0137
p4	0.1500	0.7500	0.2100	0.4105	0.3113	0.4728	-0.0728	0.1019
p5	0.0300	0.0200	0.0200	0.1518	0.1129	0.1129	0.0175	-0.0117
Σ	1.0000	0.9600	1.0000	1.4977	1.1516	1.4962	0.0203	0.0214
λ	0.0717							0.0417

Fig. 11 Parameters and measures of intervention effect (for λ=0.05 after 1st step)

In Fig. 9 and Fig. 11 are quoted λ values computed by least squares method as mentioned in Section 3. These values are slightly different from applied ones caused by the effect of reputation, recommendation, and trusting disposition parameters, which influence computed measures.

5.2 Real data experiments

Data of trust into Czech Government (Confidence in constitutional institutions and satisfaction with political situation published in January 2010) shown in Fig. 12 were obtained from reports on the web pages of the Institute of Sociology of the Academy of Sciences of the Czech Republic [9].

In April 2009, 20% respondents trusted to Miroslav Topolanek's Cabinet and 80% respondents distrusted or gave no answer. Then, Jan Fischer's Cabinet was constituted in May 2009. Clearly, the intention was to increase the trust into government as such.

In the questionnaire in June 2009, respondents answered the question: "Tell us, please, whether you trust Jan Fischer's Cabinet?" The values changed to 55% respondents which trusted Fischer's Cabinet and 45% respondents which do not trusted or gave no answer.

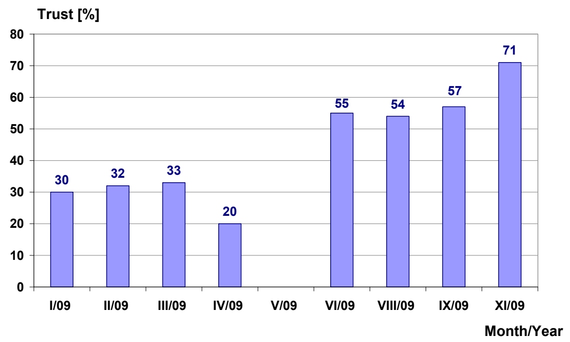


Fig. 12 Trust into Czech Government in 2009

In the model, the phenomenon values represent two points of view: "Government is trusted" and "No trust into Government". As the initial probability distribution, the values of trust from April 2009 are taken (first columns in the graph in Fig. 13).

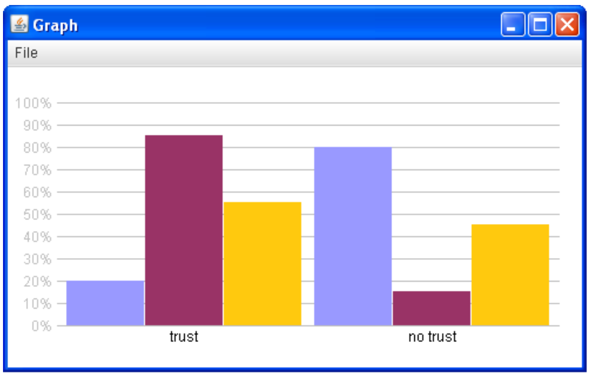
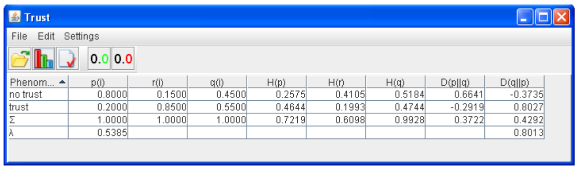


Fig. 13 Trust to Government: April ⇨ June 2009 (probability distributions)

Values of intervention probability distribution are set for indented increase of trust into the Government to 85% (column in the middle), and as the target probability distribution, values of trust in June 2009 are taken (third column).

The parameters of the intervention on increasing the trust into the Government together with measures of the intervention effect (probability distributions, entropy, relative entropy, symmetric relative entropy) are summarized in Fig. 14.



Phenom...	p(i)	r(i)	q(i)	H(p)	H(r)	H(q)	D(p||q)	D(q||p)
no trust	0.8000	0.1500	0.4500	0.2575	0.4105	0.5184	0.6641	-0.3735
trust	0.2000	0.8500	0.5500	0.4644	0.1993	0.4744	-0.2919	0.8027
Σ	1.0000	1.0000	1.0000	0.7219	0.6098	0.9928	0.3722	0.4292
λ	0.5385							0.8013

Fig. 14 Parameters and measures of intervention (April ⇨ June 2009)

In the next experiment, we used the questionnaire from November 2009, in which the respondents answered the same question: "Tell us, please, whether you trust Jan Fischer's Cabinet?" The values changed to 71% respondents, which trusted Fischer's Cabinet and 29% respondents which did not trust or gave no answer.

Again, as the initial probability distribution, the values of trust from April 2009 are taken (first column in the graph in Fig. 15). Values of intervention probability distribution are the same (85% trust into the Government) as were considered in the previous experiment (column in the middle), and as the target probability distribution, values of trust found out in November 2009 are taken (third column).

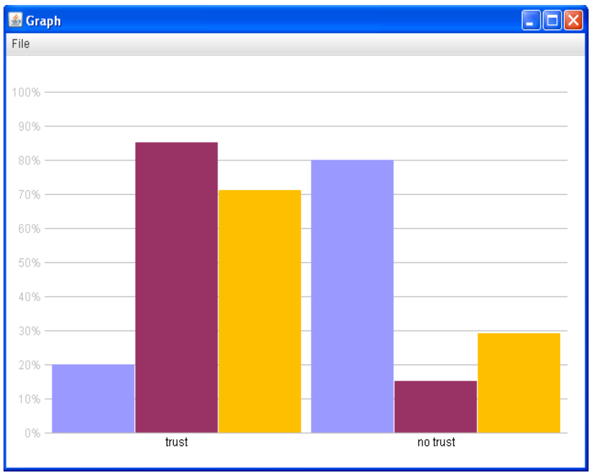
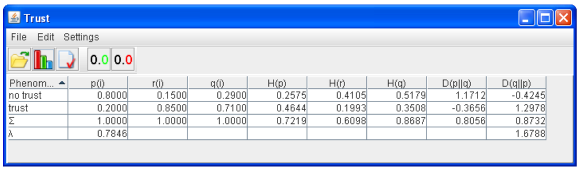


Fig. 15 Trust to Government: April⇨November 2009 (probability distributions)

The parameters of the intervention on trust into the Government together with measures of the intervention effect in this case are summarized in Fig. 16.



Phenom...	p(i)	r(i)	q(i)	H(p)	H(r)	H(q)	D(p‖q)	D(q‖p)
no trust	0.8000	0.1500	0.2900	0.2575	0.4105	0.5179	1.1712	-0.4245
trust	0.2000	0.8500	0.7100	0.4644	0.1993	0.3508	-0.3656	1.2978
Σ	1.0000	1.0000	1.0000	0.7219	0.6098	0.8687	0.8056	0.8732
λ	0.7846							1.6788

Fig. 16 Parameters and measures of intervention (April ⇨ November 2009)

We compared these two cases from two points of view; required intervention intensity and symmetric relative entropy values. In the first case, intervention intensity was 0.54 and in the second increased to 0.79. Impact of intervention represented by symmetric relative entropy increased from 0.8 in the first case to 1.68 in the second case. So, the usual visual presentation of investigation results, e.g. on trust in the Government, can be expressed quantitatively.

6 Conclusion

We developed phenomenal trust model integrating intervention effect for trust evolution. The experiments proved fair behavior of the model. Proposed evaluation of trust intervention effect by entropy and symmetric relative entropy gives quantifiable information in accordance with visual assessment of trust evolution behavior. We demonstrated the application of the model to real data. The model itself will be deployed in upcoming agent based trust management model.

7 Acknowledgement

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8 References

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