Propagation of Trust and Confidence using Intervals

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Abstract— **Trust propagation is a widely-used approach to estimate the trustworthiness level of a target node in a web of trust, especially when the source node has no experience of direct interaction with the target. It is important to have not only an accurate estimate of trust, but also a measure of confidence in the propagated trust. In this paper we introduce a novel approach for propagation of trust and confidence through a web of trust based on our proposed idea of representation of trust and confidence using intervals. We consider this propagation method as a kind of multiplication among trust intervals. We show that this operator is more accurate for evaluation of propagated trust than the current approaches. We also report and analyze the results of experiments carried out on a well-known trust dataset which show that our proposed method improves the accuracy of trust propagation.**

Keywords- trust, trust propagation, confidence, interval, trust interval

I. Introduction

Trust management has obtained an increasingly important role in various fields of computing science including semantic web, computer networks, game theory, multi-agent systems, social networks, e-commerce, etc.

Among different definitions of trust including definitions in [4, 14, 15], the one from Mui et al. [14] is very popular: “[Trust is] a subjective expectation an agent has about another’s future behavior based on the history of their encounters.”

There are also various definitions for trust management. Josang et al. [8] define trust management as “the activity of creating systems and methods that allow relying parties to make assessments and decisions regarding the dependability of potential transactions involving risk, and that also allow players and system owners to increase and correctly represent the reliability of themselves and their systems.”

Reputation is considered as a trust measure. Each entity maintains reputation information on other entities, thus creating a “web” that is called the web of trust. If there is no link between a pair of entities, it means no trust decision has yet been made. This is the case in which trust transitivity can be applied: if A trusts B and B trusts C, then A trusts C. We may generalize this property in a web of trust: if there is a path from a source node, say S, to a sink(destination) node, say D, we can consider this path as a “chain of trust” and the trust can be “propagated” through this chain. However there is discussion on how much transitivity is valid and which formula or algorithm should be used for calculating the propagated trust value in each field. Multiple researchers are exploring ways to transfer trust within a web of trust. We refer for example to [13, 16, 17].

One important problem in trust propagation is that we should also consider or evaluate the confidence of each edge in the chain of trust and based on them estimate the confidence in the final propagated trust. As an example, suppose a trust chain S-A-B-D where S and D are source and destination (target) nodes, respectively and A and B are intermediate node in the chain. Suppose also that the values of trust from S to A, from A to B, and from B to D are 0.7, 0.8 and 0.5, respectively. If S, A and B’s confidence values in their own assessments are 0.9, 0.5 and 0.75 respectively, what is the indirect (propagated) trust from S to D, and how confident this estimation is?

In this paper we introduce a novel approach for propagation of trust and confidence through a chain of trust. This approach is based on our proposed idea of representation of trust and confidence using intervals [18]. We may consider this propagation method as a kind of multiplication among trust intervals. We show that this operator is more accurate for evaluation of propagated trust than the current approaches. We also report and analyze the results of experiments carried out on a well-known trust dataset which show that our proposed method improves the accuracy of trust propagation.

The rest of this paper is organized as follows: Section 2 describes the related work. In section 3 we review our interval notation for representation of trust and confidence from [18]. In section 4 we introduce our new approach to propagation of trust and confidence using intervals that is the operator of trust interval multiplication. We propose an algorithm to estimate the propagated trust based on the introduced operator in section 5. In section 6 we report and analyze the results of experiments carried out on a trust dataset. Finally we conclude in section 7.

II. Related Work

Many researchers have worked on the algorithms for how trust is transferred, combined, or resolved. In [20, 21] a set of hypotheses and experiments are described for testing how trust is transferred between hyperlinks on the Web.

Other more recent works look at how to compute trust transitivity given actual quantities for trust or distrust. A key work in this area is [16] whose goal is to provide a means of merging trust that is robust to noise. Emphasizing personalized trust, as opposed to globally computed values, this approach is described as a generalization of PageRank [1] to the Semantic Web.

In several models of access control for pervasive environments (including [5] and [17]), propagated trust is computed by iteratively multiplying the trust values on the path from a source entity to the target entity. This approach is called IMS (Iterative Multiplication Strategy). RTBIMS, an improvement to IMS is introduced in [19].

Ding et al. in [2] classified trust into two broad categories:

- Referral Trust: Trust to the other's knowledge in a particular domain
- Associative Trust: the value of similarity between two agents' ideas.

Then they identified five types of trust, one of which, STT is used in our algorithm. STT stands for Similar Trusting Trust and is an associative trust that evaluates the similarity of two agents' trust knowledge. STT_{ijd} refers to the similarity of agent a_i and agent a_j's referral trust to the other agents within domain d. Intuitively STT clusters trustors (agents who maintain trust knowledge). This paper formalizes trust network inference notions, providing both data and computational models, and suggests an evaluation model for benchmarking.

Hasan et al. in [6] used a method for eliminating subjectivity from trust recommendations. In another work, they evaluated the effectiveness of iterative multiplication for trust propagation using the dataset of Advogato which is a real web of trust [5].

Some works in the area of trust concentrated on trust applications in specific domains. For example, [12] and [23] use the concept of trust in wireless sensor networks and [11] introduces a method for computing global trust in P2P networks.

Among different approaches to trust management, some works paid attention to soft computing techniques. For example [3], [12] and [23] use Ant Colony Optimization algorithm to improve accuracy in trust estimation.

There exist a few works in the area of confidence and its role in trust management in the literature. One of the key works in this area is Josang's one [7] which though does not use the term confidence explicitly, takes into account the concept of uncertainty that has a close relevance to confidence. Josang represents an opinion on trust as a triple {b, d, u} in which b, d and u designate belief, disbelief and uncertainty, respectively.

Josang then introduces a formula for calculating the opinion as a result of recommendation:

"Let A and B be two agents where $w_B^A = \{ b_B^A, d_B^A, u_B^A \}$ is A's opinion about B's recommendations, and let p be a binary statement where $w_p^B = \{ b_p^B, d_p^B, u_p^B \}$ is B's opinion about p expressed in a recommendation to A. Then A's opinion about p as a result of the recommendation from B is defined by:

$$w_p^{AB} = w_B^A \times w_p^B = \{ b_p^{AB}, d_p^{AB}, u_p^{AB} \}$$

where

$$b_p^{AB} = b_B^A . b_p^B$$

$$d_p^{AB} = b_B^A . d_p^B$$

$$u_p^{AB} = d_B^A + u_B^A + b_B^A u_p^B$$ "

In [9] and [10] the value of confidence is estimated using similarity measures. In [22] a model for the aggregation of trust evidences is proposed that computes confidence scores taking into account the dynamic properties of trust.

In [18] we introduced a novel method for representing trust and confidence using intervals. We will review that idea in the next section.

III. Representation of Trust and Confidence using Interval Notation

In trust management area, confidence denotes the capacity in which an entity is assured about its own or another entity's assessment on a target entity's trustworthiness level. For example suppose that entity S asks entity A about D's trustworthiness and A replies as 0.7. However S's (or A's itself) confidence in this opinion may be 0.8.

Since trust and confidence are denoted with two distinct numbers, the calculations dealing with both of them are difficult. We propose integrating these two values in a new representation using intervals. We introduce (1) for this purpose.

$$TI = [C*T, C*T+1-C] \quad (1)$$

Where TI is Trust Interval, and C and T are confidence and trust values respectively.

In other words, to determine the lower bound of the trust interval, we should consider the case when trust is 0 in the uncertainty area. C is the level of confidence and so 1-C is the value of uncertainty. Since trust is reported as T, the minimum of confident trust is C*T. So the lower bound is as (2) shows.

$$L = C*T + (1-C)*0 = C*T \quad (2)$$

To determine the upper bound of the trust interval, on the other hand, we should consider the case when trust has, in the uncertainty area, its maximum value, i.e. 1. So we obtain (3) for the upper bound.

$$U = C*T + (1-C)*1 = C*T+1-C \quad (3)$$

As an example suppose T=0.7. With some different values of C, the trust interval will be as follows:

C = 0 ➔ TI = [0, 1]

C = 0.5 ➔ TI = [0.35, 0.85]

C = 0.8 ➔ TI = [0.56, 0.76]

C = 1 ➔ TI = [0.7, 0.7]

In fact, in the case of C=0, there is no confidence in the opinion of the appraiser at all. This means that no valuable knowledge is obtained about the trustworthiness level of the target. Therefore trust interval is [0, 1]. Note that in the case of C=0, the trust interval is independent of the value of T and is always equal to [0, 1]. As C is increased, the trust interval becomes narrower and the lower and upper bounds approach to T. Finally in the case of C=1, there is absolute confidence in the appraiser's opinion. So the trust estimation is quite accurate and the lower and upper bounds of the trust interval are same and equal to T, that is [0.7, 0.7] in our example.

Although we believe that using an integrated interval for representing both trust and confidence is clearer and more intuitive than using two distinct variables for them, we can again extract the values of trust and confidence from the trust interval anytime needed, especially for evaluation purposes where different methods should be compared. To do that, we may consider (2) and (3) as a system of two equations and solve the system for T and C. Trust and confidence will be obtained as (4) and (5).

$$T = \frac{L}{1 + L - U} \qquad (4)$$

$$C = \frac{L}{T} \qquad (5)$$

Our proposed idea of using interval concept for representing trust and confidence is conceptually similar to the notation introduced by Josang in [7]. As we mentioned in section 2, Josnag's model uses a triple to represent belief, disbelief, and uncertainty. We believe that due to using the well-known concept of interval, our notation is more intuitive than Josang's one. However these two notations are convertible to each other. For example we can use (6) and (7) to convert Josang's notation to our one.

$$L = b \qquad (6)$$

$$U = 1 - d \qquad (7)$$

Note that in Josang's notation u is not an independent variable and may be obtained having b and d as u = 1-(b+d). The value of u is equivalent to the width of the trust interval in our representation. For example the triple {0.5, 0.3, 0.2} in Josang's model is represented as the interval [0.5, 0.7] in our notation.

IV. TRUST INTERVAL MULTIPLICATION

Suppose that the entity S (source) has some trust in the intermediate entity X represented by $[L_{SX}, U_{SX}]$. S asks X to report its opinion about the trustworthiness level of the entity D (destination or target). X replies in the form of trust interval $[L_{XD}, U_{XD}]$ (In practice S may first receive from X the values of trust and confidence as distinct variables. In such a case it should calculate the trust interval form (1): It should replace T in (1) with X's reported trust for D, and C with X's confidence in its own opinion). To determine what is the final assessment of S on D's trustworthiness as the value of propagated trust, and in what capacity this estimation is confident, we define a special kind of multiplication operator for trust intervals. We show this operator in (8), (9) and (10). Note that we do not mean the classic interval multiplication operator which has a well-known definition in interval algebra, but we mean a novel operator that reflects trust and confidence propagation.

$$[L_{SX}, U_{SX}] \times [L_{XD}, U_{XD}] = [L_{SD}, U_{SD}] \qquad (8)$$

such that:

$$L_{SD} = L_{SX}.L_{XD} \qquad (9)$$

$$U_{SD} = 1 - L_{SX}.(1-U_{XD}) \qquad (10)$$

where $[L_{SD}, U_{SD}]$ denotes the final propagated trust interval.

Equations (9) and (10) are obtained from transferring the corresponding equations in [7] into the interval space.

In order to illustrate the concept and applications of interval notation as well as the multiplication operator defined in (9) and (10), we have computed the product of some different pairs of intervals and show the results in table 1.

According to (9) and (10) and the results in table 1 we investigate some of the trust interval multiplication properties in the following:

1) The proposed operation of trust interval multiplication is not commutative. For example we have

[0, 0.33] × [0.33, 0.66] = [0, 1]

whereas

[0.33, 0.66] × [0, 0.33] = [0, 0.78]

2) The product is independent of U_{SX}. In other words, only the lower bound of the left operand, that is the minimum of confident trust from source to the intermediate node, is important in the trust interval multiplication.

3) If L_{SX}=0, then the product of two intervals will be always [0, 1]. This is reasonable because in such a case the source(S) has no confident trust in the intermediate node(X) at all, so X's recommendations do not provide any confident information to S. We mentioned in section 3 that the trust interval [0, 1] represents this case.

TABLE I. PRODUCT OF SOME TRUST INTERVAL PAIRS

Intervals	[0, 0]	[0, 0.33]	[0, 0.66]	[0,1]	[0.33, 0.33]	[0.33, 0.66]	[0.33, 1]	[0.66, 0.66]	[0.66, 1]	[1, 1]
[0, x], 0≤x≤1	[0, 1]	[0, 1]	[0, 1]	[0, 1]	[0, 1]	[0, 1]	[0, 1]	[0, 1]	[0, 1]	[0, 1]
[0.33, x], 0.33≤x≤1	[0, 0.67]	[0, 0.78]	[0, 0.89]	[0, 1]	[0.11, 0.78]	[0.11, 0.89]	[0.11, 1]	[0.22, 0.89]	[0.22, 1]	[0.33, 1]
[0.66, x], 0.66≤x≤1	[0, 0.34]	[0, 0.56]	[0, 0.78]	[0, 1]	[0.22, 0.56]	[0.22, 0.78]	[0.22, 1]	[0.44, 0.78]	[0.44, 1]	[0.66, 1]
[1, 1]	[0, 0]	[0, 0.33]	[0, 0.66]	[0,1]	[0.33, 0.33]	[0.33, 0.66]	[0.33, 1]	[0.66, 0.66]	[0.66, 1]	[1, 1]

4) If $[L_{SX}, U_{SX}] = [1, 1]$, then the product is equal to $[L_{XD}, U_{XD}]$. In other words, [1, 1] is the left identity element for trust interval multiplication operator. This is justifiable because S has absolute confident trust in X and so accepts its recommendations exactly.

5) If $[L_{XD}, U_{XD}] = [0, 1]$, the product of trust intervals will be [0, 1], too. That is because in such a case, X has no confidence in its own assessment about D at all and it is obvious that the propagated trust interval will be absolutely unconfident as well. We remind again that the trust interval [0, 1] reflects "zero confidence".

V. Trust Propagation Algorithm Based on the Proposed Approach

A solution to a trust inference problem is a trust value from the interval [0, 1] that describes the amount of trust that the source, say n_0, has for the sink, say n_∞. In this section we first propose our algorithm for calculating the propagated trust. Since the confidence used in this algorithm is estimated based on the similarity measure, we then propose the sub-algorithm which performs this estimation.

A. Trust Propagation Algorithm

Our algorithm for computing the propagated trust is shown in Fig. 1. To compute the propagated trust from the source node (s_0) to the sink node (s_∞), we should find all paths (trust chains) from source to sink, determine the propagated trust through each path (TI_{path}), and finally compute the resultant of the values obtained from different paths (TI_{total}).

To compute the resultant of some trust intervals, we use our summation operator described in [18]. The identity element of this operation is [0, 1]. Accordingly, we initialize the TI_{total} with [0, 1].

In each path (trust chain) we use the multiplication operator stated in (9) and (10) for trust propagation. We initialize TI_{path} with [1, 1] that is left identity element of multiplication operator. Then we multiply the propagated trust interval (TI_{path}) by trust interval of each edge in the path (TI_{ij}).

As we mentioned before, after computing the propagated trust in each trust chain, we use the summation operator for trust intervals to determine the resultant of them.

B. Confidence Estimation Subalgorithm

The value of confidence used in the algorithm may be available directly. However in many cases the trust network contains only the values of trust. In such cases the values of confidence should be estimated in some way indirectly. Several works including [7, 9, 23] use similarity measures as an estimation of the confidence the source has in an appraiser (intermediate) node, namely how similar are the opinions of the source and the appraiser in the cases where opinions of both are available, is considered as a measure of the confidence the source node has in the appraiser's recommendations.

The confidence estimation sub-algorithm is shown in Fig. 2. In this sub-algorithm, to estimate the confidence from n_0 to n_k, we calculate MeanDiff that is the mean of absolute differences between n_0's and n_k's opinions on the trustworthiness of all nodes n_i on which both n_0 and n_k have stated their opinions.

VI. Experiments and Results

To evaluate the efficiency of using trust intervals and accuracy of the proposed multiplication operator, we applied our method among some other methods to the well-known dataset of Advogato. This dataset contains information of trust among the members of an internet community of programmers and one of its aims is to provide a source for trust experiments. Some other works including [13, 18, 19] used this dataset for evaluating their algorithms, as well.

```
Function PropagateTrust
Inputs:
    Trust Network (TN),
    source node (n0),
    sink node (n∞)
Output:
      propagated trust which describes the amount of
      trust that the source has for the sink (TIprop)
Begin
      TItotal = [0, 1]
      For all paths p from n0 to n∞ do
      Begin
         TIpath = [1, 1]
         For all edges ninj in the path p do
            TIpath = TIpath × TIij (using Equation (9) and (10))

      End
      TItotal = TItotal + TIpath
            (using trust interval summation operator from [18])
      Return TItotal
End
```

Figure 1. Trust propagation algorithm

```
Function EstimateConfidence
Inputs:
    Trust Network (TN),
    source node (n0),
    appraiser node (nk)
Output:
    The confidence n0 has in nk's opinions
Begin
      sum = 0
      counter = 0
      For all nodes ni in TN
         If T[n0, ni]≠0 and T[nk, ni]≠0
         Begin
               sum = sum + |T[n0, ni] - T[nk, ni]|
               counter = counter + 1
         End
      MeanDiff = sum / counter
      C = 1 – MeanDiff
      Return C
End
```

Figure 2. The confidence estimation subalgotithm

A. Dataset Characteristics

The dataset of Advogato is a text file including about 71000 lines of data which contains information on trust among about 14000 programmers. Each programmer has stated the value of his/her trust for another programmer in the terms of one of the words Apprentice, Journeyer, or Master. Mapping these words into the numbers in the range [0, 1] is left to the user. We considered the numbers 0.3, 0.6 and 0.9 as the numerical equivalent of the words, respectively. We also considered 0 for the cases where a programmer has not stated any opinion on another programmer.

A part of the dataset is shown in Fig. 3.

B. Experiment Results

To evaluate and compare the accuracy of the proposed method, we used the leave-one-out technique which is a common validation method in trust research works. In this method, for any pairs of nodes, say v_i and v_j, which direct trust of v_i for v_j is available, we also calculate the indirect (estimated) value of trust from v_i to v_j using each algorithm and consider the correlation and mean of absolute error between direct and indirect trust as measures of the algorithm accuracy.

We found all pairs (i,j) in the trust network, which the value of direct trust between them was available. In each case we calculated the estimated value of trust from n_i to n_j in the form of a trust interval using the proposed algorithm. To be possible to compare the results to the other methods, we then extracted the explicit value of trust from trust interval using (4). On the other hand, we calculated the estimated trust each node n_i has for node n_j using IMS and RTBIMS [19] methods independently.

```
Digraph G {
        /* dbarth */
        dbarth → mikl [level = "Journeyer"];
        /* minami */
        minami → minami [level="Apprentice"];
        minami → polo [level="Journeyer"];
        minami → movement [level="Journeyer"];
        minami → jao [level="Journeyer"];
        /* polo */
        .
        .
        .
}
```

Figure 3. A part of Advogato dataset: For example "dbarth" has evaluated "mikl" as a journeyer programmer.

To compare the methods, we compared the results of each method with the direct trust values for all pairs which the direct trust between them was available in the dataset. We computed mean of absolute error and correlation coefficient among each method's results and direct trust values. The results are shown in table 2.

As table 2 shows, mean of absolute error has been decreased in our method to less than half comparing to IMS and is also remarkably less than the value in RTBIMS. On the other hand, correlation among the indirect and direct trust values has been increased as 0.15 comparing to IMS and 0.01 comparing to RTBIMS.

VII. Conclusion

Based on our proposed idea of representing trust and confidence concepts using intervals in previous works, in this paper we introduced a novel approach for propagation of trust and confidence through a chain of trust. This propagation method is based on a kind of multiplication among trust intervals. We investigated the properties of this operator and reported the results of practical experiments on a real trust dataset which show that using the proposed formula improves the accuracy in calculating the propagated trust.

In future we intend to investigate the effect of measures other than similarity in confidence such as appraiser's distance from the source and time of assessment. We will also investigate other properties of trust interval multiplication operator. In addition we are going to study the applications of intervals in analyzing the sources of uncertainty in trust management, eliminating subjectivity from trust assessment and clustering nodes of the web of trust.

TABLE II. Comparison of IMS, RTBIMS and Our Proposed Method

Method	Mean of Absolute Error	Correlation
IMS	0.095	0.76
RTBIMS	0.043	0.91
Proposed Method	0.039	092

References

[1] Brin, S. and Page, L., "The anatomy of a large-scale hypertextual Web search engine," Computer Networks and ISDN Systems, 30(1–7):107–117, 1998.

[2] Ding, L., Kolari, P., Ganjugunte, S., Finin, T., and Joshi, A., "Modeling and evaluating trust network inference," In Proceedings of the 7th International Workshop on Trust in Agent Societies at AAMAS, 2004.

[3] Ghaemi, A., and Shakeri, H., "Improving Iterative Multiplication Strategy in Estimating Propagated Trust Using Similarity Measure and Ant Colony Optimization", Proceedings of the 16th Annual CSI Computer Conference (CSI 2011), University of Sharif, Tehran, Iran, March 8-10, 2011 (in Persian).

[4] Grandison, T. and Sloman, M., "A survey of trust in internet applications," IEEE Communications Surveys and Tutorials, 4(4):2–16, 2000.

[5] Hasan, O., Brunie, L. and Pierson, J. M., “Evaluation of the Iterative Multiplication Strategy for Trust Propagation in Pervasive Environments,” ICPS’09, London, United Kingdom, 2009.

[6] Hasan, O., Pierson, J. M. and Brunie, L., “Access Control in Ubiquitous Environments Based on Subjectivity Eliminated Trust Propagation,” In Proc of the 3rd Intl. Conf. on Embedded and Ubiquitous Computing (EUC 2008), Shanghai, China, 2008.

[7] Josang, A., “An Algebra for Assessing Trust in Certification Chains”, in the proceedings of NDSS’99, Network and Distributed Systems Security Symposium, The Internet Society, San Diego 1999.

[8] Josang, A., Keser, C., and Dimitrakos, “Can We Manage Trust?”, In Proceedings of the Third International Conference on Trust Management (iTrust) (Versailles, France, May 2005), 93-107.

[9] Kuter, Y., and Golbeck, J., “SUNNY: A new algorithm for trust inference in social networks using probabilistic confidence models”, In Proceedings of the 22nd National Conference on Artificial Intelligence, 2007.

[10] Kuter, Y., and Golbeck, J., Using Probabilistic Confidence Models for Trust Inference in Web-Based Social Networks”, ACM Transactions on Internet Technology, Vol. 10, No. 2, Article 8, Publication date: May 2010.

[11] Lei C., and Xian-Zhong, X., “A Computation Method for the Value of Globe Trust based on MAX-MIN Ant System,” International Symposium on Computer Science and Computational Technology, 2008.

[12] Marmol, F. G., and Perez, G. M., “Providing Trust in Wireless Sensor Networks using a Bio-Inspired Technique,” Telecommunication Systems, Febraury 2010.

[13] Massa, P. and Hayes, C., “Page-rank: Using trusted links to re-rank authority,” In WI’05: Proceedings of the 2005 IEEE/WIC/ACM International Conference on Web Intelligence (WI’05), pages 614–617, Washington DC, USA, IEEE Computer Society, 2005.

[14] Mui, L., Mohtashemi, M., and Halberstadt, A., “A computational model of trust and reputation,” In Proceedings of the 35th International Conference on System Science, pages 280–287, 2002.

[15] Olmedilla, D., Rana, O., Matthews, B., and Nejdl, W., “Security and trust issues in semantic grids,” In Proceedings of the Dagsthul Seminar, Semantic Grid: The Convergence of Technologies, volume 05271, 2005.

[16] Richardson, M., Argawal, R., and Domingos, P., “Trust management for the semantic web,” In Proceedings of the Second International Semantic Web Conference, pages 351–368, Spring-Verlag, 2003.

[17] Saadi, R., Pierson J.-M., and Brunie., L., Authentication and access control using trust collaboration in pervasive grid environment, In Proceedings of the International Conference on Grid and Pervasive Computing (GPC 2007), 2007.

[18] Shakeri, H., and Ghaemi B. A., “Computing Trust Resultant using Intervals”, 8th International ISC Conference on Information Security and Cryptology (ISCISC’11), Ferdowsi University of Mashhad, Iran, 2011.

[19] Shakeri, H., and Ghaemi B. A., “RTBIMS: Accuracy Enhancement in Iterative Multiplication Strategy for Computing Propagated Trust”, 8th International ISC Conference on Information Security and Cryptology (ISCISC’11), Ferdowsi University of Mashhad, Iran, 2011.

[20] Stewart, K. J. and Zhang, Y., “Effects of hypertext links on trust transfer,” In ICEC ’03: Proceedings of the 5th international conference on Electronic commerce, pages 235–239, New York, NY, USA., ACM Press, 2003.

[21] Stewart, K. J., “Transference as a means of building trust in world wide web sites,” In ICIS ’99: Proceeding of the 20th international conference on Information Systems, pages 459–464, Atlanta, GA, USA., Association for Information Systems, 1999.

[22] Urbano, J., Rocha, A. P., and Oliveria, E., “Computing Confidence Values: Does Trust Dynamics Matter?”, Proceedings of EPIA'09, Portugal, 2009.

[23] Yan, L., Pan, Y, and Zhang, J., “Trust Cluster Head Election Algorithm Based on Ant Colony Systems,” Third International Joint Conference on Computational Science and Optimization (CSO), 2010.