

Behavior Analysis through Reputation Propagation in a Multi-Context Environment

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Abstract

Reputation is a distributed, socially ascribed, and collective belief of the society towards the stand point of a single person, group, role or even a non-human identity within the context of that society. Therefore, reputation can be only formalized based on the underlying principals and values of a specific context. In this paper we propose a model that clearly depicts how the reputation of a person in one context can affect his reputation in other contexts. This model provides a reputation propagation scheme that allows us to analyze the overall behavior of a person within the scope of a multi-context environment. It also caters suitable mechanisms to anticipate a proper initial reputation value for a person within the contexts that he has not been present in before.

Index Terms— *Reputation Formalization, Multi-Context Reputation, Reputation Propagation*

1. Introduction

Reputation is a distributed, socially ascribed, and collective belief of the society towards the stand point of a single person, group, role or even a non-human identity within the context of that society [1]. It is a perspective based upon a sophisticated social opinion aggregation which is implicitly applied to the notion of trust as a means of complexity reduction [2]. One of the most important aspects of reputation is that although reputation owners are directly affected by the status of their reputation, but they have no control over the accredited reputation values. They can only affect the ascription process through self alignment with social norms. As reputation is ascribed based on the shared belief of the community's understanding of the individual's (or other subjects in the reputation process) personality and

behavior, the person can indirectly amend his reputation status by conforming to the social standards.

Reputation can also be a property assigned to a certain group of people, roles or objects [3]. In this case the ascribed reputation values represent a rough estimate of a typical group member's reputation. The concept of applying reputation to the notion of groups, helps overcome the reputation calculation of the people who are unknown to the society (they are either inactive or new comers), but are members of a certain community or group. In such cases, these people will inherit their group's reputation. In this sense joining a group or community can detriment or improve the status of its members based on its socially ascribed reputation. The members can also affect the group's reputation based on their social image.

In an electronic social setting, reputation values can be calculated from the interactions of the users in a virtual environment. In such scenario, it would be rather difficult for every user to maintain the reputation values of his counterparts. Central Reputation Repositories (CRR) are often used to preserve reputation values [4]. In this centralized approach to reputation calculation, users will send their opinions to the CRR for central reputation calculation. The CRR forms a broader visibility of opinions on a user's behavior and hence produces more stable reputation values. Although centralized reputation management is not the actual approach to reputation calculation in the real world, but it is preferred over the distributed setting, since it would be cumbersome for each user to directly interact with others to calculate the reputation value of a specific target. Social networks can also be applied to the social interaction model to allow referral opinion access which will itself bring about more available opinions that result in a more consistent reputation value.

Many of the interactions in a virtual environment are shaped on the basis of mutual reputation values. Users may only trust to interact with peers who have high reputations. They will take the reputation value for granted since it has been communally calculated and ascribed. For this reason two main features should be strongly incorporated into any reputation management

system: *Identity Continuity* and *Reputation Ubiquity* [5]. Identity continuity states that since the reputation value of a user forms a portion of other user's decision making process, the change of identity or the use of pseudonyms that result in history clearance and hence false reputation declaration should be avoided. Reputation ubiquity allows every user in the environment to access and affect the reputation value of other users. Having made reputation values universal, the users cannot hide their real identity in different cases.

The notion of reputation has been applied to many different applications such as electronic market places [10], peer to peer systems [11], and information sharing communities [6] which are just a few well known examples. It has been widely accepted that reputation is a context dependent value. For this reason the formalization of reputation is very much reliant on the context in which reputation has been modeled. Carter et al [6] have formalized reputation in an information sharing multiagent environment. An information sharing environment is a setting in which agents attempt to exchange information with each other in the hope of satisfying the users' requests. Users' reputation is therefore calculated based on the degree of their collaboration in different social roles. Social information provider (Γ), Interactivity Role (Ω), Content Provider Role (ξ), Administrative Feedback Role (θ), Longevity Role (Ψ) are the five main roles that have been specified in [6] to formalize the concept of reputation in such a society. The assembly of these five roles constitutes Reputation (R) in an information sharing MAS and is defined through a 5-tuple $R = (\Gamma, \Omega, \xi, \theta, \Psi)$. The social information provider role specifies how frequently a user contributes new knowledge to the system (Γ). To maintain the freshness of the society, a user should regularly interact with the system (Ω). Users should also provide information that is relevant to their domain of expertise and this is formulated as the Content Provider (ξ). The users that provide more feedback on the shared information will be more reputed and this is achieved through fulfilling the Administrative Feedback Role (θ). The maintenance of a constant reputation in the system is formulated by the Longevity Role (Ψ).

Reputation has also been used in file sharing applications in P2P settings. A specific formalization of reputation can be used to allocate higher reputation to more loyal file sharers in the network to fight selfish, unreliable and even free riding behavior. Reputation can be also used to detect defamation in different electronic settings. In the real world, leakage and deception clues are used to detect deceit which is a major constituent element of defamation. A person who is pursuing defamation will have contradicting behavior in different situations. This will result in the deceiver unintentionally giving away some clue that discloses the truth. In deception clues

others understand that there is an unfaithful act going on, but cannot particularly specify the case. Bitting et al [7] have exploited reputation to detect defamation in an electronic commerce environment. Users can become suspicion of defamation while interacting with other parties. Suspicion only occurs when the reputation of a given user decreases below a given threshold.

Reputation can also be applied to credibility assessment of users in an uncertain situation. It had been previously believed that information sources should be strictly secured from unauthorized access. With astonishing growth of information on the World Wide Web it has become more crucial to evaluate the credibility of these sources of information. Since the Internet is an open information sharing environment, any one can share its information regardless of its credibility. It can be inferred that users with higher commitment to social norms (in this case sharing proper information) have a higher degree of respect from other users' perspective. They are hence assigned higher reputation values. The reputation of the information source is utilized to evaluate the degree of information credibility. Although information entities can themselves receive reputation values it will be much harder to track the reputation value of every single information piece. It would be rather easier to assign the reputation of its owner to it.

Although reputation is a social phenomenon it has always been formalized in a specific context due to its nature. The main reason for this is the fact that the underlying social values of each society are totally different from each other. For example in academia, reputation of a person is to a great extent affected by his/her publications, teaching experience and credentials; however this is different in the business community where industrial experience, trading knowledge, and social relationships are more important than other factors. Having mentioned this point, it is important to state that although reputation is context dependent but reputation in every context is indirectly affected by a person's reputation in other contexts. It is common in practice that people with high reputation values in a specific context will be looked upon as successful and highly reputed members of the society even from the perspective of other contexts. The opposite situation is also true where people with low reputation values in a context will not be highly respected (because of their reputation) in other contexts. This shows that although the formalization of reputation is to a great extent context dependent but still the mutual effect of different contexts on each other cannot be overlooked.

Understanding the position of a person in a context that the person has not had any previous experience in is also a challenging task. In the real world people carry some extent of their reputation with them into new contexts. Although this is not an exact determination of

the ultimate reputation of that person in the new context (since reputation is dynamic and changes based on the person's behavior and social process), but it can be regarded as a good estimation of the person's initial standpoint. The person can further improve or damage his reputation through the social interactions within the framework of that context.

In this paper we propose a model for reputation propagation through different contexts in a specific society. The model allows the specific formalization of reputation in different contexts, and offers a layered approach to reputation migration from different contexts. Through reputation propagation, the reputation value of people in various contexts can be derived from their behavior in other diverse contexts. It also provides the means for detecting unstable behavior of a person from the observation of his behavior in different contexts. Although we do not go into the details of the latter issue in this paper, but it is worth noting that contradictory behavior in different contexts can be detected based on this method.

The paper is composed of five main sections. The next section explains the constituent elements of reputation. Section 3 introduces the reputation propagation scheme and elaborates on reputation migration. In Section 4 simulation scenarios and experimental results are given, and finally conclusions of the current work are summarized in Section 5.

2. Reputation Nuclei

Reputation is a multifaceted value ascribed socially to a member of a society [8]. It is formalized in different contexts based on the underlying social norms and beliefs of that community. The members that conform to these norms and have a positive effect on the promotion of the society will receive a higher degree of respect and therefore a superior reputation value. It is therefore rational to formalize reputation independently for every different context, as has been done in many different cases. Reputation can be formalized based on the belief of others in the degree of *role fulfillment* of a member in a society [6]. It can be based on the membership, *relationships* or social interactions with others. The more reputed one's friends are the higher his reputation would be in that certain context. Reputation can be calculated based on the *knowledge* of the person in a certain context. More knowledge in a specific field brings more reputation and respect for that person in that context. *Experience* is the other very important constituent element of reputation. "Experience" has two faces in reputation formalization. On the one hand, members with higher experience in a field have the opportunity to increase their reputation values by having the chance to contribute more to the

promotion of the society's values. On the other hand the calculated reputation value for members with higher experience is much more stable. For example a new comer can easily change its reputation value by showing a few socially accepted behaviors; however a person that has been socially observed for a longer time cannot change his social image [9] with just a few actions.

Credentials are also a very important constituent element of reputation. Members with distinct credentials are more reputed in the public opinion. *Competence* is the public estimate of one's ability in accomplishing a task. The extent to which a person is trusted to accomplish a task shows the public's opinion about his competency degree.

Honesty is the other factor that contributes in the reputation formalization process. Societies value trustworthy, reliable and truthful members. As it was explained, reputation values can be exploited to examine the credibility of information released by a person. Honesty in this case plays the most important role in allowing reputation inheritance from the owner to the subject. *Favorability* of a member of the society can bring about higher reputation for that member. Favorability can originate from sources other than merit and capability and may only derive from popularity or charisma. *Faith*, the other building block of reputation, is defined as accepting as true, something which one has been told by someone who is believed to be trustworthy. In its proper sense, faith means trusting the word of another. By incorporating faith into the reputation formalism, favorability can more densely affect one's reputation.

To that end, we define reputation as a multifaceted socially ascribed value which is implicitly defined by nine different constituent elements that were previously introduced:

- 1) Role Fulfillment (RF)
- 2) Relationship (RS)
- 3) Knowledge (K)
- 4) Experience (E)
- 5) Credential (CL)
- 6) Competence (CM)
- 7) Honesty (H)
- 8) Favorability (FV)
- 9) Faith (FT)

Reputation can be defined as a 9-Tuple: $R = (RF, RS, K, E, CL, CM, H, FV, FT)$. The main point about reputation formalism based on these nine features is that every reputation system can customize and combine these factors according to their social norms and settings to create a context dependent reputation calculation model.

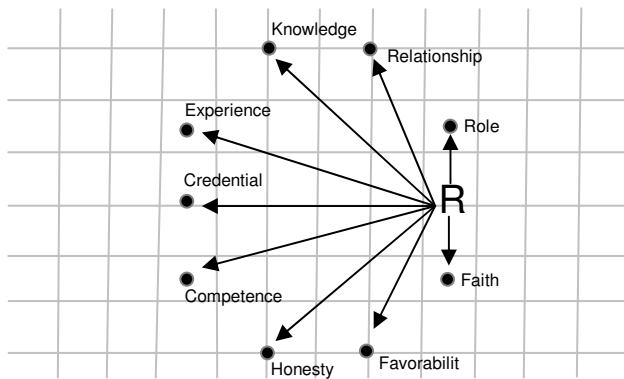


Figure 1. Reputation Formalism based on its 9 Constituent Elements.

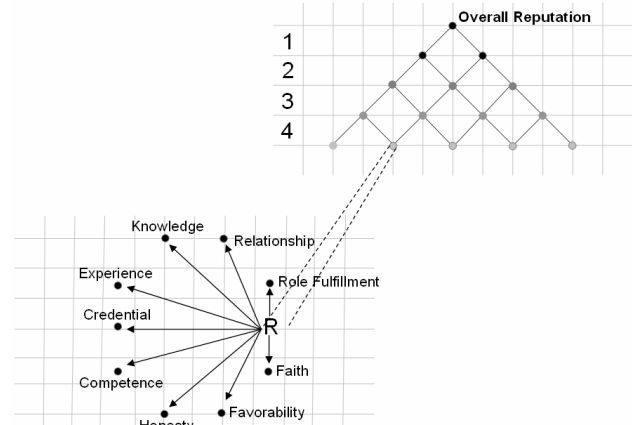


Figure 2. Overall Reputation Structure (Tree).

3. Reputation Propagation and Migration

Although reputation values are context dependent, but have implicit impact on each other. For example if a person has a high reputation in the academia he will most likely be reputed in the industrial arena as well. Despite the fact that reputation is customized for every individual context, but still different contexts can affect each other. Even if a person has had the usual behavior and performance in *Context i*, but due to his poor performance in other contexts his reputation in *Context i* will also be influenced. On the other hand, regardless of the context from which a person is assigned a reputation value he also has a very general and overall reputation in the society. When two different people that are present in three common contexts with person *j*, are talking about his reputation, they do not refer to three different values. This fact shows that although reputation is to a great extent context dependent and is created based on the underlying values of the specific society, but it can at the same time have a general face too.

It is clear that the nine constituent parts of reputation cannot be formalized in a way that can support all different contexts. For this reason a model has to be devised to inter-relate the different contexts of an environment.

Figure 2 depicts the proposed overall reputation structure. In this model the instantiations of all different reputation models have been placed in the last layer of the reputation tree. The leaves of this tree represent the different contexts that are available in the environment. The minutiae's of each leaf is shown in a separate plane. It can be seen that every context has its own formalization of reputation based on the nine constituent elements introduced in Section 2.

Layers 2 and 3 are called the intermediate layers and act as classifiers for the more related contexts based on a conceptual view. Suppose that person *i*, is present in three different contexts: research, teaching, and scientific public talks. Each of these contexts have their own formalization of reputation and person *i*'s reputation is calculated separately in each of these contexts. Since research and teaching both take place in the academia they can both be classified as "Academia" in the third intermediate layer. As person *i* is also active in giving public scientific talks, his overall reputation along with his reputation in the latter two contexts will be affected by this third context. For this reason, the *Academia* intermediate layer can be further abstracted to encompass scientific public talks and will be named "Scientific Activities". "Scientific Activities" will be placed in the second intermediate layer. If person *i* is active in other fields a similar reputation structure can be also created for those fields.

In the proposed structure no specific number of intermediate layers has been defined and any arbitrary number can be selected. The only restriction that applies to the number of layers is that the layers should be conceptually meaningful.

The root of the overall reputation tree represents the overall reputation value of the user. The overall reputation of the user can be referred to as the general public opinion about that specific person. On the other hand this reputation value can be regarded as the person's initial value in contexts that he has had no prior experience. By calculating the overall reputation, the initial reputation of the people who have very limited interactions in certain contexts can be roughly judged based on their behavior in other fields.

Two steps are taken to calculate the overall reputation and to update each context dependent reputation value:

- 1) Whenever an activity takes place in one of the leaves (in one of the specific contexts) which results in a change in the person's reputation

value, a forward update mechanism is triggered.

- 2) If the value of the internal reputation changes to a significant extent (e.g. if the change is more than one standard deviation) a backward reputation adjustment method is invoked.

a. Forward Update

Whenever one of the nine constituent reputation features changes in any of the members' profile, his reputation will be also affected. In such a case the change in a context specific reputation should propagate to other contexts to adjust their values. To allow the propagation to happen, the new reputation value will move upwards towards the root of the tree (which is actually the overall reputation node). The forward update mechanism is shown in Figure 3. Suppose that the reputation value of a member of Context 1 has changed due to some internal behavior. The change will be moved upwards to its parent nodes. (It is worth noting that the structure shown in the figures throughout the paper is for the purpose of demonstration and that the tree can have any other structure.)

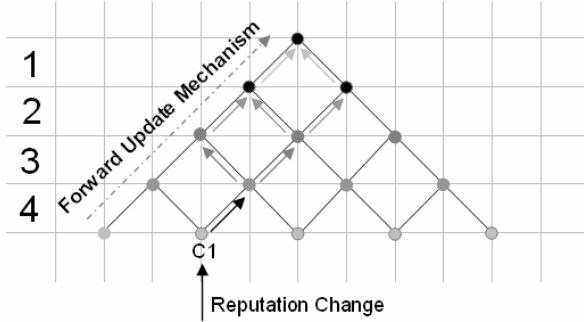


Figure3. Forward Update Mechanism

As it is clearly visible from Figure 3, as the reputation value propagates upwards in the tree structure it gradually loses its strength. Equations 1 to 3 depict how the internal reputation (IR) values in the intermediate layer nodes are calculated.

The contexts, in which a person has more interactions in, should have a higher degree of effect on the overall reputation value. For this reason NIC_i is calculated and shows the number of interactions that a person has in Context i . The aggregation of all NIC_i values illustrates the total number of interactions that a specific user has performed in all of the contexts in the environment. In Equation 1, the weight of every link between a lower layer node and its parent are calculated based on the importance of that node. The importance of each node is based on the number of interactions that have occurred in that node. β

represents the number of nodes that have participated in the last layer to provide the values for the current layer.

$$\zeta_{ij} = \frac{NIC_i}{\sum_{j=1}^{\beta} NIC_j} \times \omega(3\Delta IR) \quad (1)$$

$$\omega(x) = \frac{x}{(1+x^2)} \quad (2)$$

$$IR_j = \sum_{i \in \{\gamma\}} \zeta_{ij} \times IR_i \quad (3)$$

In Equation 3, γ shows the set of nodes from the previous layer that have participated in the calculation of the current node's IR value. A regulating function $\omega(x)$ has been applied to filter extreme changes. As it can be seen in Figure 4, the regulating function devalues the changes that are more than a certain amount. By this it filters out incidental activities that may be rare and should not affect the overall reputation of the member to a great extent. ΔIR denotes the difference between the current internal reputation value and the newly calculated value. A moving average scheme could have also been applied in this case to sift extreme changes.

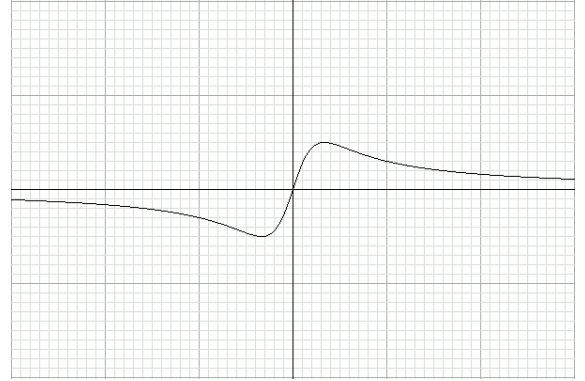


Figure4. The Regulating Function $\omega(x)$ Controls the Weight Function by Filtering out Extreme Changes

Equation 3 calculates a weighted sum of the internal reputation values of the previous layer weighted by ζ_{ij} that was calculated in Equation 1. The overall reputation value for every person would be the root's final IR value.

b. Backward Adjustment

If the calculated internal reputation value in any intermediate or root node has significantly changed in the *Forward Update* phase compared to the previous value, backward adjustment is undertaken to propagate the effect

of the change to the other contexts. On the contrary to the forward update mechanism, which assigned a higher weight to the nodes with more interactions, the backward adjustment weighs the nodes with fewer interactions higher. This is because the contexts that are less active in assigning reputation values (because the member has less activity in them) to the member are less aware of his behavior and are more susceptible to change. Figure 5 visually compares the weight of the backward adjustment on two different nodes. The node with lower *NIC* value will receive a greater effect compared with the other context.

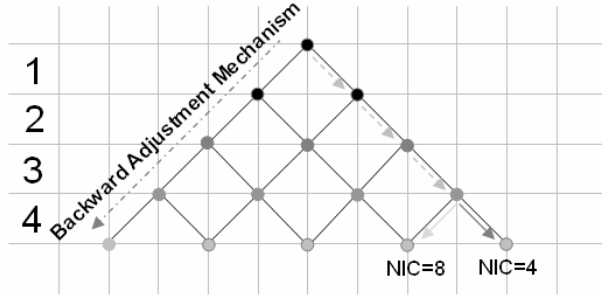


Figure 5. Backward Adjustment Mechanism

The weights on the links in the backward adjustment process are calculated similarly to equations in (1-3), with the difference that the values have been calculated logarithmically which assigns higher weights to lower *NIC* values. Equations 4 and 5 show the internal reputation adjustment in this phase.

$$\zeta_{ij} = \text{Ln}\left(\frac{\text{NIC}_i}{\sum_{j=1}^{\beta} \text{NIC}_j}\right) \quad (4)$$

$$IR_j = \sum_{i \in \{\gamma_i\}} \zeta_{ij} \times IR_i \quad (5)$$

It is obvious from Equation 4 that the values inside the logarithm always stay in the range of [0, 1]. The behavior of the weight applied to *IR* shows that the lower the value of ζ_{ij} is, the higher the applied weight would be.

To show the large picture of the reputation propagation scheme we will summarize the process here. If the reputation value of a specific member of the society changes in a given context, it propagates upwards in the reputation structure tree and alters the intermediate reputation nodes along its way to the root. The root of the reputation structure tree represents the overall reputation value of the member across all of the available contexts in the society. Having updated all of the *IR* values

including that of the root, the backward adjustment mechanism is triggered if a significant change in the internal reputation value of the intermediate nodes (including the root node) is observed. A significant change is detected when the value of the *IR* in any node changes more than one standard deviation of the history of all of the internal reputation values of one specific person (Equation 6). The backward adjustment mechanism will then propagate the change downwards to the leaves. Since the specific person has been less involved, the contexts with fewer interactions will be affected more. The contexts in which the person has a higher participation rate have more stable values and are hence not vastly influenced by the backward adjustment mechanism.

$$\delta = \sqrt{\frac{\sum_{i \in \{h\}} (IR_i - \mu)}{|h|}} \quad (6)$$

In Equation 6, {h} denotes all changes that have been applied to the overall reputation of a specific person.

The propagation of reputation through different intermediate layers and again backwards from the root provides a modeling basis for understanding the behavior and reputation of different people in contexts where they have not participated in or recently joined. In the next section we will show how reputation can be assessed in contexts where a person has not had previous presence or has recently participated in few activities. The overall reputation value calculated through the proposed model can be used in such cases. The model is also capable of fine-tuning reputation in a context based on the person's behavior in another context.

4. Simulation Results

To observe the reputation propagation and migration model, four different sets of experiments with dissimilar natures were conducted in a unique environmental setting. The environment consisted of three different contexts. The user was allowed to perform different actions within these three contexts. The behavior of the user was then observed and proper reputation values were calculated. The ascribed reputation values were then applied to the leaves of reputation structure tree in the proposed model and the intermediate nodes were updated. The overall reputation values were also calculated based on the proposed model. The overall reputation value was calculated twice in every cycle of the program to allow a comparison of the value with and without the Backward Adjustment Mechanism (BAM). The very important feature of this model that can be clearly seen in the results is that although the context specific reputation values have

been changed through the backward adjustment mechanism, still the overall reputation value calculated by the model is nearly the same. This means that although the reputation values in different contexts are adjusted, they have been correctly made inline with the overall trend of the user's reputation.

Four different strategies for the behavior of the user in various contexts were adopted:

- A) Consistent Homogeneous Reputation
The behavior of the person had been consistent in different contexts. The person is an average member of all contexts. (Figure 6)
- B) High-Consistent Heterogeneous Reputation
The person behaved in a manner that was ascribed a high reputation value in one context while in the other two contexts he/she received average

reputation values. The person seems to be a prominent member of one context while performing as average in the others. (Figure 7)

- C) Low-Consistent Heterogeneous Reputation
The reputation values ascribed to the person were near average in two contexts but he was poorly perceived in the other. The person is a poor member of one of the contexts while he performs as an average member in the others. (Figure 8)
- D) Varying Heterogeneous Reputation
The reputation values did not follow a trend in any of the contexts. The person could be regarded as an unpredictable member of those contexts. (Figure 9)

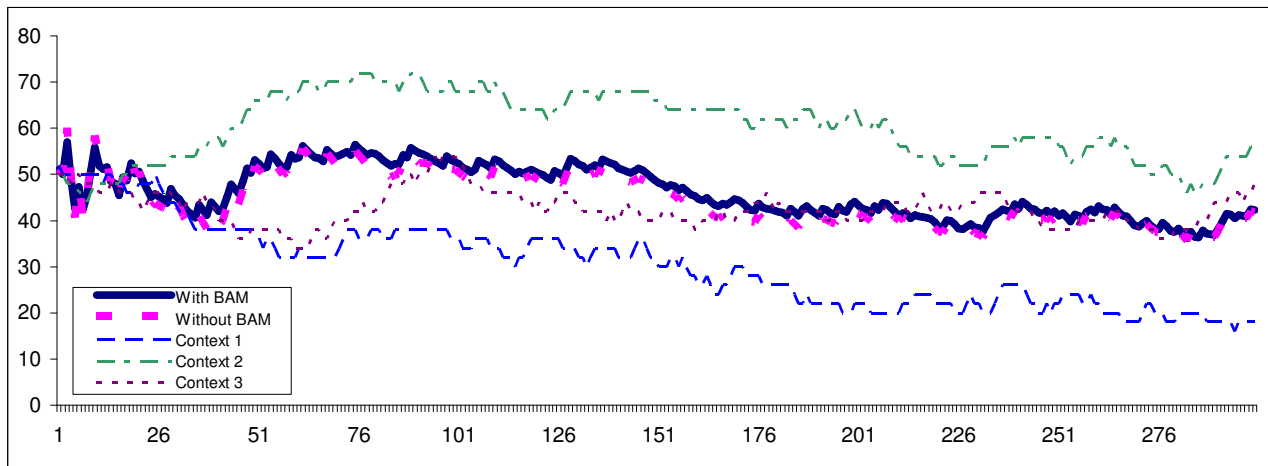


Figure 6. In the Consistent Homogeneous Reputation Ascription Approach the Proposed Model Adopts to the Average Reputation Ascription Trend (A).

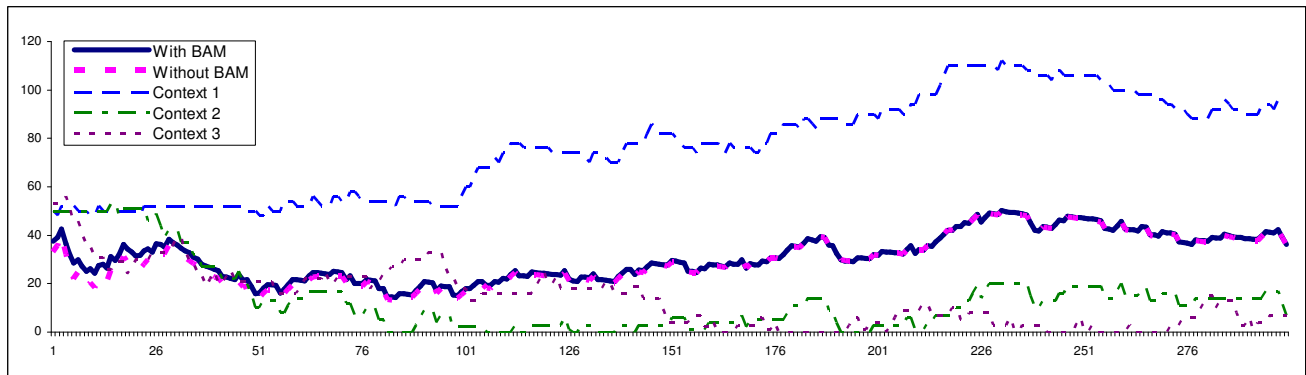


Figure 7. High-Consistent Heterogeneous Reputation Ascription Model (B)

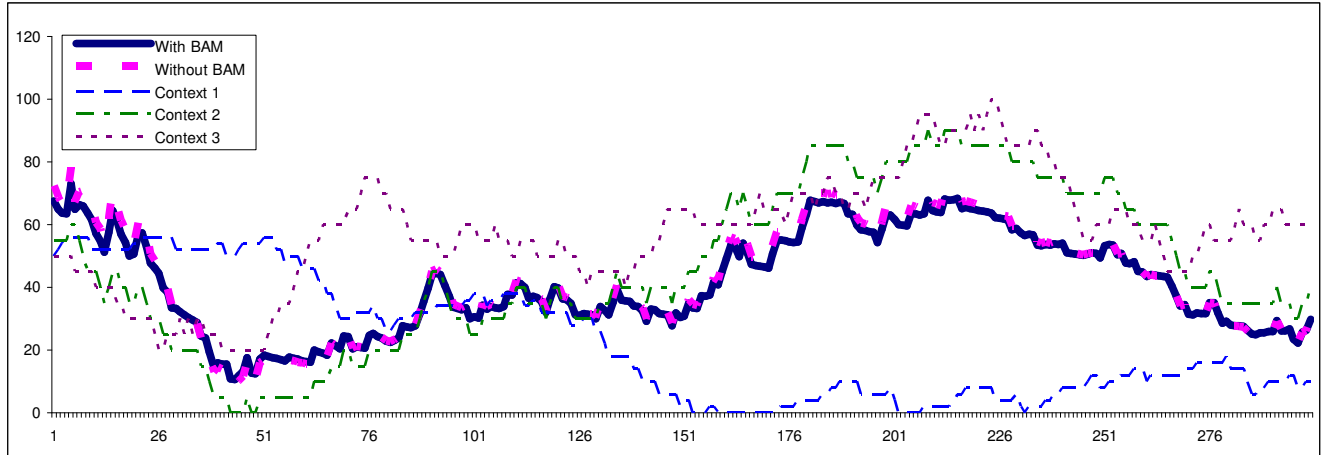


Figure 8. Low-Consistent Heterogeneous Reputation Ascription (C)

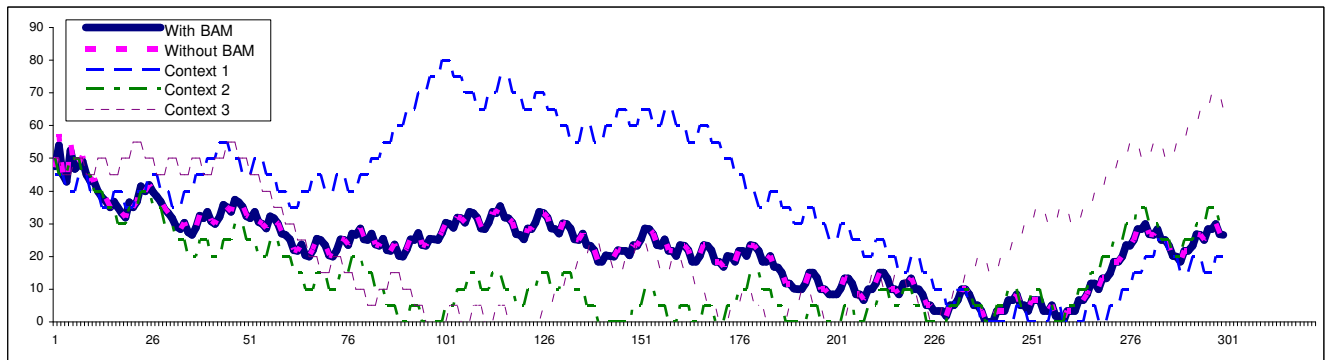


Figure 9. Varying Heterogeneous Reputation Ascription Model (D)

In Figure 6, the person shows consistent behavior towards the contexts' underlying values and hence receives steady reputation values in each of these three contexts. The proposed model infers the person's reliable behavior and suggests a fairly moderate overall reputation value for that person. In the second scenario (Figure 7), the person shows great contribution towards the values of Context 1 and hence receives high reputation values in this context; however his involvement in Context 2 and 3 is poor. The ascribed reputation values to this personal in the overall sense is neither greatly affected by his superior behavior in Context 1 and nor reduced by his poor behavior in the other two contexts. The very important point is that we do not allow the reputation value of a person to go below zero. For this reason a low reputation value may either denote uncoordinated behavior with the context norms or may indicate not enough activities within that context.

In the Low-Consistent Heterogeneous Reputation Ascription model, the person performs so that he receives high reputation in two contexts. Although his initial behavior in Context 1 receives high reputation values but his reputation decreases as time goes by. The overall

reputation ascription model in this scenario tends to favor Contexts 1 and 2, and assigns a high overall reputation value to the person. This is because he has high reputation values in two contexts and this can be a sign that shows that the person should receive a high reputation in the environment. The low reputation of the person in Context 1 can be interpreted as a cause of his low participation in Context 1 and is not necessarily his misaligned behavior.

The last scenario (Figure 9) shows an environment in which the person behaves randomly. In this setup the overall reputation value has a tendency to follow a conservative trend, however in the last 40 cycles with the rise of the reputation value in all contexts the overall reputation value also increases moderately.

5. Conclusions

Reputation is a context specific socially ascribed value. A specific reputation formalization cannot be applied to multiple contexts which prevents reputation inference in an environment which consists of multiple contexts. In this paper we have proposed a reputation propagation

scheme to provide the basis for reputation migration within a unique environment that can contain many diverse contexts. Applying such scheme to an environment enables cross domain reputation inference. The proposed model provides the basis for anticipating the behavior of the user in contexts in which the person has newly joined or has not had any previous presence.

The analysis of the model in several diverse scenarios shows that the proposed model tends to reveal a roughly correct estimate of the users overall reputation in the environment and is not biased towards very high or extremely low reputation values in a specific context.

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