# Social ReGreT, a reputation model based on social relations

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Social network analysis has been used for a long time by sociologist as a mechanism to infer and explain social behaviours. Analysing social relations between individuals in a society using social network analysis techniques allows to identify a lot of features of that society that can be very valuable in an e-commerce environment. In this paper we describe how these techniques can be used to improve a reputation system and also how this system can be integrated with a negotiation model to increase the succes of negotiations.

## 1. INTRODUCTION

According to the Oxford English Dictionary, *reputation* is "the common or general estimate of a person with respect to character or other qualities". This estimate is necessarily formed and updated along time with the help of different sources of information. Direct interactions and information coming from witnesses are the main sources to build reputations. Although convenient, they are not free of problems. Direct interactions are not always available and witness information can be false, biased or incomplete and suffer from the *correlated evidence problem* (see section 6.1). The aim of this article is to show how social analysis can be used to minimize these problems and how it can be incorporated as a new source of information to calculate reputations.

As a direct consequence of the interactions it is possible (even in simple societies) to identify different types of social relations between their members. Sociologists and psychologists have been studying these social networks in human societies for a long time. These studies show that it is possible to say a lot about the behaviour of individuals using the information obtained from the analysis of their social network.

In this article we show an evolution of the **Regret** [Sabater and Sierra 2001] system (a reputation system oriented to e-commerce environments) that incorporates social network analysis in different points of the model. These add-ons increase the reliability of the calculated reputation and extend the range of situations where it is feasible to use it.

We have removed all the formulae and implementation details and we have left just the general description of the system. For a detailed version refer to forthcoming [Sabater and Sierra 2002].

In Section 2 we introduce the application of social network analysis to agent communities. In Section 3, a scenario is presented that will be used in the rest of the paper to ilustrate how the system works. Sections 4- 8 describe the system, in section 9 we explain how **Regret** can be integrated with a negotiation model. Finally sections 10 and 11 present the related work, conclusions and future work.

## 2. SOCIAL NETWORK ANALYSIS AND AGENT SOCIETIES

Social network analysis is the study of social relationships between individuals in a society. Social network analysis emerged as a set of methods for the analysis of social structures, methods that specifically allow an investigation of the relational aspects of these structures. The use of these methods, therefore, depends on the availability of relational rather than attribute data [Scott 2000].

A graph structure that shows social relations is called a *sociogram*. A different sociogram is usually built for each social relation. Depending on the type of relation we have a directed or non-directed sociogram, with weighted edges or without.

We know that social network analysis can be used to analyse human societies, but could it also be suitable for agent societies? A drawback in social network analysis is that, sometimes, the translation of human social structures into their sociological meaning is difficult and artificial due to the complexity of the individuals and their relations. The greater simplicity, in social terms, of multi-agent systems suggests that social network analysis could be applied to agents with even better results.

We have exposed the pro but, of course, there is a con. Obviously, the more relational data the better the network analysis is. However, these data can be difficult to obtain. Sociologists usually obtain them through public-opinion polls and interviews with the individuals. This procedure is, of course, not possible in agent societies. Moreover, the analysis of human social structures is usually done by a sociologist external to the society. This external position gives the analyst a privileged watchtower to make this kind of analysis. In our case, as we want to use social analysis as part of the reputation system to be included in each agent, each agent has to do this analysis from its own perspective.

It is beyond the scope of this paper to propose solutions about the way an agent builds such sociograms. From now on, we will assume that the agent owns a set of sociograms that show the social relations in its environment. This sociograms are not necessarily complete or accurate. We suppose they are built by each agent using the knowledge it has about the environment. Therefore, sociograms are dynamic and agent dependent.

## 3. RUNNING EXAMPLE

The scenario for this running example is one link in a supply chain. In this scenario each seller is specialised in a single type of product and can be independent or part of a company that groups several sellers specialised in different products (in that case we consider they are grouped under a single brand). The buyers buy the products they will sell in another layer of the supply chain.

To simplify, the buyers buy one product at a time (it is not possible to buy in bulk) and the elements that are taken into account for each transaction are price, quality and delivery date. The buyer chooses a seller. If the seller wants to deal with that buyer, then it sends an offer. The buyer has then to decide if he wants to accept the offer or not. If the buyer accepts, the transaction is performed.

It is important to note that the above result of the transaction may not necessarily be equal to the initial offer from the seller. A swindler seller can increase the price, decrease the quality or deliver the product late. On the other hand, the buyer can decide to pay less or even not to pay at all. We consider that the process of obtaining the actual result of the transaction is atomic, that is, the buyer and the seller have to decide their strategy (to pay less, to overcharge the price, to deliver late, do things exactly as specified in the offer, etc.) before knowing the behaviour of the other. Although the latest point is not very realistic, it makes the example simpler and allows us to focus our attention only on reputation.

We can identify many types of relationships between agents in an supply chain and it is beyond the scope of this paper to present a survey on all of them. We will refer just to a set of relations that can be found in our scenario and that will help the reader to go through the explanation of the system.

We assume that in our scenario the great majority of agents are rational and have a behaviour according to their goals and affiliation (in an environment with random or contradictory agents it makes little sense to use social relationships to predict the behaviour of agents). We note a non-directed relation of type *rel* between two agents $a$ and $b$ as $rel(a, b)$. The three relation types considered in this example are:

1) *Competition* (*comp*). This is the type of relation that appears between two agents that pursue the same goals and need the same (usually scarce) resources. In this situation, agents tend to use all the available mechanisms to take some advantage over their competitors, for instance hiding information or lying. In our running example this is the kind of relation that could appear between two sellers that sell the same product or between two buyers that need the same product.

2) *Cooperation* (*coop*). This relation implies significant exchange of sincere information between the agents and some kind of predisposition to help each other if possible. Notice that we talk about "sincere" information instead of "true" information because the agent believes that information is true. We consider that two agents cannot have at the same time a competitive and a cooperative relation.

3) *Trade* (*trd*). This type of relation reflects the existence of commercial transactions and is compatible either with cooperative or competitive relations.

As we said before, we assume that each agent owns a sociogram for each of these relation types. The three sociograms are non-directed graphs with weighted edges. Weights go from 0 to 1 and reflects the intensity of the relation.

In our scenario, the variables that appear in contracts between buyers and sellers (price, quality and delivery date) determine the reputation types. For the seller, we consider four reputation types:

**to_overcharge**: A high reputation value of this type means that the seller tends to overcharge the prices specified in contracts.

**to_deliver_late**: As the name suggest, is the reputation of delivering the products later than the delivery date specified in the contract.

**quality_swindler**: A seller with a reputation to deliver products with less quality than specified in the contract.

**swindler**: A swindler is a seller that overcharges the price and/or delivers products with a quality lower than the quality specified in the contract.

For the buyer we consider only one type of reputation:

**defaulter**: A high reputation of this type means that the buyer does not pay the products he buys.

## 4. THE REGRET SYSTEM

The **Regret** system structure is based on what we call the three *dimensions* of reputation. If an individual is considering only its direct interaction with the other members of the society to establish reputations we say that the agent is using the *individual dimension* of reputation. If it also uses the information coming from other members of the society and the social relations, we are talking about the *social dimension* of reputation. Our previous work explored just the individual dimension [Sabater and Sierra 2001].

On the other hand, we consider that the reputation of an individual is not a single and abstract concept but rather a multi-facet concept. The different types of reputation and how they are combined to obtain new types is what we call the *ontological dimension* of reputation. In the following sections we explain each one of these dimensions.

We will refer to the agent that is calculating a reputation as $a$ (what we call the "source agent") and the agent that is the object of this calculation as $b$ (what we call the "target agent").

## 5. INDIVIDUAL DIMENSION

The *individual dimension* models the direct interaction between two agents. The reputation that takes into account this dimension is the most reliable. This is because it takes into account all the peculiarities of the target agent.

We define the *outcome* of a dialogue between two agents as:

—An initial contract to take a particular course of action and the actual result of the actions taken.

—An initial contract to fix the terms and conditions of a transaction and the actual values of the terms of the transaction.

Agents store these outcomes in what we call an *outcomes database*. These outcomes are the building blocks of the *individual dimension*. We call *outcome reputation* the reputation calculated directly from an agent's outcomes database.

The subset of issues of an outcome taken into account to calculate a given reputation type $\varphi$ is domain dependent. We define a *grounding relation* ($gr$) as the relation that links a reputation type $\varphi$ with a list of issues. This set of issues allows us to select the right subset of outcomes from the general outcomes' data base. Each issue is a tuple with the form $(I_i, \{+, -\}, \alpha_i)$. The first parameter ($I_i$) is a label that identifies the issue. The second parameter ($\{+, -\}$) indicates how an increment of the value of the issue affects the reputation, that is, a + means that if the value of the issue increases, the reputation also increases while a − means that if the value

of the issue increases, the reputation decreases. Finally, the last parameter is the weight that that issue has in the general calculation of the reputation.

As an example, the *grounding relation* for a seller in our scenario is defined in the following table:

| $\varphi$ | $gr(\varphi)$ |
|---|---|
| to_overcharge | $\{(Price, +, 1)\}$ |
| to_deliver_late | $\{(Delivery\_Date, +, 1)\}$ |
| quality_swindler | $\{(Quality, -, 1)\}$ |

We only define the *grounding relation* for the reputation types to_overcharge, to_deliver_late and quality_swindler. The reputation type swindler is a complex reputation type calculated from more basic reputations as we will see in section 7.

To calculate an outcome reputation we use a weighted mean of the outcomes evaluation, giving more relevance to recent outcomes.[1]

Besides the reputation value, it is important to know how reliable is it. There are many elements that can be taken into account to calculate how reliable an outcome reputation is but we will focus on two of them: the number of outcomes used to calculate the reputation value and the variability of their rating values. This approach is similar to that used in the Sporas system [Zacharia 1999].

The intuition behind the *number of outcomes factor* is that an isolated experience (or a few of them) is not enough to make a correct judgement about somebody. You need certain amount of experiences before you can say how a person is. As the number of outcomes grows, the reliability degree increases until it reaches a maximum value. From a social point of view, this stage is what we know as a close relation. More experiences will not increase the reliability of our opinion from then on. We believe that the maximum value is domain dependent: it depends on the interaction frequency of the individuals in that society.

The *outcome reputation deviation* is the other factor that our system takes into account to determine the reliability of an outcome reputation. The greater the variability in the rating values the more volatile will the other agent be in the fulfillment of their agreements. To have a measure of this variability we take into account the impact on the expected utility of the actual execution of the contracts.

The reliability of an outcome reputation is calculated as a convex combination of these two aspects.

## 6. SOCIAL DIMENSION

Although direct interaction is the most reliable source of information, unfortunately it is not always available. Not only because the agent can be a newcomer to a society but also because the society can be very large. Therefore, when the interactions with another agent are scarce it is not possible to assign it a reputation based just on direct experiences. It is n these situations when the *social dimension* of an agent may help by using information coming from other agents. In the **Regret** system we use three types of social reputation depending on the information source:

— *Witness Reputation.* Based on the information about the target agent coming from other agents.

[1] There are many psychological studies that support recency as a determinant factor [Karlins and Abelson 1970].

—*Neighbourhood Reputation.* Uses the social environment of the target agent, that is, the neighbours of the target agent and their relations with it.

—*System Reputation.* It is a default reputation value based on the role played by the target agent.

Each of these reputations requires a different degree of knowledge of the agent society and the target agent.

### 6.1 Witness reputation

Beliefs about the reputation of others can be shared and communicated by the members of a society. The reputation that an agent builds on another agent based on the beliefs gathered from society members (witnesses) is what we call *witness reputation.* In an ideal world, with only homogeneous and trusted agents, this information is as relevant as the direct information. However, in the kind of scenarios we are considering, it may happen that:

—*The information is false.* Either because the other agents are trying to lie or because the information they own is not accurate, and agent has to be prepared to deal with false information.

—*Agents hide information.* An agent cannot assume that the information coming from the other agents is complete.

Besides that, the information that comes from other agents can be correlated (what is called the "correlated evidence problem" [Pearl 1988]). This happens when the opinions of different witnesses are based on the same event(s) or when there is a considerable amount of shared information that tends to unify the witnesses' way of "thinking". In both cases, the trust on the information shouldn't be as high as the number of similar opinions may suggest. Because the event(s) that have generated the opinions for each agent may be hidden, the agent cannot identify directly which agents are correlated. Schillo et. al [Schillo et al. 2000] propose a method based on the analysis of "lying" as a stochastic process to implicitly reconstruct witness observations in order to alleviate this problem. We take a different approach based on the social relations between agents. Analysing these relations, an agent can obtain useful information to minimize the effects of the correlated evidence problem.

6.1.1 *Identifying the witnesses.* The first step to calculate a witness reputation is to identify the set of witnesses (**W**). The initial set of potential witnesses might be the set of all agents that have interacted with the target agent in the past. In the example, the initial set is composed by all the agents that had had a trade relation with the target (it seems logical to think that the best witnesses about the commercial behaviour of the target agent are those agents that had a trade relation with it before). This set, however, can be very big and its members probably suffer from the correlated evidence problem.

We take the stance that grouping agents with frequent interactions among them and considering each one of these groups as a single source of reputation values minimizes the correlated evidence problem. Moreover, grouping agents and asking for information to the most representative agent within each group reduces the number of queries to be done. A domain dependent sociogram is what **Regret**

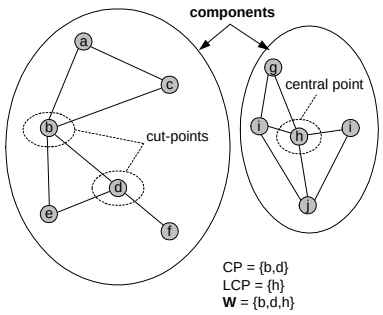


Fig. 1. Witness selection within **Regret**.

uses to build these groups and to decide who is their most representative agent (in our example the sociogram of the cooperative relation).

There are many heuristics that can be used to find groups and to select the best agent to ask. In the **Regret** system we use a heuristic based on the work by Hage and Harary [Hage and Harary 1983]. Taking the subset of the selected sociogram over the agents that had had interactions with the target agent as the initial graph, the heuristic that **Regret** follows is:

(1) To identify the *components* of the graph. A *component* is defined as a maximally connected subgraph.

(2) To find the set of *cut-points* ($CP$) for each component. A *cut-point* is a node whose removal would increase the number of components by dividing the sub-graph into two or more separate sub-graphs among which there are no connections. A cut-point can be seen from a sociological point of view as indicating some kind of *local centrality*. Cut-points are pivotal points of articulation between the agents that make up a component [Scott 2000].

(3) For each component without cut-points, to choose as a representative for that component the node with the larger degree. The degree can be regarded also as a measure of *local centrality* [Scott 2000]. We refer to this set of nodes as $LCP$.

(4) The set of selected nodes is the union between the set of *cut-points* and the set of $LCP$. That is, $\mathbf{W} = CP \cup LCP$.

Figure 1 shows an example of the application of the heuristic. At this point, the agent has to ask for information to all the agents in the so calculated set of witnesses $\mathbf{W}$.

6.1.2 *Who can I trust?.* The next step is to aggregate the received information to obtain a single value for the *Witness Reputation*. However, as we said before, it is possible that this information be false so the agent has to be careful to give the right degree of importance and reliability to each piece of information. The degree of importance relies on the trust that each witness has. The system uses two different methods to calculate this trust: social trust and outcome trust reputation.

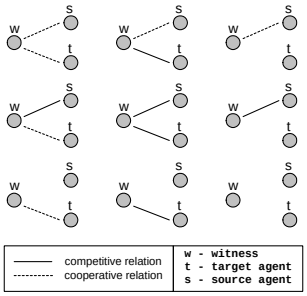


Fig. 2. Relevant social structures in the example.

We define the *socialTrust* of a witness that is giving information about a source agent as the degree of trust based on the social relations between the witness, the target agent and the source agent.

**Regret** uses fuzzy rules [Zadeh 1965; 1975] to determine how a social structure provides a reliability degree on the information coming from a given agent in that structure. The antecedent of each rule is the type and degree of a social relation and the consequent is the reliability of the information from the point of view of that social relation. In our scenario, a possible rule would be:

$$\text{IF coop}(w_i, b) \text{ is high THEN socialTrust is very\_bad}$$

that is, if the level of cooperation between $w_i$ and $b$ is high then the trust from the point of view of the agent who is evaluating this rule on the information coming from $w_i$ related to $b$ is very bad. The heuristic behind this rule is that a cooperative relation implies some degree of complicity between the agents that share this relation so the information coming from one about the other is probably biased.

Which relations are relevant to calculate the reliability depend on the meaning that each relation has in the specific agent society. In our scenario, for instance, a trade relation cannot cast any light on the reliability of an agent from the point of view of social analysis. In other societies this could be the other way around.

Hence, together with the "no relation" possibility and with the fact that the most relevant links are between the witness and the agent and the witness and the target, there are 9 social structures to be considered as shown in Figure 2.

Although the influence of each social structure is currently static and based in human common sense, we will improve the system with a rule learning mechanism.

A second way to calculate the degree of trust of an agent is using the *outcome trust reputation* of the 'trust' that other agent deserves. The *outcome trust reputation* is like any other outcome reputation (see section 5). In our running example the *grounding relation* for this reputation type could be:

| $\varphi$ | $gr(\varphi)$ |
|---|---|
| trust | $\{(Price, -, 0.3), (Quality, +, 0.4), (Delivery\_Date, -, 0.3)\}$ |

That is, in our example we consider that an agent that maintains the price, the quality and the delivery date of a contract is a trusty agent.

The trust values calculated using an outcome trust reputation are more useful than those based on social relations ($socialTrust$) because an outcome trust

reputation is based on the individual experiences and thus takes into account its particularities while the analyses of social structures rely on global expected behaviours. However, in those situations where there is not enough information to calculate a reliable outcome trust reputation, the analysis of social relations can be a good solution. Therefore, to calculate the degree of trust of a witness, the agent uses the trust reputation based on direct interactions but if the outcome trust reputation is not reliable enough then it is used the $socialTrust$.

Finally, to calculate the *witness reputation* the agent uses the trust of the witness to weight each opinion in the final value and its reliability.

### 6.2 Neighbourhood reputation

The reputations of the individuals that are in the neighbourhood of the target agent and their relation with him are the elements used to calculate what we call the *Neighbourhood Reputation*. Neighbourhood in a MAS is not related with the physical location of the agents but with the links created through interaction. The main idea is that the behaviour of these neighbours and the kind of relation they have with the target agent can give some clues about its possible behaviour.

To calculate a *Neighbourhood Reputation* we use fuzzy rules as well. These rules, that are domain dependent, relate the outcome reputation of a target's neighbour and the social relation they have, with a reputation of the target agent.

The application of these rules generates a set of *individual neighbourhood reputations*. For instance, using again our running example, one rule could be that if the neighbour of the target agent is a swindler and there is a relation of cooperation between the target and this neighbour, then the target is also a swindler.

To calculate a *neighbourhood reputation* and its reliability we have to use the reliability of each *individual neighbourhood reputation* to weight the contribution to the final result.

### 6.3 System reputation

The idea behind *System reputations* is to use the common knowledge about *institutional structures* and the role that the agent is playing for that *institutional structure* as a mechanism to assign default reputations to the agents. An *institutional structure* is a social structure the members of which have one or several *observable* features that unambiguously identify them as members of that social structure. The fact that there are *observable* features to identify its members is what differentiates an institutional structure from other social structures. Examples of institutional structures in human societies are the police, a company, a club, or a family. We assume that the role that an agent is playing and the institutional structure it belongs to is something "visible" and trustworthy for each agent.

Each time an agent performs an action we consider that it is playing a single role within the institutional structure. An agent can play the role of buyer and seller but when it is selling a product only the role of seller is relevant. Although in some situations an agent can play two or more different roles at a time, we consider that there is always a predominant role so the others can be disregarded.

In **Regret** the reputations associated to each role within an institutional structure are domain dependent and part of the initial knowledge of the agent. The value for these reputations can be different depending on which institutional structure

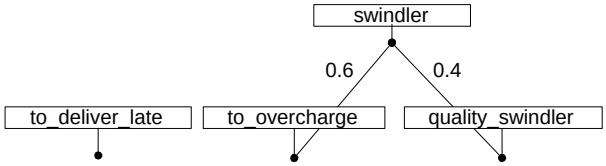


Fig. 3. Ontological structure for a seller.

the agent belongs to. This models the idea that groups (in our case institutional structures) influence the point of view of their members [Karlins and Abelson 1970]. Another important point is that an institutional structure does not always associate a reputation value to each contract issue.

*System reputations* are modelled as a table where the rows are the possible roles, and the columns the leaves of the *ontological dimension*.

Table I shows an example of *system reputations* for agents that belong to company B from the point of view of an agent of company A. Using a similar table we would define the reliability for these reputations.

| | defaulter | to_overcharge | to_deliver_late | quality_swindler |
|---|---|---|---|---|
| seller | 0.7 | - | - | - |
| buyer | - | 0.5 | 0.9 | 0.7 |

Table I. Example of *system reputations*.

## 7. ONTOLOGICAL DIMENSION

Along the individual and social dimensions, reputation is always linked to a single behavioural aspect (a contract issue). With the ontological dimension we add the possibility to combine reputations on different aspects to calculate complex reputations. To represent the *ontological* dimension we use graph structures. Figure 3 shows an *ontological dimension* for a seller in the running example. In this case, the reputation of being a swindler is related with the reputation of overcharging prices and the reputation of delivering products with less quality than specified in the contracts. For the owner of this ontological structure, the delivery date is something that is not relevant to be considered a swindler.

Hence, to calculate a given reputation taking into account the *ontological dimension*, an agent has to calculate the reputation of each of the related aspects that, in turn, can be the node of another subgraph with other associated aspects. The reputation of those nodes that are related with an atomic aspect of the behaviour (in the example: to_deliver_late, to_overcharge and quality_swindler), are calculated using the individual and social dimensions.

Note that the importance of each aspect is agent dependent and not necessarily static. The agent can change these values according to its mental state.

## 8. PUTTING IT ALL TOGETHER: THE REGRET SYSTEM.

The **Regret** system is an experimentation tool where the reputation of the participating agents is modeled using all the aspects mentioned in this paper. In particular

it defines a reputation measure (and its reliability) that takes into account the *individual dimension*, the *social dimension* and the *ontological dimension*.

The most reliable reputation is the *outcome reputation* followed by the *witness* and the *neighbourhood* reputations and finally by the *system reputation*. Therefore, we want the agent to give more relevance to the *outcome reputation* in detriment of the others. If the *outcome reputation* has a low degree of reliability (for instance because the agent does not have enough information) then he will try to use the *witness* and the *neighbourhood* reputations. Finally, if its knowledge of the social relationships is short, the agent will try to use the *system reputation*.

## 9. INTEGRATING REGRET WITH A NEGOTIATION MODEL

In this section we show how the **Regret** system can be used together with the negotiation model presented in [Faratin et al. 1997] to improve the success of the agent in its negotiations. The purpose of the negotiation is to reach an agreement about the provision of a service. This service is reflected in the contract, and the issues of this contract are what the agents negotiate. In our example the negotiation issues are the prize, the delivery date and the quality. It is beyond the scope of this article to explain how the negotiation model works. If you want a complete description refer to [Faratin et al. 1997]. We will focus our attention on the connection point between the negotiation model and **Regret**.

In the negotiation model, when an agent $a$ receives an offer from agent $b$ at time $t$, it evaluates the offer using a utility function. If the utility value for that offer is greater than the utility value that the counter offer that agent $a$ is ready to send at time $t+1$ has then, agent $a$ accepts. Otherwise, the counter offer is submitted.

The problem arises when the fulfillment of the contract is not as expected. If the fulfillment of the contract is worse than expected, probably the agent will not cover its needs. If the fulfillment is better than expected then it means that the agent may have lost time in negotiation. For instance, the agent could have accepted a not so good offer knowing that at the end it would be good enough. Also, arriving to an agreement sooner minimizes the risk of partners withdrawal.

We propose to use reputation to "modulate" the shape of the score function. The idea is that depending on the reputation, the scoring function will have a more preservative or a more confident behaviour. Therefore, a very good reputation meaning that the partner is splendid in the fulfillment of contracts implies that the agent can accept a deal that does not satisfy completely its requirements knowing that, in the end, it will be ok. On the other hand, a bad reputation implies that the agent has to be harder in its negotiation.

To achieve this, we introduce the notion of a utility function that takes into account reputation. A good reputation with a high reliability increases the value that the agent gives to the offer.

## 10. RELATED WORK

The study and modeling of reputation has attracted the interest of scientists from different fields such as: sociology, economics [Celentani et al. 1966; Marimon et al. 2000], psychology [Bromley 1993; Karlins and Abelson 1970] and computer science [Castelfranchi and Falcone 1998; Abdul-Rahman and Hailes 2000]. Due to the

wide scope of the subject, we will focus our attention only in a set of representative e-commerce oriented models.

The idea of using the opinion of other agents to build a reputation is not new. The work of Michael Schillo, Petra Funk and Michael Rovatsos[Schillo et al. 2000] and the work of Bin Yu and Munindar P. Singh [Yu and Singh 2000] are good examples of this. In both cases they use a trust-net for weighting the other agents' opinions. Our structure to calculate the witness reputation can be considered also a trust-net. In our case, however, besides the previous experiences with the witnesses we also consider the information about the agents' social relations.

The model described in [Yu and Singh 2000] merges information that comes from agents that have good reputation. In [Schillo et al. 2000] the same agents that can provide you with information are also competing with you. Although agents are assumed to never lie, they can hide information or bias it to favour their goals. We go one step further and consider that the agents can also lie.

In electronic marketplaces, the reputation that a user has is the result of aggregating all the experiences of the other users that interacted with him/her in the past. Amazon Auctions [Amazon ], eBay [eBay ] and OnSale Exchange [OnSale ], for instance, are online auction houses where users buy and sell goods. Each time a new transaction is finished, the buyer rates the seller. These ratings are used to build the reputation of a seller. Sporas [Zacharia 1999] is an evolved version of this kind of reputation models. Sporas introduces the notion of reliability of the reputation and is more robust to changes in the behaviour of a user than reputation systems like Amazon Auctions, based on the average of all the ratings given to the user. In all these systems each user has a global reputation shared by all the observers instead of having a reputation biased by each observer. Histos [Zacharia 1999], also oriented to electronic commerce, is a more personalized reputation system where reputation depends on who makes the query, and how that person rated other users in the online community.

The reputation models described before use one or both of the following information sources to build reputation: (i) the direct interaction and (ii) the information provided by other members of the society about experiences they had in the past. The **Regret** system adds a new information source to this list: the social structure of the community.

Finally, we would like to stress that unlike **Regret**, all the previous models consider reputation as a single concept instead of a multi-facet concept.

## 11. CONCLUSIONS AND FUTURE WORK

In this paper we have presented how social network analysis can be used in a reputation system that takes into account the social dimension of reputation. The system has also a hierarchical ontology structure that allows to consider several types of reputation at the same time. The combination of complementary methods that use different aspects of the interaction and social relations, allows the agent to calculate reputation values at different stages of its knowledge of the society.

The use of the social network analysis techniques as part of a reputation system opens a new field for experimentation. Our first objective is to validate the system in a realistic e-commerce environment where social relations are an important factor. To be able to exploit all the capabilities of the **Regret** system we need environments

more sophisticated than the actual e-markets like Amazon Auctions or eBay. We are working in several tools that allow the specification and implementation of these kind of e-markets.

Once you introduce the social dimension in reputation systems and the agents start to take into account social relations, it becomes more and more important to consider not only which is the reputation of the other agents, but what can an agent do to get and maintain a good reputation. Using the **Regret** system, we want to study reputations from this new perspective.

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