Effects of Reciprocal Social Exchanges on Trust and Autonomy

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Abstract

In this paper we present effects of reciprocal exchanges on trust and autonomy of peer level agents. We present models of trust and autonomy and show changes to autonomy and trust in an abstract problem domain. As social exchanges increase, average agent autonomy is increased. Autonomy and trust are more susceptible to certain number of social ties among agents mirroring the principle of peak performance.

1. Introduction

A proper balance between trust and autonomy is necessary in modeling an agent society. The two notions are inter-related. This paper explores the variations of trust and autonomy when agents are engaged in reciprocal exchanges [6]. The objects of exchange in this paper are requests for action and free agreements to perform actions, i.e., favors. In reciprocal exchanges, agents initiate an exchange without knowing whether, when, or to what extent the other will reciprocate in the future. Thus, agents offer benefits unilaterally and the exchange does not depend on negotiation. Any expectation of return is implicit and not reasoned about. Exchange networks are states of interaction among a group of agents engaged in reciprocal exchange. These states change over time with each interaction. Exchange networks and our proposed trust networks based on reciprocal exchanges are dynamic. Exchanges among agents may lead to familiarity and a social relation. However, general social ties captures a broader sense of closeness between partners and exchanges may or may not contribute to social distance between individuals. For example, giving to a call for a charitable cause does not necessarily bring the giver and receiver any closer. Later in this paper we will warrant a social network to be derived from an exchange network under further assumption about social conditions.

A main position of this paper is that different levels of reciprocal exchange contribute to different trust and autonomy values, which are used as part of the decision to perform a task or to delegate it. Another point in this paper that average

autonomy and trust among individuals in a group is highest when there is a certain number of social connections in the groups. Just as there is a curvilinear relationship between the number of ties in the organization's structure and their performance, too many or too few ties degrade trust and autonomy.

The social connections among the agents in a social network influence the willingness of an agent to delegate a task. Jean Ensminger describe cattle herding behavior of East African Orma where cattle owner make sure a close relative be on the cattle camp [3]. Such trust of the kin has motivated owners to adopt young men. This is a form of generalized reciprocity. With increased relationship, the owners keep loose account of services and payments. They may reward their loyal hired help with paying them bridewealth after many years of loyal service or to marry the hired herder to one of their own daughters. We present a model of trust that combines tit-for-tat reciprocity (process-based trust) with this generalized reciprocity. Although we agree on competence being important in forming trust, we feel that Castelfranchi's definition [2] could apply to complete strangers and does not take the interpersonal sense of trust we are interested in. The "willingness" component does not capture trustee's attitude towards trusted. Interpersonal trust is also a function of familiarity and benevolence. Interpersonal trust, which is the focus of this paper, differs from system and institutional trust. System trust is an individual's trust in the reliability of social structures in its environment. Institutional trust is the trust that exists among individuals due to their participation in social norms and values of various institutions they are members of.

Social exchanges affect interpersonal trust based on the types of connections an agent has on another and the variation in the connections. Usually, trust levels accumulate and diminish gradually unless there are radical changes in agent attitude toward one another, such as major changes in benevolence [1]. Another conceptualization is that, trust is not a precursor to delegation but one between collaborating individuals who communicate. Trust is in the degree of belief in validity of messages. In this notion of trust, capability and benevolence of trustee is not in question but the agents' social interaction is taken into consideration. We have modeled benevolence among agents when agents successfully accept and complete a delegated task. The change in benevolence is our model of alliance among agents. This is combined with balance of reciprocity. We conceptualize that agents strengthen their ties as they interact about their assigned tasks and delegate tasks to others who are benevolent. Strengthening ties between agents in social ties increases their interpersonal trust. In summary, we suggest that agent X's trust in agent Y about task T (we will denote that by Trust (X, Y, T)), is partly a function of agent's X's perception of agent Y's benevolence towards it, partly a function of agent X's perception of agent Y's capability toward task T, and partly due to balance of tit-for-tat. This approach to conceptualizing trust lends itself to formulating delegation between two individuals, which requires trust between delegator and delegee [7,2].

An agent's autonomy toward a task is affected by its capability and the sense of freedom it receives from other agents [5, 4]. This sense of freedom can be approximated by a combination of factors such as social ties (both the number of ties and strength of ties) and trust it receives from others. An agent's trust in others

generates benevolence and return of trust. Therefore, an agent who trusts is likely to experience autonomy. Network of social exchange might have asymmetries. In addition to direct exchange, agents might experience indirect exchange via other agents.

In the remainder of this paper we will begin by elaborating our model of trust, autonomy, and delegation. In section three, we present implemented simulation we have used for our experimental results. In section four, we will describe a series of experiments that show effectiveness of approach. In section five, we draw conclusions about relationships between trust and autonomy.

2. A Model of Trust, Autonomy, and Delegation

Our model of trust is aimed at capturing a precondition to the formation of intentions to delegate a task, i.e., asking for a task to be done by another agent. An agent's assessment prior to delegation may include an analysis of risk and utilities, creating an intermediate notion of trusting value, prior to adoption of an intention. In most applications, trust has the consequence of reducing the need for the trusting agent to supervise or monitor the trusted agent.

The variety of definitions has added to the confusion about, and misconceptions of trust. In multi-agent systems, trust has been related to models of other social notions such as autonomy, delegation, dependence, control, and power, which influence interactions between agents. In this paper, we treat trust as a dyadic relation, i.e., the amount of trust each agent has on other agents. We define Trusting value to be the amount of trust an agent has on other agents with respect to a particular task. The Trusting value can be computed for multiple agents or for individual agents. This value among the agents is subject to many factors such as benevolence of resources, general reputations, competencies, reciprocity among agents, histories or prior experiences, environmental factors: cultural factors and organizational factors.

Although all these factors are relevant in conception of trust among humans, we assume an agent environment where only competency, benevolence, and reciprocity are more central. The following Eq. (1) summarizes Trusting value:[1]

$$\text{Trusting value}(A, B, t) = (1/3)^* [\text{capability}(B, t)+\text{benevolence}(B, A, t)+10^* \text{DH}(A,B)] \qquad (1)$$

Here A, B are agents and t is the task to be performed by agent B. Capability(B, t) is the agent B's ability to perform a task t and we assume both A and B perceive the same value. benevolence(B, A, t) is agent B's (i.e. trustee's) level of well wishing towards agent A (i.e. trusted) in performing a task t. This value may be a result of many factors such as kinship (i.e., thick relationship), social ties (i.e., a variety of familiarity, relationships), positive regard, alliance, coalition, team allegiance, predictability, shared values and norms, dependence, even commitment. Argua-

[1] Coefficients 10 and 1/3 are used to equalize the three effects of factors and to normalize Trusting value to be in the range 0-10.

bly, this value is difficult to perceive. However, since we are building agents we can artificially have control for this component and approximate this quality in biological organisms.

Assuming agents relate at an interpersonal level, using values on exchange networks, we define a value that reflects harmony in delegation. DH(A, B) is the number of times agents A and B have agreed to the delegation request from one another after internally weighing all other considerations divided by the sum of number of times agents A and B have made a delegation request. DH is considered typically to increase with time. Delegation of a task is an opportunity to increase delegation harmony. The DH value range from 0.0 to 1.0. When this value is 1.0 these agents have been in perfect harmony honoring one another's delegation request. Value of 0.0 is when they have never agreed on delegation or have never interacted. DH is only computed when agents interact at the interpersonal level. This condition is established when agents are considered to be in a social network explicitly. In the beginning of this paper we stated that many relationship types do not fit this condition such as when someone is making an anonymous purchase from a generic store.

Autonomy value for an agent is the amount of trust the agent has for itself to perform a task and is computed by the following Eq. (2.2).[2]

Autonomy value (A, t) = (1/3)*[capability(A, t) +Average(T)+ 1/(n-1)*(Balance of reciprocity)] (2)

If we do assume agents relate at an interpersonal level, using values on exchange networks, we define a value that reflects a balance of reciprocity they have with other agents. Balance of reciprocity for an agent A is counting two values and subtracting two values:

- Add the number of times delegated tasks by agent A has been agreed upon divided by the number of such agents.
- Add the number of times agent A has made a delegation request regardless of accepting that request divided by the number of such agents.
- Subtract the number of times agent A has agreed to a delegation request by another agent divided by the number of such agents making the request.
- Subtract the number of times agent A has been asked for delegation regardless of whether A has agreed to work on the task divided by the number of such agents.

Considering solely an agent's self-ability in performing the tasks might not evaluate an agent's autonomy reasonably in an exchange network. A good rate of exchange among the agents will increase an agent's autonomy significantly. Hence, the two values in the balance of reciprocity that relate to an agent's self-ability were subtracted.

[2] Coefficients 1/(n-1) and 1/3 are used to equalize the three effects of factors and to normalize Autonomy value to be in the range 0-10.

Capability(A, t) is the agent A's ability to perform a task t. Average(T) is the average trust of all the agents on agent A and is measured by

$$1/(n-1) \sum_{i=1}^{n} T_i$$

where $T_1, T_2 \ldots T_n$, are the trusting values of the agents on agent A on a particular task t. The amount of trust an agent has on itself determines its competence for performing a task. We call this *autonomy* value of the agent as trusting value of an agent on itself. Said differently, the autonomy Eq. (2) of an agent is same as the trusting value of the self-agent. Obviously, Eq. (1) affects Eq. (2). When there is good harmony among the agents the exchange rate among them would increase. This affects the autonomy, as trust is one of the factors. To have an equal range for all the factors in the equation the factors were multiplied by the required number. The range of all the factors is set from 0 to 10.

Autonomy is compared with the trusting values of all the agents to determine which agent should perform a task. Every agent has an individual task assigned to perform. This autonomy of an agent to perform the pre-defined task is compared with the autonomy of the overall tasks determined. The agent performs a task for which the autonomy is highest. When multiple agents determine to perform a unique task, an agent whose autonomy is higher with respect to the task performs the task. For agents with equal autonomy their capabilities with respect to the task are compared and the agent with the higher capability performs the task. If the agent's capabilities are equal, the task is performed by one of the agents selected randomly.

The following two cases illustrate how the Autonomy value is affected by the variations in capability, benevolence and social exchanges among the agents.

Case 1: When there exists no social exchange among the agents, they tend to increase their capability, as there is no exchange even though there exists trust among the agents. Their autonomy value varies depending on the change in the capability of the agent.

Case 2: When social exchanges exist among the agents, both social exchanges and capability affects the autonomy value, as they are used in deriving it. i.e. the agent's capability increases or decreases depending on the success or failure of the tasks. Even the trusting values among the agents vary.

Trust and autonomy of the agents tend to increase much in an exchange network where there exists good harmony among the agents. Experimental results in section 4 supports this.

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1.Initialize the values of capability matrix (C[][] ) to random values between 0 to 10.
2.Initialize the values of Benevolence (B[][][] ) to 0.0  initially.
3.While (tasks remain) {                    /* main body of the algorithm*/
4.   for all agents and tasks {             /* trusting values */
5.     if  (a = b)                          /* a, b – variables stand for agents*/
            TV[t][a][b] = (1/3)*[ C[a][t] + average(T) + (Balance of reciprocity)/(n-1) ]
6.     else TV [t][a][b] = (1/3)*[ C[a][t] + B[t][a][b]+10*DH(a,b) ]
7.    A[a][t] = (1/3)*[ C[a][t] + average(T) + (Balance of  reciprocity)/(n-1)] /*autonomy */
8.    compare A[][] with TV[][][] to find the suitable agents performing task t
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compute the number of tasks being executed per iteration and unsuccessful attempts
C[][] = C[][] + i                          /*Update C[][]  with success */
C[][] = C[][] – i                          /*Update C[][] with failure */
B[][][] = B[][][] + i                      /*Update B[][][] with success */
B[][][] =  B[][][] – i                     /*Update B[][][] with failure */
AA[a][t]  = A[a][t]/(n*n)                  /*average autonomy*/
ATV[t][a][b] = TV[t][a][b]/((n*n)*(n-1))  /*where a!=b ; average Trusting values */
    }  /* for loop*/
  }  /*while loop */
```

Fig. 1. Algorithm to calculate the average trust and average autonomy

- AA[][] is an average autonomy of all the agents with respect to tasks and is used in plotting the graph.
- Average(T) is the average trusting values of all other agents with respect to self agent.
- TV[][][] is the matrix that holds the trusting values of agents with respect to tasks.
- B[][][] is the benevolence matrix of the agents.
- B[][][] is zero initially but varies with time.
- ATV[][][] is the average trusting values of all agents except the self-trusting values with respect to the tasks and is used in plotting the graph.
- DH is the delegation of harmony among the agents.
- Balance of reciprocity is defined in the equation 2 above.
- n is the number of agents.
- i is the increment.

3. A Simulated Testbed

In our implementation simulation, N agents considered N tasks repeatedly, i.e. each agent has its own task, which is same in each time period. This does not mean that each agent has to perform the assigned task. Agents may perform tasks assigned to other agents. The tasks are performed basing on the amount of knowledge an agent have on other agents in the environment and harmony that each agent have with the other agents. The ranges of capability and trust are between 0.0 and 10.0. In our simulation we assume in general, agents perform certain tasks and develop trust, capability, benevolence and contacts among them in exchanging the tasks. In the algorithm, the aim is to focus on the performance of agents in a social exchange network. The pseudo code for our simulation is shown in Fig. 1.

The success or failure of an agent can be determined by comparing the capability values of an agent with a randomly generated number ranging 0 to 10. If the random number has a value greater than the capability value of an agent, it is considered as a failure and if the number is lesser, then it is considered as a success. The above range is set because, when an agent has a capability say x units in performing a task t. The agent can perform a task only when the task requires units

less than or equal to its capability (i.e., <= x). If the required unit for a task is more than the agent's capability then the agent might not be able to perform the task which leads to failure. An agent may perform one task each time and no two agents can do the same task in same time unit. The success of a task is dependent only on the capability of the agent (as compared to the random number). The capability, trust and relations among the agents are updated with the success or failure in performing the tasks. Before the values are updated the average autonomy and trusting values of the agents are calculated to observe a relation between the two with respect to the social exchanges among the agents. The rate of successful tasks and unsuccessful attempts is measured as a factor of time with respect to social exchanges.

4. Experiments and Discussions

This section presents results of using our abstract simulation of agents and tasks. Two different sets of experiments were performed. In the first set of experiments the results were observed for 25 units of time. In each time unit the average autonomy, average-trusting values, number of successful tasks and the number of unsuccessful attempts were noted. In the first set of experiments, autonomy and trust of agents in two different social networks were considered and compared.

The average trust and average autonomy of the agents were computed with and without social exchanges among the agents in a network. In the case where we consider social exchanges among the agents, there exists certain delegation of harmony among the agents. Figs. 2 and 3 show the results of agents with and without social exchanges. From Fig. 2 we observe that the average trust and average autonomy values without any social exchanges (marked Tb and Ab in Fig. 2) were very low. These values change slightly over time. There was a gradual increase in both curves that reached a constant level after a certain time. The average trust and average autonomy values where social exchanges take place were significantly greater (marked Tn and An in Fig. 2). There was a gradual increase in both curves that might reach a constant level or vary over time. This is because of the exchanges and delegation of harmony that agents have among them. The average autonomy climbed with time and reached almost a constant high level. The fluctuations in the curve may also be due to variations in capability of the agents. The magnitudes of the average trust and autonomy with social exchanges were consistently greater than without any exchange among the agents. Benevolence value in both cases started at zero but changed as agents successfully delegated tasks to one another.

Figure. 3 show the results of cumulative task executions over time. It is observed that the number of successful tasks (Sn in Fig. 3) where we considered social exchanges was higher than when agents have no exchange among them.

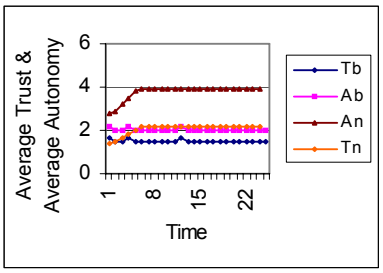

Fig. 2. Average trust and average autonomy with respect to time

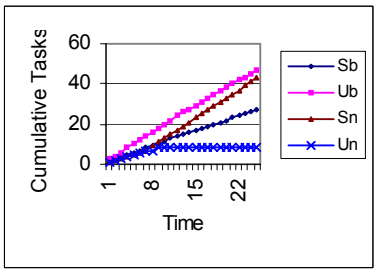

Fig. 3. Cumulative tasks with respect to time

In addition, the number of unsuccessful attempts (Un in Fig. 3) is very low with social exchanges. Sb and Ub in Fig.3 show that when there were no social exchanges it results in the lowest number of successful tasks being performed (Sb in Fig. 3). At time t = 25 the number of tasks were 27 successful and 48 failed respectively where there were no exchanges among the agents. With an exchange among the agents, the number of tasks was 43 successful and 8 failed respectively.

The second sets of experiments were performed to observe the effects of social exchanges in varying size of agent community. In one experiment, we considered that there were no social exchanges among the agents i.e., the agents have no delegation of harmony. While in the other we considered there exists high delegation of harmony among the agents, a maximum level. In both cases, a given population size was run for 25 time units. Average autonomy and trust values at the 25th unit of time were plotted for different population sizes.

Figures. 4 and 5 show autonomy and trust in various population sizes. Fig. 4 shows the average trust and average autonomy of the agents where there is no social exchange among the agents. It is observed that the average autonomy (shown as A in Fig. 4) and average trust (shown as T in Fig. 4) of the agents decreases with larger populations. In a network where the number of agents is three, the average trust and average autonomy were 5.61 and 5.81 respectively after 25 time units. With eight agents, the values were 2.83 and 3.5 respectively. These values clearly show that the average trust and average autonomy of the agents were lower in larger communities where there exist no exchanges among the agents in the network; there is no delegation of harmony. Autonomy and trust is low and almost stable in populations of 23 or more.

Figure. 5 show the results of the average trust and autonomy of the agents when there is high delegation of harmony among the agents (i.e., DH = 10). It is observed from Fig.5 that the average autonomy (shown as A in Fig. 5) of the agents increased with larger number of agents and the average trust (shown as T in Fig. 5) among the agents increased with larger number of agents. Average autonomy and average trust of the agents reached almost a constant level with populations greater than 23. The average trust and average autonomy values were 4.25 and 5.25 respectively when the network had three agents. When the network consisted of eight agents, the values were 4.8 and 6.22 respectively.

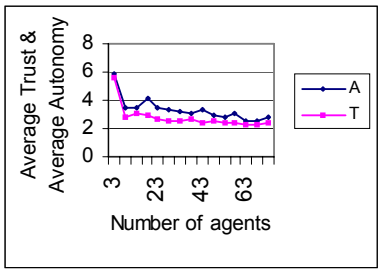

Fig. 4. Average trust & average autonomy for each population size, were the values at 25th time unit. No delegation of harmony i.e., DH = 0

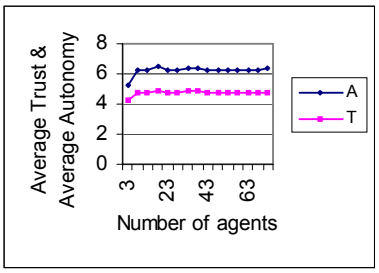

Fig. 5. Average trust and average autonomy for each population size, the values at 25th time unit. Delegation of harmony is high i.e. DH = 10.

We have been talking about exchange network. The term "exchange network" defines a network representation of agents where directed arcs denote the number of times an agent assigns a task to a particular agent and the number of times the assigned agent agree to the delegated task. We observe that trust network affects exchange network. The exchange rate in the network is high among those agents that have high and equal trust for each other and fewer among those agents that have low and equal trust for each other. Also, the chances of successful delegation will be high when an agent assigns a particular task to an agent that has more trust on it i.e., if agent A has more trust on agent B than B on A then agent A delegating the task for agent B will be more likely to occur when agent B assigns a task to A. As we have discussed in section 2, a social network is derived from an exchange network. Fig. 7 shows an exchange network of three agents A, B and C. From Fig. 7 we see that the exchange rate between agent A and agent C is high. Fig. 8 shows a social network where we have allowed all agents to be in personal relationship, i.e., the number of ties = 3.

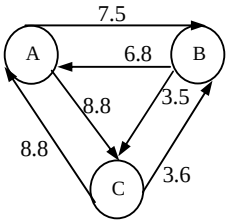

Fig. 6. A trust network corresponding to Fig. 2 at run = 25

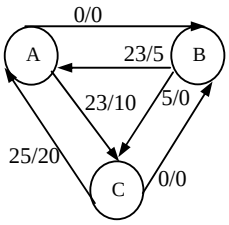

Fig. 7. An exchange Network

Figure. 6 show a graph that represents trust among agents. In Fig. 7 just as the exchange rate between agent A and agent C is high, the trust between them is high and equal. Also, in the trust network, agent A has more trust on agent B and hence

agent A delegates the tasks assigned by agent B. As trust between agent B and agent C is low and almost equal, exchange rate between agents B and C is zero.

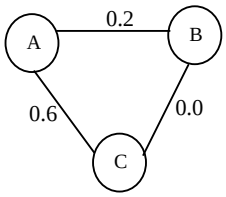

Fig. 8. A social network corresponding to the exchange network in Fig. 7

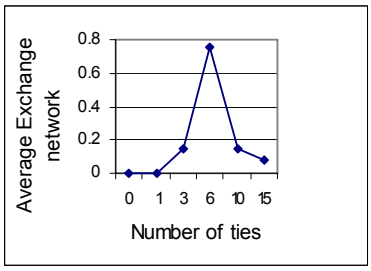

Fig. 9. Average Exchange networks for 6 agents after 25 units of interaction at 0, 1, 3, 6, 10,15 ties

5. Trust, Autonomy and Exchanges Mirror Performance in a Social Network

Experiments were performed to observe how varying ties in the social network affects average trust, average autonomy, average exchanges and performance of agents. Here, ties are considered to be established among agents who are assumed to relate at an interpersonal level. In this section we use DH(A, B) values we described in section 2 to approximate strength of ties between agents A and B. As we described in section 2, we used values on exchange networks, to update harmony in delegation, i.e., DH(A, B) values.

Figure. 9 show an average exchange network for a network of 6 agents. The maximum number of bi-directional ties in a network of n agents is (n*(n-1))/2. For n = 6 the maximum number of ties is 15. The average exchanges among the agents in Fig. 9 are average of all the DH values between the agents in the network. The values are taken after the agents have had 25 time units of interaction.

The average trust and average autonomy of the agents is low when there exists few ties among the agents. The trust and autonomy among agents is high when there exists moderate ties among the agents within the network. The trust and autonomy levels increase gradually with increase in ties from low to moderate ties among the agents. I.e., it reaches a peak and then it drops. In a network with many ties among the agents, trust and autonomy of the agents is once again low. This pattern is mirrored in performance. The number of successful tasks performed by the agents will vary same as trust and autonomy of the agents with varying ties in the network. I.e. the exchange is more common in a moderate network with which the trust and autonomy of the agents increases.

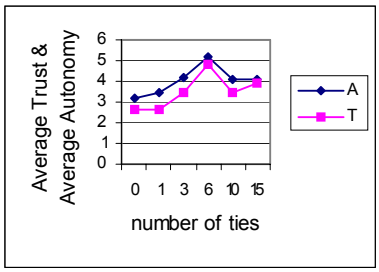

Fig. 10. Average trust and Average Autonomy

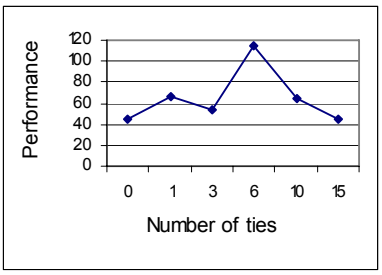

Fig. 11. Number of tasks completed

Figures. 10 and 11 support our discussion. Fig. 10 shows the average trust and average autonomy of the same network of 6 agents as in Fig. 9. We show the variations of autonomy and trust against the number of ties we permit among the agents ranging from 0 to (n*(n-1))/2. The average trust and average autonomy of the agents at the 25th time unit of each run is plotted for different number of ties in the network. The number of ties is the number of interpersonal relationships allowed to flourish.

We observe from the graph that the average trust and average autonomy curves gradually increase with increase in the ties from low range to medium range and then decrease as the ties increase further. From this we infer that the average trust and average autonomy of the agents has a peak in the middle range of ties.

The performance curve of the agents with increasing number of ties among the agents in a network is shown in Fig. 11. It is observed that the number of successful tasks performed by the agents is high when the agents are moderately connected when compared to the situation where the agents are either not connected or highly connected. This is a standard proposition well explored in sociology. We have shown that autonomy and trust values mirror that pattern. This is significant in that such peaks are not only good for performance, but afford the highest trust and autonomy levels.

6. Conclusion and Future work

A simple model of autonomy and trust that relied on social exchange network where there exists delegation of harmony among the agents was presented. This model is deliberately kept simple to illustrate the role of social exchanges that plays in the relationship between autonomy and trust. An agent trusts a second agent in consideration of delegating a task to it if the second agent is capable of performing the task and the amount of relation it has towards the first agent. An agent experiences autonomy with respect to a task if it is capable of performing and it is trusted by other agents with regard to the task along with the balance of exchange it has with other agents. There are many other parameters that affect

trust and autonomy. These parameters in general have to do with the relationship among agents and their interactions. Our simple model can be easily extended to include other parameters. Presenting many parameters will have obscured our observations. We have seen from our experiments that when social exchanges among the agents in a social network are weak, their autonomy and trust are lower than that of the agents with high exchanges among the agents. Also, when there exists harmony in a social network, the trust and autonomy of the agents increase when compared with that of the trust and autonomy where there is no social network. When there exists no harmony in a social network, fewer tasks are completed and vise versa. The latter makes sense in terms of fewer agents considering task delegation. The human interaction with the agents may be considered in developing a better relation among the two social notions trust and autonomy along with the factors that exists in our model.

Acknowledgements

This work is supported by AFOSR grant F49620-00-1-0302.

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