How do norms emerge in multi-agent societies? - Mechanisms design

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Abstract

Norms are shared expectations of behaviours that exist in human societies. Norms help societies by increasing the predictability of individual behaviours and by improving co-operation and collaboration among members. Norms have been of interest to multi-agent system researchers as software agents intend to follow certain norms. But, owing to their autonomy, agents sometimes violate norms which needs monitoring. There are two main branches of research in normative agent systems. One of the branches focuses on normative agent architectures, norm representations, norm adherence and the associated punitive or incentive measures. The other branch focuses on two main issues. The first issue is on the study of spreading and internalization of norms. The second issue that has not received much attention is the emergence of norms in agent societies. Our objective in this paper is to propose mechanisms for norm emergence in artificial agent societies and provide initial experimental results.

1. Introduction

Norms are behaviours that are expected by the members of a particular society. These expected behaviours are common in human societies and sometimes even in animal [8] societies. The human society follows norms such as tipping in restaurants, exchange of gifts during Christmas, dinner table etiquettes and driving vehicles on the left or right hand side of the road. Some of the well established norms may become laws.

The norms are of interest to researchers because they help to improve the predictability of the society. Norm adherence enhances co-ordination and co-operation among the members of the society [3, 20]. Norms have been of interest in different areas of research such as sociology, economics, psychology and computer science [11].

Sociologists and economists are divided on their view of norms based on the theories of *homo economicus* and *homo sociologicus* [11]. The former view is argued to be guided by rationality and the later by the quasi-inertial forces of the social environment. Sociologists consider that the norms are always used for the overall benefit of the society. Economists on the other hand state that the norms exist because they cater for the self-interest of every member of the society and each member is thought to be rational [15]. A more integrated view of norms from sociology and economics point of view is provided by Conte and Castelfranchi [9, 11].

Applying social theories in multi-agents is synergetic as agents are modelled using some of the social concepts such as autonomy and speech act theory. Both the disciplines complement each other as agents serve as a platform to design, test and validate social theories. Some researchers [5, 24] have undertaken agent based simulations of social theories. Even though researchers in different fields have been trying to answer questions such as why agents follow certain norms and the implications of not following these norms, there has been limited work on mechanisms that propose the emergence of these norms. In this paper we explain our initial effort towards the emergence of norms.

This paper is organized as follows. Section 2 gives an overview of the background information related to our work on normative agent systems. Section 3 provides the description of two mechanisms for norm emergence. In section 4, the experimental results are described. A discussion of the results obtained and how our work differs from other researchers is also provided in Section 4. The conclusions are presented in Section 5. [1]

1 The primary author is a student.

2. Background

In this section we describe different types of norms and the treatment of norms in multi-agent systems. We also describe the work related to norm emergence.

2.1. Types of norms

Due to multi-disciplinary interest in norms, several definitions for norms exist. Habermas [16], one of the renowned sociologists, identified norm regulated actions as one of the four action patterns in human behaviour. A norm to him means *fulfilling a generalized expectation of behaviour*, which is a widely accepted definition for social norms. Researchers have divided norms into different categories. Tuomela [22] has categorized norms into the following categories.

- r-norms (rule norms)
- s-norms (social norms)
- m-norms (moral norms)
- p-norms (prudential norms)

The rule norms are imposed by an authority based on an agreement between the members. Social norms apply to large groups such as a whole society (for example, a society of students). The moral norms appeal to one's conscience. The prudential norms are based on rationality. When members of a society violate the societal norms, they are either punished or imposed with certain sanctions.

Many social scientists have studied why norms are adhered. Some of the reasons for norm adherence include:

- fear of authority
- rational appeal of the norms
- feelings such as shame, embarrassment and guilt that arise because of non-adherence.

Elster [11] categorizes norms into consumption norms (e.g. manners of dress), behaviour norms (e.g. norm against cannibalism), norms of reciprocity (e.g. gift-giving norm), norms of cooperation (e.g. voting and tax compliance) etc.

2.2. Normative multi-agent systems

The research of norms in multi-agent systems is fairly recent [20, 5, 10]. Norms in multi-agent systems are treated as constraints on behaviour, goals to be achieved or as obligations [7]. There are two main research branches in normative multi-agent systems. The first branch focuses on normative system architectures, norm representations and norm adherence and the associated punitive or incentive measures.

Lopez et al. [25] have designed an architecture for normative BDI agents and Boella et al. [4] have proposed a distributed architecture for normative agents. Some researchers are working on using deontic logic to define and represent norms [14, 4]. Several researchers have worked on mechanisms for norm compliance and enforcement [17, 2, 3]. A recent development is the research on emotion based mechanism for norm enforcement by Fix et al. [13].

Conte and Castelfranchi [9] have worked on integrated view of norms. Their views are similar to that of Elster [11]. The second branch of research is related to emergence of norms.

2.3. Related work on emergence of norms

The second branch focuses on two main issues. The first issue is on norm propagation within a particular society. According to Boyd and Richerdson [6], there are three ways by which a social norm can be propagated from one member of the society to another. They are

- Vertical transmission (from parents to offspring)
- Oblique transmission (from a leader of a society to the followers)
- Horizontal transmission (from peer to peer interactions)

Norm propagation is achieved by spreading and internalization of norms [5, 24]. Boman and Verhagen [5, 23, 24] have used the concept of normative advice (advise from the leader of a society) as one of the mechanisms for spreading and internalizing norms in an agent society. Their work focuses on norm spreading within one particular society and does not address how norms emerge when multiple societies interact with each other. The concept of normative advise in their context assumes that the norm has been accepted by the top level enforcer, the Normative Advisor, and the norm does not change. But, this context cannot be assumed for scenarios where norms are being formed (when the norms undergo changes).

So, the issue that has not received much attention is the emergence of norms in multi-agent societies. But, there are lots of literature in the area of sociology on why norms are accepted in agent societies and how they might be passed on. Karl-Dieter Opp [18] has proposed a theory of norm emergence. Epstein [12] has proposed a model of emergence based on the argument that the norms reduce individual computations and has provided some results. Our objective in this paper is to propose mechanisms for norm emergence based on the concept of oblique norm transmission in artificial agent societies. We also provide our experimental results.

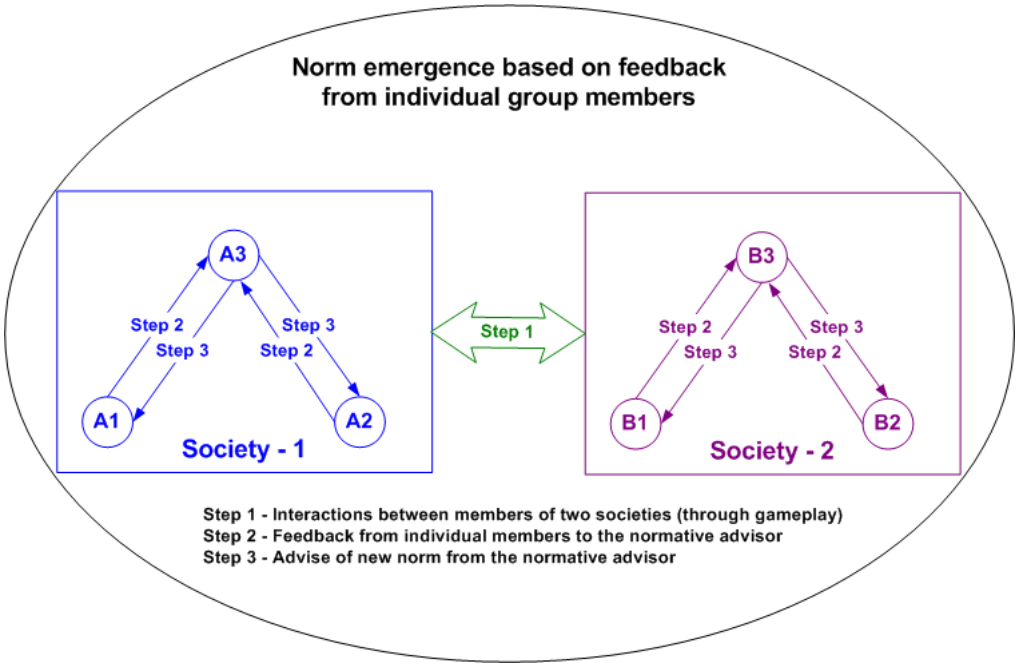

Figure 1: Architecture of collective individual feedback mechanism for norm emergence

3. Proposed mechanisms

In this section we propose and demonstrate mechanisms that help norm emergence when different agent societies with different norms interact with each other.

Assume that two agent societies with different norms inhabit a particular geographical location. When these societies are co-located, interactions between them are inevitable. When they interact with each other, their individual societal norms might change. The norms may tend to emerge in such a way that it might be beneficial to the societies involved. Our working hypothesis is *Interactions between agent societies with different norms in a social environment (with a shared context), results in the convergence of norms. Norm convergence results in the improvement of the average performance of the societies.*

To demonstrate our hypothesis we have experimented with agents that play the Ultimatum game. The shared context of interaction is the knowledge of the rules of the game. This game has been chosen because it is claimed to be sociologists' counter argument to the economists' view on rationality [11].

3.1. Ultimatum game

The Ultimatum game [21] is an experimental economics game in which two parties interact anonymously with each other. The game is played only once against another player, so reciprocation is not an issue. The game is played for a fixed sum of money (say x dollars). The first player proposes how to divide the money with the second player. Say, the first player proposes y dollars to the second player. If the second player rejects this division, neither gets anything. If the second accepts, the first gets (x-y) dollars and the second gets y dollars. For example, assume that each game is played for a sum of 100 dollars by two agents, A and B. Assume that A offers 40 dollars to B. If B accepts the offer, then A gets 60 dollars and B gets 40 dollars. If B rejects the offer both of them do not get any money.

3.2. Concepts used in simulation environment

In this section we describe the concepts associated with our work, the experimental set up and the parameters used.

3.2.1. Concepts used - An agent society is made up of a fixed number of agents. For our experiments we have designed two kinds of societies, namely selfish and benevolent societies as shown in figure 1. Society 1 and Society 2 correspond to selfish and benevolent societies respectively. Society 1 is modelled after the materialistic world where agents try to maximize their personal income. Selfish agents propose least amount of money and accept any non zero amount. The second kind of society is the benevolent society such as the Ika tribe of Ethiopia [11]. The benevolent agents are generous agents. They propose more than the fair share [2]. But, they expect nothing less than the fair share. They also reject high offers.

Each agent has two types of norms:

2 The fair share for an agent playing Ultimatum game for a sum of 100 dollars is 50 dollars. Source - http://www.sciencemag.org/cgi/content/full/289/5485/1773.

- Group norm (G norm)
- Personal norm (P norm)

The G norm is shared by all the members of the society. The P norm is internal to the agent and it is not known to any other member.

Autonomy is an important concept associated with choosing either a G norm or a P norm when an agent interacts with another agent. When an agent is created, it has an autonomy value between 0 and 1. Depending upon the autonomy value, an agent chooses either the G norm or the P norm. For example, if the autonomy of an agent is .4, it chooses P norm four times and the G norm six times out of ten games.

Normative Advisor is one of the agents in the society, which is responsible for collecting the feedback from the individual agents. It modifies the G norm of the society and advises the change to all the members of the society. As shown in figure 1, the Normative Advisor agents of the two societies are A3 and B3 respectively.

3.2.2. Experimental parameters - The G norm and P norm are made up of two sub norms namely the proposal norm and the acceptance norm. The proposal norm corresponds to the range of values (minimum and maximum values) that an agent is willing to propose to other agents. The acceptance norm corresponds to the range of values that an agent is willing to accept from other agents.

A sample G norm for an selfish agent looks like the following where min and max are the minimum and maximum values when the game is played for a sum of 100 dollars.

- G-Proposal norm (min=1, max=30)
- G-Acceptance norm (min=1, max=100)

The representations given above indicate that the group proposal norm of the selfish agent ranges from 1 to 30 and the group acceptance norm of the agent ranges from 1 to 100. A sample P norm for a selfish agent might look like the following:

- P-Proposal norm (min=10, max=40)
- P-Acceptance norm (min=20, max=100)

Initially the G norm of a society is assigned with a particular value which will be shared by all the members of the society. The personal norms will vary from one agent to another. An agent can accept or reject a proposal based on the norm it chooses (which is based on its autonomy).

3.3. Mechanism 1 - Collective feedback from individual agents

In this section we describe our mechanism for norm emergence that is based on collective feedback of individual agent experiences when playing the Ultimatum game against agents in the other society. The agents have a common G norm to start with. They also have an internal P norm. Both the norms continuously evolve based on social learning to maximize the benefit of the society. In the context of Ultimatum game, the goal is to improve the performance of the overall society while maximizing their own benefit.

As shown in figure 1, the mechanism consists of three steps. Step 1 refers to one iteration of game play. In one iteration, every agent in a society plays an equal number of games against all the agents in the other society. After the end of each game the agents record the history of interactions (both successes and failures). At the end of each iteration, all the agents submit their successful proposal and acceptance values to the Normative Advisor Agent of their society. This is indicated by step 2 in the architectural diagram. The algorithm that describes steps 1 and 2 is shown in figure 2.

```
for a fixed number of iterations do
          for each agent in a society (S1) do
               play a game against all agents in another society (S2)
                    if the outcome of a game is a failure
                         record failure
                         change the internal norm closer to the group norm
                    else
                         record success
                    end if
          end for
          send success and failure information to the normative advisor agent
          receive group norm information from the normative advisor agent
          modify group norm
end for
```

Figure 2: Algorithm that describes the collective feedback mechanism

Figure 3 explains, how the Normative Advisor Agent works (step 3 of the architectural diagram). The Normative Advisor Agent uses the average successful values submitted by all the agents in a society and derives the new G norm value for the group. In each iteration the Normative Advisor Agent fractionally increases or decreases G norm values for a society so that it can accommodate the norms of the other society. This mechanism will reduce the overall losses and increase the overall income. After each iteration, the group norm will be propagated to all the agents in the society.

```
for a fixed number of iterations do
     for each agent in a society do
          receive feedback information of success and failures
     end for

     calculate the new norm based on successful feedback

     for each agent in a society do
          send advise message
     end for
end for
```

Figure 3: Algorithm that describes how a Normative Advisor Agent works

Similar to the G norm, P norm of an agent will also change continuously. While G norm changes only at the

end of each iteration, P norm changes within each iteration. When an agent chooses P norm over G norm, the outcome of that game determines whether the P norm will change or not. For example, when an agent's proposal that is based on a P norm is rejected *n* consecutive times, the agent modifies its P norm. The agent modifies its P norm fractionally so that it moves closer to the G norm.

3.4. Mechanism 2 - Using Role Model Agents

This mechanism is a modified version of the collective feedback mechanism. Here, we use the concept of Role Models. The Role Models are agents whom the societal members may wish to follow. The inspiration is derived from the human society where one might want to follow successful people as a guide. The Role Model Agent will provide normative advise only to those agents that ask for help. In this mechanism (shown in figure 4), each agent has only a P norm. This decision has been made to test the implications of not having a G norm on norm emergence.

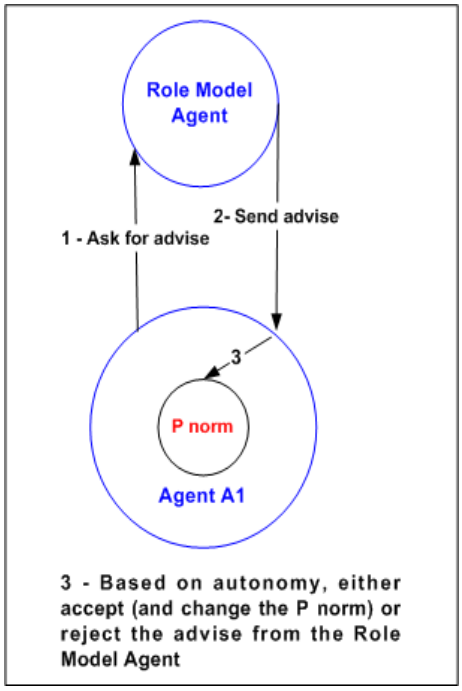

Figure 4: Architecture of the mechanism that uses Role Model Agent

At the end of each iteration the Role Model Agent collects the feedback from all the agents in the society. Based on the successful acceptances of proposals, it modifies its P norms. An agent can choose to ask for advise from the role model agent. For example, whenever an agent's proposal is rejected *n* times, the agent asks for advise from the Role Model Agent. The Role Model Agent sends the feedback to that agent. The agent is autonomous to choose or ignore the advice (in the previous mechanism, each agent accepts the G norm as advised by the Normative Advisor Agent). The agent modifies its P norm based on the advise it receives from the Role Model Agent.

So, this mechanism is different from the previous mechanism in two ways namely the omission of G norm and the option to accept or reject the advice based on autonomy. Also, there can be more than one Role Model Agents in a society. An agent can choose to follow one of the Role Model Agents.

4. Experimentation and results

The agents in our experiments are built on Otago Agent Platform [19] and they communicate using FIPA ACL messages [1]. Our experimental set up is made up of two societies with 50 agents in each society. In each iteration an agent plays the ultimatum game with all the players in the other group. The games were played over a fixed number of iterations (5 to 5000). In the first experiment the agents do not use the designed mechanisms. In the second and third experiments, the agents use mechanisms one and two respectively. At the end of each experiment, we observe whether norms emerge (whether the proposal norms stabilize or not). The initial G norms associated with the three experiments are given below.

- G-Proposal norm for selfish society (min=1, max=30)
- G-Acceptance norm for selfish society (min=1, max=100)
- G-Proposal norm for benevolent society (min=55, max=70)
- G-Acceptance norm for benevolent society (min=45, max=55)

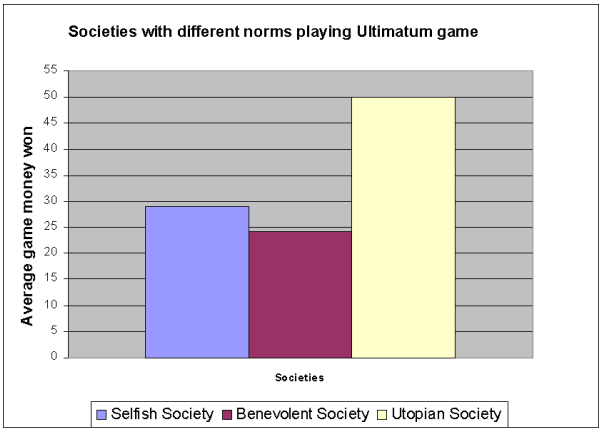

Figure 5: Performance of societies based on initial societal norms

In our experimental set up the minimum and maximum values are parameterized and can be changed easily. We have chosen these sample values to demonstrate the results that we obtained.

4.1. Experiment 1 - Societies that resist changes

Assume that the two societies that play the Ultimatum game resist changes to their G norms and P norms. In this scenario the G norms are the same across all agents in one society. The P norms will be different from one agent to another. The agents do not change their G or P norms over all iterations. The results of the average game money won by both the societies in this scenario is shown in figure 5. It can be observed the performance of both the societies are well below what could be achieved by both the groups if they were rational such as the Utopian Society. Utopian Society, in its most common and general meaning, refers to a hypothetical perfect society. It is synonymous to a fair society where the average income for the Ultimatum game will be 50. When sociologists conducted Ultimatum game experiments in modern societies, many of the societies proposed the fair 50-50 split. This indicates that the *norm of fairness* had evolved in these societies [11].

The performance of the selfish society in this experiment is better than the benevolent society because the selfish agents accept any non zero proposal.

4.2. Experiment 2 - Societies that use collective feedback from agents

In this experiment both the societies use the collective feedback mechanism. Figure 6 shows the G-Proposal norm changes of the benevolent as well as the selfish societies over 100 iterations. It can be observed that both the groups are continuously changing their G-Proposal norm to accommodate the G-Proposal norm of the other group. Initially, the G-Proposal norm values for the benevolent group decrease because the Normative Advisor Agent changes the the norm closer to the selfish societies' G-Proposal norm (based on the collective feedback). For the same reason the G-Proposal norm values for the selfish society increase (till iteration 32). Then, the norms in both the societies oscillate to move closer to each other. When, one societies' maximum and minimum values are closer to the other, the G-proposal norms start to converge (around iteration 80).

These experiments show that the overall performance of the societies have improved as a result of norm emergence as shown in figure 7. It can also be observed that the ideal values are not reached as the agents are autonomous and may choose to ignore the G norm particularly when the autonomy values are high. But, when the number of iterations increased to 5000, the outcomes were closer to the *norm of fairness* .

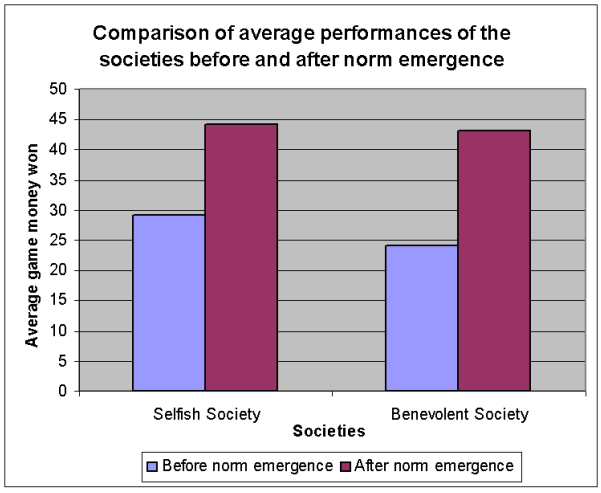

Figure 7: Comparison of performances before and after norm emergence

4.3. Experiment 3 - Societies that use Role Model Agent mechanism

In this experiment both the societies use the mechanism based on Role Model Agents. We have used one Role Model per society. The result of this experiment is similar to that of the previous experiment. The convergence results were similar to that of figure 6. But, the average G-Proposal norm values obtained using this mechanism were marginally lower (2 to 6% decrease in initial iterations) than the previous mechanism.

4.4. Comparison of the proposed mechanisms

Figure 8 shows the comparison of the two proposed mechanisms. It can be observed that there is not much difference between the convergence of both the mechanisms. But, the second mechanism trails to a smaller extent when the number of iterations are low. This is because, mechanism one uses both the P norms as well as the G norms. When G norms and P norms are chosen based on the autonomy value, the chances of an agent improving the average score is higher in mechanism one than mechanism two. For example if the autonomy value of an agent is .5, it chooses the G norm five out of 10 times in the first mechanism. So, the chances of this agent increasing its performance is higher than an agent that uses the second mechanism that does not have the concept of G norm. So, mechanism one produces higher performance averages than mechanism two. But, the average scores for both the mechanisms

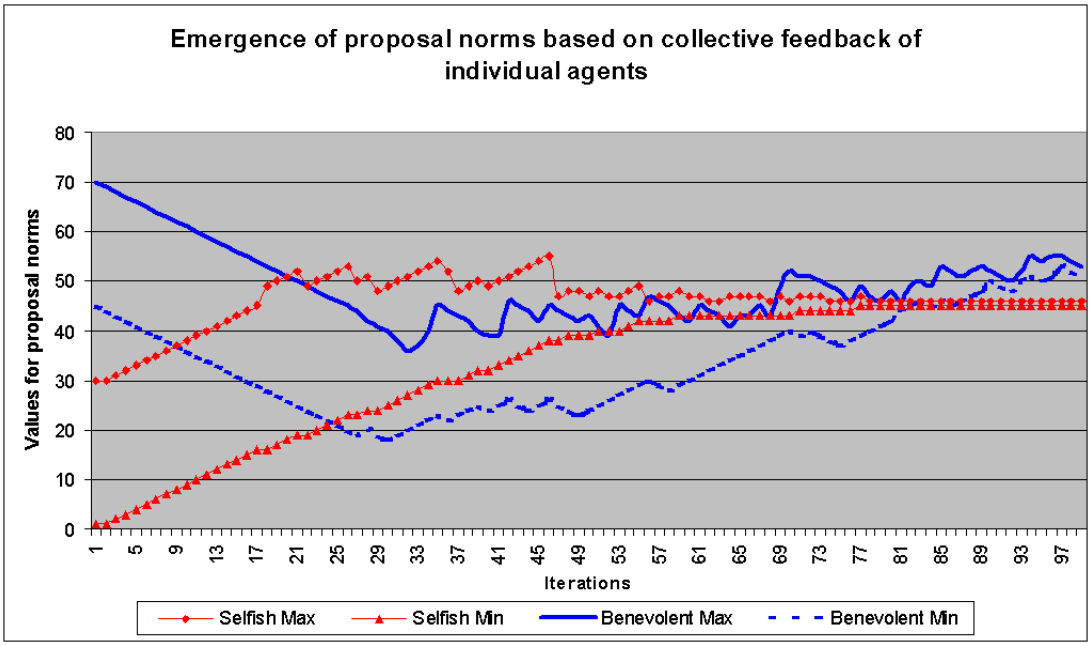

Figure 6: Emergence of norms based on collective feedback

are the same for larger number of iterations. This is because over large iterations, the changes to the G norm or P norm are marginal from one iteration to the next.

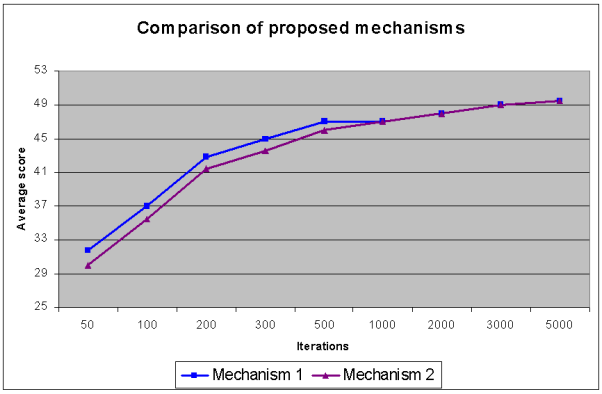

Figure 8: Comparison of proposed mechanisms

4.5. Discussion

Our work is different from other researchers in this area as we use the concepts of oblique transmission in the mechanisms we have proposed. Verhagen's thesis [23] focuses on the spreading and internalizing of norms. This assumes that a norm is agreed or chosen by a top level entity (say, a Normative Advisor) and this G norm does not change. The G norm is spread to the agents through the normative advise using a top-down approach. Our work differs from this work as we employ a bottom-up approach through the collective feedback mechanism. Another distinction is that our work focuses on norm emergence across societies while the former concentrates on norm propagation in one particular society. In our work both the P norm as well as G norm evolve continuously. In their work, P norm changes to accommodate the predetermined G norm. In a nutshell, the difference between the two works is that of norm propagation versus norm emergence.

The success of norm emergence using the proposed mechanisms can be explained by the theory of *instrumentality proposition* proposed by Karl-Dieter Opp [18]. The four positive criteria for norm emergence specified by Karl are given below.

- *Homogeneity of goals G* - In our experiments, the goal of an agent was to maximize it's personal and societal income.
- *Knowledge that a norm N leads to G* - The agents in our system worked towards establishing a norm that leads to an increase in overall score of the society.
- *Knowledge that behaviour B leads to N* - The agents are aware that by reporting their experience to the Normative Advisor Agent, they can help to achieve the group goal.
- *Incentives to perform B* - The agents know that they can increase their own personal score by providing feedback and receiving the advice. Another incentive for an agent to report experiences is its eagerness to predict other agents' behaviour (e.g. knowing the acceptance range of the other agent).

We agree that the experiments described in this paper are limited. The norm emergence results shown in this paper

have used the proposal norms while maintaining the same values of acceptance norms in both the groups. Further experiments should be undertaken to explore the emergence of both kinds of norms. We will experiment with more number of Role Model Agents which would be of interest as each Role Model Agent will advise a sub-group of agents within a society.

The current experiments use two kinds of societies. We are interested to undertake social simulations to observe what emerges when three or more societies with different norms interact with each other. We will incorporate the idea of horizontal norm transmission where norms can emerge due to peer to peer interactions. These peer to peer interactions will use normative referrals. Furthermore, we are planning to experiment with the emergence of norms in scenarios that involve negotiations among agent societies such as buyer-seller societies in electronic markets and Web Service implementer-consumer societies.

5. Conclusions

We have explained two mechanisms for norm emergence in artificial agent societies. The first mechanism used collective feedback of individual agent experiences. The second mechanism used the concept of Role Model Agents. We have demonstrated the use of oblique norm transmission in these mechanisms for norm emergence. We have shown our initial experimental results. We have compared our work with the researchers in this area and also discussed the future work.

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