

Mechanisms for Norm Emergence in Multi-Agent Societies

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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 Systems (MAS) researchers as software agents may violate norms due to their autonomy. In order to build robust MAS that are norm compliant and systems that evolve and adapt norms dynamically, the study of norms is crucial. Our research focuses on how norms emerge in agent societies. In this paper we propose two mechanisms for norm emergence.

Categories and Subject Descriptors

I.2.11 [Artificial Intelligence]: Distributed Artificial Intelligence—Multiagent systems; J.4 [Computer Applications]: Social and Behavioral Sciences—Sociology

General Terms

Design, Experimentation

Keywords

Norms, Agents, Societies, Normative Advice, Mechanisms

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 societies. The human society follows norms such as tipping in restaurants, exchange of gifts at Christmas and driving vehicles on the left or right hand side of the road. Some of the well established norms may become laws.

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 [1, 12]. Norms have been of interest in different areas of research such as Sociology, Economics, Psychology and Computer science [7].

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Sociologists and economists are divided on their view of norms based on the theories of *homo economicus* and *homo sociologicus* [7]. Sociologists consider that the norms are always used for the overall benefit of the society. Economists on the other hand believe 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.

Sociology and multi-agent systems complement each other. Agents are modelled using some of the social concepts such as autonomy and speech act theory. Multi-agent systems serve as a platform to design, test and validate social theories. Some researchers [3, 14] 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.

2. BACKGROUND

Due to multi-disciplinary interest in norms, several definitions for norms exist. Habermas [9], a renowned sociologist, 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. When members of a society violate the societal norms, they may be punished. Many social scientists have studied why norms are adhered. Some of the reasons for norm adherence include a) fear of authority b) rational appeal of the norms and c) feelings such as shame, embarrassment and guilt that arise because of non-adherence.

2.1 Normative multi-agent systems

The research of norms in multi-agent systems is recent [3, 6, 12]. Norms in multi-agent systems are treated as constraints on behaviour, goals to be achieved or as obligations [5]. There are two main research branches in normative multi-agent systems. The first branch focuses on normative system architectures, norm representations, norm adherence and the associated punitive or incentive measures [2, 8, 10]. The second branch deals with the emergence of norms. Please refer to the full version of the paper for the works related to first branch of norm research [11].

2.2 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 Richerson [4], there are three ways by which a social norm can be propagated from one member of the society to another. They are a) Vertical transmission (from parents to offspring), b) Oblique transmission (from a leader of a society to the followers)

and c) Horizontal transmission (from peer to peer interactions).

Norm propagation is achieved by spreading and internalization of norms. Boman and Verhagen [3, 14] have used the concept of normative advice (advice 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 advice is based on the assumption 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 second issue that has not received much attention is the emergence of norms in multi-agent societies. However, there is abundant literature in the area of sociology on why norms are accepted in agent societies and how they might be passed on. Our objective in this paper is to propose two mechanisms for norm emergence based on the concept of oblique norm transmission in artificial agent societies.

3. MECHANISMS FOR NORM EMERGENCE

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.

We have experimented with agents that play the Ultimatum game [13]. 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 [7].

3.1 Ultimatum game

The Ultimatum game [13] is an experimental economics game in which two parties interact anonymously with each other. 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. Assume that 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.

3.1.1 Concepts used

Our agent society is made up of a fixed number of agents. We have designed two kinds of societies, namely selfish and benevolent societies. The selfish society 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 [7]. The benevolent agents are generous agents. They propose more than the fair share¹. But, they expect nothing less than the fair share. They also reject high offers.

Each agent has two types of norms, Group norm (G norm) and 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

¹The 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>.

agent. When an agent is created, its autonomy value is initialized using a uniform distribution within a range of 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 all the agents in the society. It modifies the G norm of the society and advises the change to all the members of the society.

3.1.2 Experimental parameters

Both 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.

- Proposal norm (min=1, max=30)
- 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. The P norm of an agent has a similar representation.

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 P norm 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).

3.2 Mechanism 1 - Collective feedback from individual agents

Our first mechanism for norm emergence 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 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 (game money won) of the overall society while maximizing their own benefit.

The mechanism consists of three steps. The first step corresponds 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.

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 in order to accommodate the norms of the other society. This mechanism will reduce the overall losses and increase the overall income of a society. After each iteration, the group norm will be propagated to all the agents in the society.

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.

3.3 Mechanism 2 - Using role model agent

This mechanism is a modified version of the collective feedback mechanism. Here, we use the concept of a role model. A role model is an agent whom the societal members may wish to follow. The inspiration is derived from the human society where one might want to follow a successful person. In our mechanism, the best performing agent in the society becomes the role model. The role model agent will provide normative advice only to those agents that ask for help. In this mechanism, each agent has only a P norm.

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 advice from the role model agent. For example, whenever an agent's proposal is rejected n times, the agent asks for advice 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 advice it receives from the role model agent.

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.

4. EXPERIMENTS AND RESULTS

We have experimented with norm emergence using both mechanisms described above. The experimental setup was made up of two societies (selfish and benevolent) with 50 agents each. For each iteration an agent plays the Ultimatum game with all the players in the other society. The games were played for a fixed number of iterations (5 to 5000). We have observed complete norm emergence (100% norm emergence) using both mechanisms. We conducted experiments to compare the performances (average game money won) of both societies before and after norm emergence. We observed that the performances of both the societies are higher after norm emergence.

We also compared both mechanisms for norm emergence. We have not observed any marked difference in the rate of norm emergence in both mechanisms. Please refer to the full version of the paper for more details of the experiments and results [11].

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 [14] focuses on the spreading and internalizing of norms. This assumes that a norm is agreed or chosen by a top level entity (Normative Advisor) and this G norm does not change. The G norm is spread to the agents through the normative advice 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 his work, P norm changes to accommodate the predetermined G norm.

The current role model based mechanism uses only one role model for all the agents in the society. In real life, agents are free to

choose their own role model. We are extending the current mechanism by allowing agents to choose their own leaders. Another important aspect in norm emergence is the underlying topology of connections between agents. We are currently experimenting with the role of different network topologies on norm emergence. Network topologies such as random networks and scale-free networks can be used to study how local interactions lead to global norm emergence.

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