2011 IEEE/WIC/ACM International Conferences on Web Intelligence and Intelligent Agent Technology

Emergence of a sharing norm in a simulated hunter-gatherer society

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Abstract— **Sharing is a behaviour that is observed in humans and other primates. In this paper, our objective is to demonstrate how the norm of sharing changes based on environmental conditions. Using agent based modeling, we have simulated a hunter-gatherer society where the norms of the society are affected by changing environmental conditions. In particular, we demonstrate how norms might change in a society based on the changes to the type of resources available in the society. We present several experiments that have been conducted on the emergence of the sharing norm and discuss the results obtained.**

I. Introduction

Norms are expectations of an agent about the behaviour of other agents in the society [1]. Upon knowing a norm that constraints the behaviour, an agent expects that the other agents in the society should follow the norm. Human societies follow different types of norms such as exchanging gifts at Christmas. In human societies norms facilitate coordination [8] and also they enable informal social control.

The social concept of norms has been of interest to multi-agent system researchers for about two decades. Norms are of interest to researchers from two different perspectives, the prescriptive approach and the emergence approach. In the prescriptive approach, an institution prescribes what the norms of the societies are. In the emergence approach, based on individual interactions between the agents in the society, norms emerge [8], [9]. The dynamic nature of societies can lead to different norms under different circumstances. In human societies, the norm against smoking is an example of such a dynamic norm that has emerged. Not very long ago, smoking was allowed in public places such as restaurants. As non-smokers became more informed about the ill-effects of second-hand smoke, they started sanctioning the smokers. Gradually, the norm against smoking came into existence. Here, the change in circumstances (i.e. being informed) lead to the emergence of the norm against smoking in public places. In this paper, we are interested in investigating how norms change dynamically in an agent society as a response to changing environmental conditions.

II. Background

Several researchers have experimented with the emergence of norms [4], [7]. For an overview of categorization of simulation works on norms and associated mechanisms employed by researchers refer to the work of Savarimuthu et al. [5]. However, the emergence of sharing has not been dealt with by many researchers in the field of multi-agent systems. In a pervious work, Savarimuthu et al. [6] have shown how tags can be used to achieve emergence of sharing behavior in a multi-agent societies. They have used the sharing of knowledge as their domain model where agents use tags to identify those who are similar to them. They have not investigated how the norms of sharing change based on changing environmental conditions. In this paper, a sharing norm broadly refers to the sharing behaviour of agents with other agents in its group (i.e. an agent forms a group in order to jointly obtain and share resources which is also commonly referred to as communal sharing)[1].

We note that some social scientists have experimented with the sharing norm (i.e. sharing of resources). From an anthropological view point, Kaplan and Hill [3] have studied Ache society of hunter-gatherers in Paraguay. They have found that sharing norms in the Ache society were established for resources that were scarce. The resources that were available in abundance were not shared among non-kin members while the scarce resources such as meat were shared. They have developed a mechanism for sharing norm emergence. Kameda et al. [2] have demonstrated how the sharing norm might emerge and is sustained in such an agent society. They have provided solutions to second order free rider problems.

Our objective in this work is to demonstrate that under changing circumstances norms can change using sharing norm as an example. Using simulations we show that under different circumstances the presence of sharing norm might vary in a society.

III. Experimental set-up

In our experimental set-up an artificial agent society is populated with certain number of agents (e.g. 50) that move around in a two dimensional grid environment (25*25 grid). There are two types of consumable resources that appear in the environment. The two types of resources are the collectible

[1]In a stricter sense, sharing behaviour should be seen as a convention rather than a norm since norms are associated with sanctions. However, in this paper we use the word norm in a broader sense to refer to commonly observed behaviour or a convention. We intend to consider sanctions in the future.

978-0-7695-4513-4/11 $26.00 © 2011 Crown Copyright
DOI 10.1109/WI-IAT.2011.141

resources (e.g. vegetables, plants and nuts) and the resources that can be devoured upon hunting (i.e. meat). We call these resources, resource A and B respectively.

Each agent in the society is initialized with an initial energy level. As the agents move from one cell to another, they lose energy. They can gain energy by consuming resources. While resource of type A can be collected by an individual agent, resource type B can only be hunted if they form a group. Agents can then share the food with the members of the group. On consumption, each resource provides certain energy to the consumer. The total energy obtained from resource B is greater than the energy from resource A.

An agent cannot survive when it reaches below its minimum survival score. An agent has a warning threshold which warns the agent when its energy level reaches below a certain value. An agent initially starts as a non-sharer which only gathers the collectible food (resource A). If an agent's energy level goes below the warning threshold (e.g. during drought when the collectible resources are scarce), it will look for partners to form a group and hunt larger preys. The warning threshold is half the initial energy level. An agent can also withdraw itself from the partnership if its energy level is higher than its desired energy level (e.g. 2.0 times its initial energy level)[2]. When they are a part of a group, all the agents share the resource equally. Each type of resource has certain amount of life time (time to live, TTL). At the end of its TTL, the resource disappears from the environment. The pseudocode for the interactions between the agents and the environment is given in Algorithm 1.

Algorithm 1: Pseudocode for agent interactions in a society

```
foreach iteration do
    foreach agent X in the society do
        if energyLevel < warningThreshold then
            seekPartnershipAndHunt;
        end
        else if energyLevel > desiredEnergy then
            withDrawFromPartnership;
        end
        else
            if ∈ resource A in an adjoining cell then
            consumeResourceA;
            else if ∈ resource B in an adjoining cell AND
            X belongs to a group then
            huntAndShareResourceB;
            else  moveToNextLocation;
        end
    end
end
```

We have conducted simulation studies using NetLogo [10].

[2]The desired energy level refers to the comfort zone of an agent upon reaching which the agent does not need the support from the group for its survival.

TABLE I
SIMULATION PARAMETERS

Parameters	Values
Grid environment size	25*25 (625 cells)
Initial energy level	1000
Minimum survival energy	1
Warning threshold	500
Desired energy level	2000
Energy loss through movement	1
Energy of resource A (collectible resource)	10
Energy of resource B (huntable resource)	100
Arrival rate of resource A (r_A)	0.02
Arrival rate of resource B (r_B)	0.0 (varied)
Time to Live (TTL) for resource A	5 ticks
Time to Live (TTL) for resource B	5 ticks

At any tick (an iteration), certain amount of food is available to the agents in the environment (based on the arrival rates of resources, i.e. r_A and r_B). If a resource of type A appears in an adjoining cell to an agent, then the agent can consume it. Resource B (a huntable resource) can only be hunted by a group and atleast one of the members of the group should be present in the adjoining cell to the huntable resource.

An agent whose energy level goes below its warning threshold will seek out another agent in its proximity which is in a similar position (i.e. energy below warning threshold) so that they can form a team. A video of the sample simulation set-up can be viewed at http://unitube.otago.ac.nz/view?m=qZqp1bj224W. Initially all agents (stick men) are in yellow. Resource A appears as green and resource B appears as blue. When agents form groups their color changes from yellow to orange.

IV. EXPERIMENTAL RESULTS

In this section we show the experiments we have conducted and discuss the results obtained.

A. Experiment 1: Sharing behaviour of agents

First, we demonstrate the waxing and waning of the sharing behaviour under changing circumstances. In our experimental set-up, we have simulated a scenario where there is plenty of resource A available for certain amount of time. Then, the availability of resource A drastically decreases over certain amount of time while resource B becomes available. Later, the availability of resource A increases. This is analogous to a fertile period followed by a drought which then is followed by a fertile period again.

For the first 1000 iterations resource A was available in plenty (r_A=0.02, r_B=0)[3]. This corresponds to the overall arrival rate of 12.5% (0.02*625) of resource A in each tick of the simulation. Then from iterations 1001 to 4000, the availability of resource A decreases (r_A=0.001) and the availability of resource B increases (r_B=0.004). Then from iteration 4001 to 5000 the availability of resource A increases (r_A=0.02) while the availability of resource B decreases (r_B=0.001). The parameters of this experiment are given in Table I.

[3]The arrival rates are for each cell in the grid environment.

Figure 1 shows the sharing behaviour of agents in the society (i.e. the number of sharing groups formed in the society) averaged over 30 runs. In the first 1000 iterations, the agents in the society do not share. As resource A becomes scarce, their energy level goes down. Hence there is a need for agents to form groups. So, they start forming groups. When they form groups, they are able to hunt food in plenty. Hence, energy levels of some agents surpass their desired energy level. So, they break away from (or leave) their sharing group. So, the total number of groups starts to decrease. At a later stage if their energy levels become low they would again join a group (i.e. agents join and leave groups dynamically). This is the reason why every agent does not necessarily form a group under drought conditions (i.e. when resource B is scarce). Agents dynamically form groups based on their needs. After 4000 iterations, it can be observed that most agents do not have the sharing norm as resource A is available in plenty. Some agents in the system can potentially die because of the unavailability of partners to form groups (not shown here). This demonstrates that agents can form a sharing norm dynamically.

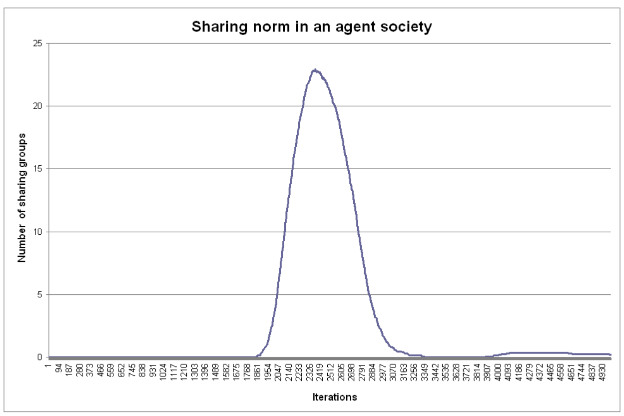

Fig. 1. Sharing norm in an agent society

Figure 2 shows the energy levels of an agent in the society and Figure 3 shows the norm of an agent (0 indicates no-sharing and 1 indicates sharing). It can be observed from Figure 2 that the energy level of the agent increases till iteration 1000. After iteration 1000, as the rate of resource A decreases the agent's energy level starts decreasing. The agent's energy level goes below its warning threshold in iteration 3030. The agent then seeks for a partner in its vicinity and finds one in iteration 3035. The agent's energy level starts increasing after finding a partner. When it forms the partnership it shares resource B with the partner which is shown by Figure 3 (see iterations 3035 to 3117). The energy level of the agent increases till iteration 3117.

After iteration 3117 the energy level for this agent drops because the other agent in sharing group has withdrawn itself from the group (because its energy level is higher than the desired energy level). At this point, this agent starts finding a new partner. It finds a partner successfully in iteration 3657 (see Figure 3). This sharing group remains intact until iteration 3815 at which the agent reaches its desired energy level. Now this agent does not have a sharing norm. So, its starts dropping (iterations 3816 onwards). After iteration 4000, as more resources of type A start appearing, the agent has more food to consume. Hence its energy level goes up (see Figure 3).

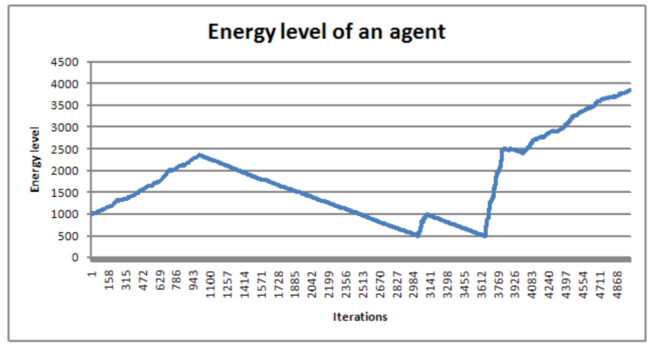

Fig. 2. Energy level of an agent in the society

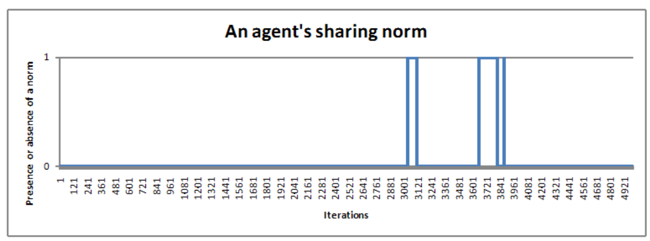

Fig. 3. Dynamic change of a norm in an agent society

B. Experiment 3: Effect of the arrival rates of resources on the sharing behaviour

In this experiment we demonstrate the effect of arrival rates of resources on the sharing behaviour. The variables that govern the sharing behaviour are the reduction in resource A and the availability of resource B. From iterations 1000 to 4000 we maintained three different arrival rates for resource B while maintaining the same reduced rate for resource A. The reduced rate for resource A is 0.001 and the original arrival rate of resource A used in iteration 1 to 1000 is 0.02. The arrival probabilities of resource B (for each cell) which were varied in the three experiments that were conducted are 0.02, 0.01, and 0.004[4]. The group size was kept constant (two) for all the three experiments. After iteration 4000, the arrival rate for resource A was set to 0.02 and the arrival rate for resource B was set to 0.001. All the other parameters were kept constant.

[4]These correspond to arrival rates 12.5%, 6.25% and 2.5% for a particular society for each tick.

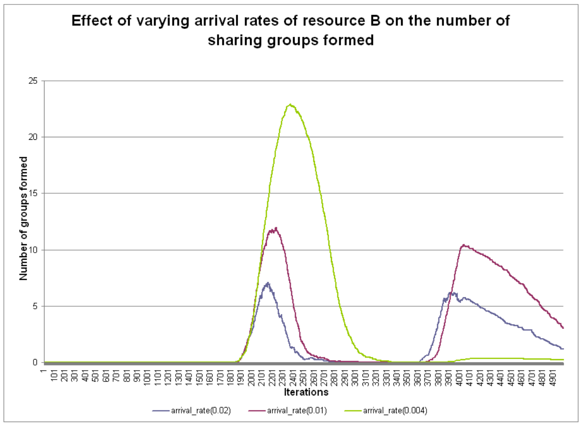

Fig. 4. Effect of varying arrival rates on the number of sharing groups formed

Figure 4 shows that when the arrival rate for resource B is low (arrival rate = 0.004), more groups formed (based on the average of 30 runs). When the arrival rates for resource B is high (arrival rate = 0.02), fewer groups are formed on average (see the first set of peaks between iterations 1800 and 3300). This is because, when more food is available, agents reach their desired energy levels fast and hence they break off from their sharing group. Hence, faster arrival rates of food correspond to fewer, short-lived groups. Lower arrival rate encourages more groups to be formed that are long lived.

A second set of peaks can be noticed for arrival rates of 0.02 and 0.01, closer to iteration 4000. This is because after all the groups have disbanded about iteration 3000, the individual agents' energy levels go below the warning threshold and the agents start forming groups again before iteration 4000. However, when the arrival rate for resource B is 0.004, the groups are disbanded later than the groups formed for the other two arrival rates. So, around iteration 4000, the energy levels of most of the individual agents have not gone below the warning threshold unlike the groups formed based on the other two values of arrival rates. Hence, there aren't substantial number of groups with the sharing norm. Additionally, after 4000 iterations more resources of type A start to appear which deter the need for forming groups.

It should be noted that there appears to be phase difference in the waxing and waning of sharing based on the arrival rates (i.e. the groups for the arrival rate of 0.02 were the first one to be disbanded completely (blue line) and were also the first ones to be formed again and the groups for the arrival rate of 0.01 were the second to be disbanded completely (red line) and they were the second ones to form groups again).

V. Discussion

The simple simulation experiments described in this paper demonstrate the waxing and waning of sharing norms in a hunter-gatherer society. The hunter-gatherer society considered in this paper should be seen as an example of a society where norms change dynamically. The behaviour of sharing can be extended to the sharing of electronic resources and can be applied to a variety of contexts such as file sharing, sharing of information, skills and gossip. Additionally, other norms of human societies that change due to environmental conditions (e.g. norms of peace and war and global warming) can be investigated. The agent based modeling approach can be applied to any of these contexts. We realize that norms are domain specific and parameters of the system should reflect the domain under consideration.

We note that the work described in this paper can be extended further. First, parameter sweeping technique can be employed to identify conditions under which sharing norm emerges in the society. Second, adaptive learning techniques can be employed by the agents. Currently, agents use a simple strategy for deciding whether to find a partner. They seek a partner if their energy threshold is low. Alternatively, agents can monitor the rate of arrival of different types of resources in their local environment and then dynamically decide which strategy to follow.

VI. Conclusion

Through the simulation of hunter-gatherer societies, this paper demonstrates how the norm of sharing changes based on environmental conditions. In particular, this work demonstrates how the changes to two types of resources impacts the sharing behaviour in an agent society. The paper also investigates the effects of arrival rates of resources on the stability of the sharing norm.

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