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Social Cooperation in Autonomous Agents to Avoid the Tragedy of the Commons

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ABSTRACT

In this paper, we address the "Tragedy of the Commons" (TOC) problem for shared-resource systems by considering different types of behaviors of agents. On one extreme are self-interested agents while on the other one, agents are concerned about the welfare of the society. Algorithms to capture the different behaviors of the agents with and without interaction among the agents are proposed. An extensive experimental analysis for the different cases has been carried out as well as comparisons of our algorithms with an existing approach. Our study shows that if the agents are willing to sacrifice for some period of time, the sustainability of the society increases considerably.

KEYWORDS

Cooperation, Eagerness, Tragedy of the Commons

INTRODUCTION

The "Tragedy of the Commons" (TOC) (López, 2005; Hardin, 2009; Diekert, 2012) is a problem in which the sustainability of the society (group of agents) reduces due to self-interested individual agents using a shared resource (a commons). This problem first appeared in the seminal paper of Hardin in 1968 (Hardin, 2009). Many areas of interest to society like climate change, fisheries management, and preservation of rainforests exhibit this phenomenon (Turner, 1993).

Researchers in the area of Distributed Artificial Intelligence (DAI) and Multi-agent systems (Saha & Sen, 2003; Doebeli & Hauert, 2005; Killingback, Doebeli, & Hauert, 2010; Castelfranchi, 1998; Turner, 1993; Sen & Sen, 2010) have also addressed the TOC problem. In (Turner, 1993), how the TOC is applicable to a DAI setting is studied. In (Saha, 2003) an algorithm is suggested to give optimal resource utilization by the individuals (agents) of the society, where the agents have only local information. In (Sen & Sen, 2010) the performance of the society is studied when aspiration levels are associated with an individual. An aspiration level corresponds to the satisficing return for an individual. Such an aspiration level is adjusted based on past experience.

Any attempt to avoid the tragedy of the commons should incorporate in to the decision-making process of an agent the following: the individual gains as well as the social welfare. However, these two aspects often conflict. This issue has been addressed in (Hogg & Jennings, 2001) in the context of designing socially intelligent agents, although the TOC problem is not studied in the paper. In (Hogg & Jennings, 2001) a framework is proposed for making socially acceptable decisions.

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Consider a society where a public good is available for free (or very little cost) to the members of the society. If there is no law associated for the utilization of the public good, an individual of the society would like to act in a manner that maximizes its utility of the public good. From an individual perspective, this is the best decision. However, if all individuals act in the like manner, the public good would soon get depleted due to the synergistic behavior and so the society collapses. Thus, laws are necessary for the proper functioning of a society. When there is a law in effect it entails a member to abide by it. TOC is concerned with the situation when there is no such formal law or rule. This is where the behavior of an individual comes in to effect that should consider (i) its utility from the public good and (ii) the depletion rate of the public good. If only (i) is considered, we are faced with what is called the tragedy of the commons. When (ii) is taken into account the decisions are to some extent based on the welfare of the society.

If we view the public good as a resource, the survival of the society depends directly on the rate of depletion of the resource. The slower the rate of depletion, the longer the time of survival of the society. Although the algorithms developed in (Saha & Sen, 2003; Sen & Sen, 2010) can use the shared resource optimally, the issue of survival time of the society is not considered. In this paper, we consider socially motivated agents. The agents make decisions that consider the welfare of the society. This helps the society to survive for a longer period of time compared to the situation when the agents would have acted for their individual gains only.

This paper is organized as follows. In Section 2 we give a model of the TOC problem. We present an algorithm that corresponds to the behavior of self-interested agents and give some experimental results. In Section 3, we present an algorithm that corresponds to the behavior of an agent that is socially motivated and give some experimental results. In Section 4 we define a parameter to quantify an agent's willingness to sacrifice for the society. We present an algorithm that corresponds to socially motivated agents and give some experimental results. In Section 5 we analyze the validity of the results. In Section 6, we present an algorithm that is based on interaction among agents. We conclude in Section 7.

MODELLING THE TRAGEDY OF THE COMMONS

The tragedy of the commons as developed in Hardin (Hardin, 2009) is as follows:

Picture a pasture opens to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work reasonably satisfactorily for centuries because tribal wars, poaching, and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning, that is, the day when the long-desired goal of social stability becomes a reality. At this point, the inherent logic of the commons remorselessly generates tragedy. (Hardin, 2009)

We assume that there is a finite number of agents (herdsmen), that we call the society. We denote the agents by the numbers 1, 2, …, n. Each agent i has g_i^t number of cattle at time t. Total number of cattle grazing in the field at time t is denoted by G^t. Each cattle consumes Q unit(s) of grass (commons). The field, shared by the cattle of the agents, is available for free to the agents. We refer to the field as the shared resource (initially it is R units).

Resource Available (RA) at time t is denoted as RA^t, ($RA^0 = R$). RA^t denotes the shared resource available to the cattle for consumption and is calculated using (3). All agents increase their cattle from time to time to increase their profit. $incRate_i$ denotes the rate at which an agent i increments its number of cattle. Profit of agent i at time t is denoted by $profit_i^t$ and is calculated using equation (2). Profit of an agent is directly proportional to the number of cattle it uses. Total