

On modeling punishment in multi-agent systems

(Extended Abstract)

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ABSTRACT

In this paper we study isolation as a form of punishment. Although an isolated violator is punished as it can not benefit from the interactions with other agents, compliant agents may also suffer from not engaging with the violators. In this paper we analyze such problems. Certain modifications of multi agent systems are needed to solve this problem. These modifications are aimed to make the violator redundant so that it can be ignored and hence isolated. Deciding on these modifications is NP-complete and approximation algorithms exist.

Categories and Subject Descriptors

H.4 [Information Systems Applications]: Algorithms

General Terms

theory

Keywords

Punishment, Multi-Agent Systems, Norms

1. INTRODUCTION

Compliance with norms makes an agent's behavior more predictable, which enhances coordination among agents [9, 10, 8]. Besides improving coordination, compliance with norms also satisfies some system level conditions set by the designer of the norms. Although norms are beneficial for the agents, violations of norms occur because certain self interested agents may prefer to achieve some individual goals over compliance with the norms. To encourage compliant behaviors various norm enforcement techniques have been developed. Norm enforcement can be classified [11] into two categories: (a) self enforcement and (b) third party enforcement. In self enforcement the agents themselves execute the punishment and in case of third party enforcement, an external agent decides the amount of punishment and executes the necessary procedures for it. Downgrading the violators reputation is a common practice in various enforcement models [2][5]. As the reputation is downgraded

the compliant agents do not interact with the violator as it do not treat the violator as trustworthy. Although there is vast literature dedicated towards norm enforcement models, there is a lack of formal models of punishment. Most of the existing models of punishment suggests that a violator must not be engaged in further joint actions or other multi agent activities. But these models do not consider the effects of this isolation on compliant agents. As compliant agents are not interacting with the violators, they may lose some utility. This can happen because a violator owns certain unique abilities, and it can no longer act as a mediator. In this paper we assume that abilities of a violator are not replaceable but its role as mediator can be replaced. Let us consider the following example that illustrates the adverse effect of isolation: consider the normative multi-agent system $nmas$ depicted in Figure 1 as a graph where the nodes (a_1, \dots, a_7) represent compliant agents and v represents the violator. The edges represent communication links between agents. Agents can perform joint actions if they are connected. Due to isolation, the edges connecting the violator with other agents are removed as a form of punishment. One of the adverse effects of this isolation is that a_5 can not perform any joint actions with other agents. Also, suppose that, agents interact with other agents if they are trustworthy. An agent computes the trust of other agents by recommendations from their neighbours. Trust propagation models typically assume that the trust between two agents is proportional to the number of mediators between them. So, it may happen that, as v is not mediating between a_7 and a_4 , the trust on a_4 by a_7 results lower after the isolation of v , and as consequence a_4 and a_7 will not interact. Research

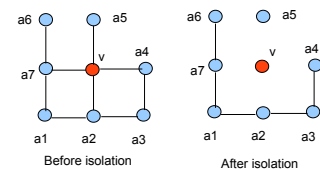


Figure 1: Effect of Isolation

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in multi agents has shown that *mediators* play an important role in a variety of multi agent problems, for example trust and joint actions [12], recommendation systems [6], and multi agent negotiation [3, 7]. Thus punishment mechanisms based on isolation have to take into account how to minimise the adverse effects of isolation. In this paper

we propose a model of punishment which neutralizes these adverse effects of *isolation*. Our model of *isolation* is as follows: a *nmas* is represented as a graph. Due to isolation of the violators, all edges with the violators are deleted. The effect of isolation on the compliant agents is modeled as follows: **Problem 1** Assume that there is a set of nodes called *sources*. Agents preferences over the sources are described as an order over the sources such that an agent is willing to pay more to connect with a more preferred source than a less preferred one. Agents coordinate their actions to form a minimum cost spanning tree over the *nmas* such that the costs to connect with the sources along the spanning tree is according to their preferences. Assume that, before isolating a violator, there was such a spanning tree. So the isolation problem becomes the creation of new edges at a minimum cost such that it is possible to construct such a spanning tree. Thus addition of the new edges makes the violators redundant as the compliant agents can form an optimal tree without cooperation from the violators and hence they can afford to ignore the violators. Notice that this problem can be used to simulate general coordination problems in multi agent systems. **Problem 2** Assume that, before the isolation for every agent there is a subset of agents who can be reached within a predefined length (say K). Due to the isolation of the violators, some edges are no longer in use. So an agent loses certain agents within its reachable range. So in this case the isolation problem becomes the creation of certain new edges at a minimum cost such that each affected agent can reach the previously lost agents. Thus after the addition of the new edges the role of violators as mediators become redundant. Hence the compliant agents can isolate the violators as they do not need cooperation from them. This problem is motivated by trust propagation models and recommendation system models. In both cases, an agent's reputation or trust ranking usually can be changed if the topology of the system is changed. Isolating the violators triggers such changes and hence it must be neutralized by creating alternate paths between the compliant agents.

2. RESULTS

Theorem 1. *Isolation with preference is NP-complete for 2 sources.*

Theorem 2. *Isolation with preference is NP-complete for more than 2 sources.*

Theorem 3. *A polynomial time ($\frac{1}{1-m}$)-approximation solution for the problem of isolation with preference exists.*

Theorem 4. *K -dedicated source-minimum cost spanning tree is NP-complete for two sources.*

Theorem 5. *K -dedicated source-minimum cost spanning tree with variable peer limit is NP-complete for 2-sources.*

Theorem 6. *K -dedicated source-minimum cost spanning tree with variable peer limit is NP-complete for 2-sources.*

Theorem 7. *A polynomial time 2-approximation solution to 2-dedicated source minimum cost spanning tree exists.*

As a comparison with relevant works in *nmas*, [1] gives a notion of enforceable social laws in terms of the efficiency of the system to remain compliant. In [4] a similar concept of punishment is introduced. By the adverse effect of

punishment on the compliant agents is never analyzed in *mas* literature. In that regard this paper is the first towards formalizing the cost of punishment. A theory of cost of punishment helps to build enforcement laws in *mas* in such a way that the cost to punish the agents becomes affordable.

3. ACKNOWLEDGMENTS

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