A Simulator for Multi-Agent Partnership Formation Based on Dependence Graphs

Júlio de Lima do Rêgo Monteiro

Intelligent Techniques Laboratory (LTI)
University of São Paulo (USP)
Av. Prof. Luciano Gualberto, 158 trav. 3
05508-900 – São Paulo – SP – Brazil
+55 11 30915397

monteiro@lab.pro.br

Jaime Simão Sichman[1]

Intelligent Techniques Laboratory (LTI)
University of São Paulo (USP)
Av. Prof. Luciano Gualberto, 158 trav. 3
05508-900 – São Paulo – SP – Brazil
+55 11 30915397

jaime.sichman@poli.usp.br

ABSTRACT

The PartNET++ system is an experimental multi-agent-based simulation tool that uses a new model based on hyper-graphs for understanding partnership formation among heterogeneous agents. Based on a previous tool called PART-NET, by Conte and Pedone [1], the agents of the system have goals to achieve and actions that lead to these goals, which must be performed by other agents. When choosing preferred partners, the agents may have different strategies. In PART-NET, partnerships were restricted to two agents, and the authors have shown that some social hypotheses were proved to hold. By using the PartNet++ simulator in several experiments, it is shown in this work that most results that are valid for partnerships between two agents can be generalized for multiple agents.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence – *multiagent systems, intelligent agents.*

General Terms

Algorithms, Measurement, Design, Economics, Experimentation, Human Factors, Theory, Verification.

Keywords

Artificial Intelligence, Dependence Theory, Multi-Agent-Based Simulation, Social Sciences, Social Strategies.

1. INTRODUCTION

Multi-Agent-Based Simulation (MABS) is increasingly becoming an important instrument for the social scientist. These researchers more and more rely on agent-based models to formulate and even verify social theories. However, the major obstacle for this kind of approach is the steep curve in learning programming languages and complex APIs.

The main goal of this work is to develop a tool focused on studying partnership formation among multiple heterogeneous agents. This tool is the next generation of PART-NET [1], a tool that did the same kind of simulation, but restricted to analyzing partnerships between pairs of agents. Thus a secondary goal of this simulator is to show that the different hypotheses proposed in [1] are also valid for multiple agents.

2. PART-NET

The PART-NET system [1] was originally developed to study partnership formation among pairs of agents that use heterogeneous strategies.

This simulation tool intended to prove a social theory about the importance of having different strategies in a society where agents are able to perform actions and have a number of individual goals that need to be fulfilled by partnerships with other agents.

Each agent in PART-NET is comprised of a set of goals, and a set of actions. Each goal has an associated importance, and each action has an associated cost to be performed. A goal can be achieved by accomplishing a single action of the same type.

Besides their goals and actions, each agent in PART-NET follows a strategy that dictates what kind of partnerships will be sought. The three different strategies are: (i) **utilitarians**, that try to maximize the importance of the achieved goal while minimizing the cost of the action used; (ii) **substantialists**, that choose partnerships with most important goals, no matter what the cost is; and (iii) **misers**, that seek the partnerships with minimum cost, no matter the goal importance.

In a strong economical perspective, substantialists are less rational than utilitarians. In a social environment, however, an agent does not always try to maximize the net benefit; sometimes there are more important goals that need to be carried out first. With this in mind, the following experimental hypotheses were defined [1]:

H1. In heterogeneous societies, utilitarians have the best net benefit, followed by substantialists, then by misers;

H2. In homogeneous societies, substantialists get better net benefits, as there are more objectives per agent in the society;

H3. In heterogeneous societies, substantialists end up supercedeing utilitarians in terms of accumulated net benefit;

H4. In heterogeneous societies, the accumulated net benefit is greater than the mean of the accumulated benefits of similar homogeneous societies.

In this article, the focus will be centered in hypothesis **H2**.

3. PARTNET++ SYSTEM

The original PART-NET agent architecture is not complex enough to support the important concept of **plan**. By using plans, it would be possible to express that in order to achieve a certain goal a sequence of actions must be executed, instead of a single one. These actions could be carried out by multiple and different agents. Consequently, plans must be represented within the agent architecture in order to cope with multiple partnerships.

PartNet++ uses hence a structure called social *dependence graph* [2], in which all agents are interconnected in a 4-partite graph, where nodes are agents, goals, plans and actions, with edges weighted as importance or cost, respectively for goals and actions.

In every simulation step, each agent in a random order chooses partners to achieve one of his goals, according to his strategy, by trying to find cycles in this dependence graph, representing partnerships. This graph cycles, however, can be *n*-fold, each fold corresponding to one of the *n* different actions in the chosen plan.

When setting up an experiment in PartNET++, it is needed to specify one or more societies. In general, the societies are randomly generated for each run of the simulator, according to ten (10) specified parameters:

nU, nS, nM: number of utilitarians, substantialists and misers in the society;

NAS: number of distinct actions in the society;

APA: maximum number of actions an agent can have;

GPA: maximum number of goals for an agent to achieve;

PPG: maximum number of plans that can be generated for each agent goal;

APP: maximum number of actions per plan;

STR (*stratification*): maximum number of agents that can participate as intermediaries in each branch of a partnership;

INT (*intolerance*): maximum number of agents that will refuse to participate in a partnership unless all actions in its chosen plan are matched to a certain partner, i.e., the agent does not accept partial goal achievement.

4. RESULTS

Given a large set of experiments using the PartNET++ simulator, most of the experimental hypotheses proposed in [1] can be confirmed, although some more clearly than others.

In order to prove hypothesis **H2**, two homogeneous society setups, with different quantities of goals per agent (GPA), were run 100 times. The experimental setup is described in Table 1.

Since these experiments have different GPA values, if one intends to compare these results appropriately it is needed to divide each simulation totals by the number of partnerships. The result of this division is called partitioned benefit (BP). The partitioned benefit for societies S1 and S2 are as follows:

$$BP_1 = 2,223.7 \ (\pm 46.4)$$

$$BP_2 = 2,071.3 \ (\pm 50.7)$$

Table 1. Experimental setup to simulate H2

#	nU	nS	nM	NAS	APA	GPA	APP	STR	INT
S1	-	60	-	20	5	10	1	1	1
S2	-	60	-	20	5	5	1	1	1

Using Student's T test for the two samples results a value of 22.17. This value indicates that the distribution of BP_1 is greater than BP_2 with an error of smaller than 0.0001%.

The charts including linear regressions of the samples can make it even clearer, as it may be seen in Figure 1.
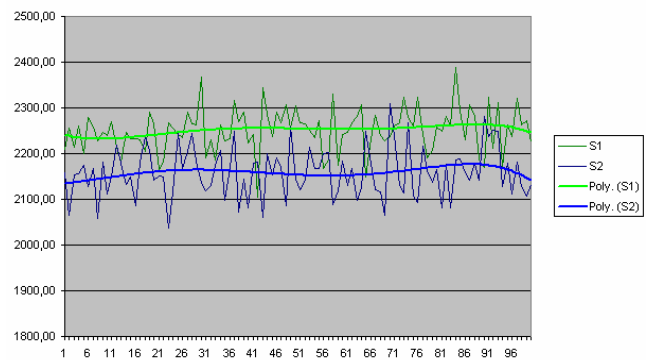

Figure 1. Simulation results for hypothesis H2

5. CONCLUSIONS

Given a large set of experiments using the PartNET++ simulator, most of the experimental hypotheses proposed by the original authors can be confirmed for multiple agent partnership. A more detailed description of these hypotheses and experiments can be found in [3].

6. REFERENCES

[1] Conte, R., Pedone, R. Finding the Best Partner: The PART-NET System. *Proc. 1st. International Workshop on Multi-Agent-Based Simulation (MABS'98)*, Springer-Verlag, LNAI vol. 1534, p. 156-168, Heildelberg, Paris, France, 1998.

[2] Conte, R., Sichman, J. S. Dependence Graphs: Dependence Within and Between Groups. *Computational and Mathematical Organization Theory*, 8(2), 87-112, 2002.

[3] Monteiro, J. L. R., Sichman, J. S. PartNet++: Simulating Multiple Agent Partnerships Using Dependence Graphs. In: Proc. 6th. International Workshop on Multi-Agent-Based Simulation (MABS'05), Utrecht, The Netherlands, 2005.