Right-based Coordination for Environments with Changing Complexity
Results in Traffic Simulation

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Abstract: In this paper we analyse three different approaches to multi-agent co-ordination, with an accent on the concept of "right-based" agents as opposed to free-rider agents and normative agents. We claim that a balance between unrestricted behaviour and regulatory systems would make collections of agents perform more efficiently, particularly when the complexity and the dynamicity of the environment increases. We present preliminary results on a set of experiments using a traffic simulator.

1 INTRODUCTION

How a collection of agents gets coordinated is the object of study in various disciplines including organisation theory, political science, social psychology, anthropology, law, sociology, and recently computing. Indeed, to ensure that agents function in a social environment some type of coordination mechanism is required. Such mechanisms allow all agents to co-exist, and in some cases to cooperate, so that they can perform their tasks without clashes with other agents. More specifically, in the age of the Internet and of cloud computing, it is paramount that we develop coordination mechanisms so that systems of software agents, the so-called Multi-Agent Systems (MAS), work efficiently. There are two main schools of coordination in MAS, one that extends shamelessly Rational Choice Theory (RCT) from single-agent scenarios to MAS, and a complementary one based on social norms, which directly addresses multi-agent interactions.

The dilemma is that the agents either do whatever they feel like or are constrained by the designer and thus lack the freedom to make their own choices. As an answer to this problem Alonso (2004a, 2004b) proposed a "right-based" coordination mechanism that allows agents to reason and make decisions, but that implies enforcement of rules at the same time. A middle-way between freedom and norms, the idea of "right" has been modelled formally as a system of axioms in (Alonso, 2004b).

In the next section the notion of "right" in MAS is explained in some detail. We shall then present a series of experiments we carried out with a traffic simulator to test the relative efficiency of "right-based" agents with regards to RCT agents and normative agents. We shall finish with an analysis of the results and some conclusions.

2 RIGHTS

Roughly stated, a right is considered as a set of restrictions on the agents' activities that allow them enough freedom, but at the same time constrain their behaviour.

In their work on commitments Norman *et al*., (1998) introduced a "right" operator to help in governing agent interaction and in the creation of inter-agent agreements. According to this model, if an agent wants to achieve its goals it will need to seek "permissions" to perform all the necessary actions. The notion of right we test is stronger in that if an agent has the right to execute a set of actions then

- It is permitted to perform any action in the set (under certain constraints or obligations);
- The rest of the group is not allowed to execute any action inhibiting the agent from exercising its right, and

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- The group is obliged to prevent this inhibitory action (and, eventually, to sanction the offender).

This third meta-right contextualizes the "right to claim" (Castelfranchi, 1995) and plays a crucial role in any social interaction: it means that any agent has the right to ask for help if its counterpart in the interaction (a short term deal or a long term established pattern of behaviour) doesn't abide by the terms of the "contract".

It is not the purpose of this position paper to evaluate thoroughly the validity of such theoretical gains in co-ordination; rather, we have developed a MAS simulator and tested the efficiency of right-based agents against RCT agents and normative agents in various settings of increasing complexity.

3 SIMULATION

We used as a core the VisSim traffic simulator at http://www.vissim.de/index.php?id=1801, and adapted it to include the agent architectures, information provided by the system to the agents, data saving, statistics and interaction between the agents.

3.1 System Features

The system allows agents to perceive their environment forward, backwards, and to the sides back and forth. It gives full information about the distance to other agents as long as the other agent is on the same stretch of the road. It also gives their speeds and direction. In the system the agent can only see one agent ahead, meaning that if we have three agent-cars driving in a row in front of us, we will only see the closest one. The agents can change their speed and position on the road (lane) in order to go past other agents. Each car's initial speed is set randomly.

The system allows building and redefining roads and junctions, defining the number of lanes in each direction and the type of junction and the traffic-light rules. It also enables defining the rate of new incoming agents, where new agents enter the system every n time steps (one car every n time units, $1/n$), and are removed from the system when crashed (after 10 time units) or when they reach the end of the lane. The entry per time unit is connected to each lane.

3.2 Experiment Parameters

All the experiment results are based on 100 time steps, where the data for each 10 steps is averaged. The basic scenario upon which complexity builds is a junction that cars approach from the four cardinal directions. Lights regulating the traffic may be red, yellow or green.

In total we have run 8 experiment scenarios, 4 for a single lane and 4 for double lanes. In each case, the scenarios differed according to how often a new car entered into the system: every 50, 100, 300 and 500 time steps, respectively (1)-(4) in the Results tables. That is, we used two parameters to increase the complexity of the scenario, namely, the number of lanes in each direction and the rate of incoming agents.

The efficiency of the three agent architectures (RCT, right-based, and normative) in the different scenarios was assessed against the following values:

(A) Number of cars that entered the junction;
(B) Number of cars that exited the junction;
(C) Number of cars that crashed in the junction;
(D) Average speed in the junction;
(E) Average time spent in the junction.

Obviously, the rates of entries and exits are not informative in themselves, rather they relate directly to the speed averages, the time spent by the cars in the system and the number of crashes. The time spent in the system depends in turn on the other two factors –on which we focus the analysis of results in section 5.

Before presenting the results, we describe how the agents were represented –taking into account that a utility function that rewards speed and punishes crashes underlies the RCT agents' architecture, as it does the right-based architecture when rights allow it.

3.3 RCT Architecture

The free agent architecture is based exclusively on its perceptions of what is in front of the agent. The agent will always try to find the best possible way to get to its selected target exit from a junction. In pursuing this goal the agents are free to do whatever they want.

3.4 Normative Architecture

The normative architecture uses traffic lights to manage the flow. What the agent does depends on the light in the junction. Only one light will be green at any time. The norms used were (assuming the English traffic code):

- When the light is green go;
- When the light is yellow stop;
- When the light is red stop;
- If more than one lane, you can only go straight ahead and left from the left lane;
- If more than one lane, you can only go straight ahead and right from the right lane;
- If while being in the junction someone gets in front to you, stop.

3.5 Right-based Architecture

The purpose of this architecture is to create a coordination structure that depending on the situation can be either very strict or a very lax one. The rights used were:

- The right to not being obstructed while in junction;
- The right to enter the junction if the agent's light is green;
- The right to enter the junction if junction is empty;
- The right to do drive wherever the agent wants.

4 RESULTS

We are presenting the results as a 4x4 matrix according to how long it takes for a new vehicle to enter the system (1-4 above) and the different assessment criteria (A)-(E).

Table 1: Single lane junction entry for a normative agent.

	(1)	(2)	(3)	(4)
(A)	799	1331	3236	3236
(B)	799	1331	3235	3235
(C)	0	0	0	0
(D)	5	9	22	22
(E)	12	13	13	13

Table 2: Single lane junction entry for a right-based agent.

	(1)	(2)	(3)	(4)
(A)	798	1332	3293	3297
(B)	798	1331	3293	3296
(C)	0	0	0	0
(D)	6	9	22	22
(E)	12	13	13	13

Table 3: Single lane junction entry for a RCT agent.

	(1)	(2)	(3)	(4)
(A)	737	1154	2890	3975
(B)	707	1099	2591	3309
(C)	30	55	299	666
(D)	4	8	18	19
(E)	13	13	13	13

We repeat the experiments with double lane roads, for each agent architecture, RCT agents, normative agents and right-based agents.

Table 4: Double lane junction entry for a normative agent.

	(1)	(2)	(3)	(4)
(A)	1598	2663	6405	6045
(B)	1585	2622	6371	6371
(C)	12	40	32	32
(D)	15	23	23	23
(E)	23	23	23	23

Table 5: Double lane junction entry for a right-based agent.

	(1)	(2)	(3)	(4)
(A)	1596	2659	6564	6557
(B)	1592	2634	6525	6508
(C)	4	25	37	45
(D)	15	15	23	22
(E)	23	23	23	23

Table 6: Double lane junction entry for a RCT agent.

	(1)	(2)	(3)	(4)
(A)	1565	2615	7548	12408
(B)	1346	2185	5053	4064
(C)	217	429	2495	8336
(D)	12	17	20	3
(E)	24	23	24	34

5 CONCLUSIONS

In this position paper we have introduced the concept of right and right-based as an alternative to traditional approaches to MAS co-ordination. The core of the paper focuses on a set of experiments that test the hypothesis that right-based agents may prove efficient in scenarios, a traffic network in our study, of increasing difficulty. Needless to say, the results we report are very preliminary both in terms of the complexity of the environment and, consequently, in the analyses of the results. Having said that, there is some useful data that we can speculate on.

All the experiments show the same trends. As the complexity of the environment increases, the worse the RCT architecture performs. At the same time the better the normative agents behave. In the experiments one can clearly see that the norms create a very well defined environment. An environment which is easy to predict, as no agent will behave in any other way then what the rules prescribe. The problem with the free rider architecture is that the free choice it has (to do whatever it chooses) creates the complexity of the environment. Thus the more agents with free choice turn up the more complex the situation becomes. The norms remove that problem but in doing so they create a static environment where agents are bound by the norms. What we gain in efficiency we lose in autonomy. In the right-based case one can see a different situation. Rights do not bind the agent in the same way. Rights affect what is happening in the system but only when the situation becomes too complex to be handled without rights. Rights do not have to be obeyed at any time, which is the case with norms. In summary: RCT agents cannot cope with complex situations. In such domains, agents with rights behave the same way as “enslaved” agents –yet they preserve their autonomy. Though tempting, we are not extrapolating this preliminary conclusion to real-life social scenarios.

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