Using Emergence in Participatory Simulations to Design Multi-Agent Systems

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ABSTRACT

In this paper, we present, through simulations of the coffee market of the state of Veracruz, how emergence of specialized roles in participatory simulations could be used to design and improve multi-agent systems.

The design process of the participatory simulation followed the regular design process of multi-agent simulations: starting from a domain model of coalitions among coffee producers, we built a participatory simulation where humans take the control of agents. Special care was brought to make the simulations playable by humans and to favor the apparition of coalitions. Being controlled by humans, the agents of the initial model became completely pro-active and were able to exchange coffee and money and to form coalitions to fulfill the buyer's offers. Coalitions appeared as expected.

Besides, during these experiments, we observed the emergence of specialized roles which were not included in the initial model. We implemented a regular multi-agent system based on the initial model to test the distributed system solving improvements brought by the roles that emerged.

1. INTRODUCTION

The usual design of multi-agent simulations as described by Vanbergue [10, 6] is iterative. It involves domain experts (thematicians as she calls them) on the outermost loop of the design iteration. Comparatively, participatory simulations for the social sciences put the stakeholders in the inner loop. Such simulations have numerous outcomes: they favor negotiations [7] and they are adequate tools to teach notions such as emergence and complexity to students [8, 4].

The use of a participatory approach to design multi-agent systems is not new. It is the foundation of the MAS/RPG methodology as developed by Barreteau [2] and other signatories of the ComMod charter [1].

A significant drawback of role playing games is that roles are fixed and are not tailored to best solve distributed problems. The same limitation occurs when roles are defined with stakeholders in a self-design role playing game [5].

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Instead, our experiments, targeted to yield the emergence of coalitions, also yielded emergence of specialized roles to better solve the distributed problem submitted to the human players. Faced with this emergence, the problem is to determine whether this method improves multi-agent systems distributed resolution capabilities.

In the first part, we will describe our approach, based on a multi-agent simulation design methodology. The second part will focus on the discussion of what happened during the experiments. The third part will present an implementation of the specialized roles that emerged and it will compare the initial model with and without these roles.

2. DESIGNING A PARTICIPATORY SIMULATION AS A MULTI-AGENT SIMULATION

The design of our participatory simulations followed the design process (figure 1) of multi-agent based simulations with a domain model, a design model and an operational model.

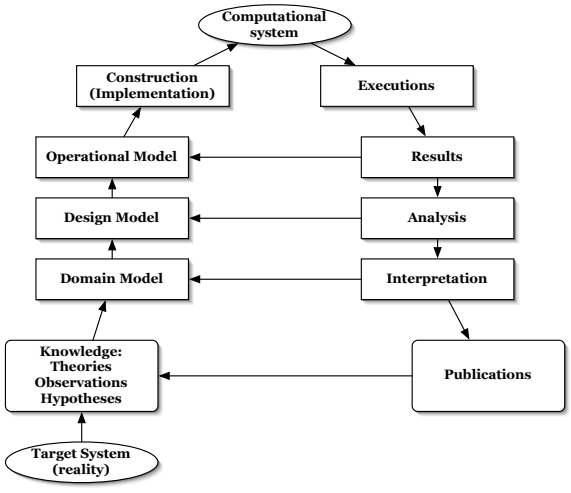

Figure 1: Iterative design process of multi-agent based simulations (from [6] and [10]

2.1 Domain model: coffee production in Veracruz

Coffee production consists in four steps:

- Crop of the fruit, called “el café cereza” in Mexico, once a year on coffee trees.
- Transformation in factories called “beneficio húmedo” of the cereza beans into “pergamino” coffee.
- Transformation in factories called “beneficio seco” of pergamino in “café oro” or “verde”.
- Torrefaction

The 67,500 coffee producers[1] of the state of Veracruz mostly are part-time tree growers. Some producers own a beneficio húmedo and either crop their own trees or, more frequently, buy cereza coffee from tree growers. They then transform the coffee in pergamino and they usually sell it to beneficio seco owners. The beneficio seco owners reply to offers on the global market.

The most critical step of coffee production, according to local producers, is the transformation of cereza coffee into pergamino. This transformation takes three days and the throughput of the transformation depends on the size of the beneficio.

Producers receive offers from buyers (either for oro coffee or for pergamino coffee) and because of the production process and the delivery constraints, these offers are not immediately accepted by producers. They usually run for a week. Some producers are organized in cooperatives (called “alianzas”), but most aren’t and domain experts suspect they may nevertheless try to accept offers they cannot fulfill alone by buying coffee from fellow producers.

2.2 Design model: various forms of coalitions

The initial model describes several forms of coalitions.

The cooperative (figure 2) is a form of coalition where producers share information, offers, stocks and risks.

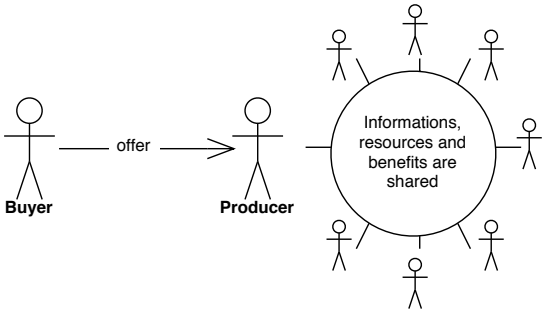

Figure 2: Coalition as a cooperative (Alianza or Sociedad)

Domain experts suspect that producers who do not belong to cooperatives form coalitions nevertheless and try to buy coffee from fellow producers to fulfill buyer offers. This is called a direct coalition scheme (figure 3). Some of the producers the coalition leader contacts may have also received the same offer from the buyer.

Finally, to accept offers as fast as possible, we can imagine broadcast offers (figure 4) inspired from the Contract Net protocol [9]. The producers send an offer to many other producers.

2.3 Operational model: relaxing constraints

The simulation was implemented using a framework for participatory simulations called Simulación. The simulation can be considered as a multi-agent simulation where the control architecture

[1]According to local government data: http://www.veracruz.gob.mx/

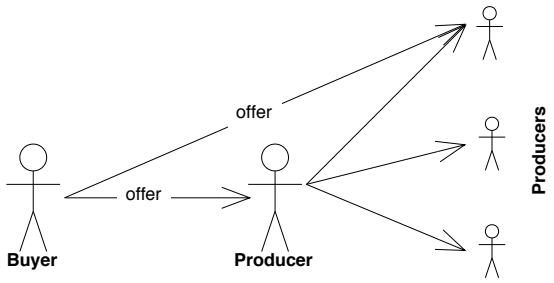

Figure 3: Direct negotiation

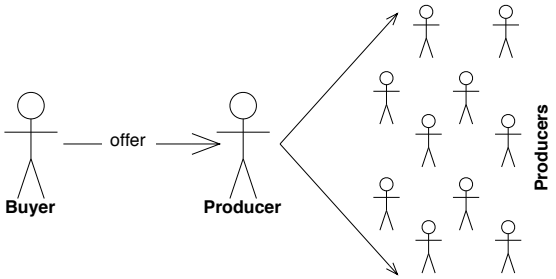

Figure 4: Coalition with a broadcast offer from a producer

of agents are played by humans. Each player sit at a computer where an instance of the program is running, providing them with tailored information and letting them act and interact with other agents on the network.

Two roles were defined: the buyer and the producers.

The coffee buyer’s behavior was to trigger as many coalition as possible by sending offers that producers could not fulfill alone. To achieve this goal, the buyer was omniscient, being able to see the production progress, the budget and the amount of coffee owned by each producer. Because the producers were not allowed to send messages to the buyer, it could have been implemented as a software autonomous agent. However, because participatory simulations cannot be reproduced as easily as non participatory simulations, and in order to be as close as possible to the initial model, the buyer’s role was played by the author of the design model.

Coffee producers in our simulations were beneficio húmedo owners. They could buy cereza at a fixed price, produce pergamino in their beneficio, exchange pergamino coffee and money and discuss together. They were also able to accept offers from the buyers. Who the buyer sent an offer to was disclosed to the producers. Additionally, producers were told before the third experiment that they were able to broadcast messages to each other and quickly share coffee or money among them.

The sensors matched the design model (each producer knew the size of the other producers’ beneficios but they only knew their own budget and the level of their own stocks) and the actions made each form of coalition possible, even if there was no risk to share.

Additionally the model was relaxed by breaking the exchanges in smaller primitives such as send money or send pergamino. This was required to both avoid enforcing players into the models of coalitions defined by the domain experts and to allow them to exhibit new forms of coalitions or new roles.

3. RESULTS OF THE PARTICIPATORY EXPERIMENTS

We conducted three different experiments about an hour and a half long each. Coalitions were formed as expected. More surprisingly, specialized roles appeared.

3.1 Apparition of coalitions

During the third experiment, among 35 offers were sent to producers, 10 were fulfilled, and 2 fulfillments relied on coalitions. A third offer could have been fulfilled thanks to a coalition but a producer outside the coalition was faster to accept it.

Table 1 summarizes the resolutions. An offer consists in an amount, a price and a deadline. The three first columns describe the offers. Time is expressed in hours of simulation (pergamino is produced in 72 hours).

Table 1: Resolutions during the third experiment

Amt	Price	Time	Agent	Resolution
200	15	200	Hector	direct
50	15	40	Abelardo	direct
500	20	200	Hector	coalition (bought 470 from others)
30	10	40	Abelardo	direct
100	15	40	Francisco	direct
25	50	40	Clemente	direct
50	10	40	Benjamin	direct
10	20	40	Daniel	direct (Francisco was preparing a coalition)
120	10	50	Abelardo	direct
800	25	250	Hector	coalition (bought 480)

For the first coalition, Hector, the leader, bought 94% of the amount of the offer from 3 different producers (Francisco (290), Emiliano (80) and Abelardo (100)). For the second coalition, he bought 60% of the amount from 3 producers as well but in 5 different transactions (Francisco (10), Emiliano (160+80) and Ignacio (130+100)).

3.2 Emergence of specialized roles

Coffee producers were provided with the same information. The only difference was the size of their beneficios, represented graphically by a gauge on the map of the state of Veracruz (figure 5). Still, the logs with both the actions and the discussions show that several specialized roles emerged.

Several players tried to ally together during the various experiments. For example Ignacio and Emiliano tried to ally each other during the last offer of the third experiment. However, in the end, they both sold coffee separately to the coalition leader.

Alliances were somehow forecast by the initial model, but Abelardo's specialized behavior during the last experiment really surprised us. While he did produce coffee himself, he could be described as a trader. For example, during a single offer of the buyer (the last one for 800 bags), Abelardo first broadcast a message saying he was selling 200 bags "para satisafacer la oferta vendo 200 costales de pergamino a 22 pesos", found a buyer (Clemente) and later on tried to buy 300 bags at 20 pesos each.

Figure 5: The producer's graphical interface

4. COMPARING EMERGENT ROLES WITH THE INITIAL MODEL

The interest of forming a coalition for coffee producers is that it increases their capability to satisfy buyer offers. The question raised by the emergence of specialized roles is whether these roles improve the problem solving capabilities of the system or not. In our case, the question is whether the producers better fulfill the buyer offers if one of them behaves like a trader.

The initial models of coalitions were implemented and variants were added with a trader.

4.1 Implementation of the model in Cormas

The model was implemented in SmallTalk in Cormas [3]. We did not keep the cooperative model of coalitions because the operational model of the participatory simulations did not include any risk to share.

During each time-step, agents could perform one or no action. Actions were: accepting an offer, starting production of pergamino (production took 12 time-steps), buy cereza at the market price and send an offer to one or all the producers. Combining these actions, several strategies of the producers were implemented.

The solipsist does not exchange anything with other producers. Its strategy consists in:

- accepting the best buyer offer it can fulfill
- or producing pergamino
- or buying as much cereza as possible.

The direct coalition strategy was implemented after the direct coalition model. This strategy consists in:

- accepting the best possible offer from the buyer
- or randomly accepting an offer from a producer (the probability depends on the price)
- or producing pergamino
- or buying if there is no cereza left
- or accepting an offer from a trader if it would allow the producer to accept a buyer offer

- or randomly sending a coalition offer to a randomly chosen producer
- or finally buying cereza to increase the cereza stock up to twice the size of the beneficio.

The broadcast coalition strategy is exactly like the direct coalition except that offers are sent to all producers.

The trader strategy is like the broadcast strategy except that offers sent to other producers are either sell or buy offers (half the offers are offers to sell).

The buyer was designed to trigger coalitions but allowed direct resolution of offers. The price was fixed to twice the price of the cereza and the deadline and the amount were chosen randomly around the maximum that individual producers could provide alone. If an offer is accepted, another offer is sent, thus favoring quick resolutions of offers.

4.2 Results

The model was adjusted to obtain results coherent with the amount of coalitions happening during the participatory simulations. For example, the producers only sent offers when a new offer from a buyer was received.

Figure 6 shows the number of buyer offers accepted in 5 scenarios, each with a single buyer.

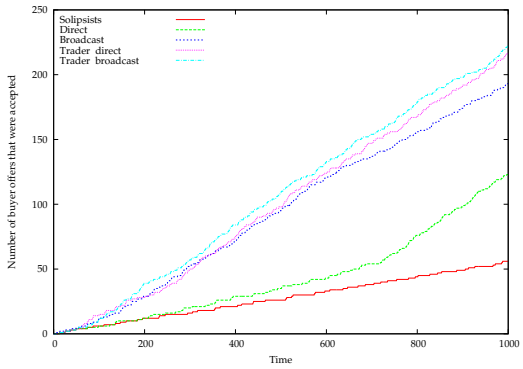

Figure 6: Comparison of various scenarios

- The solipsists scenario was a simulation with 10 solipsists.
- The direct scenario was a simulation where the 10 producers adopted a direct coalition strategy.
- The broadcast scenario was a simulation where the 10 producers adopted a broadcast coalition strategy.
- The trader-direct scenario was a simulation where the 9 producers adopted a direct coalition strategy and one of the producer was actually a trader.
- The trader-broadcast scenario was a simulation where the 9 producers adopted a broadcast coalition strategy and one of the producer was actually a trader.

As in the participatory simulation, the key of the multi-agent simulation is the time allocated to each agents. Consequently and unsurprisingly, broadcast coalitions provide better results than direct coalitions.

While the role of the trader was not present in the initial model, the improvement it brings is not surprising either. In the model, the decision to accept to sell pergamino to another producer depends on the price sent and therefore does not necessarily yield to a successful coalition, while the decision to accept to buy pergamino from the trader depends on the capability to fulfill the buyer offer and therefore yields to a successful coalition unless another producer is faster to accept the buyer offer. Figure 7 displays the number of such offers sent by the trader during the trader-direct simulation.

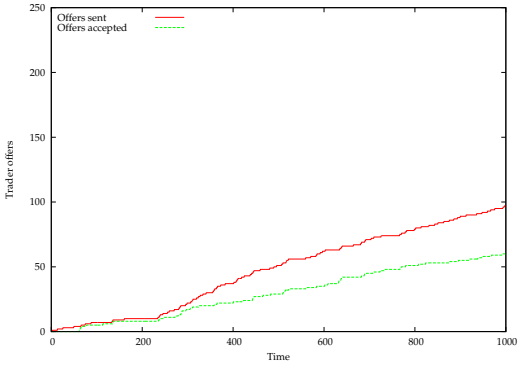

Figure 7: Trader offers (sent and accepted)

5. CONCLUSION

This paper presents a method consisting in using participatory simulations and particularly emergent roles in such simulations to improve multi-agent systems. While this method could be compared to participatory design, its key element is to adopt a multi-agent simulation design process methodology to build the participatory simulation and to replace the control architecture of the autonomous agents of the simulation with human players.

The broadcast strategy imagined by computer scientists does not yield to better results than the mere specialization of the role of a single agent, as it appeared during a participatory simulation.

Future work includes automatic extraction of the specialized roles to directly build a multi-agent system from the participatory simulation and to capture smaller specialization than what obviously appears from the logs.

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