Two-sides of Emergence in Participatory Simulations

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Abstract

Starting from an agent-based model of the coffee market in the state of Veracruz, we conducted participatory simulation experiments where human players were given the roles of reactive agents. The simulations were tuned to favor the apparition of coalitions among coffee producers. In addition to the expected coalitions, we witnessed another kind of emergence: roles were specialized with the apparition of traders among the coffee producers. Drawing from this first-hand experience, we came to consider participatory simulations as a way to create multi-agent systems where humans improve problem solving capabilities of the system.

1 Introduction

In this paper, we describe the emergence of behaviors within a participatory simulation as a way to create multi-agent systems where humans improve problem solving capabilities of the system.

Whether at work on multi-agent simulations or multi-agent systems, the computer scientist specializing in complex systems tries to produce an emergent behavior. Multi-agent simulations can be conceived as an attempt to reproduce an emergent behavior of a target system and can be used by a domain expert to determine the conditions of the emergence of this behavior. Multi-agent systems are fairly complex systems designed by the computer scientist to solve a problem, often using emergent properties of these systems.

The SimCafé experiments, part of a LAFMI[1]-funded project, were conducted in Xalapa, Veracruz, within the Laboratorio Nacional de Informática Avanzada (LANIA). These experiments were participatory simulations inspired by an agent-based approach where the agents' control architectures were performed by human players.

In a first part, we will describe the experiments as a multi-agent simulation approach. We will then interpret it as a distributed problem solver and present the roles that emerged. Finally, we will draw lessons from the participatory approach and explain how emergence in our experiments is different from what can be observed in other approaches.

[1] http://lafmi.imag.fr/

2 SimCafé as a multi-agent simulation

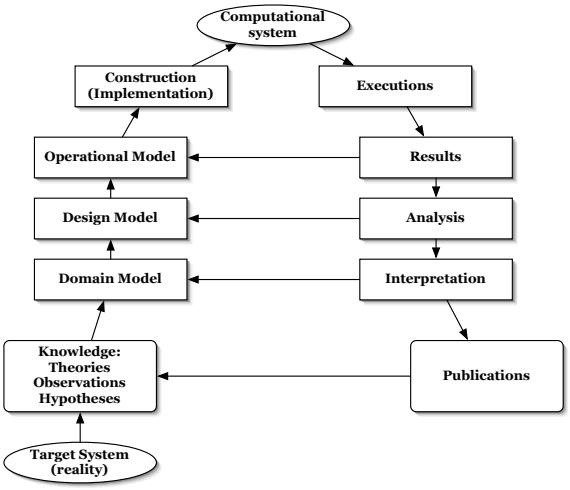

Figure 1: Design of multi-agent simulations (from Vanbergue (2003) and Drogoul et al. (2002))

The design process of the SimCafé experiments was very similar to the design of multi-agent simulations (figure 1). We started from a domain model of coffee production and coffee market. Then we tailored it as a design model for the very purpose of the participatory simulation. Finally, we implemented it as an operational model by building a distributed participatory simulation tool.

2.1 Coffee production in Veracruz

We started from hypotheses and theories about the coffee market of the state of Veracruz. The domain model, elaborated by our Mexican partners from the LANIA, covered both coffee production and coffee market.

Coffee production is a four-step process:

- The fruit, called “el café cereza”, is cropped once a year on coffee trees.
- After picking, the beans are transformed into pergamino in factories called “beneficio húmedo”.
- Then, they are transformed in “café oro” or “verde” in factories called “beneficio seco”.
- Finally, coffee is torrefied

The most critical step, according to local producers we met, is the transformation of the beans into pergamino. It takes three days.

In the state of Veracruz, according to local government data[2], there are 67,500 coffee producers for 3,000 full time jobs. Most of the producers only are part-time tree growers. Owners of beneficios need to buy cereza or pergamino and sell transformed coffee, either pergamino or oro coffee depending on the beneficio they own. Very few producers control the whole process, owning lands with trees, beneficios and torrefying the coffee themselves. Multinational companies such as Nestlé buy the fruits before they are cropped and process them themselves, but a lot of the production of beans is bought from beneficio owners.

Buyers make offers to beneficio owners and they usually have one week to accept and fulfill the offer. During this period, domain experts we worked with thought that the producers could form coalitions in order to fulfill the offer. Assuredly, the offer sometimes exceed the amount of coffee producers currently have. However, while alianzas (cooperative) exist, there is no sound evidence of the existence of other forms of coalitions among producers. For various reasons, producers refuse to talk about any coalition behavior they may have.

2.2 Coalitions in the coffee market

Our Mexican partners defined three types of coalitions that may happen within the coffee market of Veracruz.

[2]http://www.veracruz.gob.mx/

In the first kind of coalition (figure 2), a producer initiates negotiations with other producers. Some of the producers he contacts may also have had received the same offer from the buyer.

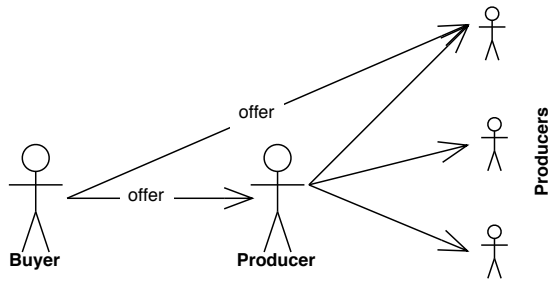

Figure 2: Direct negotiation

Cooperative of producers form the second kind of coalitions (figure 3). Cooperatives (called Sociedad or Alianza) gather producers who share risks, information and benefits. They fulfill offers together.

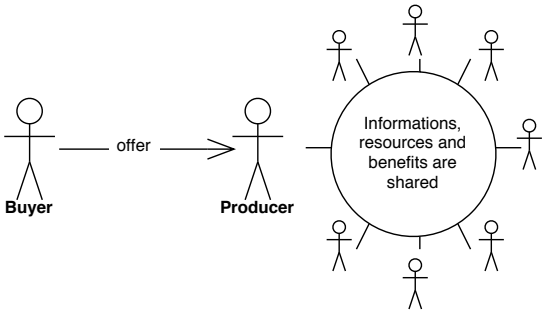

Figure 3: Coalition as a cooperative (Sociedad/Alianza)

The third kind of coalitions determined by our Mexican partners is inspired from the Contract Net protocol (Smith, 1980). Instead of talking directly to other producers, the initiator sends a broadcast offer to many producers who may then accept or reject the offer.

2.3 A model for participatory simulations

The goal of the domain experts was to determine whether coalitions occurred and to validate their model of coalition formation. The domain model needed to be transformed in order to achieve this goal.

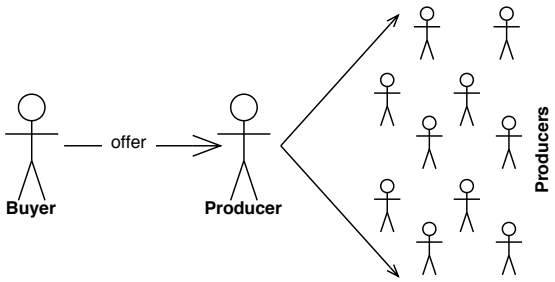

Figure 4: Coalition with a broadcast offer from a producer

Agents were sorted into two classes. Coffee producers in our simulations are beneficio húmedo owners. They can buy cereza at the market price and transform it into pergamino. The other class consists in pergamino buyers.

In the original model, coalitions are always initiated by the coffee buyer. Coffee producers can be described as reactive agents. However, the operational model allowed agents to communicate and to exchange coffee and money without any initial offer from a buyer. We decided to break the operations into smaller primitives and give as much freedom to the players as possible. The model needed to be relaxed in order to validate the hypothesis of the existence of coalitions.

We also had to specify what information agents would have. The coffee buyers are omniscient because their roles, assumed by the animators of the simulations, consist in favoring the apparition of coalitions. Coffee producers, on the other hand, only know the size of other producers' beneficios. The size determine the amount of pergamino that can be produced during a three days period.

Offers of a buyer to one or several producers consisted in a contract for a given quantity at a given price with a given deadline. Because the buyers were played by animators, the offers could not be negotiated. Producers could refuse an offer at any time. To accept an offer, they had to react before the deadline and be able to fulfill it, i.e. they had to own the required amount of pergamino. The first producer to accept an offer won the contract and other producers could not accept it afterwards. Recipients of an offer were aware of who else received it.

2.4 Emergence of coalitions

The experiments consisted in three simulations about an hour and a half long each with a single buyer. During the last experiment, there were two coalitions to satisfy an offer, a third was nearly completed but the offer was accepted by another producer. Table 1 lists the offers that were accepted and fulfilled by producers during this experiment. The first three columns describe the offer (quantity, price and time) and the last two columns describe who won the offer and how it was resolved.

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)

The time is in hours (of simulation) and the amount in bags. Hector bought pergamino from other players in both cases of coalition. In the first case, he bought them from Francisco (290), Emiliano (80) and Abelardo (100) and in the second case from Francisco (10), Emiliano (160+80) and from Ignacio (130+100).

3 SimCafé as a multi-agent system

While the SimCafé experiments can be viewed as multi-agent simulations trying to reproduce a real target system, the coffee market in the state of Veracruz, it can also be seen as a multi-agent system designed to solve the problem of the fulfillment of buyer offers. Within this frame, we can reinterpret the emergence of coalition as a specialization of roles.

3.1 Distributed Problem Solver

The SimCafé experiments can be considered as a distributed problem solver. As such, the system formed by the players and their interface to the simulation is very similar to a multi-agent system. Traditionally, agents are composed of sensors, effectors and a control architecture. In our case, sensors and effectors consist in the SimCafé interface (Figure 5). Effectors are broken into small primitives within the domain model: agents can send money or pergamino without any counterpart. They can also send messages to other agents. The human participants play the role of the control architectures.

Figure 5: The SimCafé interface

The problem can be solved in a distributed way because offers sent to players can be fulfilled with cooperation among the producers. Producers could accept offers either by producing coffee themselves, provided that the time permitted it, or by buying coffee from other producers or by combining both. A proper choice of the deadline allowed the omniscient buyer to cast offers that could only be solved with cooperation of the producers. Players were not informed of this bias and the first offers actually could be solved directly. Consequently, agents, played by human players, were conducted to form coalitions without being intrinsically designed or required to.

3.2 Emergence of roles

While the emergence of coalitions was not a surprise, a very interesting outcome of the simulation consisted in the analysis of the actual roles of the agents. On the contrary to what the initial model defined, agents were not reactive but pro-active since they were controlled by human players who could communicate and exchange coffee without any initial offer from the buyer.

Players had exactly the same information. The only difference consisted in the size of their beneficios, represented by a little gauge under the house of each player (figure 5). It ranged from 15 for Ignacio, meaning that Ignacio was able to produce 15 bags every three days, to 100 for Francisco.

While cooperative were not expected because there was no risk to share, some players apparently tried to ally in order to fulfill the offer before other players. We witnessed several attempts of alliances. For example, Ignacio and Emiliano tried to ally each other during the last offer. In the end, they both separately sold coffee to Hector who won the offer.

The most striking particular behavior that emerged was Abelardo's. Abelardo is not an important producer because his beneficio is just the second in size with a throughput of 30 bags every three days. Instead, in addition to producing coffee himself, he became a trader. He has been broadcasting several messages to buy and sell large quantities of bags at a given price, and he often found sellers and buyers. During the third experiment, seeing the offer of 800 bags, he sent two messages to all other players saying that, in order to fulfill the current offer, he was selling 200 bags at 22 pesos each and he happened to have actually sold 200 bags to Clemente. While this offer was still running, he even offered to buy 300 bags at 20 each, announcing he would pay after having accepted the offer: "compro 300 costales pago 20 pesos por costal, cheque postfechado" (I buy 300 bags at 20 pesos each, postdated check). With less than 800 pesos, he could not buy such an amount of bags then. Sending money after having fulfilled an offer is possible because the exchange was broken into smaller primitives (send money, send pergamino).

Other less surprising roles included producers of large quantities of coffee who did not try to fulfill the offers but preferred to sell their production to other players and recurring privileged cooperations between some players.

4 Lessons of participatory simulations

Introducing human players in multi-agent based experiments brings several outcomes directly linked to participation itself. The SimCafé experiments belonged to only one of several methodologies of participatory simulations and could be compared

with the Multi-Agent System/Role Playing Game (MAS/RPG) methodology.

4.1 Emergence and outcomes of participation

The outcomes of participatory experiments are closely linked to the actual participatory approach used.

In the pedagogical approach, participants are students who are taught the link between individual and collective behaviors. Colella (1998) immersed students in a simulation of virus propagation and asked them to determine the rules of the propagation. This pedagogical tool is actually used to teach students, through role playing activities, the mechanism of the emergence in complex systems (Resnick and Wilensky, 1997).

The negotiation approach aims at helping stakeholders to negotiate. Usually, they are required to explicit their behavior through the participation in the simulation. Sometimes, the roles are exchanged (Etienne, 2003). Emergence in this approach would rather be what Barreteau calls "social learning" (Barreteau, 2003): observers learn through the learning of players.

The SimCafé experiments belong to the sociological approach, aiming at validating and consolidating models (Guyot, 2003). In this approach, participants are stakeholders and the witnesses of the emergence are domain experts, usually social scientists. Participatory simulations are used as a tool to determine the condition of the emergence. As a matter of fact, this approach belongs to the experimental approach in social sciences (Earley et al., 1990; Chesney and Locke, 1991), especially experimental economics: even if the SimCafé experiments were not led by economists, they could be interpreted as an experience to understand the economic behavior of coffee producers (Castro and Weingarten, 1970).

4.2 Emergence within MAS/RPG

The introduction of participation in multi-agent system design historically lead to what is now called the multi-agent system/role playing game methodology (figure 6). This methodology applies to natural resource management. It consists in first elaborating a multi-agent system to simulate the evolution of the natural resources. This system is then used within a role playing game with the participation of stake holders. Stakeholders are then represented in the multi-agent system. This introduction is not only done from the role playing game experiments, but it can also be done with the help of the stakeholders themselves.

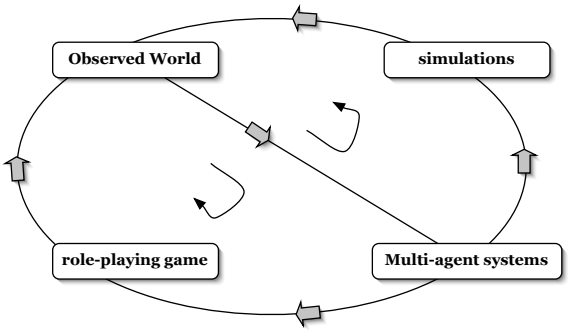

Figure 6: The MAS/RPG Methodology (from Barreteau et al. (2001))

What may emerge in this methodology is an improvement of the multi-agent system with the help of the stakeholders. Understanding the link between reality and what appears on the screen, i.e. the multi-agent system, thanks to role-playing game experiments, stakeholders are able to improve the underlying model of the multi-agent system in order to more closely match reality. This emergence, being only one of the outcomes of this methodology, may or may not be the priority of the domain experts. Some researchers prefer to focus on the negotiation help properties of participatory simulations.

Moreover, the emergence in the MAS/RPG methodology does not include all the features of the specialization of roles observed during the SimCafé experiments. It is rather a participatory design of the multi-agent system. Stakeholders actually help the scientist to adjust his multi-agent system in order to make it more closely match the reality they experiment in their everyday life. Typically, a stakeholder could explain that some behavior of a cell of his land in the multi-agent system could not happen because his land has such and such property that the domain expert ignored.

5 Conclusion

SimCafé was designed as a multi-agent simulation. We started from a domain model and we were able to quite fully follow the traditional multi-agent simulation design process even if what we were building was a participatory simulation instead. The reason is that humans actually take the role of the control ar-

chitecture. And as expected in these multi-agent simulations, several coalitions emerged.

However, such an interpretation of the experiments are insufficient to understand the two sides of the emergence that occurred during these participatory simulations. To understand why roles emerged, we need to interpret the SimCafé experiments as a multi-agent system, i.e. as a distributed problem solver. Humans, by specializing their roles, tried to improve the capability to fulfill offers of the coffee buyer.

This interpretation intrinsically could not be applied to participatory approaches such as multi-agent systems coupled with role-playing games: in a role-playing game, humans play a pre-defined role. In SimCafé experiments, the problems solving capabilities of the system were improved by the emergence of unexpected roles played by human participants.

Future work include analysis of another experiment, SimBar, based on the El Farol Bar model, where specialized roles apparently didn't emerge. SimCafé also is the first step in the design of multi-agent based participatory simulations (Guyot and Drogoul, 2004) where humans are assisted by semi-autonomous agents.

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References

Oliver Barreteau. The joint use of role-playing games and models regarding negotiation processes: characterization of associations. *Journal of Artificial Societies and Social Simulation*, 6(2), 2003. URL `http://jasss.soc.surrey.ac.uk/6/2/3.html`.

Oliver Barreteau, François Bousquet, and Jean-Marie Attonaty. Role-playing games for opening the black box of multi-agent systems: method and lessons of its application to senegal river valley irrigated systems. *Journal of Artificial Societies and Social Simulation*, 4(2), 2001. URL `http://jasss.soc.surrey.ac.uk/4/2/5.html`.

Barry Castro and Kenneth Weingarten. Towards experimental economics. *Journal of Political Economy*, 78(3):598–607, 1970.

Amelia A. Chesney and Edwin A. Locke. Relationships among goal difficulty, business strategies, and performance on a complex management simulation task. *Academy of Management Journal*, 34 (2):400–424, 1991.

Vanessa Colella. Participatory simulations: Building collaborative understanding through immersive dynamic modeling. Master's thesis, MIT, 1998. URL `http://xenia.media.mit.edu/~vanessa/part-sims/thesis.html`.

Alexis Drogoul, Thomas Meurisse, and Diane Vanberge. Multi-agent based simulations: Where are the agents? In Jaime Simão Sichman, François Bousquet, and Paul Davidsson, editors, *Multi-Agent-Based Simulation, Third International Workshop, MABS 2002, Bologna, Italy, July 15-16, 2002, Revised Papers*, volume 2581 of *Lecture Notes in Computer Science*, pages 1–15. Springer, 2002. ISBN 3-540-00607-9. URL `http://www-poleia.lip6.fr/~drogoul/papers/drogoul.mabs02.pdf`.

P. Christopher Earley, Gregory B. Northcraft, Cynthia Lee, and Terri R. Lituchy. Impact of process and outcome feedback on the relatiojn of goal setting to task performance. *Academy of Management Journal*, 33(1):87–195, 1990.

Michel Etienne. Sylvopast: a multiple target role-playing game to assess negotiation processes in sylvopastoral management planning. *Journal of Artificial Societies and Social Simulation*, 6(2), 2003. URL `http://jasss.soc.surrey.ac.uk/6/2/5.html`.

Paul Guyot. Simulations multi-agents participatives: Vers une méthode de validation et de consolidation des modèles de pratiques collectives. Master's thesis, Université Pierre et Marie Curie, 2003. URL `http://www-poleia.lip6.fr/~guyot/files/2003-dea-simulation.pdf`.

Paul Guyot and Alexis Drogoul. Designing multi-agent based participatory simulations. In Helder Coelho and Bernard Espinasse, editors, *Proceedings of 5th Workshop on Agent Based Simulations*, pages 32–37, Erlangen, San Diego, May 2004. SCS Publishing House. ISBN 3-936150-31-1. URL `http://www-poleia.lip6.fr/~guyot/files/2004-abs-designing.pdf`.

Mitchel Resnick and Uri Wilensky. Diving into complexity: Developing probabilistic decentralized thinking through role-playing activities. *Journal of Learning Sciences*, 7(2), 1997. URL `http://ccl.northwestern.edu/cm/papers/starpeople/`.

R. G. Smith. The contract net protocol: High-level communication and control in a distributed problem solver. In *IEEE Transaction on Computers*, number 12 in C-29, pages 1104–1113, 1980.

Diane Vanbergue. *Conception de simulation multi-agents: application à la simulation des migrations intra-urbaines de la ville de Bogota*. PhD thesis, Université Paris VI, December 2003.