Modeling Swarm Phenomena using Logistic Agents: Application to a Predators-Prey Pursuit.

(Extended Abstract)

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ABSTRACT

In this paper, we study swarm intelligence phenomena using the logistic multi-agent system model (LMAS). This model derives from the "coupled map lattice" family of models, which is usually considered in the field of complex systems. After recalling the fact that the LMAS enables simulating flocking phenomena in a self-organized way, we study its adaptive capabilities by applying it to a predators-prey pursuit simulation, in order to visualize the effect of the environment on the control variable of the agents.

1. INTRODUCTION

The root principle of Swarm Intelligence consists in simple agents self-organizing so as to achieve some goal, or in other words to solve some specific problem. Our approach to address the issues of this field derives from a theoretical domain: our main working hypothesis is that the swarm phenomena may be described and analyzed in terms of synchronization processes in a group of coupled chaotic units as studied in physics. The model we use is a reactive multi-agent system (MAS) model called Logistic Multi-Agent System (LMAS) already presented in [2]. The LMAS is composed of N reactive situated agents called logistic agents, because they contain a logistic map as internal decision function. A logistic map is defined on the interval $[0, 1]$ ($[0, 1]$ is invariant through f) by the following recurrent equation:
$x(t + 1) = f(x(t)) = 4\ a\ x(t)(1 - x(t))$
where a is the control parameter of the map, that governs the chaotic level of the generated series. The internal state s of the logistic agent is consequently a tuple of two variables belonging to the real interval $[0, 1]$: $s = \langle x, a\rangle$, where x is the decision variable, a the control variable. The environment for LMAS may be a discrete or continuous space, which is the medium of all interactions between agents. The LMAS approach is summarized in the following master equation – which derives from the mean-field instance of the CML class called a CML gas [3]– on the internal variable x of agent i:

$$x_i(t+1) = (1-\epsilon(t))f_{a(t)}(x_i(t)) + \frac{\epsilon(t)}{N(V_i(t))} \sum_{j \in V_i(t)} f_{a(t)}(x_j(t)) \tag{1}$$

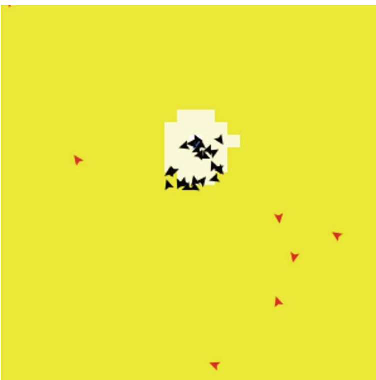
Cite as: Modeling Swarm Phenomena using Logistic Agents: Application to a Predators-Prey Pursuit, (Extended Abstract), Rodolphe Charrier, Christine Bourjot, François Charpillet, *Proc. of 8th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2009),* Decker, Sichman, Sierra and Castelfranchi (eds.), May, 10–15, 2009, Budapest, Hungary, pp. 1245–1246

where all parameters may depend on time (through the influence of the environment) and where the mean field is reduced to the current neighborhood $V_i(t)$ of agent i containing a number $N(V_i(t))$ of other agents. This master equation gives the rooting principle of the computational model we use. As the coupling variable ϵ will be a constant in our simulations, we omit its variable aspect and will denote it ϵ_0 from now on. The most simple implementation of the LMAS –that is a and ϵ are some constants– leads to some flocking phenomena [2]. In this paper, we further explore the organizing and adaptive capabilities of the LMAS by adding a perception capability of the environment, which modifies the a value.

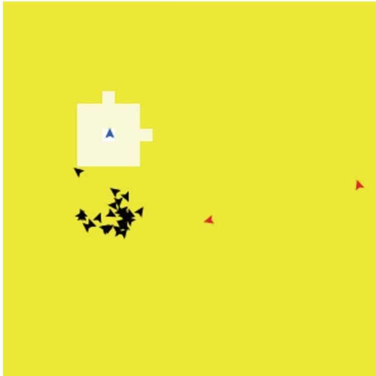
2. ADAPTIVE CAPABILITIES OF LMAS IN A PREDATOR-PREY PURSUIT

In this section, we deal with the effects of adding a capability for the logistic agent to perceive its environment. This capability is related to the adaptive aspect of the LMAS, it being agreed that the adaptation process involves a stimulus-like influence of the environment on agents.
To illustrate this with a key example, we present a derivative case of predators-prey pursuit. This type of problem has been formulated for the first time in [1]. We propose to modify the terms of the original problem to fit with our situation: the system is composed of one or a few preys and many predators. The goal of predators consists in flocking around a prey to prevent it from moving. Since agents move in a continuous space—preys as well as predators—, we define a terminating state as soon as more than ten predators surround a prey in its neighborhood, that is to say when they are in the vicinity of the prey and stay in. These steps are described and formulated more precisely in the following:

- The environment is a 2D continuous torus where agents can move. The environment holds a discrete field denoted $\mathcal{D}$ for "data", which is a grid whose cells are initialized to 1.0.
- The perception function associated with the a component consists in reading the data in the $\mathcal{D}$-field in the current site k which leads to the expression:
$a(t + 1) = (1 - \epsilon_0)a(t) + \epsilon_0\mathcal{D}_k(t)$
- The updated $x(t + 1)$ (by equation (1)) is interpreted as the angle of the agent's velocity according to the following equation:
$\theta_i(t + 1) = \theta_i(t) + (0.5 - x_i(t)) * \delta$



(a) The prey is captured



(b) The prey escapes

Figure 1: (a): the prey is surrounded by many predators and is about to stop. (b): the prey escapes from its predators. $\epsilon = 0.2$, radius of prey vicinity= 4.0, radius of predator perception= 1.0

where δ is the maximum angle variation per time step. The velocity magnitude changes as well with respect to x according to the following rule: $v(t+1) = x(t+1) * v(t)$.

- The $\mathcal{D}$-field is modified by the prey marking action: a prey marks locally the environment around itself. This marking process is not persistent in the environment and quickly "evaporates" at each time step. This marking is achieved by setting every site gradually from the value 0 in the center of the prey vicinity of presence to 1.0 in the border. The specific value is to be related to the bifurcation behavior of the logistic map used as a decision function: 0 is a fixed point of the map until $a = 0.25$. This perceived area implies a strong decrease of the velocity magnitude of the predator until it stops on the prey. Correlatively, a special rule is added for decreasing the velocity of a prey inversely proportionally to the number of surrounding predators (in its vicinity).

3. SIMULATION RESULTS AND DISCUSSION

Figure 1 presents two snapshots of a simulation run. The left image shows a prey about to be captured, with many predators in its detection vicinity and the right image shows a prey escaping its pursuers. The velocity of the prey never equals zero with the formula above, that is why the prey can get away in these simulations. With $n = 50$ predators, the time to capture a prey is a few hundreds of time steps. When a capture fails, the predators around leave the prey and return to the environment.

A capture occurs because predators perceive the vicinity of the prey through the field $\mathcal{D}$ of the environment. Then these predators almost stop there, because their internal control variable decreases to 0 with the perceived values in this vicinity and because their internal decision variable is influenced by their neighbors through the coupling process. This low control value implies that the x-value decreases as well and consequently the velocity magnitude of the predator. Depending on the value of the coupling neighborhood radius—that is the perception neighborhood radius— we may obtain larger surroundings of predators. If we increase the number of preys, the process does not disrupt. It is to be noted that the LMAS involves only reactive mechanisms. Although we didn't need any potential field to achieve this, predators are attracted by the prey in a nonlinear way, even if the prey is moving. It is important at this stage to notice the fact that all decisions and actions are generated from the internal variable x of the agent state s and that the data flow is well defined for control, coupling and decision processes.

4. CONCLUSION

This last simulation has shown the capabilities of the LMAS in terms of adaptation within the environment. To achieve this, we have involved a flow from the environment to the agent control variable. The predator-prey simulation does not correspond exactly to the original one but achieves the same goal: to surround a moving prey with many predators. This mechanism occurs in a $2D$-space, although the decision processes occur in a $1D$-space through the x variable of the agent state: this constitutes a striking aspect in LMAS, that phenomena in a high dimensional space could be generated from a less dimensional one, by means of nonlinear maps. More simulations have to be done to establish the optimal range of parameters for predators to capture a prey.

5. REFERENCES

[1] M. Benda, V. Jagannathan, and R. Dodhiawala. On optimal cooperation of knowledge sources - an empirical investigation. Technical report, Boeing Advanced Technology Center, July 1986.

[2] R. Charrier, C. Bourjot, and F. Charpillet. Flocking as a synchronization phenomenon with logistic agents. In *ECCS'07, European Conference on Complex Systems, Dresden*, Dresden, October 1-5 2007.

[3] T. Shibata and K. Kaneko. Coupled map gas: structure formation and dynamics of interacting motile elements with internal dynamics. *Physica D*, 181:197–214, 2003.