Quasi-PSO Algorithm for Modeling Foraging Dynamics in Social Mammals

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ABSTRACT

In this paper, the authors present a computational model of a fundamental social phenomenon in the study of animal behavior: the foraging. The purpose of this work is, first, to test the validity of the proposed model compared to another existing model, the flocking model; then, to try to understand whether the model may provide useful suggestions in studying the size of the group in some species of social mammals.

Keywords: Agent-Based Modeling, Animal Behavior, Flocking Model, Foraging Behavior, Particle Swarm Optimization

INTRODUCTION

The Foraging Theory is a branch of behavioral ecology that studies the behavior of foraging animals in response to a (more or less) complex environment in which they live. The Optimal Foraging Theory (OFT) (see MacArthur & Pianka, 1966; Emlen, 1966) is a refined version of this theory which establishes that animals must find, capture and consume food with more calories as possible, using the shortest possible time.

Essentially, there are three main versions of the OFT:

- The optimal diet model that describes the behavior of a forager that meets with different types of prey and must decide which one to attack;
- The patch selection theory describing the behavior of a forager whose prey is concentrated in small areas, but one far from the other so that the forager must spend a significant amount of time (and energy) to over from one to another;
- The central place foraging theory, which describes the behavior of a forager who must return to a particular place (usually always the same) to consume is/her own food or to give it to his/her offspring.

The research field that deals with developing models of behavior related to foraging and hunting has a long and established tradition and has worked for more than thirty years; since from the mid seventies, many aspects of the
dynamics and behaviors related to the activity of foraging and hunting were investigated.

Some authors (Caraco & Wolf, 1975) have proposed to investigate the influence of ecological factors in determining the size of a group of (social) foragers (rather than to adopt the traditional analytical approach to model this type of phenomenon); other researchers (Nudds, 1978) have attempted to extend the research on determining the size of a social group of carnivorous mammals from the case of lions to that of wolves. Others (Caraco, 1980) have presented models of foraging in stochastic environment; incorporating the responses of forager to environmental unpredictable changes, these models may be useful to make different predictions from those obtained with traditional deterministic models. Analytical models (Rodman, 1981) have been proposed to explain the dynamics and behaviors related to foraging (such as a simple model that expresses the inclusive fitness in function of the group size, when social groups contain relative and the individual fitness varies with the size of the group). Some researchers (Clark & Mangel, 1984) have theorized that i) the group foraging (or group flocking) may increase the rate of individual feeding as a result of information sharing among group members, and also ii) the group foraging reduces the variation in the rate of the feeding for its members. Both of these benefits grow with decreasing amounts of food and if it is patchy distributed. Finally, some models of foraging dynamics based on rules (Rands, Cowlishaw, Pettifor, Rowcliffe, & Johnstone, 2003; Rands, Pettifor, Rowcliffe, & Cowlishaw, 2004; Rands, Pettifor, Rowcliffe, & Cowlishaw, 2006) and evolutionary optimization algorithms (Cecconi & Campenni’, 2010; Campenni’ & Cecconi, 2009) have been proposed in recent years.

MATERIAL AND METHODS

Particle Swarm Optimization (PSO)

Our model, agent-based (Cecconi, 2008) and created using NetLogo (n.d.), is strongly inspired by PSO algorithm. The PSO algorithm is a stochastic optimization population-based algorithm that derives from Evolutionary Optimization (EO). The goal of EO is to determine values for parameters or state variables of a model that will provide the best possible solution to a predefined cost function or objective, or a set of functions, in the case of two or more competing objectives (Goldberg, 1989; Fonseca & Fleming, 1996; Back, 1996; Ravindran, Phillips, & Solberg, 2001; Taha, 2011; Sarker, Mohammadian, & Yao, 2002). Several approaches have been proposed for efficiently finding i) the best solutions to problems with single objective function and ii) Pareto-optimal solutions to complex problems of multi-objective optimization. In particular, evolutionary algorithms have shown a powerful approach to solving search and optimization problems that consider multiple conflicting objectives. Although the class of multi-objective optimization problems has been sufficiently investigated (see Pardoulis & Vrahatis, 2002; Hu, Eberhart, & Shi, 2003; Radicchi, Castellano, Cecconi, Loreto, & Parisi, 2004), the evolutionary algorithms today available, typically implement a single algorithm for the evolution of the population. However, existing theories (see Wolpert & Macready, 1997) and numerical experiments have shown that it is impossible to develop a single algorithm for population evolution that could be always efficient for a set of different optimization problems. Thus, in the last years memetic algorithms (also called hybrid genetic algorithms) have been proposed to increase the efficiency of optimization population-based algorithms. These methods are inspired by models of adaptation in natural systems and use genetic algorithms for global exploration of the space of combining them with local heuristic search for exploitation of the most promising areas. The original version of PSO was introduced by Kennedy et al. (2001) (see Kennedy, Eberhart, & Shi, 2001; Kennedy & Eberhart, 1995); in the PSO (see also Engelbrecht, 2005) a swarm of particles move in the n-dimensional space of solutions to a problem (multi-objective), trying to find the best solution. This algorithm can be
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