

Chapter 28

Evolutionary Multi-Objective Optimization of Autonomous Mobile Robots in Neural-Based Cognition for Behavioural Robustness

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ABSTRACT

The utilization of a multi-objective approach for evolving artificial neural networks that act as the controllers for phototaxis and radio frequency (RF) localization behaviors of a virtual Khepera robot simulated in a 3D, physics-based environment is discussed in this chapter. It explains the comparison performances among the elitism without archive and elitism with archive used in the evolutionary multi-objective optimization (EMO) algorithm in an evolutionary robotics study. Furthermore, the controllers' moving performances, tracking ability and robustness also have been demonstrated and tested with four different levels of environments. The experimentation results showed the controllers allowed the robots to navigate successfully, hence demonstrating the EMO algorithm can be practically used to automatically generate controllers for phototaxis and RF-localization behaviors, respectively. Understanding the underlying assumptions and theoretical constructs through the utilization of EMO will allow the robotics researchers to better design autonomous robot controllers that require minimal levels of human-designed elements.

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INTRODUCTION

Evolutionary Robotics (ER) is a methodology to develop a suitable control system for autonomous robots with minimal or without human intervention at all through evolutionary computation, to adapt itself to partially unknown or dynamic environments (Floreano, 2000b; Nelson, 2006; Pratihari, 2003). In other words, ER is defined as the synthesis of autonomous robots and/or controllers using artificial evolutionary methods (Teo, 2004a; Teo, 2005). ER is mainly seen as a strategy to develop more complex robot controllers (Floreano, 1996; Floreano, 2000b). Algorithms in ER frequently operate on a population of candidate controllers, initially selected from some random distributions (Alba, 2002; Urzelai, 2000). The evolutionary processes involve a set of operators, namely selection, crossover, mutation and other genetic algorithm (GA) operators (Coello, 2005a; Floreano, 2000a). Using different approaches of evolution, for example Genetic Algorithm, Genetic Programming, Co-evolution, and anytime learning, researchers strive for an algorithm that is able to train robots to perform their tasks without external supervision or help.

A number of studies have already been successfully conducted in evolutionary robotics for phototaxis, phonotaxis and obstacle avoidance tasks (Floreano, 2000; Teo, 2005; Floreano, 1996; Floreano, 2000a; Horchler, 2004; Reeve, 2005). In previous studies related to phototaxis tasks, the researchers used a fixed amount of hidden neurons in the neural network or just a two-layer neural network for their robot's task (Floreano, 1996; Floreano, 2000b; Teo, 2004b). They have not emphasized on the relationship between the robot's behavior and its corresponding hidden neurons. Additionally, to the best of our knowledge, there have not been any studies conducted yet in applying the multi-objective algorithm in evolving the robot controllers for phototaxis behavior. Besides, the literature also showed that other researchers have successfully synthesized some fitness functions to evolve the robots for the required behaviors (Floreano, 1996; Floreano, 2000a; Floreano, 2000b; Nolfi, 2000). However, the fitness functions used can be further improved or augmented in order to increase the robot's ability in completing more complex tasks (Marco, 1996). In addition, research regarding radio frequency (RF) signal localization has yet to be studied in ER. The RF signal is defined as radio frequency signal (abbreviated RF, rf, or r.f.) (Gibson 2007; Pike, 2007; NOAA 2008). It is a term that refers to an alternating current having characteristics such that, if the current is an input to an antenna, an electromagnetic field is generated suitable for wireless broadcasting and/or communications used (Gibson 2007; Pike, 2007; NOAA 2008). The RF signal source has provided the capability for improvements in tracking, search and rescue efforts. As such, robots that are evolved with RF-localization behavior may potentially serve as an ideal SAR assistant (Gibson 2007; Pike, 2007; NOAA 2008).

Previous studies of evolution mainly focus on achieving a single objective and they were unable to explicitly trade-off in terms of their different objectives when there is problem that involves more than one objective (Billard, 2001; Floreano, 2000b). With respect to the other ANN studies, the EMO application is advantageous compared to some conventional algorithms, such as backpropagation, conventional GAs, and Kohonen SOM network (Alba, 2002; Floreano, 1996; Urzelai, 2000). For example, the number of hidden neurons used in multiple layer perceptrons (MLP) and the number of cluster centers in Kohonen's SOM network need to be determined before training (Alba, 2002; Floreano, 1996; Urzelai, 2000). Meanwhile, the traditional learning methods for ANNs such as backpropagation usually suffer from the inability to escape from local minima due to their use of gradient information (Nehmzow, 1992; Teo, 2005). In addition, EMOs are able to solve two or more objectives in a single evolutionary process compared to conventional GAs (Teo, 2005). An EMO emphasizes on the generation of Pareto optimal

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