Chapter 100
Flexible and Hybrid Action Selection Process for the Control of Highly Dynamic Multi–Robot Systems

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ABSTRACT

This chapter presents a behavioral mechanism of control in order to break the complexity of multi-robot control systems. Specifically, this chapter proposes a Hierarchical Action Selection Process (HASP) which aims to coordinate a set of elementary controllers endowed in behavioral control architectures. This process allows at the scale of the robot to coordinate in a hierarchical and flexible way the activity of a set of elementary controllers, and at the scale of the group, the coordination of robots' interactions for reaching global objective and desired mass effects. The performances of the HASP were improved via the addition of an appropriate mechanism of fusion of actions leading thus to a Hybrid-HASP. Two architectures of control using respectively the HASP and the Hybrid-HASP are proposed to achieve the cooperative box-pushing task. The validation of the proposed mechanisms of control was made through experimentations using minimalist mobile robots and more intensively according to statistical studies achieved on a large number of data gotten thanks to MiRoCo simulator.

1. INTRODUCTION

The domain of cooperative robotics constitutes an active research field and is currently linked to many key application areas with large importance. A variety of tasks is performed in a more reliable and flexible way by teams of robots cooperating among them and/or with humans. These tasks concern collaborative manipulation, cooperative search and transportation, ground, space and underwater exploration, surveillance and autonomous rescue operations. The scientific problems associated to multi-robot systems concern formation analysis and control, cooperative perception, multi-robot self-localization,

DOI: 10.4018/978-1-5225-1759-7.ch100

multi-robot task coordination, architectures for cooperation and communication Cao et al. (1997), Ota (2006). Multi-robot cooperation offers advantages like acceleration of performance due to the parallel processing and coordination among robots and also robustness due to the presence and the modularity of multiple robots. Nevertheless, the coordination of multi-robot team in dynamic environments constitutes one of the fundamental problems. Coordination implies normally synchronization of robot actions and exchanges of information among the robots. The amount of synchronization and communication depends heavily on the tasks requirement, characteristics of the robot and its environment. More particularly, the control of simple and reactive group of robots in a distributed manner is a complex problem because global behaviors must emerge as a result of many local interactions Forrest (1991), (Arkin, 1998, p.105), Shen et al. (2004). The objective of our works is to control as minimalist as possible robotics entities Melhuish (2001), Adouane and Le Fort-Piat (2004a) and to use the local interactions between them to produce a form of advanced collective intelligence. More specially, the presented work concern the design and development of a control architecture exhibiting as well individual features adapted to highly dynamic multi-robot systems (a swarm of robots) than collective features favoring global goals. The architectures presented in this chapter are fully distributed and are based on reactive behaviors in order to perform complex cooperative tasks while using robots with limited sensorial and computational capabilities. The proposed process of coordination between behaviors is based on one hand, on a hierarchical coordination and on the other hand, on fusion mechanism. The goal is to select and combine appropriately elementary behaviors responses so that the robots will be able to perform complex tasks.

1.1. Related Works

While most efforts had focused in the past on centralized architecture of control Noreils (1993), Causse and Pampagnin (1995), the concepts more recently studied are based on decentralized (distributed) approach Parker (1998), Kube and Bonabeau (2000). The motivation comes from many applications where teams of a potentially large number of autonomous robots must cooperate without needing any global information about the evolution of the overall system. In the literature, many different approaches for coordination and self-organization among a large number of autonomous robotics entities are proposed. Among them, behavioral approaches take an important place. They are based on the concept that a robot can achieve a global behavior while using only the coordination of several elementary behaviors Arbib (1981), Brooks (1986), Anderson and Donath (1990). In the design of behavioral architectures, the mechanisms used for behaviors coordination are based on two major principles: action selection or fusion of actions leading respectively to competitive and cooperative architectures of control. Figure 1 shows a tree representing the different mechanisms of coordination.

In competitive architectures (action selection), the command sent to the robot actuators at each sample time, is given by an unique behavior which has been selected among a set of active behaviors. The principle of competition can be defined by a set of fixed priorities like in the subsumption architecture Brooks (1986) where a hierarchy is defined between the behaviors. The resulting actuators commands is given by the active behavior with the highest level of priority. The selection of behaviors can be also dynamic without any hierarchy between the behaviors. All behaviors can mutually activate or inhibit each other. At each sample time, the selected behavior is the one with the highest level of activation. This level of activation is generally computed according to a linear combination between a number of internal and external stimuli. Among the different competitive architectures, we can cite Maes (1989), Mataric´ et al. (1995) with the Dynamical Action selection architecture, or Drogoul (1993) with the Ethomodeling