Chapter 51
Formal Modeling and Analysis of Collaborative Humanoid Robotics

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ABSTRACT

A humanoid robot is inherently complex due to the heterogeneity of accessory devices and to the interactions of various interfaces, which will be exponentially increased in multiple robotics collaboration. Therefore, the design and implementation of multiple humanoid robotics (MHRs) remains a very challenging issue. It is known that formal methods provide a rigorous analysis of the complexity in both design of control and implementation of systems. This article presents an agent-based framework of formal modeling on the design of communication and control strategies of a team of autonomous robotics, to attain the specified tasks in a coordinated manner. To ensure a successful collaboration of multiple robotics, this formal agent-based framework captures behaviors in Petri Net models and specifies collaboration operations in four defined operations. To validate the framework, a non-trivial soccer bot set was implemented and simulation results were discussed.

1. INTRODUCTION

Due to the inherent complexity of humanoid robotics systems, the design and analysis of multiple humanoid robotics systems (MHRSs) is more challenging than for their wheeled peers in both motion planning and control design. Furthermore, the heterogeneity and the various interactions of multiple devices and the numerous degrees of freedom (DOF) increase the complexity of task coordination and

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overall system behavior analysis. Therefore, the design and implementation of collaborative MHRSs remain a very challenging issue in the domain.

The multi-agent system has been studied for several decades and can be considered as the most popular emerging technology. Several frameworks relevant to the multi-agent systems (MASs) have been defined to address the system control and organization concepts with the optimization of the complexity of the system (Greaves, Stavridou-Coleman, & Laddaga, 2004; Heragu, Graves, Kim, & St Onge, 2002; Khosla & Dillon, 1998; Weiss, 1999). The methodology of agent-oriented design is widely used to coordinate autonomy (Reveliotis, 2015) and, thus, ensure the trust of the system.

An intelligent and autonomous system can be represented by several degrees of coordination. Therefore, a MAS is a concurrent and distributed software-intensive system in the domain of cyber physical space. The complexity and capability of an agent and the MAS are commonly greater than any distributed software system. In this sense, formal methods and techniques of analysis play a critical role in the task coordination and in the control of the behavior of multiple robotics by integrating with the MAS.

It is known that Petri nets have a well defined mathematical structure that performs accurate and quantitative analysis of disconcurrent systems. Petri nets have been successfully used in the model, design, and analysis on disconcurrent systems, in past decades (Martinik, 2013).

In this paper, we will present a hierarchical formal framework for task coordination and motion planning using agent-oriented design, which provides a venue to study the collaboration of a team of robotics accurately. Section 2 will introduce the primary concepts of MAS and Petri nets, with a short introduction of our case study platform (i.e., Bioloid humanoid robot kit). Section 3 will introduce the agent-oriented formal framework for the collaborative motion planning and task. Section 4 will present our implementation study on the Bioloid GP educational kit, a team of soccer bots to play a defense and offense scenario in a multiple Bioloid humanoid robotics platform. Section 5 will discuss the work related to the formal modeling of multiple robotics systems. Finally, section 6 will provide the conclusion and illustrate future works.

2. PRELIMINARIES

In this section, we will introduce the fundamental concepts of an agent-based system, first. Subsequently, we will introduce Petri nets, which we use as the tool of the behavior in our integrated formal framework. Then, we briefly describe our application platform Bioloid robot kit.

2.1. Agent and Multi-Agent Systems

An agent is a dynamic responsive entity that performs actions with response to the external events automatically. In Woodridge's (2009) definition, "an agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its delegated objectives" (p. 21).

A MAS denotes an intelligent architecture with which the system is able to make decisions and perform actions to respond to the signal from the environment. MASs have several typical characteristics, including autonomy, perception, decentralization, and self-organization. In order to ensure that MHRSs respond to their environment, the typical first-hand information about the environment is from sensory