Chapter 71
Reconfiguration of Autonomous Robotics

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ABSTRACT

Autonomous robotics systems (ARSs) consist of multiple heterogeneous objects and intelligent inferences that are expected to take appropriate actions even in unforeseen circumstances. Dynamic reconfiguration of ARSs is a key enabling technology and plays a major role in the future cyber-enabled battle field. This research work, focused on the development of a formal approach to the specification and verification of reconfigurability of ARSs. Two typical problems w.r.t. the dynamic adaptation and reconfiguration of ARSs were identified and studied. The first problem is how to formally represent the ARSs and describe the reconfigurable behavior precisely so that the ARSs can adapt to the new changes. The second problem focuses on how to analyze and verify the formal model of the reconfiguration and ensure the correctness of the system during reconfiguration. Considering behavior preserving in the reconfiguration model, a net reconfiguration based on the natural transformation is introduced.

1. INTRODUCTION

Dynamic reconfiguration refers to the ability of a system to dynamically change its structure and interface according to different situations. It provides feasible and flexible modeling and simulation environments with powerful modeling capability and the extra flexibility to design and analyze complex systems. In addition, the goals of dynamic behaviors of autonomous robots make them ideally suited for numerous environments with challenging terrain or unknown surroundings. Applications are apparent in exploration, search and rescue, and even medical settings where several specialized tools are required for a single task. The ability to efficiently reconfigure between the many structures and behaviors of which an autonomous robot is capable is critical to fulfilling this potential. Thus, it is important for making autonomous robotics systems (ARSs) adaptable to changes and it is one of the main challenges facing autonomous robotics systems.

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Moreover, considering the correctness of change and ensuring the appropriate behavior during reconfiguration, it'll be more important that the mechanism for change be explicitly represented into the model so that at each stage of product development, designers can experiment with the effect of structural changes, by prototypes and verification tools. This means that the structural and behavioral changes are taken into account from the very beginning of the design process rather than handled by an external and global system, e.g. some exception handling mechanism, designed and added to the model describing the system normal behavior. Thus we favor an internal and incremental over an external and uniform description of changes, and a local over a global handling of changes. This approach is compatible with the bottom-up modular synthesis of Petri Nets where a complex system is derived from successive refinements of places or transitions by sub-systems.

Exploiting the results in the above two parts of the modeling and verification of reconfiguration, it is worth to notice that the behavior preserving is not included or considered. As a matter of fact, it is very challenging to consider behavior preserving in the reconfiguration model, not only in the Petri Net technique. Another significant contribution of this research work is to introduce a framework for PrTR net reconfigurations based on the natural transformation. The fact that PrTR net components are combined by means of categorical push-out and pull backs or limit and co-limits, suggests a setting for specifying net reconfigurations, based on transformation rules on the net specification. Using the congruence result for bi-similarity we identify classes of transformation rules which ensure that reconfigurations of the system do not affect its observational behavior.

The remainder of the paper is organized as follows: Section 2 discusses research goals and objectives. Section 3 introduces the proposed reconfiguration method – a formal representation of PrTRN model for autonomous systems. Section 4 presents the component based architecture of motion planning for a humanoid robot, a case study of button pressing action was presented. Section 5 describes a state space graph based analysis of the reconfiguration. Section 6 and 7 pointed out the future research direction based on current result, and concluded the work.

2. RATIONALES AND GOALS OF THE PAPER[1]

2.1. Rationale and Problems

It is widely realized that the development of military or industrial applicable robots is subject to change, which is mainly caused by two major aspects – unexpected environment and higher customer orienta-

Figure 1. Impact factors of reconfigurable autonomous robots