Chapter 2.20
Robust Intelligent Control of Mobile Robots

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ABSTRACT

An appropriate control architecture is a crucial premise for successfully achieving truly autonomous mobile robots. The architecture should allow for a robust control of the robot in complex tasks, while it should be flexible in order to operate in different environments pursuing different tasks. This chapter presents a control framework that is able to control an autonomous robot in complex real-world tasks. The key features of the framework are a hybrid control paradigm that incorporates reactive, planning and reasoning capabilities, a flexible software architecture that enables easy adaptation to new tasks and a robust task execution that makes reaction to unforeseen changes in the task and environment possible. Finally, the framework allows for detection of internal failures in the robot and includes self-healing properties. The framework was successfully deployed in the domain of robotic soccer and service robots. The chapter presents the requirements for such a framework, how the framework tackles the problems arising from the application domains, and results obtained during the deployment of the framework.

INTRODUCTION

An appropriate control architecture is a crucial premise for successfully achieving truly autono-

mous mobile robots. The architecture should allow for a robust control of mobile robots during the execution of a wide range of different tasks. Moreover, it should be flexible enough to facilitate different control strategies and algorithms. In addition, the architecture should be adaptable in order to handle more complex tasks and to be able to operate in different environments.

Finding an appropriate architecture for a specific purpose is a challenging task. In fact, no single architecture can be sufficient for all purposes. There is always a trade-off between general applicability and usability. The issue of determining an appropriate architecture suitable to robustly control an autonomous mobile robot can be divided into several sub-problems:

- The first and easier one is the question of which control paradigm to choose. In this chapter the different control paradigms are introduced. It is then motivated why a hybrid paradigm is the most appropriate for applications where robots carry out complex and non-trivial tasks.

- The second problem is more related to software engineering and concerns the software architecture. The software architecture determines how the functionality of the software is physically organized. Several projects working on an architecture sufficient for the needs of mobile robots are introduced. For an in-depth discussion of the issue of choosing or implementing an appropriate software framework, the reader is referred to Orebäck (2004). Finally, an example of a successful solution to this issue is illustrated.

- A more or less strong, deliberative component is part of every hybrid control paradigm. The use of symbol-based abstract decision making has two major drawbacks. First, in general, planning techniques are insufficiently reactive for unpredictable and highly dynamic environments. A solution

to this problem is presented, which enables the deliberative component to react more quickly to such effects. Second, if an abstract deliberative component is used, then some kind of connection between the quantitative world of the sensors and actors and the qualitative world of planning and reasoning is necessary. If sensors and actors are prone to uncertainties, then this abstraction of knowledge is difficult. Unfortunately, such uncertainties are nearly always adherent to sensors and actors. Therefore, a novel symbol grounding mechanism is presented, which significantly relaxes this problem.

- The final problem is especially important in the area of autonomous mobile robots. Tolerance of the robot and its control system against faults is crucial for long-term autonomous operation. It is shown how a model-based fault-diagnosis and repair system improves the overall robustness of the control architecture.

Consideration of all these features and requirements has resulted in a control architecture that serves as a platform for research in several areas in autonomous mobile robots, for example, RoboCup robot soccer and service robots. This robust and flexible architecture will serve as a running example and as a guideline throughout this chapter.

SOFTWARE FRAMEWORKS FOR MOBILE ROBOTS

This section addresses the problem of software frameworks for autonomous mobile robots. For this, the applicable control paradigms are introduced. Control paradigms describe how control is organized. Then, general requirements for software architectures in order to be usable for autonomous robots are identified. Finally, popular publicly available software frameworks are reviewed.

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