Chapter 42
Prototyping of Fully Autonomous Indoor Patrolling Mobile Robots

Xiaojun Wu
*Data Storage Institute, A*STAR, Singapore*

Jun-Hong Lee
Dyson Operations, Inc. Singapore

Bingbing Liu
*Institute for Infocomm Research, A*STAR, Singapore*

Vikas Reddy
Kiva Systems, Inc. USA

Xi Zheng
Thinking Dots, Inc. Singapore

ABSTRACT

In this chapter, the design and prototyping of an indoor patrolling mobile robot is presented. This robot employs a modular design strategy by using the ROS (Robot Operating System) software framework, which allows for an agile development and testing process. The primary modules - omni-directional drive system, localization, navigation, and autonomous charging - are described in detail. Special efforts have been put into the design of these modules to make them reliable and robust in order to achieve autonomous patrolling without human intervention. With experimental tests, the authors show that an indoor mobile robot patrolling autonomously in a typical office environment is realizable.

INTRODUCTION

Robotics, especially mobile robotics, has attracted intensive research efforts in the past decades. A real autonomous mobile robot, i.e. a robot that can run by itself without any human intervention, can function as a reliable platform and transform into many practical and useful service robot forms, and subsequently benefit humans in their daily life. For example, an indoor service robot can act as a patrolling security guard, a house servant, a tour guide, an entertainer and a tutor.

The first indoor mobile robot that was really deployed for practical applications probably is RHINO, a museum robot guide developed by Burgard *et al.* (1998). As pioneering work in this field, this robot guide was deployed mainly for experimental purposes. During its 6-day deploy-

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ment and tens of hours of operation, it had successfully demonstrated its localization and navigation, and functioned well to fulfill tour requests with very few exceptional failures. According to the authors, this robot achieved "overall success rate of 99.75%" and thus concluded that "time is ripe for developing AI-based commercial service robots that assist people in everyday life". It has been more than twelve years since this promising prediction about service robots was made by these expert researchers in this field. However, the development and practical application of service robots, even in the relatively simple indoor environments, have not reached the optimistic level as predicted. A fully autonomous robot platform that requires no human intervention seems like "mission impossible".

The reason for slow progress lies in the challenges that the robot has to deal with in typical people inhabited indoor environments. Let us assume that an indoor mobile robot needs to perform a simple task, e.g. patrolling, inside a typical, medium size office (in a scale of 50×50 meters). Inside the office are cubicles, normal office furniture and obviously, a lot of people, with normal working behaviors. The robot has to function in a fully autonomous mode (i.e. 24 hours in a day with 7 days a week) without any human operation and it has to be able to localize itself accurately and reliably while planning a drivable path (loop) to patrol the environment. It has to avoid any obstacles en-route by maneuvering itself in any direction to pass narrow passages safely, and return to the docking station for power recharging whenever the onboard energy is lower than a threshold.

The above challenges are similar to those faced by an indoor patrolling robot. A robot is a complex system comprising multiple electronic and mechanical sub-systems. Thus, it is important to design the robot such that each sub-system can be built and tested separately. This requires the robot to be highly modular and modularity is a key element in prototyping robotic systems. The concept of modular design is best illustrated with an example. Let us consider our robot *Rio*, which is an indoor holonomic, patrolling robot. Rio's mechanical system consists of static structures such as the frames and dynamic structures such as the drive train. Rio's electronic systems consist of Li-Ion battery packs, voltage regulators, charging and discharging circuitry, power distribution circuits, motor and emergency stop circuits. Rio's sensors include a single axis Gyro, a 2D Laser Radar (LADAR), a 3D scanning LADAR, optical wheel encoders, and a docking station for autonomous recharging. Given the large number of components present in Rio, it is important to follow a systematic approach in the design where the components are grouped into modules as shown in Figure 1.

Out of all the modules listed inside Figure 1, in this chapter, we will mainly discuss those key modules that handle the challenges defined for a patrolling robot, i.e. the omni-directional drive module, the localization module, the path planning and obstacle avoidance module, and the auto-docking module for power recharging. The rest of the chapter is arranged as follows. We will provide the background information in the next section. After that, each of these key modules we developed for the indoor patrolling mobile robot will be discussed, each in one individual section, i.e., omni-directional drive module, localization module, path planning and obstacle avoidance, and auto-docking module. After these sections, an integrated testing case of our developed patrolling robot will be given. Finally, conclusions and future research directions will be presented.

BACKGROUND

In the literature, each of the challenges we defined for the patrolling robot has been addressed individually in certain degree.

In order to move effectively in narrow areas and to avoid static or dynamic obstacles, an omni-