Chapter 50

Indoor Localization and Navigation for a Mobile Robot Equipped with Rotating Ultrasonic Sensors Using a Smartphone as the Robot's Brain

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ABSTRACT

Identifying the current location of a robot is a prerequisite for robot navigation. To localize a robot, one popular way is to use particle filters that estimate the posterior probabilistic density of a robot's state space. But this Bayesian recursion approach is computationally expensive. Most microcontrollers in a small mobile robot cannot afford it. The authors propose to use a smartphone as a robot's brain in which heavy-duty computations take place whereas an embedded microcontroller on the robot processes rudimentary sensors such as ultrasonic and touch sensors. In their design, a smartphone is wirelessly connected to a robot via Bluetooth by which distance measurements from the robot are sent to the smartphone. Then the smartphone takes responsible for computationally expensive operations like executing the particle filter algorithm. In this paper, the authors designed a mobile robot and its control architecture to demonstrate that the robot can navigate indoor environment while avoiding obstacles and localize its current position.

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INTRODUCTION

The demand of indoor autonomous mobile robots has increased for last few decades. Commercial success of cleaning robots is a good example of such high-demand. In 2012 about three million service robots for personal and domestic use were sold according to the International Federation of Robotics (IFR) (World Robotics 2013 Service Robots). The IFR prospects about 22 million units of service robots for personal use to be sold during the period 2013 to 2016.

There have been many approaches in indoor localization and navigation for a mobile robot for last couples of decades. To be autonomous, a robot must be able to identify its exact current position. Based on the knowledge the robot is aware of how to proceed to arrive at a goal position. To enhance robot localization, high-quality sensors such as laser scanners and 3D cameras are preferable. But most micro-controllers in a small robot cannot afford the computation required to process such high-fidelity sensor data. In this paper we propose to use a rotating ultrasonic range sensor to measure distance to the walls and detect obstacles. With its Bluetooth wireless connectivity to the robot a smartphone can be used as robot's brain in which all heavy-duty computations are executed. State-of-the-art smartphones outperform a few year old laptop computers not to mention all the high performance sensors in a smartphone including a multi-million pixel camera, an ambient light sensor, an accelerometer, a pressure sensor, a temperature sensor, a GPS, a gyroscope, and many more. With a proper connectivity and communication methods to a robot a smartphone is capable of being the robot brain.

The block diagram in Figure 1 shows the overall design of the robot and its components. A smartphone is in charge of processing complex algorithm that requires heavy-duty computations. A microcontroller powered by Arduino (Arduino, an open-source electronics platform) is only responsible to control DC motors for four wheels and a servo motor for rotating ultrasonic sensors. The smartphone wirelessly communicates with the microcontroller through Bluetooth technology. Higher level commands such as setting a goal position and starting navigation are from the smartphone to the microcontroller. Obstacle detection and distance measurement using ultrasonic range sensors are executed by the microcontroller. The measurement data are sent to the smartphone to calculate the probability of the robot location in the next step.

In following sections, relevant studies will be discussed. Then the design and implementation details will follow the discussions. To demonstrate the practicality and effectiveness of our robot design several experiments will be shown. The experimental results show that the layered control architecture using a smartphone as the robot's brain with rotating sensors is a valid approach to balance the quality and affordability of a mobile robot.

RELATED WORKS

A laptop has been a popular processor unit for mobile robot (Xu, Tan, & Li, 2009; Rolf, Whitlock, Min, & Matson, 2013; Duchon, Dekan, Jurisica, & Vitko, 2012; Cunha, Pedrosa, Cruz, Neves, & Lau, 2011). As the processor of smartphones becomes faster and the size of the memory becomes larger, smartphones have been gaining popularity as a processing unit for a mobile robot. As far as the performance of smartphones is sufficiently strong, smartphones have many obvious advantages against traditional laptops. The small size and light-weight are evident benefits. Heavy load of a laptop requires more battery power that must be saved as much as possible for a mobile robot. For the reason, small mobile robots are restricted

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