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Learning Motion Patterns for Mobile Service Robots

Abstract

In the past decade there has been a substantial progress in the field of mobile robotics. Mobile robots have successfully been deployed in hospitals [9,15], office buildings [1,2,13,20,25], department stores [8,11], and museums [5,24,26]. Existing robotic systems are already able to perform various services such as deliver, educate, provide tele-presence [10,12,23], clean [14], or entertain [27] (see for example the book by Schraft and Schmierer [22] for an overview). One example is the mobile robot Albert which operated as an autonomous tour-guide in the Deutsches Museum during Summer 2003. The robot served as an on-site tour-guide and at the same time provided tele-presence over the Internet [6] (see Figure 1). Furthermore there are prototypes of autonomous wheel-chairs [16,18] and intelligent service robots which are designed to assist people in their homes [17,19,21].

Many of these applications have in common that the robots co-exist with people in their environments. Robots that operate in populated environments obviously can improve their service if they appropriately react to the activities of the people in their surrounding and do not interfere with them. This, however, requires that robots can locate and track persons using their sensors. Furthermore, the robots need to be able to identify and potentially learn intentions of people so that they can make better predictions about their future actions.

Figure 1: The mobile robot Albert guiding people through the Deutsches Museum during summer 2003.

Whenever people move through their environments they usually do not move randomly. They typically follow specific trajectories or motion patterns corresponding to their intentions. Knowledge about such patterns may enable a mobile robot to robustly keep track of persons in its environment or to improve its behavior. The capabilities to learn

motion behaviors of persons from sensor data, to utilize these motion patterns to maintain a belief about where the persons are, and to adapt the navigation behavior of the robot can be useful in various kinds of situations. For example, they allow a robot to reliably predict the trajectory of a person and to avoid that the robot blocks the path of that person. Furthermore, a home-care robot can more robustly keep track of the person it is providing service to and this way increase the time it stays in the vicinity of the person. Thus, the knowledge about motion behaviors of a person can be quite useful for several tasks such as collision avoidance, strategic positioning, and verbal assistance.

In this presentation we describe an approach to learning motion patterns of persons [3]. This algorithm, which is purely probabilistic, is motivated by the observation that people usually do not move randomly when they move through their environments. Instead, they usually engage in motion patterns, related to typical activities or specific locations they might be interested in approaching. The input to our algorithm is a set of trajectories of persons between so-called resting places where the persons typically stop and stay for a certain period of time. Our approach clusters these trajectories into so-called motion patterns using the EM algorithm. It then derives Hidden Markov Models (HMMs) from the learned motion patterns and uses these HMMs to maintain a belief about the positions of persons [7]. The robot can use theses HMMs to reliably predict future poses of the persons and to choose appropriate navigation actions based on these predictions [4].

The right image of Figure 2 depicts an image obtained with the robot's camera as well as two segments extracted from these images according to the features detected with the robot's laser range scanner (see left image of Figure 2). A typical belief about the position of a person after the robot detected and identified it is shown in Figure 3. In this figure the big square indicate locations at which the person is with high probability. Finally, Figure 4 depicts a scene in which our robot Albert leaves a doorway in order to give space to a person that with high likelihood wants to enter the corresponding room.

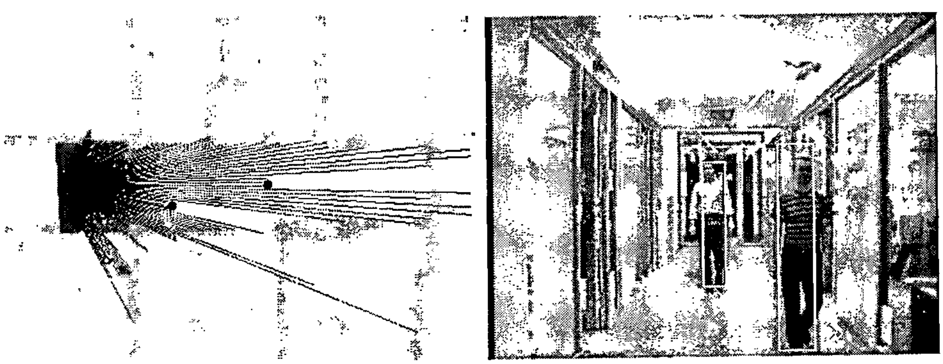

Figure 2: Laser-based people detection system (left image) and segmentation of two persons from the image grabbed with the camera of the robot (right image).

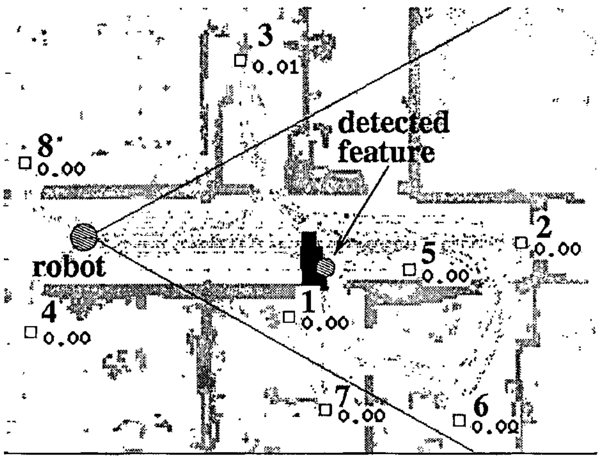

Figure 3: Corresponding belief over the position of the person after integrating an observation. The size of the squares represents the probability that the person is currently in the corresponding state.

Figure 4: Albert moves away from a doorway in order to let a person enter the corresponding room.

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