White Paper - Human-Robot Following using UWB Tags
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Authors:
Uri Kartoun, Helman Stern, and Yael Edan¹
Craig Feied, Mark Smith, Jonathan Handler, and Michael Gillam²

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1. Introduction

A system developed by Parco Wireless, a developer of an ultra-wideband (UWB) Radio Frequency Identification (RFID) technology was installed at the Washington Hospital Center (WHC). The system allows tracking of humans and equipment in three dimensions. The deployment covers several zones centered on the emergency department including Annex-4 and the Medial Media Lab located nearby. Parco real-time location system uses tags and readers licensed from Multispectral Solutions, an ultra-wideband specialist allows hospitals and clinics to track the status and exact location of patients, staff and essential equipment. UWB RFID active tags can be wore by patients, medical staff and robots. The credit card-size tags (Fig. 1) can be detected at a range of 600 feet at a frequency of up to 30 times a second. The tags are tracked by unique three-digit identification numbers emitted by each tag every second. Data delivered by UWB tags is used for a whole range of decisions and focused here on human-robot following.

¹ Ben-Gurion University of the Negev, Be’er-Sheeva, Israel.
² Washington Hospital Center, Washington, D.C., U.S.A.
2. Methodology

In order to follow a human, a mobile robot needs to “know” the position of the person and must be able to determine its own path in order to follow him. In our human-robot following application, we have equipped both the human and the robot with 4HZ tags. Since an initial robot heading angle is not known at the beginning of the tracking, a calibration procedure is required. During tracking, in order to estimate the distance between the human and the robot, a simple trigonometry calculation is made based on readings of the two tags x and y coordinates. Hence, the robot is able to know the distance to the human. It can also calculate dynamically its direction toward the human based on these readings and make angle corrections. In addition, if the robot is too close to the human (distance is smaller than a pre-defined distance value) it is triggered to stop.

2.1. Calibration

The objective of calibration is to let the robot find an initial heading angle, i.e., when the robot is placed in a random location, it has no information about its relative orientation; thereby a heading angle should be calculated. Determining an initial heading angle is based on linear regression analysis. The idea behind using linear regression here is to let the robot to find the relationship between its tag coordinates. This is done by letting the robot to drive straight a pre-defined distance (e.g., two meters) while sampling coordinates measured by its tag.
readings, e.g., \((x, y)\) pairs. Linear regression allows the robot to examine the existence and extent of the relationship between the coordinate pairs to estimate the heading angle. Once this relationship is established, the robot can start tracking a human.

Regression shows here the relationship between one independent variable \((x)\) and a dependent variable \((y)\) coordinate read from a tag placed on the robot. The measure parameter of correlation we used is the coefficient of determination, \(R^2\). \(R^2\) is the percentage of variation in the dependent variable that results from the independent variable, i.e., it shows how much of the variation in the data is explained. High \(R^2\) values (e.g., close to one) indicate precise starting heading angles. Fig. 2 shows a robot initial heading angle calculation \((\theta_R)\).

![Figure 2. Robot initial heading angle calculation](image)

2.2. Tracking Algorithm

Tracking is achieved based on dynamic calculations between \(X_H\) and \(Y_H\) coordinates of a tag located on the human (Fig. 3(a)) and \(X_R\) and \(Y_R\) coordinates of a tag placed on the robot (Fig. 3(b)).
In order to accompany a person, the robot should estimate the next position of the person in order to move without any delay. This is done by letting the robot calculate both the distance and angle required to reach the person. If the human moved above a distance greater than a pre-defined value and the difference between both the human and the robot relative angles to a reference surface (Fig. 2) is higher than a threshold value, the robot recalculates the distance and angle required to reach the human and heads toward him (Fig. 4).
3. Conclusions and Future Directions

We designed and implemented a prototype for real-time human-robot following method allows a robot to follow a human using Parco UWB RFID tags. We intend to develop a considerably low-cost system functioning at a hospital environment with characteristics close to an ideal system. An optional mobile robot system we consider consists of ActivMedia’s PatrolBot robot. PatrolBot is designed for 24x7 usages and is equipped with navigation capabilities. It includes an embedded laser, sonar, bumpers and charging station. It can map rooms and labs in short time, plan paths to goals, avoid obstacles along the way and navigate through tight spaces for delivery of up to 50 pounds or docking.