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A Real Time Locating System based on TDOA estimation of UWB pulse sequences

Summary

One of the most popular technologies adopted for indoor localization is Ultra Wideband impulse radio (IR-UWB). Due to its peculiar characteristics, it is able to overcome the multipath effect that severely reduces the capability of receivers (Sensors) to estimate the position of transmitters (Tags) in complex environments. The architecture of the localization system requires time synchronization among the Sensors by means of very precise, high cost clocking mechanism or by means of a complex high level communication protocol between Sensors and Tags.

In this thesis work, we introduce a new low-cost real-time locating system (RTLS) that does not require time synchronization among Sensors and uses a one-way communication scheme to reduce the cost and complexity of Tags. The system is able to evaluate the position of a large number of Tags by computing the time difference of arrival (TDOA) of UWB pulse sequences received by at least three Sensors in known positions. In the presented system, the Tags transmit sequences of 2-ns UWB pulses with a carrier frequency of 7 GHz. Each Sensor processes the received sequences with a two-step correlation analysis performed first on a field-programmable gate array (FPGA) chip and successively on an on-board processor (ARM). The result of the analysis are the Time Of Arrival (TOA) of the pulse sequence at each Sensor and the Tag ID associated to it. These results are sent to a host PC implementing the trilateration algorithm based on the TDOA computed between couples of Sensors. To compute the 2D position of a Tag it is sufficient to use the TDOA among three Sensors.

Two different applications are developed. The first application, called LOCalization SYstem (SILOC in Italian) has the goal of localizing and tracking the position of different Tags inside a localization area with high precision and accuracy. The application is optimized to track moving Tags using a standard operating mode with good accuracy and high responsiveness and super-resolution operating mode with better accuracy but slower responsiveness. The second application, called Package Tracker (PackTrack) integrates new features on top of the SILOC application. It allows the user to monitor Tags attached to valuable goods (e.g. packages) in fixed positions over long periods of time. The application triggers an alarm whenever a Tag moves away from its position by a distance larger than the tolerance and continuously update a data log to keep track of each Tag's movement.

In the following Chapter 1, we first introduce the UWB signal in general and its application to indoor localization, we then briefly describe the most commonly used modulations and which one we adopted. The last part of the chapter introduces the different methods used for indoor localization and describes the details of the pulse sequence adopted in this project.

In Chapter 2 we discuss the design choices and implemented solutions of the developed hardware. We introduce the custom UWB transmitter with its digital and RF components and the UWB receiving chain, made up of a custom UWB antenna and receiver. The chapter concludes with the description of the custom processing board and the system final prototype.

In Chapter 3 we discuss the details of the developed software. The chapter is divided in three main sections: The first section deals with the design of the FPGA firmware implementing a custom architecture able to receive a continuous stream of data, to recognize the presence of a transmitted sequence and to compute its TOA. The second section describes the ARM processor software that uses the information

obtained by the FPGA, refines it and associate it to the correct Tag ID. The last section deals with the graphic user interface (GUI) developed to compute the TDOA among Sensors, to perform the trilateration algorithm and plot the localized Tags on a 2D map for user visualization.

The last chapter shows the results obtained with the RTLS system installed in our institution laboratory. The system tracking capabilities and localization accuracy have been evaluated by means of a measurement campaign. The obtained localization accuracy of 10 cm is demonstrated and discussed.