SS 2014-2015, Politecnico Torino, No. DISAL-MP26 Project Summary

Methods for Ultra-Wide Band indoor localization using robotic fingerprinting in complex environments

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Nowadays, the possibility to track objects and people is of essential importance for an always increasing number of applications. So far, the revolution brought by Global Positioning System (GPS) has indeed been able to satisfy this need with a relatively good level of accuracy. Over the recent years, the relocations of many activities from outdoor to indoor environments, together with the advent of new technologies, has opened the doors to the new field of indoor localization.

One of the most effective technologies, in terms of accuracy and coverage, for indoor localization makes use of the exchange of Ultra-Wide Band (UWB) radio pulses between two kinds of devices known as "anchors" and "tags": the former are in known position, while the latter have to be localized. The localization can be performed in different ways, all based on the principle of finite propagation speed of the electromagnetic wave. The presence of obstacles between tags and anchors (NLOS condition) and reflections of the radio signal represent a hard challenge for these systems, and their performances tend to significantly decrease in dense indoor environments.

A way to improve the performance of a UWB localization system in these critical conditions is to build, through a process known as "fingerprinting", a map of the error measured by the system in the environment of interest. This process requires (i) taking as many measurements as possible with the UWB system in the whole environment, (ii) knowing the ground-truth for each of them. These two requirements make the use of robots very suitable for this purpose. This approach has been studied in a very controlled environment by Amanda Prorok for the purpose of robot localization: she performed experiments inside a laboratory, using artificially added obstacles.

In this project we tested the performances of UWB indoor people localization with and without fingerprinting in a more realistic scenario which involves multiple rooms and walls. Two main activities have been carried out.

The first activity is the comparison of the accuracy of a low- and a high-class UWB solutions without fingerprinting. The tests have been carried out both in single- and multi-room environments, also considering different orientations of the tag with respect to all its axes. In absence of NLOS, both the technologies performed according to their specs, with an average accuracy respectively below 30 and 15 cm. However, in multi-room environments, full of NLOS conditions, the accuracy was much worse. We also noticed a significant impact of the tag orientation on the localization accuracy for both the systems.

In the second activity, mobile robots have been used to perform the fingerprinting phase automatically. These robots scan the error in a known environment, where they can self-localize using AMCL and laser range finders. The error map was obtained by setting the parameters of a general error model on the basis of the fingerprinting data. During the localization phase, where a person wearing the tag on his head was walking in a multi-room environment, the measurements of the UWB system were fused with the data of the error map, by the Monte Carlo Localization Algorithm that we implemented in Matlab. The results showed up to 50% of improvement in the localization accuracy.

Using the lower-class UWB localization system (with four anchors) plus fingerprinting, we managed to achieve a localization accuracy of roughly 30 cm in a 300 sq. meters environment, extremely dense of NLOS conditions. Finer fingerprinting could lead to even better performances. However, the error map will always strongly depend on the environment that, in general, cannot be considered completely static.