Hybrid Localization Solutions for Robotic Logistic Applications

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1 Introduction

This paper presents some results concerning rovers localization, achieved within the framework of the Italian Regional project MACP4Log [1]: the project investigates how to coordinate a team of mobile robots in order to deliver assistance services in a large logistic space (programmed and pro-active surveillance, goods tracking and mapping, truck navigation, etc.).

The adopted robotic platform consists of a wheeled vehicle driven by electrical motors and equipped with several sensors (vision sensors, proximity sensors, laser range-finders and odometry information) and with a WiFi node, mainly aimed at wireless communication with other robots and with a supervisor. The team coordination is performed once the position of each rover is known, that is considered being an essential prerequisite in MACP4Log.

However, the logistic environment sets critical constraints on how to solve the localization problem: large and high stacks of containers are supposed to be symmetrically distributed over a large area and to be frequently moved. For this reason GPS cannot be used, due to the metallic canyons affecting the GPS signal, visual information is influenced by lighting conditions and joint odometric and laser-scan position is subject to slow convergence and even ambiguity due to symmetries [2].

Localization techniques based on WiFi [3] [4] exploit received signal strength to infer position by reverse functions based on fingerprinting and/or radiomaps: they provide coarse results which however are exempt from the issue of ambiguity which laser scan suffer from. Moreover WiFi is cheap and already useful for rover communication.

2 Localization Approaches

Considering the initial hypotheses, the proposed study concerns the assessment of the efficiency in localization (precision, convergence, reliability) achievable by the following approaches:

- Laser rangefinder information processed by particle filters.
- WiFi positioning based on received signal strength from a set of fixed APs.
- Integration of WiFi positioning and laser scan data within the particle filters.

The analysis is mainly aimed at evaluating the benefits coming from the data fusion of different localization techniques, based on technologies that are already available on-board the robotic prototype.

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2.1 Laser rangefinder information processed by particle filters

Laser rangefinders provide high precision distance estimates, with errors of approximately 0.001 m in the range [0-32m]: in the tests proposed in this paper a SICK LMS200 laser rangefinder is used.
In the first proposed approach, data coming from the laser rangefinder are processed by a particle filter: particle filters are non-parametric implementations of Bayes filters and in the context of rover localization are able to represent and track the position of mobile robots in a given reference frame [5].
Usually, when dealing with symmetric environments and using only sensors that do not provide information on the absolute position, the localization process may fail or, at least, be slow, due to the persistent ambiguity in the believes that feed particles: symmetries may keep alive two or more hypotheses on the positions, without disambiguating them. This slows down the convergence of the algorithm and the choice of the final position estimate may be casually driven by noise. Tests confirm that this approach is precise but vulnerable to ambiguities and/or slow convergence when used in symmetrical environments (see for instance [2]).

2.2 WiFi positioning based on received signal strength from a set of fixed APs

In the second approach, the only information used to compute the estimated position is the Received Signal Strength (RSS) of an existing WiFi network. This approach is aimed at building a probabilistic model based on a mathematical approximation of the radio environment and requires at least 3 different fixed APs in order to work properly. The precision achieved using this technique varies from 5 to 8 meters. The first step is to perform a certain number of measurements to gather information about the mean RSS by using a WiFi card. After sampling, a radio map (Figure 1) is built for each AP as a fitting surface computed with a triangle based linear interpolation. For

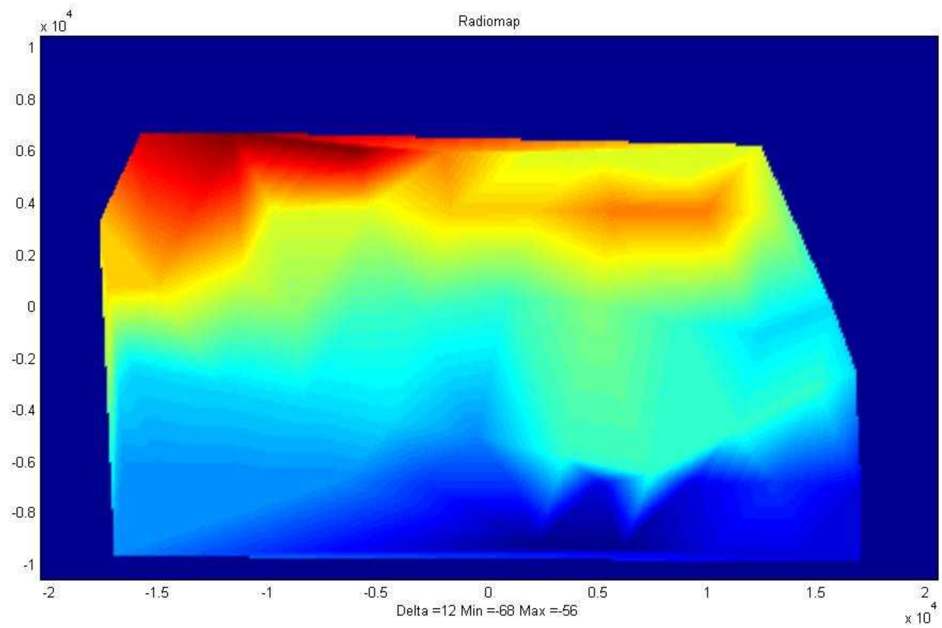

Figure 1: The radiomap, that shows the distribution of the RSS in one of the considered environments.

each point of the map, the Euclidean distance between all the approximated values in the radio map and the corresponding actual values is computed. The resulting matrix, is then converted in a probability function whose maximum value is the estimation of robot position.

2.3 Integration of WiFi positioning and laser scan data within the particle filters

The third approach aims at the integration of WiFi positioning and laser scan data within the particle filters. The idea to exploit the advantages of both laser (high precision, but subject to ambiguity in symmetrical environments) and WiFi (less precise, but exempt from the previously mentioned ambiguity) positioning.

Two different types of integration are considered: a loose and a tight information coupling. In the loose coupling, given the radio maps of a particular environment, WiFi localization provides a position with a fixed covariance error: the particles that fall in a certain area are selected with a higher probability; the area is defined as an ellipsoid centered on the hypothesis given by the WiFi positioning and the two radii equal to the x and y variances. With the tight-coupling method, radio maps are integrated within the particle-filter algorithm as additional inputs. Preliminary results show that this kind of integration guarantee a fast convergence of positioning hypothesis and also solve the problem of ambiguity in symmetrical settings.

3 Analysis of the Results

The experiments have been performed in two areas and we present here some preliminary results. The first area is a corridor (70 m) of a building, and the localization problem reduces approximately to a monodimensional localization problem; the second area is rectangular (40×20 m), therefore a complete bidimensional localization problem is faced. In Figure 2 the results of the localization process in the first area are shown. The black line is the error of the WiFi positioning algorithm

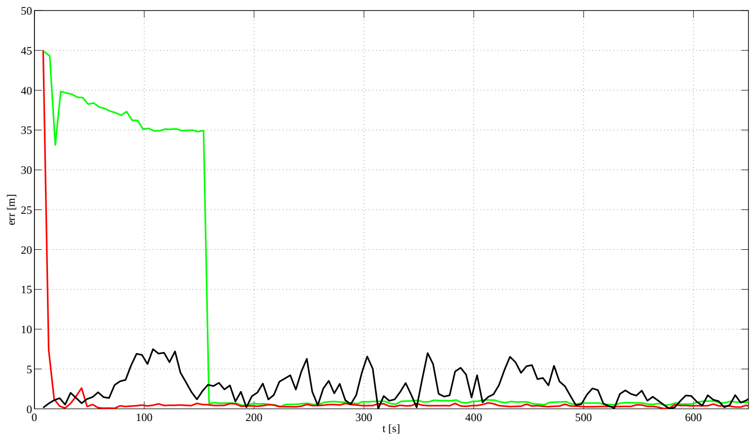

Figure 2: The localization error in the first area

described in the subsection 2.2, the green line is the result of the particle filter algorithm described in subsection 2.1 and finally the red line is the result of the loose integration described in subsection 2.3. As can be noticed, the localization process has a faster convergence when WiFi and Laser technologies are integrated, since the localization time is decreased from 160s to 20s.

References

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