A MULTI-SENSOR FUSION FOR INDOOR-OUTDOOR LOCALIZATION USING A PARTICLE FILTER

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ABSTRACT: The location of people and objects relative to their environment is a crucial piece of information, and the need to obtain a precise position in a short time at any point, leads to use an efficient navigation system. We distinguish the outdoor and the indoor environments, for the first case the localization information can be provided by a constellation of satellites called a Global Navigation Satellite Systems (GNSS) such as GPS or Galileo, but in the indoor environments other techniques are used. This paper provides a Multi-sensor fusion (GPS and UWB) for indoor-outdoor localization using a Particle Filter and we evaluate the combination of both technologies.

KEY WORDS: indoor localization; fusion data; UWB; GNSS; RF localization; particle filter.

1 INTRODUCTION

Several systems for position detection have been proposed and implemented. For applications in outdoor environments (excluding buildings), Global Navigation Satellite System (GNSS) such as GPS system, based on a constellation of satellites, is generally used (Qiu 2012). However, the GNSS signal doesn't strong sufficiently to penetrate through different materials used in construction, also the phenomena of reflection and multipath fading limit the utility of GNSS in dense urban or in the indoor environments. This is why indoor location systems have been developed. They can be classified into three broad categories based on the transmission medium used: InfraRed (IR), UltraSound (US) and RadioFrequency (RF).

InfraRed System: Infrared Localization is a method to determine localization of mobiles or people by using different infrared transceivers. The localization method using Modulated Infrared (IR) technology provide advantages such as confinement of the signals inside the room (IR does not penetrate through walls) and the absence of radio electromagnetic interference. In addition the power of transmitted IR signal can be easily adjusted to cover only the area of interest. The position of the mobile is determined using the position of the closest receiver. This technique requires the line of sight between the transmitter and the receiver, which is not possible in all cases.

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In addition, the presence of sunlight is an obstacle for this technology because it disturbs the infrared transmission.

UltraSound System: Ultrasonic localization system use ultrasonic waves to measure distance between fixed point station and the mobile system whose position is being determinate. To implement such a system there are needed multiple ultrasonic receivers. Synchronizing receivers is done via IR or radio waves, because the speed of radio waves is much greater than the speed of ultrasonic waves. The transmitter sends at the same time a radio signal and an ultrasonic wave. Radio signal reaches receivers almost instantaneous, giving them the synchronization signal. Receivers start to measure time between synchronization signal and the detection of ultrasonic waves, and then calculate the distance between transmitter and them.

RadioFrequency System: Today, many public and private buildings are equipped with wireless IEEE 802.11b, a popular and inexpensive RF technology. Unlike ultrasonic and infrared signals, radio waves have the ability to penetrate walls which increases the coverage area, and minimizes the number of necessary equipment. Most 802.11b devices measure the signal strength of the received packets natively. A tracking system operator only information received power level allows implementing easily a location service. This is why systems are the most efficient location based on the analysis of the power level of the received signal. These systems are limited by the complex nature of radio signal (the effects of multipath, noise and interference) but have the advantage of not requiring line of sight between the transmitter and receiver (Cypriani 2008). Among the radio frequency tracking systems, we find localization techniques based on: WLAN [3] [4], ZigBee (Riaz 2009), Bluetooth, UWB (Ultra Wide Band) and RFID (Mori 2008).

Current approaches are moving towards hybridization using two or more localizations techniques and could realize independently the estimation of the position and provide continuity of service sought (Patwari 2005).

In general, the function is provided by GNSS (Global Navigation Satellite System, such as a GPS, GLONASS or the future system Galileo) in the outdoor environment, and then complemented by another indoor technique. According to the different researches conducted in this area, the accuracy of the localization techniques are shown in Table 1.

Table 1: Comparison of the localization system.

System	Accuracy	Range	Signal	Cost
GPS	1 – 5 m	Outdoor	R F	High
Active Badge	7 cm	5 m	I R	Moderate
Active Bat	9 cm	50 m	U S	Moderate
Cricket	2 cm	10 m	U S	Low
UWB	10 cm	15 m	R F	Moderate
LANDMARC	1 - 2 m	50 m	R F	Moderate
INS/RFID	2 m	Indoor	R F	Moderate

2 THE PROPOSED SYSTEM

The performances of the hybrid system are a promising area of research which we develop and propose a new design of a hybrid system based on the combination of different kind of technologies to provide an accurate localization Figure 1.

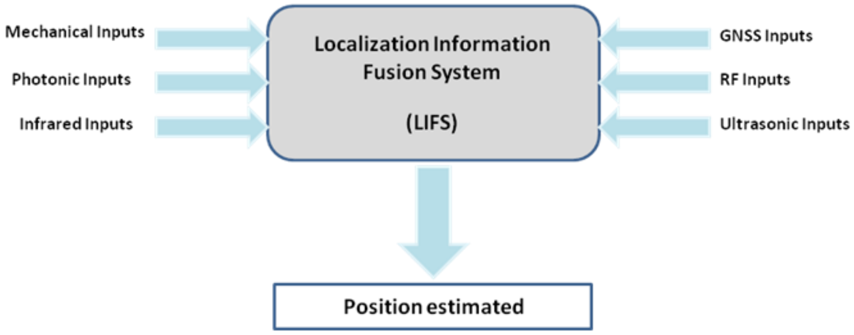

Figure 1. Synoptic diagram of the system proposed (LIFS)

In the first step of our researches, we focused to deploy the two technologies GPS and UWB sensors, used for localization in both outdoor/indoor environments.

2.1 UWB Technology

Ultra-Wide Band (UWB) is a quite new technology with major advantages for wireless communications . It is based on the transmission of short pulses in the band between 3.6 and 10.1GHz. Apart from communication, it can also be exploited for positioning, since the distance between two antennas can be accurately derived through TOF (time-of-flight).

From the localization point of view, the main advantages of this system are:

- UWB signals have a low susceptibility to multipath fading.
- The signals can penetrate through objects.
- It exhibits precision ranging at few centimeter.
- UWB pulses are time modulated with codes unique to each transceiver pair and provide a secure communications.
- As the signals are of very-low power, there can be small transceivers.

2.2 Particle Filter & Algorithm Formulation

The location information is often noisy (ambient noise, susceptibility of equipment, interference, etc.). To improve the position's estimation, it is recommended to use a specific filter which takes into consideration the measurement, the historical trajectory and the characteristics of mobile's movements (Ferris 2006).

In this paper we propose to use a Particle Filter which is a general Monte Carlo method. It works by representing the posterior estimation of the possible mobile's poses by means of a set of weighted samples (particles) and compute the position estimate. The major advantage of this approach is its capacity to combine measures from different kind of technologies and the Particle filters are easy to implement. In our work we follow the *Sampling Importance Resampling* (SIR) algorithm (Verma 2012). We denote x_t, m_t as the system state and the measurement at time t. Figure 2.

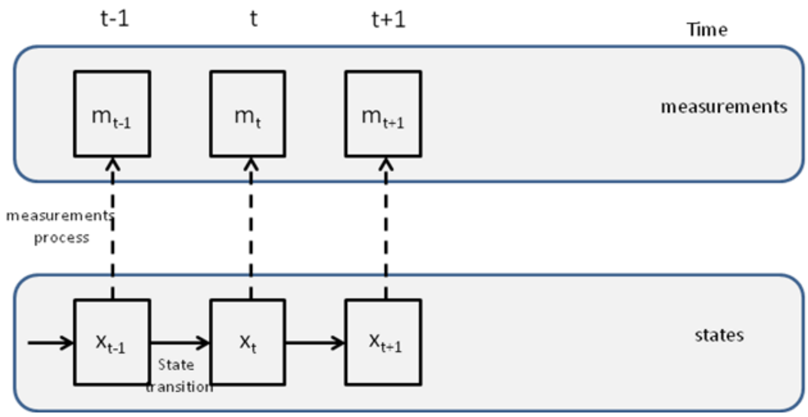

Figure 2: State transition and measurement process in *Particle Filter*

This filter is generated by the following steps (Orhan 2012):

Initialization: sampling N particles {xi(0), i=1 … N} according to the initial probability density function p(x(0)).

Prediction sampling: For each particle xit, get a new particle xit+1 from the transition p(xt+1|xit).

Importance Sampling: For each new particle xit+1, calculate ωit+1 = p(mt+1 | xit+1).

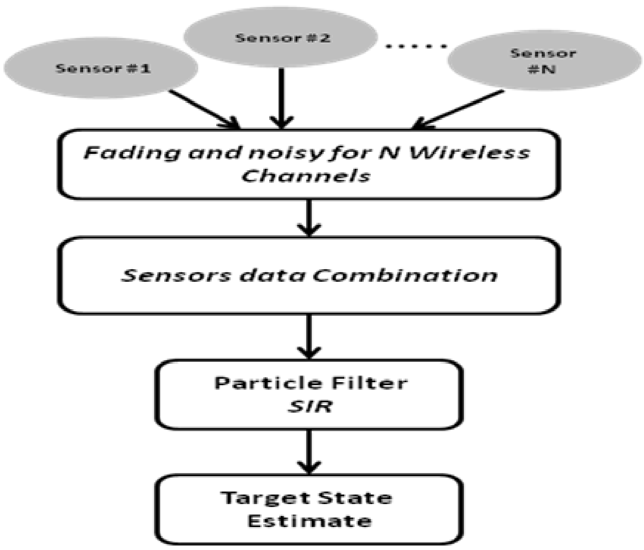

Figure 3: Structural Framework of the proposed Indoor-Outdoor positioning system

3. EXPERIMENTS

Normalization and resampling: The weights are normalized and finally resampled. In the resampling step, particles with low weight are deleted and particles with high weight are duplicated such that each particle has the same weight.

In this study, a model was established, based on the Figure 3, in order to measure the real positions to investigate more precisely the combination of these two tracking systems that are complementary in terms of radio coverage. The architecture implemented allows for interactions between different technologies to provide a final location more accurate compared to that given by each of these sensors. Each location technology gives an estimated position of the mobile, after combination and filter applying, we extract a single position which is the best position returned by each of these sensors

In our test scenario, nine UWB sensors are placed, in different place in the building as showed in Figure 4, at the coordinates $R_i(X_{UWBi},Y_{UWBi})$ i=[1,…,9] to cover the indoor part, the mobile is equipped with UWB antenna (PulsON410), GPS Receiver and odometry system.

Before starting the test, we have established a database which contained the real coordinates of the positions that the mobile will pass while testing (Off line phase). During the mobile's movement, the signal from UWB, GPS, and the combination of both, when available, is used for estimating the Mobile location. We stored these different values and compared to the real coordinates collected in the first phase.

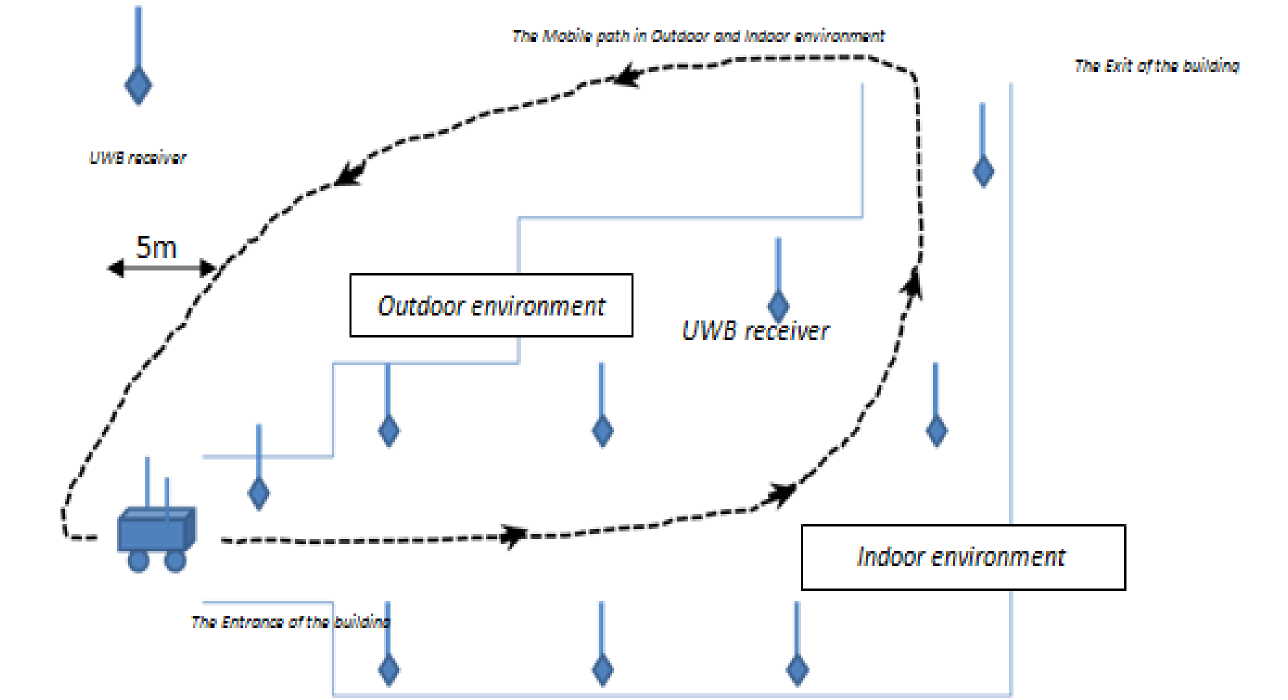

Figure 4: Plan of the laboratory, including the location of the UWB sensors

We have compared three different situations:
a) The Mobile position is determined only by the odometry system,
b) The Mobile position is estimated based on the UWB sensors,
c) In the Outdoor environment, the GPS information is also combined to improve Mobile localization.

We defined the error function ε(x,y,z) as:

$$\varepsilon(x,y,z) = \sqrt{(x - xi)^2 + (y - yi)^2 +}$$

With:- (x,y,z) the real coordinates (Off line phase)

- (x_i,y_i,z_i) the estimated coordinates

Note that in certain phases of our test scenario, the mobile received the signal from only one or two sensors (three sources are, at least, necessary to estimate the mobile by triangulation) which explains the localization errors on the Indoor part. In our experience, the first 30 s and the last 3 min correspond to the outdoor environment Figure 5.

4. CONCLUSION

In this paper, after a theoretical study, we have presented and tested our positioning system for indoor and outdoor environment by the fusion of data from two kinds of technologies GPS and UWB in order to estimate the mobile's position. This hybrid system provides a result more accurate than a system based on one technology and the simulated experiments have demonstrated the suitability of our particle filter approach to merge readings from these two kinds of sensors for mobile localization in indoor and outdoor environments.

In the future we plan to implement our LIFS (Localization Information Fusion System), which combines data from more sources (RF, IR, Visual sensors) also using another GNSS such as the European system called Galileo.

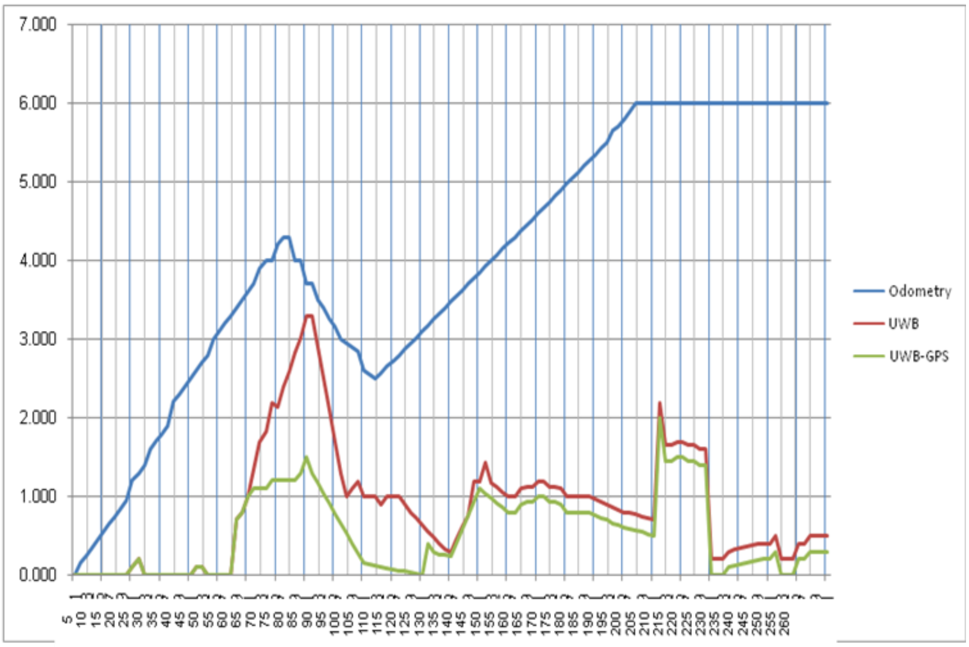

Figure 5: Localization error for the three situations along two loops

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