INMOTION

MOTION COMPATIBILITY AND ADAPTIVE FILTERING FOR INDOOR

Motivation

Localization in the Indoor context (IL) enables Context-Dependent Information Sharing, Navigation (in airports, shopping centres…) and empowers Workforce Management, Social Networking and Healthcare. It also makes Ambient Assisted Living possible, optimizing energy use and enabling people, especially the elderly or disabled, to be more autonomous.

Signals used for Outdoor Localization (namely GPS) are either not precise enough for IL or unavailable. Current solutions exploit the distribution of wireless signals (Wi-Fi, Bluetooth beacons) or magnetic disturbances, which comes with the added cost of fingerprinting the building beforehand and/or maintenance.

Design

Pedestrian Dead Reckoning (PDR) based on Inertial Sensors is an intriguing possibility as it does not require fingerprinting or calibration. However, large error is accumulated very quickly. In order to make PDR stable over longer periods of time, the estimated trajectory of the user is matched with the building floor plan to correct (or at least bound) the localization error.

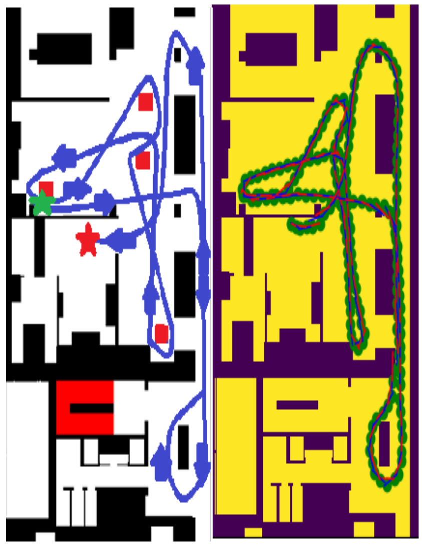

Fig1. Actual route (Left) vs System Estimate (Right). Red Squares represent obstacles that were placed to be walked around.

While the smartphone does have its own set of Inertial Sensors, the fact that its position relative to the user is unknown makes using this inertial knowledge an almost intractable problem. By using an external Inertial Measurement Unit – IMU (Fraunhofer's Pandlets Technology, optimized for use with the Android OS), one can fix the sensor location to the foot. As a result, Zero Velocity and Zero Angular Rate Updates (ZUPT/ZARU) can be used to filter the data and bound errors. The foot attitude (position and orientation) can be continuously estimated.

Additionally, using more than one IMU enables sensor drift estimation, as their noise and bias are independent. As a tradeoff between cost and precision, two foot-mounted, low-cost IMUs will be used.

Contact

Rua Alfredo Allen, 455
4200-135 Porto, Portugal

+351 220 430 300
info@fraunhofer.pt
www.fraunhofer.pt

System Overview

The system provides (near) real-time position estimates. It was developed with computational cost in mind, being more efficient than current state of the art solutions.

The system works with each IMU independently and the information fusion is done at a step level simplifying synchronization.

The IMUs communicate with the Android Phone through Bluetooth.

System Modules

- Attitude Estimation
- Zero Velocity Detection
- Step Quantification
- Fusion of Information from the IMUs
- Map Matching

Results

The system provided an average error of 1.37m over 23 trials in 5 different routes for 5 different subjects (with length between 100 and 121m) with a max error of 2.77m.

In three additional longer routes (300 – 700m) with distributed checkpoints the error was kept below 2m at all times.

Fig2. Placement of the IMU on the foot – under the shoelaces.

Step Detection and Quantification

As the basic element of human gait, movement can be segmented in steps. Additionally, knowledge of the ZUPT periods means that this segmentation results in the window between two ZUPTs, which are detected by multiple Boolean tests. By processing displacement on a step-basis, the respective velocity and position and signals can be forwards and backwards-filtered and reconstructed with added precision.

As the desired output is the displacement on Earth coordinates, it is necessary to convert the inertial signals that are obtained in the sensor frame to the Earth frame. Gyroscope and accelerometer data is fused through a Gradient Descent Algorithm to obtain continuous estimates of the foot attitude.

IMU Fusion

Using an IMU on each foot brings an added source of information – anatomical constraints. By enforcing a maximum distance between the feet, sensor drift can be estimated and compensated.

This is done through a Gaussian Filter Algorithm, which returns a given foot position estimate as a result of the previous foot position, the detected step and the position of the opposite foot (with respective uncertainty).

Map Matching

The Gaussian Algorithm of the previous module is expanded to include a third source of information – the map. Truncated Gaussian distributions (when the position estimates overlap obstacles) are generated through sampling.

Additionally, a Geometric Algorithm specifically tailored for the Indoor context is applied to correct larger errors that may accumulate.

Conclusion

A PDR-based IL solution with multiple foot-mounted IMUs is stable enough to work as a standalone solution (error bounded below 2m) for some scenarios, especially when calibration and fingerprinting is unfeasible.