Master Thesis Proposal

Data fusion and estimation techniques in pedestrian navigation based on inertial/magnetic measurements

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Candidate profile: Preferably with a background on inertial navigation, state estimation, Kalman filter, complementary filter.

Context

This proposal is the continuation of collaboration between the NeCS team (Gipsa-Lab) and the Tyrex team (LIG, INRIA) owing to the Persyval funded exploratory project “LOCATE-ME (LOcalization teChniques for pedestriAn navigaTion based on inErtial MEasurements in indoor environments)”. The LOCATE-ME project already allowed us to build a common and shared vision of state-of-the-art in the domain of sensors fusion and map-based pedestrian dead-reckoning navigation. Both teams develop two fundamentally different estimation methods for pedestrian localization, based on measurements from inertial and magnetic sensors. The candidate will work within the two laboratories and can find easily a room on the campus Saint Martin d’Hères, near to Grenoble University.

Description and main objectives

With the continual miniaturisation of sensors and processing nodes, Pedestrian Dead Reckoning (PDR) systems are becoming feasible options for indoor/outdoor tracking. These use inertial and other sensors, often combined with domain-specific knowledge about walking, to track user movements. There is currently a wealth of relevant literature spread across different research communities. Techniques for step detection, characterisation, inertial navigation [1], step-and-heading-based dead reckoning and map-matching [2], with hybrid systems that use absolute position fixes to correct dead-reckoning output, are proposed in literature. Recent works on developing taxonomies of modern PDRs [3,4] contextualise the contributions from different areas.

More precisely, in the available body of research, two main approaches to measure distance walked and/or to track position (position tracking) are identified. One method is an adaptation of the well-known strapdown navigation algorithm (called also Inertial Navigation Systems (INSs)), which incorporates double integration of the measured acceleration to estimate distance and or position. The solution consists of pedestrian dead reckoning system based on shoe-mounted inertial measurements units (IMUs) [5], [6]. Drift errors, introduced by corrupted IMU measurements, are estimated and corrected via an assisted zero-velocity updating (ZUPT) Kalman filter (KF) [7]. The solution relies on detecting the foot stance phase in order to deliver the zero velocity-based pseudo-measurement to the KF. In its most basic implementation, the state-of-the-art solution consists of a small 9-DOF IMU providing rate of rotation, acceleration and Earth’s magnetic field measurements. These self-contained tracking systems, using small inertial/magnetic measurement units (IMMUs), will not have limitations due to occlusions in the covered tracking space [8]. The other main approach estimates the position based on counting the number of steps, and estimating an
approximate step length (called also Step-and-Heading Systems (SHSs)). This yields an estimation of the distance travelled which is combined with an estimation of the general heading of the body. The main advantage of this kind of methods is that it overcomes the growth in position error that arises from the double integration of acceleration. The system requires an initial calibration (for estimating step length) typically performed as a 30 meters long walk performed once. However, the accuracy with which the step length can be determined, as well as the accuracy for estimating the general heading of the body may both limit this approach. Some researchers reported good results with this method based on the seminal works found in [9], [10]. Results are even better when leveraging on the knowledge of the map of the building in which the pedestrian is moving. In this case, map-matching techniques such as the one found in [11] help in improving the precision of the estimated position. Although these methods have been largely deployed before in literature, it still corrupted with errors. For the first method based on double integration, most of the complexity and any errors come from the fact that the accelerations are measured in the coordinate space attached to the IMU (the sensor frame), and not in a coordinate space easily associated with the room in which the experiment is taking place (the navigation frame). Moreover, the foot stance phase detection need to be improved. Also, there still some limitations of ZUPT for aiding a foot-mounted inertial navigation system (INS) and the implications on sensor error modelling. Multiple significant modelling errors related to the ZUPTs are poorly estimated [12]. For the second method based on step detection, the methods for estimating the general heading of the body still need to be improved in particular when the map is not available, and when the pedestrian is moving in a large unstructured area in which case the map-matching technique is unable to increase the precision.

This master proposal will advance the state-of-the-art by developing new approaches for localization that consider hybrid mixing between INS and SHS existing approaches for enhancing the quality of localization and tracking. Simulation results should be carried out using real data from Smartphone for a selected number of such position estimation. Their performance in the presence of noisy measurements, as well as their advantages and disadvantages should be discussed which will lead to open new issues in this area.

Bibliography