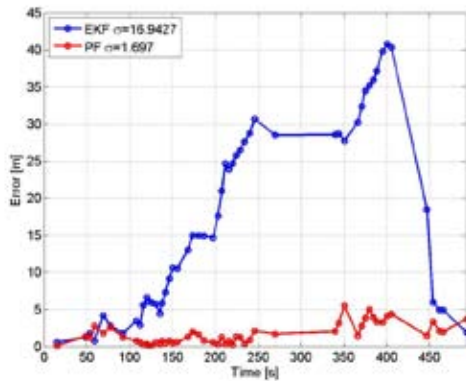


3D track of a pedestrian walking from outdoors into a building and back out through the underground garage.
Sensors used: Compass, GPS, foot mounted IMU and barometric altimeter



The corresponding position error over time for a particle filter that uses the building plan information to constrain motion (red) and a straightforward EKF (blue) that does not use this information and hence suffers from severe drift once GPS reception is no longer possible

DLR at a glance

DLR is Germany's national research center for aeronautics and space. Its extensive research and development work in Aeronautics, Space, Transportation and Energy is integrated into national and international cooperative ventures. As Germany's space agency, DLR has been given responsibility for the forward planning and the implementation of the German space program by the German federal government as well as for the international representation of German interests. Furthermore, Germany's largest project-management agency is also part of DLR.

Approximately 6,000 people are employed at thirteen locations in Germany: Koeln (headquarters), Berlin, Bonn, Braunschweig, Bremen, Goettingen, Hamburg, Lampoldshausen, Neustrelitz, Oberpfaffenhofen, Stuttgart, Trauen and Weilheim. DLR also operates offices in Brussels, Paris, and Washington D.C.



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Information



Reliable Pedestrian Localization with Multi-Sensor Fusion



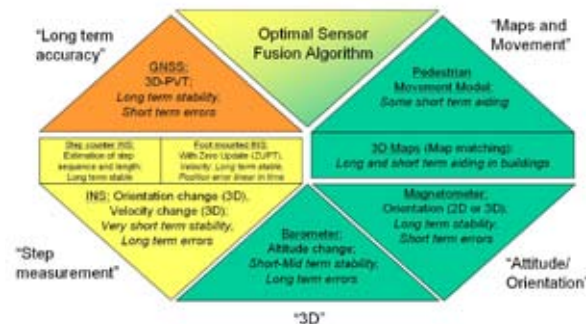
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Indoor Positioning

The location of a mobile user is perhaps the most powerful service and content discriminator and is the central component for personalized navigation services such as ubiquitous travel assistance. The European Satellite Navigation System Galileo will significantly contribute to the quality of positioning services. Together with GPS, it will drastically increase the availability in critical environments such as urban canyons. Compared to GPS, Galileo will provide more signal power at the user's device and not only one but two open signals. Thus, Galileo will open the door for applications based on localization in difficult environments. Since mobile devices are very often used indoors or in urban canyons, new technical solutions to enable accurate indoor positioning and navigation have to be developed.

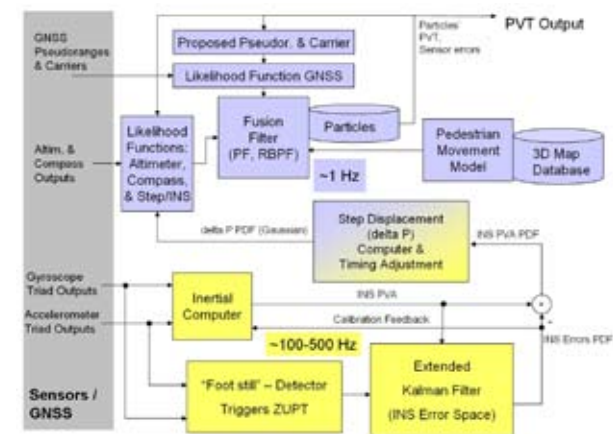
During our work on localization technology we have pioneered the Soft Location principle that allows us to optimally combine different localization sources such as signal level measurements of radio systems, satellite navigation (GNSS), orientation sensors, INS, RFID, as well as appropriate probabilistic models of subjects' movement patterns. The purpose is to ensure consistent Bayesian inference (in particular Sequential Monte Carlo or Particle Filtering) of the subject's movement, activity, and location. Furthermore, applications benefit from the availability of soft location rather than just a point estimate since it allows the reliability of the estimated location to be taken into account. For instance, a routing algorithm will try and compute directions to aid the user that take into account any multi-modalities of the location estimate. Soft information of altitude information is important for emergency applications: the system needs to handle the probabilities with which the subject is located at different stories of the building.

In our work we are addressing sensor combinations that are particularly suitable for addressing such challenging environments. Long-term stability and accuracy as well as global coverage will, of course, be provided by GNSS. Pedestrians' motion can be estimated particularly well if their steps are measured using a foot-mounted INS or step counter. To ensure accurate altitude information – which is particularly difficult for GNSS alone – simple barometric sensors are suitable. In addition, magnetometers provide heading information that improves location accuracy as well as orientation which itself is vital for navigation services. Finally, maps of building layouts and a human movement model are an important ingredient of optimal sensor fusion. Animations of fusion algorithms, reference sensor data recordings and publications can be found at <http://www.kn-s.dlr.de/indoornav/>.



Overview of different sensor combinations which are useful for pedestrian positioning. Long term accuracy and global coverage are provided by GNSS, and this is augmented by additional sensors and a suitable movement model that includes maps. Sensor Fusion is the keystone

In order to process sensors at their appropriate rates we have developed an architecture that operates at two different clock rates: one for high rate INS data using an Extended Kalman Filter and one at a lower clock rate to incorporate the step measurements with all other sensors and maps.



Block diagram of sensor fusion for combining foot mounted INS with additional sensors



Prototype of a pair of boot equipped with MEMS inertial sensors for indoor / outdoor positioning of personnel with high accuracy