Smart Localization Systems

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Accurate localization anywhere and anytime – of vehicles, robots, humans, and gadgets in both the absolute and relative sense – is a fundamental component in achieving high levels of autonomy. The research challenge is to provide scalable, available and reliable smart localization technology needed to enable future intelligent and autonomous systems.

Vision for the project

Background: Smart localization is crucial for all future autonomous systems, including autonomous functions and self-driving vehicles, indoor positioning systems, Internet of Things, as well as asset management and other industrial applications. The challenges in these applications include high complexity, cost reductions, distributed cloud computations, as well as high demands on position accuracy and integrity. Scalability is ubiquitous in all autonomous systems, in particular cloud-based localization systems where many trade-offs are needed in the system optimization, and where the future number of users and nodes in many applications are more or less unlimited.

Objective: Our domain expertize offers a toolbox of algorithms and solutions for localization challenges, and our research aims at analyzing their efficiency in terms of accuracy and integrity for different sensor configurations (cost perspective) and implementation constraints (distributed cloud, time delays, power constraints, etc.). The span of these challenges goes all the way from the very high integrity demands of aircraft navigation to the low integrity demands of personal devices, from the high accuracy of self-driving cars, via the law-enforced accuracy of cellular devices, to the user-defined acceptable accuracy needs of VR-tools.

Connection to other WASP Projects: One important application domain is of course autonomous systems in vehicles, such as self-driving cars and future safety systems, so ATS (Automated Transport Systems) is naturally connected. IPLVIAS includes many central sensor fusion concepts that also apply to localization. It is anticipated that many future localization systems are implemented in the cloud, or are cloud-assisted, so the Autonomous Cloud project is highly relevant. Situational awareness is crucial in all decision support systems, and particular in sensor rich environments the localization is a challenge, so there is a close connection to ICAASE.

Future Demonstrations: There are demonstration arenas suitable for localization at KTH, Lund and LiU, which all include well-defined indoor environment where ground truth reference systems are available. However, localization eventually needs to be evaluated in the real environment. Our industrial partners have access to suitable arenas in many different environments, ranging from vehicles operating underground to in the air. We have had five regular workshops since 2011 where we invite industry to participate in our presentations and see our live demos, a tradition we will continue under the WASP umbrella.

Research Challenges

High-cost and high-accuracy localization in outdoor environments is today relying on GPS, and there is no support to monitor its reliability or backup when it fails to achieve availability. The current challenge lies in developing cost-efficient localization solutions for environments and situations where GPS based solutions are not sufficient. Our research will therefore focus on enabling localization solutions that fulfil the three following performance metrics.

1. Scalability over geographical area and cost of deployment.
2. Availability over space and time, including an ability to adapt over space and time.
3. Reliable, providing trustworthy position information, not only concerning the position accuracy, but also an uncertainty description.

We want to explore these areas using a sensor fusion and learning approach, where redundancy and large data sets are tools to achieve our goals. Cloud solutions including crowd sourcing concepts provide promising ways to access large amount of data from various sensor modalities. New sensor technologies and radio standards offer a steady stream of new sensor fusion challenges, and old paradigms have to be revised for each technology leap. Centralized off-line sensor fusion solutions provide upper bounds on performance, while distributed real-time implementations on incomplete data streams frame our research themes.

Our PhD/sub-projects all relate to these key questions, from both a methodology and an application oriented point of view.

Industrial Challenges

The listed research challenges have strong connections to classical automotive, manufacturing, and communications industry, as well as many new startups and SME companies. One main challenge for our industrial partners is to provide domain expertize which leads to relevant research goals, including specifications of feasible hardware, on-going standardization efforts, and performance needs for their future localization systems. Localization is also of industrial relevance for many other Swedish companies such as Volvo Cars, Volvo Trucks, Volvo CE, and Scania, which are developing autonomous vehicles. Moreover, as localization is a fundamental capability in the design of smart products and systems it is a enabling technology for hospitals, industry asset management, infrastructure for traffic, logistics, water, gas, electricity and building control, etc. Localization is also a hot topic in the gaming industry and AR and VR applications. Noteworthy is that we have a number of successful spin-offs in the area of localization, including Combain Mobile and MAPCI from Lund, Senionlab and NIRA Dynamics from Linköping, and the OpenShoe project and 13th Lab from KTH.

Sub-projects

Distributed autonomous systems for localization and mapping

Andreas Bergström (industrial student), Ericsson and LiU

In this project we will investigate and develop new methods and software for modeling, analysis, and design of interconnected control systems that: 1) scale well with problem size, 2) can be implemented in a distributed fashion, and 3) respect privacy. The choice of wireless communication strategy has big impact on what performance can be achieved. The context in which we will study this in is a distributed autonomous system for localization and mapping.

Management of Distributed Autonomous Systems

Per Boström (industrial student), SAAB and LiU

Previous works related to this research area have covered coordination (trajectory planning) of multiple heterogeneous flying sensor platforms in order to optimize tracking performance of ground targets. This project will also make use of an aerial vehicle system-of-systems setting, but rather than trajectory planning it will be focused on autonomous resource management and how the sensors in a network of flying autonomous systems should cooperate to obtain an overall situational awareness.

Localization using large arrays of inertial sensors

Håkan Carlsson, KTH

This project considers the use of large arrays of low-cost inertial sensors to form cost efficient virtualized high performance sensors through local sensor fusion. Such sensor arrays will both offer new sensing modalities, as well as through redundancy enable the ability to self-calibrate during operation. The research challenges in this project relate both to classical questions applied to the new sensor structures, such as parameter identifiably – what can be measured and corrected for in a given array – and also to the development of computationally efficient optimization procedures for the high dimensional and typically non-convex optimization problems that arise in the parameter estimation step of the sensor fusion.

Localization and Monitoring of Vehicles supported by Inertial Sensors
Martin Lindfors, LiU
This PhD project investigates how cheap inertial sensors can be used to monitor wheeled vehicles. One aspect is to estimate the speed of the wheels, and use this in an odometric navigation system. Another aspect is to monitor the driveline for faults and the road/track state. Field tests data are obtained from NIRA Dynamics. The research includes new ways to pre-process almost periodic signals to suit a sensor fusion framework.

Positioning in Underground Mines
John Svensson (industrial student), Boliden and LiU
This PhD project concerns localization in mines co-habited with humans and machines using different radio technologies. The research targets both autonomous driving and safety aspects. Collaborations with Ericsson for 5G technologies and Cisco for next generation WiFi products serve as drivers for research. There is a rich literature on sensor networks, with generic scenarios with agents (moving) and anchors (stationary), while we here have a unique application that fits the standard models, but adds all aspects of a real application, that is believed to lead to a revised set of research questions.

Robot mapping
Jiexiong Tang, KTH
The main scenario for this robot mapping project is a flying robot equipped with a set of sensors such as cameras and laser scanners. The focus will be on mapping where GPS or other infrastructure solutions to localization is not available. The environment can be anything from a structured indoor setting such as an office building to a tunnel or mine. Two avenues for research are initially envisioned both connected to a long-term autonomy scenario. One is to study how to improve the model over time, for example, by increasing geometric accuracy, more details in textures, and by associating common structures across space and time. Another one is to study how to extract and incorporate semantic information into the map and to explain as much of the data in it as possible by, for example, being part of objects.