UNIVERSITÄT ZU LÜBECK
INSTITUTE FOR ELECTRICAL
ENGINEERING IN MEDICINE

Bachelors / Masters Thesis

Localization and Motion Estimation for Autonomous Mobile Robots

Supervisor & examiner: Prof. Dr. Georg Schildbach

Localization is a fundamental building block of autonomous mobile robots [SN2004]. It is essential for decision making, motion planning, and control. Over the past decade, algorithms and systems for localization have been the subject of intensive research, with great advances made in this field.
At the Autonomous Systems Laboratory, we offer a **variety of projects** on localization. These projects typically comprise a theoretical part, the set-up of a simulation, and the implementation on a real system. All projects can be tailored to a Bachelors or Masters thesis. Here are three examples of **possible topics** (details below):

1. Sensor fusion using factor graphs,
2. Visual odometry for autonomous mobile robots,
3. Implementation of an indoor satellite positioning system.

1. Sensor Fusion using Factor Graphs

Localization can be based on a variety of **sensor systems**, which differ according to their accuracy, availability, and price. They provide absolute positions in space (e.g., the global positioning system, GPS), relative information about the position (e.g., accelerometer, gyroscope), or positions relative to a map (e.g., by landmarks).
The data provided by single sensor systems is often very noisy, not consistently available (e.g., GPS in a tunnel), or not complete in terms of all robot coordinates. Therefore, algorithms for **sensor fusion** are needed to combine the measurements of multiple sensors into the best possible estimate of the robot's position and orientation.
Factor graphs (FGs) offer an intuitive and versatile framework for handling random noise and disturbances in dynamic systems [Loe2007]. In this holistic approach, any observations can be used to update the current belief state and hence they are naturally suited for the design of sensor fusion algorithms.

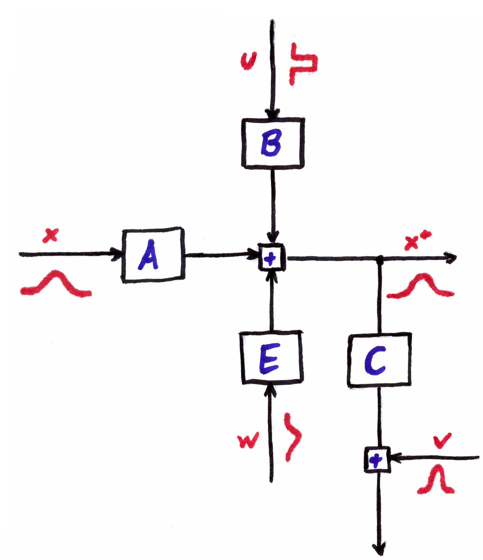

Fig. 1: Factor graph of a linear state space representation.

.

2. Visual Odometry for autonomous mobile robots

Visual odometry (VO) means estimating the motion of an agent (e.g., vehicle, human, and robot) based on the image data from an attached camera [SF2011]. The basic idea is that visual points are tracked over time, and the motion can be computed based on a distance estimate, cf. Fig. 2. The name of VO relates to the term "odometry", which stands for estimating the motion of a vehicle based on information from its wheel sensors.

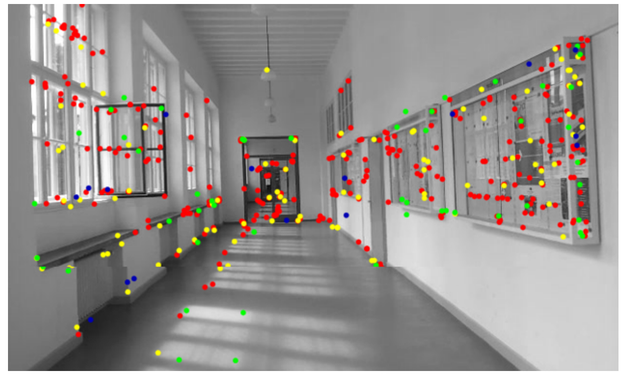

Fig. 2: Visual key points to be tracked by the algorithm (*source*: Sebastian Hilsenbeck, TU München).

The advantage of VO over odometry is that it can not be affected by tire slip, and hence it works also on slippery surfaces or uneven terrain. It has been used, for example, by NASA for its Mars exploration rover. A **video camera** is inexpensive equipment and a standard component of most autonomous mobile robots. Hence image data is readily available for motion estimation.

In this project, **different algorithms for VO** are explored and implemented. The goal is to examine their accuracy and robustness in a laboratory experiment. All of the algorithms have to be real-time capable. Potentially, their weaknesses can be overcome by sensor fusion (see above) with another sensor, for example, an inertial measurement unit (IMU).

3. Satellite Positioning Systems

The global positioning system (GPS) uses distance measurements to three (or more) satellites to calculate an absolute position. While GPS is only available outdoors, the same principles can be used for **indoor localization**.

Here, an off-the-shelf system offered by Faller using **ultra-sound** and **toy satellites** shall be used [FAL2018]. Its basic principle is as follows, cf. Fig. 3. The satellites are mounted to the room's ceiling. The localized robot emits an individual ultra-sound signal, which is measured by the satellites. The distances are computed from the travel time of the ultra-sound signal and sent, by wireless communication, to a base station. There the position is computed up to a few millimeters in accuracy. A PC can be connected to the base station to evaluate the position data.

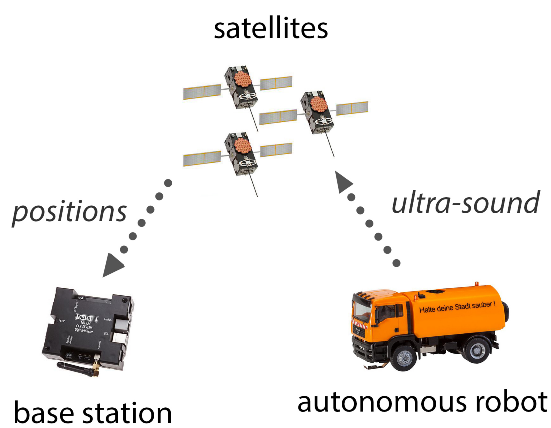

Fig. 3: Principle scheme of indoor satellite positioning based on ultra-sound (*source*: Faller Car System Digital).

The first aim of this project is to better understand the working principles and limitations of the system. To this end, the necessary hardware and a toy robot is available. The second aim is to make the position data available in real-time for **remote control** of the robot via the PC.

References

[SN2004] Siegwart, R., and Nourbakhsh, I.R.: *Introduction to Autonomous Mobile Robots*. MIT Press, Cambridge (MA), 2004.

[Loe2007] Loeliger, H.-A., Dauwels, J., Hu, J., Korl, S., Ping, L., and Kschischang, F.R.: The Factor Graph Approach to Model-Based Signal Processing. *Proceedings of the IEEE* (95), 2007, pp. 1295-1322.

[SF2011] Scaramuzza, D., and Fraundorfer, F.: Visual Odometry. Part I: The First 30 Years and Fundamentals. *IEEE Robotics & Automation Magazine* (18), 2011, pp. 80-92.

[FAL2018] FALLER GmbH: *Car System Digital 3.0*. Available online at: https://www.faller.de/App/WebObjects/XSeMIPS.woa/cms/page/pid.14.18.153.464/lg.en/Car-System-Digital-3-0.html