UNIVERSITÄT ZU LÜBECK
INSTITUTE FOR ELECTRICAL
ENGINEERING IN MEDICINE

Bachelors / Masters Practical Project *or* Bachelor / Masters Thesis

Indoor Positioning using Ultra Wideband (UWB) and Factor Graphs (FGs)

Supervisor & examiner: Prof. Dr. Georg Schildbach

Indoor positioning is rapidly growing research field with a great number of potential applications. It allows the tracking of people or objects inside buildings – e.g., localizing visitors in museums or coordinating firemen during critical operations, or tracking machines and equipment inside a factory.

Using the same principle as the **global positioning system (GPS)**, indoor positioning relies on distance measurements to signal transmitters. For GPS the signal transmitters are satellites in space, allowing accuracies of a few meters and below. However, GPS requires a direct line-of-sight of the sensor to the satellites, which makes it unsuitable for indoor applications.

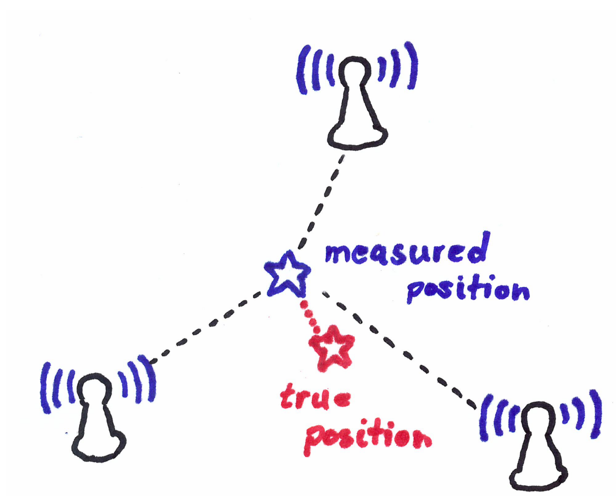

Fig. 1: Localization by distance measurement (principle of GPS and UWB).

Ultra Wideband (UWB) is currently the most promising technology for indoor localization [Ala2016]. It is based on distance measurements by UWB signals, achieving accuracies of a few centimeters and below. Its signals can pass through walls and it is therefore highly suitable for application inside buildings. It consumes very little energy and the necessary hardware is small in size and low in costs. Thus it offers several advantages over other technologies for indoor localization such as infrared, ultrasound, or vision-based systems.

In this project, the goal is to install and improve an **UWB positioning system** in the Autonomous Systems Laboratory, similar to the work of [LA2017]. To this end, Loco Positioning Nodes by Bitcraze, as shown in Fig. 2, will be used (https://www.bitcraze.io/getting-started-with-the-loco-positioning-system/). It features a Decawave DWM1000 module for UWB communication (https://www.decawave.com/products/dwm1000-module).

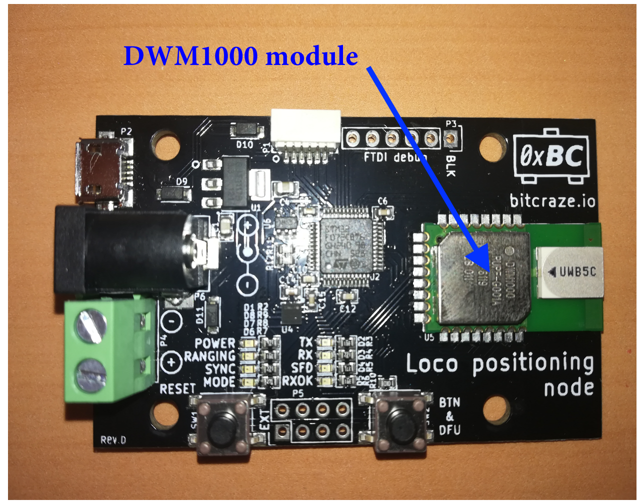

Fig. 2: Loco Positioning Node with a DWM1000 module.

The positioning accuracy of this system is around 10 cm. Thus additional algorithms of **sensor fusion** (using techniques such as factor graphs [Loe2007]) and **machine learning** (using approaches such as sparse pseudo-input Gaussian processes [LA2017]) are needed to improve the accuracy of the system. The goal is to achieve position estimates that are accurate up to a few centimeters and below.

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.

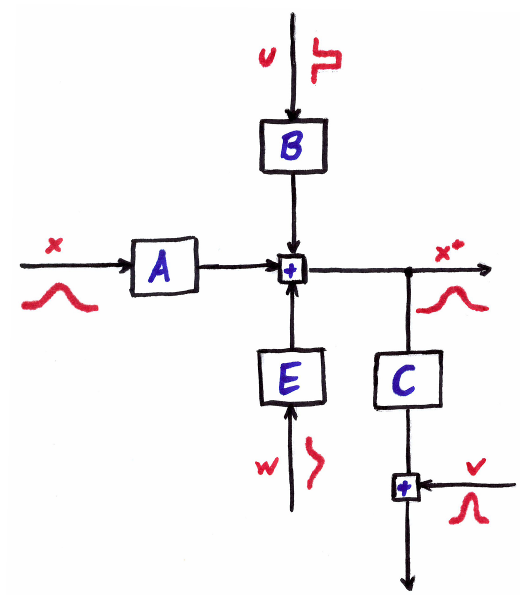

Fig. 3: Factor graph of a linear state space representation.

References

[Ala2016] Alarifi, A., Al-Salman, A., Alsaleh, M., Alnafessah, A., Al-Hadhrami, S., Al-Ammar, M.A., Al-Khalifa H.S.: Ultra Wideband Indoor Positioning Technologies: Analysis and Recent Advances. *Sensors* 16(5), 2016. Available online at: https://www.ncbi.nlm.nih.gov/pubmed/27196906

[LA2017] Ledergerber, A., and D'Andrea, R.: *Ultra-Wideband Range Measurement Model with Gaussian Processes*. IEEE Conference on Control Technology and Applications, 2017. Available online at: https://doi.org/10.3929/ethz-b-000229319

[**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.