Radio Beacon Modules for Relative Localization and Communication

Graduate Candidates

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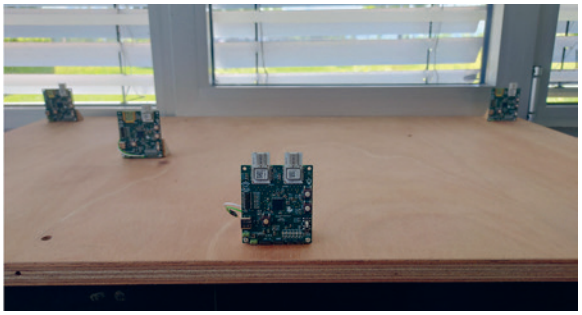
Introduction: These days the use of autonomous robots is increasing. When the robots are outdoors, they can be located with the global navigation satellite system (GNSS). However, when they are indoors, this is no longer feasible.
The goal of this thesis is to develop a system consisting of multiple beacon modules that is capable of locating the devices indoors as well as outdoors. The localization process should be accurate, quick and applicable to networks of varying sizes.
Besides localization, the system should also allow for data transfer between its members.
This work is intended to modularly extend an existing system rather than being a stand-alone product. It provides the required information and means to control and coordinate the networked devices but does not necessarily need to serve as the main control instance.

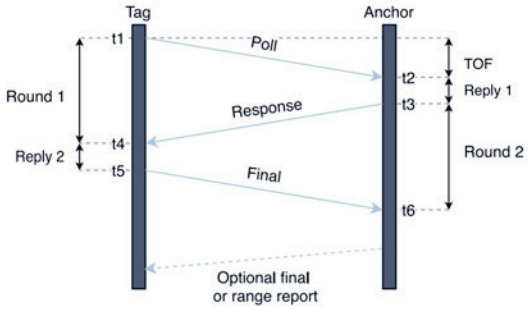
Approach / Technology: The RF standard chosen for this thesis is ultra-wideband (UWB). It has been chosen for its unmatched accuracy for indoor localization, even in non-line-of-sight conditions. For the communication over UWB the Qorvo DWM3000 module has been selected, together with a STM32WB55 microcontroller. The circuit board has been designed by us for the best possible flexibility. The board provides for different communication interfaces and power supplies as well as possible extensions like the integration of an inertial measurement unit (IMU) or a second UWB module.
The distance measurement between two points is done with double-sided two-way ranging, where two ranging message exchanges are done between the points. A timestamp is recorded from each transmission and reception, which allows for the calculation of the duration between initial transmission and final reception without propagation delay.

Result: This thesis serves as a proof of concept. Our hard- and firmware are designed as versatile as possible. There is a variety of possible extensions that could be made, depending on the application. With our work we were able to measure the accuracy of the position as well as the position update rate. It was confirmed that the system works up to a range of ten meters with sub meter accuracy and in a network with ten devices with a refresh rate of 5 Hz. Ultra-wideband prooved itself as a well-suited technology for the purpose of relative localization and communication among multiple networked devices, by virtue of its precision, speed and reliability.

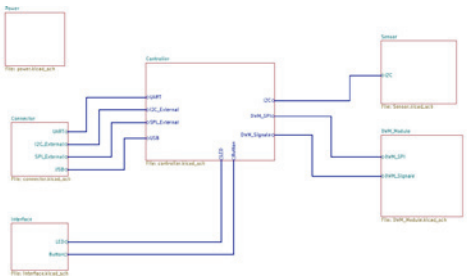
Radio beacon modules deployed in a test setup.
Own presentment



Double-sided two-way ranging
(TOF: Time of Flight, [t1, ..., t6]: timestamps).
https://doi.org/10.1016/j.adhoc.2021.102637



Schematic block diagram of the designed radio beacon modules.
Own presentment



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Subject Area
Embedded Systems