Laser-Based Localization

Two-Dimensional Localization System of a Photodiode

Graduate

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Initial Situation: Many technical processes require the accurate localization of objects in three-dimensional (3D) space. Existing solutions address this issue across various application domains, but are expensive. An established low-cost system for the 3D localization is offered by Valve Corporation in collaboration with HTC as part of virtual reality (VR) headsets and gaming trackers. While primarily used for VR gaming, this system is unsuitable for many industrial applications due to position-dependent deviations of up to several centimeters. The objective of this thesis is to design and implement a two-dimensional optical localization system, consisting of a laser-emitting base station and a mobile receiver tag. The system aims to achieve high-precision and extensibility to 3D localization at a sampling rate of 5 Hz.

Approach: The principle of operation chosen for this work is deflection of plane shaped lasers. Among different deflection methods, the Lighthouse method was identified to be most appropriate. Similar to Valve's solution, a modulated laser is split to form two plane shaped beams rotating around a mechanical axis. The rotation rate is set to 5 Hz which is considered sufficient for industrial applications like product or robot tracking.
Figure 1 illustrates the conceptual model of the adapted Lighthouse method along with the system's key components. The adaptation includes on/off modulation of the emitted laser and encoding the rotor angle with so called de Bruijn codes. This code family supports elegant decoding of the rotor angles at the time instants the receiver was hit by the laser beams. This allows the receiver to determine the azimuth and elevation angles relative to the lighthouse. The de Bruijn codes also admit the distinction of multiple lighthouses, which is a prerequisite for an extension to 3D localization.
Based on this conceptual model, additional requirements were defined to guide the selection and implementation of the necessary components for both transmitter and receiver. The transmitter is developed to reliably emit the rotating laser planes throughout the room in accordance with applicable safety standards. The mobile receiver is responsible for capturing, processing, and reliably digitizing the incoming optical signal. This digital signal is then transferred to a Personal Computer, which decodes the data, calculates the receiver's position, and generates the corresponding real-time visualization of the system.

Result: A high-precision and functional prototype supporting the required sampling rate was implemented successfully, as shown in Figure 2. A corresponding real-time visualization was developed to intuitively display the measurement results, as shown in Figure 3. The system is capable of reliably detecting and determining the position of the receiver at distances of up to 1.5 m. The angular assignment of the decoded signal is correct in 90% of cases, which after processing with a robust tracking algorithm will result in a robustness meeting the needs of practical applications. The standard deviation for a positioning at a 1 m distance between lighthouse and receiver is in the range of 1.03 mm to 0.17 mm, depending on the position of the receiver. These results demonstrate the system's potential, which can be further optimized through technical adjustments.

Figure 1: Conceptual model of the adapted Lighthouse system
Own presentment

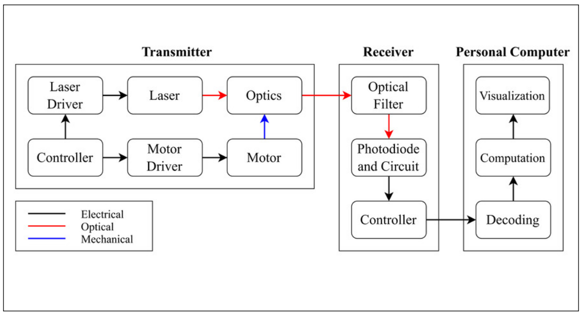


Figure 2: Prototype implementation of the transmitter with laser deflection and shaping (left) and receiver (right)
Own presentment

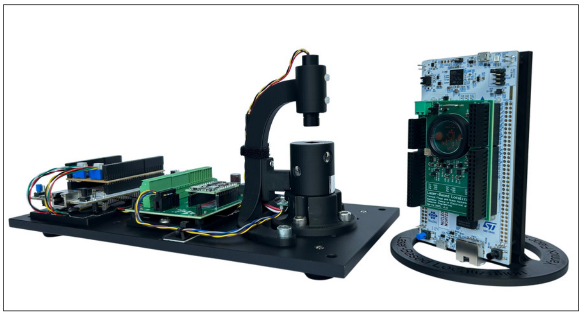
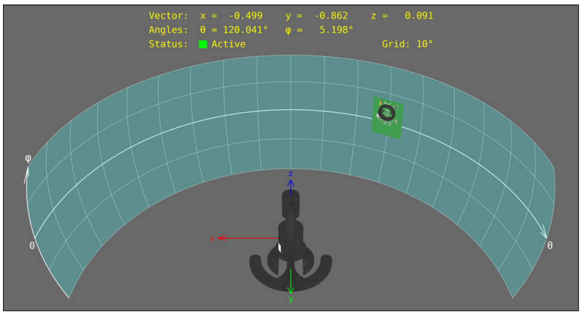


Figure 3: Visualization of the computed receiver position
Own presentment



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