

Topic for Thesis

Ultrasound-based Distance Measurement of digital Name Tags in Relation to a Master Node

Background

Helicoph is a system that was developed in collaboration with Helios Klinikum in Stralsund, Germany, that has improved overall hygiene in hospitals by creating incentives for hand disinfection. A digital name tag allows the hand disinfections performed by individuals to be tracked, which enables self-monitoring as well as subsequent analysis at the hospital level. (Explanatory video from Helios: <https://youtu.be/K3RcfRq9xdg> – only available in german)

The smart name tag and the disinfectant dispensers are each equipped with a Bluetooth transmitter module. When a dispenser is activated, it searches for the name tag that is closest to the dispenser in order to record a disinfection process. The name tags regularly transmit information about themselves in the form of a Bluetooth beacon, which is collected by the dispenser. The distance between the dispenser and the name tag is derived from the reception strength of the received data packet. However, if there are several people in the immediate vicinity of the dispenser, the determination is prone to errors. The signal strength of the beacons can be affected by possible reflections or sources of interference, which can lead to incorrect results when determining the distance.

For this reason, research shall now be conducted to determine whether such a system can also be implemented using sound signals. Unlike electromagnetic waves, sound propagates at only approximately 343 m/s through the air, which means that a distance of just a few meters already results in a difference in the millisecond range. The idea is now to measure the distance of the device based on the time difference in sound propagation. One method in which the dispenser emits an ultrasonic signal when activated and the distance of the name tags is estimated based on the volume at which this signal is received has already been investigated. In practice, however, this method has some shortcomings, which is why other methods are being sought. For example, since ultrasound is emitted in a very directional manner, people who are not standing directly in front of the dispenser with their name tag are generally disadvantaged in the measurement.

Task description

In this thesis, another method shall be developed together with the creation of a prototype to carry out experiments and to enable comparisons between the different methods. Small development boards such as Raspberry Pi, Arduino, or ESP32 can be used for the development. In addition to these boards, (ultrasonic) microphones and (ultrasonic) loudspeakers are required to transmit and record the sound signals. The necessary components will be provided and do not need to be procured independently. Initial experience with C/C++ and the use of development boards is desirable, but not essential.

The following steps can be considered:

- Literature review and analysis of the state of the art
- Familiarization with audio libraries for the modulation of sound signals, such as <https://github.com/pschatzmann/arduino-audio-tools>
- Development of a protocol for determining the distance between transmitter and receiver
- Familiarization with Bluetooth Low Energy and data exchange (direct & broadcast)
- Setting up a test environment, conducting experiments with prototype
- Analysis and comparison of the various options for determining the name tag

Possible research questions

The practical usability of the developed methodology shall be tested using various experiments. The following questions can be used as a basis for possible experiments. A sensible selection should be made – not all questions need to be answered. If further interesting questions arise during the course of the work, these can also be addressed in more detail.

- How accurately can the distance between the transmitter and receiver be determined using sound?
- How precisely must the transmitter and receiver be aligned with each other in order to achieve good results?
- How error-prone is the system? Do conversations or background noise interfere with the process?
- How much energy do the devices consume during the determination?
- How much time is required to complete the process?
- Depending on the implementation: What is the limit on the number of name tags that can participate in this process, assuming that the determination must be completed in a maximum of n seconds?

References

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- [Sha+10] Bilal Shahid, Anushiya A. Kannan, Nigel H. Lovell, and Stephen J. Redmond. “Ultrasound user-identification for wireless sensor networks”. In: *2010 Annual International Conference of the IEEE Engineering in Medicine and Biology*. 2010, pp. 5756–5759. DOI: [10.1109/IEMBS.2010.5627849](https://doi.org/10.1109/IEMBS.2010.5627849).