Room-Sized Indoor Localization Using Convolutional Neural Networks

Graduate

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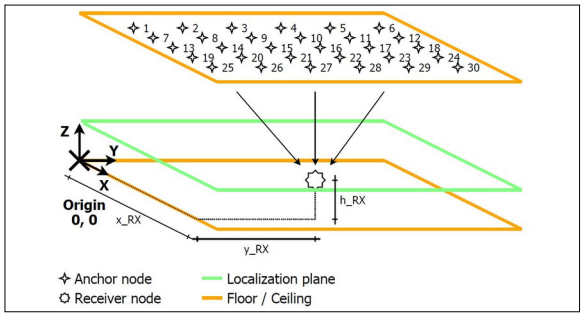
Introduction: Accurate indoor localization using common wireless protocols is a still-evolving research topic with varying technologies and approaches. The received signal strength indicator (RSSI), a measure of the received power level, is available in wireless protocols such as IEEE 802.15.4 (Zigbee) and IEEE 802.11 (WLAN). The goal of this thesis is to implement a localization algorithm capable of close-range indoor localization using only RSSI information. A broadcast wireless sensor network (WSN) consisting of thirty anchor nodes is built using provided hardware operating according to the Zigbee standard. While the received signal power depends on the distance between transmitter and receiver, multipath shadowing limits the achievable accuracy of trilateration algorithms in an indoor environment. Because of this limitation, RSSI fingerprinting using artificial neural networks has become popular for accurate indoor localization. Recent convolutional neural network (CNN) approaches have achieved remarkable accuracy.

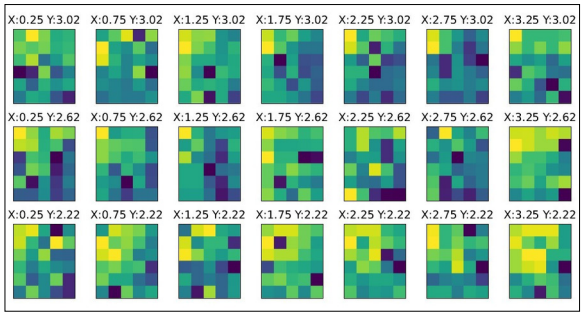
Approach: First, theoretical background regarding multipath propagation interference for wireless protocols operating in the low GHz spectra is given. The advantages and disadvantages of trilateration algorithms and fingerprinting approaches are discussed. Hard- and software tools for RSSI fingerprinting data set collection are built and tested. Using these tools, two independent data sets for training and testing of indoor localization algorithms in a two-dimensional space are collected. Artificial neural network architectures (FFNN, RNN, CNN) are introduced and compared for the application in an indoor localization algorithm. The best performing trained network is implemented on a Raspberry Pi, demonstrating that inference in handheld devices is possible.

Result: Multipath propagation will dominate the RSSI signal for a WSN operating in a close-range indoor application. The interference pattern is defined by the room and obstacle geometry. The RSSI interference pattern can be used for increasing accuracy of a fingerprinting localization algorithm if a sufficiently small measurement grid is chosen. In practice, a fingerprint measurement grid of a third of a wavelength of the WSN carrier frequency has shown to produce good results. Two large data sets with a small and accurate measurement grid for training and testing of indoor localization algorithms are collected and pre-processed. The training data set consists of 1.7 million individual network samples and over 21,000 labeled measurement positions. The best performing pre-trained CNN achieves a localization accuracy with RMSE = 0.34m over a test bed area of 3m x 2.84m. To the author's knowledge, there is no report of a more accurate indoor localization system using only IEEE 802.15.4 RSSI inputs.

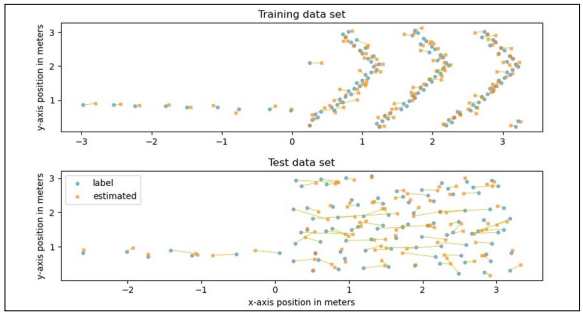
Sketch of the implemented WSN. Thirty anchor nodes mounted to the ceiling, receiver node on the localization plane.
Own presentment



RSSI input samples of the training data set sorted according to the receiver position on the localization area.
Own presentment



Quasi random evaluation samples of the final convolutional neural network architecture.
Own presentment



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Subject Area
Sensor, Actuator and Communication Systems