Indoor localization simulation framework for optimal sensor placement to increase the position estimation accuracy

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Indoor position estimation is an important part of any indoor application, which contains object tracking or environment mapping. Many indoor localization techniques (Angle of Arrival - AoA, Time of Flight - ToF, Return Time of Flight - RToF, Received Signal Strength Indicator - RSSI) and technologies (WiFi, Ultra Wideband - UWB, Bluetooth, Radio Frequency Identification Device - RFID) exist, which can be applied to the indoor localization problem. Both the techniques and the technologies have their advantages and disadvantages. Certain techniques might require fingerprinting (RSSI), others might need time synchronization between the devices (ToF, RToF) or a more complex hardware configuration (AoA). Furthermore, not all technologies work well with every technique. While the WiFi, Bluetooth and RFID might be good with RSSI, they might not be the optimal choice for ToF or RToF. Since the precision of the ToF and RToF depends highly on the sampling rate and signal bandwidth, it is more suitable for the UWB.

The UWB has several advantages over the aforementioned technologies. It uses ultra-short pulses with time period of less than a nanosecond, resulting in a low duty cycle which leads to lower power consumption. Its frequency range is from 3.1 to 10.6 GHz with a bandwidth of 500 MHz. These make it practically immune to interference with other systems since it has radically different signal type and radio spectrum. Moreover, the signal (especially in its lower frequencies) can penetrate through walls, because signal pulses are very short. Utilizing this attribute it is easier to differentiate the main path from the multipaths, providing more accurate ToF estimations.

Once the distances are measured the position can be calculated. There are various algebraic methods to estimate the position (for example triangulation, multilateration). Both of these methods require a few devices with known fixed positions (anchors) to calculate the position of the moving device (tag). While both methods give an exact position in theory, real distances have an error which depends on the technique and technology used, and it is making the calculated estimates less reliable.

The aim of this research is to propose a simulation framework, which uses genetic algorithm and the multilateral method to determine an optimal anchor placement for a given pathway in an indoor environment. In order to make the simulation more realistic, we measured the error characteristics of the DWM1001 module (a commercially available localization system) and implemented it in the simulated model. The module uses UWB technology and RToF to determine the distance between 2 devices.

ACKNOWLEDGEMENT

This research was supported by the projects ”Extending the activities of the HU-MATHS-IN Hungarian Industrial and Innovation Mathematical Service Network” EFOP-3.6.2-16-2017-00015.