Indoor Localization using IR-UWB

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Ultra-wideband technology provides an excellent mean for wireless positioning due to its high resolution capability in the time domain. UWB is particularly well suited for localization indoors, where multipath environments make classical narrowband positioning unsuitable. Many commercial and industrial applications rely on positioning, such as retail, logistics and tool/robot/vehicle/people tracking, and could benefit from this technology.

The large bandwidth of ultra-wideband (UWB) radio (e.g. 500 MHz or more) offers high temporal and spatial resolution, which is beneficial for performance in strong multipath indoor propagation environments. More specifically, UWB enables centimeter accuracy in ranging. This feature is particularly interesting for many applications, from industrial (logistics, retail), consumer (home appliances), robotic, medical and sports (tool/vehicle/people tracking) to safety (access). When coupled with the Global Navigation System, UWB localization is seen as a means for augmenting the global navigation experience by enabling enhanced indoor accuracy.

Several techniques have been investigated in the past for indoor positioning, such as Wi-Fi-based or methods using received signal strength (RSS) and the "fusion" of inputs from multiple sensors. Recently, UWB has proven to be the most promising technique for improved indoor positioning, due to a combination of performance, affordable complexity and cost. During the last ISPN Localization Competition [1], 6 out of 10 of the winning localization technologies were based on UWB. Among them, the best were solely based on two-way time-of-flight (TWTOF) ranging and reached a 3D accuracy of 16 cm without calibration, whereas the best Wi-Fi based systems achieved not better than 1.2 m 2D accuracy with calibration.

CSEM has also been focused on TWTOF ranging with UWB for several years. This solution has been identified as offering the best trade-offs in terms of integration (small and low-power), cost and deployment (no calibration required). Other methods using angle-of-arrival (AOA) and time difference of arrival (TDOA) can also be used by TOF-based devices depending on the system and infrastructure requirements.

Recently, CSEM in cooperation with the startup 3db Access developed a highly integrated ASIC using Impulse Radio UWB (IR-UWB) for TWTOF ranging. The successful implementation of this circuit enabled the rapid development of a localization test setup. First experiments focused on 2D localization over a restricted indoor area as depicted in Figure 1 (top left).

For 2D localization, the minimum of three fixed UWB anchors were placed on the corners of a 2 × 4 m area on the floor (blue dots on the top right figure). Several points were accurately reported on a track representing a rectangle defined by the anchors (ground truth position, red crosses). TWTOF ranging measurements were taken between the unknown positions and the anchors. Trilateration using a least mean square (LMS) algorithm was used to extract positions (black dots). The latter points represent raw positions. For each of the 30 measured positions on the rectangular track, 10 ranging measurements were performed with each of the three anchors. The median position is extracted out of these 10 positions. To improve LMS accuracy, the previous position has been used as first guess for the actual position.

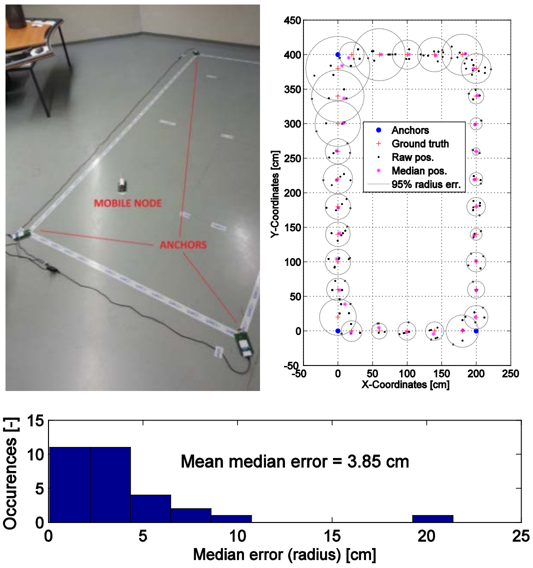

Figure 1: 2D indoor localization setup (left), raw results (right) and histogram of median position error for 10 measurements per position.

Results illustrated in the Figure 1 (top right) show non-optimum situations where the positions are close to anchors, the concrete wall and the floor. Individual measurements were found to have errors of up to 30 cm (grey circles); however, the median position (Figure 1, bottom histogram) over an average of 10 measurements displayed an outstanding performance, with a mean error of less than 4 cm, and a maximum error of 20 cm (due to first calculated position).

Initial experiments demonstrated the robustness and the accuracy of UWB for indoor localization. Future work will focus on three topics: 1) the addition of sensor information, such as accelerometers, gyros, RSS or GPS (sensor data fusion) in order to enhance accuracy; 2) the improvement of the localization using algorithms (such as Kalman or particle filter) and/or the diversity (channel frequency, antenna polarization); and 3) self-localization and self-configuration of the anchor nodes. The latter feature is particularly interesting with respect to the potential to reduce the complexity of network installation and therefore increase user acceptance, as manual measurements and configuration methods for obtaining anchor locations are tedious and error-prone. Deployment will be much easier using self-configuring methods where nodes cooperate with each other, estimate local distances to their neighbors, and converge to a consistent coordinate assignment.

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[1] https://www.microsoft.com/en-us/research/event/microsoft-indoor-localization-competition-ipsn-2016/