Demonstration: Low-Cost, User-Friendly, Indoor Localization Device

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ABSTRACT

This demonstration presents a user-friendly, low cost, indoor localization system. The localization is achieved using an integration of inertial sensors, barometer, magnetometer, and a pseudolite constellation that transmits a UWB-standard RF signal. The sensor fusion and localization are performed in two steps. In the first step, we use the signal received from the UWB constellation to generate the location estimate based on TDOA. In the second step, we use sensor fusion and the Extended Kalman Filter (EKF) to generate another location estimate, which has the same accuracy, but improved precision. As a by-product of the EKF localization, we are also able to estimate the orientation of the device.

There is no limitation on the total number of devices that can be simultaneously localized. The update rate is 10 Hz. Higher update rates are possible but they come at the cost of higher power consumption. Once calibrated, the standard deviation of the localization in the horizontal-plane is approximately 6 cm. The EKF further improves the localization accuracy. The total BOM cost of the UWB device is less than $20 USD when purchased in single-digit quantities. The user device is battery-powered; therefore, it is important to keep the power consumption low. This is accomplished by providing a reduced-power sleep mode.

1. INTRODUCTION

In outdoor environments, the most prevailing approach for navigation is to use Global Navigation Satellite System (GNSS) Constellations. The quality of the GNSS service critically depends on the GNSS device having a direct Line Of Sight (LOS) to the satellite constellation. In the urban canyon environment, or indoor environment, the satellite link budget for the user device prevents the signal from being strong enough to provide reliable localization service.

Many techniques have been developed in an attempt to solve the indoor localization problem. The prior work includes: Inertial Navigation System (INS) [6], WiFi fingerprint and ranging [8], BLE ranging [5], Synchronous Light Transmission (which was adopted by HTC Vive Lighthouse [2]), and Visual Light Communication [4]. In addition, the SLAM technique [3] typically integrates several of the previously-mentioned techniques.

2. BODY

In order to improve the accuracy of methods that are based on signal propagation time, we need improved ranging accuracy. The Cramer-Rao lower bound of the pseudo-random code synchronization accuracy, i.e., the ranging accuracy, is inversely proportional to the mean square bandwidth of the RF transmitted signal [7]. The UWB standard, or IEEE 802.15.4, has the advantage that it occupies a much larger bandwidth than most methods and, therefore, it provides a much better ranging performance and an improved immunity to multipath effects.

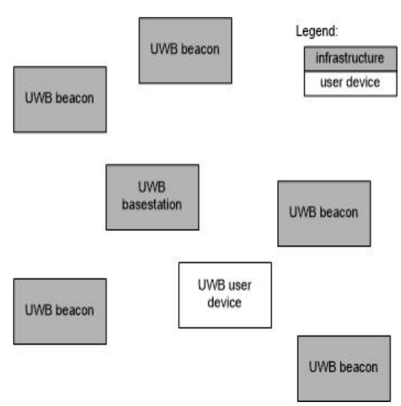

Figure 1: Summary of the system architecture of the UWB localization system.

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Figure 2: Picture of the Hardware.

2.1 Evaluation

Fig. 1. illustrates the system configuration. The coordinates of the UWB beacons need to be known. A base station is required to provide the interferometry reference. Each UWB user device working in receiver mode estimates its pseudo-range to each UWB beacon. The hardware implementing the UWB standard is based on Decawave chip DW1000 [1], which is shown in the left-hand side of Fig. 2. Since the DW1000 chip is a UWB transceiver, the same hardware could be used as the UWB beacon and the UWB user device. The right-hand side of Fig. 2 shows the hardware implementation of the EKF fusion, which is based on the accelerometer, gyroscope, magnetometer, barometer, and UWB-based estimates. The EKF hardware is an add-on option to the indoor localization device. The EKF can, alternatively, operate on a GNSS receiver output for outdoor operation.

3. DISCUSSION AND FUTURE WORK

The indoor localization results of the proposed UWB are shown in Fig. 3. We include both the bias and standard deviation of the 3D-localization results. The bias component comes from several sources, including: the error in the a-priori knowledge of the coordinates of the beacons, the antenna group delay difference, and non-linearity in the correlation process. After proper calibration, the remaining error has a Gaussian distribution, which is shown in the right-hand side of Fig. 3.

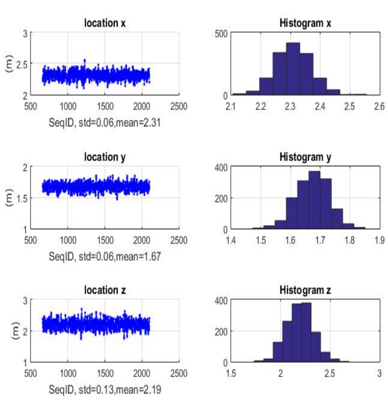

Figure 3: UWB indoor localization results.

The deployment locations determine the dilution of the precision (DOP) in each direction. In typical indoor test scenarios, such as the one used in generating Fig. 3, the z-axis (vertical direction) measurement is often of less importance than the other two orthogonal directions. If we want to optimize the DOP differently and the indoor space prevents the required adjustment, extra UWB beacons may be needed to augment performance.

The UWB user device and its complementary attitude and heading reference system both operate in the passive mode; consequently, there is no limitation on the total number of devices that can be localized at the same time.

Each DW1000 transceiver IC is able to transmit and receive. In any UWB beacon module or UWB user device, only one of these two functions is needed. Hence, the system cost could be reduced further by finding an IC that only transmits and an IC that only receives. Since the UWB signal is very weak, the EKF measurement from the inertial measurement can be used as an extra check of the integrity of the signal that is used for UWB localization.

4. REFERENCES

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