UWB Localization complemented by Impulse Radar

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***Abstract*— This paper describes a novel approach for 3D localization of an object based on fusion of the UWB radio localization techniques and UWB Impulse Radar ranging possibilities. We present a 3D localization system which includes five base stations and a TAG, and introduce the principles of our localization method. The simulation and experimental results indicate that the UWB technology based localization method is suitable for accurate 3D localization even in harsh environments including LOS and NLOS conditions.**

***Keywords*—UWB radio; UWB impulse radar; localization**

I. Introduction

The ultra-wideband (UWB) technology has being applied in different applications such as short-range communication, sensor networks and radar systems. The UWB signals have a large bandwidth which offer several benefits; accurate ranging, robustness to propagation fading, superior obstacle penetration, covert operation, resistance to jamming, interference rejection, and coexistence with narrow bandwidth systems [1].

We present a novel approach for 3D localization based on emerging the UWB radio 3D localization technique with UWB Impulse Radar. The UWB radio localization method is based on the weighted least-square algorithm [2] and provides the (x,y,z) location information. However, the simulation results performed in Matlab environment showed that that positioning accuracy in z-direction is worse than in x- and y-directions in case of UWB radio based localization technique. To achieve more accurate 3D localization results we used a UWB Impulse Radar to provide more precise z - location. The overall system has not yet been tested, because the development for data fusion of the UWB 3D localization and UWB Impulse Radar is still in progress.

II. System overview

The system overview is shown in Fig.1. Five base stations are used for 3D localization of a TAG object. Each base station comprises the UWB radio system, while tag includes both the UWB Radio system and Impulse Radar module. The UWB Impulse radar provides the information on the height of a TAG object measuring the distance from the TAG to the floor. The UWB Radio system consists of a UWB radio chip [3] and ARM CPU unit to control the UWB radio and compute the 3D location of a TAG. All the control and computation functions of the UWB radio 3D location system run on embedded ARM units.

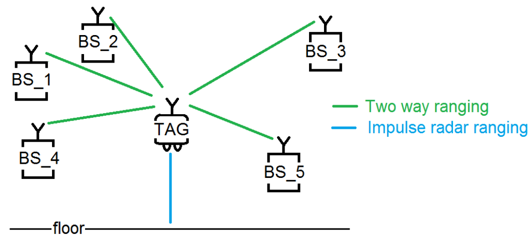

Fig. 1. 3D localization system

The UWB Impulse radar is a commercially available Novelda Impulse radar module [4]. The radar is connected to a computer through the USB interface and is controlled in MATLAB environment. The algorithm development and signal processing has also been performed using the MATLAB in Windows PC environment.

A. UWB radio 3D localization system

The UWB radio 3D localization system is based on a Time of Arrival (TOA) measurement method. UWB radio uses the symmetric double-sided two-way ranging (SDS-TWR) method to remove the need to synchronise base-station clocks and to minimise the error caused by the drift of crystal oscillators in individual base-stations. In the TOA positioning system, TAG measures the ranges to all five BSs. The location of a TAG is then calculated based on the BS's fixed, thus known, locations.

Calibration of the UWB ranging system can be done either by single-point calibration method or linear curve calibration method. Linear curve fitting was carried out to improve the range accuracy.

One of the major challenges of localization systems is the mitigation of non-line-of-sight (NLOS) effects. In NLOS propagation there is no visual line-of-sight from the transmitting antenna to the receiving antenna. Error is usually biased since the first arriving signal has travelled an extra distance. Here, a weighted least-square (WLS) localization technique is used to mitigate the NLOS effects.

B. Impulse UWB Radar System

The ultra-wide band (UWB) impulse radar operation is based on transmitting very short non-sinusoidal pulses and receiving reflected waveforms. The signal reflected by a target is filtered and interpolated at the receiver to achieve better accuracy.

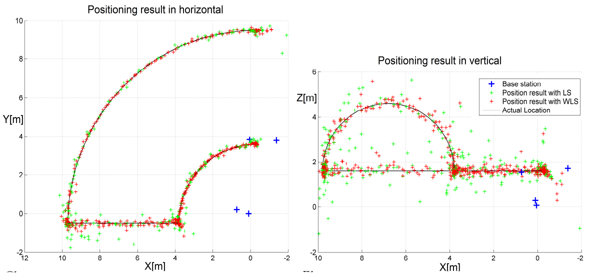

Fig. 2. A). Simulation result in horizontal, B). Simulation result in vertical

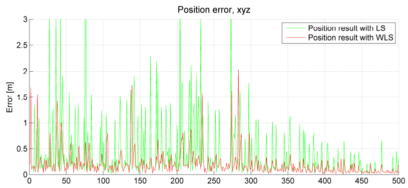

Fig. 3. Position errors in 3D in simulation

In order to determine the unknown target distance the correlation between the reflected signal at an unknown distance and a reference signal is computed. The reference signal is the reflected signal for a known distance. Here, the distance to the target corresponds to the height of the TAG object, its z-location.

III. Overview of the UWB radio 3D localization system performance

A. *Modelling the UWB radio 3D localization system*

The WLS parameters of the location system's positioning were optimized by this simulation. We used Monte-Carlo simulation method. The system simulation was modelled for non-line-of-sight (NLOS) and line-of-sight (LOS) scenarios. Performing the simulations we assumed that the range errors are unbiased normal distributed in the LOS cases and biased normal distributed in the NLOS cases.

In our simulations the least square (LS) based localization technique was compared with the weighted least-square (WLS) localization technique. The UWB Radio is able to detect whether the measuring is done under the NLOS or LOS channel states. In WLS, more reliable LOS range measurements are associated with the higher weights while the NLOS range measurements are associated with the lower weight values. The WLS mitigation technique performs better than the LS technique in NLOS cases.

B. *Simulation results of the UWB radio 3D localization system*

Simulation results for the localization error using LS and WLS algorithms are presented in Fig. 3. The results indicate that the positioning error decreases when using WLS technique. Simulation results in horizontal dimensions (X, Y) are and in vertical dimensions (X, Z) in presented in Fig. 2 A and in Fig. 2 B respectively. Here, the results show that the localization accuracy in the z-direction is worse than x- and y-direction.

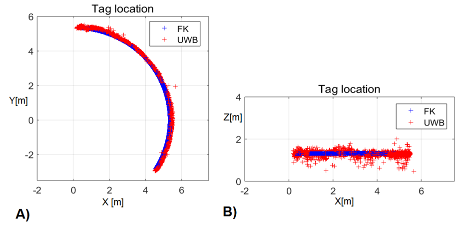

Fig. 4. Experimental test result of UWB radio 3D positioning system in workin machinery environment. A). UWB location and reference location in horizontal. B). UWB location and reference location in vertical.

C. *Experimental results of the UWB radio 3D localization system*

Location system experimental test result is showed in Fig.4. Test is executed on working machinery environment. The main difference between basic indoor positioning system and environment of this experimental is test that the TAG is almost all time outside of area that is formed by base stations. Test result also showed that the positioning accuracy in the z-direction is worse than x- and y-direction.

IV. Impulse radar ranging accuracy

The UWB Radar distance measurements accuracy was evaluated by measuring the distance between the UWB Radar and metal plate. During the measurements robots were used to relocate the radar to predefined distances (1m-10m) from the metal plate. The accuracy of robots movements is within 1 mm range. The measurement results are shown in Fig.5. The maximum error for the distances 1-2 meters is 4mm, and for distances 2-10 meters 8mm.

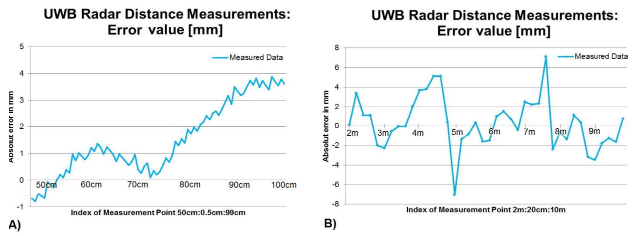

Fig. 5. A). Results from 1-2m distances, B). Results from 2-10m distances

Acknowledgment

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References

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