KAUST Acoustic Positioning System

Hui Chen
King Abdullah University of Science and Technology
Hui.Chen@kaust.edu.sa

Tarig Ahmed
King Abdullah University of Science and Technology
Tarig.Ahmed@kaust.edu.sa

Mohammed AlSharif
King Abdullah University of Science and Technology
Mohammed.AlSharif@kaust.edu.sa

Tareq AlNaffouri
King Abdullah University of Science and Technology
Tareq.Alnaffouri@kaust.edu.sa

Mohamed Saad
King Abdullah University of Science and Technology
Mohamed.Saadeldin@kaust.edu.sa

ABSTRACT

Position information of an object is of great importance in a variety of applications such as navigation and location-based services. Ultrasonic location in indoor environments has recently emerged as an interesting topic, and researchers are considering different systems, algorithms and signals to improve positioning accuracy. The position of an object is frequently calculated based on the range/distance of the object from fixed landmark points.

Normally, three or more distance measurements are required to calculate the position of an object. In our work, target object will send ultrasonic and FM signals at the same time. 4 ultrasonic receivers work as beacons to estimate the 3D position of the target. Each beacon works with a FM signal receiver to realize synchronization. An accuracy of few centimeters can be achieved within the $10 \times 10\ m^2$ indoor environment.

Keywords

Ultrasonic; Localization; Zadoff-Chu; RF signal; Synchronization,

1. SYSTEM OVERVIEW

The Acoustic Positioning System consists of 1 MD (Mobile Device) and 4 BSs (Base Stations) with known locations which is shown in Figure 1. In order to estimate the position of MD, the target will send a series of ultrasonic pulses as well as RF pulses at the same time. Compare to the low speed of ultrasound signal, the propagation time of RF signal is ignorable and hence the BSs can synchronize with the MD to estimate the ToF (Time of Flight) of the acoustic signal. By applying the localization algorithm we can finally estimate the location of the MD.

DOI:

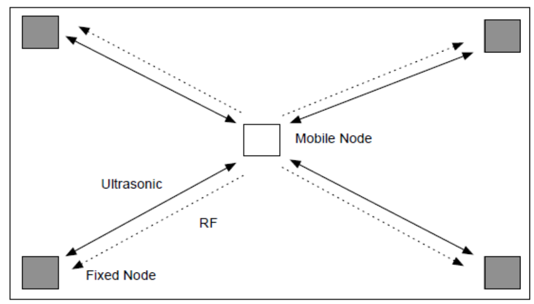

Figure 1: System Configuration

2. SYSTEM REALIZATION

2.1 Hardware

The device hardware is depicted in Figure 2. The MD and the BS are using the same configuration, but their roles of playing as the transmitter and receiver are different. The ultrasonic signals with the central frequency 20KHz and bandwidth of 6KHz are transmitted and recorded through the soundcard connected to a Mini PC. Due to the directionality of the ultrasound transmitter, we placed three sensors in one MD facing different directions in order to make sure all the BSs can receive signal.

All the hardware forming the system are off-the-shelf products with the type information in Table 1.

2.2 Software

All the nodes are connected in a WLAN (wireless local area network) and controlled by a server using TightVNC. The real-time audio processing software Reaper is used to play the signal we designed and record data.

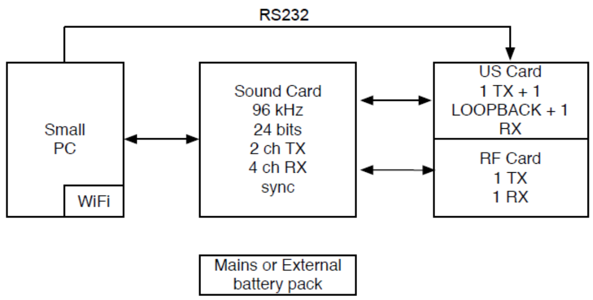

Figure 2: Device Hardware

Table 1: Hardware Type

Device	Type
Mini PC	Stealth LPC-700F
Soundcard	Lynx Studio E44 PCI express
Transceiver Board	Customized
UTx	Clarion Super Tweeters
URx	Knowles SPH1611LR5H-1
RF signal	Stealth Wireless FM kit

The collected data will be uploaded to the shared folder at the server and be processed then. The algorithms are developed in MATLAB and both ultrasound pulse and RF pulse will be pre-defined and stored in .wav format.

3. ALGORITHM DESIGN

3.1 Ranging

A TOF method which depends on measuring the time taken by an ultrasonic signal to travel between a transmitter and a receiver is adopted in our system [1]. The distance between the transmitter and the receiver is then calculated by multiplying the estimated Time of Flight by the acoustic propagation velocity. The delay of the peak of the cross-correlation between the transmitted and the received signals can be used to estimate the TOF relative to a Radio synchronization signal.

Instead of using narrow bandwidth signal, we are using a wideband Zadoff-Chu ultrasonic signal to increase robustness to noise and reverberation. The method applies cross-correlation with earliest peak search and a novel minimum variance search technique to correct the error in the cross-correlation Time of Flight estimate to within one wavelength of the carrier before applying a phase shift technique for sub-wavelength range refinement. The method can be implemented digitally in software and only requires low cost hardware for signal transmission and acquisition.

3.2 Locating

Once we know the real distance between the target and the beacons as well as the locations of all the receivers. A trilateration algorithm can be implemented to estimate the location of the object.

4. REFERENCES

[1] M. M. Saad, C. J. Bleakley, T. Ballal, and S. Dobson. High-accuracy reference-free ultrasonic location estimation. *IEEE Transactions on Instrumentation and Measurement*, 61(6):1561–1570, 2012.