AIDLOC: AN ACCURATE ACOUSTIC 3D INDOOR LOCALIZATION SYSTEM

Minlin Chen[1], *Lei Zhang*[1], *Xinheng Wang*[2] *and Zhi Wang*[1*]

1 State Key Laboratory of Industrial Control Technology,Zhejiang University,
Hangzhou 310027, China;
chenminlin1995@foxmail.com(M.C.);zhlei0202@163.com(L.Z.);wangzhi@iipc.zju.edu.cn(Z.W.)
2 School of Computing and Engineering, University of West London, UK.;
xinheng.wang@uwl.ac.uk

ABSTRACT

We present AidLoc, an inaudible acoustic indoor localization system based on acoustic ranging, which is convenient for commercial off-the-shelf devices such as smartphones and laptops without modification. The frequency of sound signal is too high to hear so that its imperceptible to humans. An AidLoc system consists of 4 or more acoustic beacons and a smartphone. Beacons are deployed in different height to establish a beacon space. This gives a 3D relative coordinate for 3D target localization. We use time difference of arrival (TDOA) localization approach, which means the smartphone sends the sound signal, and beacons receive it. According to our experiment in conference room, we can provide sub-meter ($90\% < 10cm$) accurate indoor positioning.

***Index Terms*—Smartphone, Localization, Acoustic signal, AidLoc.**

I. INTRODUCTION

Recently, as the mobile devices such as smartphones have been already available for a majority of people over the world, location tracking on mobile devices like smartphones has already begun to revolutionize personal navigation[1], [2], [3]. As a result, the demand of user localization for navigation in large structures such as mall, airport and railway station is of increasing significance. Despite their achievement in outdoor applications, these general services perform poorly indoor, for the GPS signals are almost unavailable. Yet fortunately, many systems in Microsoft Indoor Localization Competition have achieved high positioning accuracy by using modified commercial off-the-shelf technologies such as UWB or ultrasound.

Studies have shown that most of humans cannot hear audio frequencies higher than about 19kHz[3]. On recently mobile devices such as smartphones, the sampling rate of speaker and corresponding Digital-to-Analog Converters (DACs) can reach 48kHz, therefore, according to Nyquist-Shannon Sampling Theorem it can send sound signal as high as 24kHz, which is way beyond human hearing upper limit and will not bring about noise to humans.

Based on what is mentioned above, we proposed an acoustic indoor localization system, AidLoc, which is fully compatible with commercial off-the-shelf devices and doesnt need to interface with any hardware. The demo system of AidLoc includes a smartphone and 4 beacons, which receive the sound sent from the smartphone and then send the timestamp to PC. The whole system is economic with each beacon about 10$. The beacon used in this demo system is shown in Fig.1.

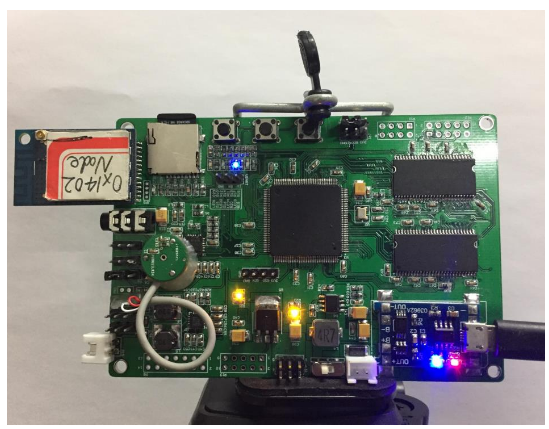

Fig. 1. The photo of the beacon.

II. SYSTEM OVERVIEW

A complete demo system of AidLoc includes 4 sound beacons, a sink node, a computer and a smartphone. All beacons and sink node are connected through Zigbee network. The sink node is connected to computer with serial port. The conceptual architecture of AidLoc demo system is shown in Fig.2. Each beacon is mainly composed of a STM32F4 and our own circuit board with WM8978 codec, microphone, Zigbee communication battery, etc.

Target positioning can be split in three main stages: coordinate calibration, measurement and position estimation.

- Coordinate calibration: Before ranging and position estimation, 3D relative coordinate established by 4 beacons should be calibrated by manpower to obtain accurate coordinate figure.
- Measurement: First the sink node sends a synchronizing signal to make sure that every sound beacon has the same clock time. Second the smartphone sends a modulated LFM audio signal to all the beacons. Then beacons receive the sound signal, calculate the timestamp and send it to the Sink node by Zigbee.
- Position estimation: The computer obtains the T-DOA information from the sink node and estimate the position of smartphone by method of maximum likelihood.

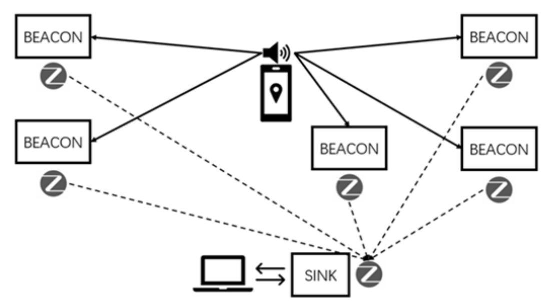

Fig. 2. Conceptual architecture of AidLoc demo system.

With the TDOA information from 4 sound beacons, AidLoc system can estimate 3D coordinate of the smartphone. Of course, more beacons lead to more accurate localization. According to our experiment in conference room with 4 beacons, the localization error is observed to be less than 10cm in 90% of cases. A main source of error affecting the final position estimation accuracy is caused by TDOA due to sound speed uncertainty and multipath propagation of sound.

III. DEPLOYMENT

The conceptual deployment of beacons in AidLoc demo system is shown in Fig.3. For the aim of accuracy of 3D localization, beacons should be deployed in different height, namely varying z coordinates. To ensure most of beacons and smartphone are in line of sight, we should put them on ceiling. In practice, we can put beacons on ceiling, on wall or hang them in the air of a specific height as Fig.3.

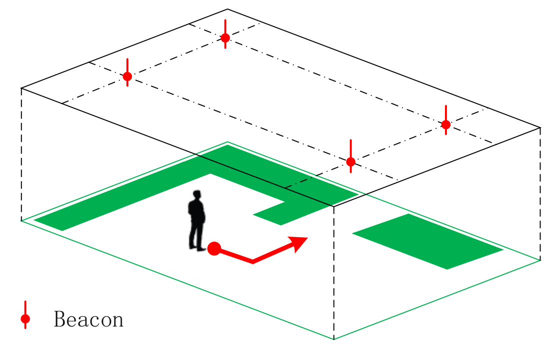

Fig. 3. The deployment of AidLoc demo system.

IV. REFERENCES

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