Demo Abstract: A BeepBeep Ranging System on Mobile Phones

Chunyi Peng[1], Guobin Shen[1], Zheng Han[1,2]*Yongguang Zhang[1], Yanlin Li[1,3]*Kun Tan[1]

[1]Microsoft Research Asia, Beijing, 100080, China
[2]Beihang University, Beijing, 100083, P.R.China
[3]Tianjin University, Tianjin, 300072, China

{chunyip,jackysh,v-zhhan,ygz,v-yanlli,kuntan}@microsoft.com

Abstract

The demo, BeepBeep, shows a high-accuracy acoustic-based ranging system without relaying on any pre-planned infrastructure or inter-device time synchronization. Moreover, the BeepBeep is a pure software-based solution and readily applicable to many low-cost sensor platforms and to most commercial-off-the-shelf mobile devices. Our demo using two common cell phones shows that BeepBeep can achieve average two centimeters accuracy within a range of more than ten meters.

Categories and Subject Descriptors

C.3 [**Computer Systems Organization**]: Special-Purpose and Application-Based Systems–Signal Processing Systems

General Terms

Algorithms, Experimentation

Keywords

Acoustic Ranging

1 Introduction

High-accuracy ranging is a key enabling technology in sensor networks. However, compared with the existing solutions that require special-purpose hardware special-purpose hardware (such as [1, 2]) or pre-existence of precision location infrastructure [3], a commodity-based solution will obviously have more desirable features and will be widely applicable in many sensing and mobile networks.

To address this need, we have developed the BeepBeep, a high-accuracy acoustic ranging system, using only common hardware capabilities – a speaker, a microphone and some form of inter-device communication. For the same reason, it is implemented in software and can be applicable to COTS mobile phones without any kernel or driver modification.

Technical details about this demo are presented in [4]. In this demonstration, we will show how the system operates, in particular demonstrating the high-accuracy ranging despite long distance and background noise (about 2 cm precision in 10m range).

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*The work was done while Zheng Han and Yanlin Li were visiting students in Microsoft Research Asia.

2 BeepBeep Ranging Scheme

The idea of high accuracy ranging lies in three key technologies: two-way sensing, self-recording and sample counting. First, the two devices will each in turn emit a specially-designed sound signal, called a "Beep", within one second of each other. Meanwhile, each device will also record a few seconds of continuous sound from its microphone, and thus each recording should then contain exactly two Beep signals picked up by its microphone. It is proven that the differential of the elapsed times between two signals at each microphone represents the sum of the time of flight of the two Beeps and hence the two-way distance between the two devices, therefore, device ranging can be obtained without inter-device time synchronization or any pre-deployed infrastructure.

Furthermore, by using sample counting instead of timestamping, our mechanism mitigates all the uncertainties from the possible clock skew and drift, the possible misalignment between sender and the actual signal emission, and the possible delay of a sound arrival being recognized at receiver, and thus avoids the source of inaccuracies found in traditional timestamp approaches. The theoretical analysis reveals that our mechanism can achieve up to 0.7cm accuracy under today's prevailing hardware standard of 44.1KHz sampling rate.

3 System Implementation

The BeepBeep provides a software-only high accuracy ranging solution on the minimum commodity hardware set we specified before. We have developed it as a user-mode dynamic linkable library that other applications can load and use it for ranging service. Furthermore, we have implemented the BeepBeep prototype in COTS mobile devices, running in Microsoft Windows Mobile 5.0 environment.

3.1 Hardware Configuration

BeepBeep demo is deployed onto two models of COTS Pocket PC phones, HP iPAQ rw6828 and Dopod 838, as shown in Figure 1. Both are running Microsoft Windows Mobile Version 5.0 (Phone Edition), with WiFi and Bluetooth radios, a QVGA display, 64 MB RAM, two built-in speakers and one microphone that supports 16-bit 44.1 KHz sampling rate. The HP iPAQ rw6828 features a more powerful Intel XScale 416 MHz processor while Dopod 838 is equipped a 195 MHz TIOMAP 850 processor. The speakers are laid out at the bottom on the front face for the HP phones and at the two sides on the Dopod phone.

Figure 1. Two COTS mobile devices used in the evaluation of BeepBeep ranging system.

3.2 Software and APIs

The whole procedure flow for BeepBeep ranging is illustrated in Figure 2. Once received initiation message, the device configures the sound signal and phone size related parameters, and start recording and playing particular designed sound; during the detection procedure, it adopts some signal processing techniques – cross-correlation peak localization and window filters – to mitigate multipath effects and detect the time of arrival of two "Beep"s; after ETOA exchange, the device can compute the actual ranging from two ETOA differential and finalize it through a phone-size factor calibration.
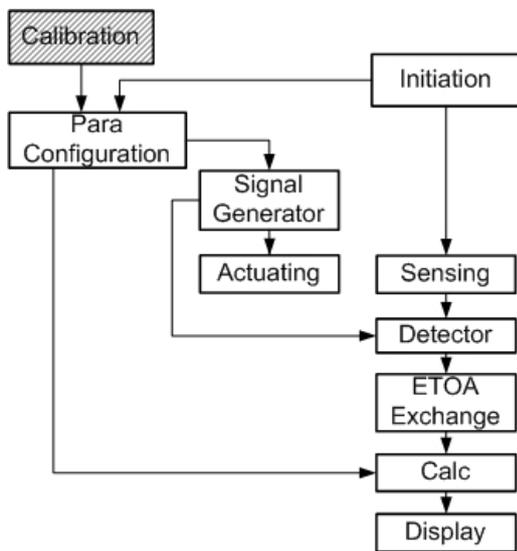
Figure 2. Procedure flow in BeepBeep ranging system.

The calibration module is provided to compensate ranging bias resulted from device factors, such as the layout of speaker and microphone. It can run when placing two phone side by side.

4 Demonstration Tests

In the demonstration, we will put two mobile phones apart and perform distance detection. After two short "Beep"s, their ranging will be shown in one phone's display screen. Figure 3 shows one BeepBeep experiment result using two HP iPAQ rw6828 apart from 10 cm. We will randomly pick up one phone and move it to a different location, and then observe the updated ranging result.

Figure 3. One snapshot of BeepBeep ranging experiment using HP iPAQ rw6828.

The demo is also open and welcome user participation. We will bring our laptop to provide BeepBeep installation package to whoever have interest. The package is also available in *http://research.microsoft.com/wn/beepbeep.aspx*, applicable to Microsoft Window Mobile 5.0 Version (Pocket PC). Attendees are encouraged to install BeepBeep system on his/her phone and join our ranging experiment, or run ranging experiments with another phone equipped with BeepBeep functionality. Note that in this case, to obtain a more accurate ranging, the calibration procedure is recommended running before the actual measurement.

5 References

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