Demo Abstract: The SpiderBat Ultrasound Positioning System

Georg Oberholzer, Philipp Sommer, Roger Wattenhofer
Computer Engineering and Networks Laboratory
ETH Zurich, Switzerland
sommer@tik.ee.ethz.ch

Abstract

Having access to accurate position information is a key requirement for many wireless sensor network applications. We present SpiderBat, an ultrasound-based ranging platform for wireless sensor networks. It is designed to extend existing node platforms with ultrasound ranging capabilities. SpiderBat features four pairs of independently controllable ultrasound transmitters and receivers, which point towards different directions of the compass. Having multiple ultrasound transmitters and receivers provides an increased spatial coverage. Furthermore, our design allows to determine the angle of arrival of an ultrasound wave, which can be exploited for improved accuracy of the positioning.

1 Introduction

Accurate position information is vital for many wireless sensor network applications. While nowadays many mobile devices are equipped with a receiver for the Global Positioning System (GPS), it is limited to outdoor applications only. Ultrasound ranging is a common alternative for GPS in indoor settings [1, 2]. By measuring the propagation delay of ultrasound waves, we achieve distance estimations with a precision of a few millimeters. Since ultrasound transducers exhibit a limited beam angle, the ranging capability suffers substantially at an increasing angle offset between transmitter and receiver. In this demonstration, we present SpiderBat, a novel ultrasound platform featuring four transmitters and four receivers. Having ultrasound transducers in all directions of the compass solves the limited beam angle problem that previous ultrasound platforms (e.g., the Cricket platform [1]) experienced. In addition, thanks to multiple senders and receivers, we are able to measure the angle of an incoming ultrasound wave up to a few degrees. A digital compass allows to take into account the orientation of the node for an accurate positioning.

2 System Architecture

SpiderBat is an extension board for existing node platforms, e.g., the Telos or Mica node families. It features four independent ultrasound transmitters and four ultrasound receivers. The board has a symmetric shape (see Figure 1), the eight edges are alternately equipped with a receiver and a transmitter, respectively. A Texas Instruments MSP430 low-power microcontroller is used to control the transmit operation and to process the received signals. The microcontroller is responsible for all hardware related operations and to receive commands from the host node. Furthermore, a Honeywell HMC6352 digital compass provides information about the absolute rotation of the node. The extension board is powered by the host sensor node and is connected using the serial peripheral interface (SPI).

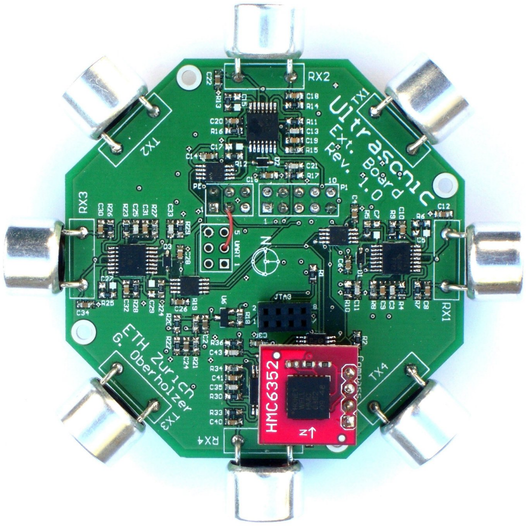

Figure 1. The SpiderBat extension board with an attached digital compass. The board diameter is 6.5 cm.

The output signal of an ultrasound receiver needs to be amplified for a reliable detection of ultrasound pulses. Thus, each receiver is connected to an amplifier that provides an adjustable gain to control the detection threshold and to prevent saturation of the sampled signal. Furthermore, the amplified signal of each receiver is connected to an analog-to-digital converter input of the microcontroller. To unburden the microcontroller from continuously sampling the input signal, a comparator circuit is used to indicate the presence of ultrasound signals. This detection signal is connected to a capture pin of the microcontroller allowing for accurate time-stamping of detection events in hardware. A measurement of the ultrasound detection signal of the four receivers is shown in Figure 2.

SenSys'10, November 3–5, 2010, Zurich, Switzerland.
ACM 978-1-4503-0344-6/10/11

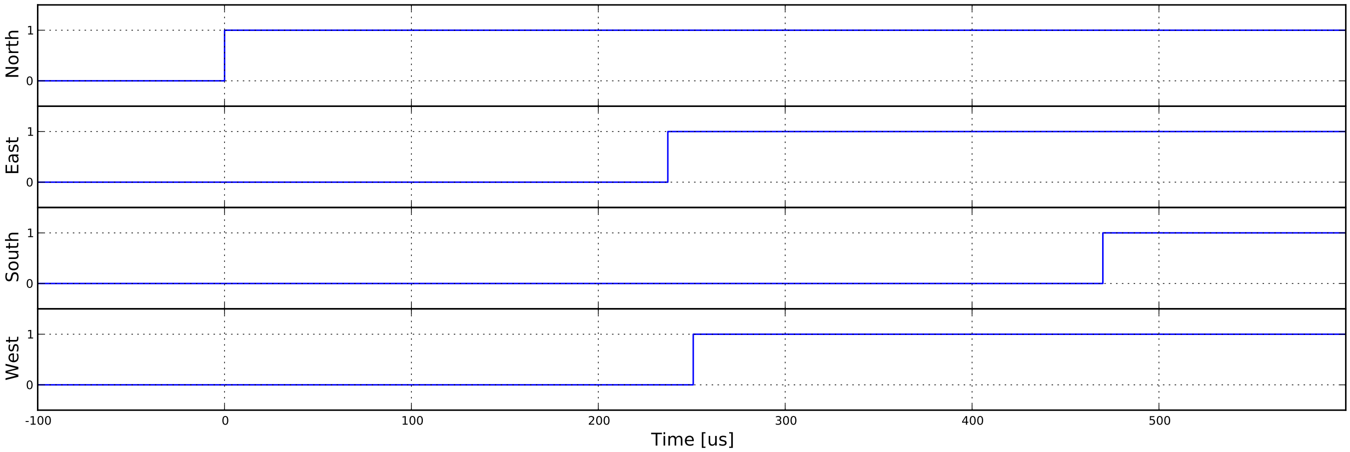

Figure 2. Measured ultrasound detection signal for all four ultrasound receivers. In this example, the source is located opposite to the North receiver of the extension board. Thus, the signal is detected by receiver North first (t=0µs). After passing receivers East (t=237µs) and West (t=250µs), the signal is finally also detected by receiver South (t=470µs).

Since ultrasound pulses are transmitted only sporadically, the power supply of both the receiver and transmitter parts can be disabled by the software to save energy. This allows the operation of the extension board at low duty-cycles.

3 Distance and Angle Estimation

Distance measurements between two nodes exploit the difference in the propagation speed between ultrasound and radio waves. While radio packets travel at the speed of light, ultrasound signals propagate at the much lower speed of sound, which is around 343 meters per second at room temperature. Thus, the distance between two nodes can be calculated from the difference in the arrival time between the radio packet and the ultrasound wave. The hardware counter of the SpiderBat platform is sourced by an 1 MHz clock, which provides a theoretical resolution of less than 1 mm for distance measurements. An ultrasound ranging operation is always unidirectional and initiated by the sender node. First, the sender node broadcasts a radio packet followed by the transmission of multiple ultrasound pulses. The reception of a radio packet initiates the ultrasound measurement on the receiver node and serves as a time synchronization point between the sender and the receiver of the ultrasound pulse. As soon as the signal strength of the incoming ultrasound wave exceeds the detection threshold, the current counter value is captured in a hardware register and an interrupt is triggered. The distance to the sender node and the angle of arrival of the ultrasound wave relative to the board orientation can be calculated based on the difference in the detection times of the ultrasound wave at the four receivers. Finally, the measurement data is sent to the base station for further analysis. The digital compass on the SpiderBat board provides absolute node orientation. Based on the measurement data collected from the sensor network, we can estimate the position of nodes using a localization algorithm on the base station.

4 Demonstration Setup

We will show the operation of the SpiderBat platform in the context of ultrasound-based indoor localization. The demonstration setup will consist of four SpiderBat ultrasound boards attached to Pixie wireless sensor nodes and a base station. A laptop connected to the base station can be used to control and monitor the ultrasound measurements. One node is fixed and acts as an anchor node, while the other nodes can be placed freely within our demo setup. Nodes continuously initiate ultrasound measurements to estimate the distance and angle to neighboring nodes. The current estimation of the node positions is visualized on the laptop screen. Furthermore, a four-channel oscilloscope is used to measure and display the amplified output signal of all four ultrasound receivers of the anchor node. We encourage conference participants to reposition the nodes and place obstacles between them to explore the performance of the ultrasound-based positioning system.

5 Conclusions

We presented SpiderBat, a novel hardware platform for ultrasound localization in wireless sensor networks. The use of multiple ultrasound transducers provides an improved spatial coverage and accurate measurement of distances and angles. The SpiderBat platform allows for new applications of ultrasound positioning in sensor networks thanks to its ability to measure the absolute angle of arrival of ultrasound waves.

6 Acknowledgments

This work was partially supported by the Swiss National Competence Center in Research on Mobile Information and Communication Systems (NCCR-MICS). We thank Sebastian Cartier for implementing the graphical user interface.

7 References

[1] N. B. Priyantha, A. Chakraborty, and H. Balakrishnan. The Cricket Location-Support System. In *MobiCom'00: Proceedings of the 6th Annual International Conference on Mobile Computing and Networking*, pages 32–43, 2000.

[2] A. Savvides, C.-C. Han, and M. B. Strivastava. Dynamic Fine-Grained Localization in Ad-Hoc Networks of Sensors. In *MobiCom'01: Proceedings of the 7th annual international conference on Mobile computing and networking*, pages 166–179, 2001.