A Range-Bearing based Ultrasonic Positioning System (RB-UPS)

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Abstract*—We introduce an indoor positioning system based on measurements of range and Angle-of-Arrival (AoA/bearing), using ultrasonic signals. Custom-made sensor anchor nodes deployed on the area of interest detect incoming signals from a mobile ultrasonic transmitter. Any one anchor node can determine with a single measurement the position of a transmitter which stands within its field of view (FoV). The current system delivers 2D locations. For 2D-positioning (x, y) one range and one angular measurement are required, while the height of the transmitter is assumed to be known and stay constant. 3D positioning (x, y, z) requires knowledge of two angles. Implementation of 3D location is currently under work. Some portions of this abstract have been extracted from [1] to be published in *IEEE/ION Position Location and Navigation Symp., 2016.

Keywords—ultrasonic sensor; indoor positioning; angle-of-arrival measurement; range-bearing positioning

I. INTRODUCTION

The range-bearing based ultrasonic positioning system uses narrowband ultrasonic signals for measuring range *r* and angle-of-arrival (AoA/bearing) Φ to a device being located. Fig. 1 pictures one sensor anchor node measuring to a transmitter (mobile beacon). Knowing the location of the anchor node in an absolute position reference system allows determining the location of the mobile beacon out of *r* and Φ measured relative to the anchor node.

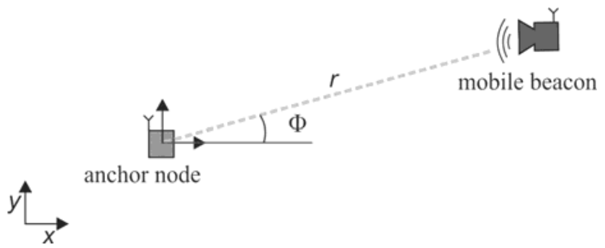

Fig. 1. Range-bearing positioning method.

A. Measurement Principle

The range to a mobile beacon is determined by measuring the time of arrival (ToA) of an ultrasonic burst signal at 40 kHz to the receiver of the anchor node. Using the speed of sound *c*, range is computed with

$$r = \text{ToA}\, c. \tag{1}$$

Bearing is obtained by measuring AoA of the incoming ultrasonic signal with an array of ultrasonic transducers at the receiver on the anchor node.

B. Positioning Method

The range-bearing, or polar point positioning method uses a distance and an angular (azimuth) measurement from the same station (in our case each anchor node) to determine the coordinates of a nearby station (the mobile beacon) [2]. This method is particularly useful, because it requires measurements from only one station (under the assumption that the station's orientation is also known). 3D positioning requires measurement of two angles; i.e. azimuth and elevation angles.

C. Positioning System Architecture

Our positioning system has a centralized architecture, so that position determination is carried out at a central server (a laptop) where all anchor nodes locations are stored, and to which all measurements are reported. Communication between the central server and the anchor nodes takes place through a radio frequency (RF) channel. The positioning system can operate under two topologies:

1) Centralized remote-positioning: the result of positioning the mobile beacon is available at the central server, which could physically be anywhere inside the room (see Fig. 2).

2) Centralized indirect self-positioning: the central server is mobile and in motion together with the beacon being tracked. This way the positioning result is known at the location of the mobile beacon (see Fig. 3).

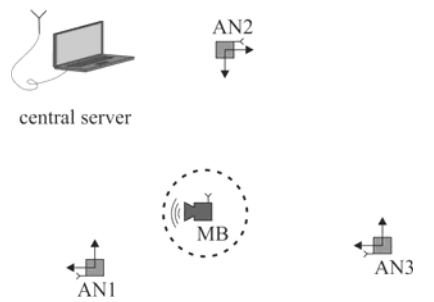

Fig. 2. Centralized remote-positioning architecture. The mobile beacon (MB) is located, and the result is available at the central server.

The central server will check the input from each anchor node for plausibility and determine the location of the mobile beacon. If previous knowledge on the beacon's location is available, the central station could decide to poll measurements only from those anchor nodes for which plausible *r* and Φ readings are expected, i.e. the beacon stands inside the anchor's field of view (FoV).

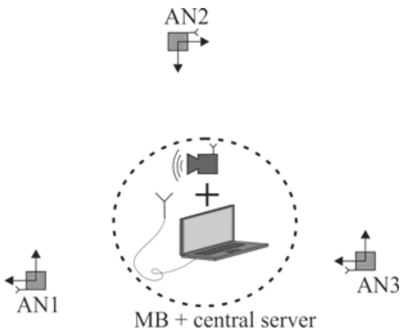

Fig. 3. Centralized indirect self-positioning architecture. Mobile beacon and central server move together. Positioning result is known at the location of the beacon.

II. Deployment Requirements

A. Infrastructure

The sensor anchor nodes are custom-made devices. The amount of nodes to deploy depends on the extension and topology of the surveyed indoor scenario. A single anchor node can survey an area of approx. 45 m^2. However, the FoV of an anchor node has a conical topology. Therefore, care must be taken in order to conveniently place the anchors to cover the area in which it shall be tested, exemplified in Fig. 4.

Every node is powered by its own 12 VDC source consuming max. 200 mA. This could be either a battery or a VAC/VDC source connected to a power plug at 120V/230V, and 50/60 Hz. Where available, the later will be preferred to avoid having to deal with batteries.

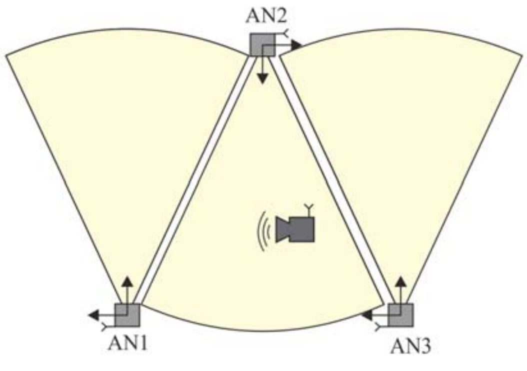

Fig. 4. FoV of a sensor anchor node with conical topology.

B. Deployment

Each anchor node is placed at a fixed location either using a tripod or holding it with a vise to some furniture or frame structure available at the room. An anchor node is pictured in Fig. 5, its dimensions are 120 x 80 x 55 mm, and it weighs about 0.3 kg (not considering power source). Typically, they would be placed somewhere between 2-2.5 m above the floor level. A real measurement scenario is pictured in Fig. 6.

Fig. 5. Anchor node mounted with a vise on a tripod.

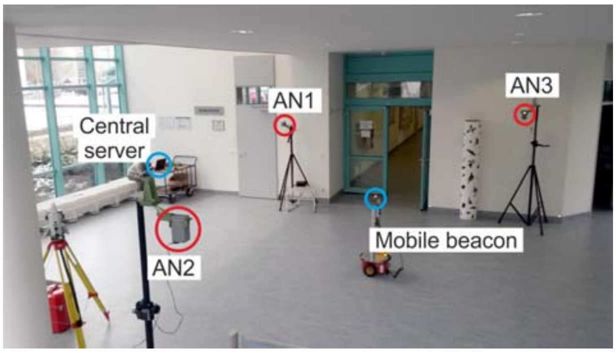

Fig. 6. Real measurement scenario.

C. Storing Anchor Node Locations

Once the anchor nodes have been placed, a reference coordinate system is chosen within the room. Then the location of each anchor node is measured with an optical tachymeter (Leica TS30) and stored in the central server.

III. Summary

The Range-Bearing based Ultrasonic Positioning System uses custom-made sensors to measure ToA and AoA of ultrasonic signals from a mobile beacon. The sensor is the centerpiece of an anchor node in the positioning system. Measurements from every anchor node are processed at a central server containing the locations of each anchor node. The result of locating a mobile beacon is available at the central server. Typical positioning errors are well below 20 cm.

Acknowledgment

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References

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