April 05, 2017

Low-Cost Indoor Micro-Location

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ABSTRACT

Devices and methods are disclosed that can determine the location of an object in 3d space based on low-cost, small, battery powered devices that can be used in an indoor setting. The "Dots" operate using a combination of low power wireless communication and ultrasonic sound. The wireless communication may be typically BLE, Thread or WiFi. Dots also are provided basic processing ability and an ultrasonic microphone capable of sensing. Dots are passive and are controlled by the device whose location is being identified, referred to as the Control Point (CP). Multiple Dots are placed within an indoor space and distance to each Dot is determined by measuring time taken for sound to travel between each Dot and the CP. The system is capable of providing indoor location accurate in 3d space to within a foot or less and can be used for navigation, or tracking of pets or children.

BACKGROUND

Devices or users sometimes need to know the location of a device or object in order to provide the best functionality. Many small companies have attempted to create technologies that allow a user to locate keys, wallet, or other devices. Another aspect of the problem is that end users are used to being able to navigate roads and other outdoor spaces using their phones these days. While phones can enable a user to get to the mall or airport, the GPS receiver cannot get a signal indoors and navigation stops. Some devices can then use WiFi to approximate location, but precision is often not high enough to provide useful navigation.

DESCRIPTION

Devices and methods are disclosed that can determine the location of an object in 3d space based on low-cost, small, battery powered devices that can be used in an indoor setting.

The location identification system uses devices called “Dots” that operate using a combination of low power wireless communication and ultrasonic sound as illustrated in FIG. 1. Dots may use a protocol for wireless communication such as BLE, Thread, WiFi, or any other low power technology that satisfies the power consumption and range requirements. Dots also need to have basic processing ability and an ultrasonic microphone capable of sensing sound at frequencies that cannot be heard by humans. Some variants of the technology may also require a speaker in the Dot that is capable of producing ultrasonic frequencies. Dots are passive and are controlled by the device whose location is being identified, referred to as the Control Point (CP).

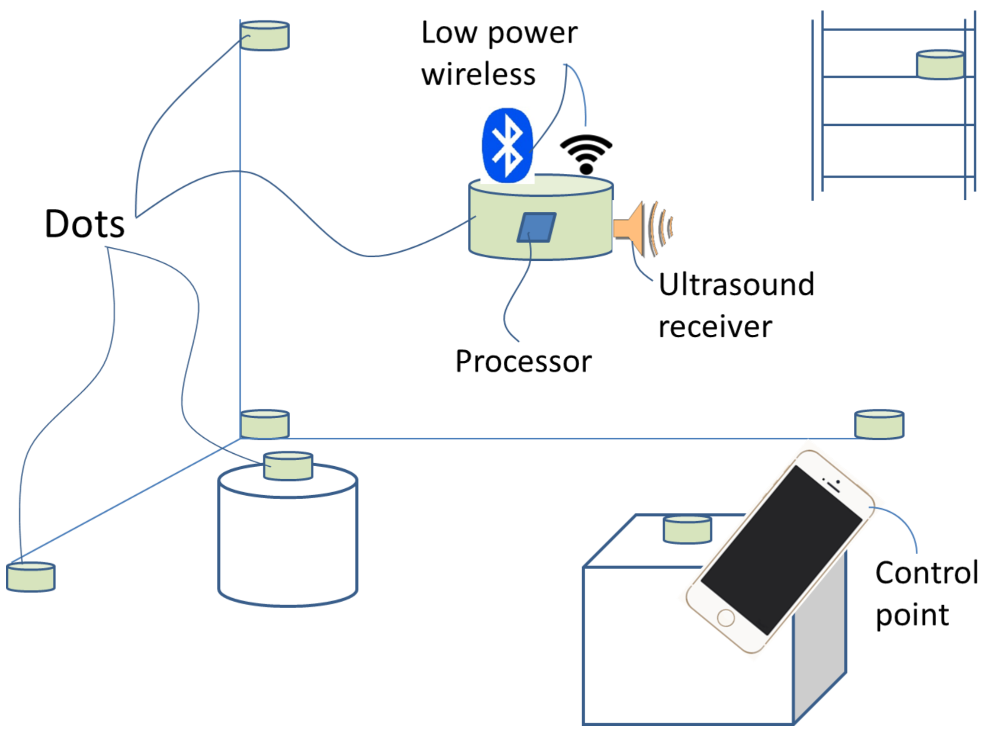

FIG. 1: System passive low power devices (Dots) for indoor location

The first method of distance measurement using the system shown in FIG. 1 allows all Dots in range to determine their distance to the CP at the same time. This is done through a series of steps outlined with reference to FIG. 2. In step 1, the CP determines the Dots present in range using the low power wireless communication. Dots advertise their presence such that the CP can tell which Dots are currently in range without any previous pairing. CP connects to all Dots in range using the low power wireless without any prior pairing (step 2). In step 3, CP synchronizes time with Dots. Dots and the CP need a reference time that is accurate within under a millisecond. The implementation of this synchronization depends on the wireless technology being used. Synchronization over Wi-Fi is known to work with 25 µs accuracy, while synchronization over BLE provides 10 µs accuracy. The CP in step 4 sends out impending transmission of an ultrasound pulse ahead of time communicated via the low power wireless communication. The CP (step 4a) emits the brief ultrasonic pulse at a predetermined frequency at the appointed time. In step 5, each Dot informs the CP of the time that the ultrasonic sound is heard. The Dots all listen for the ultrasonic sound and record the time since the reference time when they first heard the ultrasonic frequency. As soon as they are able, the Dots communicate the recorded time to the CP. The CP converts the times into distances in the final step. The CP can use the reference time to determine how long it took to reach each Dot.

Given the speed of sound, each millisecond spent in transit is approximately one foot that the sound had to travel. With sub-millisecond transit time measurements, the CP can determine the distance to each Dot to within a foot. This algorithm can be executed quickly whenever the location of the CP is desired. In addition, the algorithm may be executed multiple times in succession to average out error and produce a more accurate measurement.

An alternate algorithm is proposed if sub-millisecond time synchronization between the CP and Dots is not possible. This algorithm requires the CP to determine distance to Dots one at a time, and requires the Dots to contain a speaker capable of emitting ultrasonic sound. The CP determines the Dots present nearby and connect to a single dot in range. It then sends out a single ultrasonic pulse at frequency A. Dot sends out a response ultrasonic pulse at frequency B on receiving pulse A. The CP measures the time for both ultrasonic pulses and determines the distance to the Dot. Since the pulses went both directions, the time taken may indicate the distance to the Dot and back. As this method is repeated for all Dots in range, the algorithm takes longer in proportion to the number of Dots. The CP can choose a subset of Dots, if required, based on the wireless communication signal strength.

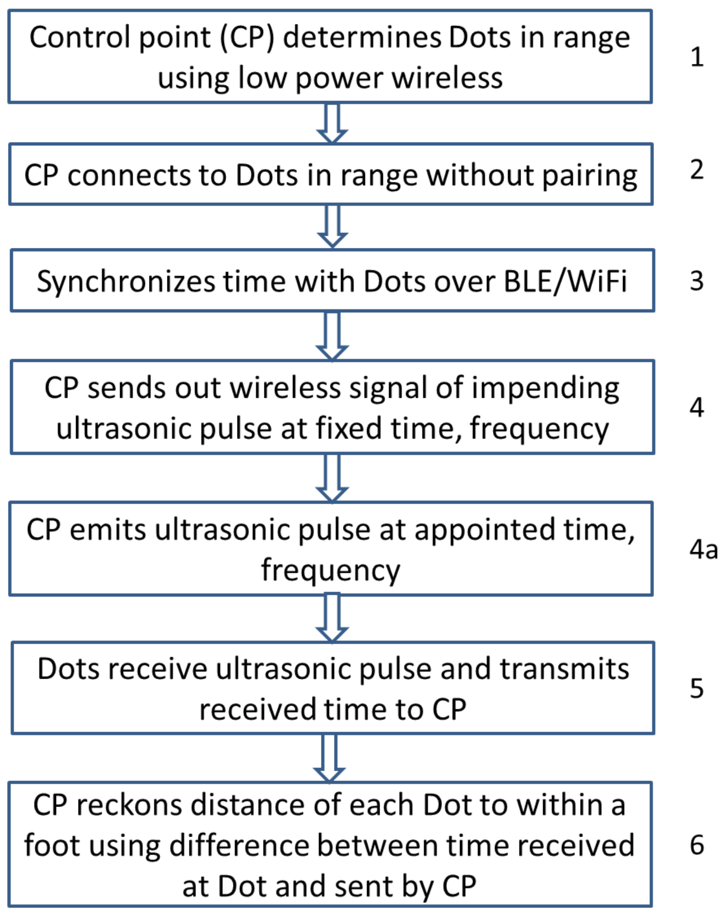

FIG. 2: Method of location of an object using multiple Dots

A faster and lower power distance measurement can be done for approximate estimation. This type of measurement may be useful for example if the desired information is simply what room, or which side of a room an object is in. This measurement is done by simply measuring the wireless signal strength for each Dot. This signal strength is compared against canonical signal strength measurements determined in a lab based on distance. The signal strength is then converted into a rough distance estimate. This distance can be distorted by interference and objects between the CP and the Dot, and is therefore approximate.

It may be possible to determine the angle between the CP and the Dot when using ultrasonic sound. This would be accomplished by including three microphones in the Dot instead of one, and spreading them out as far as possible. If an ultrasonic frequency of 80 kHz were used, the wavelength would be about 1/6th of an inch. At a distance of 5 feet this would give an angle accurate to within about 10 degrees assuming timing may be measured at whole wavelength intervals. This accuracy would improve if the microphones were spaced further apart, higher frequency were used, or phase differences between the sounds may be detected to provide more than 1/6th inch accuracy. With this additional angle measurement, location within a reasonable sized room may be provided with only one or two Dots rather than four or more. As the microphones are not expensive, this may significantly reduce the cost of outfitting a space.

A typical Dot device operates on coin cell batteries that can last for years between changes. The final size of this design is smaller than a tea light candle and may easily be hidden in almost any decor.

The second most obvious use case is attaching a tag to objects like keys so that they can be found easily with location identifiable quite precisely and in three dimensions. Given sufficient coverage of Dots, it is expected that location may be accurate in 3d space to within a foot or less. In ideal conditions, location may be accurate to within a centimeter. Rather than telling you that your keys might be approximately 5 meters away, this system may tell you that they are in the back of the drawer by the front door on the left side. With this level of precision, object finding may also be implemented with augmented reality.

This technology would allow navigation to continue indoors not only in 2d but in 3d as well. With a very small investment in Dots, an indoor space may be outfitted with location tracking for all users. Navigation in the airport may take you directly to the ticket counter, security checkpoint, and your gate. Navigation in the mall may take you exactly to the store you want and even tell you where customer service or the nearest checkout counter is. In office complexes, navigation may tell you how to get to the exact conference room you need to go to.

Current mobile devices can relatively accurately determine the orientation of the device, which can be helpful for augmented reality purposes. With accurate location tracking, augmented reality can become much more useful in an indoor setting. Since the location of the device can be known accurately, the position of AR overlays can be much more stable and accurate. The disclosed system of Dots may be effectively augmented with motion sensors or other tracking technologies to provide VR tracking.

The disclosed system does not require any setup or configuration and can be used simply by placing a sufficient number of Dot devices around a space and then walking around. The disclosed system and method would be useful for tracking in malls, airports, and other indoor places. This may also be useful for robotics companies to provide low cost location information for their robots, including household robots such as vacuum cleaners. It would also allow tracking of pets or children or locate one’s wallet or mobile phone.