The Bat System

3D Ultrasonic Positioning for People and Objects

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Bats are lightweight wearable devices featuring ultrasonic transducers, a 433Mhz radio transceiver and a long-life battery, amongst other components. They are used throughout the DTG to precisely locate people and objects, providing a location-aware environment. Each Bat is distinguished by a unique identification code and permits input through two small buttons on its side.

An irregular matrix of networked, ultrasonic receivers are daisy-chained together above the ceiling of the lab. The absolute position of each receiver is recorded in a database. The goal is to use the propagatoin of ultrasound from a Bat to its local receivers to determine the Bat's position.

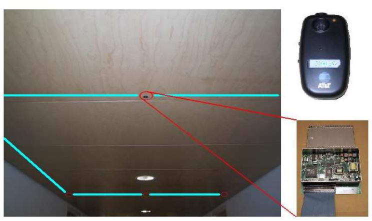

Figure 1: *A Bat and an installation of ceiling receivers*

System Principles

The Bats and the system that is connected to the sensor network communicate using a radio channel available throughout the DTG, which is used to synchronise all components. Each Bat is polled over the radio channel and emits an ultrasonic chirp when instructed.

Following a chirp, an accurate clock is used to measure the time-of-flight to each receiver that registered the chirp. This allows us to calculate the Bat-receiver distances calculate the most likely 3D position of the emitting Bat.

Each bat has two ultrasonic transducers, pointing in different directions to create an ultrasonic emission cone that is in fromt of the wearer. This allows a crude estimate of orientation based on the local distribution of receivers that heard the Bat.

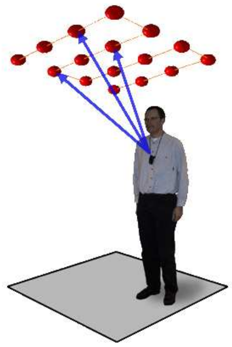

Figure 2: *A Bat is heard by multiple receivers*

Power

Power usage on the Bat is achieved through a dynamic positioning update rate, keyed to the present motion of a Bat, sensed using a jitter switch. Bats that have been motionless for a while are thus polled less frequently than those that are moving. The maximum update rate (15Hz) is determined by the time taken for a given ultrasonic chirp to dissipate. Using these techniques, a Bat battery lasts approximately 18 months.

Accuracy

In open areas, an accuracy of 3cm, 95% of the time is achieved. Reflections of the signals from smooth surfaces such as walls and the absorption of sound by soft material means some areas, such as corners of a room, give worse results. These results are obtained by having a high redundancy in the data: up to 15 receivers may contribute to a single position calculation.

Applications

Applications of the Bat system are based on a paradigm of "programming with space". Events are triggered by interaction between tracked entities and pre-defined *spatial zones*. For example, a tracked person approaching the main door to the DTG will enter a pre-defined space and cause the door to unlock automatically.

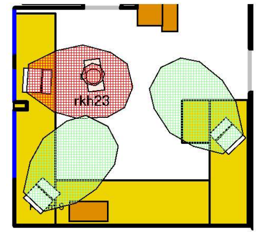

Figure 3: *A spatial zone*

A further example are *follow-me* applications, where outputs are keyed to locations. For example, phone calls may be routed to the nearest phone, audio may follow the listener from room to room, or a computer desktop can move from display to display with its owner.

Interaction with the system can be achieved using *spatial buttons*. These are small spatial zones that trigger a system event when a Bat is within them and a button is clicked. No hardware other than the Bat is thus required to emit an event. Examples of spatial buttons can be found on the whiteboards outside each office, where they are used to set alerts for the return of their owner(s).

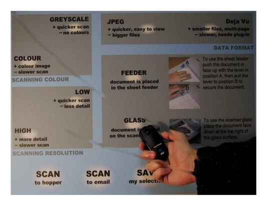

Figure 4: *Examples of spatial buttons*

The Future

The co-ordinate location data provides very basic semantic information, yet the potential for more natural conclusions to be drawn from it exists. For example, if a cluster of people is detected in a space, is it possible to determine whether they are in a meeting with each other, working individually or just passing each other in a corridor? Integrating the location information with other contextual clues offers the opportunity to revolutionise the interaction of humans and computers.

Papers

[1] A. M. R. Ward. *Sensor-driven Computing*. PhD thesis, Cambridge University, August 1998.

[2] Andy Harter, Andy Hopper, Pete Steggles, Andy Ward, Paul Webster The anatomy of a Context-Aware Application In *Wireless Networks, Vol. 8, pp. 187-197*, February 2002.