our future through science

GPS-deprived localisation for underground mines

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INTRODUCTION

South Africa plays a major role in the international mining fraternity. Location information will enhance the safety in mines by permitting the realisation of wireless sensor networks (WSN), which are persistent and ubiquitous environmental monitoring systems. The second consequence of accurate location information is the capability to allow for robot navigation and guidance in the underground mining environment. This would apply to safety monitoring robots, rescue robots and even production robots.

Opencast mines utilise the global positioning system (GPS) to obtain location information. The unavailability of this technology in underground mining has actuated numerous researchers to investigate possible alternatives. These attempts exploit new sensors that measure inter-nodal ranges, signal strengths, acceleration or angles for location as well as research high sensitivity algorithms for signal acquisition and tracking in harsh environments [1]. The combination or integration of these sensors has also been investigated. The common signal technologies used in localisation systems include radio frequency (RF), ultrasound, infrared, vision and magnetic fields [1].

GPS-DEPRIVED LOCALISATION (GDL) – AN OVERVIEW

Ultrasonic-based localisation has received focus in recent years. This is because ultrasonic systems are power efficient when compared to other signal technologies and hence are suitable for untethered or wireless systems. Some of the latest, and best publicised, research in GPS-deprived localisation include indoor localisation systems like the Active Bat [1], a derivative of the work done at Olivetti Research Lab under the banner of the Active Badge [1], the DOLPHIN [2][3], which introduced a robust least square (RLS) algorithm and is developed at the University of Tokyo, and the Crickets [4], a hardware and software platform developed at the Massachusetts Institute of Technology. All these projects use beacons that transmit an RF pulse and an ultrasonic chirp simultaneously. Listeners utilise the RF signal to identify the transmitting beacons and the difference in arrival times between the RF signal and the ultrasonic chirp to estimate distances between the receiver and the transmitter. The main difference between the three systems is in their implementation.

THEORY OF OPERATION

The CSIR CMI has developed a 2D underground localisation system. The vertical axis plays little significance in the measurement because typical heights of deep-level roof-walls are less than 1 m. The localisation system utilises ultrasonic and electromagnetic signals to facilitate a *differential time-of-flight* (D-TOF)-based trilateration to localise a receiver in a network of transmitter beacons. The transmitting beacons are installed in the strike gullies of the mine. Their location is surveyed and programmed onto its memory.

Trilateration is a technique that determined the location of an object from distances to known locations. In **Figure 1**, RC represents a receiver surrounded by three transmitting beacons, T1, T2 and T3. The positions of all transmitting beacons are surveyed into the beacon. The distance between the receiver and the transmitting beacon is deduced from the D-TOF. The transmitters take turns in transmitting the desired waveform. Each transmitter transmits an electromagnetic signal and an ultrasonic signal simultaneously. The ultrasonic signal carries two important pieces of information about the beacon, the identity number and the beacon position.

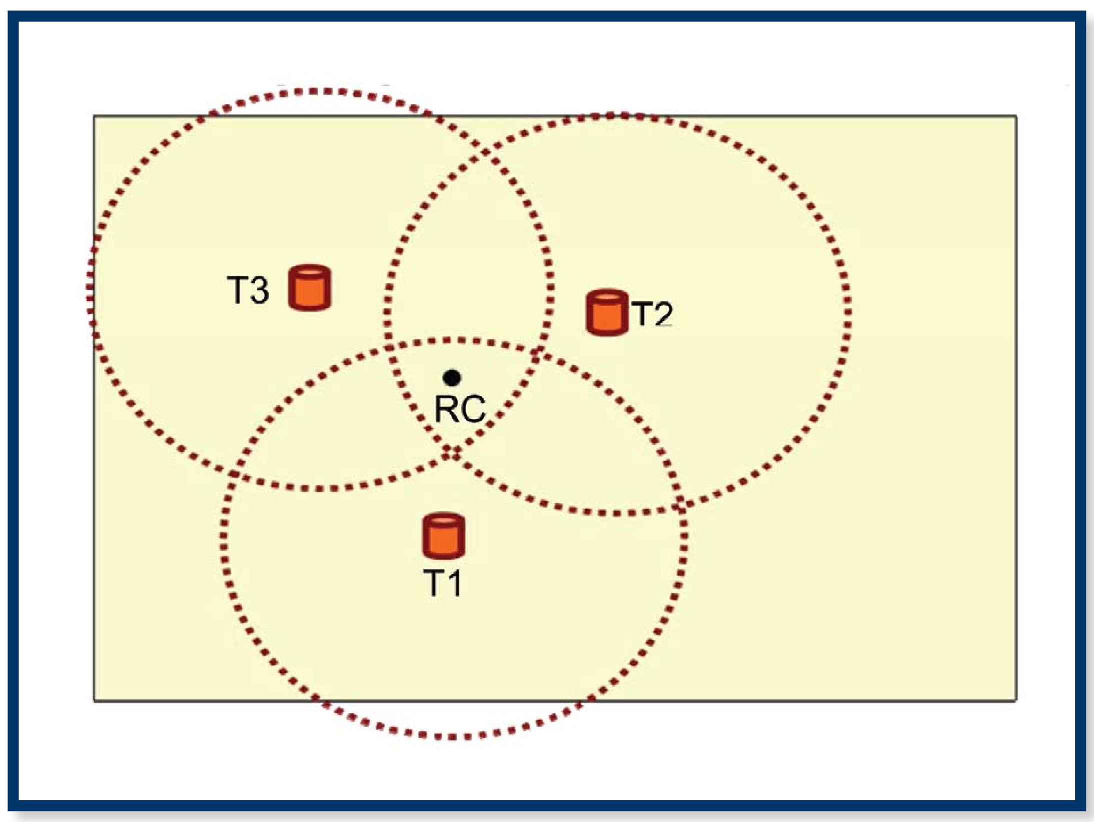

Figure 1: 2-D Trilateration

The electromagnetic signal acts as a synchronisation signal with an assumption that it travels instantaneously. **Figure 2** shows the beacon transmit cycle. The electromagnetic signal occupies the channel for the whole 30 ms to prevent other beacons from commencing their transmission. Beacons wait in RF receive mode. They randomly listen for a transmission. If a beacon is transmitting, the rest of the beacons remain in RF receive mode. Once a beacon establishes that no beacon is transmitting, it can then begin its own transmission. The distance is therefore related to the D-TOF by the travelling speed of the ultrasonic waves for specific environmental conditions.

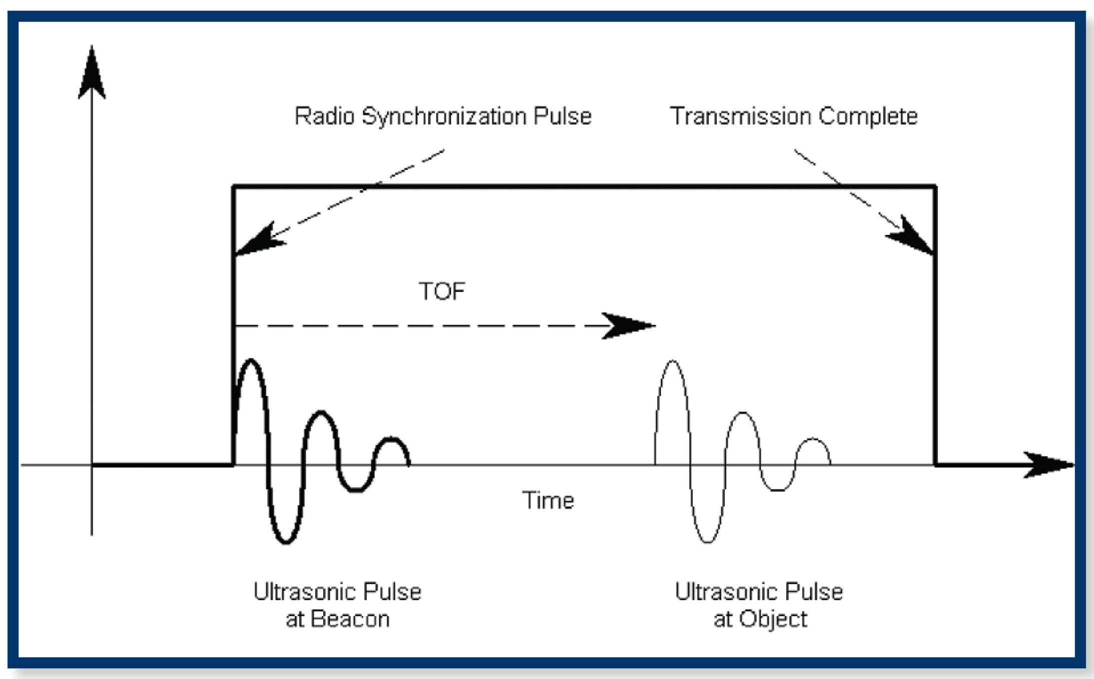

Figure 2: Beacon transmit cycle

Figure 3 and **Figure 4** show the beacon and a prototype receiver respectively. The beacon is encased in a water resistant resin case to prevent corrosion. The prototype receiver system has an LCD screen to display the position within the desired reference frame. The prototype board also comes with a serial communications port and a USB port to import the data to a computer.

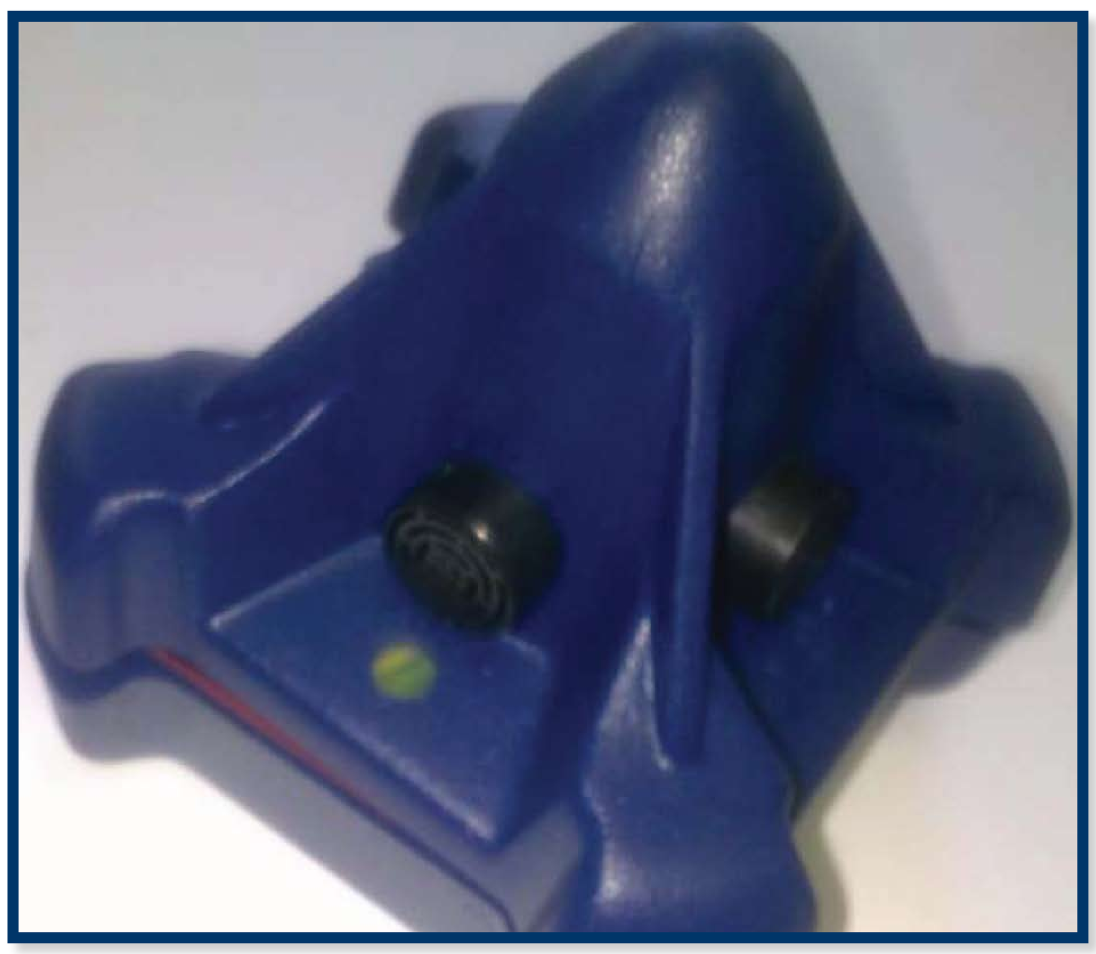

Figure 3: GDL Beacon

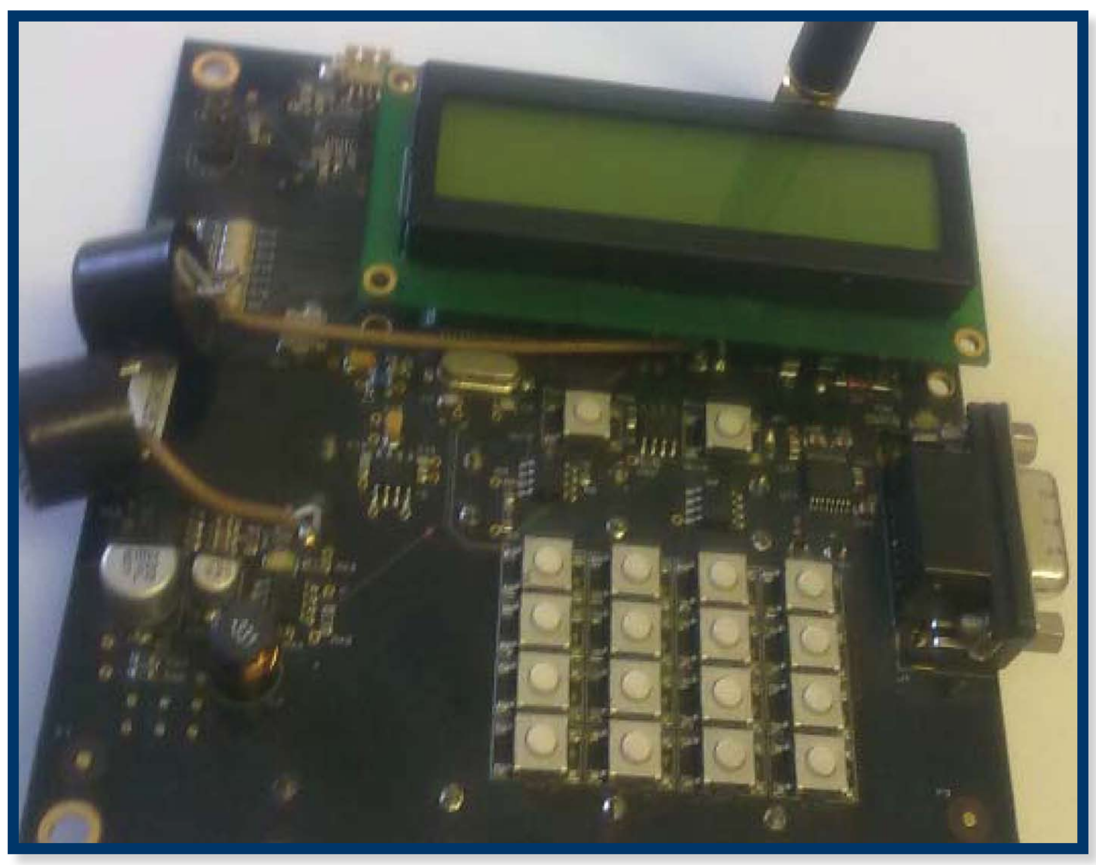

Figure 4: GDL Receiver v1.0

Contributing to mine safety, the CSIR has successfully demonstrated a GPS-deprived localisation system suitable for underground mines and other indoor environments.

CONCLUSION

Conventional localisation systems are not suitable for underground mines. Indoor localisation techniques are more suitable for underground mines because the two environments closely resemble each other. Current indoor localisation techniques are labour intensive, have a slow refresh rate and use their power supplies inefficiently. The CSIR has demonstrated a system suitable for underground mines and even other indoor environments like office parks and factories.

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