Demo Abstract: Magneto-inductive tracking of underground animals

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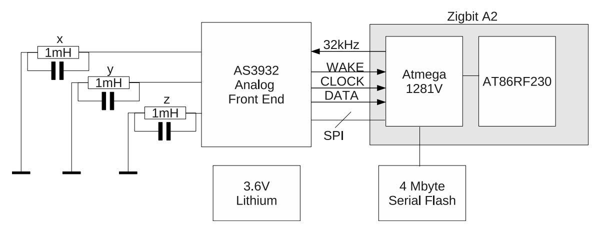
1 Overview and Motivation

Existing sensor network deployments for wildlife tracking (e.g. ZebraNet [1]) have concentrated on monitoring animal behaviour *above-ground*. However, a wide variety of animals create underground tunnels for shelter and protection whilst the animal is asleep. The extent and internal architecture of the underground structure varies considerably amongst species. For example, badgers excavate wide ranging underground tunnel systems which a number of animals inhabit in a community [6]. In addition, their tunnel structure is something which is often only determined by the destructive extreme of excavation [6]. As fossorial animals spend a large proportion of their lifetimes underground, this means that zoologists only have a partial view of their behaviour and habits. There is thus a need for a system which can localize animals whilst they are underground, in a non-invasive and automatic way.

Localization techniques based on using radio transmissions (whether RSSI, time-of-flight or angle of arrival) all suffer from severe attenuation of the electric field component of the electromagnetic wave by the soil. This also precludes the use of technologies such as GPS. As some animals can burrow up to a depth of 3 m, even high powered radio approaches are unsuitable. Localization through dead reckoning [2] or inertial tracking has major issues with drift which can result in large cumulative errors, reducing the confidence in drawing significant biological conclusions from location information. Although electric fields are strongly affected by the presence of soil and water, magnetic fields on the other hand are subject to negligible levels of attenuation. This makes them an ideal modality for tracking animals underground.

2 Magnetic Localization

The use of magnetic fields for localization was first proposed by Raab et al.[5], but to date, the focus has been on high-precision operation over a small volume (e.g. 3 m radius). Moreover, existing approaches have not considered operation through soil. The devices used in these systems are not designed for long-term low power operation and typically have lifetimes in the range of a few hours, not the months required for an animal tracking system. Thus, custom devices had to be designed to meet the requirements of the application. To reduce power consumption of the animal tracking devices, they are made to sense (rather than emit) a magnetic field. This necessitates the use of an additional radio communication link that is used when the animal is above ground to transfer the measurements made whilst underground, but overall this strategy results in a low power device, capable of months of operation.



(a)

Figure 1. System overview of the animal tracking tag.

To localize a device, it is necessary to know the spatial distribution of the generated magnetic fields. Unlike other localization modalities such as time-of-flight ranging, where round trip-time is proportional to distance, the relationship between magnetic field distribution and distance is more complex [4]. On axis, the field decay can be approximated by an inverse cube law which limits the achievable range of the system. However, as the field is non-propagating (quasi-static), there are no issues with multi-path interference, unlike conventional RF localization. To determine the location of the device, non-linear least squares estimation is used, along with knowledge of the coil locations and transmitter power.

3 Prototype and Demonstration

In this section, we describe the components of the magnetic tracking system.

The *antenna system* generates the coded 130 kHz magnetic fields which are used to localize the animals and can drive up to five antennas or loops. It consists of an PIC24F48GA002 microcontroller, half bridge MOSFET drivers and the LC antennas. The antennas are formed from loops of wire which are tuned with capacitors to resonate with at the centre frequency. Each antenna is driven in turn, transmitting a unique digitally coded signal.

The animal *tracking tags* receive the generated magnetic

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(a) (b)

Figure 2. (a) An assembled badger tracking board. (b) A tracking collar with the tracking board encased in epoxy resin.

fields using a triaxial low frequency analog front-end, the AS3932. By using three orthogonally arranged receiving transponders, the device can be made rotationally invariant. This is important as the orientation of the animal is not known. The core of the tracking tag is a Zigbit A-2 wireless module. This compresses field readings using a combination of the Haar lifting wavelet transform and Elias-Gamma encoding before storing them in external flash memory. When possible (i.e. when the animal is above-ground), the device opportunistically uploads the buffered data. The device has been optimized for low power operation, with average power consumption in the order of 100 μA. The system overview of an animal tracking tag is shown in Fig. 1.

The *basestation* retrieves the stored data from the tag. It also listens for beacons sent by the tracking tag which indicate the presence of an animal within the radio radius of the basestation. Thus, the same system can be used for both above- and below- ground tracking. The data from the animal tracking tags is decompressed on a PC and the localization algorithm executed.

4 Demonstration Description

In the demonstration, four small loop antennas will be arranged around a volume to be monitored. For practical reasons, the tracking volume will be considerably smaller than used in the real animal tracking deployment [3]. The animal tracking device will be moved through the volume of interest. The basestation will be periodically switched on and off with a push-button switch which will simulate periods when the animal is above or below ground respectively. The received data will be decompressed and the location trajectory reconstructed and displayed on a PC. The power consumption of the tracking device will be monitored by another microcontroller and displayed on the PC to demonstrate the low power operation. Tracking devices in various states of assembly will also be on demonstration, including devices mounted on tracking collars, suitable for deployment on badgers, as shown in Fig. 2.

5 Conclusions

Current technology does not allow fossorial animals to be tracked when they are in their underground burrows. As such zoologists are unable to investigate important habits and behaviours. In this demonstration, we show how magneto-inductive localization can be used in order to determine animals' trajectories within their tunnel system. The tracking devices developed are extremely low power and opportunistically upload compressed data to the basestation. This system has the potential to greatly improve the understanding of underground animal habits and interactions.

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7 References

[1] P. Juang, H. Oki, Y. Wang, M. Martonosi, L. Peh, and D. Rubenstein. Energy-efficient computing for wildlife tracking: Design tradeoffs and early experiences with zebranet. *ACM SIGOPS Operating Systems Review*, 36(5):96–107, 2002.

[2] J. Link, G. Fabritius, M. Alizai, and K. Wehrle. BurrowView–Seeing the world through the eyes of rats. In *Proc. of IEEE IQ2S*, 2010.

[3] A. Markham, N. Trigoni, S. Ellwood, and D. Macdonald. Revealing the hidden lives of underground animals with magneto-inductive tracking. In *Proc. of ACM SenSys 2010, Zurich, Switzerland*, 2010.

[4] M. Misakian. Equations for the magnetic field produced by one or more rectangular loops of wire in the same plane. *Journal Of Research-National Institute Of Standards And Technology*, 105(4):557–564, 2000.

[5] F. Raab, E. Blood, T. Steiner, and H. Jones. Magnetic position and orientation tracking system. *Aerospace and Electronic Systems, IEEE Transactions on*, AES-15(5):709–718, Sept. 1979.

[6] T. J. Roper. Badger *Meles meles* setts - architecture, internal environment and function. *Mammal Review*, 22(1):43 – 53, 1992.