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# Listening to Nature: Acoustic monitoring of the environment

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## INTRODUCTION

The requirement to monitor the rapid pace of environmental change due to global warming and to human development is producing large volumes of data but placing much stress on the capacity of ecologists to store, analyse and visualise that data. To date, much of the data has been provided by low level sensors monitoring soil moisture, dissolved nutrients, light intensity, gas composition and the like. However, a significant part of an ecologist's work is to obtain information about species diversity, distributions and relationships. This task typically requires the physical presence of an ecologist in the field, listening and watching for species of interest. It is an extremely difficult task to automate because of the higher order difficulties in bandwidth, data management and intelligent analysis if one wishes to emulate the highly trained eyes and ears of an ecologist. This paper is concerned with just one part of the bigger challenge of environmental monitoring – the acquisition and analysis of acoustic recordings of the environment. Our intention is to provide helpful tools to ecologists – tools that apply information technologies and computational technologies to all aspects of the acoustic environment.

The on-line system which we are building in conjunction with ecologists offers an integrated approach to recording, data management and analysis. The ecologists we work with have different requirements and therefore we have adopted the toolbox approach, that is, we offer a number of different web services that can be concatenated according to need. In particular, one group of ecologists is concerned with identifying the presence or absence of species and their distributions in time and space. Another group, motivated by legislative requirements for measuring habitat condition, are interested in summary indices of environmental health. In both case, the key issues are scalability and automation.

## DATA COLLECTION

We have developed two kinds of acoustic recording device, data loggers and autonomous wireless sensors. Data loggers have the advantage of being simple and work well for short term monitoring. However they do not scale well due the need for frequent retrieval, depending on storage and battery capacity. Our autonomous wireless devices record audio according to a user defined protocol and upload it to a server over a 3G network. The challenge with autonomous devices is power consumption, especially if they are expected to operate for long periods without intervention. Processing and transmitting large volumes of data requires storage space (consider that a one minute MP3 recording occupies about one megabyte), CPU power, bandwidth and, by implication, energy. We prefer transmitting the data rather than local processing to ensure that nothing is lost for subsequent analysis. We have successfully constructed and deployed sensors which utilise Smartphones to capture and transmit sound [1]. When combined with a 12W solar panel and 35Ah battery, we have maintained such sensors in remote locations for 6 months without human intervention. However, with such hardware, security becomes an issue, which is why simple data loggers are more useful in populated areas.

## DATA ANALYSIS

It is gratifying to discover that even relatively basic web services, such as, the automated acquisition of and listening to recordings, are a valuable research tool for ecologists. In one study [2], our system was used to find the distribution of a rare bird (the Lewin's Rail) by careful deployment of sensors. In a second study of koala bear behaviour [3], it was discovered that, contrary to previous belief, koalas are actively calling during the night as well as morning and evening. However, while users must have the option of listening to any recording, in reality the huge amount of data collected demands automated analysis. In some cases, it may be sufficient to take a second simple step – convert the acoustic data to spectrograms in which the spectral signatures of the desired vocalisations can be easily identified. Using this method, we enabled a user to search 12 hours of recordings in about 30 minutes and to identify the presence of the ecologically significant Australian Ground Parrot.

But even this simple time saving technique will not be practical for the large volumes of data obtained from 24 hour recordings over consecutive days. To this end we have developed a three step analysis sequence; energy analysis, event analysis and template analysis.

Energy analysis locates acoustic energy in frequency and time. It allows the user to focus only on those parts of a recording that are likely to be of interest. When energy data are averaged over weeks, months or years, it is possible to derive useful indices of environmental health [4]. Acoustic event analysis identifies events in a spectrogram attributable to a single source. It complements energy analysis, because the latter is confounded by proximity of the source to the sensor. Event analysis has a number of uses including: The event distribution at a location can be used to characterise its acoustic landscape and to make comparisons with other locations; The kinds of events detected in a recording can be used to select a shortlist of templates for more detailed analysis; and the properties of an event (frequency band, duration, energy distribution) can be used to determine broad categories of non-vocal events, such as wind and mechanical noise. Finally, template analysis adapts speech recognition and machine learning techniques to the recognition of specific animal calls, such as bird calls and Koala bellows.

## AN ACOUSTIC WORKBENCH

We have developed a web interface, to support ecologists with the analysis and annotation of their recordings [5]. Data is stored in a SQL Server database. Users can assign recordings to *projects* and access to them is controlled through *user accounts*. Annotation is achieved using a *folksonomy* approach. Events of interest can be labelled with newly created or existing tags, which can be used to find, sort and filter recordings. Recordings are simultaneously heard and viewed using a Microsoft Silverlight control. Figure 1 shows the sonogram of a koala bellow, with a portion selected for tagging. Tag information (e.g. start and end time) can be saved to the database.

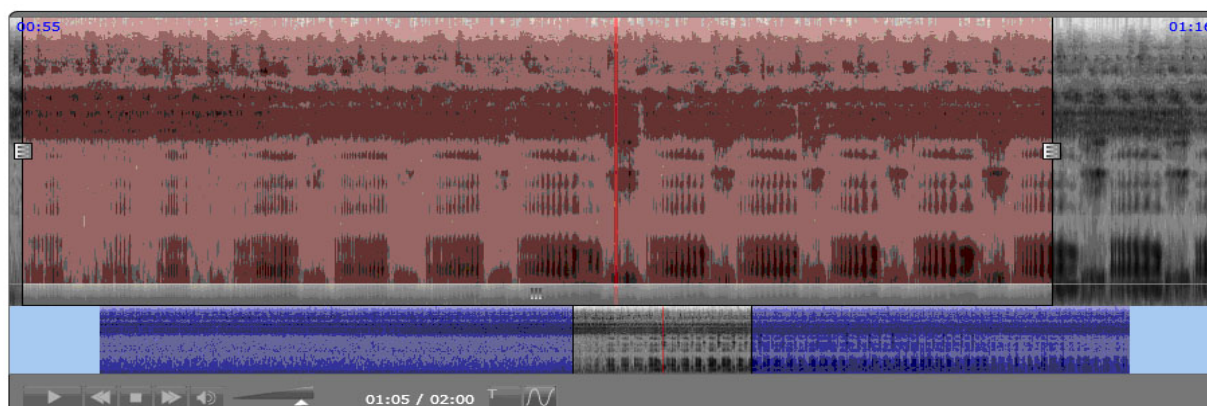


Figure 1. A Koala bellow as it appears in the Silverlight user interface.

The web interface allows the user to initiate jobs, that is, to analyse multiple recordings and to rank them by score. Ranking recordings is the principle mechanism we use to focus an ecologists attention where it most likely to be productive. At present, we offer two kinds of analysis, the detection of acoustic events and the detection of vocalisations pre-defined as templates. Analyses are computationally expensive therefore jobs are run in a batch fashion. A simple interface has been developed enabling jobs to be offloaded and run by other computers, including a small cluster computer.

## RESULTS

Figure 2 displays the output of energy analysis (top) and event analysis (bottom) for a location on the edge of Brisbane city. The data were accumulated over a two week period and are displayed as the averages of one minute recordings taken every 30 minutes over a 24 hour cycle. The energy map is dominated by crickets (~8 kHz) and distant traffic (~500 Hz), the former being prominent due to their ubiquity and proximity to the microphone. However event analysis reveals a prominent morning and evening chorus and an abundance of bird calls in the mid frequency band. A comparison of these two acoustic maps illustrates the importance of having multiple views over the acoustic landscape.

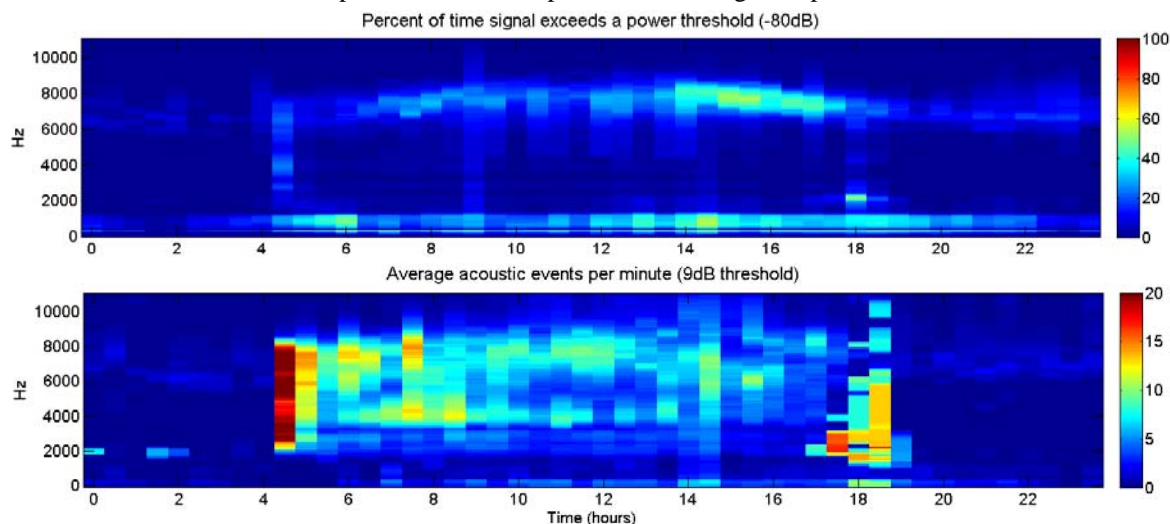


Figure 2: 24 hour maps of acoustic energy (top) and acoustic events (below).

Templates have been constructed for the recognition of the Currawong and the rare Lewins Rail. The former template achieves an accuracy of 94% on unseen test data. The latter (derived from the vocalisations of one bird) achieves only 60% accuracy due to confusion with similar bird calls in the locality but is nevertheless sufficiently accurate to have been of help in determining the distribution of this reclusive and difficult to study species.

We conclude that acoustics has much to contribute to the investigation of species distributions, biodiversity and ecosystem health in general. Furthermore the capture and analysis of sound requires novel hardware and software infrastructure and innovative computational techniques.

## REFERENCES

1. J. Zhang, P. Roe, R. Mason, B. Pham, **“Archiving nature heartbeat using smart phones”**, in *Movement-aware applications for sustainable mobility: technologies and approaches*, Editor: Monica Wachowicz, Technical University of Madrid, Spain, recommended for publication.
2. Gibson, Jennifer. (2008) Unpublished Master’s Thesis, School of Natural Resource Sciences, Queensland University of Technology, Queensland, Australia.
3. FitzGibbon, S., W Ellis, F Carrick Ellis, Bill (2009) *Mines, farms, koalas and GPS-loggers: assessing the ecological value of riparian vegetation in central Queensland*. Poster Presentation, 10<sup>th</sup> International Congress of Ecology, Brisbane, Australia, 16-21 August 2009.
4. Joo, W., S. Gage, and S. Biswas. (2008) Analysis and interpretation of the “Heartbeat of the City” using acoustic signatures along an urban-rural gradient. In *the 93rd ESA, Annual Meeting, Milwaukee*. 88-155.
5. Mason, R., P. Roe, M. Towsey, J. Zhang, J. Gibson and S. Gage. (2008) Towards an Acoustic Environmental Observatory. In *Fourth IEEE International Conference on eScience*. 7-12 Dec 2008, 135-142, DOI:10.1109/eScience.2008.16.