Computer Recognition of Sounds That Have Never Been Heard Before

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Abstract
Computer sound recognition is a maturing art, but recognizing sounds that no one has heard before is a real challenge. We are employing a new sound recognition technique to identify rare parrots (Boucher *et al*. 2007) including the Night Parrot, for which no recording exists. Using massive negative files and a lot of computing power we are eliminating all non-Night Parrot calls and leaving humans to do the rest. This paper discusses the detection and monitoring techniques that have been developed for this task over the last 5 years (Boucher *et al*. 2006).

The recognizer can process 8000 hours of recordings in about one day, depending on the processing power of the PC. Using pattern matching and a new similarity metric we can sift out all expected background sounds and isolate any sounds that are not in the library of known background noises. The resultant sounds are then analysed by human experts who can either add the sounds to the negative or to the positive library as appropriate.

The recognition system's accuracy has been informally rated as "comparable with an expert human listener", by the experts themselves. The recognizer is not limited to bird calls but can in principle be used to identify any sound as it has no bird-specific components.

Keywords: Fourier; Geometric Distance; Pezoporus; ARU

Introduction
In 2002 a project was begun to automatically record and recognize the calls of rare parrots. The undertaking included the design and construction of a recorder that was capable of recording at high quality and continuously for months at a time, and writing software that could identify the calls of the target species on a PC. Because the targets were very rare parrots the system had to be capable of recognizing calls by their similarity, as reliably accurate call recordings were non-existent. The result was the implementation of a new method of sound recognition based on the concept of Geometric Distance as a measure of similarity and the construction of an autonomous recorder capable of terabyte sized records. Although the initial use of the method is for the study of rare parrots there is nothing parrot-specific in the methodology and the system could be used to find and recognize any other sound be it bird, other animal or source.

The Recorder
The recorder is based around a net-book PC, which has sufficient computing power for real-time recognition and power consumption low enough for long-term solar powered operation of about 10 watts. The unit has survivability built in and will hibernate during extended periods of cloud that exceed the 6 days of battery standby, awakening periodically to reassess the battery status before continuing the monitoring. In one version the 60 watt solar panel is connected to the recorder by an armored cable, so that the solar panel can be mounted optimally for sunlight, and the recorder can be placed in a sheltered spot (Figure 1).

Figure 1. The recorder with a terabyte HDD and the recorder in the field

Our purpose-designed recorders can record and save up to 8000 hours (one year) of CD quality sounds. They have a wide range, low noise, AGC amplifier which permits clear recordings at distances from less that one metre and up to more than a kilometer from the microphone(s). The monitors are solar powered and autonomous. Seven monitors have been built as of July 2008.

The Recognition Software

The recognition software is based on pattern recognition. The sound is transformed into a frequency domain pattern using the LPC (Linear Predictive Coding) transform and then this transform is compared to the library of transforms of calls and parts of calls of the reference bird calls. Although most recognition systems use the Fourier Transform, the computationally more demanding LPC has better frequency resolution. More importantly the frequency transform produced by the LPC is more definitive than the FFT and so is more suited for pattern recognition as can be seen in figure 2 below.

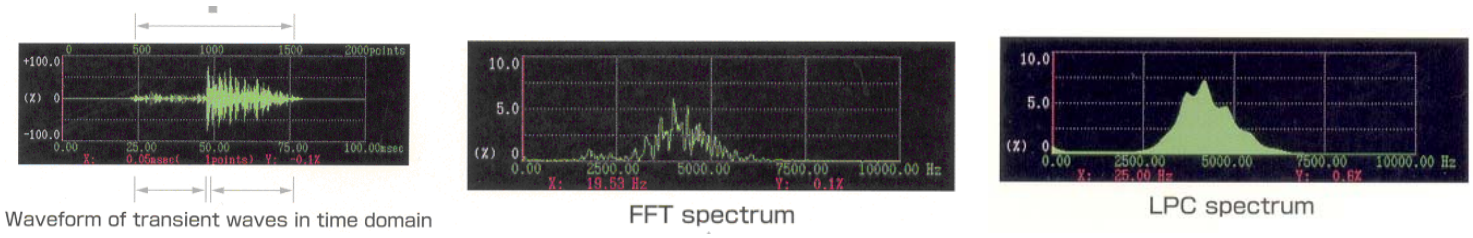

Figure 2. The FFT and LPC compared

What is different about the recognition software is that it uses a new Geometric Distance as a measure of likeness and this allows better assessment of similarity than previous methods. The process for calculating the Geometric Distance is shown in Figure 3. Our testing has shown that the Geometric Distance easily outperforms the Euclidean Distance for recognition of similar patterns both in quiet and noisy environments.

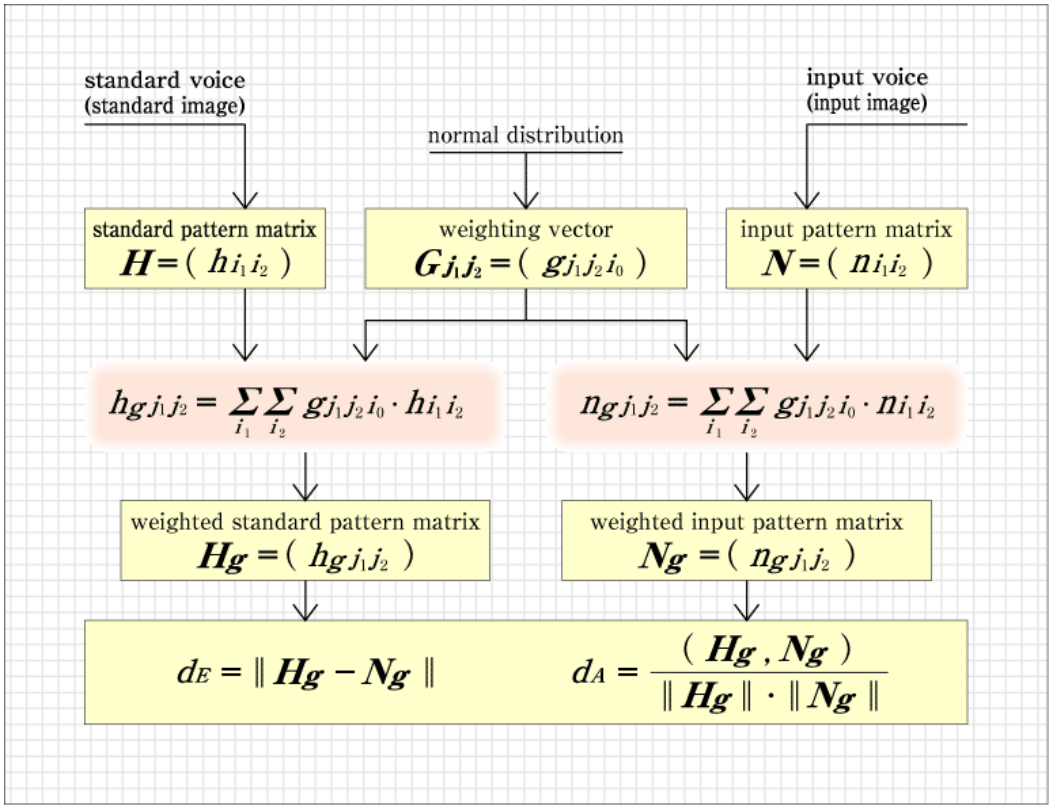

Figure 3. The calculation of the Euclidean Distance d_E and the Cosine Geometric Distance d_A

Speed is of the essence if terabyte files are to be processed (1TB= 3000 hours of mono recording at CD quality approximately). A 1 TB file can be processed in about 30 hours on a Pentium 4, 3.00 GHz machine or in about 5 hours on a good quad processor machine.

Real-time recognition by the recorder is possible but, in general, due to the remote locations that are proposed, most recognition will be post-recording. There is some justification for real-time recognition even in remote locations so that the operator can get an instant summary of the results during visits that may help decide whether the recorder should be left in place or moved on to another location.

Reference Files for the Unknown Calls

While in the case of the Night Parrot there are no authenticated reference calls, there are some recordings that are suspected to be those of the Night Parrot. We can use these by setting the matching parameter to a high value (and hence to a fuzzy match). This will return any call or sound that is remotely similar to the reference and even if it turns out that the call is not that of the Night Parrot it may well identify these calls.

Preliminary testing has shown us that the night time soundscape is very quiet compared to the day. The system detects the energy levels of the recordings and does not waste time analyzing parts of the recording that are obviously just noise. As a consequence there is the advantage when seeking a night-time target that there are fewer generators of potential false positives and that the processing will be considerably faster.

The essence of the recognition however is the negative file. We generate this by making a field recording in the target area and having an expert listen to a part of the recording (say 20 hours). The expert needs to certify that all or most of the sounds detected are *not* those of the target and cut these sounds into a negative file. The recognition software can then process a larger file of say 20 days, and identify only those calls that are *not* in the negative file. The expert then listens to those calls and adds all non-target calls to the negative file. And so the negative file grows.

There is no limit to the size of the negative file, and because the reference calls (negative or positive) are pre-processed (they are stored as LPC transforms) having large numbers of references does not significantly slow the recognition.

The Night Parrot is the Target

The Night Parrot (*Pezoporus occidentalis*) is an enigmatic, unusual and extremely rare parrot known only from arid regions of Australia. So little is known about it, and so many people have searched for it, that it is surrounded with mystery. The future of the species is most likely tied to sustainable management of Australia's red centre, but the species is difficult to locate and study by conventional means, so innovative approaches are required if we are to conserve this iconic component of Australia's unique biodiversity.

The Night Parrot is arguably Australia's most threatened, least understood and most cryptic bird. In the last 25 years none of the dedicated searches have resulted in confirmed records of the bird, although there has been a constant trickle of unconfirmed reports emerging from right across the species' distribution. On the other hand, two dead specimens have been found during that time. It is known to be have been widespread in arid regions of Australia (Figure 4), inhabiting spinifex or low shrubby samphire vegetation, usually in or near rocky country.

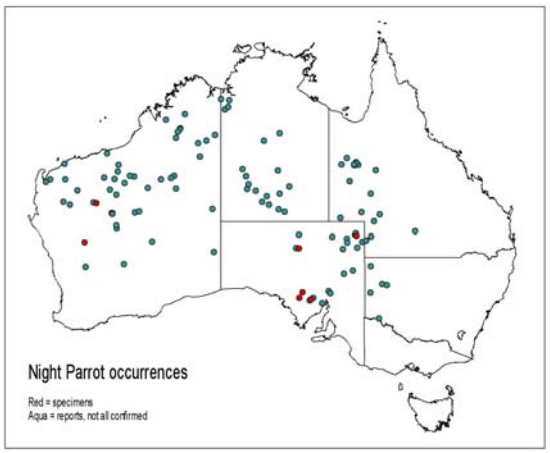

Figure 4. The range of the Night Parrot

Two approaches are being used to learn how to find the birds. First, a GIS project is underway (S. Murphy *et al.*) to examine the relationship between historical records and patterns of rainfall and fire across the Australian arid zone, as significant

rainfall events in areas that are long-unburnt will result in heavy seeding events in spinifex (*Triodia* species) and it is thought that Night Parrots may be nomadic, following such seeding events for food.

The second approach is to deploy remote sound recorders to listen constantly in areas where it is believed that Night Parrots occur, or are highly likely to occur. Calls of the Night Parrot are described as whistling calls, varying from sweet two-note calls to long drawn-out mournful whistles and short, sharp repeated notes, often given in flight at night. Another call is described as a frog-like croak (Higgins 1999). It is likely that the calls have a close similarity to the whistling calls of the Ground Parrot, which are quite well documented (eg Chan and Mudie 2004). The major obstacle to using this approach is that no living ornithologist has heard a Night Parrot call with certainty, although some experienced field workers have heard calls that they believe were most likely Night Parrots. It follows that there are no known sound recordings.

Initial trials are being held in the Pilbara region of Western Australia, where there has been a recent report of Night Parrots (Davis and Metcalf 2008) and where there is a clear need to obtain better information on Night Parrot occurrence in the face of numerous major resource development proposals, some of which may need to take into account the possible occurrence of this Critically Endangered species.

Calls of the Night Parrot are believed to be similar to the more common Ground Parrot, which can be used as a reference to confirm the technique.

Results and Discussion

Live field testing commenced in September of 2008, with 5 units deployed and preliminary testing suggests that a lot can be expected from this system. Although we have been unable to induce a system crash on the XP based net-book PC, the stability of this platform remains in question. The housing has been tested for months in the open and while it has proven highly water resistant it is *not* waterproof. The cost of building a fully waterproof housing is prohibitive. Additionally, the unit can be expected to be called on to operate in areas from the Pilbara to the wet tropics and the Tasmanian West Coast so an independent data logger is installed in each unit to monitor temperature and humidity.

The recognition system can perform with false positives of less than 1% and in tests performed by experts themselves is rated comparable to a human expert in positive identification. No other bird call identification system has yet approached this standard.

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