Chapter 6

CONCLUSION

The current chapter presents a summary of the procedures of the study and provides recommendations for further research.

6.1 SUMMARY OF THE WORK

1. An exploration of existing literature on elephant vocalizations and the application of speech processing techniques to animal sounds was conducted. This led to the identification of several shortcomings in the current body of knowledge. These include the need for the development of a reliable way to collect large quantities of acoustic data from elephants in the wild and a way to automatically isolate rumbles from these recordings. The different types of existing VAD techniques were invesigated to find a suitable technique that could be used for the automatic detection of elephant rumbles.

2. An elephant recording collar was designed and built in an attempt to provide a reliable means of recording large quantities of acoustic data from elephants in the wild. An electronic design was made from component level focussing on low power consumption, physical robustness, small size and lightweight. A PCB was designed for the physical realization of the electronic design.

3. The resulting device recorded 16-bit encoded sound digitally to onboard memory at a sampling rate of 3000 Hz. The recorded sound was stored on an array of

flash memory cards that have enough capacity to store sound continuously for a period of 133 days. Sound files were saved in the wave file format on an FAT32 file system together with GPS coordinates and temperature information.

4. The electronic recording device was fitted into an elephant collar and protected mechanically by moulding it into a hard plastic epoxy and covering the memory card section with a layer of polycarbonate.

5. Experiments were done to find the most effective way to mount the microphone under the polycarbonate sheet so that it remained physically protected, water-tight and able to pick up the desired bandwidth of sound frequencies.

6. An automatic elephant detection algorithm was developed by using an existing VAD technique as a basis. The algorithm divided the input signal into 32 sub bands and took the autocorrelation of each band in windowed frames. Correlograms with good SNRs were added together to form an estimate of the dominating pitch present in that time window.

7. A method was devised to determine the presence of an elephant rumble from the summed correlation data and then track the pitch within a rumble. A program was written to realize the algorithm using Matlab software. The output was displayed graphically as well as in table format.

8. The automatic rumble detection algorithm was tested on a combination of clearly recorded rumbles and rumbles occurring in common background noises, but under generally good conditions, resulting in 90.47% of the rumbles being correctly detected. Tests were done to find circumstances under which the algorithm would fail.

9. Finally, potential improvements of the algorithm to enable processing of non-ideal recordings were examined. This included modification of the algorithm to enable detection and tracking of overlapping elephant rumbles.

6.2 FUTURE WORK

The objective of the current study was to introduce new research tools to the field of acoustic elephant research. During the course of the study, a number of difficulties were

encountered. Solutions to some of these problems were found, while others remained unsolved. As the study progressed and a better understanding of the issues at hand developed, several new ideas were conceived that might prove valuable in future work on the same topics.

It is preferable for the elephant recording collar to remain active for a very long period of time so that the amount of data obtained would justify tranquillizing the elephant. Currently, the collar has a battery pack weighing less than one kilogram. This battery can power the device for six months. The rapid technological advances made in the field of low power electronics should make it possible to redesign the electronics in a manner that would prolong the battery life. High density flash memory technology is also advancing at a steady pace which should make it possible to reduce the number of memory cards needed in the system. Reducing the operating voltage of the system to 3 V would result in a battery pack half the weight and size of the current design.

One of the unsolved problems encountered with the elephant recording collar was the temporary blockage of the microphone by mud. The possibility of replacing the existing microphone with a surface microphone could be explored. A surface microphone is a very sensitive microphone mounted on the backside of a surface like the polycarbonate sheet that can pick up sound waves that collide with the surface. This could provide much better protection against physical damage of the microphone and would prevent the possibility of the microphone getting clogged by mud. However, methods to prevent these highly sensitive microphones from recording unwanted noises if something should brush against the collar would still need to be investigated.

In this study, a number of different algorithms for VAD were considered as a possible base for the automatic detection of elephant rumbles. A technique that has been implemented successfully in the past for the detection of human speech in recordings containing background noise was chosen. This technique worked well, but the bank of autocorrelators used in the technique makes it computationally expensive. In the future, the use of other noise robust algorithms (Barros, Rutkowski, Itakura and Ohnishi, 2002) that are less expensive could be explored and the results compared to those of this study. The method devised in this study for the final detection and pitch tracking phase of the algorithm (from the raw autocorrelation data obtained from the first stages of the algorithm) appears to be less than optimal. The use of an optimal method (Wang and Willett, 2003) for this task could be explored and the trade off

between the gained accuracy and reduced speed of the optimal method should be examined.

The elephant detection algorithm developed in this study could be used as a basis for further signal processing on elephant rumbles. Using the algorithm, a system could be developed that would automatically detect rumbles from a large collection of unprocessed recordings (like those obtained from the elephant recording collar), and automatically isolate and place the detected vocalizations in a database. Such a system could help to provide the necessary resources needed for work combining speech processing and elephant acoustics.