Listening to the Giants: Using Elephant Infra-Sound to Solve the Human-Elephant Conflict

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ABSTRACT

The continuing human-elephant conflict in Sri Lanka has resulted in loss of human as well as elephant lives. Detecting and localizing elephants is an essential component of any viable solution to this problem. Currently, we conduct feasibility tests on using low cost sensors to detect elephants from a long distance, leveraging the infra-sounds emitted by them. In this paper we present the test environment that we have set up for this purpose and some preliminary, but promising results.

1. INTRODUCTION

In the year 2011, the Department of Wildlife Conservations (DWC) in Sri Lanka reported the presence of 5879 elephants within the area of 65,000 km^2 on the island [5]. Humans are increasingly encroaching on the natural habitats of elephants, depriving them of their feeding grounds as well as restricting their movements. In particular, farmers have settled closer to areas where elephants are present and started growing crops. Rural villagers store their crop harvests inside their houses, which attracts elephants into those domestic areas in dry seasons. 98.3 % of such elephant raids occur in the nighttime where people do not notice the presence of an elephant until it starts an offensive behavior [2]. Such raids damage the crops, harvest storages and homes in addition to causing deaths of elephants and humans.

Residents of the areas affected by elephant raids have resorted to legal as well as illegal countermeasures. Such legal solutions range from implementing electric fences covering domestic areas to using fire crackers to drive away elephants. Electric fences are often subjected to breakages and maintaining such fences requires considerable financial and human effort. Therefore, rural villagers also practice various illegal and destructive methods to protect their property such as placing poisoned vegetables and shooting crop raiding elephants.

A solution to the human-elephant conflict is not complete without a system to detect and localize elephants. The sounds emitted by elephants can be used to detect them. It has been three decades since the first discovery of infrasonic waves emitted from Asian Elephants [8]. Elephants emit various kinds of vocalizations such as rumbles and trumpets. Those vocalizations start from very low frequencies which are considered as infrasonic into audible sounds. In contrast to the other frequencies in elephant vocalizations, the importance of infrasonic emissions lies in the fact that lower frequencies of sounds travel longer distances than their audible counterparts. Therefore, infrasonic emissions from wild elephants can open a new door for detecting and locating them over a significant distance, which has many benefits.

For example, in order to build electric fences, it is necessary to clearly identify the movement patterns of elephants closer to domestic areas that need to be protected. Improper laying of electric fences makes them ineffective in protecting humans and waste deployment costs. Furthermore, long distance detection and localization can help to warn villagers about raids from aggressive elephants where electric fences are not available or not functioning properly.

In this paper we present preliminary results of our effort in detecting and localizing elephants using the infra-sounds emitted by them. To achieve this goal, we need to record infra-sound, ensure that it is really emitted by an elephant and then finally use a localization method to locate the elephant. While we have not yet reached this goal, this paper presents our insights and discusses the challenges ahead. This work contributes to a larger system that we are devising to address some causes of the human-elephant conflict in Sri Lanka [4].

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2. RELATED WORK

Payne et al. [8] discovered that most of the fundamental frequencies of acoustic calls from elephants are in the range between 14 Hz to 24 Hz. They point out that the higher frequencies, which Asian elephants can hear the best (about 1000 Hz), attenuate more significantly than the lower frequencies (less than 30 Hz) in the presence of trees and thick grass. Payne et al. also note that Asian elephants hear infrasonic calls better than high frequencies if the distance from the source is greater than 300 m. Langbauer et al. [6] have shown this by playing back low frequency calls of elephants from distances about 2 km and observing the responses of the elephants to these infrasonic emissions. This shows the importance of using infrasonic calls to detect elephants from longer distances.

Fundamental frequencies of elephant infrasonic calls generate higher frequency harmonics, resulting a wide spectrum of audible sounds. Zeppelzauer et al. [13] present a signal enhancement technique for identifying sounds from elephants in the presence of various types of noise sources such as wind and automotive engines. They have used a large dataset that consists of prior recordings in such noisy environments with the presence of elephants. According to their observations, higher frequency harmonics of the fundamental infrasonic vocalizations decrease when the distance from elephants to the infrasonic microphone increases. This observation agrees with the conclusions by Payne [8] as these experiments were conducted in an environment with similar conditions.

Zeppelzauer et al. [12] also present a method for automated detection of elephant vocalizations which is targeted towards a future automated early warning system for elephants. They have considered a broad range of low frequency elephants sounds from 0 Hz to 500 Hz, which include infrasonic waves. Even though they were able to detect unique patterns of elephant vocalizations, detecting them at longer distances where higher harmonics are highly attenuated is questionable. In [10], another method of automatically detecting elephant infrasonic calls from recordings is presented. However, still their method relies on the availability of harmonics structure for an accurate identification.

Localization is a well explored area with both radio waves and audible sounds [11, 7] while infrasonic localization has been used in domains such as locating explosions [9]. We intend to explore those methods to identify a suitable method to localize elephant infrasonic calls. However, in this study we have not attempted to localize the infrasonic source.

3. EXPERIMENTS

In contrast to the previous work discussed in Section 2, our goal is to detect elephant infrasonic calls using a low cost solution. Towards this end, we choose the *Infiltec Model INFRA-20* device [1] that implements the microbarograph principle. The device comes with relevant software in order to save sampled data to a computer in a standard data format for later use or analyze in real-time. It consists of a built-in filter which helps to monitor frequencies below 25 Hz and can sample infrasonic sounds at a rate of 50 Hz. The device costs 345 USD which is significantly cheaper than many other infrasonic detectors available in the market for this purpose.

3.1 Recording Elephant Sounds

We made sound recordings with two domesticated elephants, first with *Nedungamuwe Raja* who is 56 years old and then with *Pulasthi* who is 20 years old.

We fixed the infrasonic detector onto a tripod and placed it in front of the elephant a few meters away from it in an open area surrounded by large trees and grass on the ground (see Figure 1). To save the digitized infrasonic data at a sampling rate of 50 Hz, we connected a laptop to the infrasonic detector using a long serial cable. As ground truth, we placed a video camera near the infrasonic detector in order to capture the elephant behavior throughout the experiments which are about 2 hours long for each elephant. The mahout (caretaker) fed the elephants and sometimes stimulated them during this time period.

Figure 1: Experimental setup used for field recordings. Our infrasonic recorder was fixed onto a tripod and placed in the field. It was connected to a laptop for data storage through a long serial cable.

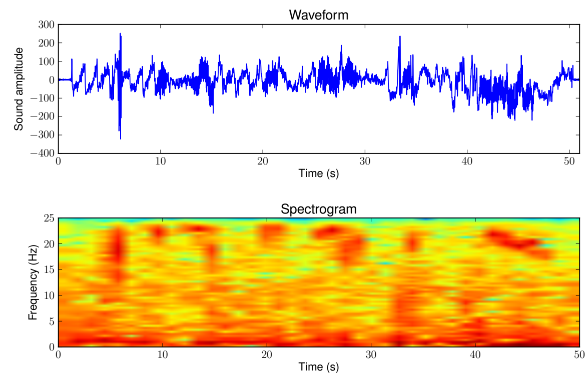

Figure 2: Waveform and the spectrogram of an elephant rumble. Fundamental frequency components lie in the range from 14 Hz to 24 Hz.

In our analysis, we played the recorded video and the spectrograms of the infrasonic data in a time-synced manner to observe any behavioral change that could be associated with infrasonic emissions. We identified various infrasonic emissions from the elephants; Figure 2 depicts such a waveform and its spectral view. This detected signal lies in the range below 24 Hz and lasts for few seconds.

3.2 Detecting Infrasonic Calls

We evaluated the detectability of infrasonic calls over long distances in the presence of trees and buildings. Since it is not possible to receive continuous infrasonic emissions from an elephant, we emulated the elephant presence by playing back the identified elephant sounds using a subwoofer. Our initial tests to characterize this subwoofer confirmed that it is good enough to emulate elephant sounds. Figure 3 shows such a sound generated by the subwoofer and captured using infrasonic detector. The output power of the subwoofer

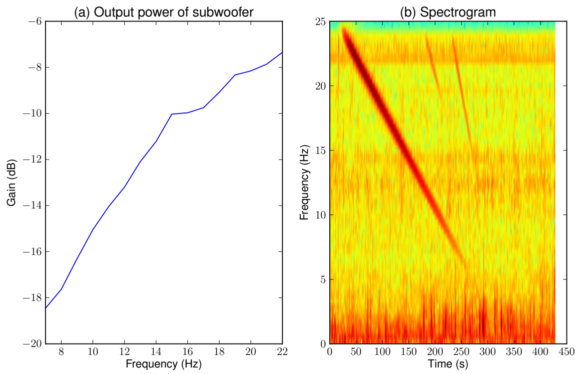

Figure 3: Characteristics of the infrasonic emitter. Subfigure (a) depicts the output power of the subwoofer for various frequencies. The spectrogram in subfigure (b) depicts a chirp sound emitted by the subwoofer which is captured using an infrasonic detector.

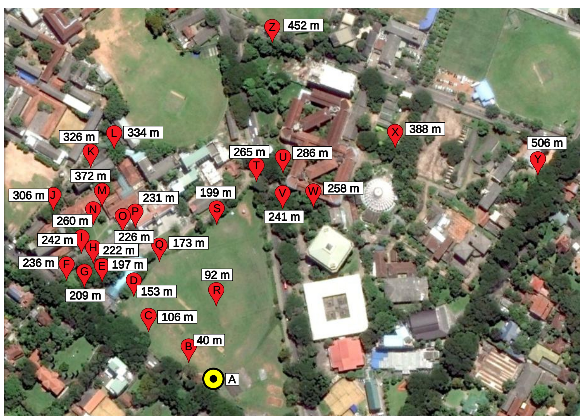

Figure 4: The area where we performed the experiment of measuring elephant infrasonic attenuation. The yellow circle in the bottom of the map represents the location of the infrasonic emitter while every other pin represents a location where we placed the infrasonic detector.

proves that it can effectively emit infrasonic sounds in the range that we are interested in between 14 Hz to 24 Hz.

For the long distance infrasonic detection experiment, we selected our university premises that consists of large trees and thick vegetation as well as various buildings as shown in the aerial map in Figure 4. The yellow circle in the bottom margin of the map depicts where we placed the subwoofer to repeatedly play the recorded elephant infrasonic call. In between the elephant calls we also played a 15 Hz beacon tone to verify whether we actually received the signal at the data collection points. We collected samples from the infrasonic detector at various geographic locations which are marked as red pins in the map. There is a busy road through the university premises, and note that vehicle engines are also known to generate infra-sound.

After collecting data at different places around the university premises, we analyzed them to detect the beacon tone.

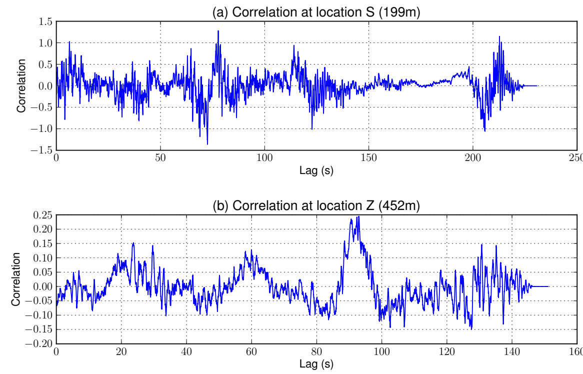

Figure 5: Cross correlation of the recorded infrasonic waves at a few locations in the map against the original elephant infrasonic pattern.

We could detect this tone at some locations, but not at the others. For example, there were clear indications of the tone at the location S (199 m away from the source) and Z (452 m away), but not at the location Y (506 m away). The collection point Y is located near a noisy construction site. There are buildings and vegetations in between the location Z and the source.

Figure 5 depicts the cross-correlations for some locations that received the beacon tone. The peaks in the plots indicate that it is possible to detect the pattern of the rumble at a distance. The sound recorded in the vicinity of the subwoofer has about 30 dB less power compared to the sound recorded directly from the elephant, indicating that our simulation setup cannot match the elephant in terms of the infrasonic generation power. Therefore, the results are encouraging since we managed to collect evidence of the call at about 452 m away even with a significantly low powered source.

This exploratory experiment uses a simple cross correlation. Venter et al. [10] have described a more sophisticated method that uses a bank of gammatone filters to detect the elephant rumble of African elephants. We intend to use similar techniques in the future.

4. DEPLOYMENT CHALLENGES

In this research we are only considering fundamental frequency components of elephants in the infrasonic range. Unlike other researchers who have considered broader frequency ranges where multiple harmonics are present, we are left with a very small band of frequencies in order to find emissions from the elephants. However, it is highly necessary in order to detect them from longer distances for an early warning system. In addition, the following other practical concerns need to be addressed before we move to a real-world deployment.

4.1 Data Communication

We plan to collect data from multiple infra-sound recorders deployed across a large area to a central server, which uses the time-stamped data to detect as well as localize elephants. The INFRA-20 infra-sound recorder collects 16 bit samples at the rate of 50 samples per second. This amounts to a data rate of 800 bits per second. Therefore, it is quite possible to use the cellular data network to connect the sensors to the central server. A continuous collection of data for a month only results in just 260 MB of data. 600 MB of data package from a popular mobile telecom operator in Sri Lanka costs about 0.75 USD.

Connectivity to the Internet is an important challenge to face on delivering infrasonic data to a central server. However Sri Lanka, being a small island, is reaching cellular network coverage throughout the country in a rapid speed. In case of any inability to connect to the Internet from the place where the infrasonic detector is deployed, we may be required to look for alternative ways to reach a place that has no cellular network coverage. Long range 802.11 links is a possibility in such a context [3] in addition to traditional multi-hop communication options. More importantly, due to low interferences in the 2.4 GHz ISM band in remote areas, we may be able to deliver data with lower packet loss rates, an assumption which needs to be investigated in real world scenarios.

4.2 Hardware Equipment

Sri Lanka is a country with a tropical climate. It receives heavy rainfalls for one period of the year and then faces a dry season. It is inevitable for a field deployment of an infrasonic based elephant detection and warning system to face these harsh environmental conditions. As such, a warning system is supposed to save lives of both humans and elephants, it must operate 24/7 and be extremely reliable. Difficult weather conditions may require continuous maintenance and care by humans to the equipment deployed in remote areas. Due to this reason, we are more focused on low cost hardware which is easy to maintain by non-experts but at the same time, reliable and accurate enough to provide the necessary data for elephant infrasonic detection. We plan to develop our own low cost infrasonic detector for this purpose based on open hardware designs and components.

We plan to connect the infra-sound recorder to an Arduino board fitted with a GPRS/GPS shield (such as SIM908). This shield provides the network connectivity as well as accurate time information through the GPS signals. A single sensor unit consisting of the INFRA-20 device, Arduino board with GSM and USB shields, re-chargeable battery, and a solar panel can be built for a cost around 500 USD. However, we need a large number of such units deployed over a large area to accurately detect and localize elephants. Therefore, we still need to bring down the cost further.

5. CONCLUSION

This paper presents our initial attempts to use infrasonic emissions of Sri Lankan wild elephants as a way to detect and localize them from long distances. Our preliminary experiments hint at the possibility of detecting infrasonic waves with a low cost hardware platform, which is necessary for large scale deployments in rural areas of Sri Lanka. We plan for a field deployment in the near future to investigate the effectiveness of the methods and hardware we tested in this work in the real world.

Acknowledgment

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