Jurnal Teknologi

Full paper

Elephant Tracking with Seismic Sensors: A Technical Perceptive Review

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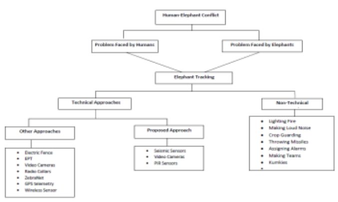
Article history

Received :28 October 2014
Received in revised form :
21 January 2015
Accepted :15 March 2015

Graphical abstract



Abstract

This paper presents a systematic literature review of elephant tracking approaches via seismic sensors. Elephant tracking is broadly divided into two categories: technical approach and non technical approach. Among these two research directions technical approach has proved to be risk-free. It helps accumulation of the life of both human and elephants in the Human-Elephant Conflict (HEC) scenario. In the technical approach, seismic sensors have been preferred as an effective methodology for elephant tracking as reported in the literature. Seismic scenarios address research gap in the existing methodologies through their efficiency and precision in monitoring elephant movements without causing any harm to them while, at the same time, helping humans to solve their problems and saving environment from hazards. The main contribution of this paper is review of and address to the technical approaches that are employed for elephant tracking using seismic sensors which also include seismic communication through sensor devices and encourage future research on this topic.

Keywords: Elephant tracking; human-elephant conflict; seismic sensors

1.0 INTRODUCTION

The conversion of forest lands into human settlements happens due to the expansion of human population. This results in wild animals and humans sharing the common place. The sharing gives rise to and acts as a reason behind Human-Elephant Conflict. Minimizing HEC is done effectively only through Elephant Tracking. Hence, this paper focuses on the problem of HEC and provides the solution for Elephant Tracking. Earlier studies have considered various methodologies for Elephant tracking, namely, fetching radio collars, electric fencing, monitoring using video cameras and using wireless sensors etc (Matthias 2009). Similarly, the earlier researches (Günther RH (2004) have incorporated and reported the significance of seismic sensors in a wide variety of applications (O'Connell-Rodwell (2001, 2000, 2006)).

The objectives of this research is to investigate and analyze the various methods used for Elephant Tracking and to minimize HEC, by considering their importance, and to review various approaches for elephant tracking especially focusing on the role of seismic sensors in Wireless Sensor Network (WSN) environment. This review will obviously support the coherency between the varieties of directions of elephant tracking research and find enhanced representation of possible solutions for the problems faced in HEC through seismic sensors.

The paper is structured as follows: In Section 2 of this paper, a short analysis of earlier surveys, conducted on Elephant Tracking and seismic sensors have been elaborated. Section 3 elaborates on the reasons for the continuation of HEC. The occurrence of Elephant Tracking is briefly discussed in Section 4. Research method is explained in Section 5. Section 6 presents the main clarification arising out of the study. Section 7 gives the conclusion of the paper.

2.0 RELATED WORK

In this literature, the problem of HEC and the solution for Elephant Tracking have been considered broadly from the perspective of Wireless Sensor Networks. A significant review work has been reported on the subject of Elephant Tracking. Some of the considerable survey works relating to the HEC are as follows.

The analysis of elephant characteristics is complex to study, as the survey depends solely on the environment. Daniel (1980) and Sukumar (1989) have investigated and found that elephants have suffered very much due to lack of resources and shrinking of habitat. In addition, Santiapillai and Jackson (1990), Balasubramanian *et al*. (1995), Desai and Baskaran (1995), Baskaran *et al*. (2007) have made a comprehensive survey on the reasoning of HEC. Moreover, earlier studies have discussed that, the reason behind this HEC is a massive increase in human population. The studies have suggested solutions for mitigations of HEC problems via intelligent Elephant Tracking system. Subsequently, the earlier studies (Wing & Buss (1970), Jachmann & Bell (1979), Walsh & White (1999), Barnes & Dunn (2002), Laing *et al*. (2003)) have presented a technique called elephant's dung ball counting, which was the first applied census technique for estimating elephant numbers. In addition, earlier studies (Ullrich (1996), and Jason D.Wood (2005)) have addressed the support of seismic sensors in estimation of elephant numbers.. The seismic sensors are collecting the data that could be communicated through satellite and downloaded by officials at remote points.

This paper explores the character of seismic communication in elephant tracking. Moreover, in an earlier study Michael Garstang (2013) has addressed the ability of elephants to send and receive seismic signals has been reviewed from different perspectives. Seismic cues are produced through percussion on the earth surface. Percussion can produce both short and long-distance seismic waves (Nishant Kishore Rai (2009)). Moreover, this study reveals such role of seismic sensors, and how seismic detects the elephant path in a diverse perspective. In addition, this technique is mainly used for pachyderms to detect their path through vibration in footfalls (O'Connell-Rodwell (2001)). The above referred contributions reveal the availability (in literature) of information on the attempts at elephant tracking. But a review of elephant tracking with seismic sensors has been very limited. Thus, this paper extends the above contributions further by suggesting the problem and solution in depth for HEC.

■3.0 HUMAN-ELEPHANT CONFLICT

Asian countries like India have been witnessing steep population increase, with agriculture and industry helping survival. Growth in these areas has necessitated conversion of forest areas into human occupation areas, giving rise to shrinking of resources (food and water) needed for animals. This in turn drives animals to barge into human habitation areas. The elephants, among the pachyderms, play a major role in the loss of forest resources, leading to increase in HEC which plays a dual role affecting two broad categories---problems faced by humans and those faced by elephants. Solutions have to be found for both—loss of human lives caused by elephants and elephant deaths caused by poachers.

3.1 Problems faced by Humans

HEC describes any situation where elephants cause problems for people. Elephants may damage crops raised by humans, apart from houses and property. They may even endanger people's lives. Human settlement areas were once used by elephants and this becomes the only reason for the conflict of elephants with human. The other reason is that, human settlement areas targets around the sources of permanent water sources and this forces the elephant to enter into human habitats to drink, especially during the dry season.

3.2 Problems faced by Elephants

Problems faced by elephants are not just those arising from vagaries of nature but man-made too. In actual practice, more are caused by the latter than by the former. Senseless mining in the hills and forests which is lucrative for investors, massive deforestation which drives elephants away from their natural habitat, practice of poachers involved in illegal smuggling valuable forest resources are among the man-made causes which have the drying up of food and water resources as a corollary. Drying up of water in rivers and pounds due to scarcity of rains is a problem of nature but this pales into insignificance when compared to the man-made problems. Whatever be the cause, the solution to the problem of HEC lies in the intellectual supervision and tracking systems. Many solutions and methods have been recommended by researchers and scientists for implementation. They are real time solutions, says Prithiviraj Fernando (2008).

■4.0 ELEPHANT TRACKING

There is a med race between humans and elephants to share a common space. This is the reason behind Human-Elephant Conflict. This conflict can be minimized only by elephant tracking system. Tracking is the science of observing animal paths and signs. The objective of tracking is to gain a clear knowledge about the animal (being tracked). It depends on environmental factors. This makes elephant tracking mandatory to know the status of HEC.

A large number of deaths occurred in the last decades due to HEC. Human paths and their habitation are well known to everyone. But it is difficult to trace elephant habitation. Hence elephant tracking is mandatory to minimize HEC. Elephant tracking involves technical and non-technical methodologies (Baskaran, 2009). In India many measures have been practiced to alleviate HEC. Some of these have provided short-term solutions which are rather expensive. These have not been found to be long-term solutions. The methods to avoid elephant's entry are categorized into two, namely non-technical and technical.

4.1 Non-Technical Methods

Many of the non-technical solutions are not just historical but have relevance even today. These methods are followed by the farmers for protecting their crops and to save themselves from elephant attacks. The descriptions of various non-technical methods are as follows. Crop Guarding (Ranjit Manakadan, 2010) is a method consisting of huts in the fields and trees which helps getting a clear view of elephant movements even from a distance. Noise and throw method (Osborn F.V 2002) consists of creating huge noise and throwing (or showering) objects, demonstrating human aggression.

4.2 Technical Methods

Various technical methods have been proposed by researchers Pakhomov (2008) and Matthias (2009). These have universal applicability. Each has its own merits and limitations, the latter helping only in finding short term solutions for elephant tracking.Zeppelzauer (2013) has suggested Amplified Monitoring studies using video (Standalone cameras for getting a clear vision of movements of wild animals form at a distance, with the help of radio collars attached (to elephants). There are also wireless sensors that can be attached to animals or fixed at various points in the environment. A detailed explanation of these is provided in section 6.3, 6.4 and 6.5.

■5.0 RESEARCH METHOD

This research design has been undertaken as an organized literature analysis based on the unique guidelines as proposed by Kitchenham (2004). The first step is to identify the research questions toward the direction of Systematic Literature Review (SLR). Research questions have an important role in the literature review. Some basic questions related to elephant tracking using seismic sensors have been considered in this study.

5.1 Research Questions

The research questions identified by this study are:
RQ1: Whether Elephant Tracking is mandatory for the benefit for Human/Elephant?
Motivation: The purpose is to get an idea about the problems faced by HEC and to know the importance of Elephant Tracking.
RQ2: What are the existing approaches of elephant tracking?
Motivation: Obtain an overview of the existing methods in order to know the strengths, weaknesses and to find research gaps.
RQ3: What is the role of Seismic sensor in Elephant Tracking?
Motivation: Obtain an overview of how to track and identify elephants using seismic sensors.
RQ4: How to use Seismic devices?
Motivation: To obtain a clear knowledge about the principles of working of seismic sensors.
RQ5: What are the other applications of seismic sensors?
Motivation: To evaluate the effectiveness of these in other applications by listing its advantages.

5.2 Search Process

The search process was a manual investigation of certain specific conference proceedings and journal papers published from 1980 to 2014. The investigation is divided into two parts, namely sequential and random. Research papers related to elephant tracking has been searched sequentially from the year 1970. Research papers related to seismic sensors is searched sequentially from the year 1976. Research papers related to elephant tracking using seismic sensors is searched sequentially from the year 2000. During random search research papers have been searched in the search engine like Google Scholars by using the keywords: Human-Elephant Conflict, Elephant Tracking, and Seismic Sensors.

■6.0 OBSERVATIONS

This section summarizes the observations on elephant tracking. Table 1 presents the different existing Elephant Tracking approaches and Table 2 gives the performance parameters of those existing approaches and the tick mark "√" shown in respective cells indicate that those performance parameters are taken into account in the respective approach. This section also answers the research questions listed in Section 5.1.

6.1 Whether Elephant tracking is mandatory for the beneficial for Human/Elephant?

6.1.1 Difficulties faced by Humans and Elephants

N.Baskaran and P.Venkatesh (2009) have proposed that in ancient times, Asian elephant (*Elephas maximus*) has a wider geographical distribution. But today the wider habitat is getting shrunk due to of the rising populations in human. This gives rise to conflicts between humans and elephants, according to various authors (Santiapillai and Jackson 1990, Balasubramanian *et al*. 1995, Desai and Baskaran 1995, Baskaran *et al*. 2007).

The conflicts produce problems for both humans and elephants. A brief study of the problems faced by humans has been explained in section 3.1. This section gives the detailed proof and the approximate calculation on the damages caused by elephants annually. The damages include loss of human lives, crop loss, and loss in property for humans. As per the records of Bist (2002) annually 175–200 manslaughters cases are happening, Rs. 10 lakh loss happens in crop raiding and 15,000-houses were stamped and destroyed because of the violent activities of elephants. Majority of the farmers and the villagers located at the boundary of the forest lands suffer maximum losses. Rs 15 crores were spent annually on control measures and for ex-gratia payments. Hence human elephant conflict is becoming a survival issue for the humans.

Section 3.2 describes a short study on the problems faced by elephants. This section accounts the percentage details of elephant mortality caused by humans. Bist's (2002) records death of 41 elephants as annual average loss. The main reason for elephant death is poisoning and electrocution. The year 2003 saw intensity as 53 elephants died due to the same reason. The Project Elephant accounts for 36% of total elephant mortality in 2009. Human–elephant conflict is becoming a challenging issue for the researchers too considering that loss of humans is considered on par with elephants. Many research projects are ongoing for developing new methodologies which give a long term solution for protecting both human and elephant lives. Human lives and environmental damage by elephants and elephant transience by human should come to an end. (Barua and Bist 1995, Sukumar 1989, Balasubramanian *et al.* 1993, Zhang and Wang 2003).

6.1.2 Elephant Tracking- The Only Solution

The above problem faced by human and elephants needs a protected solution. The term protected is deliberately mentioned due to equal importance given to humans and elephants. For this reason the solution must be harmless for both categories. Tracking gives the clarification to stay away from the conflict. Human Tracking is not required, though, we humans knows the behavior, habitation and fragmentation of humans. Therefore tracking is must for tracing the elephants. Hence the only solution for Human-Elephant Conflict is Elephant Tracking. Elephant tracking is the science of observing Elephant's paths and signs. The objective of elephant tracking is to gain a clear knowledge about the elephant. It depends on the environmental factors. This makes elephant tracking mandatory to know the status of HEC.

6.2 What are the Existing Approaches of Elephant Tracking?

6.2.1 Existing Approaches of Elephant Tracking

Two major categories of Elephant Tracking approaches, namely, the technical approach and the non-technical approach have been briefly explained in section 4, which describes the technical approaches of elephant tracking in depth referring to different methodologies presented by different authors. The popular elephant tracking methods include monitoring elephants using video cameras, ZebraNet, GPS Collars, census tracking of elephants by counting dung balls which further modified using wireless sensors and many real time experiments were done for observing the characteristics of elephants.

Matthias Zeppelzauer (2013) has proposed a fully automated method for tracking elephants using wildlife video cameras. The method is based on the color model of elephants with dynamism from a few training images. They place elephants in video sequences with various backgrounds and lighting conditions, based on the color model. For improving the effectiveness of the approach, they have developed temporal clues from the video. Their method help in getting spatially and temporally steady detections. Their system also suite for other animal species. Hence this method addressed that usage of video cameras is one of the easiest way to monitor elephants.

M. D. Graham (2008) has made a challenging approach for a thorough evaluation of elephant movements in unauthorized areas. Using radio telemetry, they have assessed the movement of

13 elephants. The observed that elephants spent more time at night than during the day, in view of the possibility of mortality caused by human occupants. These findings highlight the importance of land-use setting up to preserve refugia, motivation to avoid further habitat fragmentation and the testing and application of conflict lessening actions where fragmentation has already taken place. Hence this method addressed that using radio telemetry elephant behavior can be observed clearly.

Table 1 Different existing approaches of elephant tracking

Year	Publication Title	Study Area	Methods for Elephant Tracking –Non-Technical Approach	Focused on	Experimental methods
2002	Elephant/Human Conflict and Community Development Around Niassa Reserve, Mozambique	Zimbabwe	Initial Review Report, Physical Clearing, Sting fences	Elephant Tracking/Human-Elephant Conflict	Physical(Manual) methods
2006	Estimating Population Sizes for Elusive Animals: The Forest Elephants of Kakum National Park, Ghana	Ghana	Field Observation, Dung Counts	Population Estimation/Elephant Tracking	Physical(Manual) methods
2009	HEC Mitigation a Training Courses for Community Based Approaches in Africa	Africa	Elephant Behavior and Habits	Human-Elephant Mitigation	Physical(Manual) methods
2009	Dung Survey Bias and Elephant Population Estimates in Southern Mozambique	Zimbabwe	Dung Survey	Population Estimation	Physical(Manual) methods
2009	Trials of Farm-Based Deterrents to Mitigate Crop-Raiding by Elephants Adjacent to the Rumuruti Forest in Laikipia, Kenya	Kenya	Chilli rope Fence, Bicycle alarms	Avoid Human-Elephant Conflict	Physical(Manual) methods
2010	Identifying Elephant Movement Patterns by Direct Observation	Sri Lanka	Sex, Ear(R &L) Tail, Shape of Spine ,body	Elephant Tracking/Elephant Movement	Physical(Manual) methods
2011	Using Molecular and Observational Techniques to Estimate the Number and Raiding Patterns of Crop-Raiding Elephants	Kenya	Habitual Raiders, Dung observations	Elephant Tracking	Physical(Manual) methods
2005	Conservation of Asian Elephants in the Nilgris-Eastern Ghats Landscape Summary Report 2001-2004	India	Dung Density	Population Estimation/Elephant Tracking	Physical(Manual) methods
2006	Capacity Building on Elephant Research and Conservation Issues in Northeast India	India	Review Report	Population Estimation	Physical(Manual) methods
2010	Securing the Future for Elephants in India	India	Block Count Method	Elephant Counts	Physical(Manual) methods
2010	Karnataka Elephant Census 2010	India	Survey of Elephant Landscape	Elephant Census	Physical(Manual) methods
2010	Human Elephant Conflict in Hosur Forest Division, India	India	Mitigation measures	Elephant Tracking/ HEC	Physical(Manual) methods
2010	A Case History of Colonization in the Asian Elephant: Koundinya Wildlife Sanctuary	India	Records available in forest department, local villagers	Elephant Movement/ Elephant Tracking	Physical(Manual) methods
2010	An Investigation Into the Status, Management and Welfare Significance	India	Behavior/habits	Elephant Tracking/ habit Monitoring	Physical(Manual) methods
2013	Automated Detection of Elephants in Wildlife Video	Matthias Zeppelzauer	Video Cameras	Elephant Tracking	Camera
2004	Individual Identification of Elephants of North Kanara District, Karnataka, India	India	Digital Cameras	Elephant Monitoring	Camera
2010	The use of GPS Radio Collars to track Elephants in the Tarangire National Park	Tanzania	Radio Collars	Elephant Tracking	Radio/GPS Accessories

Patrick I. Chiyo (2011) has proposed the concept for tracking the crop raiding elephants. This method is based on getting the count of elephants, their gender, and their patterns of raiding. Their tracking system traces the footpath, and genotyped DNA extracted from faeces collected from raided farms. They observe that only male elephants are involved in crop raiding.

Hence this method emphasizes on elephant census as imperative for elephant tracking.

Philo Juang *et al*. (2002) has proposed a ZebraNet system. This system makes animals to carry custom racking collars. The peer-to-peer network is used to send logged data back to the researchers. The authors believe that ZebraNet will have universal applicability in further wireless sensor applications. Valeriag Alanti (2000) proposed GPS (Global Positioning System) telemetry to find elephant's relocation routes. In November 1997 five female elephants were captured and fixed with GPS collars. The GPS collar gathers signals from various satellites. The received data permits automatic detection of its location. They have also discussed the merits and demerits of GPS-telemetry. Hence these methods addressed that need of some external agents like collars to be carried by elephants for tracking them easily

6.2.2 Research Gaps

In section 6.2.1 some of the popular existing approaches of elephant tracking were discussed. This section talks of the research gaps of those approaches. The mitigation measures also include electric fencing (EF), and elephant-proof trench (EPT), in which forest department supplies fire crackers to the villagers. Elephant tracking using video cameras and solar electric fencing in which devices were repaired, damaged (by animals, human or natural hazards), covered by plants and or stolen by the local communities. In ZebraNet, radio telemetry and GPS telemetry, elephants were carrying an external agent called collars, which will annoy and make them to behave violently (B*askaran 2009)*. These reasons made the approaches to exist only for a short time and providing short term solutions.

Table 2 Performance parameters of different elephant tracking approaches

Elephant Tracking Approaches	**Performance Parameters**							
	Result of the Approach			**Cause by the Approach**			**Current Status of the Approach**	
	Size of the Group (Large)	Long Term Process	Short Term process	Human Deaths	Animal Deaths	Man Power	Still in Use	Focused on
Radio Collars (Graham M.D *et al*., 2008)	√	√			√	√	√	Human-Elephant Conflict Issues
Video Cameras (Matthias 2013)	√		√			√	√	Elephant Tracking
ZebraNet (Philo Juang 2002)	√	√			√	√	√	Elephant Tracking
Seismic Sensors (O'Connell-Rodwell *et al*., 2005)	√	√				√	√	Census of Elephants
Electric Fence (N.Baskaran *et al*., 2009)		√		√	√	√	√	Human-Elephant Conflict Issues
GPS Telemetry (Valeriag Alanti et. al., 2000)	√	√			√	√	√	Human-Elephant Conflict Issues
Previous Records and Reports (Ranjit Manakadan *et al*., 2010)	√		√	√	√	√	√	Colonization in the Asian Elephant
Individual Identification (Prithiviraj Fernando et a., 2010)			√	√	√	√	√	Elephant Movements
Dung Counts (Eggert *et al*., 2003)	√	√		√	√	√	√	Estimating Elephant Population
conserving elephants and human care (Raman Sukumar *et al*., 2010)	√	√		√	√	√	√	Conserving Elephants

Many other approaches have been used to address HEC including destroying problem elephants and translocation of elephants. Alongside these centralized interventions, there are also traditional (Non-Technical) methods that farmers use to protect their crops from elephants such as lighting fire, making loud noises and throwing various kinds of missiles. The construction of various barriers like electric fences and radio collars were sophisticated due to the expense and frequent failure. Consequently technical methodologies were widely used in recent years. Because technical aspects are always considered to be harmless. This review targets to fill this research gap because it tries to provide a long term solution for HEC. Accordingly as per this review the long term solution for HEC can be given only by wireless sensors, by investigating various articles which are explained in the next section 6.3.

Seismic sensors overcome the problems found in the existing approaches. These sensors cannot be damaged by animals or humans as they are buried inside the ground. Elephants are averse to carrying external agents as they get oblivious to the presence of sensors. The future proposed work of this review targets to minimize HEC and to provide a long term solution or a permanent solution for HEC. The solution should drastically minimize the death ratio of human and elephant together caused by HEC. The proposed avoidance method needs the support of two different techniques, one is seismic sensors and the other is video camera. Both of these techniques does not harm neither human nor elephants as per the performance parameter listed in Table 2. Figure 1 shows the taxonomy of Elephant Tracking approaches.

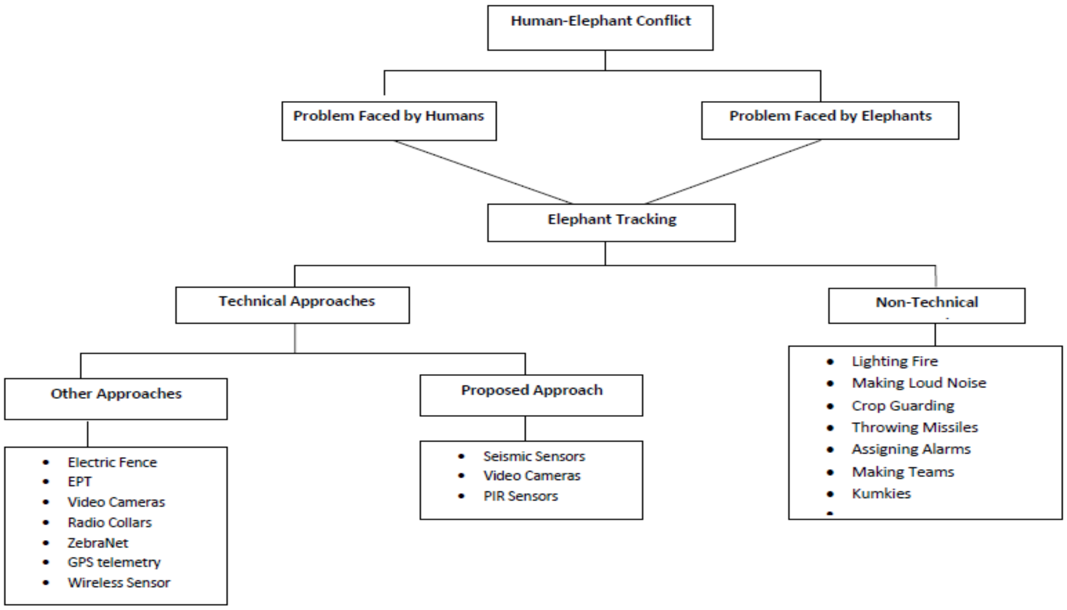


Figure 1 Taxonomy of elephant tracking approach

6.3 What is the Role of Seismic Sensor in Elephant Tracking?

6.3.1 Elephant Tracking Using Seismic Sensors

Seismic Sensor is a wireless sensor, which is becoming very popular in recent days in view of its capability for detecting even minute vibrations caused on earth. A crystal clear view of the working and nature of seismic sensor is described in the next section 6.4. This section tells about the role of seismic sensors in elephant tracking proposed by various authors.

E. Kanniga *et al*. (2014) have designed a system based on Seismic sensors and PIR sensors to find the target which is vibrating on the ground. The existing system uses Unattended Ground Sensors in target detection. The effectiveness of the existing system is restricted by false alarm rates and high power consumption. Their proposed system includes PIR and seismic sensors. The PIR Sensor tracks down whether the vibrating object is living body or machine. Seismic sensor is used, if it is living body, and detects whether it is human being or animal. Seismic sensor is again used, if it is vehicle, and detects to classify the type of vehicle moving on the ground.

Jason D Wood (2005) has presented the difficulties in and necessity for making a census the elephant population in remote areas. Seismic sensors and geophones are found to be the boon for facilitating the getting of the census ratio and ensuring its accuracy. They conclude that elephant footprints are sensed effectively by the detection method using seismic sensors. Connell-Rodwell (2006) states that the elephant produces a low frequency vocalization. The vocalization includes seismic components that spread in ground. They conclude that seismic component detects important environmental clues which include changes in weather patterns and other seismic disturbances. The objective of the research reported by Ruwini Edirisinghe (2013) is the design and verification of the alternative techniques for wired fence based on altering mechanism and its limitation.

Their article presents a comprehensive study of the alternative solution and concludes Wi- Alert is the best alternative technique for wired fence detection method. A. Pakhomor (2006) developed a small size, very low cost and high performance seismic sensor called general sensing systems (GSS) intended for up-to-date security. Their sensor detects footprints by almost 3 times large distance between the sensor and walking person. J. Cechak (2010), has summarized the potential features, usable properties, merits, demerits and generalizes the results of seismic –acoustic communication. In addition the paper includes descriptive photographs of the realistic design and graphical results of real measurements. Table 3 and Table 4 lists the existing approaches and the performance parameters addressed in the earlier works with the help of seismic sensors for animal tracking and other applications.

Table 3 Existing seismic sensor approaches

Year	Article title	Animal Tracking with Seismic Sensors		Experimental Methods	Performance parameters
		Approach	**Focused on**		
2005	Using Seismic Sensors to Detect Elephants and Other Large Mammals: A Potential Census Technique	Footfalls/ Seismic/Vibration	Census and Monitor the path	Sensors	Census count, accuracy rate
2005	Seismic Source Model for Moving Vehicles	Ground Loading	simulations of seismic wave propagation	Seismic	response to vehicle acceleration, ground features such as bumps, forces transmitted to the ground
2006	Wild Elephant (Loxodonta Africana) Breeding Herds Respond to Artificially Transmitted Seismic Stimuli	Sensors/Geophones	Weather Pattern	Seismic Devices	Alarm Vocalizations, Observes signals
2006	Lab Testing of New Seismic Sensor for Defense and Security Applications	Seismic Sensors	Military and Security	Seismic	small size, frequency response range, signal discrimination, ensuring efficient signal interpretation
2007	Communication in Elephants Keeping an "Ear" to the Ground: Seismic	Seismic Sensors	Elephants Nature	Sensors	Elephant's Fitness and survival
2007	Intelligent Seismic Acceleration Signal Processing for Damage Classification in Buildings	Seismic Acceleration	Damage Classification	Seismic	Classification methods, classification rates
2007	Abundance, behavior, and movement patterns of western gray whales in relation to a 3-D seismic survey, Northeast Sakhalin Island, Russia	Gray Whales	Abundance, behavior, and movement patterns	Seismic	Scan Sampling Focal follow Ttheodolite tracking methodologies.
2008	Testing of New Seismic Sensors for Footstep Detection and Other Security Applications	Geophones/seismic	Security applications	Seismic	high performance, lost cost, small size
2010	Seismic Sensors Communication	Seismic Communication	Military Applications	Seismic signals	Frequency Band
2010	Automatic detection of African elephant (Loxodonta africana) infrasonic vocalisations from recordings	Detection of Vocalizations	Automatic detection of African elephant	Seismic Sensors	Size,emotional condition and sexual state determination
2012	Classification of Moving Objects Based on Spectral Features of Seismic Signals	Active objects	Classification of Moving Objects		automatic detection of seismically active objects, estimation of their trajectories, and determination
2014	Wireless Based Target Detection and Object Identification Using Seismic and PIR Sensors	vehicles and human or animals.	to detect the vehicles and human or animals	PIR Sensors/ PIC16F877A microcontroller.	Target detection, False alarm rates, power consumption

Table 4 Performance parameters of existing seismic sensor approaches

Animal Tracking with Seismic Sensors	Parameters									
	Accuracy Rate	Vehicle Acceleration	Target Detection	Power Consumption	Moving Objects	Scenery	Classification Rater	Environmental Transform	Frequency	Alarm
Jason D. Wood and CaitlinE. O'Connell (2005)	√		√			√	√			
O'Connell-Rodwel (2006)			√		√			√		
O'Connell-Rodwell (2007)	√				√	√	√	√		
Pieter J. Venter a, (2010)	√		√		√	√	√	√	√	
S. J. Sugumar (2013)	√		√	√			√		√	√
E. Kanniga, (2014)		√	√	√	√					√
Sokolova (2012)	√		√		√		√		√	√
Glenn Gailey & Trent L. McDonald (2012)	√		√	√		√		√	√	
Stephen A. Ketcham (2005)		√	√		√		√		√	
Ioannis Andreadis, Ioannis Tsiftzis (2007)	√		√	√	√		√	√		
Pakhomov, D. Pisano, A. Sicignano (2008) [	√		√	√	√		√		√	
J. Čechák(2010)			√	√	√		√		√	

The proposed work considers three important performance parameters, namely, accuracy rate, target detection and alarm. Accuracy refers to classification of species. The accuracy percentage in seismic sensors is found to be 91.25 says Sugumar *et al*. (2013). Target detection of the species in seismic sensor can be confirmed and cross verified using high quality video cameras. Alarm helps to give prior alerts to forest authorities and the public about the arrival of the species. The proposed work tries to give a long term solution for HEC, by being unique in the target- no human death as well as elephant death.

6.4 How to Use Seismic Devices?

6.4.1 What is Meant by Seismic?

Seismic sensors are a type of vibration sensors. Seismos is a Greek word meaning shaking. These sensors are sensitive to up-down motions of the earth. The findings of the seismic sensor are displayed as waves. Four types of seismic waves are generated (Michael Garstang(2009)):

Primary or P-waves, Secondary or S-waves, Love waves and Rayleigh waves. The P-wave is of small amplitude, the latter two waves generate the greatest amplitude at the earth's surface. The Love waves are transverse shearing waves which generate horizontal vibrations in the ground perpendicular to the direction of travel. Being transverse waves, they cannot be transmitted in either the ocean or the atmosphere. They are formed by the interaction between the S-wave and the surface and are dispersive waves.

Dispersive waves break down into different frequencies and hence wavelengths and wave speeds. Love waves range in frequencies from 1000 Hz to less than 1 Hz and speeds can range between 2 and 6 km per sec or 7,000 to more than 20,000 km per hour (4,000 to more than 12,000 mph).

Rayleigh waves are compression waves, moving particles in an elliptical trajectory thus displacing particles upwards and downwards about a mean horizontal position. Rayleigh waves can propagate at speeds between 1 and 5 km per sec but are typically the slowest of the above four waves.

6.4.2 Working Principle of Seismic Sensors

Vibrations are generated depending on the activities on ground, such activities may happen due to small or large animals, human or vehicle. These vibrations caused by any activities are converted into seismic waves. Seventy percent of those seismic vibrations are transmitted by Rayleigh waves which spread on the surface of the world. The remaining part of that energy is moved by body waves which spread perpendicular to the Rayleigh waves (Evernden, 1976; Suyehiro, 1968). In order to detect humans and vehicles, Rayleigh waves can be very useful because of the transmission direction.

These vibrations also have frequency-dependent attenuation characteristics (Suyehiro, 1972). In addition, ambient environment plays a crucial role in footstep and vehicle detection. For example, due to the increased seismic noise levels, detection distances are lowered during daytimes (Hatai, 1932). The relationship between the noise level and footstep detection distance is further examined in (Brown DJ, 2005). Another important parameter of the ambient environment is the vibration transmission filter of the ground. Vibration speed in the ground varies depending on the vibration frequency (Payne, 1998). Once seismic signal is detected and digitized, wireless sensor node is used to transmit the data for processing or transmitting low-level alarm generation.

6.5 What are the Other Applications of Seismic Sensors?

Seismic sensors have the following applications too:

Alain Lemer and Frederique Ywanne presents different acoustic and/or seismic systems, for detecting, localizing and categorizing targets on the battlefield. This paper addresses mainly weapon fire detection and localization, wheeled and tracked vehicles detection/localization/tracking and aircraft helicopters, drones) detection, localisation and classification. Depending on the application requirements, they include either stand-alone acoustic/seismic sensor, or networks of acoustic sensors. They concluded on the means to build upon these target-focused devices for providing an integrated multi-targets acoustic/seismic remote sensor for passive battlefield monitoring. They have listed few interesting advantages for battlefield applications namely Non-Light-of-Sight detection, fully passive (stealthy, low power) and panoramic (360 degree) coverage, Non-Cooperative Target Recognition capabilities.

Seismic sensors were developed for tracking enemy troop movements during the Vietnam War. Seismic signals provide ecologist with an innovative satisfactory way to monitor elephant populations. It confirms the provision of an accurate count of elephants. Connell *et al.* (2006) have stated that seismic communication can also be utilized for very small living beings namely, insects, amphibians, replies of small mammals. Jason, D. Wood *et al.* (2005) presented that seismic sensors did not require large efforts to record the accurate number of animals.

7.0 PROPOSED SEISMIC SENSOR FRAMEWORK FOR ELEPHANT TRACKING

The choice of seismic sensors is based on several advantages which account for its suitability for HEC. The advantages consist of accurate detection, larger detection range, proper system functionalities, cost, power consumption, detects without spotlights even at dark, not harmed or affected by human, animal, wood pickers and natural hazards, hence provides a long term solution. The applications include tsunami, earthquake detection, used as a security force for unauthorized entry of vehicles, animals and human, already provided a successful result in detecting elephant census count and in other existing approaches of elephant tracking.

In this survey many studies based on seismic sensor have been catalogued for elephant tracking. However, the existing works relating to seismic sensors with respect to Human-Elephant conflict playing various roles according to the views of different authors. As a result, seismic sensors in existing elephant tracking systems pay attention towards census count of elephants, monitoring the path of elephants and automatic detection of elephant. The existing work also utilizes seismic to study elephant's nature, abundance, behavior, and movement patterns. The combination of seismic sensors and elephants were also exploited for military and security applications. Seismic sensors are extremely useful to classify the moving objects and detect vehicles and human or animals (in specific elephants). The proposed research on the development of seismic sensors for elephant tracking expected to afford an early warning system for HEC and hold up for long term HEC administration. Early warning system be effective by providing prior information to the forest authorities about the imminent entry of elephants into human settlements. This advance information can effectively utilized by the forest authorities for providing alert to the public and to chase the pachyderms back to the forest. Long term HEC administration can be accomplished by the oblivious nature of underground seismic sensors.

The architecture for the proposed methodology includes three important sections namely, forest with elephants, human settlements with human and the sensor unit. The location of the sensor unit lies in between the forest and the human settlements. The intention of this location is that no pachyderms should cross the boundary. If happens, then alert should be sent to the forest authorities. The only way for the elephants to reach human settlements is via sensor unit. The research is planned to be conducted in a small sector of Hosur forest division, Tamil Nadu, India which is highly affected by elephants in recent days. The successful result of the same will be implemented for the complete Hosur forest region after the approval.

Figure 2 illustrate the proposed framework and the process of detecting elephants and acquiring seismic sensor as an early warning system. In order to maximize the suggested framework's contribution, it should be deployed as wireless sensor unit over the network. As this framework depicts, elephants reach the sensor unit, which are buried under the ground [1]. The sensor unit suggested is the fusion of PIR sensor and seismic sensor. PIR sensors are useful for target detection, they detect and track down the objects irrespective of being living objects or machines [2]. Seismic sensor then tabulate the results of PIR. If living body, seismic detects whether it is human or animal. If machine, it detects the type of vehicle [3]. The results of seismic are displayed in seismogram as waves [4]. There are different types of waves as discussed in section 6.4.1, is helpful for classifying the type of species in specific elephants [5]. If elephant is detected, then alert will be sent to forest authorities [6]. For avoiding false alert, it can be cross verified and conformed with the cameras kept at the boundaries [7]. After conformation, it will be the job of the forest authorities to chase the elephants back to the forest and to announce the public about the entry of elephants into human settlements [8]. The purpose of this framework is to provide a more effective solution than the existing techniques employed nowadays. We are not aiming at providing a holistic solution. However, we try to present a better solution for the existing problem. Our framework can reduce HEC and provide a long term solution.

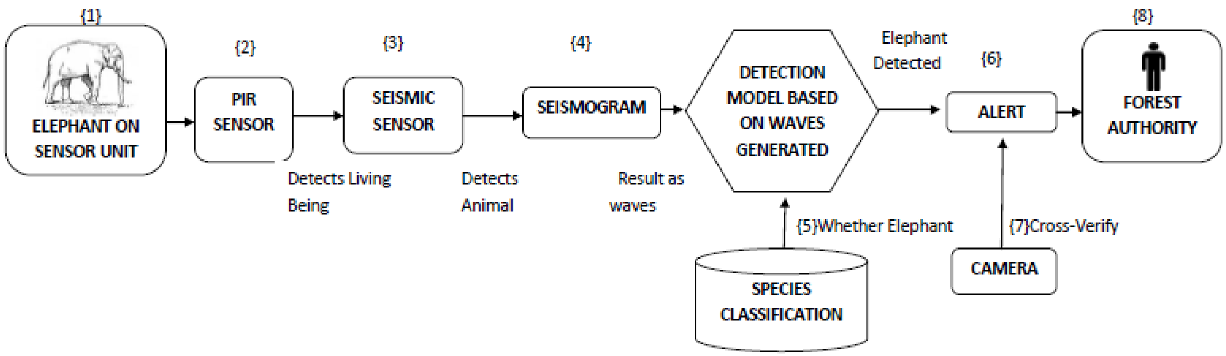


Figure.2 The process of tracking elephant using seismic sensor unit

8.0 CONCLUSION

This work reviews the available literature on elephant tracking system in the perspective of wireless sensor networks, namely seismic sensors. This analysis covers various paths of elephant tracking research. Human-Elephant Conflict is assumed as a real time problem or the survival problem by the public. Researchers have found Human-Elephant Conflict as a challenging problem and indicated various approaches using different methodologies. A revelation of various methodologies has been mentioned in order to locate strength and weaknesses of those approaches.

The necessity for an alternative solution arises due to the realistic boundaries of the existing elephant tracking system. Wireless sensor network based solution is preferred as the best substitute among many others considering different practical implications and limitations.

The identified issues and challenges concerning the methodologies used for elephant tracking system may help in future research in this area. The initial intention of such a survey may be persistently used by the academician and researchers and the corresponding valuable comment may be analyzed. It calls for further widespread research oriented studies, by all concerned, for the discovery of newer issues and challenges in this topic.

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