

Review on Recent Advances in Elephant Tracking and Detection: A Sensorial Approach

M. Prabu and G. Praveen kumar

Adhiyamaan College of Engineering, MGR Nagar, Hosur, 635109 Tamil Nadu, India

Abstract: Human-Elephant Conflict (HEC) is on rise along the forest borders of the Western Ghats and Eastern Ghats of South India as it is a major habitat of the Asian Elephants. To reduce the HEC several automated and manual techniques are in practice. This study, presents a literature review on the recent advances and techniques followed to monitor, track and detect the intrusion of elephants into the habitat of humans. These tracking and detection of the elephants allows humans to take precise counter measures that can alleviate the HEC. The elephant tracking approaches falls in two broad categories: technical and non- technical approaches. The technical approaches involve effective research improvements of science to track the elephants. These techniques involve the use of sensors like vibration sensor, acoustic sensor, camera, PIR sensor. The technical approach does not risk human lives as the monitoring and tracking of elephants is done with automated systems. The non-technical approaches involves humans to track and detect elephants. These techniques may risk lives of both humans and elephants. This study, reviews techniques followed for tracking and detection of elephants with the analysis of parameters considered for detection, drawbacks of the techniques and future research recommendations to track elephants.

Key words: Human-elephant conflict review, sensors, elephant tracking, detection, sensorial

INTRODUCTION

Southern region of the Indian sub-continent holds the dense forests of Western Ghats and Eastern Ghats. These forest ranges are the major habitat for the Asian elephants. In recent years, the forest lands have been converted into human settlements due to population explosion. This results in the reduction of the perimeter of elephant's habitat and share common land by both the humans and animals. This gives rise to newer problems; scarcity of food, water scarcity, aggressiveness due to habitat acquisition. These reasons build circumstances for intrusion of elephants into human settlements and Human-Elephant conflict (HEC). HEC can be effectively reduced by tracking the elephants in the forest borders. Previous research works have used various tracking techniques using camera, radio collars, wireless sensors especially seismic sensors plays a major role in the detection of elephants.

The study, investigates and analyzes the various detection and tracking techniques used from earlier days. The paper also presents a comprehensive analysis of the recent advances and research made to reduce the HEC. The recent advances involve wireless sensors producing an effective way of detection and tracking of elephants with higher precision.

Literature review: The study of the previous research works and the field research, the contributing factors for the intrusion of elephants into the human habitation are summarized below:

- Vegetation on unprotected farm lands with no protection fences attracts the elephants to damage the vegetation
- Damage of natural or artificial constructed in the forest borders either by humans or natural disasters
- Shortage of food resources in the forest areas
- Degradation of climate in the forest region
- Artificial water holdings constructed near the habitat of the elephants
- Habituating traditional migration paths of elephants by human constructions
- Trenches constructed improperly, damaged or not maintained for longer periods
- Periodic migration of the herd to other comfortable habitats traditionally followed by the herd.
- Forest fire causing habitat loss to the wildlife and sometimes loss of life

With these factors contributing to intrusion; the researchers developed automated systems and initiatives developed to reduce human-elephant conflict around different regions of the world.

Arivazhagan and Ramakrishnan (2010) presented a study on the conservation of elephant's with the focus on connectivity of elephant's habitat. The authors aimed to increase the population of elephant and protect the habitat of elephants from degradation and fragmentation. The study was done in southern part of the Indian sub-continent.

Oliver *et al.* (2009) discussed a method to detect the elephants using their dungs. With the dung decay rates and distance sampling techniques they have detected and estimated the population size, age group in Southern Mozambique region.

Fernando *et al.* (2012) and Olivier *et al.* (2009) proposed a solution to track elephant movement patterns in their habitat by direct observations to conserve elephants and to avoid human elephant conflict. They have used radio collars to get GPS locations of elephants every 4 hours. Data received from the individuals are interpreted in a Excel sheet with statisticXL 1.8 add-in. the data is then mapped on the toposheets to visualize the collected data.

Balch *et al.* (2006) and Fernando *et al.* (2012) has proposed a methodology for animal tracking using RFID system. The RFID tags are detected and interpreted by a control hub and the locations is determined. It has a drawback of short range detection and it has low update rate of the locations.

Sugumar and Jayaparvathy (2013) has proposed an analytical model for surveillance and tracking of elephant herds using a three-state Markov chain. The design gives the migration pattern of elephants and behavior of the elephants over the whole year in different climatic periods of three villages near forest borders. The study is conducted in the coimbatore forest division which falls in the dense forests of the western ghats of India. The intrusion detection system is developed based on pattern of movement of the herd to detect the intrusion of the elephant herds into the locality or habitat of the humans. On intrusion of the elephants the system warns the forest officials with an alert message. The system is hardware implemented as a prototype to detect intrusion of elephants into the forest borders.

Ramkumar and Rajanna (2013) have developed a simulation model called ASRET to reduce the Human Elephant Conflict (HEC). This system generates early warning to prevent conflict between humans and elephants. The system is a simulation model simulated in MATLAB Simulink with the central processing unit, primary unit and secondary unit. The signals from the sensor nodes are processed by the central processing unit and the secondary unit is responsible for the transmission of signals to and from the sensor nodes.

Since the system is a simulation model the results of the real time implementation model is not elaborately discussed.

Manakadan *et al.* (2010) presented a case study on the dispersal and movement of the elephants between the hosur-dharmapuri forest division and koundinya wildlife sanctuary. The migration of the elephants is due to the various parameters like vegetation, scarcity of shade, scarcity of grass, water scarcity, forest fires and human elephant conflicts. The study also concluded that the aforementioned conservation issues there is a decline in population of the elephants in KWS as most of the elephants have translocated to the hosur-dharmapuri forest divisions. The research also suggested evaluation and restoration of the forest division to improve the elephants count in the forest region.

Wood *et al.* (2005) presented a technique to estimate the population of the elephants in Central Africa where it is hard to enter the dense forest. Since the forest is very denser aerial surveys are not possible so they developed a system using seismic sensors to estimate the total population of large mammals in a specific region. The seismic detection system has successfully detected large mammals with higher accuracy.

Sugumar and Jayaparvathy (2014) presented a system to detect elephant intrusion along the forest borders using real time imaging. The proposed system is an automated unsupervised elephant image detection system that reduces human elephant conflict in the context of elephant conservation. The elephant's image captured in the forest border areas and is sent to a base station for processing the image using Haar wavelet and image vision algorithm. The system also proposes an optimized distance metric for lesser retrieval time compared to Euclidean and Manhattan algorithms.

The research by Sugumar and Jayaparvath (2013) presented a study on a low cost infrasonic recording system. The system is built to record the infrasonic calls made by elephants. With the recorded infrasonic calls the elephants can be detected efficiently with low cost compared to other systems. The system also records infrasonds generated by other sources of the environment which can be used for research purposes.

Analysis of HEC issues: South India experiences larger growth in the population which in turn has great effect in the land reformation. The forest ranges has been converted into agricultural lands, human settlements and commercial buildings which makes food and water resources shrink for wildlife in the forest. This makes the major factor of intrusion of the wild animals into the human settlements. The conflict between the humans and elephants can be classified as follows.

Issues with the humans: With HEC there are situations where loss of the humans lives are frequent. As the elephants weigh from half tonne to an average of 4 tonne they will damage almost all the objects in its path. The major reason for elephant intrusion into human settlement is the conversion of their habitat into human settlements and the other reason is looking after the permanent water and food resources which will be extensively available near the human settlements. Loss of human lives is extremely costly. Most of the southern Indian states experiences loss of lives due to sudden intrusion of the elephant herd into farm lands and human habitations.

Issues with the elephants: Elephant herd also experiences severe loss of health and life as humans use sharp weapons and some deadly techniques to raid the elephants from their farm lands. Some of the techniques that causes severe damage to the elephants are discusses below.

Some of the traditional, conventional and experimental methods proposed by the humans are discussed below:

- Air guns: Air guns produce sudden shock waves on air producing burst sounds that annoys elephant herd
- Non-electric fences: Simple spike fencing technique used to block the path of the expected intrusion
- Electric fences: An electric fence uses low voltage AC power supplies (either solar powered or normal power) to avoid the intruding animals into habitat
- Chilli rope fences: Two stringed fences are constructed around the vegetation or habitat with the mixture of dry chilli powder and engine grease and/or oil applied on the strings
- Loud alarms: Alarms producing loud noise or annoying sounds triggered by a trip wire is used to defer the elephants back into forest
- Chilli smokes: Animal dung's and/or red hot chillies mixed and burnt to produce pungent smoke clouds blown in the direction of the elephants helps the people by raiding herd away
- Watch towers: A watchtower of certain height is constructed and is used as surveillance tower for monitoring elephant's intrusion to avoid the damage caused by them
- Solar powered torches: solar torches are specially designed to produce powerful light and are used to raid elephants in the forest borders
- Trenches: Trenches of considerable width and depth is constructed in the forest borders to prevent the intrusion of the elephants

- Fire: A considerable amount of fire is burnt on the expected intrusion path of elephants to defer them back into forest
- Fire crackers: Crackers producing loud noise is used on intrusion of elephants to raid them
- Throwing arrows/stones: On intrusion of elephants sharp objects on considerable mass like arrows or stones are thrown on them to raid the herd

Additional to these manual surveillance methods there are several automated system developed as a result of scientific advances to detect the elephants.

Issues with the society: In addition to above the discussed issues by HEC there are factors that have impact on the society. The intrusion of elephants in the denser human settlement areas will collapse all the ordered actions carried out in the area. And also there will be a severe loss and damage to the public property which will be costlier to handle. These reasons also have indirect impacts on the social life of the people as like reduction of people movement out of their villages due to fear of elephant's attack

MATERIALS AND METHODS

The literature review is biased to get clear vision on the various traditional and automated systems that are commonly used to keep away elephants from human habitation. People have excelled in developing various techniques and they have improved a lot from the past. Some of the research questions playing key role in this literature review are discussed in the following section.

Research questions: The research questions answered in this study are:

- RQ1: How elephant tracking and detection will help in reduction of HEC? Motivation: To obtain an idea of how tracking of elephant's herd will help in the reduction of the huge loss of lives and properties by taking precautionary measures
- RQ2: What are the traditional and automated approaches in practice? Motivation: To know the approaches and experimental methods in practice to raid the elephants away from the human habitat
- RQ3: What are the environmental aspects that force the elephants to intrude human habitations? Motivation: To get an idea about the factors influencing the intrusion of the wild pachyderms into the farm lands and the human habitat

- RQ4: Which method is efficient in terms of safety and cost? Motivation: To evaluate the best and efficient method from the list of traditional and automated approaches with the consideration of safety and cost effectiveness
- RQ5: How this literature review helps in developing effective detection and tracking approach to mitigate HEC? Motivation: To obtain idea for future research works to reduce HEC and also avoid pitfalls from the previous researches

Search process: The search process to collect the data about HEC was a manual search of specific and random conferences and journal papers. The search was narrowed to collect recent research works and published study. The collection stands with the age of two decades. Random search was made for research study in the search engines like Google scholars using the keywords: human elephant conflict, damage by elephants, detection and tracking techniques for elephants and other related terms. The Table 1 gives the details of the surveyed papers. The collected data hold% percent of journal and conference papers, 8% of research reports, 21% of survey reports and 14% of discussion study.

Survey focus: The survey is focused on the issues faced by the human-elephant conflict and the present status of HEC in the country like Indian Sub-continent located in South Asia. The survey mainly focuses on the basic living structure of the elephants and their paths. Surveys conducted in the past 5 years are taken into consideration to produce the conclusion of this study.

RESULTS AND DISCUSSION

Observations: This section gives a brief description on the elephant intrusion detection and tracking techniques. Table 2 provides the existing tracking and detection techniques proposed by various authors and Table 3 gives the performance evaluation of the existing approaches with the indication of the various parameters considered by the authors. This section also discusses the research questions that are listed in this study.

How elephant tracking and detection will help in reduction of HEC?: The study of research works and field surveys concludes that the prediction of elephant intrusion will effectively reduce the damages caused by the elephants in the human habitat. As the mammals are massive in size they can easily damage any kind of vegetation, trees, crops and also buildings on their path. Also, there are reports showing considerable losses of human live in the recent years in Southern India which makes the loss even more costly. By prediction of the

Table 1: Detail of surveyed papers

| Discussions | Value |
|-------------------|-------|
| Conference papers | 22 |
| Discussion papers | 11 |
| Journal papers | 26 |
| Research reports | 7 |
| Survey reports | 17 |

movement of the wild pachyderms the humans can find their way to minimize the loss of properties and also both the lives of humans and elephants.

The research by Fernando *et al.* (2012) proposed a system that tracks the elephant movement path to predict the movement patterns of the elephants with the use of GPS collars but the GPS collars installed/tied around their necks produced severe consequences among the elephants in the herd. Excessive aggressiveness due to irritation caused by the collars made the situations tough even it took the elephant to death.

What are the traditional and automated approaches in practice?:

The humans have been experimenting from the earlier days to mitigate the HEC by implementing new techniques to raid away the elephants entering their habitat. With the experimentations some of their practices produced better results than the other techniques. The most common traditional and modern techniques used for detection and tracking of the elephants has been discussed. By these techniques almost 75% of the damage to the properties is reduced. The traditional techniques involved manual intervention to raid away the elephants; these actions make the humans to risk their lives to raid the wild pachyderms. To reduce the risk of loss of human lives the automated systems are developed which can alert the intrusion of wild elephants into the habitat.

What are the environmental aspects that force the elephants to intrude human habitations?:

The climatic conditions and the natural land forms are major factors that influence the migration of elephants from a region to the other. In dry seasons, the natural water sources in the forest area dries up making all the wild animals look for other alternate sources of water which may extensively available near the human settlements. The climatic conditions like dry seasons and rainy reasons will force the elephants to migrate to other regions.

During the dry seasons there exists a situation where there is a severe scarcity of the food availability and will make the herd of elephants raid the areas where they find food. Usually, the farm lands with dry vegetation crops are available during the dry season which attracts the wild pachyderms to have it as food.

Table 2: Existing techniques of object detection and tracking

| Paper title | Years | Technique | Considered parameter | Study area | Study method | Result |
|--|-------|-----------|---------------------------------------|---|----------------------------------|---|
| A case history of colonization in the Asian elephant: Koundinya wildlife sanctuary (Andhra Pradesh, India) | 2010 | | Case study | Colonization | Andhra Pradesh, and distribution | Case study India Statistics of the distribution and colonization |
| A review of the role of acoustic sensors in the modern battlefield | 2005 | | Wireless sensors: Acoustic sensors | Target detection and identification | Georgia | Experimental Review Acoustic signal processing for target identification |
| An automated system for remote elephant tracking to reduce human elephant conflict | 2014 | | Wireless sensors | Simulated seismic signal processor | - | Simulation of the processing algorithm to produce alerts on elephant intrusion |
| An early warning system for elephant intrusion along the forest border areas | 2013 | | Three state Markov chain | Movement prediction and species classification | Coimbatore, India | Experimental evaluation Analytical model for movement prediction and higher detection rate |
| An improved real time image detection system for elephant intrusion along the forest border areas | 2014 | | Wireless sensors: Cameras | Object recognition and detection | Coimbatore, India | Experimental Analysis Detection of elephants and evaluation of distance |
| Detection of people and animals using non-imaging sensors | 2011 | | Wireless sensors: non-imaging | Detection of animals and humans | United states | Experimental evaluation Detection of humans and animals movement |
| Target detection and classification using seismic and PIR sensors | 2012 | | Wireless sensors: Seismic | Target detection and classification | - | Experimental evaluation Classification of targets using patterns |
| Towards an automated acoustic detection system for free-ranging elephants | 2015 | | Wireless sensors: Acoustic sensor | Pattern Recognition of elephant acoustics | South Africa | Experimental evaluation Successful recognition of elephant sounds |
| Using seismic sensors to detect elephants and another large mammals: a potential census technique | 2005 | | Seismic sensors | Spectral information of seismic signals of elephant footfalls | Africa | Experimental analysis Classification of the mammals based on the spectral differences |
| Wireless based target detection and object identification using seismic and PIR sensors | 2014 | | Wireless sensors | Feature vectors for target detection | - | Experimentation of hardware Object identification |

Table 3: Parameters considered in the different approaches of target detection and tracking

| Method/Approach | Parameters | | | | | | | | |
|-----------------|---------------------|--------------------|-------------------|-------------------|---------------------------|----------------------|-------------|----------|---|
| | Accuracy | | | | | | | | |
| | False positive rate | True positive rate | Power consumption | Life time (years) | Classification of Species | Implementation point | | | |
| | | | | | Local | Remote | Maintenance | Alert | |
| Kumkies | - | - | - | NA | NA | Yes | No | Moderate | - |
| Air Guns | - | - | - | 5 | NA | Yes | No | Moderate | - |
| Fences | | | | | | | | | |
| Non-Electric | | | | | | | | | |
| Spiked | - | - | - | 7-9 | NA | Yes | No | Moderate | - |
| Ordinary | - | - | - | 3-5 | NA | Yes | No | Moderate | - |
| Electric | | | | | | | | | |
| Solar powered | - | - | Moderate | 2-6 | NA | Yes | No | High | - |
| AC powered | - | - | High | 2-6 | NA | Yes | No | High | - |
| Chilli ropes | - | - | - | 1-3 | NA | Yes | No | Low | - |
| Chilli smokes | - | - | - | AN | NA | Yes | No | Moderate | - |

Table 3: Continue

| Method/Approach | Parameters | | | | | | | | |
|----------------------------|---------------------|--------------------|-------------------|-------------------|---------------------------|----------------------|--------|-------------|-------|
| | Accuracy | | | | | Implementation point | | | |
| | False positive rate | True positive rate | Power consumption | Life time (years) | Classification of Species | Local | Remote | Maintenance | Alert |
| Fire | - | - | Moderate | AN | NA | Yes | No | Low | - |
| Fire crackers | - | - | - | AN | NA | Yes | No | Low | - |
| Arrows/Stones | - | - | - | AN | NA | Yes | No | Low | - |
| Watch towers | - | - | - | 2-5 | NA | Yes | No | Moderate | - |
| Radio collars | Low | Moderate | High | 0.1-0.6 | NA | Yes | Yes | High | Yes |
| GPS collars | Low | Moderate | High | 0.1-0.6 | NA | Yes | Yes | High | Yes |
| Video cameras | | | | | | | | | |
| Automated | Very Less | High | Very High | 0.6-3 | Possible | Yes | Yes | High | Yes |
| Human surveillance | Low | High | Very High | 0.6-5 | Possible | Yes | Yes | High | Yes |
| Zebra net | Low | Moderate | High | 0.6-2 | NA | Yes | Yes | Moderate | Yes |
| Dung Counts | - | - | - | AN | NA | Yes | No | - | No |
| Non-imaging sensors | | | | | | | | | |
| Acoustic | Low | High | Moderate | 1-5 | Possible | Yes | Yes | High | Yes |
| Seismic | Very Less | Very High | Low | 1-7 | Possible | Yes | Yes | Moderate | Yes |
| PIR | Low | High | Low | 1-7 | Not supported | Yes | Yes | Moderate | Yes |

*NA: Not Applicable; AN: As Needed; AC: Alternating Current

Table 4: Performance analysis of various techniques/approaches for detection/tracking and deferring elephants

| Technique/approach | Human Intervention | Automated System | Damage to Elephants | Damage to Humans | Detect/Track/Defer | EfficacyPercentage |
|----------------------------|--------------------|------------------|---------------------|------------------|--------------------|--------------------|
| Kumkies | Yes | No | Yes | Yes | Defer | 80 |
| Air guns | Yes | No | No | Yes | Defer | 57 |
| Fences | | | | | | |
| Non-Electric | | | | | | |
| Spiked | No | Yes | Yes | No | Defer | 55 |
| Ordinary | No | Yes | No | No | Defer | 40 |
| Electric | | | | | | |
| Solar powered | No | Yes | Yes | Yes | Defer | 63 |
| AC electricity | No | Yes | Yes | Yes | Defer | 61 |
| Chilli ropes | No | Yes | Yes | No | Defer | 38 |
| Chilli smokes | Yes | No | Yes | No | Defer | 47 |
| Fire | Yes | No | Yes | No | Defer | 55 |
| Fire crackers | Yes | No | Yes | Yes | Defer | 68 |
| Arrows/Stones | Yes | No | Yes | Yes | Defer | 43 |
| Watch towers | Yes | No | No | Yes | Defer/Detect | 34 |
| Radio collars | No | Yes | Yes | No | Detect/Track | 65 |
| GPS collars | No | Yes | Yes | No | Detect/Track | 72 |
| Video cameras | | | | | | |
| Automated system | No | Yes | No | No | Detect/Track | 73 |
| Human surveillance | Yes | No | No | No | Detect/Track | 63 |
| Zebra net | No | Yes | Yes | No | Detect/Track | 70 |
| Dung counts | Yes | No | No | Yes | Detect/Track | 49 |
| Non-Imaging sensors | | | | | | |
| Acoustic | No | Yes | No | No | Detect/Track | 82 |
| Seismic | No | Yes | No | No | Detect/Track | 89 |
| PIR | No | Yes | No | No | Detect/Track | 82 |

Which method is efficient in terms of safety and cost?

Although many techniques are available for keeping the wild animals away from the human settlements there are no systems/techniques that is completely reliable for the detection and tracking of the elephants. With the different systems/techniques available for tracking and detection of objects/animals the analysis of their performance is summarized in the Table 4.

How this literature review helps in developing effective detection and tracking approach to mitigate HEC? The

review of the various approaches will help the researchers to get an idea of better approach that can effectively detect and track the elephants and mitigate the loss of properties and lives caused by the elephants. The systematic literature review covers all the parameters that can be helpful in estimating the count of elephants, tracking and detection systems used for the reducing HEC. Table 4 gives a summarized analysis results of the various detection techniques with the efficiency percentage calculated by considering the parameters like loss of human lives, loss of elephant lives, damage to

property, cost of implementation, cost of the system, maintenance cost of the system, ease of handling the system, human supervision needed for the system.

CONCLUSION

With this literature review the researchers contributing for the detection/tracking and deferring of the wild animals can have better idea for the improvement of existing techniques. Even though, traditional techniques help in raiding the elephants away from their farm lands and human settlements, the human interventions in handling the traditional systems leads to the loss of lives of humans as well as elephants. To reduce the loss of both humans as well as elephants lives automated systems have been developed which may partially reduce the loss of human lives. The use of combined wireless networks and the sensors will help the humans by remote monitoring and tracking of elephants which can be automated to any extent. There are systems that can alert the forest officials to take precautionary measures against the intrusion of elephants into the human settlements. This literature review on the detection/ tracking/deferring systems concludes that the use of wireless low powered sensors will improve the efficiency by 94 percent. The identified issues, challenges and pros and cons of the existing system will help the academicians and the research scholars to have a widespread knowledge on the previous works related to the HEC.

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