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Using Graph Theoretical Concept in Elephant Intrusion Detection System

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Abstract: Elephant intrusion in human habitats resulting destroying of crops and loss of human life is major issue for the states where elephant's populations are large. As per statistics North Eastern States of India including Assam are facing elephant intrusion problem resulting destruction of the properties of common people and also human death causalities. The forest department of the states took measures to get rid of such problems, however stringent measures are to be taken to mitigate the conflicts between human and the elephants. Elephants intrude to the human habitats due to different reasons, which includes, search for food, search for water, traditional migration routes, attraction to stored foods and crops. Moreover increased number of elephant population and decrease of forest cover due to deforestation. Elephants moves to or through the human habitats in herds, with big numbers and destroys the crops, houses, and stored foods of the villagers. Government agencies such as forest departments are taking different measures including early warning systems to prevent the damages to the properties and human lives. One such measure is early warning system, which warns the people to be cautious about the presence of the elephants in the human habitat areas. GPS Tracker, Drones, Camera traps, SMS alerts are few to cope up with early warning system. Movements of elephants can be easily identified if elephants are having GPS collars fixed by the forest officials. Graph theoretical concepts can be used to represent the places where elephants generally resides or moves, these includes as forest, water reservoirs such as lakes or small water bodies or Crop fields. These places can be represented as graph Nodes and the paths through which the elephants moves can be represented as graph edges. Real time elephant movements to and from the places can be identified if the elephants are fixed with GPS collars. Once we represent the whole system of elephant movements as graph the graph theoretical applications shortest path, optimizing routes, analysis of, designing corridors etc can easily be planned for efficient management a system. This research paper finds most frequent elephant's movement paths and also can be used to generate early warning messages about the presence and movement of elephants nearby the human habitats using graph theoretical concepts.

Keywords: Human-Elephant Conflict, Elephant tracking, Seismic sensors, Ecology, Application of Graphs, GPS Trackers

1. INTRODUCTION

Human–elephant conflict (HEC) has emerged as a major environmental and social challenge due to increasing interaction and conflict between humans and elephants for natural resources and land uses. The increased and rapid destruction of forest habitats caused by different reasons such as agricultural expansion, deforestation, mineral and coal mining, and infrastructure development has forced elephants to move into human-dominated areas in search of food and water. As a result, conflict and encounters between humans and elephants have become more, leading to serious consequences including death for both species. In India alone, such conflicts result in the deaths of large number of people every year, while large number of elephants also dies annually due to causes such as electrocution, poisoning, train accidents, and retaliatory killings.. Farmers suffer huge financial losses due to the destruction of crops land and crops, houses and households, food storage facilities causing out of elephant intrusions. In addition to financial losses, rural communities experience psychological stress and fear, as farmers are frequently required to guard their crops at night to prevent elephant raids. Meanwhile, elephants are increasingly affected by habitat fragmentation, which restricts their natural movement and forces them to pass through agricultural fields and settlements in search of resources. To solve this burning problem, several strategies have been proposed, including non-lethal protections such as electric fences, chili-based repellents, and beehive fences, along with technological solutions like monitoring systems and early warning mechanisms that help predict elephant movements and reduce conflicts. Northeastern India includes several states such as Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Tripura, Sikkim, and the northern part of West Bengal. The region extends over a huge area and is recognized internationally as a major biodiversity hotspot due to its exceptional ecological richness (Myers et al., 2000 [10]). The physical landscape of this region is highly varied, consisting of the Eastern Himalayan mountain system, the Meghalaya Plateau, numerous hill ranges, the fertile plains formed by the Brahmaputra and Barak rivers, and the Manipur valley. Northeast India supports a wide range of habitats, including grasslands, wetlands, marshes, tropical evergreen forests, tropical deciduous forests, subtropical forests, temperate forests, and alpine tundra at higher altitudes. This environmental diversity provides suitable conditions for a large number of wildlife species. A considerable number of these species are categorized as threatened, emphasizing the ecological importance of conserving this biologically rich region. Elephants are critical ecosystem engineers and keystone species that maintain biodiversity by dispersing seeds, clearing paths, and creating water holes. They shape habitats, fostering vegetation regeneration in forests and keeping savannas and grasslands open for other wildlife. Their loss threatens ecosystem stability, as they directly impact tree diversity and carbon storage.

2. LITERATURE REVIEW

King et al. [2] conducted an experimental behavioral study to determine whether elephants respond to the sound of disturbed honeybees. The study involved playing recorded bee buzzing sounds to elephant families in Samburu National Reserve in Kenya. The experiment showed that most elephant groups reacted strongly to the bee sounds by moving away quickly from the source. This study suggests that beehive fences and bee sound playback systems can act as natural deterrents to prevent elephants from entering crop fields. The method is eco-friendly and cost-effective compared to electric fences. Anni et al [1] proposed a technological solution for reducing human–elephant conflict using seismic sensors and video cameras. The system detects vibrations caused by elephant movements and processes these signals to track elephant paths near human settlements. The proposed system integrates vibration sensors with surveillance cameras to generate early warning alerts when elephants approach agricultural lands or villages. The study highlights that tracking elephant movement using sensors can provide timely alerts to both forest authorities and villagers, thereby reducing casualties and crop damage. Suganthi et al. [3] developed an elephant intrusion detection system designed for forest border areas. The system combines several technologies such as seismic sensors, cameras, microcontrollers, and communication networks to detect elephant movement. When the system identifies elephant activity, it sends alert messages to farmers and forest officials through GSM networks, allowing immediate action to repel the elephants. Studies on elephant behavior and conservation have contributed significantly to understanding the causes and mitigation of human–elephant conflict. Fernando [5] et al highlighted the importance of integrating scientific knowledge with conservation policies to protect elephant populations in Sri Lanka. The study emphasized that effective elephant conservation requires a combination of ecological research, policy implementation, and community involvement. It also suggested that conservation strategies should consider elephant movement patterns and habitat requirements in order to reduce conflict with human populations. Genetic and behavioral studies have also been used to understand elephant social organization. Fernando and Lande et al [6] conducted molecular genetic analyses to examine the social structure of Asian elephants. Their findings revealed complex social relationships within elephant populations, which are influenced by kinship and behavioral interactions. Understanding these social structures is important for conservation planning because disruption of social groups may influence elephant movement patterns and increase the likelihood of human–elephant encounters. Several researchers have investigated practical strategies to mitigate human–elephant conflict in South Asia. Fernando et al. [7] reviewed various conflict mitigation techniques implemented across the region. These methods include physical barriers such as electric fencing, community-based crop protection strategies, and early warning systems for detecting elephant movements. The review highlighted that successful mitigation strategies require collaboration between local communities, wildlife authorities, and conservation organizations. Research on elephant movement patterns has also provided important insights into habitat use and ranging behavior. Fernando et al. [8] studied the ranging behavior of Asian elephants in Sri Lanka and found that elephants often travel long distances between feeding and water sources. Habitat fragmentation and the presence of human settlements within these movement corridors can lead to frequent human–elephant interactions. Therefore, protecting migration routes and maintaining habitat connectivity are essential for reducing conflict. In addition to studies on wild elephants, research has also been conducted on captive elephant populations. Ilangakoon et al [9] carried out a preliminary study on captive elephants in Sri Lanka, examining their management, health, and living conditions. Although the study focused on captive populations, it provided valuable information on elephant behavior and welfare that can be applied to conservation and management strategies. Another important approach to reducing human–elephant conflict is the establishment of wildlife corridors. Wildlife corridors allow elephants to move safely between fragmented habitats without passing through densely populated areas. The Elephant Corridor Project implemented by Mount Kenya Trust [10] is an example of such an initiative. The project aims to restore natural migration routes for elephants and reduce conflicts with nearby communities. Overall, existing literature highlights the importance of combining ecological research, technological solutions, and community participation to address human–elephant conflict effectively. Understanding elephant behavior, social organization, and movement patterns plays a crucial role in designing conservation strategies that ensure coexistence between humans and elephants.

3. TECHNOLOGY BEHIND

Elephants moves from one place to another due to search of foods, search of water and also migrating from one place to another due to climatic condition or environmental changes. So the routes of movement are generally static for a period of time and may change due to climatic condition or change of environmental conditions. The places where the elephants move may be forest areas, water reservoir, crop fields. These places can be considered as nodes as represented in a graph and the routes of movement can be considered as edges of a graph. The number of elephants presents at a node and also present at the routes can be estimated using GPS Tracker or Solar Cameras fixed at different locations of the forest reserve or at its adjacent areas. Moreover, the movement of the elephants can also be tracked using GPS or Solar Cameras. The movement of the elephants towards particular location is very important while it moves to the human habitat in search foods. Thus the possibility of the presence of an elephant or a herd of elephants can be taken as important information to cope up with elephant intrusion in at human habitat or crop fields.

Role of GPS trackers : GPS trackers play a significant role in accurately determining the position of objects in real time. By utilizing satellite signals and modern communication technologies, they provide reliable location information for various applications such as navigation, security, and asset monitoring. Although certain environmental factors can affect signal accuracy, advancements in GPS technology continue to improve positioning precision and tracking efficiency. GPS trackers provide an effective method for determining the exact position of elephant herds and studying their movement patterns. The technology plays a crucial role in wildlife conservation, habitat management, and reducing human–elephant conflicts. By enabling real-time monitoring, GPS tracking supports better decision-making for wildlife protection and sustainable coexistence between humans and elephants.

Role of Image Processing Cameras: Image processing cameras provide an effective and non-intrusive method for monitoring elephant movements in forest areas. By combining camera surveillance with computer vision techniques, wildlife authorities can detect elephants early, study their behavior, and take preventive actions to reduce human–elephant conflicts. This technology significantly contributes to wildlife conservation and ecological research.

4. METHODOLOGY

Let us consider a representation of a area where elephants intrusion occurs frequently at different places. The places and the corresponding routes of the forest cover is represented a diagram in Figure-01. Three important parameters are considered in assigning the weight of an edge Viz Distance of the route, Condition of the route and Speed of the elephant or herd of elephants.

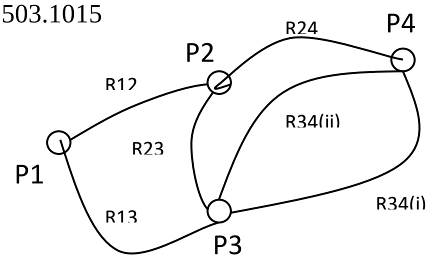

Figure -01: Elephant intrusion places and paths

In the figure – 01 P1, P2, P3, and P4 represents the places and R12, R13, R23,R24, R34(i), R34(ii) represents the routes of elephant movements with the following descriptions.

4.1 Description of the Places (Nodes)

Place	Description
P1	Human habitat and Crop field/ Storage
P2	Dense forest of elephant habitat
P3	Human Habitat and Crop field/ Storage
P4	Dense Forest Water reservoir

4.2 Description of the Routes (Edges)

Route	Description	Approx time to cross
R12	Hilly route	3 Hrs
R13	Plain Route	1 Hr
R23	Plain Route	1 Hr
R24	Hilly route	2 Hrs
R34(i)	Plain route	1 Hr
R34(ii)	Hilly route	2 Hr

We can represent the above figure-1 into a graph as follows:

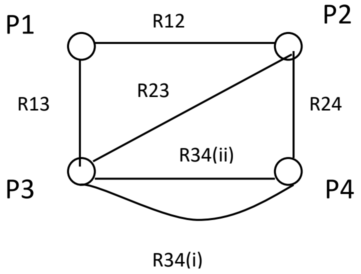

Figure -02: Graph representation of figure-01

We can represent the undirected graph as the above figure-2 into an incidence matrix as follows:

	R12	R13	R23	R24	R34(i)	R34(ii)
P1	1	1	0	0	0	0
P2	1	0	1	1	0	0
P3	0	1	1	0	1	1
P4	0	0	0	1	1	1

Figure -03: Incident matrix of figure-02

Consider, a particular situation of the above graph which shows the presence of elephant(s) at some particular edge together with direction of movement:

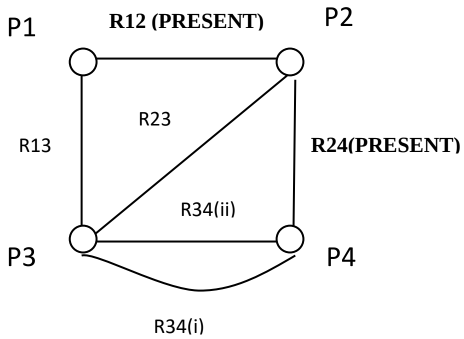

Figure -04: Presence of elephants in R12 and R24 edge

R12 edge has a presence of elephants which is approximately 35 hours distance from P1 and approaching towards P2 approximately 25 hours distance from P2. Similarly edge R24 has a presence of elephants which is 90 hours from P2 and 30 hours from P2 and the elephants are approaching towards P4.

	R12	R13	R23	R24	R34(i)	R34(ii)
P1	35	0	0	0	0	0
P2	-25	0	0	90	0	0
P3	0	0	0	0	0	0
P4	0	0	0	-30	0	0

Figure -04: Matrix Representation of graph of figure -04

The matrix is a dynamic matrix and the values will change as per the direction of the movement of the elephants towards a particular place.

5. APPLICATION

5.1. Generation of early warning messages

The data can also be used for early warning generation to the Forest authorities, other Government authorities, Villagers and others who are directly and indirectly involved with the incidents. Matrix represented in Figure -05 can give a picture about the presence of an elephant or herd of elephants. The vulnerability and warning matrix computed has been represented as follows:

Sl No	Place	Information	Warning Messages
1	P1	Human habitat and Crop field/ Storage	Elephants are nearby the place but moving to opposite direction.
2	P2	Dense forest of elephant habitat	Elephants are approaching towards the place and it is forest place.
3	P4	Human Habitat and Crop field/ Storage	Elephants are approaching towards the place. The inhabitants of the area must be alert.
4	P5	Dense Forest Water reservoir	Elephants are nearby the place but moving to opposite direction.

Warning messages can be delivered through mobile applications, SMS notifications, or automated alarm systems installed in vulnerable areas. By receiving timely alerts, villagers as well as Government officials can necessary actions to and also can take precautionary measures to protect themselves and their crops. SMS Notifications can be delivered immediately to the Villagers and the forest officials as Mobile Area networks are a common and available system.

5.2. Finding most frequent movement paths

The data generated at the figure -03 and figure-05 are dynamic and changes over the period of time. However the data can be represented as an array. The data can be

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stored over a period of time as set of arrays. The arrays of observations can be used to find the most frequent movement path of the elephants. The most frequent movement paths can be used to find places for elephant corridors, finding elephants for periodical medications, etc.

6. FUTURE WORKS

However, the identification of frequent paths and warning generation will depend on the efficiency of data collection technologies and the environmental conditions also. Future improvements in elephant intrusion early warning systems should emphasize the integration of artificial intelligence, IoT-based monitoring technologies, aerial imagery, and efficient community communication systems. Artificial intelligence can be used to analyze large volumes of historical GPS tracking data collected from elephant herds. By studying these movement records, predictive models can estimate possible routes and identify areas where elephants are likely to approach human settlements. Such predictions can help authorities and villagers prepare in advance and reduce unexpected encounters. Another important direction is the deployment of IoT-enabled monitoring devices along forest boundaries and known elephant corridors. Sensors such as motion detectors, infrared cameras, and vibration sensors can detect animal movement and transmit signals to a central monitoring station in real time. These technologies allow continuous observation of wildlife activity even in remote forest regions. When combined with GPS tracking devices attached to selected elephants, the monitoring system can provide more precise information about herd locations and movement patterns.

Future systems may also incorporate satellite imagery and drone-based surveillance to improve the detection of elephants over large forest areas. Advanced image processing and computer vision techniques can analyze aerial images and automatically identify elephant herds. This is particularly useful in dense forests where ground-based cameras may have limited visibility. Equally important is the development of community-oriented alert systems that can quickly inform nearby villages about approaching elephants. The combination of these technologies within a unified monitoring framework can greatly improve the accuracy, reliability, and response time of early warning systems. Such integrated approaches can play a key role in reducing conflicts between humans and elephants while also supporting wildlife conservation and sustainable coexistence.

7. REFERENCES

[1] Anni, D. J. S., & Sangaiah, A. K. (2015). Early warning system for preventing human–elephant conflict using seismic sensors.

[2] King, L. E., Douglas-Hamilton, I., & Vollrath, F. (2007). African elephants run from the sound of disturbed bees. *Current Biology*.

[3] Suganthi, N., Rajathi, N., & Inzamam, M. F. (2018). Elephant intrusion detection and repulsive system. *International Journal of Recent Technology and Engineering*.

[4] Ardovini, A., Cinque, L. & Sangineto, E. (2008) Identifying elephant photos by multi-curve matching. Pattern Recognition. 41: 1867-1877.

[5] Fernando, P. (2006) Elephant conservation in Sri Lanka: Integrating scientific information to guide policy. In: Principles of Conservation Biology. Groom, M.J., Meffe, G.K. & Carroll, C.R. (eds.) Sinauer Associates, Sunderland, USA. pp 649- 652.

[6] Fernando, P. & Lande, R. (2000) Molecular genetic and behavioral analyses of social organization in the Asian elephant. Behavioral Ecology and Sociobiology 48: 84-91.

[7] Fernando, P., Kumar, M.A., Williams, A.C., Wikramanayake, E., Aziz, T. & Singh, S.M. (2008b) Review of Human-Elephant Conflict Mitigation Methods Practiced in South Asia. WWF-World Wide Fund for Nature.

[8] Fernando, P., Wikramanayake, E.D., Janaka, H.K., Jayasinghe, L.K.A., Gunawardena, M., Kotagama, S.W., Weerakoon, D. & Pastorini, J. (2008a) Ranging behavior of the Asian elephant in Sri Lanka. Mammalian Biology 73: 2-13.

[9] Ilangakoon, A.D. (1993) A preliminary study of the captive elephants in Sri Lanka. Gajah 11: 29- 42. Mount Kenya Trust (2011) Elephant Corridor Project.

[10] Norman Myers, Russell A. Mittermeier, Cristina G. Mittermeier, Gustavo A. B. da Fonseca & Jennifer Kent (2000), Biodiversity hotspots for conservation priorities, Nature volume 403, pages853–858 (2000)