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Transformative Solutions through AI and Digital Platforms in Human-Elephant Conflict Management

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Abstract: The research emphasizes integrating artificial intelligence (AI) technology and technological solutions, notably the Anukampa web portal and mobile app, to address human-animal conflict, with a focus on mitigating human-elephant conflicts. Through an approachable digital platform, the Anukampa Application, launched in Odisha, India, simplifies the process of giving compassionate compensation (ex gratia) to people impacted by wildlife depredation. This action not only speeds up the compensation process but also improves accountability and transparency, giving impacted residents more trust and promoting goodwill between local communities and wildlife officials. The research also addresses how AI technology can improve on current approaches to managing conflicts between humans and elephants. AI algorithms can boost detection of intrusions and alerting systems like eleAlert, improve early warning systems for crop raiding occurrences using AI-driven communication platforms, and greatly increase the accuracy of species classification in footfall detection approaches. These technologies can help with more effective, precise, and rapid responses to human-animal conflicts by using AI to computerize data processing, boost monitoring mechanisms, as well as enhance communication systems. The research highlights how integrating AI and technology might be revolutionary in addressing socio-environmental issues, especially conflicts between humans and animals. The study emphasizes the move toward a more sustainable and successful method of handling disputes between people and wildlife through the Anukampa application and AI-driven solutions. In addition to helping impacted parties get compensation in a timely manner, this integrated strategy encourages a harmonious coexistence of humans and wildlife, which helps protect species. In the end, the research supports the ongoing investigation and application of cutting-edge technical solutions, such as artificial intelligence (AI), to lessen conflicts between people and animals and foster peaceful coexistence between human societies and the natural environment.

Keywords: Anukampa App, Human-Animal Conflict, Wildlife Conservation, Technological Innovation

1. Introduction

Key insights into patterns and mitigation techniques in a socio-legal setting are provided in the introduction section on human-elephant conflict (HEC). Strong seasonal and location-based tendencies are seen in HEC, which is frequently found in areas bordering forests during agricultural harvesting seasons and close to protected areas that serve as elephant refuges. Mitigation calls for a variety of site-specific approaches that include a broad range of farmer-used deterrent tactics, such as time-honored practices like yelling, drumming, and setting off firecrackers. Effective conflict management requires cooperation between farmers and assistance from forest department representatives, including the deployment of domestic elephants. Moreover, growing substitute crops in areas with high levels of conflict is a well-established tactic. This comprehensive strategy highlights the intricacy of HEC and the requirement for integrated socio-legal solutions to protect Asian elephant populations while resolving local communities' socioeconomic issues.

The research delves into various methods and initiatives aimed at mitigating human-elephant conflict (HEC), encompassing traditional practices devised by local communities and innovative solutions. Traditional methods involve creating noise, using light and missiles to deter elephants from crop fields, but these approaches have limitations, such as elephants being less visible at night and farmers facing risks when confronting elephants directly. The evolution of mitigation strategies has led to a distinction between traditional and intelligent methods, with the latter incorporating advancements like intelligent fencing, disturbance techniques, and translocation strategies. However, effective HEC mitigation remains challenging and complex, requiring a combination of measures used flexibly across different scales.

A multidisciplinary approach to research can significantly enhance HEC mitigation efforts. By integrating expertise from fields such as ecology, wildlife biology, technology, social sciences, and law, researchers can develop holistic solutions that address not only the ecological aspects of HEC but also the socio-economic and legal dimensions. For instance, ecological studies can help understand elephant behavior and movement patterns, leading to better design of deterrents and land-use planning strategies. Social sciences can contribute by assessing community perceptions and implementing community-based conservation initiatives. Legal frameworks can be strengthened to ensure effective implementation of mitigation measures and to address issues related to compensation and conflict resolution. Such collaboration across disciplines is essential for developing comprehensive strategies that promote coexistence between humans and elephants while safeguarding both biodiversity and human livelihoods.

2. Traditional Solutions

2.1. Biological Considerations

The research goes into detail on conventional approaches to reducing human-elephant conflict (HEC), emphasizing vegetation-based barriers and biological factors. Using sustainable bio-fencing technology, such as planting Palmyra palm rows in zigzag patterns along territorial boundaries or around impacted farmlands, is one noteworthy strategy. This approach resolves the dispute with advantages for both humans and elephants by reducing the number of elephant and human deaths while also producing additional advantages like elephant feed. Elephants also tend to avoid regions with dense vegetation, therefore utilizing thorny plants or repellent plants like lemon trees, red chile, and citronella grass to create vegetative barriers has proved successful in keeping them away. Elephants have been deterred by chili-based products in trials; aerial spraying of capsicum oleoresin has proven to be an effective short-term repellent without provoking aggressive behavior from elephants.

Acoustic deterrents, including loud noises from beating drums, tins, and trees, as well as setting off explosive bombs, have been widely used by farmers globally to scare wildlife, particularly elephants. Disturbance shooting, involving gunshots over crop-raiding elephants' heads, is another traditional method, although it requires intervention from animal control units or administration representatives. Alarm systems triggered by tripwires or set on fences, along with more sophisticated techniques like tape recordings of animal noises, are being tested to alert farmers about elephant presence. Visual deterrents, such as fires, burning sticks, and tobacco-based deterrents, also play a role in deterring elephants from raiding crops. Moreover, research in Kenya has explored the use of African honey bees integrated into fences to deter elephants, leveraging the insects' disturbance caused by elephant contact with the barrier. These traditional methods, coupled with ongoing research and innovative approaches, contribute to the multifaceted efforts in mitigating HEC and promoting coexistence between humans and elephants.

King et al. (2011) proposed using beehives as a novel method to mitigate elephant crop depredation. The key element of their concept is the design of “beehuts”, interconnected by a hanging wire with a gap of 7 meters between each beehut. A strong piece of plain wire links one beehive to the next, spaced 10 meters apart. If an elephant attempts to enter the farm, it will naturally try to pass between the beehuts. As the wire stretches under pressure, the beehives swing erratically, potentially releasing bees if occupied. The disturbance caused by the bees then deters the elephants from the area. However, the efficacy of beehives along fences is questioned, as elephants typically raid at night when bees are inactive. Furthermore, there are concerns about bees biting elephants and causing injuries that may intensify the elephants’ reactions. This innovative approach highlights the potential of using natural deterrents, such as bees, to deter elephants from crop raiding, although further research is needed to address practical challenges and optimize effectiveness.

2.2. Physical Considerations

Elephant-proof trenches (EPTs) are constructed worldwide to prevent elephants from crossing into farmlands, but they face challenges similar to electric fences. The typical dimensions for EPTs are 3 meters wide at the top, 1 meter wide at the bottom, and 2 meters deep, although these dimensions vary based on regional conditions. However, elephants have been observed kicking spoil back into the trenches, effectively filling them and allowing crossings. Soil erosion and caving-in of trench walls are common issues, particularly in areas with high rainfall or unstable soil conditions. Measures like stabilizing trench walls with concrete, stones, or tar/asphalt can increase costs significantly. EPTs are also ineffective near streams and require regular maintenance, making them costly and impractical for sloping or wet terrain. Additionally, human interference, such as creating crossing points in EPTs, contributes to their ineffectiveness. Elephant calves are at risk of falling into trenches, further highlighting the unsuitability of EPTs for certain landscapes. These challenges underscore the need for alternative or supplementary strategies to effectively mitigate human-elephant conflict, especially in areas with challenging terrain or high erosion rates. To enhance the effectiveness of elephant-proof trenches (EPTs), a combination of strategies can be employed, such as placing vegetative barriers along with constructing trenches around the boundaries of protected areas. The recommended trench specifications include a top width of 2.10 meters, a bottom width of 1.20 meters, and a depth of 2.40 meters, with the dug-out earth used to create mounds towards the inner side of the protected area. This integrated approach aims to further deter elephants from crossing boundaries and accessing farmlands, reducing human-elephant conflict.

In addressing human-elephant conflict, the Coimbatore Forest Division has implemented extensive measures within Elephant Reserve No. 8, which is part of the Project Elephant Perspective Plan of the Tamil Nadu State Forest Department. Over 210 kilometers of elephant-proof trenches have been constructed in the division, contributing significantly to preventing elephants from straying into human settlements and agricultural areas. These efforts reflect a proactive approach to wildlife conservation and conflict mitigation, emphasizing the importance of integrated strategies and continuous monitoring to ensure the effectiveness of protective measures. Here is a practical demonstration of the five types of elephant fencing based on the classifications provided by Hoare (1994):

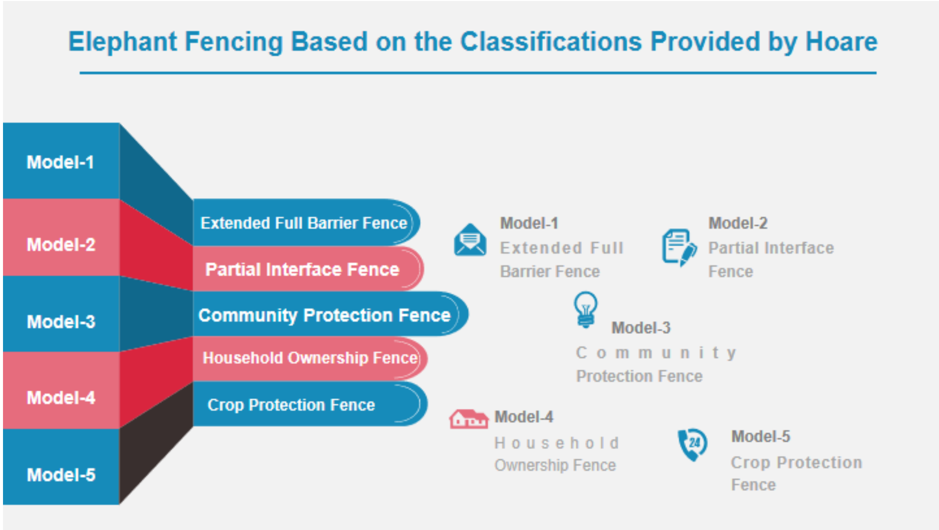

Figure 1. Elephant fencing based on the classifications provided by Hoare (1994)

1. Extended Full Barrier Fence (Model 1):
   - This type of fence is typically long and serves as a complete barrier, often separating different land uses such as national parks from agricultural lands. It is designed to prevent elephants from entering specific areas entirely.
   - Practical Example: Imagine a long, sturdy fence stretching across the border of a national park, preventing elephants from crossing into nearby agricultural fields.

2. Partial Interface Fence (Model 2):
   - This fence is open-ended but incorporates natural barriers like an escarpment or a lake. It aims to guide elephants away from certain areas while allowing them some degree of movement.
   - Practical Example: Picture a fence running along the edge of an escarpment, directing elephants away from a village while allowing them to access water from a nearby lake.

3. Community Protection Fence (Model 3):
   - This fence encircles an entire village along with its crops and facilities, providing comprehensive protection against elephant intrusion.
   - Practical Example: Visualize a fence surrounding a village, including agricultural fields, houses, and community buildings, creating a safe zone for both humans and elephants.

4. Household Ownership Fence (Model 4):
   - This type of fence encircles the dwelling and crops of a single household, offering localized protection against elephant damage.
   - Practical Example: Picture a fence around a specific house and its surrounding crop fields, protecting the household's property from elephant raids.

5. Crop Protection Fence (Model 5):
   - A crop protection fence is designed to encircle small areas dedicated to crop cultivation, safeguarding them from elephant damage.

- Practical Example: Imagine a small farm with a fence around the crop-growing area, keeping elephants away from the cultivated plants while allowing them access to other parts of the landscape.

These practical examples illustrate how different types of elephant fencing can be implemented based on the specific needs of different areas, whether it's protecting large territories or individual households and crops. The use of electrified fences, particularly in the context of mitigating human-elephant conflict, presents both advantages and challenges. When properly maintained, electric fences can be highly effective in deterring elephants from crop raids and restricting their movements to specific areas. The high voltage but low amperage pulsed current of electric fences delivers a powerful but non-harmful shock to elephants upon contact, making them wary and less likely to challenge the barrier. However, elephants have demonstrated various strategies to breach electric fences, such as using their tusks, pushing down fence posts, stepping over wires, or simply adapting to the shock over time. Proper maintenance and strategic placement are crucial for the success of electric fences as a psychological barrier. Fences erected along the ecological boundary between elephant habitat and human areas tend to be more effective due to easier maintenance and reduced likelihood of challenges by elephants. However, electric fences within forest areas face logistical difficulties in maintenance and are often less effective in deterring elephants.

While electric fences are seen as a permanent solution by local communities, they come with significant costs and maintenance requirements. Illegal tapping into mains AC power supply for electric fences has resulted in fatalities among elephants and humans. Additionally, the effectiveness of electric fences depends on various factors such as fence design, voltage, maintenance, and elephant behavior. More research is needed to better understand these factors and improve the effectiveness of electric fences in mitigating human-elephant conflict and reducing crop raids. The deployment of nearly 1,700 kilometers of solar fences in Tamil Nadu, including 100 kilometers in the Coimbatore division, has required constant maintenance, with mixed results observed. Despite these efforts, human-elephant conflict remains a significant challenge, as evidenced by the tragic toll of 81 human fatalities caused by elephants in the Coimbatore Forest Division between 2000 and 2011. Furthermore, in 2012 alone, wild elephants ventured into human habitations over 3,000 times in this division, indicating the persistent nature of the conflict.

Joshi & Singh (2007) highlight how various human activities and infrastructure, such as railway lines, highways, canals, industrial establishments, and settlements along migration corridors, have impacted the migratory movements of elephants. The report suggests alternative approaches and modifications to manmade structures (Civil Engineering) to facilitate elephant movement, safeguard the species from extinction, and mitigate animal-human conflict in the Rajaji Corbett Elephant Range. In response to the challenges posed by human-elephant conflict, the Coimbatore Forest Department has implemented measures such as establishing 32 waterholes in forest areas and deploying a team of 250 field staff and 120 anti-poaching watchers who work tirelessly throughout the year to drive elephants back into forests. These efforts underscore the complex and multifaceted nature of addressing human-elephant conflict, requiring a combination of strategies including infrastructure modifications, habitat conservation, and proactive management approaches to ensure the coexistence of humans and elephants while protecting both biodiversity and livelihoods.

Loarie et al. (2009) discuss the significance of artificial water sources and food availability in influencing elephant presence in forests during dry seasons. Planting food trees in elephant habitats and corridors has proven beneficial, along with efforts to regenerate bamboo and cultivate sugarcane along stream courses. However, the long-term effectiveness of such practices over large areas is limited due to the extensive variety of plants elephants consume, making restocking challenging. Elephants can consume up to 200 kg of forage daily, showcasing the immense challenge of providing sufficient resources. The presence of surface water and rivers strongly influences elephant distribution, and manipulating water sources can potentially influence their presence in specific areas. Water provisioning may attract elephants to previously unused habitats, leading to changes in population density that can impact forest vegetation quality and overall biodiversity. These findings highlight the complex dynamics of elephant habitat management and the need for comprehensive strategies that consider both food resources and water availability to ensure sustainable coexistence with elephants.

3. Intelligent Solutions

The existing solutions discussed by Wood et al. (2005), Graham & Hebert (2011), and Wijesinghe & Jeon (2012) could be significantly enhanced with the integration of Artificial Intelligence (AI) technologies.

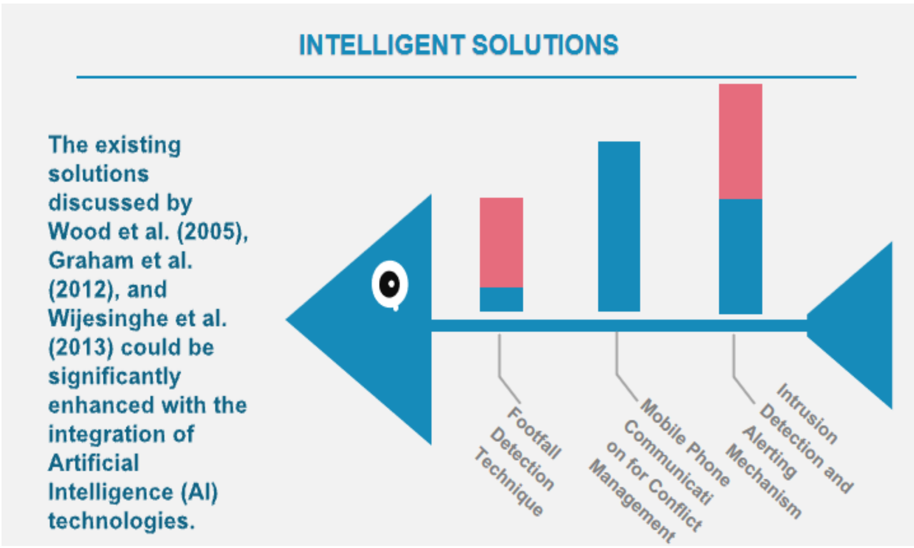

Figure 2. Intelligent solutions

1. Footfall Detection Technique:
    - AI algorithms can be employed to analyze the spectral content of footfalls recorded by geophones, improving the accuracy of species discrimination beyond the 82% achieved in the study by Wood et al. (2005). Machine learning models can learn patterns in footfall data to differentiate between various large mammal species with higher precision.
2. Mobile Phone Communication for Conflict Management:
    - AI-driven communication platforms can facilitate early warning systems for crop raiding incidents, as discussed by Graham & Hebert (2011). Natural Language Processing (NLP) algorithms can analyze text and voice messages to quickly identify and relay information about elephant movements, enabling timely responses from farmers and wildlife management authorities.
3. Intrusion Detection and Alerting Mechanism:
    - AI-based intrusion detection systems, such as eleAlert proposed by Wijesinghe & Jeon (2012), can leverage computer vision and sensor data analysis to detect damages to fences separating wildlife habitats and human settlements. Machine learning

models can learn to distinguish between normal activities and potential intrusions, sending instant alerts to communities via mobile networks.

Overall, AI technologies can enhance the efficiency, accuracy, and timeliness of existing solutions for human-elephant conflict management. By automating data analysis, improving communication systems, and enhancing detection mechanisms, AI can contribute significantly to mitigating conflicts and promoting coexistence between humans and elephants. The use of satellite technology in monitoring elephant movement and mitigating human-elephant conflict is discussed in Venkataraman & Wafar (2005). The study explores the potential of GPS radio collars attached to elephants to transmit their geo-locations to satellites, allowing for real-time tracking of elephant herds in forest regions. This tracking enables the prediction of elephant movements towards villages, providing advance information to inhabitants to prepare for potential conflicts. However, the study notes that for this data to be relevant and timely, it needs to be updated more frequently than the current 24-hour interval.

Despite the advantages, challenges such as the high cost of equipment limit the widespread use of this technology to monitor only a small number of animals. Additionally, elephants tagged with radio collars have shown violent reactions, damaging the collars in some cases. The study highlights a tragic incident involving the death of a 20-year-old male elephant during an attempt to fix a radio collar. The elephant collapsed in an uncomfortable position due to sedation, leading to respiratory problems and ultimately, its death. This incident underscores the complexities and risks associated with using radio collars for tracking wildlife. The study also includes a visual representation of an elephant connected with a radio collar, illustrating the technology's application in wildlife monitoring. Overall, while satellite technology holds promise for conflict mitigation, including early warning systems, its implementation requires careful consideration of ethical and practical challenges to ensure the safety of both wildlife and researchers involved.

The study by Juang et al. (2002) delves into the complexities of designing sensor networks for tracking wildlife positions, highlighting challenges such as susceptibility to destruction by elephants and human disturbances. Venter & Hanekom (2010) explore the potential of elephant communication signals for detecting herds, while Seneviratne et al. (2004) propose an electronic sensor system for detecting infrasound elephant calls and deterring rogue elephants. Vermeulen et al. (2013) suggest using Unmanned Aircraft Systems to survey elephants, while Dabarera & Rodrigo (2010) and Ardovini et al. (2008) present image-based identification systems for elephants based on appearance and photo comparison. Goswami et al. (2011) focus on identifying elephants from photographs using visual features like tusk and ear shape, offering a reliable method for individual identification. Walas et al. (2011) discuss control mechanisms for walking robots, and Filho et al. (2010) design robots capable of navigating obstacles and complex movements using contact sensors. Szrek & Wójtowicz (2010) introduce the LegVan wheel-legged robot with autonomous leveling and obstacle detection, while Raibert et al. (2008) develop BigDog, a rough-terrain robot with sophisticated sensors and control systems mimicking living creature mobility.

These studies demonstrate diverse approaches to wildlife monitoring and robot design, showcasing innovations in sensor technology, communication systems, image recognition, and robotic locomotion. From infrasound detection to aerial surveys and robotic mobility, these advancements contribute to better understanding and management of wildlife populations and environmental challenges. Each study presents unique insights and solutions, collectively contributing to the evolving landscape of wildlife conservation and robotics technology.

4. Need For Early Warning System

Sitati et al. (2005) emphasize the importance of proactive measures in mitigating human-elephant conflicts, highlighting the effectiveness of early warning systems and active deterrents. The study underscores that preventing elephants from entering cultivated fields is more feasible than trying to drive them away once they have caused damage. The proposed early warning system serves a dual purpose:

1. Providing Warning to People: By alerting communities about the potential entry of elephants into human habitation areas, the system enables residents to take precautionary measures and minimize encounters with elephants, thereby reducing conflict incidents and property damage.
2. Alerting Authorities: The system also provides advance information to authorities, allowing them to mobilize resources and take proactive measures to deter elephants from straying into human settlements. This timely intervention helps in preventing potential conflicts and ensures the safety of both humans and elephants.

The implementation of such an early warning system is crucial in fostering coexistence between humans and elephants, as it enables proactive measures to be taken to avoid conflict situations and protect both livelihoods and wildlife habitats. The work proposed in this study aims to develop an early warning system for detecting elephant movement in forest border areas to minimize human-elephant conflicts. Here are the key points from the summary:

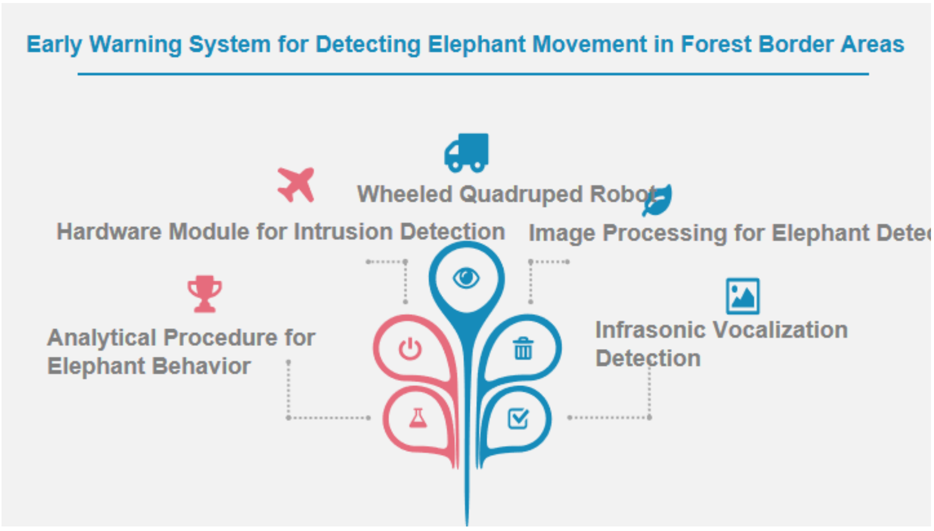

Figure 3. Early warning system for detecting elephant movement in forest border areas

1. Analytical Procedure for Elephant Behavior: The study uses a three-state Markov chain model to analyze elephant behavior, considering migration data. This analytical approach helps in understanding and predicting elephant movements, particularly near human habitation areas.

2. Hardware Module for Intrusion Detection: A hardware module is designed for an elephant intrusion detection system. This module monitors elephant movement near human settlements and sends early warnings via SMS to forest officials. This timely communication enables authorities to take necessary action to prevent potential conflicts.

3. Wheeled Quadruped Robot: A specialized robot, the Wheeled Quadruped Robot, is developed to move in various terrains, including forest borders. It is deployed

strategically in areas where elephants typically exit the forest and enter human habitats. The robot follows a predetermined path to capture images of elephants in these critical zones.

4. Image Processing for Elephant Detection: An early warning system utilizing image processing techniques is developed to detect elephants even in the presence of other wildlife species like bison, tigers, and deer. The system can identify elephants in groups and optimizes the time taken to detect elephant images using an optimized distance metric.

5. Infrasonic Vocalization Detection: The study also employs recordings of elephant vocal communications, which are characterized by infrasonic frequencies. A system comprising an FM transmitter, receiver, amplifier, and audio jack connected to a PC is used to detect elephant sounds. When an elephant vocalization surpasses a set threshold, an SMS alert is automatically sent to forest officials.

The proposed early warning system combines analytical models, robotics, image processing, and infrasonic vocalization detection to enhance the detection and response capabilities concerning human-elephant conflicts in forest border areas.

5. Conclusion

The research on human-elephant conflict (HEC) patterns and mitigation strategies presents a comprehensive understanding of the challenges faced and the potential solutions available. Traditional mitigation techniques have shown limited efficiency, highlighting the need for exploring simple, low-cost active deterrence methods coupled with early warning systems. These mitigation strategies not only offer viable solutions for addressing human-elephant conflicts but also contribute to the conservation of both humans and elephants. The ongoing human-elephant conflict, rooted in the historical interaction since the advent of agriculture, underscores the urgent need for sustainable solutions. As human populations continue to encroach upon natural habitats, the potential for conflict persists. Therefore, it is crucial for researchers to delve deeper into understanding the correlates of elephant damage and developing improved strategies to manage and prevent conflicts in the future.

In this context, Artificial Intelligence (AI) can play a transformative role in enhancing research and mitigation efforts related to human-elephant conflict. AI technologies, such as machine learning algorithms, can analyze vast amounts of data to identify patterns and predict potential conflict hotspots. Early warning systems powered by AI can integrate data from various sources, including satellite imagery, sensor networks, and historical conflict data, to provide timely alerts to communities and authorities. AI can assist in optimizing mitigation strategies by evaluating the effectiveness of different deterrent methods and livelihood strategies. Through AI-driven modeling and simulation, researchers can assess the impact of habitat improvements on elephant behavior and community livelihoods, leading to more informed decision-making.

The integration of AI technologies with research on human-elephant conflict patterns and mitigation strategies offers a promising pathway towards sustainable coexistence. By leveraging AI for data analysis, early warning systems, and optimization of mitigation efforts, researchers and conservationists can work towards mitigating conflicts, conserving elephant habitats, and fostering harmonious relationships between humans and elephants.

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