Prevention of Animal Intrusion on Farms and Railways Using Laser-Ultrasound-Based and IoT Technology

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Abstract

With the global population on the rise, the demand for food production has increased, necessitating efficient and secure farming practices. Animal intrusion poses a significant challenge to modern agricultural operations, leading to crop damage, economic losses, and potential threats to food security. This paper explores the innovative approach of integrating laser-ultrasound-based technology and the Internet of Things (IoT) to prevent and detect animal intrusion on farms. By combining the precision of lasers with the connectivity of IoT, farmers can achieve enhanced security, reduced losses, and improved overall agricultural sustainability in an economic and efficient manner.

Keywords

Laser-Ultrasound-based, IoT, Animal Intrusion, Prevention, Detection, Food Security, Sustainability, Economic loss.

Introduction

The coexistence of wildlife and agricultural activities is essential to ensure protection of human lives, food security, and to prevent animal cruelty and preserve biodiversity. Between the periods of 2018-19 and 2020-21, a total of 222 elephants lost their lives due to electrocution across the nation. Additionally, during the span from 2019 to 2021, poaching led to the death of 29 tigers, while there are ongoing investigations into 197 more tiger fatalities. In terms of human casualties resulting from conflicts with animals, elephants were responsible for the deaths of 1,579 individuals over a three-year period: 585 in 2019-20, 461 in 2020-21, and 533 in 2021-22. Among the regions, Odisha recorded the highest number of fatalities with 332, followed by Jharkhand with 291, and West Bengal with 240. On the other hand, within reserves, tigers claimed the lives of 125 humans between 2019 and 2021[1]. In Maharashtra, in 2021, the forest department's statistics indicated that 84 people lost their lives due to conflicts between humans and wildlife. This number rose to 105 fatalities in 2022. During the 2019-20 period, the total compensation provided for such events across the state was ₹7,035 lakhs. This amount saw an increase in the following year, reaching ₹8,022 lakhs in 2020-21. Subsequently, the compensation disbursed in 2021-22 was ₹8,004 lakhs, and this figure further rose to ₹8,137 lakhs in the subsequent fiscal year of 2022-23[2]. It necessitates effective strategies to mitigate the negative impacts of wildlife intrusion on farms. Traditional methods have limitations, and there is a need for innovative approaches. This paper proposes the use of

laser-ultrasound-based method for detecting and preventing wildlife intrusion. The aim of this technology is to prevent animal intrusion and also human wildlife conflict by driving away the animal instead of killing it. It also aims to be as cost effective as possible, minimally intrusive, easy to install and maintain, highly efficient and easily adaptable in order to ensure widespread adaptation and use among various groups of farmers from various different areas and economic circumstances.

Agriculture in India

Agriculture has a rich history in India beginning around 9000 BCE which was soon followed by settled life.[3] The first written record of agriculture can be found in the vedas, with the Rigveda mentioning hymns describing ploughing, fallowing, irrigation, fruit and vegetable cultivation[4]. Rice and Cotton are believed to have been cultivated in the Indus Valley Civilization. In the modern era, India's green revolution, which involved adopting new technologies such as high yielding varieties of seeds, improved productivity significantly, reducing reliance of India on food imports.

India, both in the past and the present, has contributed significantly to world agriculture. Until the 18th century, India was the sole producer of sugarcane, and India also pioneered water diversion projects with the development of the Anicut Dam, developed in the second century CE. At present, India is one of the highest producers of fresh fruit, wheat, rice, sugarcane among others[5]. Though the role of agriculture in the Indian economy has been declining since independence, it is still an essential part of the economy[6]. As per the Second Advance Estimates of National Income, 2022-23, the share of Gross Value Added (GVA) of agriculture and allied sectors in the total economy in 2022-23 was 18.3%. [7]

Of the many problems faced in agriculture, one significant issue is the intrusion of fields by wildlife.

Issue of Wildlife Conflict

Due to increasing human population and rapid development,Between 1960 and 2023, India's population surged from 450.55 million individuals to 1.43 billion, marking an impressive growth of 216.5% over a span of 63 years[8]. forest cover in India has been declining rapidly. From 1990 to 2000, India's forest cover contracted by 384,000 hectares, and this number escalated to 668,400 hectares during the period from 2015 to 2020[9], leading to habitat loss and fragmentation. Moreover, to accommodate for the needs of the increasing population, human settlements have been increasingly encroaching upon forest areas. Increasing populations of some animals has also led to competition among themselves and caused animals to move out of dense forest areas into urban settlements. As an illustration, India's tiger population saw an elevation to 3,682 in 2022, displaying growth from the 2,967 count in 2018, as indicated by a

recent estimation[10]. Furthermore, a notable surge of 60% has been documented in India's leopard population in 2018 in comparison to the figures from 2014.[11]
The combination of the above two phenomena has led to increased human wildlife confrontation and conflict.

Human-wildlife conflict can have far reaching negative consequences such as economic losses, decrease in agricultural yield and productivity, risk to food security, safety risks for farmers, conservation challenges among others.Wildlife intrusion poses a direct threat to agricultural production. Herbivores, such as deer, elephants, and wild boars, can cause extensive damage to crops by trampling, grazing, or feeding on plants, leading to reduced yields, economic losses, and compromised food security for farmers and communities. Predators like wolves, coyotes, and foxes may prey on livestock, resulting in livestock losses and also trample on fields in search of food. Animal-wildlife conflict can have substantial economic implications for farmers[12]. Crop damage and livestock losses reduce the income of farmers which can disrupt the profitability and sustainability of farming operations, especially for small-scale farmers who often lack the resources to mitigate conflicts effectively. Wildlife intrusion on farms poses safety risks for farmers and their families. Large mammals, such as bears or wild boars, and various other predators may become aggressive when confronted, potentially leading to human injuries or fatalities[13]. These safety concerns create a challenging and potentially hazardous working environment. Animal-wildlife conflict also presents conservation challenges. As conflicts escalate, farmers may resort to lethal methods such as hunting or poisoning to protect their crops and livestock.[14] These practices can disrupt delicate ecosystems, endanger wildlife populations, and strain relationships between communities and conservation efforts. Balancing the needs of agricultural production and wildlife conservation becomes a complex task that requires sustainable and innovative solutions. A study showed that Crops were lost by 71% of households, livestock by 17%, and human injury and death were reported by 3% of households (losses attributed to 32 species)[15, 16, 17]
Efforts to address animal-wildlife conflict must focus on preventive measures, innovation, and community involvement to ensure the long-term viability of farming and wildlife conservation.

Laser Based Technology
Laser based technology provides an innovative avenue for prevention and detection of animal intrusion. Laser technology, an acronym for Light Amplification by Stimulated Emission of Radiation, has revolutionised various fields of science, medicine, industry, and communication since its invention in 1960. The fundamental principle behind lasers involves the emission of a coherent and focused beam of light through a process called stimulated emission. Lasers emit light that is monochromatic, meaning it consists of a single wavelength or colour. This characteristic allows lasers to deliver concentrated energy precisely and efficiently. The focused laser beam can be tightly controlled and directed to perform various tasks. One of the key

features of lasers is their ability to generate a high-intensity beam over a significant distance. These properties allow laser technology to be an effective tool for this project[18].
The Internet of Things (IoT) is a revolutionary concept that refers to the interconnection of various devices, objects, and systems through the internet. It enables the exchange of data and information between these connected entities, creating a network of smart and interconnected devices. By integrating IoT(Internet of Things), farmers can receive real-time alerts on animal intrusion and boundary breaches. This allows rapid and effective response to potential threats, enhancing farm security. [19, 20]

METHODOLOGY

Aim of the study

The aim of this study is to develop a system for preventing and detecting animal intrusion on farms using laser-ultrasound–based and Internet of Things (IoT) technology.

Research Design

This study will follow an experimental research design to assess the efficacy of the proposed laser-based and IoT system in preventing and detecting animal intrusion.

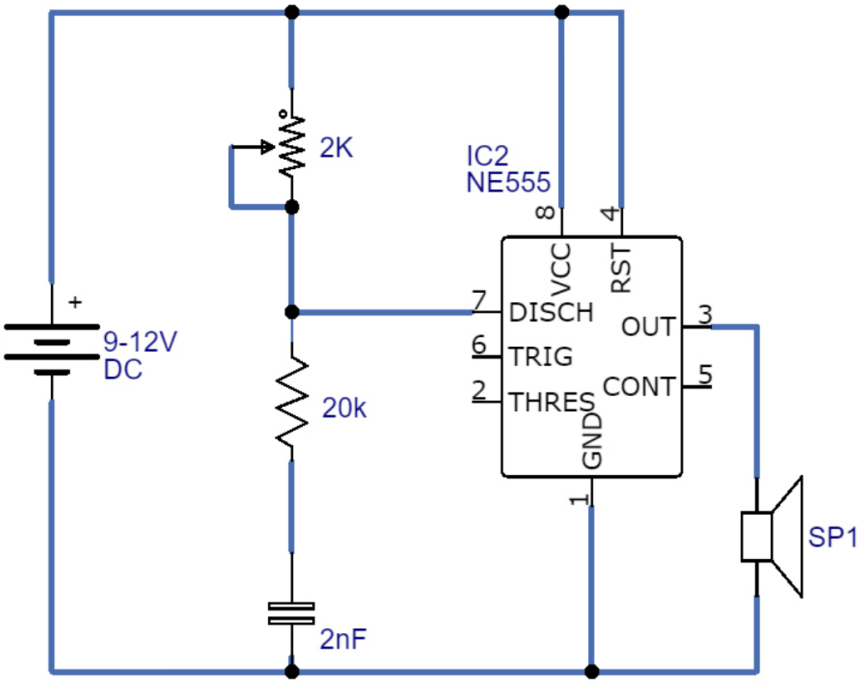
Instruments Used

Laser, Light Dependent Resistor (LDR), NodeMCU, Ultrasonic Alarm.

The Model

Laser -
Output Power - 100mW
Output Wavelength - 532nm

Ultrasonic Alarm -
The following circuit was used for creating an alarm to generate ultrasonic sound using - 555 Timer IC (NE555), Resistors (20 kilo ohm and rheostat at 2 kilo ohm), Capacitor (2nF), Transducer (ultrasonic speaker)



Sensing Module -
The sensing module consists of an LDR connected to a NodeMCU housed in a 3-D printed casing.

Casing -
The following shows the design of the casing to house the electrical components

Software -

Working Procedure -

Data Collection Procedure
The data was collected from thingspeak, an IoT platform which facilitates communication and data analytics between IoT devices, where it was uploaded through the model.[22]

RESULTS

The laser light and LDR circuit is used as a sensor to sense the intrusion of animals. The LDR data is collected for outdoor and indoor, with 20 m and 10 m distance between the LDR and laser, respectively. The data was collected using a multimeter. The data is presented in the table no 1.

ROOM - 10 m				OUTDOOR 20 m			
Light On		Light Off		DAY		NIGHT	
Laser On	Laser Off	Laser On	Laser Off	Laser On	Laser Off	Laser On	Laser Off
40-70 ohm	800 - 1000 ohm	40-70 ohm	700-800 ohm	40-70 ohm	150-300 ohm	30-50 ohm	800-900 ohm

Table No 1 - LDR resistance values : Indoor and Outdoor

DISCUSSION

The results show that there is a clear difference between the data recorded between the times the laser was turned off and when it was turned on. Hence when the animal will cross the laser it will be clearly detected.

1. *Livestock Monitoring* - The same model can be seamlessly adapted for use as a livestock monitoring system. It can be used to confine cattle within designated perimeters thus enhancing the efficiency of cattle management and minimising the risks associated with wandering livestock, contributing to animal welfare and reducing conflicts between farmers and neighbouring communities.

2. *Modernisation of Agriculture* - The adoption of the proposed model acts as a gateway for farmers to embrace modern technology and innovations, which are essential for the advancement of agriculture.

3. *Reserve Forests and National Parks* - The model can be adapted to detect animal movement around protected areas. Artificial Intelligence can be integrated to improve analytics and discover problematic areas, which can positively inform policy decisions regarding animal conservation.

4. *Railways* - Railway accidents involving animals, particularly wildlife, are a significant concern in India. The model can be adapted to prevent animal deaths resulting from

railway accidents. Not only can the animals be warned through the ultrasonic alarms, but the incoming trains can also be alerted to the presence of animals on or near the tracks. This information can enable precautionary measures, such as slowing down or stopping, preventing collisions and reducing the toll on wildlife populations.

CONCLUSION

The prevention and detection of animal intrusion on farms are crucial for sustainable and secure food production. Laser-Ultrasound-based technology and IoT integration offer a novel and effective approach to address this challenge. By combining precise Laser technology with sensor networks, farms can establish virtual barriers, detect intrusions accurately, and deter animals using ultrasonic alarms. While challenges exist, the benefits in terms of reduced losses, improved resource management, and enhanced ecological sustainability make this integrated approach a promising direction for the future of agriculture.

LIMITATIONS

1. *Safety* - Use of high power lasers can potentially pose a safety issue

2. *Scalability* - Scalability can prove to a significant barrier to widespread adoption, especially since lasers are used

3. *Affordability* - While the model is aimed to keep cost as low as possible, it can still be unaffordable for smaller scale farmers. However, this issue can be encountered by collaboration between farmers and pooling of resources

4. *Adaptation* - Adaptation of new technology can be met with significant apprehension. This can be countered with awareness efforts.

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