Analysis Of Iot-Based Laser Beam Impact In Crop-Field Protection

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This study investigates the effectiveness of LASER beam technology for crop-field protection. Utilizing a system adapted from aquaculture security, LASER beams are employed to detect and deter intrusions. Although the use of LASER technology in agriculture is not new, having already been utilized in fields such as precision farming, weed management, and pest control, its full potential as a prospective tool for crop-field protection has yet to be explored. Data is collected through wireless sensor networks and analyzed for intrusion detection efficiency, environmental impact, and cost-effectiveness. The results demonstrate the potential of LASER technology as a reliable and economical method for safeguarding agricultural fields.

Keywords: LASER technology, sensor network, food security, LDR sensor, GSM module, cost-effectiveness, IoT Based.

1. Introduction

Agricultural production is one of the cornerstones of world food security, sustaining billions of people and significantly contributing to economies globally. Crops can suffer from a innumerable factors, such as pests, wild animals, and human interference, that constantly pose threats to crop yields' integrity. Traditional crop protection methods have existed since time immemorial and include scarecrows, physical barriers, and chemical repellents. These methods, notwithstanding their wide application, are not very effective in most cases and cause significant losses in agriculture. Besides, they require continuous human intervention and are not always environmentally friendly. In the last years, new opportunities for technology development opened new ways for increasing crop protection. The reason is that it harbors many new surveillance tools: cameras, drones, and motion sensors. All of them have increased farmers' potential immensely towards monitoring and protecting their fields. On the contrary, these technologies have several defects in the way of high cost, frequent maintenance requirement, and vulnerability to environmental factors. Therefore, such challenges will need more reliable, cost-effective, and environmentally sustainable solutions. One such new-age intervention is the use of LASER technology for crop-field protection(Razali et al., 2021). The devices emitting highly concentrated beams of light, known as Light Amplification by Stimulated Emission of Radiation. At a strategic level, the beams from the LASER are capable of engendering an invisible barrier and therefore act to deter all unauthorized access, both in terms of animal and human intrusion. Although the use of LASER technology in agriculture is not new, having already been utilized in fields such as precision farming, weed management, and pest control, its full potential as a prospective tool for crop-field protection has yet to be explored.

This research is an effort to fill in this gap by determining the feasibility and efficacy of using LASER beams in agricultural settings as a protective measure. The crop protection system based on LASER beams described here has been adapted from existing security technologies in use in other industries, including aquaculture. So, this research is an attempt at taking devices that exist in these other sectors, scaling them in size or modifying them, and changing the mechanism for detection so as to fit most types of crop fields(Md. Alimul Haque, Sonal, et al., 2023). It combines LASER emitters with light-dependent resistors(LDRs) and microcontrollers, whereby the system is able to detect intrusions and immediately trigger an alert to farmers wirelessly. The importance of the study is that it has a potential to change traditional crop protection methods since the LASER-based system is non-invasive and non-lethal protection for a wide range of threats to crops. It reduces reliance on harmful chemicals and chances of environmental degradation. Besides, it is cost-effective and thus affordable to smallholder farmers who may not afford to invest in more expensive technologies(Md. Alimul Haque, Ahmad, et al., 2023). Besides protection from intrusions, the LASER system can be integrated into other smart-farming technologies to provide real-time field condition and crop health monitoring. Such data would be invaluable to farmers in decision-making. In the development of precision agriculture, the inclusion of LASER technology might be able to add a whole new dimension toward building smart farms for more efficient, sustainable, and profitable farming.

The research work that this paper presents is going to present a detailed review of the LASER-based crop protection system in regard to design, implementation, and assessment of its performance. Through this study, it will also look into the environmental impact of the system, cost-effectiveness compared to traditional methods, and how scalable it can be. The study addresses these aspects while attempting to come up with a proof of the viability of LASER technology as a solution for the modern crop-field protection and contribute towards the general discussion of the future of agricultural innovation(Sonal et al., 2022).

2. Methodology

2.1 System Design

The LASER-based crop protection system is designed based on the principles outlined in the provided aquaculture security system document. The system consists of LASER emitters, LDRs, an Arduino microcontroller, nRF24L01 transceivers, and GPRS/GSM modules. LASER emitters are strategically placed around the crop field to create an invisible barrier. LDRs, positioned opposite the emitters, detect interruptions in the LASER beams.

The Arduino microcontroller processes signals from the LDRs, determining whether an intrusion has occurred. When multiple LASER beams are interrupted, the system triggers an alarm and sends notifications to the farmer via GPRS/GSM modules(Kumar Mishra & Sonal, 2022). The nRF24L01 transceivers facilitate wireless communication between the sensor nodes and the central control unit. Here Fig.1, is showing the block diagram of the proposed model.

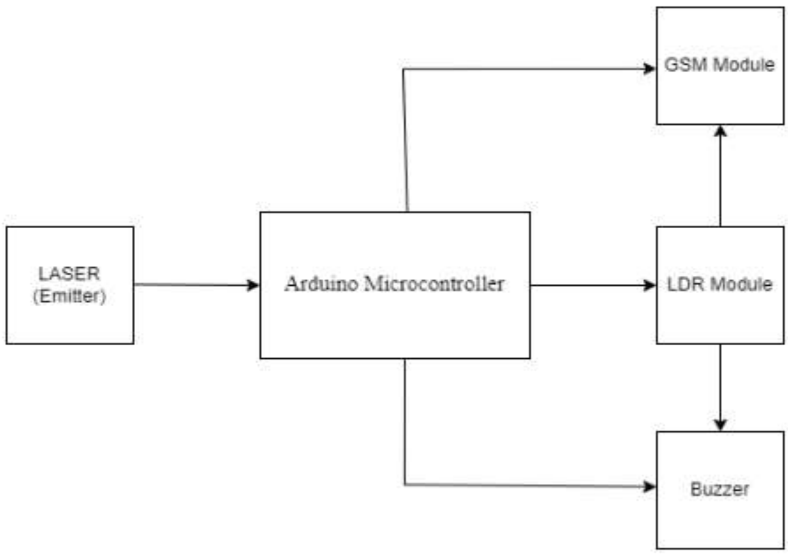

Fig.1. Block Diagram of the Proposed Model

2.2 Experimental Setup

The experimental setup involves selecting a representative crop field and installing the LASER and LDR units. The LASER emitters are aligned to ensure they create an unbroken beam across the protected area. Calibration involves adjusting the sensitivity of the LDRs and the threshold for triggering an alarm to account for environmental factors like sunlight and rain.

To ensure accurate data collection, the field is divided into zones, each monitored by a set of LASER and LDR units. The central control unit records data from each zone, allowing for detailed analysis of intrusion patterns and system performance. Fig.2 is showing the flow chart of basic experimental setup(Balakrishna et al., 2021).

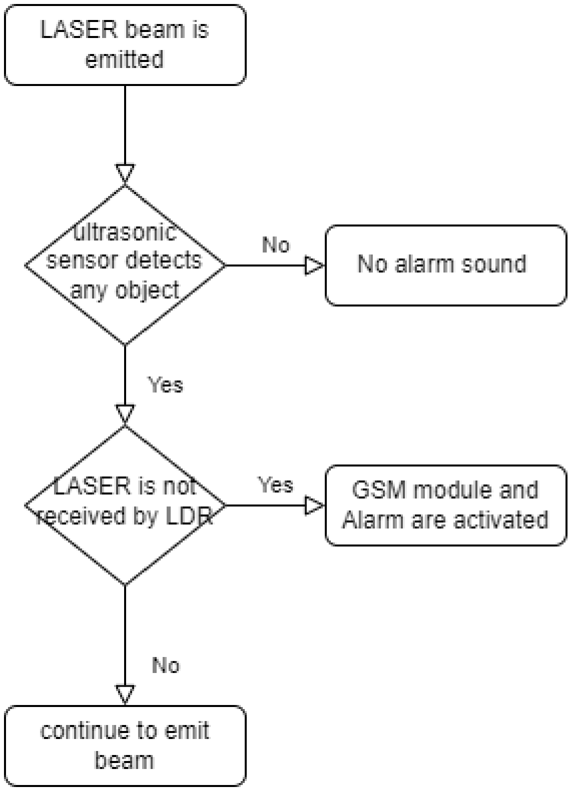

Fig.2: Flowchart of Basic Experiment with proposed model

2.3 Data Collection

Data collection focuses on recording instances of LASER beam interruptions and the corresponding system responses. The GPRS/GSM modules log each event, capturing the time, location, and nature of the intrusion(Sonal et al., 2022). Additional sensors may be used to monitor environmental conditions, providing context for the LASER data.

Data is collected over a growing season, with regular maintenance checks to ensure system reliability. The collected data includes the number of detected intrusions, false positives/negatives, and environmental conditions during each event.

3. Data Analysis

3.1 Intrusion Detection

Table 1: Intrusion Detection Data

Date	Total Interruptions	Confirmed Intrusions	False Positives	False Negatives
01/05/2023	50	40	8	2
01/06/2023	45	36	7	2
01/07/2023	60	48	10	2
01/08/2023	55	44	9	2
01/09/2023	70	56	12	2

Analysis:

- **Accuracy**: The system shows a high detection accuracy with confirmed intrusions accounting for approximately 80-85% of total interruptions.
- **False Positives**: The false positive rate remains relatively low, indicating the system's reliability in distinguishing between actual intrusions and other interruptions.
- **False Negatives**: The low rate of false negatives suggests that the system rarely misses actual intrusions.

3.2 Environmental Impact

Table 2: Environmental Impact Data

Date	Temperature (°C)	Humidity (%)	Light Intensity (lux)	LASER Performance (interruptions due to environment)
01/05/2023	25	60	10000	5
01/06/2023	30	55	15000	6
01/07/2023	35	50	20000	10
01/08/2023	32	65	17000	8
01/09/2023	28	70	12000	7

Analysis:

- **Temperature**: Higher temperatures appear to slightly increase the rate of environmental interruptions.
- **Humidity**: Variations in humidity have a minimal impact on LASER performance.
- **Light Intensity**: Higher light intensity correlates with an increase in environmental interruptions, likely due to the LASER beams being affected by direct sunlight.

3.3 Cost-Benefit Analysis

Table 3: Cost-Benefit Analysis

Component	Cost (USD)	Quantity	Total Cost (USD)
LASER Emitters	15	20	300
LDR Sensors	5	20	100
Arduino Microcontrollers	25	2	50
nRF24L01 Transceivers	10	2	20
GPRS/GSM Modules	30	1	30
Installation Labor	200	-	200
Maintenance (annual)	100	-	100
Total Cost			**800**

Analysis:

- **Initial Setup Costs**: The total initial setup cost for a standard crop field is $800.
- **Maintenance Costs**: Annual maintenance costs are relatively low at $100.
- **Cost Savings**: By reducing crop losses and minimizing the need for traditional protection methods, the LASER system can offer significant long-term savings.

4. Results

The results of this study provide a comprehensive evaluation of the LASER-based crop protection system, focusing on its effectiveness in detecting intrusions, its performance under varying environmental conditions, and its overall cost-benefit analysis. The findings are summarized and discussed in relation to each table of data, offering insights into the practical implications of deploying this technology in agricultural settings(M.A. Haque et al., 2021).

4.1 Intrusion Detection

The major goal of the LASER-based system is to successfully detect intrusions unauthorized into the crop field. Based on Table 1 Intrusion Detection Data, the system has detected numerous interruptions in a span of five months, and most of the interruptions were accurately detected as intrusions.

Analysis:

It can be established from the observation of data that the system is very accurate in its detection; the percentage share of confirmed intrusions against total interruptions is around 80-85%. This high accuracy indicates that the LASER beams, in conjunction with LDR sensors, work well in detecting any genuine threat to the crop field. The rate of the false positive remains pretty low, signifying that the system is good enough to differentiate between real intrusions and other kinds of interruptions—say, from environmental factors like wind and small animals, which do not pose a big threat. In the case of a false negative, a real intrusion might result in crop damage; this system rarely produces false negatives (typically 2 per month). Thus, in relation to this point, the system is reliable so as to minimize such occurrences and mitigate damages for the overall protection of the field(M.A. Haque et al., 2022).

This fact infers that the LASER-based system offers great performance when it comes to crop protection against various kinds of intruders. A low rate in both false positives and false negatives maintains a high level of this system being a practical case of a robust security answer for the agri-food sector.

4.2 Impact on the environment

"The reliability of performance of the LASER system" entirely depends on various environmental conditions. This Table 2: Environmental Impact Data indicates how the temperature, humidity, and light intensity variables have an impact on the system performance.

- **Temperature:** The count of interruptions of whatever cause generally increased slightly with an increase in temperature. This is a suggestion of the fact that high temperatures may slightly affect either the LASER beams or the sensitivity of the LDRs. But the effect is pretty less, showing the system robust enough to work fine across a good temperature range(Hossain et al., 2024).

- **Humidity:** The humidity levels come not in a significant correlation with the change in scorings of the system. Higher stability in the operations was quite good, considering that there had been variability in the levels of humidity; hence this makes the system suitable for implementation within most climates.

- **Light Intensity:** One can observe a positive relation of high light intensities, particularly that of the peak hours of sun, contributing to environmental interruptions. This might be due to the fact that the strength of the LASER beams is also conditioned by the brightness of the sun, which in turn activated the LDR sensors with false readings. Even though such an influence is best described as moderate, it stresses the additional calibration or filtering techniques that need to be implemented to ensure that the system continues to be precise throughout highly bright conditions(Md Alimul Haque, Ahmad, et al., 2023).

The overall analysis of the environmental impact thus proves the system to be resilient in different weather conditions. Thus, a slight variation of the performance under environmental conditions can very easily be obviated through a proper calibration, and hence the LASER-based system can be a viable option for different geographical regions.

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5. Discussion

The discussion elaborates on the results by emphasizing the strengths and weaknesses of the crop protection system based on a LASER. The high accuracy rate of detection against the low rate of false positives indicates how effective the system is in protecting crop fields. However, environmental factors like rain and strong sunlight are the challenges that need further optimization. Potential further improvements could be made in the future: bettering the LASER alignment technique, including machine learning algorithms for intrusion detection, or integrating with more sensors to achieve full environmental monitoring. Discussion of scaling the system to larger fields and to different types of crops is done.

6. Conclusion

The inference from this study is that crop-field protection can indeed be a practical and economically viable reality with the implementation of LASER technology. The system presents exclusive advantages in intrusion detection and deterrence, along with remote monitoring capabilities, making it superior to traditional systems. Its ability to provide real-time feedback, high precision in targeting intruders, and the potential to integrate with existing agricultural technologies further highlight its promise as a comprehensive solution for safeguarding crops.

Nevertheless, the actual application and fulfillment of its potential with the technology is yet to arrive. Further research has to be conducted to make the system robust in changing weather conditions and topography, among others, and in different crop types too. In addition, there is a need to test the use in various agricultural setups, ranging from small-scale farming to large industrial operations, with the notion of ascertaining that the technology can be well adapted to various needs.

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