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SPAITCD: SOLAR-POWERED ARTIFICIAL INTELLIGENCE TREE CUTTING DETECTOR

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ABSTRACT

Illegal tree cutting is a pervasive and destructive global problem that leads to deforestation, loss of biodiversity, habitat destruction, and contributes to climate change. It poses a significant threat to the environment, including fragile ecosystems and the vital services they provide, such as carbon sequestration and clean water supply. Traditional methods of detecting illegal tree cutting often rely on manual patrols, which are costly, time-consuming, and can be ineffective, especially in remote and challenging terrains. By utilizing AI and solar power, the project offers an efficient and scalable alternative to monitor and detect tree cutting activities in areas where human presence may be limited or impractical. TensorFlow Lite, as a lightweight deep learning framework, enables real-time inference on low-power devices like the Raspberry Pi. The functionality of the robot as a tree cutting detector was tested five times with different types of tree cutting tools. Success rate was determined by its functionality; 100% success rates in detecting tree cutting and non-tree cutting activities and sending an SMS message after detection indicates proper functionality. By using a monitor it can display the accuracy of the device's detection through a message on the top left corner of the camera's screen. After at least sixty seconds of the device continuously detecting tree cutting activities it sends an SMS to the registered mobile number alerting the recipient of tree cutting activities being detected.

Keywords: *tree cutting, tree cutting detector, SMS*

1. Introduction

Illegal tree cutting has always been a prominent problem here in the Philippines. According to the Global Forest Watch Organization, from 2001 to 2022, Philippines experienced a loss of its 89% of tree cover in areas where the dominant drivers of loss resulted in deforestation and loss of 1.42 Mha of tree cover, equivalent to a 7.6% decrease in tree cover since 2000, and 848 Mt of CO_2e emissions. Tree cutting is a pervasive and destructive global problem that leads to deforestation, loss of biodiversity, habitat destruction, and contributes to climate change. It poses a significant threat to the environment, including fragile ecosystems and the vital services they provide, such as carbon sequestration and clean water supply. Traditional methods of detecting illegal tree cutting often rely on manual patrols, which are costly, time-consuming, and can be ineffective, especially in remote and challenging terrains. Because of the nature of unauthorized tree cutting, monitoring, and detecting unauthorized tree cutting activities are often difficult and insufficient, since these types of activities would be often done secretively in ungated areas.

Recent advancements in technology have shown promise in addressing the challenges of illegal logging detection. For instance, Shen et al. (2019) developed a solar-powered wireless monitoring device capable of tracking environmental conditions across extensive areas, while Sousa et al. (2020) introduced an automated deforestation detection system utilizing deep learning networks to identify deforestation in the Amazon rainforest. Other studies, such as those by Hargura and Khakata (2022) and Andreadis et al. (2021), explored acoustic detection systems that alert forest authorities upon detecting chainsaw sounds, demonstrating varying degrees of success in monitoring tree-cutting activities. Ahmad and Singh (2022) proposed an algorithm that leverages acoustic signals for more accurate detection of logging activities, achieving an impressive efficiency rate of 92%. However, many existing systems face limitations, such as false alarms from non-target activities and the inability to operate effectively in the complex terrains of the Philippine forests, indicating a significant gap in reliable and targeted detection solutions.

This study proposes the development of a solar-powered artificial intelligence tree cutting detector, designed to enhance the efficiency and accuracy of monitoring illegal tree cutting activities. By leveraging advanced machine learning algorithms and solar energy, the device aims to provide continuous, real-time surveillance of forest areas prone to illegal logging. This solution not only aims to improve detection rates but also contributes to environmental conservation efforts by enabling quicker responses from authorities to unauthorized logging activities. By bridging the existing gaps in monitoring technology, the proposed device has the potential to be a vital tool in preserving the Philippines' rich forest ecosystems.

Statement of the Problem

Generally, this study aims to determine the functionality of S.P.A.I.T.C.D.

Specifically, this study aimed to answer the following questions:

1. Can the solar-powered artificial intelligence device detect tree cutting activities?
2. Does the solar-powered artificial intelligence tree cutting detector have a high accuracy rate in detecting tree cutting?
3. Is the solar-powered artificial intelligence tree cutting detector functional in terms of sending SMS?

Objectives of the Study

Generally, this study aims to determine the functionality of S.P.A.I.T.C.D.

Specifically, this study aimed to determine if:

1. The solar-powered artificial intelligence device can detect tree cutting activities;
2. The solar-powered artificial intelligence tree cutting detector has a high accuracy rate in detecting tree cutting; and
3. The solar-powered artificial intelligence tree cutting detector is functional in terms of sending SMS.

Hypotheses of the Study

Based on the problems verbalized, the following assumption is drawn:

1. The solar-powered artificial intelligence device can detect tree cutting activities.
2. The solar-powered artificial intelligence tree cutting detector has a high accuracy rate in detecting tree cutting.
3. The solar-powered artificial intelligence tree cutting detector is functional in terms of sending SMS.

Theoretical Framework

The foundation of this research is built on two significant studies: Shen et al. (2019) and Ahmad and Singh (2022). Shen et al. (2019) designed a solar-powered wireless monitoring device capable of tracking environmental conditions across expansive areas, showcasing the potential of renewable energy solutions in environmental monitoring. This concept is critical in addressing the limitations of traditional surveillance methods, which are often hampered by logistical challenges in remote forested areas. The integration of solar power not only enhances sustainability but also ensures continuous operation without dependency on traditional power sources.

This study extends Ahmad and Singh's findings by employing machine learning principles that enable the S.P.A.I.T.C.D to learn from annotated datasets of logging activities. By training the artificial intelligence model to differentiate between tree-cutting and non-tree-cutting events, the device gains the ability to make autonomous decisions based on real-time data inputs. The incorporation of a USB camera as the "eyes" of the detector allows for visual monitoring, while the GSM module facilitates immediate communication with forest authorities by sending SMS alerts to pre-registered numbers when tree-cutting activities are detected. This multifaceted approach aligns with the need for innovative solutions in environmental conservation and sustainable resource management.

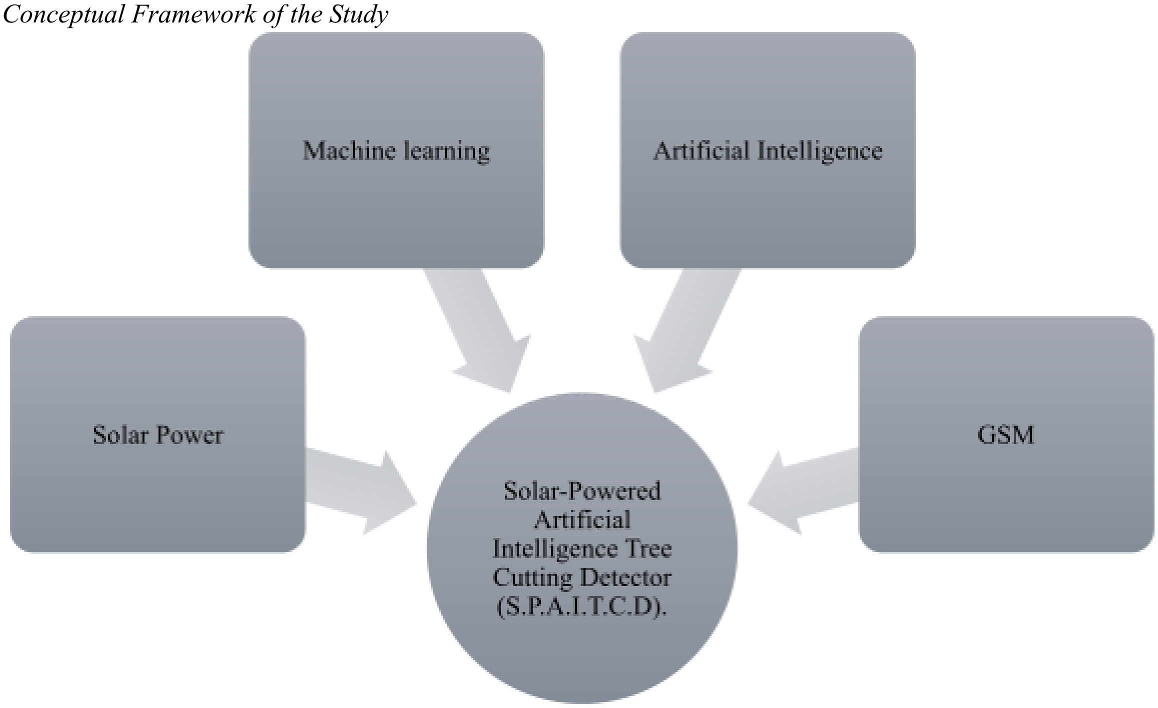
In summary, the S.P.A.I.T.C.D leverages renewable energy, artificial intelligence, and machine learning to create an efficient monitoring system for illegal tree cutting. By integrating these concepts, the device aims to enhance the effectiveness of forest surveillance and contribute to the protection of critical ecosystems, thereby addressing a significant environmental issue. The convergence of these technologies positions the S.P.A.I.T.C.D as a novel solution that can effectively combat illegal logging activities while promoting sustainable practices in forest management.

Conceptual Framework

The conceptual framework for this study centers on the development and implementation of the Solar-Powered Artificial Intelligence Tree Cutting Detector (S.P.A.I.T.C.D). The framework focuses on the application of artificial intelligence and machine learning. The S.P.A.I.T.C.D is designed to differentiate between tree-cutting and non-tree-cutting activities by utilizing an annotated dataset of logging activities for training purposes. This machine learning capability allows the device to learn from data inputs and improve its accuracy over time, thus enhancing its efficiency in detecting illegal logging. The inclusion of a USB camera as the "eyes" of the device provides real-time image data, which feeds into the AI model for analysis. Furthermore, the GSM module facilitates instant communication with relevant authorities by sending SMS alerts to pre-registered mobile numbers upon detection of illegal activities. This comprehensive approach not only improves monitoring effectiveness but also fosters timely responses to unauthorized logging incidents, contributing to the overall conservation of forest resources.

Figure 1

Conceptual Framework of the Study



2. Literature Review

Illegal tree cutting has emerged as an important environmental issue, necessitating the development of effective monitoring systems. Shen et al. (2019) created a solar-powered wireless monitoring device that can observe environmental conditions across extensive areas. This device comprises a sensor node capable of detecting various environmental elements, with sensors connected to a central processing unit that serves as both a data processor and a Wi-Fi transmitter. This innovative design enables real-time monitoring, which is essential for addressing the challenges posed by illegal logging activities, particularly in remote forest locations.

Other researches in monitoring technology have been explored by Sousa et al. (2020), who developed an automated deforestation detection system utilizing a deep learning network specifically designed to identify deforestation events in the Amazon rainforest. Their research emphasized the importance of spatial content over channel content within the self-attention processes employed for image analysis. This finding highlights the potential of deep learning algorithms in enhancing the accuracy of environmental monitoring systems and presents an opportunity for integrating similar methodologies into tree-cutting detection technologies.

Hargura and Khakata (2022) designed a system focused on detecting tree cutting through the recognition of chainsaw sounds. Their system alerts forest authorities via an alarm, providing them with the location of the detected sound, facilitating a quicker response to illegal activities. Similarly, Andreadis et al. (2021) introduced a device that uses audio event classification to automatically detect illegal tree cutting. Their experiments demonstrated an 85% accuracy rate in identifying tree-cutting events, showcasing the effectiveness of audio-based monitoring systems for forest surveillance.

Expanding on the use of acoustic signals, Ahmad and Singh (2022) proposed an algorithm for monitoring tree cutting activities within forested areas. Their method can operate through manual observation or automated techniques, achieving an impressive efficiency of 92%. This highlights the potential for utilizing machine learning algorithms in enhancing the detection and monitoring of illegal logging activities, indicating a growing trend in employing artificial intelligence in environmental protection efforts.

3. RESEARCH METHOD

Research Design

This study employed an experimental descriptive design to evaluate the effectiveness of the Solar-Powered Artificial Intelligence Tree Cutting Detector (S.P.A.I.T.C.D) as both a tree cutting detection and SMS alert system. Data were collected by capturing images and videos of both tree cutting and non-tree cutting activities in proximity to trees. The gathered data were subsequently annotated to categorize instances as either tree cutting or non-tree cutting activities, with additional metadata including location, date, and time. Quality checks were conducted to ensure the accuracy of the annotations and the consistency of the data.

Assembly and Programming of the Device

The various components of the device were assembled in accordance with the Fritzing diagram and design illustrated in Figures 2 and 3.

Figure 2

Fritzing Diagram of S.P.A.I.T.C.D

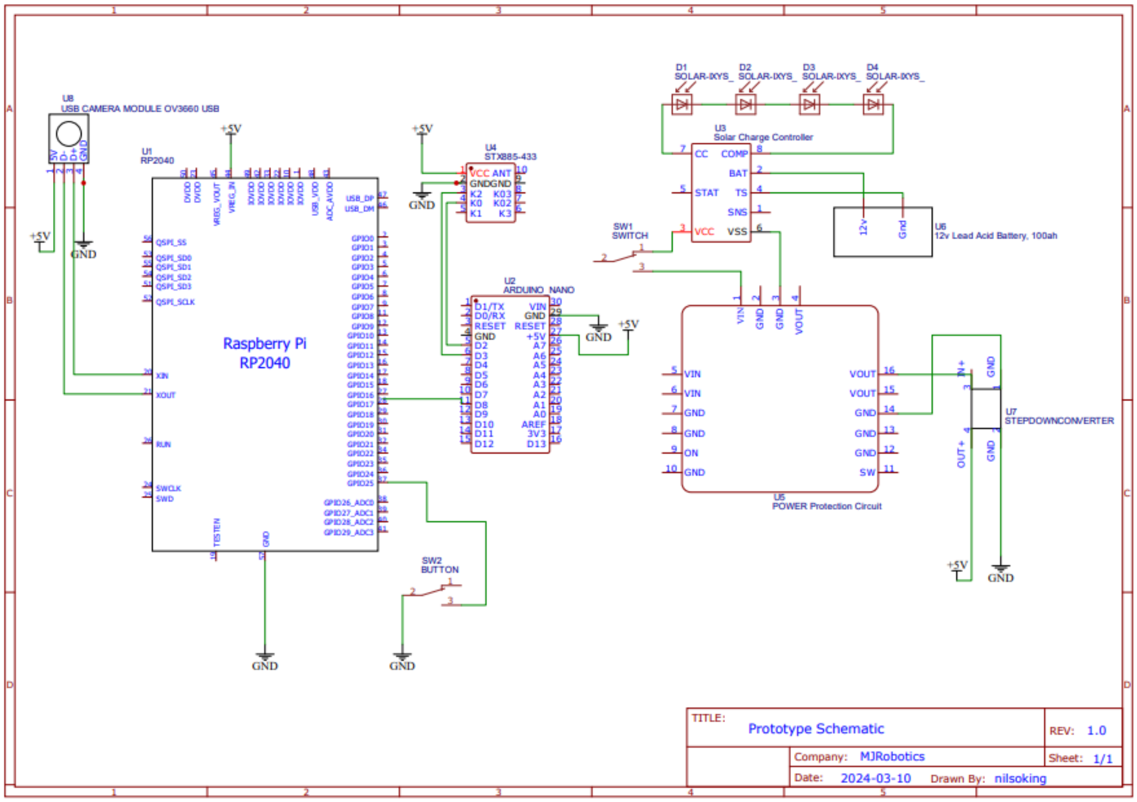
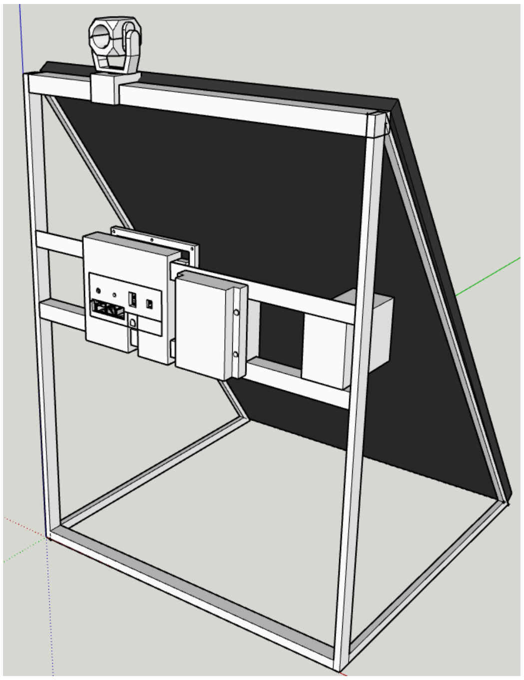
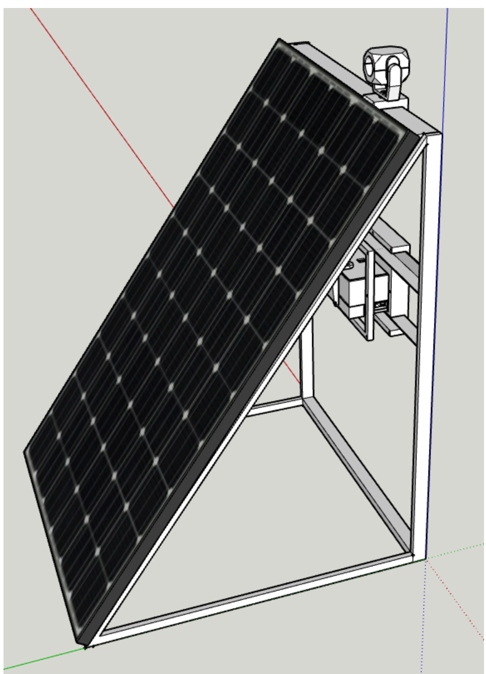
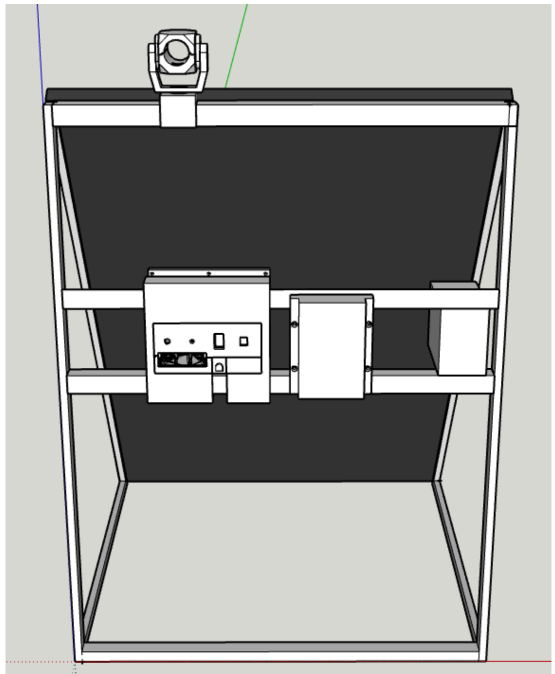


Figure 3
Design of S.P.A.I.T.C.D.







TensorFlow Lite was installed on the Raspberry Pi and configured for model deployment. For model selection, a suitable pre-trained model architecture was chosen, such as MobileNetV2, for image classification tasks. The model is then fine-tuned for illegal logging detection. Data are processed by resizing the images to match the input size of the chosen model. Data augmentation techniques like rotation, flipping, and brightness adjustments were applied. The pixel values were normalized to ensure uniformity. The annotated dataset was divided into training, validation, and test sets to train and evaluate the model. For model training, the selected model was trained using the training dataset. Transfer learning techniques were employed for faster convergence and improved performance. Training with relevant metrics (e.g., loss, accuracy) were monitored, and the best-performing model checkpoint was saved. Optimize hyperparameters, including learning rate, batch size, and dropout rates to achieve high accuracy while minimizing overfitting.

Hardware Setup

To set up the hardware, the solar-powered device, which includes a Raspberry Pi (or similar single-board computer), USB camera, solar panel, and rechargeable battery, were assembled. A power management system was developed to efficiently utilize solar energy for continuous device operation. Implement voltage regulation and battery charging controls. Ensure that the device has internet connectivity, either through cellular data or Wi-Fi, for remote monitoring and alert transmission.

Software Development

The trained TensorFlow Lite model was integrated into the software. A real-time model inference on the Raspberry Pi was implemented. An alert mechanism was created to notify relevant authorities or stakeholders when illegal logging activities are detected. This is capable of including text messages, or other communication methods.

Testing and Evaluation

The device was tested, and the model's performance was evaluated using standard metrics such as accuracy, precision, recall, F1-score, and receiver operating characteristic (ROC) curves. The false positive and false negative rates were assessed. For power efficiency testing, measure the power efficiency of the solar-powered device, including battery life and solar panel charging rates.

Ethical Considerations

For privacy and consent, privacy concerns were addressed by ensuring that the surveillance system complies with privacy regulations and obtains informed consent when necessary. For data security, secured data storage and transmission is implemented to protect sensitive information from unauthorized access.

Deployment and Practical Application

To deploy the solar-powered device for real-world monitoring, collaborate with relevant stakeholders, such as conservation organizations, local communities, and law enforcement agencies. Training for end-users on how to operate and maintain the device, as well as how to interpret and respond to alerts can be provided.

Gathering of Data

The annotated dataset of logging activities, model training and validation datasets, monitoring data from real-world tests, and ethical considerations and consent records were obtained.

The performance metrics (accuracy, precision, recall, F1-score, ROC curves), power efficiency measurements, environmental impact assessment, and cost-effectiveness analysis were also taken.

Data Analysis

The number of successful trials were determined by using 1 for every "Yes" and 0 for every "No". Success rate was calculated by dividing the total number of successful trials by the number of trials performed, then multiplying the quotient by 100. A 100% success rate of the device indicates that it is perfectly functional in terms of detecting tree cutting and sending an SMS alert for possible tree cutting to the registered mobile number.

4. Results and Discussion

Functionality of S.P.A.I.T.C.D as a Tree Cutting Detector

Table 1 presents the success rates of the device in detecting tree cutting activities under various simulated conditions. The results demonstrate that the device achieved a 100% detection rate across all tested scenarios, which included the use of different tools to simulate tree cutting. Specifically, when a chainsaw, hacksaw, cross-cut saw, and mini saw were used to replicate tree cutting actions, the device consistently and accurately identified these activities. These findings highlight the device's robust performance and reliability in recognizing a wide range of tree cutting scenarios, regardless of the tool employed.

Table 1

Functionality of S.P.A.I.T.C.D as a Tree Cutting Detector

Tool Used	Functionality as a Tree Cutting Detector			Number of Successful Trials	Success Rate
	Trial 1	Trial 2	Trial 3		
Chainsaw	Yes	Yes	Yes	3	100%
Hacksaw	Yes	Yes	Yes	3	100%
Criss-cut Saw	Yes	Yes	Yes	3	100%
Mini Saw	Yes	Yes	Yes	3	100%

Functionality of S.P.A.I.T.C.D as an SMS Alert

Table 2 illustrates the device's performance in successfully sending SMS alerts when detecting tree cutting activities simulated by different tools. The results indicate a 100% success rate in transmitting SMS notifications across all scenarios tested. Specifically, when tree cutting was simulated using a chainsaw, hacksaw, cross-cut saw, and mini saw, the device reliably detected the activity and promptly sent SMS alerts to the designated mobile numbers. This consistent success in both detection and alert transmission underscores the effectiveness of the device's communication module in ensuring timely notifications for all tree cutting simulations.

Table 2

Functionality of S.P.A.I.T.C.D as an SMS Alert

Tool Used	Functionality of S.P.A.I.T.C.D as an SMS Alert			Number of Successful Trials	Success Rate
	Trial 1	Trial 2	Trial 3		
Chainsaw	Yes	Yes	Yes	3	100%
Hacksaw	Yes	Yes	Yes	3	100%
Criss-cut Saw	Yes	Yes	Yes	3	100%
Mini Saw	Yes	Yes	Yes	3	100%

DISCUSSION

This study aimed to evaluate the effectiveness of the Solar-Powered Artificial Intelligence Tree Cutting Detector (S.P.A.I.T.C.D.) as both a tree cutting detection system and an SMS alert mechanism. The findings revealed a 100% success rate in accurately detecting simulated tree cutting activities and sending corresponding SMS alerts to registered mobile numbers. These results contribute significantly to existing knowledge in the field of forest conservation technology by demonstrating the potential for autonomous devices to enhance monitoring capabilities. By successfully integrating artificial intelligence with renewable energy sources, the study offers a scalable solution for addressing illegal logging and promotes proactive conservation efforts in forested regions.

A key strength lies in the thorough testing of the S.P.A.I.T.C.D. prototype, which involved simulating tree-cutting activities using various tools. This detailed evaluation enabled a comprehensive assessment of the device’s functionality. Moreover, the integration of SMS alerts allows for prompt communication with authorities, significantly enhancing the system’s overall effectiveness in responding to potential illegal logging. However, the study’s primary limitation is that it was conducted in a controlled environment, with all tree-cutting activities simulated. Unlike prior research involving field tests in real-world settings, this prototype has yet to be tested in actual forest environments, which could affect the reliability and accuracy of its detection capabilities. Studies like those by Andreadis et al. (2021) emphasize the critical role of field testing in improving the effectiveness of monitoring systems, suggesting that further real-world validation of the S.P.A.I.T.C.D. is essential.

the findings of this study hold considerable significance for both scientific research and practical applications in forest conservation. The successful performance of the S.P.A.I.T.C.D. as a tree-cutting detector and SMS alert system highlights its potential for enhancing automated forest monitoring technologies. These results indicate that integrating machine learning with renewable energy systems can provide an efficient and cost-effective approach to combating illegal logging. However, further research is needed to test the device in real-world environments, which will help refine its capabilities and improve its reliability. Such advancements are critical for developing more effective forest management strategies.

Ultimately, innovations like the S.P.A.I.T.C.D. could play a pivotal role in safeguarding forests and preserving biodiversity for future generations.

5. Conclusions

The results of this study confirm the effectiveness of the Solar-Powered Artificial Intelligence Tree Cutting Detector (S.P.A.I.T.C.D.) in accurately detecting tree cutting activities and sending SMS alerts, with a 100% success rate in the simulated tests. These findings support the hypotheses that the device can detect tree cutting activities with high accuracy and is functional in terms of sending SMS notifications. The study demonstrates that integrating artificial intelligence with solar power technology can provide a viable and sustainable solution to monitor and combat illegal logging, making a valuable contribution to the field of forest conservation technology.

Recommendations

Based on the findings of this study, it is recommended that the S.P.A.I.T.C.D. undergoes comprehensive field testing in actual forest environments. While the 100% success rate in simulated tests indicates the device's functionality, real-world conditions may introduce variables that could impact its performance, such as varying weather patterns, wildlife interference, and different types of tree-cutting methods. Conducting field trials will not only validate the device's reliability and adaptability but also provide insights into potential improvements and enhancements that could be made to its design and functionality.

Furthermore, it is advisable to explore partnerships with forestry management organizations and environmental conservation groups to facilitate the deployment and testing of the S.P.A.I.T.C.D. in diverse ecological settings. These collaborations can aid in gathering comprehensive data on the device's performance, and the insights gained can contribute to refining its algorithms and functionalities. Additionally, expanding the device's capabilities by integrating supplementary sensors, such as acoustic or motion detectors, could enhance its detection accuracy and further reduce the risk of false alerts. Collectively, these recommendations aim to bolster the S.P.A.I.T.C.D.'s potential as a transformative tool in the fight against illegal logging and contribute significantly to forest conservation efforts worldwide.

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