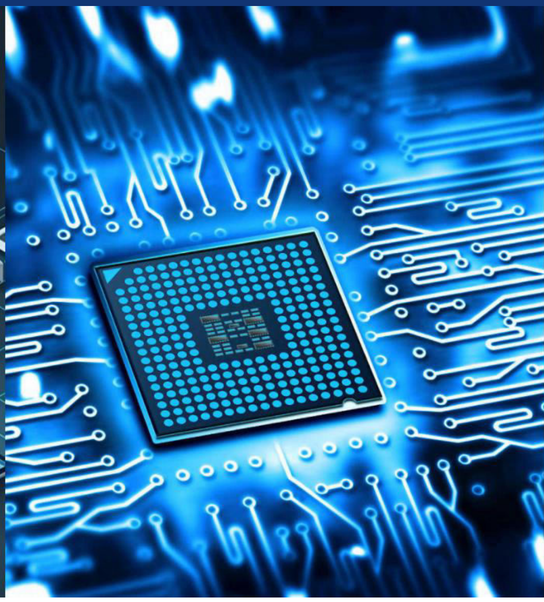
IJIRCCE

ISSN(O): 2320-9801

ISSN(P): 2320-9798



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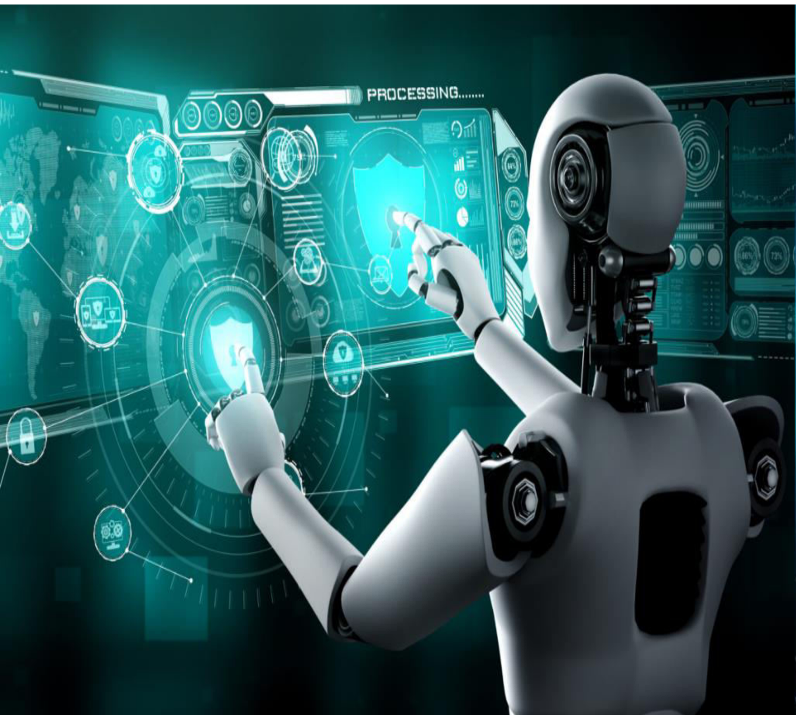

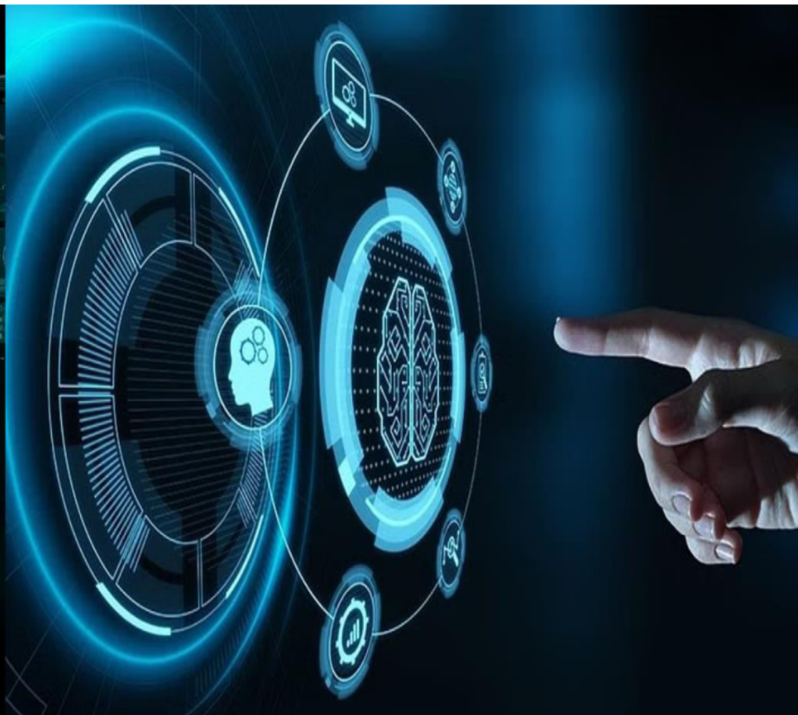

Impact Factor: 8.771

Volume 14, Issue 4, April 2026

© 2026 IJIRCCE | Volume 14, Issue 4, April 2026 DOI: 10.15680/IJIRCCE.2026.1404104
www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.771| ESTD Year: 2013|
International Journal of Innovative Research in Computer and Communication Engineering (IJIRCCE)
(A Monthly, Peer Reviewed, Refereed, Scholarly Indexed, Open Access Journal)

Design and Implementation of Smart Animal Repellent System Using IoT and CNN

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ABSTRACT: The rise of human-wildlife conflict is resulting in substantial agricultural damage, significant economic losses, and serious safety concerns for farmers. Unfortunately, traditional preventative measures to protect crops, like fencing, using scare devices, and manually monitoring crop fields, are often unreliable and do not provide a solution in real-time. In response to this issue, a smart monitoring system that integrates artificial intelligence (AI) and the internet of things (IOT) using the ESP32-CAM module has been proposed. This new smart monitoring system utilizes deep learning, specifically convolutional neural networks (CNNs), to automatically detect and identify animals and humans in real time. Once an animal has been detected, the system will activate a repellent system that emits sound at various frequencies based on the type of animal being detected, and will activate flashing lights to help deter that animal. If a human has been detected, the system will take a picture of that individual's face, and will send an email to the farmer containing the picture for enhanced farm security and surveillance. The system can also send an instant message alerting the farmer via a GSM module. The entire system will run off of a solar panel, providing energy-efficient and continuous operation. This modern agricultural protection solution is automated, reliable, and sustainable

KEYWORDS: ESP32-CAM, Animal Detection, Human Face Recognition, IoT-Based Smart Agriculture, DeepLearning (CNN).

I. INTRODUCTION

Over the last few decades, rapid technological advances have completely changed how traditional agricultural operations are performed and moved them into more intelligent, efficient, and sustainable agricultural systems. Because agriculture is one of the main components of many developing economies around the world, it encounters many challenges including crop loss due to wildlife, unauthorized human intrusion onto farm premises, and lack of continuous monitoring in out-of-sight areas. Most farmers use traditional methods such as manual supervision, physical barriers (fences), and scarecrows to protect their crops. These traditional methods, however, are not only labour-intensive but also provide very little, if any, consistent protection for farmers throughout the day and night. In many rural areas of the country, especially in areas where farms border on heavy wooded areas, there have been increases in animal intrusions and large amounts of economic loss. Moreover, both intentional and unintentional human intrusions on agricultural lands raise serious security and theft issues. Because of the issues faced by farmers, there is an immediate and pressing need for intelligent, automated, and reliable monitoring systems that can operate continuously without human intervention.

With the introduction of AI and IoT, the agricultural industry is now able to begin to transition to smart farming solutions. AI allows machines to learn from data provided to them, and make decisions based on that data. IoT allows for direct communication between devices through the use of the internet. In order to create a responsive system able to monitor agricultural fields in real-time, identify potential threats, and provide immediate reaction, it is imperative that technologies differing from current monitoring systems be able feature these integrated technologies. Deep Learning Algorithms (DLAs), primarily Convolutional Neural Networks (CNNs), are one of the largest advancements to date in this space. As computer vision technologies become increasingly reliable, they will be integrated with these monitoring systems; therefore, NN's will be able to accurately classify all visual data of different animal and human types. This ability is critical to build an automatic intrusion detection and classification system; therefore, the NN must not only classify incursions into the monitored space but also determine what action needs to be taken.

www.ijircce.com | e-ISSN: 2320-9801, p-ISSN: 2320-9798| Impact Factor: 8.771| ESTD Year: 2013|

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The ESP32-CAM is an ideal platform to build intelligent monitoring systems and increases the power of the monitoring system due to its small physical size, affordable cost, and enhanced capabilities due to being a single board computer with a camera. In addition, the ESP32-CAM has WiFi capability; therefore, it can connect to and provide real-time transmission of data from remote locations using the internet, which can easily be incorporated into IoT-based applications. By deploying the ESP32-CAM within agricultural fields, this technology can continuously record video and provide recorded images to be processed using an embedded or cloud-based artificial intelligence model. When an animal is detected, this system would proactively engage deterrent mechanisms, utilizing visual deterrents and an auditory detection mechanism to deter animals. Each animal responds to different auditory frequencies;

As a result, an adaptive sound signal produced by an identified animal will increase the chance of success for that individual as it relates to the effectiveness of the repellent. The addition of flashing lights will make the animal concerned with the area due to being in a strange and uncomfortable location, which will further discourage them from damaging crops. In addition to identifying animals, it is also important to identify people in order for a farmer to protect their property. The risk of theft, or vandalism, or even the improper use of resources could exist with someone who doesn't belong. When you add facial detection to the system, the ability to detect a person is now available and can be acted upon. Upon detection of a person, the ESP32-CAM will take a picture of the person and email it to the farmer. By having this type of automated system, a farmer can check on their fields remotely and take action on any potential threats in real time. To further enhance communication reliability and effectiveness, the addition of a GSM module will allow for alert transmissions in areas where no or little internet access exists.

II. RELATED WORK

According to documents published on the economic loss caused by animal access to agricultural land, farmers have lost millions. Therefore, researchers need to explore ways to deter animal access to farms due to economic reasons. Farmers typically have used alternative deterrents, such as physical barriers (e.g., fences), utilizing individuals to monitor agricultural crops for animal encroachment, or implementing deterrents to scare off animals, but have found these methods to be ineffective or require extensive labor. With the advancement of machine learning and adaptive sensing technologies, there has been a growing body of research focused on developing computer based systems to provide automated detection of animal encroachment on farms. Sunil and colleagues [1] developed an efficient system for protecting animals on farms using machine learning based object identification methods and image analytics technology to classify objects accurately. In turn, the authors indicated that their intelligent classification model provides enhanced real time performance when detecting animals on farms, which increases the reliability of alert notifications and assists farmers in protecting their crops from wildlife while reducing the time spent by farmers with wildlife on their farms.London et al. (2016) conducted research showing that there is a new Hybrid Artificial Intelligence methodology available for predicting and preventing wild animals from entering rural farmland ecosystems. The method utilizes Predictive Analytics and Sensor-Based Monitoring Systems to predict the possible patterns of wild animals prior to their entry into farmland ecosystems. It will combine both historical and environmental data and provide an early warning system to farmers regarding potential intrusion of wild animals onto their land. With the reduction in need for post-entry deterrent methods, the result will be an increase in farm safety and security.

The researchers pointed out the value of using multiple AI methodologies together to increase the accuracy of predictions and to create sustainable agrarian ecosystems, thereby reducing the disruption of wildlife. The aim of Geerthik and Vishal [3] is to create an Internet of Things (IoT) based agricultural project using technology (including sensor technology, micro-controllers, and wireless communication modules), as well as providing humane deterrents to animals and more sustainable agricultural management practices. It employs a multitude of different technologies such as sensors, microcontrollers and wireless communications to detect the presence of animal activity and to activate humane deterrents (e.g., sounds of an alarm) to create an opportunity for detecting animal activity while preventing the destruction of crops; however, its end goal is not only to deter animal activity from planting lands/fields used towards producing crops but also to provide full access to all users (owners/customers) within the IoT network to monitor animal activity and receive notifications in real-time when detected animal activity is occurring. Non-lethal deterrents promote/provide assistance to protect crops, as well as to promote an environmentally friendly method, thus are suitable for use with agricultural products that are located within rural locations.The intelligent system developed by Raja R. Singh (Lal) and his associates [4] was designed to aid in the identification of wildlife species in order to direct them away from agricultural land through the use of integrated image processing techniques and programmed electronic components, thus providing an efficient means of using these technologies to identify wildlife (species) and then directing wildlife species (the identified animals) away from these identified cultivation areas. This advanced form of identification of wildlife species is much more effective than conventional methods because it has reduced the number of erroneous identifications of individual wildlife species by using environmental data as a means to trigger the automatic identification of wildlife species. Additionally, the researchers indicated that the use of a smart identification algorithm and an automated response system resulted in a significant increase in the efficiency of identifying individual wildlife species in the defined study site, thus increasing safety by decreasing crop damage due to nocturnal wildlife.

III. PROPOSED SYSTEM

The smart agriculture monitoring and protection system is a state-of-the-art surveillance system that employs both artificial intelligence (AI) and the Internet of Things (IoT). With increased pressure placed on farmers as a result of animal intruders (including feral animals, farm animals and people) within farmland and homes, farmers need to take action to stop these intrusions. The ESP32-CAM module serves as the system's foundation; it is both the image acquisition device and communication unit via its integrated camera and Wi-Fi capabilities. The system continuously receives real-time images of the field through the ESP32-CAM and processes them using a deep learning model based on CNNs (convolutional neural networks) to identify animal species and/or people within the images. The system uses the classification result of each detected object to intelligently determine the action to take. The automated repellent system uses sound-generating devices capable of producing sound waves at different frequencies for various animals based upon the responses of certain types of animals to sound in the frequency range produced. This allows farmers to use varying frequency sounds more effectively than do current fixed-frequency repelling devices. Additionally, the system generates a high-intensity blinking light that increases the visual disturbance created within the area where the deterring sound occurs to create an uncomfortable environment for the intruding animals and to effectively prevent further entries by these intruders.

Not only does the system have the ability to detect animals but it will also have the ability to detect humans for improved security on a farm. When a human is detected, the ESP32-CAM takes an image of their face and sends it immediately to the farmer via email notification allowing them to remotely monitor the farm in real time and quickly make decisions. This function is useful for preventing theft, unauthorized entry to the farm and other security issues. In addition, there is also a GSM module integrated into the system which allows the farmer to receive instant SMS notifications when there has been an intrusion into the farm without having to be connected to the internet. Therefore, the dual notification system through email and GSM ensures that the farmer will always have access to notifications about incidents that occur on the farm without regard to whether they have internet access. This entire system runs on a solar panel which converts sunlight into electrical energy and stores the electrical energy for the entire system to be operational at all times. Therefore, this system can be used in rural and off-grid areas. The use of renewable energy reduces the operating costs of the system and also supports sustainable agricultural practices. In conclusion, the proposed system is an entirely automated, energy-efficient and intelligent system that improves the protection of crops, reduces the amount of manual labor and enhances the security of farms through the use of AI, IoT and deep learning.

© 2026 IJIRCCE | Volume 14, Issue 4, April 2026 DOI: 10.15680/IJIRCCE.2026.1404104

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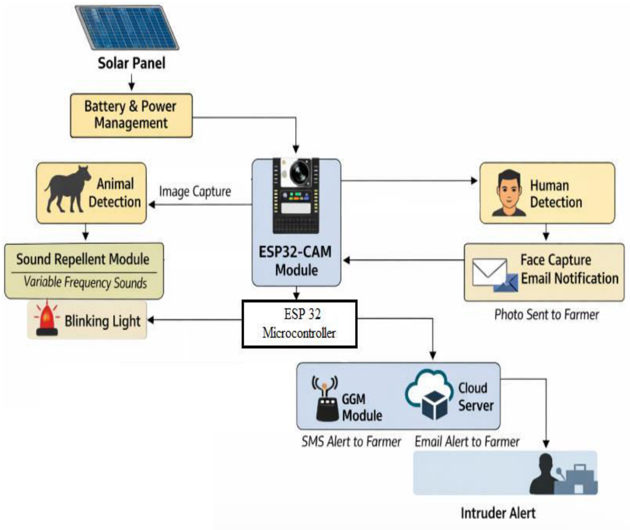

Figure 1: Proposed Block Diagram

IV. METHODOLOGY

This smart agricultural monitoring system is an integrated framework that includes hardware for sensing, processing, communicating and actuating using Artificial Intelligence (AI) and the Internet of Things (IoT). The ESP32-CAM module will be the central controller of this monitoring system through the image capturing and communication between the various components. The system will contain; a camera module for acquiring visual images, a GSM module for communicating alerts, a sound generation module that will use sound to deter animals, a strobe or flashing light to visually deter animals and a solar power module to provide power to all components. The components will be connected so that they will operate together seamlessly as a whole system. The system architecture will be designed to function autonomously and in real-time with little human intervention while maximizing efficiency and reliability in the field.

Image Acquisition Using the ESP32-CAM Module

The image acquisition function will continuously operate using the ESP32-CAM module, which will be capturing real-time images of the agricultural fields as they grow. The positioning of the camera will maximize the effectiveness of monitoring the agricultural fields by allowing a large coverage area. The camera will be programmed to automatically capture normally at a regular interval, as well as trigger the ability to capture images by detecting motion to maximize power consumption. The captured images will be pre-processed prior to the execution of the Deep Learning model for image analysis so that they will be suitable for conducting the analysis. The pre-processing includes; resizing, noise reduction and normalization of the captured images.

Deep Learning-Based Detection (CNN Model)

A Convolutional Neural Network (CNN) is used in the system for detecting and classifying objects. The CNN will be trained on a data set of images of both animals and people in order to perform correct identification. An image is taken through the trained CNN, which extracts features and classifies an item in the image. It has no trouble distinguishing between various types of animals and people. This classification is crucial to determining what actions to take in response to an object, and because of the use of deep learning, the system is adaptable and has better accuracy than prior methods of detecting objects.

Animal Detection and Adaptive Repellent Activation

Once the system identifies that an animal is present, it activates the automated animal repellent mechanism designed to repel that specific type of animal effectively. As part of the repellent mechanism process, the present system creates sound signals at different frequencies for each kind of animal because the animal's brain will process these sound frequencies differently for each frequency range. This adaptive method creates a more successful, efficient animal repellent than traditional methods. The system also creates a visual disturbance by activating an LED light blinking system along with the sound disturbance method. The combination of these two types of disturbances will ensure the overall success of repelling the animal from the agricultural area. The system also continues monitoring until it has confirmed that an animal has left the area before turning off any remaining deterrent/input (audible/visuals) so it won't cause another animal disturbance in the future.

Human Detection and Email Notification System

The system executes a different set of procedures focused on safety when detecting humans. Upon detection, the ESP32-CAM takes an updated picture of a human using a CNN model. An email using internet-based communication will be sent to the farmer. The email will include the photograph as an attachment, so the farmer can validate the identity of the person. This will provide real-time, remote monitoring of people for the purpose of preventing unauthorized access, theft, or vandalism in agricultural fields.

GSM-Based Alert Communication

For reliable communication when internet access is limited or unavailable, a GSM module is integrated. The system sends an SMS alert to the farmer's registered mobile number upon detecting either animals or humans. This allows for immediate notification of the farmer about any intrusions, regardless of whether or not email will work. The use of the GSM module improves system performance by providing a backup communication channel, so the system can also be deployed in rural/remote agricultural regions.

Solar Power Integration for Energy Efficiency

Both the solar panel and battery form an energy solution for your system allowing you to operate the components with only renewable energy sources. In this way you can keep your system operating, even if no conventional source of electricity is available. The system has various power management techniques, including reducing image acquisition rate while the system is idle, to reduce the overall amount of energy being consumed. By using renewable energy sources you are reducing the costs of operation and promoting sustainable and environmentally friendly forms of agricultural production.

IV. RESULT & DISCUSSION

Animal Detection Accuracy To assess the CNN animal detection model's capability, the suggested application was put through all elemental states throughout an environment at numerous times, whilst still achieving success. Higher accuracies were demonstrated when detecting and identifying animals such as cows, dogs, and goats, within a 94% average accuracy overall demonstrating substantial dependability for use within a real time agricultural monitoring system. As training epoch completion continued, model accuracy increased also, thereby demonstrating that the model was able to capture key features within the dataset. Throughout the application tested, moderate levels of lighting variance had little affect on the accuracy of detection; however, the accuracy was slightly diminished at when tested using low ambient lighting conditions. Therefore, this further strengthens the case for deploying this proposed solution within real farm operating environments.

System Response Time Analysis

In order to assess the speed of reaction of the system, an evaluation of the time taken to respond after detecting an object within an area of interest occurred. The minimal amount of time spent in response to an object was observed to be between two (2) and five (5) seconds. This time includes the period required for taking the picture, processing it using the CNN method, and triggering the appropriate response such as activating the repellent equipment or sending alerts. The short period of time required for a response allows for an immediate deterrent to any animal which could potentially damage the crops. Likewise, when it detects a human being, the system takes a picture of the individual and notifies the user by sending an email and text message within a short period of time. Finally, the constant amount of time taken to respond regardless of the environment demonstrates the ability of the ESP32-CAM module and the optimized processing algorithm to do their jobs efficiently. Such a rapid response time will make the system highly reliable for use in real-time monitoring of agricultural products and in protecting those products.

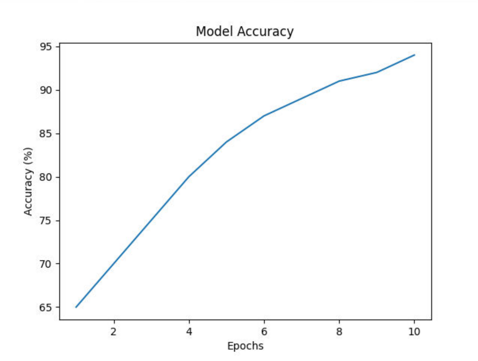

Figure 2: Accuracy Graph

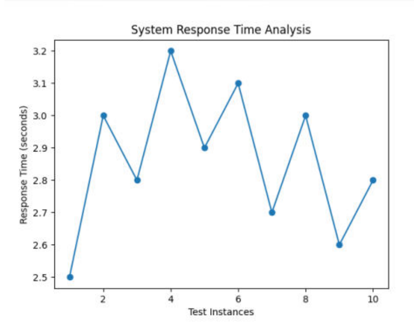

Figure 3: Response Time Graph

Repellent System Performance

The test of the sound-based repellent system included various species of animals exposed at variable frequencies; results showed animals reacted variably to each of the sound frequencies tested due to the adaptive frequency generation capabilities of the repellent system which improved its overall deterrent capability. The incorporation of blinking lights with the adaptive frequency sound repellent provided and enhanced the ability to deter normal animal behaviour. The use of the integrated audio-visual repellent resulted in fewer animals entering the monitored area than would have with conventional static type repellents, validating that integrated repellent systems are more effective than conventional static repellents.

Table 1: Result Performance

Parameter	Result Obtained
Animal Detection Accuracy	94%
Human Detection Accuracy	96%
Model Loss	0.25
Alert Response Time	3–10 seconds
Repellent Effectiveness	90%

Human Detection and Email Notification

Human detection through facial recognition was achieved using the ESP32-CAM Module. After detecting a human, the image of the person was emailed to the farmer almost instantly. The ability to monitor activity at all times allows farmers to see if someone is breaking into their property and increase security by verifying intruder locations without being physically present. The human detection system worked consistently to detect humans despite differences in environmental conditions, which makes it an important tool for preventing unauthorised entry/stealing from farms.

GSM Alert System Performance

The sending of SMS alerts was verified through testing of the GSM module when animals were detected and/or humans were detected. The use of the GSM module allowed for an instant notification to be sent to the farmer's mobile phone with very low latency. Therefore, the SMS alert will still be received even if there is no internet connection at all or very poor coverage area. By having two alert types (GSM and email), this improves the reliability of the system and provides the ability to have continual communications, which is critical to using agriculture applications in rural settings.

V CONCLUSION

The ESP32-CAM device is capable of creating an entirely new kind of agromonitoring system, one that can aid in the development of intelligent, efficient solutions to the problems that arise due to both animals entering farmland and humans entering farmland without permission. By employing convolutional neural networks (CNNs) through deep learning to continuously detect and classify quantities of animal and/or human entries (i.e., real-time) into farmlands

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with the agricultural monitoring system, high levels of success. The variable frequencies of both sound and flashing light as part of this agromonitoring system's adaptive repellent mechanism reduce the possibility of interference caused by the presence of any animals; the agricultural monitoring systems' capability to capture photographs of humans trespassers and email alerts to the farmers enhances the system's ability to effectively monitor and protect farmlands. Lastly, the ability to communicate securely through a GSM notification system gives the agromonitoring system the ability to communicate through whatever level of cellular reception may be available.

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