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Study of Methods for Animal Detection in Crop Fields

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A B S T R A C T

Animal pests can cause significant damage to crops, leading to reduced yields and profits for farmers. To mitigate this problem, various methods, and techniques for detecting and repelling animals in crop fields have been developed. In this study, we conducted a survey to investigate the current state of the art in animal detection and repellent systems in crop fields. Our survey included a review of relevant articles published in scientific journals and conference proceedings. The results of our survey indicate that a variety of methods and techniques are currently being used, including physical barriers, sensory networks, video analytics, and hybrid techniques. However, there is a lack of standardization and comparison among these methods, and further research is needed to evaluate their effectiveness and determine the most appropriate solutions for different types of crops and environments. Our findings provide a useful resource for farmers, researchers, and industry professionals working to address the problem of animal pests in crop fields.

Keywords: Animal detection, Animal repellent, Crop fields, Sensory networks, Video analytics

1. Introduction

Agriculture is a vital sector of the Indian economy, as it employs a large percentage of the country's population and contributes significantly to the GDP. India is one of the world's largest producers of agricultural products, including rice, wheat, sugarcane, cotton, and several other crops. The agricultural sector in India has undergone significant changes in recent years, with the adoption of modern technologies and techniques such as irrigation, fertilizers, and genetically modified seeds. These advances have led to increased crop yields and productivity, but have also resulted in environmental degradation and other negative impacts. In recent years, the government of India has implemented several policies and programs aimed at improving the agricultural sector, such as the National Food Security Act and the Pradhan Mantri Fasal Bima Yojana (PMFBY). These initiatives aim to increase food production, improve access to credit and markets, and provide insurance coverage for farmers against crop losses due to natural disasters.

A wide variety of crops are grown in the country. Some of the major crops produced in India like rice, wheat, sugarcane, cotton, maize, and other important crops produced in India include pulses (such as lentils, chickpeas, and beans), oilseeds (such as mustard, groundnut, and sesame), and various fruits and vegetables. There are several reasons that can lead to low yield in agricultural crops, including:

- Soil quality: Poor soil quality, such as soil that is overly sandy, clayey, or prone to erosion, can limit crop yields.
- Pest and disease infestations: Pests and diseases can severely damage crops and reduce yields.
- Weather: Extreme weather conditions, such as drought, floods, or extreme temperatures, can negatively impact crop yields.
- Lack of proper irrigation: Irrigation is essential for maintaining adequate soil moisture levels, and a lack of sufficient irrigation can lead to low crop yields.
- Lack of proper fertilization: Crops need a range of nutrients to grow properly, and a lack of proper fertilization can lead to stunted growth and low yields.
- Poor crop management practices: Poor crop management practices, such as improper planting, weeding, or harvesting techniques, can also lead to low yields.
- Genetic factors: Some crops may be genetically prone to lower yields, or may not be well-suited to the local growing conditions.
- Market factors: Low crop prices or limited market access can also affect farmers' incentives to produce high yields.

One significant cause of low crop yields is damage by animals. A wide range of animals, including birds, rodents, and larger mammals, can cause significant damage to crops, leading to reduced yields. One common way that animals damage crops is by feeding on them. For example, birds and rodents can eat the seeds or seedlings of crops, preventing them from germinating or growing properly. Larger mammals, such as deer or wild pigs, can also feed on crops, particularly when other food sources are scarce. In addition to direct feeding, animals can also cause indirect damage to crops. For example, birds and rodents can transmit diseases or parasites to crops, leading to reduced yields. Larger mammals can trample or push over crops, causing them to become damaged or to die.

There are several reasons that animals may enter agricultural crop fields, one of the most common reasons for animals entering crop fields is the availability of food. Crops such as corn, wheat, and rice can be attractive to animals, particularly when other food sources are scarce. Some animals may enter crop fields in search of shelter, particularly if natural habitats such as forests or grasslands have been destroyed or are otherwise unavailable. Some animals may enter crop fields in order to mate or breed, especially if suitable habitats are scarce. In some cases, animals may enter crop fields in order to access sources of water, such as irrigation ditches or ponds. Habitat loss, due to urbanization or other human activities, can also drive animals into agricultural areas in search of new homes. In some cases, human behavior can attract animals into crop fields. For example, if people feed wild animals or leave trash in fields, it can attract animals that are looking for food.

Overall, the prevention of animal damage to crops is an important aspect of modern agriculture, as it helps to ensure the production of high yields and secure food supplies. By implementing effective strategies for detecting and repelling animals, farmers can reduce the impact of these pests on their crops and improve their chances of success. There are several Traditional methods that farmers use to prevent animals from entering agricultural crop fields. These methods and some potential reasons why some of the above-mentioned methods may not be effective are given below:

Fig. 1 – The traditional methods used by farmers to prevent animals from entering agricultural crop fields.

- Fencing: One of the most common methods of animal control in crop fields is fencing. There are several types of fences that can be used, including physical barriers such as barbed wire or electric fences, as well as sensory fences that use motion detectors or other sensors to detect the presence of animals. Fences can be expensive to install and maintain, and they may not be practical in all situations. In addition, animals can sometimes find ways to breach fences, such as by digging under them or climbing over them. Electric fences can start fires when the energizer is combined with the vegetation.

- Noise-making devices: Another common technique for animal control in crop fields is the use of noise-making devices. These devices emit loud noises or flashing lights when triggered by the presence of animals, which can be effective in deterring them from entering the crop field. Some animals may become accustomed to the noise made by these devices and no longer be deterred by them. In addition, these devices may be annoying to humans who live or work near the crop field

- Chemical repellents: Some crop farmers use chemical repellents to deter animals from entering their fields. These repellents can be sprayed on the crops or applied to the perimeter of the field to create an unpleasant or toxic environment for the animals. Chemical repellents can be harmful to the environment and to non-target species, and they may not be effective against all types of animals. In addition, animals may become accustomed to the repellents over time and no longer be deterred by them.

- Predator decoys: Predator decoys, such as fake owls or coyotes, can be used to deter animals from entering crop fields. These decoys mimic the presence of natural predators, which can cause animals to avoid the area out of fear. Some animals may not be deterred by predator decoys, particularly if they are not familiar with the species being simulated. In addition, these decoys may need to be replaced or repaired over time, which can be costly.

- Biological control: Some farmers use biological control methods to control animal populations in their crop fields. This can involve releasing predators that prey on the animals that are causing damage, or introducing a disease or parasite that affects the target animal species. The use of biological control methods can be controversial, as they can have unintended consequences on the ecosystem. In addition, these methods may not be effective against all types of animals.
- Netting: Crop netting or bird netting can be used to physically exclude animals from entering a crop field. This method is often used to protect small fruit trees or berry bushes from birds and other small animals. Netting can be expensive to install and maintain, and it may not be practical in all situations. In addition, animals may be able to find ways to breach the netting, such as by climbing over it or chewing through it.
- Traps: Traps can be used to capture animals that are causing damage in crop fields. These can be live traps that allow the animal to be released elsewhere, or lethal traps that kill the animal. Traps can be humane if they are used properly, but they may not be effective against all types of animals. In addition, traps can be expensive to purchase and maintain, and they may be illegal in some areas.
- Repellent plants: Some plants produce chemicals that can repel animals. These plants can be used as a natural deterrent around the perimeter of a crop field. The effectiveness of repellent plants can vary depending on the specific plant and animal species. In addition, these plants may need to be replaced over time, and they may not be effective against all types of animals.
- Guard animals: Some farmers use guard animals, such as guard dogs or llamas, to protect their crops from animal damage. These animals can deter animals from entering the field by barking or chasing them away. Guard animals can be effective in deterring certain types of animals, but they may not be practical or cost-effective in all situations. In addition, guard animals may need to be trained and cared for, which can be time-consuming and costly.
- Crop rotation: Crop rotation can be used to deter certain animals from entering a crop field. For example, planting a field with a crop that is less attractive to a particular animal species can help to reduce the likelihood of that animal causing damage. Crop rotation can be an effective method of deterring certain animals, but it may not be practical in all situations. In addition, crop rotation can be time-consuming and may require the use of additional resources, such as irrigation or fertilization.

These Traditional methods are not effective in certain circumstances, while others may be less effective. Overall, agriculture continues to play a central role in the Indian economy and society, and addressing the challenges facing the sector will be crucial for the country's future development. In this study, we conducted a literature survey to investigate the methods and techniques currently being used or proposed for animal detection and repellent systems in crop fields. We discuss the advantages and limitations of these methods, as well as the factors that can affect their effectiveness. Our aim is to provide a comprehensive overview of the current state of the art in animal detection in crop fields and to identify areas for further research. We have categorized the methods in 3 sections based upon our findings, those are sensory based, video analytics and machine learning algorithms, and hybrid techniques which use both IoT and AI. The rest of this paper is organized as follows. In Section 2, we describe the methods used for our literature survey and we present the results of our survey, including a summary of the various methods and techniques for animal detection and repellent systems that have been reported in the literature. In Section 3, we discuss the implications of our findings and identify areas for future research. Finally, in Section 4, we provide a conclusion and summarize our main findings.

2. Literature Survey

In This Section, various methods and techniques are mentioned which include a review of relevant articles published in scientific journals and conference proceedings for detection and repellent of animals in crop fields are explained by considering the different domains.

2.1 Sensory Networks

Sensor networks, which consist of a network of sensors connected to a central hub, can be used to detect the presence of animals in a crop field. These sensors can be triggered by various stimuli, such as motion, sound, or temperature, and they can be used to send alerts or trigger repellent measures when needed. Wireless communication technologies, such as Wi-Fi or Bluetooth, can be used to transmit data from sensors or cameras in a crop field to a central hub. This data can be used to monitor the presence of animals and trigger repellent measures when needed.

In [5], the authors developed a IoT based system for crop protection that uses PIR sensor, camera, Raspberry Pi, TensorFlow, and ultrasonic frequency generator. The PIR sensor detects the motion of animal which then signals camera to capture image. The captured image is sent to server via wireless connection where it uses TensorFlow Image Processing to classify and identify the animal with help of pretrained dataset. This is then communicated to Raspberry Pi. The frequency generator connected to the Pi modulates the frequency to specified value and transmitted through the speaker to drive animals away.

In [6], the authors proposed a smart farmland system using Raspberry Pi, GSM module, RFID (Radio Frequency Identification) Injector and fog machine. Here RFID tag is injected in the animal skin by RFID injector which is used to identify the animal with unique id. If that animal enters the particular area, the RFID reader reads the id and detect animal. Using GSM an alert message is sent to farmer and forest department and speaker produce a repellent sound (irritating sound) to drive the animals away and fog machine is triggered to produce a fog like environment.

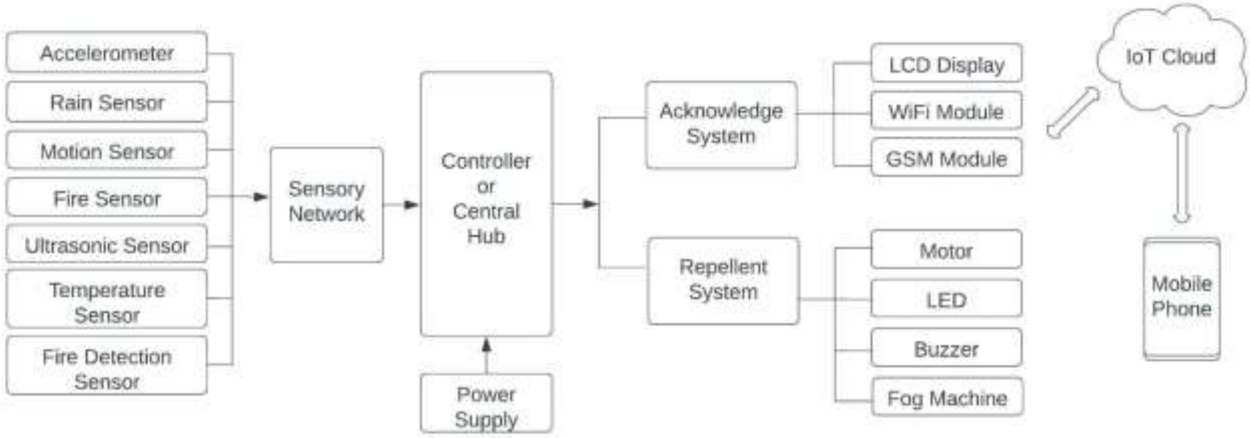

Fig. 2 – Sensory networks architecture.

In [8], the authors focused on animal and fire detection in the crop fields using Arduino Uno (ATmega328p), PIR sensor, LCD module, Wi-Fi Module (ESP826), HX711 Load cell, amplifier, LED, smoke device, ultrasonic sensor, fire detection sensor and Blynk app. PIR sensor detects the animals in a given range. Load cell and amplifier is used to measure the weight of the object. If weight is greater than 20 kg and not human, the buzzer, smoke, LED is turned on and message is sent to human via Wi-Fi module. Here the buzzer consists of 3 different frequencies according to the weight of animal. The fire detection sensor is used to detect the fire and send message to owner in Blynk app.

In [10], the authors proposed a smart irrigation and crop protection method that uses Arduino Uno R3, PIR (Passive Infrared Sensor), servo motor, soil moisture sensor, gas sensor, rain sensor, and buzzer. In the smart irrigation, when soil is dry it gets detected by soil moisture sensor and motor is turned on to pump water. When water level in field is increasing due to rain the canal gets open or else the motor is turned off. In crop protection system the entire farm is monitored by PIR motion sensor. If any motion gets detected the buzzer is turned on. Here authors described that the motion sensor range is very around 12 m.

In [11], a system is developed by authors which detects the intruders, monitors any malicious activity, and report it to owner. Arduino Uno is used as microcontroller, PIR motion sensor for detecting motion, camera (OV7670 model), GSM module (SIM 900) for text and audio transmission, buzzer for alarm. PIR sensor detects motion and this cause the camera to turn on and image of intruder is captured and displayed on TFT display. Subsequently message is sent to owner via GSM module. For small animals few buzzers are turned on and for large animals all buzzers are activated. Authors used 5 PIR sensors as the range of these sensors is low.

In [18], the authors described an ethical crop protection system which uses a PIR sensor, accelerometer sensor, thermal camera, and Raspberry Pi. PIR sensor detects object in range 5-6 meters, accelerometer detects the vibrations of the fences when an animal touches them in range of 20 meters and thermal camera measures the temperature of animals. All these readings are then fed to Raspberry Pi with KNN classifier for detecting weather the detected object by the sensors is an animal or not. The experimental results show that this system is having an accuracy of 82.7%. If animal detected the appropriate sound and light combination is used to scare the animals away.

In [19], the authors defined an IoT solution for crop protection against wild animal attacks using ARM. Here PIR sensor is used to detect the general movement of animals. Ultrasonic sensor is used to detect animals over a wide range of area with high read rate. GSM module is used for sending alert message to farmer and forest department. The animals when detected by sensors and ARM processor causes the ultrasonic speaker to produce sound of corresponding frequency to repel animals and message is sent to farmer or forest department.

In [23], the authors focused on an automatic crop protection system using PIC microcontroller, PIR motion sensor, GSM module, GPS module, LCD displays, and ARP voice player/buzzer. The PIR sensor detects the presence of animal and send input signal to controller to act. The APR board will turn on and produce sound with 3 different frequencies and flash light is turned on and SMS is sent to farmer via GSM module.

2.2 Video Analytics

Video analytics technologies, such as computer vision or object recognition, can be used to analyze video feeds from cameras in a crop field. These technologies can be used to identify and classify animals. Machine learning algorithms, such as artificial neural networks or support vector machines, can be used to classify and identify animal species based on data from sensors or cameras. These algorithms can be trained to recognize specific animals or behaviors, and they can be used to trigger repellent measures when needed.

In [1], the authors focused on wild animal intrusion detection using computer vision, ML, and Deep Learning. For this they have used surveillance camera, speaker, and Jupiter Notebook. Dataset used to train the model include elephant, boar, and monkey. The CNN model is developed with the dataset and saved which is then used to detect animals captured by camera.

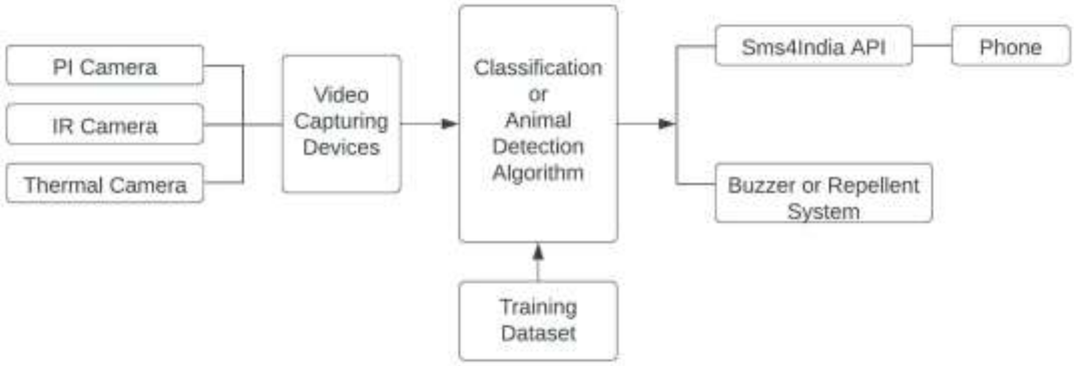

Fig. 3 – Video analytics architecture.

In [4], the authors defined a CNN (Convolutional Neural Network) for detecting animals in crop fields. They have used image dataset of animals (deer, monkey, elephant), which is fed to convolutional layer that defines an input shape function and activation function which is used for edge detection and sharpening image. Max pooling is used to reduce the number of parameters when large image is given. Flattening is done to convert 2D array into single long feature vector and fully connected layer combines the feature and predict output. The authors described that the technique is effective, consume low power and require no human supervision.

In [14], the authors proposed methods for animal detection and animal recognition. In animal detection, an infrared camera (8 frames per second) is used to take videos at night. Dataset used here consists of 10 seconds video clips of 8 fps with a total of 528 clips (deer – 477, boar – 20, fox – 8, hare – 23). Authors compared the results of Mask R-CNN and FGFA (Flow Guided Feature Aggregation) with given dataset on 4 GHz CPU, i7 Intel Processor, 16 GB RAM, Python 3 and PyTorch. Experiments showed that Mask R-CNN approach had best results than FGFA with an average precision of 63.8%. For animal recognition authors compared three different ResNet-18 variations (3D ResNet (R3D), ResNet with mixed convolutions (MC ResNet), and R(2+1)D ResNet) and SlowFast architecture on same dataset. Here the data was divided into 3 categories, eating – 257, moving – 39, watching – 50. The experiments showed that the (2+1)D ResNet reached highest accuracy of 94%, with other two ResNet of 93% and 92%. SlowFast architecture had least accuracy with 66%.

In [16], the authors developed an algorithm to detect animals in wild life. CNN algorithm is developed which consist of convolutional layer that extract features from input image, then the 2x2 pooling is done to reduce the number of parameters. Flattening is performed to convert the 2D arrays into a single long continuous linear vector. The last step is the fully connected layer which combines the features into more attributes that predict the output more accurately. The experiment conducted with dataset of elephant and cheetah 100 images each showed a result of 79.25% accuracy for elephant and 86.79% accuracy for cheetah.

In [17], the authors focused on a system that detects and classify animals in real time by implementing a CNN. Here authors used TensorFlow object detection API Protobuf, a package that implements Google's Protocol Buffer data format. The characteristics of the image are obtained and the Protobuf module gets input and converts the data into XML file. A CNN module uses a pre-trained model which includes MobileNet using SSD framework and the hidden nodes search characteristics from the saved XML file. Captured images by Pi cam and then TensorFlow module checks for characteristics in hidden nodes, and then the animal is classified. Identified animal name is sent through sms4india API to corresponding mobile number.

In [20], the authors defined a RTPPS (Real Time Pixel by Pixel Subtraction) algorithm with an ultra-wide band communication medium to protect agriculture crops from different animals in agriculture fields. Here a 5 MP infrared camera with night vision is used to capture the images of animals. To repel animals, a high-pitched noise generating alarm is used which produce 110 dB of noise. Raspberry Pi is used as controlling unit which consist of RTPPS algorithm. The gray scale image fed to RTPPS is reduced to 500x500 size, then the pixel-by-pixel subtraction is done and the brightness and sharpness is enhanced. Then the no of black pixels is counted and then if the count is greater than 77107, then the repel system is turned on. The experimented result showed that the system is found effective for animals like wild buffalo, cows, wild pigs and macaques.

2.3 Hybrid Techniques

There have been several studies on the use of artificial intelligence (AI) and the Internet of Things (IoT) for animal detection and repellent systems in crop fields. The use of AI and IoT technologies has the potential to enhance the effectiveness of animal detection and repellent systems in crop fields by providing more accurate and timely data on the presence of animals, and by enabling more targeted and efficient repellent measures.

In [2], the authors developed a device to protect crops from damage by wild animals using ML. They have used infrared camera, ultrasonic frequency generator, Raspberry Pi 3B, battery. The images of approaching animals are detected by night vision infrared camera continuously and fed to Raspberry Pi. Captured images are then fed to ML model which is developed using CNN. Authors applied convolution on image in each layer with a fitter matrix and rectified linear unit as activation function which is used to minimize error in training dataset with forward and backward propagation. Pooling is done with 2 x 2 pooling layer to reduce the size of image. Based on the animal predicted by this CNN model the Raspberry Pi will send signal to Ultrasonic frequency generator.

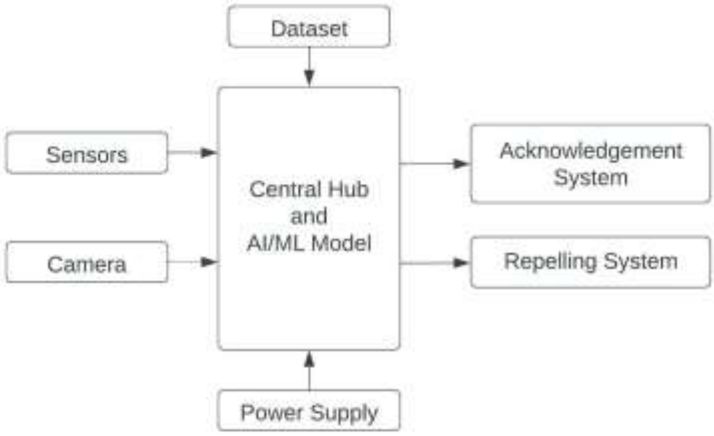

Fig. 4 - Hybrid architecture.

In [3], the authors proposed an intelligent animal repelling system for crop protection based on embedded edge AI. Here Raspberry Pi, NVDIA jetson nano and intel NGS as edge computing device. PIR sensor is used to detect activity and send message to edge computing device, which in turn activates the camera and executes its DNN software to identify the target. 1000 images of wild boar and deer are expanded to 10,000 images using data augmentation method and used for training. YOLO v3 and tiny YOLO v3 is used as animal detectors and comparison is done. The experimental results showed that YOLO v3 had better accuracy with 82.5% mAP and 64% recall.

In [7], the authors describe how the use of IoT and ML techniques can be combined to make smart irrigation and help in prevention of wild animals into the crop field. Raspberry Pi 3B is used as a heart of system. DHT11 temp and humidity sensor, soil moisture sensor, motor and motor driver are used to supply water whenever the water in low or moisture content is less by sprinklers. Character LCD display is used to display all sensor readings and alert messages. USB camera, IR sensor, ultrasonic sensor (HC-SRoG) and buzzer are used to detect wild animals and play appropriate sound. SVC (Support Vector machine) algorithm takes the sensor data, and based on pretrained dataset predicts which crops to be grown in field. CNN is used to recognize the wild animal captured by USB camera which is trained on dataset consisting elephant, horse, and hen. The message is also sent to the farmer.

In [9], authors combined the IoT and ML and compared the performance of two different algorithms R-CNN (Regin based Convolutional Neural Network) and SDD (Single Shot Detector). They have used Raspberry Pi 4, ESP826 Wi-Fi module, Pi camera (8 MP), LED, lead acid battery (12v). A 300 images dataset of horse, zebra, cheetah, elephant, cow with 60 images each was used to train the model. Pi camera captured the images every 5 seconds in both day and night. These images were analyzed by R-CNN and SDD. If animal detected buzzer is played, LED is turned on and message is sent via Wi-Fi module to app through IoT cloud. The experiments showed that the mAP (max Average Precision) of R-CNN approach is 83.42% and that of SDD is 89.32%. The SDD outstands R-CNN and authors described that R-CNN take 40-50 seconds more for detection than SDD.

In [21], the authors proposed a real-time animal detection mechanism for prevention of crop fields. It consists of two models, module 1 is animal detection and module 2 is scare away system. In animal detection 10 classes of animals are taken like elephant, wild boar, buffalo, chipmunk, goats, human, monkey, porcupines, rabbit, and rat. Infrared thermometer is used to measure the body temp of animal. If temperature is greater than 35 degrees Celsius it triggers camera to capture the images using Pi camera. A CNN model is developed using 100 images of every class of animal and this model is used for identifying the animal. In Scare away mechanism the dataset is divided into 3 classes. If detected animal is elephant, buffalo, wild boar (class 1), then honeybee sound is produced. For class 2 sudden high beam of light and ultrasound is produced and for class 3 only sound is produced for 10 seconds. The farmer gets the message on android application whenever the animal intrusion is detected.

3. Implications of Our Findings

These techniques and methods have the potential to improve the accuracy and timeliness of animal detection in crop fields, which can help to reduce the damage caused by animals and increase crop yields. The use of AI and IoT technologies can enable more targeted and efficient repellent measures, which can help to minimize the negative impacts on the environment and non-target species. From these research and conference papers we categorized the methods as techniques based upon sensory networks, video analytics and hybrid. The adoption of these techniques and methods may require significant investments in technology and infrastructure, which could be a challenge for some farmers. The use of these technologies may also raise privacy and security concerns, as they involve the collection and analysis of data from sensors and cameras.

The effectiveness of these techniques and methods may vary depending on the specific situation, and further research is needed to determine the optimal approaches in different contexts. The adoption of these technologies may also require the development of new skills and training among farmers and other stakeholders, which could be a challenge in some cases. Here when comparing the experimental results, the hybrid techniques which use both IoT and AI performed better than other two approaches. The use of AI and IoT technologies in animal detection and repellent systems in crop fields may also have broader implications for the agriculture industry, including potential impacts on employment and the adoption of other technologies.

4. Conclusion

We have reviewed various methods and techniques for detecting and repelling animals in crop fields. These techniques and methods involve the use of sensory networks, machine learning algorithms, video analytics, and other technologies to detect the presence of animals and trigger repellent measures. The use of AI and IoT technologies has the potential to enhance the effectiveness of animal detection and repellent systems in crop fields by providing more accurate and timely data on the presence of animals, and enabling more targeted and efficient repellent measures. However, the adoption of these technologies may also pose challenges, such as the need for significant investments and the development of new skills and training. Further research is needed to determine the optimal approaches for using AI and IoT technologies in animal detection and repellent systems in crop fields, and to assess the potential impacts on the agriculture industry and other stakeholders.

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