Chapter 3
IoT-Based System for Crop Protection From Animals:
Towards Smart Farming

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ABSTRACT

No one can imagine a world without agriculture. Due to overpopulation and deforestation, animal interference in residential areas is increasing day by day affecting human life and property, and causing human-animal conflict. At the present time, farmers in India and other countries are facing a serious threat from wildlife animals which causes less production in crop yielding. It is not possible to stay in the field for 24 hours to guard the crops against animals. In spite of good production, the crops on farms are many times ravaged by animals and it leads to huge losses for the farmers in terms of production, effort, quality, and money. To overcome this problem, an IoT-based crop protection system is being proposed in the present work. The system uses a microprocessor and a set of sensors to detect wild animals approaching near the field. The sensor data is analyzed through a machine learning algorithm and helps the microprocessor to take action. This system helps farmers to protect their crops from animals.

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INTRODUCTION

More than 65% of people in India as well as many people in the world are living in rural areas which depend on agriculture. Even many urban companies are based on agricultural products. Being dependent on agriculture, animal husbandry is one of the most popular livelihoods in Rural areas. The people keep animals like cows, buffaloes, goats, hens, etc. for earning through various by-products like milk, eggs, wool, etc. from the animals. In rural areas, although these animals help in farming but more often these animals pose a problem for the farmer n crop security. The boundaries of the field are vast and open. The protection of crops is a challenge for the farmers. Great efforts are required from the farmers to make their crops secure. It becomes more difficult in the weather conditions like heavy rain, and peak summer and winter seasons. The efforts needed make the life of the farmer miserable. Despite taking great care, the crops get destroyed due to the frequent entry of animals like cows, nilgai, wild boar, deer, etc. into the fields due to which the farmers do not get even full return of their labor from crop yields.

In order to reduce the effort, labor, and damage of crops and to maximize the income of the farmer, The present work is proposed a technological solution to vigil the crops. With the help of technologies like data analytics & IoT data is collected, pre-processed and analyzed to take the decision. The IoT is being used in agriculture in a variety of ways. Precision farming, monitoring climate conditions, building agriculture drones, and remote sensing smart greenhouses are few examples where IoT is being used for farming. The use of technology reduces the effort of farmers and hence improve the quality of life of farmers and their family.

To vigil the crops 24*7, it is needed to capture the data and inform the farmer on any critical situation in real time. The sensors and camera can be used as data collection in real time and further processed using microprocessor to take effective decision on findings. The Internet of Things play a important role in this. The Internet of Things (IoT) refers to a group of physical objects that are equipped with sensors, software, and other advanced technologies to enable them to communicate and share data with other systems and devices over the Internet. At this time IoT become popular in various industries, agriculture, smart cities etc. Almost every aspect of life where automation is required, are using the capabilities of IoT. Some of the areas where IoT is being used are:

- In industrial automation, IoT is being used to monitor and control industrial equipment to increase efficiency at low cost.
- In the agriculture sector IoT is being used to monitor crop conditions and weather patterns for increased production in low cost and minimum effort.
- IoT is being used in smart homes and smart cities to monitor and control the various equipment and for enhanced security system.

The proposed system comprises cameras and sensors, microprocessor etc. The cameras and PIR sensors are installed in various positions in the field. These camera and sensors are being used to capture the suspicious entry of animals in field. The real time monitoring of the field is done through continuous collection of data and by analyzing the collected data in real time. The data is being used to train the Convolutional Neural Network algorithm to assign the data in one of two classes. The proposed system uses 11 layers of Convolutional Neural Network. If any entry of animals is detected by the system, the proposed system has two ways to secure the crop from the animals.

- To inform the farmers about the entry of animals into crops through alarms and mobile messages.
- To play a pre-recorded roaring sound of dangerous animals like lions etc. to create fear in the animals.

The reminder of the chapter is organized as follows. The section 2 will explore the background work and related work. The section 3 will demonstrate the proposed work. The section 4 includes implementation of algorithm. The section 5 will explore the result and section 6 discussion followed by the conclusion and future scope.

LITERATURE REVIEW

Agriculture is one of the most popular and important work for earning the livelihood all over the world. Agriculture is tedious and laborious task due to the uncertainty involved in the agriculture. The weather, natural disasters like fire and flood make the agriculture very uncertain in terms of production. Apart from it, some other problems like protection of crop from animals, fire and being theft is also posing challenges and make the life of farmer miserable and tough. In the present work a technological solution is being proposed for protection of crops from animals. The presented work proposed a IoT-based system for crop protection from animals. This section explores the related work done by different researchers in this field.

Kumar K.B. P. et al. builds a model to detect the interference using a PIR sensor. This PIR sensor sends the signal to Arduino which gives the signal to the APR9600 module. APR9600 module gives a signal to the speaker and this speaker produces the sound. It is not able to identify whether it is a human, animal, or any non-living object. PIR sensor only detects the motion, if it finds anything is in motion under the sensor area then it sends the signal and starts producing sound.

Karlapudy A. M. et al. has proposed a system that uses a PIR sensor for the detection of motion which send a signal to the raspberry pi. This raspberry pi sends a notification to farmers' phones and provides live streaming. The farmer can see it and provide electricity to the wire fencing. A square wave is generated through a step-up transformer which is connected to a 24-volt battery. Sometimes farmers may be busy and unable to see the notification. If a farmer does not see the notification, then electricity is not provided to the fence. These square waves give a shock through which the animals get away from the field. This shock does not kill the animal. This is very harmful to small animals, and birds. This small current can kill birds and small animals.

Sandeep T. et al. has built a system using Convolutional Neural Network. In this system, the image is taken from the environment and sent to the microprocessor which takes a decision. The trained model is uploaded to the microprocessor. Only test data is provided through the camera to the microprocessor and it gives the decision. According to the decision, it sends a notification to the farmer. It does not have any system that can shoo away the animal from cropland. It only provides information on whether animals are in crop fields or not.

Priyanka R. R. et al. has proposed a system that uses deep learning algorithms to classify and detect animals. The model is trained using Convolutional Neural Network and uploaded into a microcontroller. Based on the classification, it decides whether it is an animal or not. If animals are detected then the Arduino turns on the buzzer which shoos away the animals from the crop field. This model does not provide any information to the farmers about the animals entering their fields.

Srikanth N. et al. has designed a prototype using Arduino Uno, a PIR sensor, a GSM module, and a smoke sensor that can detect the motion of any object and also can detect fire. It provides information about any object entered into the crop field and if any reason crops caught fire, then system detects it. It is also connected to a motor so it can turn on the water supply whenever it detects a fire in a crop field. It sends information to farmers using the GSM module.

Kumar K. B. P. et al. makes a system using the PIR to detect the movement of the animal and send a signal to the Arduino. It diverts the animal by producing sound by using buzzer and the signal is transmitted to GSM which sends an SMS alert to the farmers. This system also used a smoke sensor to detect fire and a DC motor is used to generate the signal receivers of 3V LCD Information. It only detects the presence of any object not sure what type of object is in the field.

Mr. P. Venkateswara Rao et al. has proposed a system in which Arduino is connected to the buzzer and GSM module in the system that captures the object from the camera and then Arduino sends the electric signal to the buzzer to produce sound and simultaneously sends the message to the owner mobile from the GSM module.

N. Penchalaiah et al. has proposed a system in which a DHT11 is attached to Arduino and it senses the temperature of the environment and soil moisture to sense the humidity of the soil. PIR and IR are used to detect the animal if the given threshold value is exceeded then a message is sent to the forest department as well as the farmer immediately and they use LCD to show the readings of the sensor.

P. A. Harsha Vardhini et al. uses raspberry pi for both irrigation systems and detection by using a camera and sensors attached to the microprocessor. If the threshold value of the soil is decreasing then the relay starts the motor in the field that sprinkles the water across the field if the soil threshold value is reached then it automatically switches off the relay for the detection of animals. They use a 360-degree camera which is rotated by a servo motor if the animal is detected by the camera, then the buzzer is ON. All the data of the sensor are stored in a cloud from where they use the mobile application to see the parameters that come from the sensor. In this system, they have to turn ON the device at all times to send the data to the cloud due to this they consume power more and their camera is not enough capable enough to detect the object at night.

Vikhram B. et al. uses an ultrasonic sensor and PIR sensor to detect the presence of any object based on this. If they cross the given threshold APR board is ON and a sound is played to divert the animal. At night time a flashlight is ON to divert the animal. At the same time, the GSM module sends a message to the forest department and makes a call to the farmer, and the LCD is used to display the presence of an animal.

Korche M. et al. uses an LDR to measure the size of the animal. PIR sensors are used to detect the position of the animal. If the animal is detected then from APR board sent a signal is sent to the speaker to produce a sound. At night time, a flashlight is attached to it that is turned ON. The LCD is used to display the presence of the animal a GSM module is used to send a message to the farmer about the entry of the animal.

Navaneetha P. et al. uses the PIR and ultrasonic sensor to detect the presence of an animal in the field if the animal is detected the APR board is turned ON. The system plays a sound to divert the animal for nighttime. A flashlight is attached to it which turns ON when the animal is detected. Then a message to the forest department and a call to the farmer. To power the system, a solar panel is used. The regulated power supply is given to show the presence of animals. They use LCD to display LDR readings.

Sumana P. B. et al. uses a camera attached to Arduino to detect the animal. If the detected object is a domestic animal or bird then a message is only sent to the farmer. But if a wild animal is detected then messages are sent to both the forest officer and the farmer. For sending message system uses noden MCU with a Wi-Fi module. The system also produces the sound using a speaker module when the animal is detected and a laptop or PC, LCD is required to see the detected object from the Arduino.

Abadi M. et al has introduced TensorFlow for large-scale machine learning which is used for building models which can detect and process images in a heterogeneous environment. TensorFlow can also support a variety of applications which is trained on deep neural networks.

David R. et al has demonstrated the TensorFlow lite micro model which is used in embedded system. Embedded systems have a limited amount of hardware in which they perform a specific task. So, they used a unique interpreter-based approach that can work with limited requirements.

Sudheer C. et al. has proposed that smart irrigation systems have proven to be effective in addressing crop damage caused by animals and water resource scarcity in the agricultural sector. The systems are designed using microcontroller such as Arduino, which are connected to sensors like infrared sensors and soil moisture sensors. The sensors help to detect animals in the field and determine when to irrigate the fields. The use of GSM modules allows farmers to monitor the fields from any location at any time, helping to increase efficiency and productivity in the agricultural sector.

Redij J. et al. the use of Arduino Uno and PIR sensors for crop protection and animal detection is a promising approach that has the potential to revolutionize the way farming is done. PIR sensor detects the motion and turns on the camera. This image is processed by a microcontroller. If an animal is detected then it turns on the buzzer and the image is sent to the farmer.

Nanda I. et al. have conducted a comprehensive study on the implementation of a smart irrigation system using Industrial IoT technology for crop protection and irrigation. The system includes DHT11 humidity and temperature sensors, PIR sensors, LDR sensors, and HC-SR04 ultrasonic sensors, all connected to an ARM Cortex-A. These IoT components are useful for agricultural purposes and can be employed for client engagement. The PIR sensors detect movement within a range of 10 meters, and when activated, the primary camera takes a picture and encrypts it using the ARM Cortex-A. The recognized data is then transmitted to the Arduino.

Shashi Kiran V. et al. has developed a device for crop monitoring in agricultural fields, farms, wetlands, and forests using a motion sensor to detect the presence of animals and birds. The PIR sensor immediately signals the Arduino board to take action when an animal or bird enters the farm area. The device comprises of a power supply section, PIR sensor, Arduino, buzzer, and LED, with each unit designed and tested separately. At night, the LED will turn on to detect any animals in the area. This system is using an Embedded PIC Microcontroller with a PIR sensor, PIEZO Buzzer, 12V Adapter, and LED. Whenever an animal attack crops in the agriculture field, the device detects the sound produced by the buzzer and generates a signal to divert the animal. This device is based on a motion-detecting sensor and is designed specifically for crop monitoring.

Munje R. et al. has made a system for intruders to come into the crop field then the PIR sensor is responsible for detecting any motion made by animals or humans that attempt to enter the farm field. Once motion is detected, the sensor sends a signal to the microcontroller, which immediately activates the system. Passive infrared sensors, in particular, use a pair of pyroelectric sensors to sense the heat energy in the environment. When infrared radiation from a human body is detected, the sensor sends a signal to the Arduino microcontroller to activate the alarm system, which includes a speaker. To record the sound of any animal or human, a sound recording module can be used for up to 20 seconds. The microcontroller, which is powered by the power supply module, serves as the main element of the system. A relay unit is used for voltage control. To detect the presence of birds in all directions, an ultrasonic sensor mounted on a servo motor rotates at 360 degrees. Once the ultrasonic sensor detects the presence of birds, it sends a signal to the controller. The signal is then displayed on the display. To notify farmers when movement is detected, a GSM module is used to make calls. The farmer is alerted when animals or birds attempt to enter the farm.

Giordano S. et al. have developed an IOT application for crop protection. To vigil the crop, it uses low pan, wifi, and Zigbee with IoT gateway. An ultrasonic sound device is used to work in partial or total darkness. Using solar panels and a lipo battery to increase the efficiency of the device, system uses a PIR sensor and uses RIOT software.

Iniyaa K. K. et al. have proposed a deep learning-based solution for crop protection. The system protects crops from animals. In their system cameras was used for detecting animals and sound devices are used to divert the animals.

Balakrishna K. et al. proposed a model in which the system has a raspberry pi 4 which takes images through a Pi camera. The detection is performed by RCNN and sends a signal to ESP8266 which is connected to the firebase. Firebase sends a signal to the application. If animals are detected then it turns on the buzzer and LED light simultaneously.

PROPOSED SYSTEM

Agriculture plays a very important role in a country's development. The quality of life of the citizen can be accessed through the quality and quantity of food they consume. In the presented work the issue related to the security of crops from animals is being addressed. The farmers have to be vigilant in their fields during cultivation to protect their crops from the animals. The anna animals pose a big challenge to the farmer. The animals enter the fields and destroy the crop severely. The manual security of crops is a big challenge in terms of effort. The farmer has to be alert throughout the day.

The present section explores the architecture and working of the proposed Internet of Things-based system for crop protection from animals that will help to protect the crop from animals with minimum effort in order to make the farmer's life easy.

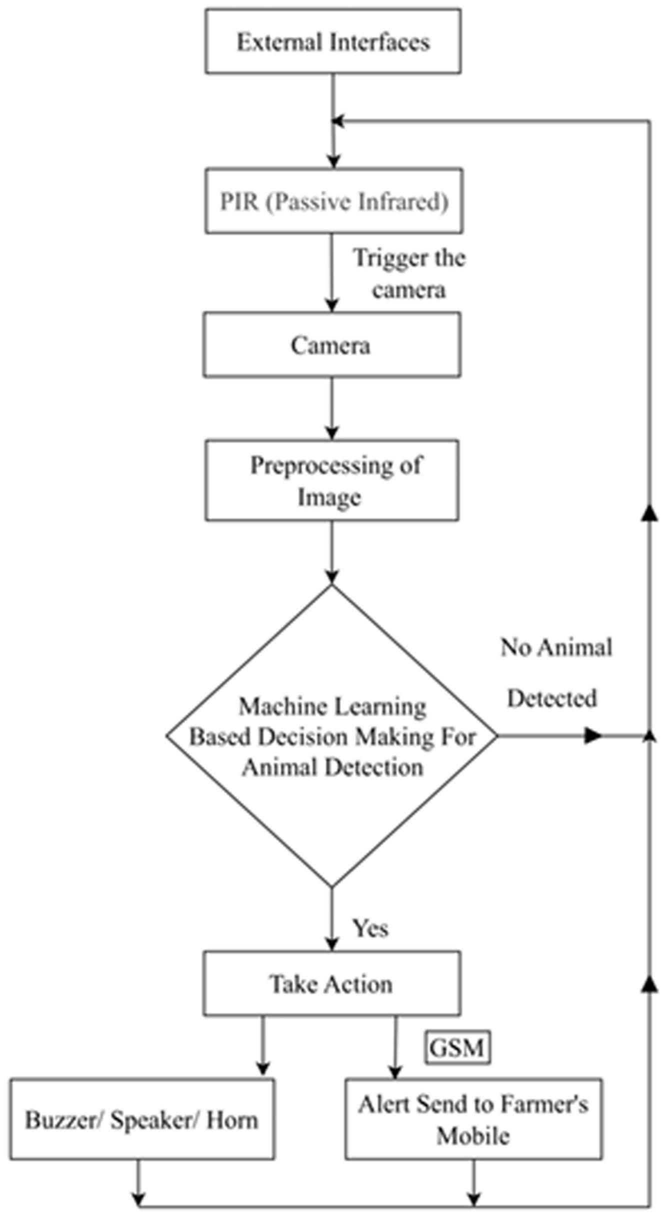
Flow Diagram of Proposed System

The flow diagram of the proposed system is demonstrated in Figure 1. The proposed system has Passive Infrared Sensor (PIR) used to detect any object which interferes with the area of the PIR sensor. The PIR sensor detects people within 10m of the sensor. The power supply is typically up to 5V. A Passive Infrared sensor (PIR) is an electronic device that is used to detect the presence of any object by measuring infrared (IR) radiation disturbance of emitted radiation with help of a sensor within its field of view and a corresponding electrical signal is sent to the microprocessor.

If interference occurs in the sensor, then it triggers the camera to capture the image of the object which enters the crop field and this image is processed in the microprocessor to detect which object is entered in the field.

The OV5647 5MP 1080P IR-Cut Camera is connected to the microprocessor. It has an automatic day-night switching mode this camera support night vision. It needs 3.3V power which is provided by the microprocessor. It is easy to attach. This Raspberry Pi IR-Cut camera can capture much higher quality images of day and night with resolutions up to 1080p.

Figure 1. Flow diagram of proposed system



After getting the signal from PIR, it started capturing the image and sends it to the microprocessor for detection. Then the captured image is pre-processed by fixing the dimension of the image. It helps to reduce the complexity of the image and remove unwanted noisy data. This pre-processed image is arranged in a queue and sent to the pre-trained model.

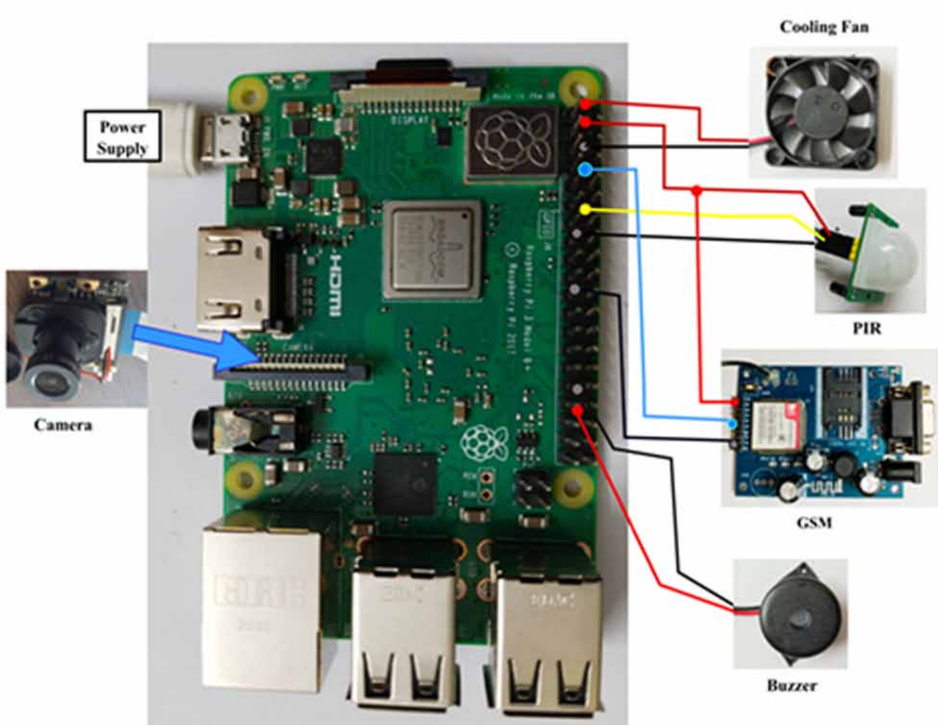
For training and testing the model, the dataset is used which is taken from an open-source platform named Kaggle given in Table 1.

Table 1. Volume of dataset

Image	No. of Images	No. of Training Images	No. of Testing Images	Image Orientation	Purpose
Cow	100	80	20	Front, Back, Left, Right, Group	Detection, Classification
People	100	80	20	Front, Back, Left, Right, Group	Detection, Classification

The pre-processed image sends to the microprocessor (Raspberry Pi). Raspberry Pi is a series of small single-board computers (SBCs). It works on a 5V DC current which is provided by a 5V DC adapter. Due to its low cost, modularity, and open design, it is widely used in many fields. It accepts both HDMI and USB devices. Raspberry Pi is a type of microprocessor that stores a pre-trained model that is working for processing the input data taken as input from sensors, and cameras. This pre-trained model takes a decision on the basis of the class system sending the signal to the buzzer or speaker, and GSM. A palm size fan is used to cool the microprocessor from heating. It works with 5V Direct Current (DC) voltage, and the main purpose of this is to exhaust the hot air. The pre-processed image is further sent to the pre-trained model which is stored in the microprocessor. This model uses Convolutional Neural Network to process the data.

Figure 2. Circuit diagram of system



Based on the predictions, the images are given a class. If the provided class is not dangerous for the crop, then it stops the further process of the system and sends a signal to the PIR sensor to run continuously. If the provided class is dangerous for crop fields, then the signal is sent by the Raspberry Pi to the Global System for Mobile Communication.

GSM is used to send notifications to the farmer. The baud rate of the GSM SIM800C modem with antenna module can be set by AT command from 9600 to 115200. GSM GPRS modems have an internal TCP/IP stack and can connect to the Internet via GPRS. It is suitable for SMS, voice, and data transmission applications over M2M interfaces. With simple AT commands, you can make voice calls, compose SMS, read SMS, make incoming calls, join the Internet, etc. This works with a system for sending SMS and calls to the farmer whenever the animals are detected by the model.

The microprocessor also sends the signal to the buzzer or speaker. A loudspeaker is an electro-acoustic transducer, a device that converts an electrical audio signal into an equal sound. It produces an irritating sound to create fear in animals. So that animals will leave the crop field. The connection of all the components with the microprocessor is shown in Figure 2.

IMPLEMENTATION OF ALGORITHM FOR ANIMAL DETECTION

The role of the IoT-based system is to detect the entry of animals into fields and inform the farmer to take the appropriate action on time, to minimize the losses. The system maximizes profit by minimizing efforts and losses. This part demonstrates the implementation of the algorithm in the system. How different modules of the system connect and operates. Some of the steps for operating this system are given below.

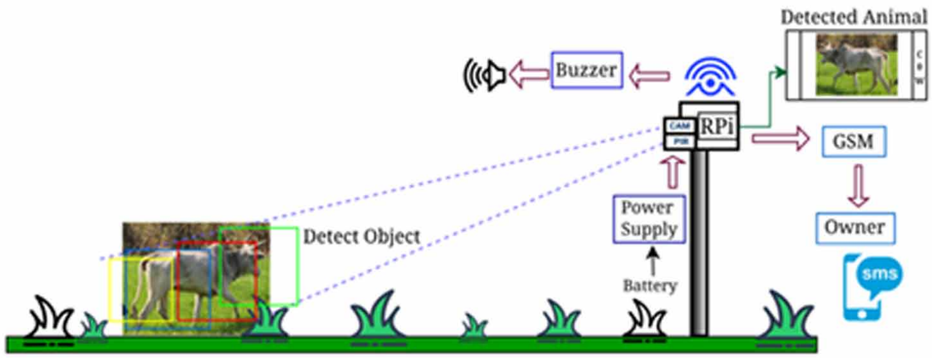
Step 1: Any object motion detected in PIR
Step 2: System turns on the camera
Step 3: Image/video collection from the camera
Step 4: The system read the image and then pre-processing image (224*224 pixels)
Step 5: Classification of image in class 0(entry of animal) or class 1
Step 6: If class 0 is provided then system turns on the buzzer and sends a message to the farmer's mobile phone
Step 7: If class 1 then go to step 1.

As shown in Figure 3. the PIR sensor is connected to a microprocessor that is used to detect the presence of an object moving in the field then it triggers the camera. A camera installed on the boundaries of the field is used to take an image or video of field boundaries. The camera is capable to work in day and night both times. The camera is 1080 megapixels that cover approx. 20m distance from the field.

The image is sent to the microprocessor. The microprocessor has an uploaded model which takes an image and pre-processes it into 224 * 224 pixels to send to CNN layers which extracted the feature of an image. This extracted image sends to the Convolutional neural network which makes predictions. Based on prediction it provides the class and label of the image.

If the class 0(animal) and label are given then an animal is present in the field. Now the microprocessor plays a sound through the speaker at the same time a message is sent to the farmer using the GSM module. If class 1(person) then goes to step 1 and there is no alarm or notification sent to the farmer.

Figure 3. Detection of animal



Convolutional Neural Network

The proposed system uses Convolutional Neural Network as classifier. Convolutional Neural Network (CNN) is popular method to capture the inherent properties of input images and classify it correctly. CNNs are mainly suitable for discovery of patterns in images to identify objects. They can also be useful for classifying audio, time-series, and signal data. CNNs can perform both the feature extraction and the classification, resulting in a highly organized and feature-dependent model output. The proposed work implements the CNN model as summarizes in Figure 4. The figure 4 describes the number and type of layers used in Convolutional Neural Network.

Significance of The CNN and its Respective Layers

- **Convolutional Layers:** These layers perform the most important operation in a CNN, which is convolution. Convolution involves applying a set of filters to the input image to extract features, such as edges, corners, and textures. The output of the convolutional layer is a set of feature maps that capture different aspects of the input image. By stacking multiple convolutional layers, a Convolutional Neural Network can learn increasingly complex and abstract features. The given formula is used to calculate the learnable parameters.

$$((s * k * d) + 1)*p$$

Where s is width of filter, k is height of filter, d is number of filters in previous layer, and p is number of filters in the current layer.

- **Pooling Layers:** These layers reduce the size of the feature maps by down-sampling them. This helps to reduce the computational cost of the network and prevent overfitting. The most common type of pooling is max pooling, which selects the maximum value from each sub-region of the feature map.
- **Flatten Layers:** This layer flattens the multi-dimensional output from previous layer which is calculated by the equation:

Figure 4. Summary of CNN model

```
Model: "sequential"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d (Conv2D)             (None, 222, 222, 32)      896

 max_pooling2d (MaxPooling2D  (None, 111, 111, 32)     0
 )

 conv2d_1 (Conv2D)           (None, 109, 109, 64)      18496

 max_pooling2d_1 (MaxPooling  (None, 54, 54, 64)       0
 2D)

 conv2d_2 (Conv2D)           (None, 52, 52, 128)       73856

 max_pooling2d_2 (MaxPooling  (None, 26, 26, 128)      0
 2D)

 conv2d_3 (Conv2D)           (None, 24, 24, 128)       147584

 max_pooling2d_3 (MaxPooling  (None, 12, 12, 128)      0
 2D)

 flatten (Flatten)           (None, 18432)             0

 dense (Dense)               (None, 512)               9437696

 dense_1 (Dense)             (None, 3)                 1539

=================================================================
Total params: 9,680,067
Trainable params: 9,680,067
Non-trainable params: 0
_________________________________________________________________
```

Number of Neurons = w * h * f

Where w is width, h is height and f are filter size of previous layer.

- **Fully Connected Layers:** These layers are used at the end of the network to perform classification or regression. The output of the last convolutional layer is flattened into a vector and fed into one or more fully connected layers, which perform a linear transformation and apply a non-linear activation function. The output of the final fully connected layer is the prediction of the network. The number of learnable is calculated by the equation:

No. of learnable parameters in dense layer = Output size * Input size + 1

RESULT

The presented work provides a technological solution for the security of crops using IoT. The present system achieves an average accuracy of 87%. It helps farmers to protect their crops with minimal vigil in crop fields 24 *7. This system reduces labor and also does not harm the animals. The Table 2 presents a comparison of proposed system with some other algorithms.

Table 2. Algorithm Performance Comparison with State-Of-The-Art

Author Name	Paper Name	Accuracy (%)
Proposed model	Proposed work	87.91
K. Balakrishna et al.	Application of IoT and machine learning in crop protection against animal intrusion	85.22
S. Giordano et al.	IoT detection against wild animal's attacks	84.51
Iniyaa K. K. et al.	Crop protection from animals using deep learning	77.45

CONCLUSION AND FUTURE SCOPE

The present work proposes an IoT-based system for crop protection. The main objective of the work is to minimize the losses incurred during agriculture and maximizing the production and profit. It also helps to improve the quality of life of farmers and their family members. The sensors and cameras are being used for detecting and capturing the image. A deep learning-based classification technique is being used in the microprocessor memory to classify the captured image. If the system detects the animal entry, it sends an alert signal to the farmer's mobile and also starts to sound in order to prevent the entry of animals into the field. This IoT-based system achieves an average accuracy of 87%. The present system can further be enhanced by training the model with more different animal samples. The functionality of proposed system can further be enhanced by adding more sensors like smoke sensors, temperature sensors, soil moisture sensors, and ph. sensors, etc. to monitor the quality of soil and water needed.

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