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Research Article

A Review of Existing Farmland Intruder Detection Systems

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Abstract

Several methods for detecting intruders in a farmland be it humans or animals has evolved overtime from traditional to evolving technologies. Some of the traditional methods include building brick fences around the farmland, installing electric fences or plant deterrent plants with spikey branches or those which give out displeasing scents while a few of the evolving technologies include wireless sensor networks, deep learning algorithms, internet of things, just to mention a few. In this paper, we provide a review of existing farmland intruder detection solutions of different authors with focus on methods ranging from electric fences to Wireless Sensor Networks to Internet of Things.

Keywords: Internet of Things; farmland intrusion detection; deep learning; wireless sensor networks

Introduction

The economy of many countries in the world is dependent on agriculture. Despite the economic growth and development, agriculture is the backbone of the economies all over the world. Agriculture contributes to the gross domestic product as it is the main stay of many countries. It is difficult for a nation to survive without agriculture and agricultural activities, not just because it is a source of food, but because it is connected to the production of all basic human needs. There is always a huge loss of crops due to animal interference in agricultural land, crops are being destroyed and lives of farmers are being lost. Security of farmlands in Nigeria is still a major challenge, as most farm owners are constantly faced with issues of curbing theft and destruction both from humans and animals alike. Common solutions might include building brick fences around the farmland, installing electric fences or plant deterrent plants with spikey branches or those which give out displeasing scents (Ajayi and Olaifa 2017). These security measures are sometimes prohibitively expensive to put in place and very ineffective as intruders can easily jump over them and cart away with as much crops as they can carry without the knowledge of the owners, especially when such fences are built around dark crevices. In the regard of making agriculture smart, important contributions can be made by using emerging technologies like Internet of Things (IoT). Shaji (2018) defined Internet of Things (IoT) as the network of physical things embedded with electronic circuits, sensors, software, and network connection which enables these things to exchange data from one another. IoT can address agriculture-based problems and enhance the quantity and quality of agricultural production, and hence making agricultural lands more intelligent and more connected (Angadi and Katagall, 2019). By combining computer vision technology with IoT, it becomes possible to secure farmlands from issues of curbing theft and destruction both from humans and animals. Computer vision is a field of computer science that deals with how computers can gain high-level understanding from digital images or videos (Huang, 1996). It is a combination of image processing and pattern recognition. The output of the Computer Vision process is image understanding. It focuses on replicating parts of the complexity of the human vision system and enabling computers to identify and process objects in images and videos in the same way that humans do (Cosido et al., 2014).

Many approaches involving sensing animal entry using IoT, communicating device to take preliminary actions, diversion of animal and sending alert to farmers have been proposed. Various methods and algorithms have also been developed to detect and recognize animal and human intrusion into a farmland. This paper presents the reviews for animal and human detection methods using digital image.

Review of Existing Systems

Shetty et al., 2021 developed an algorithm to detect wildlife animals using Convolutional Neural Networks and camera trap images. The dataset used contains 20 species of animals with about 100 image sequence for each species. The dataset is divided into ten uniform folds. The primary reason for using tenfold cross-validation is to ensure that results remain unbiased to given partitioned data. Out of ten folds, nine are considered as training data and remaining one used as test data. Hence, 90% data is used for training and 10% data is used for test purpose. Machine learning algorithms such as Support Vector Machine, K-Nearest Neighbor and ensemble classifiers and its variants were used. An accuracy of 91.4% with weighted K-nearest Neighbor and Deep CNN was obtained which outperforms previous research in anima detection. The work had low accuracy in detecting animals in night time images. Schindler and Steinhage, 2021 worked on Identification of Animals and Recognition of their Actions in Wildlife Videos using Deep Learning Techniques. Video clips are captured with 8 frames per second by camera traps using infrared cameras and infrared flash-lights. The clips were taken by camera traps and shows four kinds of animals; deer, boars, foxes and hares mostly at night time. Visual detection and identification of observed animals in the video frames of the camera traps resulted in:[1] a bounding box for each detected animal depicting its location,[2] a segmentation mask per animal depicting the exact shape, and [3] a class label depicting the type of animal (here: deer, boar, fox, hare). Mask R-CNN (He et al., 2017) and Flow-Guided Feature Aggregation (Zhu et al., 2017) algorithms where used for animal detection. At the end of the research, a deep learning-based architecture combining the detection of individual as well as precise shapes of appearances with the recognition of the actions of the observed animals. The work was limited to few video clips for experimental purposes which resulted in low accuracy [4,5].Paramasivam et al., 2020 also developed an algorithm suitable for classification and detection of animals from camera pictures of different poses and partial images of animals. The different features like color, gabor and LBP are extracted from the segmented animal images. Possibilities of fusing the features for improving the performance of the classification have also been explored. Classification of animals is accomplished using CNN and symbolic classifiers. The dataset used for training contains 13412 images with 6 classes of animals namely; Spider, Squirrel, Horse, Elephant, Chicken and Butterfly. The captured image is checked for various features of objects that match with features of animals in the training dataset after which detection and classification takes place. The algorithm calculates the accuracy based on the number of matched objects. The accuracy range achieved ranges from 53% to 81%. However, accuracy benchmark set for a detected animal is low which gave room for false detection [6].

Savagavi et al., 2020 worked on animal intrusion detection, recognition and tracking using deep learning methods to reduce human-animal conflicts by continuous and automatic monitoring of vulnerable areas. They used a network of cameras connected to a Passive Infrared Sensor. YOLO algorithm is a Deep CNN object detection model which has good performance both in terms of accuracy as well as speed of inference. For the prototype version of the system proposed in this paper, five different species of animals – elephant, zebra, giraffe, lion, and cheetah are considered. Images of humans are also included, so there are a total of six different categories in the training data. The average accuracy over detecting five species of animals is 98.8%, and for human detection the accuracy obtained is around 99.8%. However, false alarm occurs when multiple cameras detect the same individual animal which result in multiple notification been sent [7]. Singh et al., 2020 researched on animal detection in man-made environments with the aim of using transfer learning to adapt state of the art object detection methods for detecting several types of large Alberta animals in real-time video sequences captured from one or more monocular cameras in moving ground vehicles. A combination of video and static data was used to facilitate the large number of training images needed. Five high level detector architectures have been used for comparison – Faster RCNN, RFCN, SSD, Retina Net and YOLO. Three different backbone networks are used for Faster RCNN - ResNet101, InceptionResnetv2, NAS - and two for SSD - Inceptionv2, Mobilenetv2 - for a total of 8 detectors. ResNet101 and ResNet50 are used as back- bones for RFCN and Retina Net respectively. All 3 variants of YOLO were experimented with, though only YOLOv3 results are included here as being the best performer.

These methods were chosen to cover a good range of accuracies and speeds among modern detectors. The work provided insights about transfer learning gained by training and testing the models on static, video and synthetic images in a large variety of configurations. The research was limited by the reason that none of the detectors can generalize well enough to provide usable models for deployment [8]. Sabeenian et al., 2020 developed a monitoring and repelling system To safeguard farmlands from wild animals and also to protect them by driving them away automatically without causing loss of human and animal lives. The image dataset used contains about 2500 images and were divided into training and testing data. Three classes of animals namely; elephant, boar and money were considered. The hardware devices used are a personal computer, Jupyter notebook which is used to design the code of the model, surveillance camera and speaker. The surveillance camera is used to record the field area 24/7 which is fed as input for the model. The speaker is used to produce audio output which helps to amplify the sound received from the model to the field area to drive away animals. Convolutional Neural Network is used to provide the cognitive skill for classifying the animal detected into a particular

class and hence produce the appropriate output. OpenCV and Keras were used as the backend. An accuracy of 70% was achieved. However, the model developed is not cost effective because it requires high memory usage resulting in low speed to train and validate the dataset [9].

Mohandass et al., 2020 proposed a unified approach to animal intrusion detection for preventing human-wildlife conflict and crop protection. Animal entry at the farm boundary is detected by sensors like Passive Infrared sensors, optical sensors (cameras), Fiber optic sensors and are connected to the LoRa shields, which are connected to the LoRaWAN gateway through a wireless medium. The significance of LoRaWAN is that it enables long range of communication over a wireless channel, while consuming less power. The end nodes are the Arduino Uno microcontrollers along with LoRa shields or LoRa GPS shields. The gateway in turn is connected to a cloud server from which data can be extracted by the user via a webpage and/or Android app. This system will provide the exact location of the area of mishap(s) thereby facilitating timely actions to be taken by the authorities. The proposed system also involves detection of the wild animals based on camera video surveillance system. The simulation results of image classification method based on CNN show that the detected animals can be categorized with a maximum accuracy of 99.34% [10]. Banupriya et al., 2020 developed an algorithm to detect wildlife animals and to classify them based on images for easy monitoring and more efficiency. The work considered two types of wild animals to be detected; elephant and cheetah. The dataset was slit into training and testing in the ratio of 75:25 respectively. Convolutional Neural network was used to develop the detection algorithm. The work did not include sending notifications to the forest workers when an animal is detected which served as the limitation [11].

Ravoor et al., 2021 designed an animal intrusion detection system based on deep learning to reduce animal human conflict by automatically detecting animal intrusions. A prototype of the design is constructed using Raspberry Pi devices connected to a laptop computer, with Raspberry Pi devices running object detection. The performance of both the tiny-YOLO and the MobileNetv2-SSD models are compared for animal detection. The YOLO and MobileNetv2-SSD models used are pre-trained on MS COCO and Open Images datasets respectively. The distributed architecture consists the end points (the camera and processing devices), an optional edge server and the central server. The prototype is tested using three animal species – tigers, jaguars and elephants, and achieves detection accuracy of 80%, 89.47% and 92.56% respectively, while operating at 2-3 frames per second. It was noted in the research that animals tend to get accustomed to alarm sounds and subsequently ignore them which makes diversion method ineffective [12]. Muneera et al., 2020 researched on Internet of Things based Wild Animal Infringement, Identification, Diversion and Alert System. Wireless Sensor Network nodes are placed at every corner of the field by means of laser sensors that performs guarding of the perimeter. Intruder entry is sent to the base station that activates all the nodes around the animal. Animals are diverted by means of flashers and buzzer based on the proximity, time, and location with the help of the sensors on each node. Buffer crops that serve as food for the wild animals and allows the animals to be deterred thereby creating a balanced eco system. A sleep mode is activated when there are no signals received from the sensor nodes. The sensor nodes enable continuous updating of the information to the cloud. Nodes use Wi-Fi as the communication medium among each other and to the router gateway. Several small computers are used for the distribution of process instead of using a distinct power device. Thus, cloud computing is used for this purpose and the efficiency of the system is improved in terms of speed and cost. Messages are sent via Message Queue Telemetry Transport (MQTT) protocol. It helps in secure and quick communication in remote areas which require smaller code footprints. A system which detects animal intrusion, diversion and enables reduction in crop damage by less than 5% was achieved. However, the class of animals used for the scope of the research was not discussed [13]. Angadi and Katagall (2019) proposed a security system for intrusion detection in agriculture to detect motion in the farm environment, capture the scene information in the form of an image and identify the object like animal, person or the thing causing motion. The system consists of Sensor module, deep learning module which processes the acquired image using OpenCv, PiCam module, e-mail notification module and SMS notification module. OpenCv module installed in Raspberry Pi runs object identification process and gives information about the object that has caused motion or any malicious activity, and then the OpenCv module transfers that information to the Email notification module. A framework which is used for detecting malicious activities in a farmland was achieved. The limitation was that the research did not consider night view, hence the system cannot run at night [14-15].

Vidhya et al. (2019) researched on smart crop protection using deep learning approach to protect farmland from animals without hurting the animals or putting human life at stake. Farmland intrusion is detected utilizing PIR sensors and photos are taken utilizing Pi camera. Classification of the intruded animals as local or wild animals is done using Convolutional Neural Network (CNN). The network is trained with a dataset containing many images in each class. The accuracy of each epoch is calculated. A prototype of a smart farm protection system was developed which classifies the animals and can be used to ward them off. However, the system can only detect a range of animals and it cannot detect unauthorized entry of humans which is a major drawback. Mythili et al. (2019) presented IoT Based Smart Farm Monitoring System in order to reduce human intervention and increase crop cultivation. The methodology is a mixture of hardware and software additives. The hardware part includes embedded systems and software program is the Arduino IDE. The sensors used are temperature and humidity sensor, PIR sensor and soil moisture sensor. A GSM module is hooked up with the Arduino to facilitate messaging service. At the end of the research, an easy to use, low maintenance cost system

was achieved. The work could only detect motion around the PIR sensor and doesn't have knowledge of what is intruding [16]. Prajna et al. (2018) developed an IoT-based Wild Animal Intrusion Detection System with the aim to provide protection from the attacks of wild animals and thus minimizing the probable loss to the farmer. PIR Sensors and camera act as first round of security where the animal movement is detected using the sensor and the sensor in turn triggers the camera to take the picture of the animal and transmit the image for processing via microcontroller through Wireless Sensor Networks (WSN). The limitation is that the research only considered two kinds of wild animals and cannot detect human intruder. Also, the object detection model used was not stated [17].

Ibam et al. (2018) designed and implemented wireless sensor networks for farm monitoring and security. The design of the system is based on wireless sensor networks (WSN) and some of the components required are processor board, intrusion detection sensors, cameras, and buzzer alarms etc. GSM module is used for sending SMS to the farm owner indicating the nature of intrusion. A system for detecting intrusion on a farmland was developed. However, the system cannot differentiate between authorized and unauthorized entry into the farm. Also, there is no image processing module to identify the kind of intruder [18]. Iyapo et al. (2018) developed a Motion Detection Alarm and Security System whose objective was to develop close circuit security using commercially available PIR sensors and microcontroller for device control. The design was in three main phases; sensitivity phase, central processing phase and action phase. The study also utilized developmental design to observe the functionality of the device. A motion detection alarm and security system which gives good response to the motion sensor when it detects intrusion at the windows or doors was developed. However, the work could only detect motion and could not differentiate between authorized and unauthorized entry. Santhiya et al. (2018) proposed a smart farmland using raspberry pi crop prevention and animal intrusion detection system. The objective of the research was to develop an animal intrusion detection system using Raspberry PI. Raspberry pi was used to develop the system and it consist of three stages for animal repellent. Radio Frequency Identification (RFID) was used to detect the animal that enters the farm. Alert message is not only sent to the forest officer, it also sent to the people in the farm by using GSM. An automated system which does not cause any arm to animals during repellent was achieved. Exact location of the intruding animal on the farm is not achieved. Human detection was not considered and noise pollution was caused by loud irritable noise used to scare off intruders. Nagaraju and Valli (2017) presented Wild-animal recognition in agriculture farms using W-COHOG for agro-security. The objective of the research was to design an algorithm to detect animals in an image. Sliding window technique and Histogram equalization was used for image preprocessing.

After pre-processing the image, the feature vector calculation is performed using Weighted Co-occurrence Histograms of Oriented Gradients (W-CoHOG). A new algorithm for wild animal recognition was proposed. The limitation of the research was that human recognition was not considered. Bapat et al. (2017) proposed a wireless Sensor Networks application for crop protection to divert animal intrusions in the agricultural land. The objective of the work was to create closed loop animal intrusion detection and deterring system, which is capable of sensing, reporting and taking preliminary prevention actions in an automated manner. Wireless sensor was placed at the corners of the field which will detect the animal entry using a laser assisted perimeter guarding sensor and divert it by activating flashers and sound devices based on the location, time and proximity. The Graphical User Interface for the system was developed using MATLAB. A wireless sensor network-based crop protection system to divert the animals from the crop field area that is easily adaptable by farmers was developed. However, the system cannot differentiate between authorized and unauthorized entry into the farm. Also, there is no image processing module to identify the kind of intruder. Ajayi and Olaifa (2016) presented Detecting intrusion in large farmlands and plantations in Nigeria using virtual fences. The objective of the research was to develop an IoT based intrusion detection system that uses active sensors to detect the presence of intruders and logs such intrusions for monitoring purposes [19]. A sensor module prototype was constructed using a combination of an Arduino Micro Controller, WiFi Shield (ESP8266-12) to provide Internet connectivity to the Micro controller, a PIR motion sensor and a RTC module. Each sensor module was mounted inconspicuously at the edge of the area of interest with a detection range of about three meters. An intelligent system which detects intruders and records log for the purpose of decision making was achieved. The limitation of the research is that it could only detects intrusion detection but does not specify the type of intruder whether human or animal. Also, the work could cover only a short distance and cannot detect intruders from a long distance [20].

Nagpal and Manojkumar (2016) proposed Hardware Implementation of Intruder Recognition in a Farm through Wireless Sensor Network. The objective of the work was to develop a Wireless Sensor Network based system to detect movement of unauthorized entries into the farm. The sensors are connected to the Arduino and it continuously receives the sensor information and checks the signal to detect the crossing of a human or an animal. This signal is transmitted to a buzzer either to take immediate action or caution the unauthorized entry. The work used Frequency Identification (RFID) tags to avoid detection of movement of authorized persons. The sensors are connected to the Arduino and it continuously receives the sensor information and checks the signal to detect the crossing of a human or an animal. This signal is transmitted to a buzzer either to take immediate action or caution the unauthorized entry. The work used Frequency Identification (RFID) tags to avoid detection of movement of authorized persons. A Wireless Sensor Network based monitoring system capable of detecting unauthorized entries such as humans and animals into the farm was developed. The work only detects motion and immediately

moves on to acting. The kind of intruder was not considered [21]. Mahajan and Mahajan (2016) presented IoT Based Agriculture Automation with Intrusion Detection. The objective of the research was to design and implement an agriculture automation system using IOT that can control and automating most of the agriculture field through an easy manageable website interface. The proposed system consists of a server and sensors. The server controls and monitors the various sensors and can be easily configured to handle more hardware interface module (sensors). The Arduino development board and the ethernet shield acts as website server. The automation system can be accessed from the website browser of any local PC on the same LAN, or remotely from any PC or mobile handheld device connected to the internet with appropriate website browser using the server's IP address.

A low cost system that is highly scalable with less modification was achieved. However, the work can only detects motion on the farmland and did not go further determine what exactly is intruding. Roy et al. (2015) presented a prototype for agricultural intrusion detection using wireless sensor network. The objective of the research was to develop a detection system that enables the farmer to receive text messages as well as alarms on the entry of an intruder in the agricultural field. The methodology followed a four-layer approach. Layer 1 contains PIR sensors for detecting entrance into the farm. Layer 2 is for processing the data retrieved from the PIR Sensor. Layer 3 does the wireless routing and in layer 4, GSM technology is used to generate SMS to the farmer's cell phone, and simultaneously, an alarm is generated in the farmer's house. By receiving the SMS and alarm, the farmer gets the information about the entrance of an intruder in the field. Table 1 A prototype for intruder detection system that generates alarms in the farmer's house and triggers the generation and transmission of a text message, when an intruder enters the field was designed. The work only detects motion on the farmland, did not go further determine what exactly is intruding. Kuma et al. (2015) proposed iDART-Intruder Detection and Alert in Real Time. The objective of the research was to design and develop a smart intruder detection and alert system which aimed to elevate security as well as the likelihood of true positive identification of trespassers and intruders as compared to other commonly deployed electronic security systems. The research employed the use of smart sensors to monitor the presence of trespassers and possible intruders near the home's entry points such as door, windows etc. To implement the system, three processing units were used; a microcontroller, a raspberry pi single board computer and a PC (with LabVIEW installed). A system which sends relevant video data (on detection of an intrusion) to the users and homeowners directly, without the need of an additional centralized monitoring unit was achieved. However, there is no prompt notification system to inform the farm owners whenever any intrusion occurs. Wong et al. (2014) proposed An Effective Trespasser Detection System Using Thermal Camera. The objective of the research was to create a more effective algorithm for trespasser detection using pattern recognition technique. The research used a thermographic camera with an accurate temperature measurement model: Thermo Vision A- 20M model. Matlab ver. 2007b is chosen because it provides a user-friendly environment for the user to perform image processing and pattern recognition. A novel human detection algorithm embedded into a thermal imaging system to form a fast and effective trespasser detection system for smart surveillance purpose was achieved. However, the research could only detect humans and not animals [22].

Table 1: shows existing sensor based animal intrusion detection systems.

Objective	Sensors	Microcontroller	Author	Year
Animal Detection	Camera Traps	Raspberry Pi	Shetty *et al.*	2021
Animal Detection	Camera Traps	GeForce RTX 2080 Ti GPU	Schindler and Steinhage	2021
Animal Detection	Video Camera	Raspberry Pi 3	Paramasivam *et al.*	2020
Animal Detection, recognition and tracking	PIR Sensors, Cameras	Raspberry Pi 2	Savagavi *et al.*	2020
Animal Detection	Video Cameras	Raspberry Pi	Singh *et al.*	2020
Animal Detection	Surveillance camera and speaker	Raspberry Pi	Sabeenian *et al.*	2020
Animal Detection	PIR Sensors, Optical Sensors, Fiber optic Sensors	Arduino UNO microcontroller	Mohandass *et al.*	2020
Animal Detection	Camera	Raspberry Pi	Banupriya *et al.*	2020
Animal Detection	Pi Camera	Raspberry Pi	Ravoor *et al.*	2020
Animal Detection and recognition	Lases Sensors	WSN	Muneera *et al.*	2020
Animal and Person detection	PIR Sensor	Raspberry Pi	Angadi and Katagall	2019
Animal Detection	PIR Sensor	Raspberry Pi	Vidhya *et al.*	2019
Animal detection	PIR sensor and soil moisture sensor.	Arduino UNO microcontroller	Mythili *et al,*	2019
Animal Detection	RFID	Raspberry Pi	Santhiya *et al.*	2018

Animal detection and crop monitoring	Video Surveillance, Soil moisture sensor and temperature and humidity sensor.	Arduino microcontroller	Balaji *et al.*	2018
Wild animal detection	PIR Sensor	WSN	Prajna *et al.*	2018
Farm Monitoring and Security	Wireless intrusion detector	ZigBee radio transceiver	Ibam *et al.*	2018
Wild animal recognition	Cameras	Raspberry Pi	Nagaraju and Valli	2017
Animal detection	PIR Sensor	WSN	Bapat *et al.*	2017
Animal Detection	Motion Sensor	Arduino Micro Controller	Ajayi and Olaifa	2016
Unauthorized entry detection	PIR Sensors	Arduino Micro Controller	Nagpal and Manojkumar	2016
Automation System	Motion Sensor, Light Sensor	Arduino uno Micro controller	Mahajan and Mahajan	2016
Intrusion Detection	PIR and Ultrasonic Sensors	AVR micro-controller	Roy *et al.*	2015
Intrusion Detection	Motion Sensors	Raspberry Pi	Kuma *et al.*	2015
Human Intrusion detection	Thermographic camera and Temperature Sensor	Arduino Micro Controller	Wong *et al.*	2010

Conclusion

The increasing demand of safety and security of human and animals in various fields and environments has brought the challenges of time and computational efficiencies before the researchers working in this area. It is observed that the learning-based approaches are finding more and more attention in recent times due to their performances and availability of computational resources. This paper provides a detailed review of key methods for farmland intruder detection of different authors, and it was discovered that methods that used deep learning algorithms to analyze data collected from IoT sensors had the best performance. This review is also meaningful for development deep learning algorithms for IoT data analysis which provides valuable insights and guidelines for future progress.

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