Development of an Intelligent Animal Detection and Notification System Using AI and IoT for Smart Farm Security

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Abstract— **This paper presents the design and development of an intelligent animal detection and alert system for farm security using Artificial Intelligence (AI) and Internet of Things (IoT) technologies. The system is designed to monitor restricted or sensitive farm areas through automated real-time detection and notification. A Passive Infrared (PIR) sensor is integrated with an AI-enabled camera to detect motion and initiate monitoring processes automatically. Upon motion detection, the system activates visual and audio alerts, captures images, and sends remote notifications via the Telegram platform. The proposed system utilizes a Raspberry Pi 4 Model B as the main processing unit and a Sony IMX500 intelligent vision sensor capable of performing on-sensor AI inference for object detection. The PIR sensor serves as the primary trigger mechanism to improve power efficiency and reduce unnecessary processing. The system software is developed using the Python programming language with GPIO, subprocess, and HTTP communication libraries. Experimental results demonstrate that the developed system is capable of performing reliable motion detection, automated alert activation, image capturing, and near real-time notification delivery effectively. The proposed system also provides a low-cost, flexible, and scalable alternative to conventional surveillance systems for smart farming applications. Overall, the integration of AI and IoT technologies in this project demonstrates significant potential for improving automated farm security and monitoring systems.**

Keywords— Artificial Intelligence, Internet of Things, Farm Security, Animal Detection, Raspberry Pi, Smart Agriculture

I. INTRODUCTION

Agricultural farms and plantations frequently face disturbances caused by animals such as stray cats, dogs, and wildlife, which may lead to crop damage, contamination, and reduced productivity [1], [2]. Conventional monitoring methods rely heavily on manual supervision and continuous surveillance systems, which are inefficient, labour-intensive, and unsuitable for continuous operation, particularly in remote or small-scale agricultural environments.

Recent advancements in Artificial Intelligence (AI), embedded systems, and Internet of Things (IoT) technologies have enabled the development of automated monitoring systems capable of real-time detection and notification. Smart surveillance systems integrated with AI-based imaging and wireless communication technologies provide more efficient and responsive monitoring solutions compared to traditional methods.[1],[3],[4].

This paper presents the development of an intelligent animal detection and alert system using AI and IoT technologies for farm security applications. The proposed system integrates a Passive Infrared (PIR) sensor with an AI-enabled camera to perform automated motion detection, image capturing, and remote notification through the Telegram platform. The system utilizes a Raspberry Pi 4 Model B as the main processing unit and a Sony IMX500 AI camera for intelligent imaging operations.

The PIR sensor functions as the primary trigger mechanism to reduce unnecessary processing and improve energy efficiency. Once motion is detected, the system activates visual and audio alerts, captures images, and sends notifications to users in near real time. Compared to conventional surveillance systems, the proposed

system offers a low-cost, scalable, and energy-efficient solution suitable for small-scale agricultural monitoring applications. [3], [13].

The objectives of this project are:

To develop a motion detection system using a PIR sensor.

To integrate an AI-enabled camera for automated image capturing.
To implement real-time notification through Telegram.

To provide an automated monitoring solution for farm security applications.

The proposed system also contributes to the practical implementation of AI, IoT, and embedded system technologies in smart agriculture applications while enhancing monitoring efficiency and reducing dependency on manual supervision.

II. LITERATURE REVIEW

Recent advancements in Artificial Intelligence (AI), embedded systems, and Internet of Things (IoT) technologies have significantly improved the development of smart monitoring and surveillance systems. These technologies are widely applied in agricultural monitoring, wildlife observation, and security systems to enhance automation, efficiency, and real-time response capability.

2.1 Motion Detection Systems

Motion detection systems are commonly used in surveillance applications to identify movement within a monitored area. One of the most widely used technologies is the Passive Infrared (PIR) sensor, which detects changes in infrared radiation emitted by moving objects such as humans and animals. PIR sensors are preferred due to their low power consumption, low cost, and reliable detection capability. [11], [13].

Previous studies have shown that PIR-based systems are effective for automated monitoring applications; however, environmental factors such as temperature changes and airflow may occasionally produce false triggering. [11], [13]. Despite these limitations, PIR sensors remain suitable for event-driven monitoring systems because they reduce unnecessary processing and improve energy efficiency.

2.2 AI-Based Vision Systems

Artificial intelligence-based vision systems have enhanced the capability of modern monitoring systems by enabling automated object detection and classification. [8], [9]. Conventional camera systems typically require external processing devices to analyze captured images, resulting in higher processing time and increased power consumption.

Recent AI-enabled imaging technologies such as the Sony IMX500 integrate AI processing directly within the image sensor, allowing faster object detection and reduced computational load on the main controller. [7], [8]. This approach improves real-time performance and makes AI vision systems more suitable for embedded monitoring applications.

Object detection techniques based on deep learning algorithms, particularly convolutional neural networks (CNN), are widely used to identify animals, humans, and other objects within captured images. [9], [10]. Although advanced deep learning models provide higher detection accuracy, lightweight AI models are often preferred in embedded systems to balance performance, processing speed, and energy efficiency.

2.3 IoT and Remote Notification Systems

The integration of Internet of Things (IoT) technology enables monitoring systems to communicate with users remotely through internet-based platforms [3], [4]. Messaging applications such as Telegram provide Application Programming Interfaces (API) that support real-time notification delivery, including text messages and image transmission.

Compared to conventional SMS or email-based systems, Telegram offers lower implementation cost, faster communication, and easier integration with embedded platforms such as Raspberry Pi Raspberry Pi [14]. IoT-based communication systems improve monitoring efficiency by allowing users to receive alerts instantly regardless of their physical location.

2.4 Related Works and System Comparison

Several monitoring systems related to surveillance and motion detection have been developed using different approaches and technologies. Conventional CCTV-based monitoring systems utilize continuous video recording with high-resolution cameras connected to digital video recorders (DVR). Although such systems provide continuous monitoring capability, they require high power consumption, large storage capacity, and higher installation cost due to continuous operation. [3], [11], [13].

Another commonly developed solution is the IoT-based motion detection system using PIR sensors and microcontrollers such as Arduino or Raspberry Pi [3], [11]. These systems are capable of sending motion alerts through internet communication platforms. However, most PIR-based systems do not provide visual confirmation because they lack image-capturing capability, reducing monitoring reliability in real-world applications.

Compared to existing systems, the proposed project integrates motion detection, AI-based image capturing, and IoT notification into a single compact embedded system. The use of Raspberry Pi 4 Model B and Sony IMX500 enables real-time monitoring with lower power consumption through an event-driven operational approach. Table 1 summarizes the system comparison between previous systems and the proposed project.

TABLE 1

COMPARISON OF THE PREVIOUS

System	Technology Used	Advantages	Limitations
CCTV Surveillance System	CCTV + DVR	Continuous monitoring	High power and storage usage
PIR-Based IoT Monitoring	PIR + Microcontroller	Low cost and simple design	No visual verification
AI Camera Monitoring System	AI Camera + Embedded System	Object detection capability	Higher processing complexity
Proposed System	PIR + AI Camera + IoT	Real-time detection and notification	Dependent on lighting and internet connectivity

2.5 Research Gap

Recent studies have demonstrated that IoT-based monitoring systems are effective for detecting motion and transmitting alerts in agricultural environments. However, many existing systems rely solely on PIR sensors or conventional cameras without intelligent image analysis, making it difficult to distinguish between animals, humans, and other moving objects. This limitation often results in false alarms and unnecessary notifications, reducing the reliability of farm monitoring systems.

Although deep learning-based object detection has significantly improved detection accuracy, most existing implementations perform AI inference on external processors or cloud servers. Such approaches increase computational load, communication latency, bandwidth usage, and energy consumption, making them less suitable for remote or small-scale farms where network connectivity and power resources may be limited.

Commercial smart surveillance solutions provide advanced monitoring capabilities but are generally expensive, require continuous video recording, and consume considerable storage and electrical power. These factors limit their adoption by small-scale farmers.

Therefore, this study proposes an intelligent animal detection and notification system that integrates a PIR sensor, a Sony IMX500 edge AI camera, and Telegram-based IoT communication into a single embedded platform. Unlike conventional surveillance systems, the proposed solution performs AI inference directly on the image sensor, allowing only relevant detection results and captured images to be processed and transmitted.

The event-driven architecture, where the AI camera is activated only after PIR motion detection, further reduces unnecessary processing, lowers energy consumption, minimizes network bandwidth, and enables a low-cost, real-time monitoring solution suitable for smart farm security applications.

A key innovation of the proposed system is the use of the Sony IMX500 intelligent vision sensor, which integrates AI processing directly within the image sensor. Unlike conventional embedded vision systems that transmit captured images to the Raspberry Pi or a cloud server for analysis, the IMX500 performs AI inference at the sensor level. This edge AI capability reduces processing latency, lowers CPU utilization, decreases network bandwidth requirements, and improves the overall energy efficiency of the monitoring system. These characteristics make the proposed solution particularly suitable for real-time agricultural monitoring in resource-constrained environments.

III. METHODOLOGY

3.1 System Architecture

The proposed intelligent animal detection and notification system adopts an event-driven architecture consisting of three main modules: sensing, processing, and notification, as illustrated in Figure 1. The PIR sensor continuously monitors the surrounding environment for infrared radiation changes caused by moving objects. Upon detecting motion, the sensor outputs a HIGH logic signal to the Raspberry Pi 4 Model B through the GPIO interface.

The Raspberry Pi then activates the Sony IMX500 AI camera to capture an image and perform on-device AI inference [7]. If the detected object matches predefined animal classes, the captured image is stored temporarily and transmitted to the user via the Telegram Bot API over a Wi-Fi connection [5], [6]. Simultaneously, the red LED and buzzer are activated as local warning indicators, while the green LED indicates normal standby operation. After the notification process is completed, the system automatically returns to standby mode.

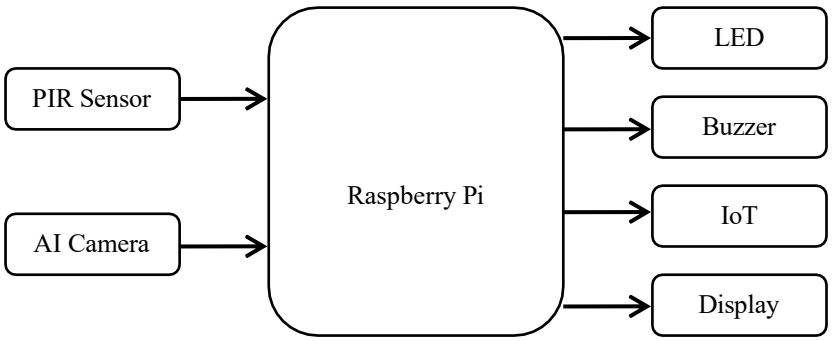


Fig. 1 Block Diagram of the module

3.2 Hardware Design

The hardware components used in this project include the Raspberry Pi 4 Model B, Sony IMX500 AI camera, PIR sensor, LEDs, and buzzer. The Raspberry Pi functions as the main controller responsible for processing sensor input and controlling system operations. The PIR sensor is connected to the GPIO input pin and acts as the primary motion detection device.

The green LED indicates standby mode, while the red LED and buzzer function as alert indicators during motion detection events. The AI camera is connected through the CSI interface of the Raspberry Pi to enable image capturing and intelligent monitoring.

The circuit was initially prototyped using a breadboard and jumper wires for testing and debugging purposes before being integrated into a compact prototype enclosure.

TABLE 2

HARDWARE SPECIFICATIONS

No.	Component	Specification	Function
1	Raspberry Pi	Raspberry Pi 4 Model B (4 GB RAM)	Main controller
2	AI Camera	Sony IMX500 Intelligent Vision Sensor	Image capture and AI inference
3	PIR Sensor	HC-SR501	Motion detection
4	Green LED	5 mm LED	Standby indicator
5	Red LED	5 mm LED	Alert indicator
6	Buzzer	Active buzzer (5 V)	Audible alert
7	Power Supply	5 V / 3 A USB-C	System power
8	Network	Wi-Fi IEEE 802.11ac	Internet communication

TABLE 3

GPIO ASSIGNMENT

No.	Device	Raspberry Pi GPIO
1	PIR Sensor	GPIO17
2	Green LED	GPIO22
3	Red LED	GPIO23
4	Buzzer	GPIO24
5	Sony IMX500	CSI Camera Port

3.3 Software Development

The software was developed using the Python programming language running on Raspberry Pi OS [15], [16], [17]. Several Python libraries were utilized for GPIO control, camera management, and Telegram communication.

The system software continuously monitors the PIR sensor input. When motion is detected, the system activates the AI camera, buzzer, and red LED. The captured image is analyzed to determine the presence of animals such as cats or dogs. If an animal is detected, the image is automatically transmitted to the user through the Telegram platform [14]. Figure 2 shows the software flowchart of the proposed system.

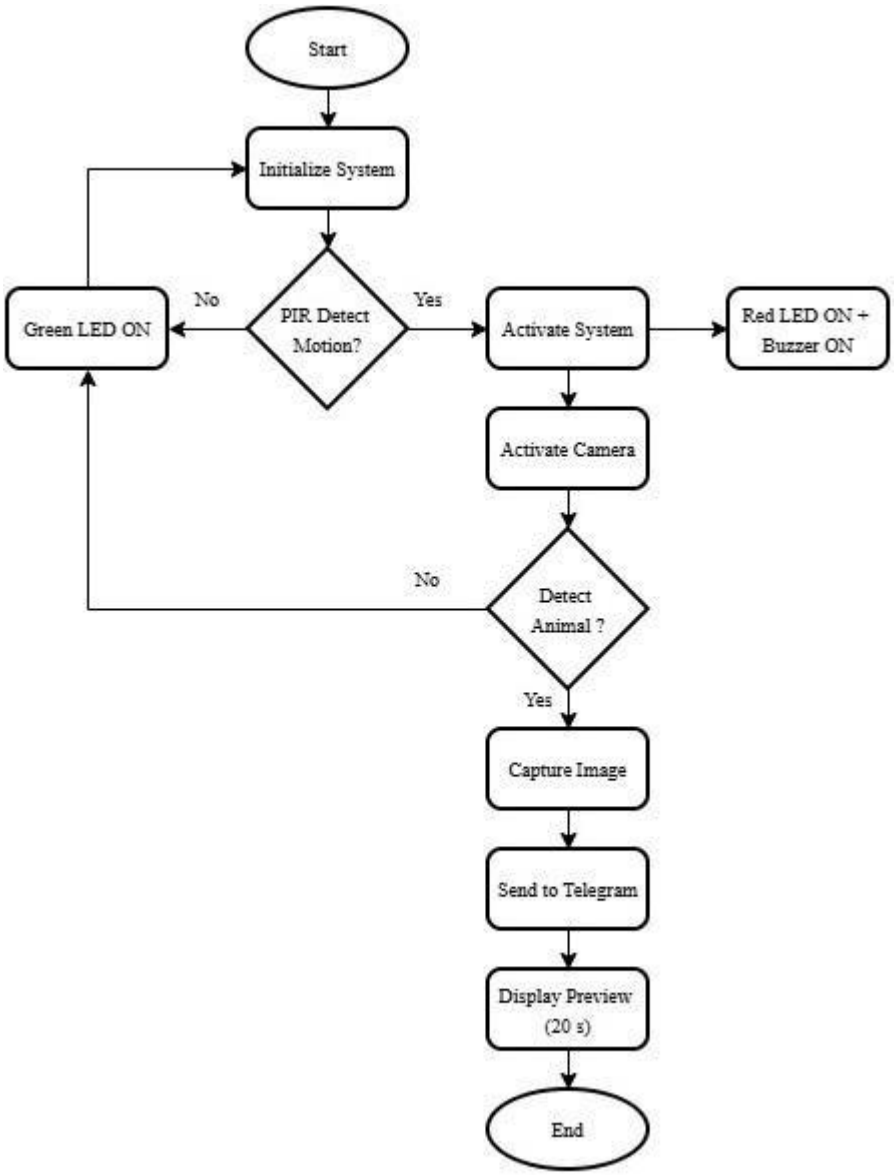


Fig. 2 Flowchart of the module/system

The operational flow of the system is summarized as follows:

1. System initialization
2. PIR sensor monitoring
3. Motion detection
4. AI camera activation
5. Animal detection and image capture
6. Telegram notification transmission
7. System reset to standby mode

3.4 Prototype Development

The prototype was developed by integrating all hardware and software components into a compact enclosure suitable for real-world monitoring applications. The arrangement of the PIR sensor, camera, LEDs, and buzzer was designed to ensure effective monitoring and alert functionality.

The system operates using an event-driven approach, where processing and monitoring functions are only activated when motion is detected. This method reduces unnecessary power consumption and improves overall system efficiency.



Fig. 3 Prototype Development for the system

IV. RESULTS AND DISCUSSION

The developed intelligent animal detection and notification system was evaluated based on motion detection performance, animal detection capability, response time, image capturing, and Telegram notification delivery. The testing process was conducted using the developed prototype consisting of the Raspberry Pi 4 Model B, Sony IMX500 AI camera, PIR sensor, LEDs, and buzzer.

The PIR sensor was calibrated to optimize motion detection accuracy and minimize false triggering. Experimental testing showed that the effective motion detection range of the sensor was approximately 3–5 meters. The sensor successfully detected movement and triggered the system consistently under normal operating conditions.

When motion was detected, the system activated the red LED and buzzer while simultaneously enabling the AI camera for object detection and image capturing. If an animal was identified, the captured image was transmitted to the user through the Telegram platform in near real time. The average system response time was recorded between 2 and 5 seconds depending on network connectivity and processing conditions. Table 1 summarizes the overall performance of the developed system.

TABLE 4

PERFORMANCE OF THE DEVELOPED SYSTEM

No.	Parameter	Result
1	Motion Detection Range	3–5 meters
2	Response Time	2–5 seconds
3	Image Capture	Successful
4	Telegram Notification	Successful
5	Animal Detection Accuracy	Approximately 85%
6	Power Consumption	Low

The results demonstrate that the proposed system is capable of performing automated monitoring and notification effectively. The integration of motion sensing, AI-based image processing, and IoT communication enabled efficient real-time monitoring suitable for small-scale agricultural applications.

Several challenges were identified during system testing. False triggering occasionally occurred due to environmental factors such as temperature variation and non-target movement. In addition, animal detection accuracy was reduced under poor lighting conditions or when objects were partially obstructed. These limitations indicate that the system performance is highly dependent on environmental conditions and camera visibility.

Another limitation involves dependency on internet connectivity for Telegram notification delivery. Weak network coverage may increase transmission delay and affect real-time monitoring performance. Despite these limitations, the system maintained stable operation during most testing conditions and successfully achieved the project objectives.

Compared to conventional continuous surveillance systems [3], [13], the proposed event-driven approach improves energy efficiency by activating processing functions only when motion is detected. This reduces unnecessary power consumption and processing load while maintaining effective monitoring capability.

Overall, the developed system demonstrates strong potential for real-world applications in farm monitoring, smart agriculture, and low-cost security systems. Future improvements may include enhanced AI detection models, infrared illumination for low-light operation, cloud storage integration, and multi-camera monitoring support [8], [9].

V. CONCLUSION AND FUTURE WORK

This paper presented the development of an AI-based animal detection and notification system for farm security applications using embedded system and IoT technologies. The proposed system integrates a PIR sensor, Raspberry Pi 4 Model B, Sony IMX500 AI camera, LEDs, buzzer, and Telegram communication platform to provide automated monitoring, real-time animal detection, and remote notification capability.

The developed system successfully achieved its primary objectives, including motion detection, AI-based image capturing, and real-time alert transmission through Telegram. Experimental results demonstrated that the system was capable of detecting motion within a range of approximately 3 to 5 meters and delivering notifications within a short response time of 2 to 5 seconds. The integration of AI-based image processing enabled the system to identify animals such as cats and dogs with satisfactory detection accuracy. In addition, the implementation of LED and buzzer alerts improved immediate local response capability.

Compared to conventional CCTV surveillance systems, the proposed system offers several advantages including lower power consumption, reduced storage requirement, compact design, and cost-effective implementation through event-driven operation. The integration of IoT communication also enhances remote monitoring capability, making the system suitable for small-scale agricultural and security applications.

Despite the successful implementation, several limitations were identified during system evaluation. Detection accuracy may decrease under poor lighting conditions, and notification performance depends on stable internet connectivity. Environmental factors may also occasionally affect PIR sensor sensitivity and system reliability.

For future work, several improvements can be considered to enhance system performance and functionality. Future development may include the implementation of more advanced AI detection models to improve object classification accuracy, particularly under low-light conditions. The integration of infrared or night-vision capability can also improve nighttime monitoring performance. In addition, cloud storage integration, mobile application development, and renewable energy sources such as solar power can be implemented to improve scalability, accessibility, and sustainability of the system.

Overall, the proposed AI-based animal detection and notification system demonstrates strong potential as an efficient, low-cost, and scalable smart monitoring solution for farm security and agricultural monitoring applications.

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