WSN application for crop protection to divert animal intrusions in the agricultural land

A major project report submitted in partial fulfilment of the requirement for the award of degree of

Bachelor of Technology

in

Computer Science & Engineering / Information Technology

Submitted by

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled "**WSN application for crop protection to divert animal intrusions in the agricultural land**" in partial fulfilment of the requirements for the award of the degree of B.Tech in Computer Science & Engineering and Information Technology and submitted to the Department of Computer Science & Engineering, Jaypee University of Information Technology, Waknaghat is an authentic record of work carried out by "Prakhar Singh(201194)", "Meghna Chaudhary(201286) and Nitin Saini(201308)" during the period from August 2023 to May 2024 under the supervision of Dr. Ravindara Bhatt, Associate Professor, Department of Computer Science and Engineering, Jaypee University of Information Technology, Waknaghat.

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CANDIDATE'S DECLARATION

We hereby declare that the work presented in this report entitled **'WSN application for crop protection to divert animal intrusions in the agricultural land'** in partial fulfilment of the requirements for the award of the degree of **Bachelor of Technology** in **Computer Science & Engineering / Information Technology** submitted in the Department of Computer Science & Engineering and Information Technology**,** Jaypee University of Information Technology, Waknaghat is an authentic record of my own work carried out over a period from August 2023 to May 2024 under the supervision of **Dr. Ravindara Bhatt** (Associate Professor, Department of Computer Science & Engineering and Information Technology).

The matter embodied in the report has not been submitted for the award of any other degree or diploma.

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LIST OF ABBREVIATIONS

WSN	Wireless Sensor Network
IOT	Internet Of Things
PIR	Passive Infrared Sensor
ETSI	European Telecommunications Standard Institute
USB	Universal Serial Bus
YOLO	You Only Look Once
CDPD	Cellular Digital Packet Data
API	Application Programming Interface
AI	Artificial Intelligence

ABSTRACT

The encroachment of wildlife onto agricultural lands poses a significant challenge in preserving crop fields, necessitating a proactive approach to observe and mitigate potential disturbances. This project addresses the persistent issue of protected animals such as deer, nilgai, and wild boar causing damage to crop arenas. Current methods have proven ineffective, prompting the proposal of an innovative system leveraging IoT technology tailored to deter and alert against wildlife intrusions.

The devised system aims to identify specific animals and emit deterrent sounds that discourage their presence, prompting them to retreat. Simultaneously, the system alerts authorized personnel by transmitting a notification. The implementation relies on an IoT-based network comprising motion detection devices strategically positioned around the farm. These devices communicate detected movements to a central controller via GSM modules. Upon detecting unauthorized entry, the system triggers an alert, notifying the farm owner through GSM calls.

To differentiate between authorized and unauthorized access, Radio-frequency identification (RFID) tags are utilized. This IoT-driven framework enhances habitat monitoring and building surveillance, capturing real-time data on environmental changes. Collected data pertinent to intrusion attempts is relayed to the farmer, enabling swift response measures. The integration of intrusion detection systems fortified by IoT technology serves as a vital tool for investigative purposes and preemptive security measures, ultimately safeguarding crop fields against wildlife incursions. This report explores the current landscape of IoT-based Intruder Recognition Systems, highlighting their relevance and efficacy in combating agricultural threats.

CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION

Agriculture sustains livelihoods globally, yet outdated farming practices have adversely impacted crop productivity. The looming threat of animal intrusion, coupled with the manual demands of large-scale irrigation, necessitates innovative solutions for sustainable agricultural practices. This project endeavors to harness IoT technology to combat these challenges effectively.

The persisting reliance on age-old farming techniques has resulted in diminished crop yields, adversely affecting farmers' livelihoods. Among the multiple factors contributing to this decline, animal intrusion stands out as a primary concern. The incursion of wild animals wreaks havoc on crops, causing significant financial losses for farmers. Additionally, the manual irrigation of expansive agricultural lands poses logistical hurdles and inefficiencies.

The proposed solution involves the deployment of an IoT-based application tailored to detect and repel animal intrusions, thereby safeguarding crops. Leveraging the interconnectedness afforded by IoT, this application integrates various smart devices, sensors, and actuators to facilitate real-time monitoring and response mechanisms.

The implementation of this IoT-based solution entails the strategic deployment of sensors across agricultural landscapes. These sensors, equipped with motion detection and environmental monitoring capabilities, identify and relay data regarding animal presence to a central control system. Upon detection of intrusions, the system triggers responsive actions, such as activating deterrent mechanisms or notifying farmers through alerts on their smartphones.

The integration of IoT technology into agricultural practices offers multifaceted advantages. By proactively detecting and deterring animal intrusions, the application safeguards crops, thereby preserving farmers' incomes. Moreover, the automated irrigation systems enabled by IoT streamline the management of vast agricultural lands, reducing manual labor and enhancing overall efficiency.

The convergence of IoT technology with agricultural practices presents a transformative opportunity to mitigate the challenges faced by farmers. By proactively addressing animal intrusion and optimizing irrigation processes, this IoT-based application holds the potential to revolutionize crop protection and enhance agricultural sustainability, empowering farmers for a more prosperous future.

1.2 PROBLEM STATEMENT

The agricultural sector plays a pivotal role in sustaining human populations by supplying essential food and raw materials. However, farmers worldwide grapple with the persistent challenge of safeguarding crops from animal intrusion, which leads to significant crop damage, reduced yields, and substantial economic losses. Traditional methods such as physical barriers and manual surveillance are labor-intensive, inefficient, and unsustainable in the long term.

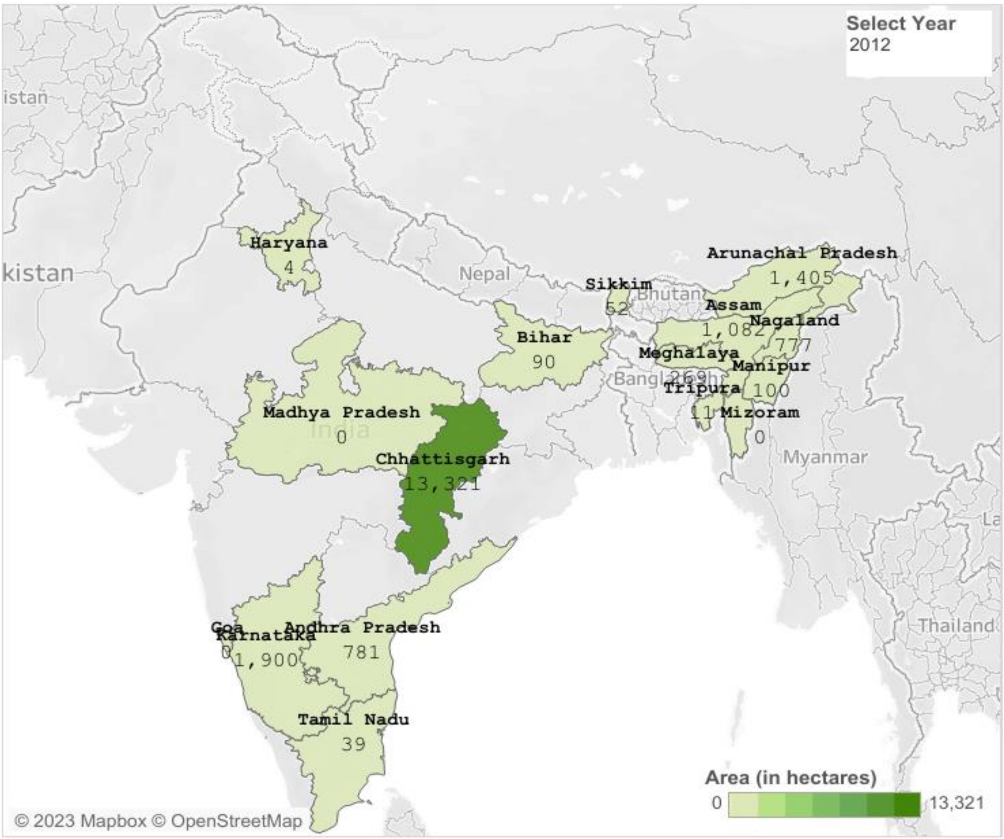

Fig 1.1: Crop Damage by Wild Animals [17]

Our project aims to tackle the pressing issue of animal intrusion in agricultural fields by leveraging Wireless Sensor Networks (WSNs) in an innovative manner. The envisioned solution strives to establish a technologically advanced system capable of swiftly detecting animal presence and initiating effective measures to protect crops. By amalgamating agricultural practices with modern technology, our goal is to fortify crop protection, diminish human intervention, and elevate overall agricultural productivity.

The primary challenge we aim to address is the development of an intelligent and dependable WSN application for real-time animal intrusion detection[4]. Standard sensor systems often lack optimization for agricultural settings and may generate false alarms due to environmental factors like wind or rain. Furthermore, the diverse range of animal sizes and behaviors complicates accurate detection. Therefore, crafting a WSN capable of distinguishing genuine threats from false alarms stands as a crucial aspect for the success of our project.

Beyond detection, our focus encompasses the implementation of an integrated solution. We plan to design a network comprising strategically positioned sensors to comprehensively monitor agricultural land. Upon detecting animal activity, the system will trigger appropriate responses, such as activating deterrent devices, sending alerts to farmers' mobile devices, or initiating automated scare tactics. Executing this aspect successfully necessitates a fusion of hardware expertise, algorithm design, and user interface development.

To achieve these objectives, we intend to utilize various resources, including specific hardware components like motion sensors, microcontrollers, and communication modules. Software resources will involve programming languages such as Python for data analysis, microcontroller programming, and user interface design. Simulation tools like Proteus will aid in virtually testing the system before its deployment in the field.

1.3 OBJECTIVES

- Construct a resilient Wireless Sensor Network (WSN) infrastructure with high precision capabilities to accurately detect and report instances of animal intrusions in designated areas.
- Employ sophisticated algorithms and intelligent analysis techniques to differentiate between genuine instances of animal intrusion and false alarms triggered by environmental factors or other non-threatening sources. This differentiation aims to minimize unnecessary interventions and maximize accurate responses.

- Develop a centralized control unit that is intuitive and user-friendly, allowing for real-time monitoring of the WSN data. This control unit should facilitate prompt and appropriate responses to detected intrusions, ensuring timely actions to mitigate potential crop damage caused by invading animals[7].
- Enhance the agricultural productivity of fields by implementing measures that effectively protect crops from the detrimental impacts of animal intrusions. This involves employing the WSN infrastructure and responsive actions to safeguard crops, ultimately contributing to increased yields and reduced losses due to wildlife interference.
- Identify specific species or types of invading animals detected within the fields and deploy targeted measures to deter their presence. These measures could include strategies to repel or discourage animals from accessing and damaging crops, thereby minimizing agricultural losses.
- Utilize an Internet of Things (IoT) system integrated with the WSN to actively discourage animal intrusions by employing non-harmful deterrents. Additionally, this system enables convenient and efficient monitoring of crop fields for any signs of intrusion, triggering user notifications through a user-friendly interface to ensure timely and informed responses.

1.4 SIGNIFICANCE AND MOTIVATION OF THE PROJECT REPORT

This project focuses on designing WSNs for farm security and monitoring. Such is a move that would transform traditional farming methods. This essentially means to put in place various technological methods of optimization for purposes of plant growth promotion and food security enhancement.

Currently in our farming areas there are crude securities like; stick and ropes this kind of insecure though it employs a lot of labour, can cause unwarranted results. Traditional methods may also be disturbing to some animals or people running away thus the need to keep them at bay. However, in an effort to improve on these weaknesses, WSN technology leveraged towards less invasive but more powerful monitoring and alarm system is adopted.

Essentially, such adaptation and affordability are among the reasons that make these network technologies the best fit for smooth incorporation in farming areas [2]. Significantly, it is an ethically-based technology that does not cause any problems or inconvenience of its own yet informs the farmer through SMS messages as well as the use of triggers and buzzers, which have been optimized for immediate practical operation.

This initiative was born out of pure curiosity about the unknown aspects of IoT. Not just a prepared journey, but an involved expedition that demanded innovativeness, troubleshooting, and application of conceptual ideas into practical solutions. The attraction was that it will allow more things to be discovered within the IoT world with a hope of being able to contribute fresh perspectives on the subject.

The technical objective of this project goes beyond the technical aspect, it is also about personal growth and skills development. It provides a unique chance to understand the complexity involved in building an IoT model for practical training and knowledge acquisition. This is an attempt that extended beyond mere exploration of the subject matter; it also sought to become a physical representation of passion and commitment.

In fact, this project is important on a much greater level than at the purely technical level. As a demonstration of interest and dedication towards learning about IoT technology, it serves as an essential milestone in deepening one’s understanding of this topic. Personal development, enhancing knowledge, and ongoing linkage between technology and agriculture.

1.5 ORGANIZATION OF PROJECT REPORT

Chapter 1: Introduction: A new way of sensing and quickly alerts on wildlife intrusions using up-to-date sensors, and machine learning. Aids offers total and regular guarding of your property in advance to prevent damage and preserve peace within your neighbourhood. Feel safe with our watchful guardian that ingeniously blended technology and nature.

Chapter 2: Literature Review: Literature on animal intrusion detection system stresses the need for reduction of human-wildlife conflicts. Research proves that sensor-based technology coupled with the machine learning algorithms alert the property owners in a short time of wildlife existence near properties. One important finding from this literature review is that more and more people need to take preventative measures aiming at maintaining human security as well as conserving nature.

Chapter 3: System Development: Developing the Animal Intrusion Detection System that will use advanced sensors in conjunction with machine learning algorithm to sense wild life activities in live time. Through iterative testing and refining, this technology provides precise and reliable performance whereby only correct alarms are delivered to property owners.

Chapter 4: Testing: The testing of Animal Intrusion identification system also involves a careful evaluation of sensor accuracies and algorithms effectiveness for accurate identification of as many types of animals as possible. This field testing creates confidence in its effectiveness and ensures that the system will work properly under different environmental conditions by recreating real life scenarios. Such constant improvements to the system are designed to maximize outputs and lower false positives.

Chapter 5: Result and Evaluation: Thorough testing reveals that our Animal Intrusion Detection System reliably senses any intrusion by wildlife, providing a sensitive and accurate warning signal to users. It is effective at minimizing on false positives hence enhancing the reliability of the system thus providing a robust property protection solution. The effectiveness of the system was affirmed by the evaluation findings which guarantee users that it reduces encounters of humans with wildlife.

Chapter 6: Conclusion and Future Scope: At last, one can say that the Animal Intrusion Detection System is an efficient, forward-looking solution towards protecting property from wild animal trespasses. The future work should involve improving the precision of some of the existing algorithms, exploring wireless communication, and extending the scope of the present applications for conservation of wild species in the field of ecology. This approach facilitates improvements in the co-habitation of human settlements with animal preservation.

CHAPTER 2: LITERATURE SURVEY

2.1 OVERVIEW OF RELEVANT LITERATURE

2.1.1 INTRODUCTION

India, renowned for its agricultural heritage, relies heavily on this sector for sustenance and economic stability. However, despite its significance, farmers grapple with numerous challenges that hinder their livelihoods. Among these, human-animal conflict stands as a critical issue, leading to substantial resource depletion and jeopardizing human lives.

The escalation of human-animal conflicts in recent times poses a pressing concern that necessitates continuous monitoring and preventive measures. Encroachments into animal habitats, poaching activities, expansion of agricultural lands, and rapid industrialization contribute significantly to this conflict. The resulting urban sprawl encroaches upon natural habitats, compelling animals to venture into nearby villages in search of water during dry spells, especially in the summer.

Instances of elephants and wild boars ravaging farmlands for sustenance further exacerbate this conflict[9]. The pressing needs of both humans and animals often lead to perilous encounters, causing substantial damage to resources and, tragically, sometimes resulting in loss of life. South Asia and Africa, in particular, witness a higher prevalence of human-elephant conflicts.

Efforts to safeguard farmlands against animal intrusion involve the installation of protective measures such as electric fences. However, animals attempting to breach these defenses often display abnormal behaviour, adding to the complexity of the situation.

Addressing this conflict demands a multifaceted approach involving enhanced monitoring, sustainable land use practices, and innovative solutions to minimize human-wildlife encounters. Collaborative efforts between communities, agricultural experts, and conservationists are crucial to striking a balance between human needs and wildlife preservation, ensuring the safety and sustainability of both.

2.1.2 A SUMMARY OF THE RELEVANT PAPERS

Sr. No.	Paper No.	Key Findings	Limitations
1	1	High accuracy in identifying intrusions using deep learning (97% precise accuracy).	Still in its infancy for real-time applications and requires further improvements for better real-time capabilities and performance.
2	2	High accuracy achieved by Kasongo's IDS (97.1%) and Use of advanced datasets like UNSW-NB15 for evaluating IDS effectiveness.	Reliance on outdated datasets (NSL-KDD) and Lack of consideration for both performance and security issues in some works.
3	3	Superior performance of Single Shot Detection (SSD) algorithm and Potential in protecting crops from animal intrusion.	No explicit mention of limitations and Effectiveness may vary based on specific conditions.
4	4	Efficient identification of humans, elephants, and tigers and High efficiency rates in animal identification.	Instances of misidentification and Performance in different conditions not evaluated.
5	5	Automatic detection of intruders. Different levels of alerts based on intruder danger	No explicit mention of limitations and Effectiveness may depend on sensor range and accuracy.

6	6	Effective border intrusion detection and video surveillance and Differentiation between human intruders and objects.	Data security concerns and Efficiency on large-scale border security not assured.
7	7	Use of sensors and cameras for intrusion detection Integration of GPS and GSM technologies.	Range limitations and Reliance on battery and solar power for camera operation.
8	8	Reduction in crop damage observed by farmers Detection and alert provision for animal intrusions.	Potential technical faults and Effectiveness dependent on circuit operation.
9	9	Improved detection accuracy using CNN and classifiers and Automatic feature extraction eliminating manual effort.	No explicit mention of limitations and results dependent on specific datasets.
10	10	Comprehensive IDS implementations for IoT security and Anomaly detection techniques showing promise.	Challenges with antivirus software for smart devices and Computational limitations of RFID technology.
11	11	Radar and WSN-based system preventing wildlife collisions and Accurate detection and tracking capabilities.	Limitations of ultrasound modules and False alarms by passive infrared sensors.

12	12	Potential benefits of WSN in border surveillance and Elimination of human intervention in information gathering.	Challenges with low processing power and battery life and Communication reliability concerns.

Simla, A.J. et al. [1], Introduced a system utilizing IoT and deep learning with an enhanced lightweight M2M protocol for high-accuracy animal intrusion detection. Utilized datasets with various animal classifications. However, the proposed system lacked testing in real-world scenarios.

Z. Chiba et al. [2], Conducted an in-depth study on eleven novel IDS/IPS between 2019 and 2022, exploring the adoption of advanced datasets and new ML/DL algorithms. The paper comprehensively analysed emerging IDS/IPS technologies without specifying explicit limitations.

K Balakrishna et al. [3], Demonstrated the use of IoT and AI technologies for crop protection using a database with 300 animal image datasets. Implemented an SSD-based detection algorithm for real-time animal classification through IoT. However, potential limitations included data bias, scalability issues, and the absence of detailed cost analysis.

Suman, P. et al. [4], Developed a system relying on light reflection in fibre optic cables and ML algorithms for animal identification. Tested the efficiency of the optical fibre cable sensor setup but highlighted challenges regarding generalizing ML models to diverse farm environments and addressing cost and energy consumption aspects.

S. Yadahalli et al. [5], Presented a system employing PIR sensors, ultrasonic sensors, cameras, GSM modules, and buzzers for detecting and alerting farmers about intrusions. While the system showcased multiple functionalities, its limitations revolved around scalability, power requirements, false positives/negatives, and implementation costs.

N. Bhadwal et al. [6], Integrated sensors, cameras, hardware, and software to create a smart border surveillance system focusing on improved security, cost-effectiveness, and resource savings. However, challenges included initial costs, maintenance, potential false alarms, and ethical concerns regarding automated response measures.

P. Prajna et al. [7], Employed PIR sensors and cameras at field borders, utilizing a wireless sensor network for animal intrusion detection. Successfully detected animal intrusions and classified animals through image processing. Limitations included challenges in accurate animal classification and the possibility of false alarms.

V. Bapat et al. [8], Utilized PIR sensors, sound generating devices, light flashers, and RF modules for crop protection. While capable of preventing crop damage and providing timely alerts, the system faced challenges such as false alarms, sensor maintenance, and cost considerations during implementation.

W. Xue et al. [9], Utilized UWB signals collected from different targets for effective human and animal invasion detection. Highlighted challenges related to the influence of various environmental factors on UWB signals.

A. Gendreau et al. [10], Explored the importance of Intrusion Detection Systems in IoT networks for security. Discussed limitations revolving around the early stage of IoT security development, vulnerabilities of IoT devices, and the lack of security awareness among users.

F. Viani et al. [11], Developed a system integrating radar technology, wireless communication, and field testing for effective wildlife movement detection. Identified limitations related to environmental noise, sensor sensitivity, and power consumption.

E. Felemban et al. [12], Implemented intrusion detection algorithms within wireless sensor networks for cost-effective surveillance. Highlighted limitations such as limited communication range, power constraints leading to battery issues, and potential data security vulnerabilities.

2.2 KEY GAPS IN THE LITERATURE

Throughout the literature surveyed, a notable recurring gap revolves around the absence of real-world testing for the proposed agricultural intrusion detection systems. The lack of comprehensive field-based validation casts uncertainties on the practical applicability and reliability of these systems in diverse agricultural settings. Real-world scenarios are essential for evaluating system performance amidst the complexities, variabilities, and challenges inherent in agricultural environments, weather conditions, and diverse animal behaviour.

In the reviewed papers:

1. "**Simla, A.J. et al. [1]** emphasized the necessity of testing the proposed system in actual agricultural landscapes to determine its practical effectiveness.

2. **Z. Chiba et al. [2]** discussed various IDS/IPS systems without explicitly addressing their limitations or suggesting areas for improvement.

3. **K Balakrishna et al. [3]** acknowledged potential data bias, scalability concerns, and the lack of detailed cost analysis, potentially impacting practical implementation.

4. **Suman, P. et al. [4]** raised concerns regarding generalizing machine learning models to diverse farm environments and the need to address cost and energy consumption aspects in implementing smart fence solutions.

5. **S. Yadahalli et al. [5]** highlighted scalability, power requirements, and cost-related challenges during practical implementation, indicating potential issues in adapting the proposed system to various agricultural settings.

6. **N. Bhadwal et al. [6]** identified limitations related to initial costs, maintenance, false alarms, and ethical considerations, affecting system feasibility and sustainability.

7. **P. Prajna et al. [7]** implied limitations in accurately classifying animals through image processing and the potential for false alarms, questioning the system's reliability in differentiating intrusion types.

8. **V. Bapat et al. [8]** identified challenges during implementation, such as false alarms, sensor maintenance, and cost considerations, posing barriers to practical deployment.

9. **W. Xue et al. [9]** acknowledged limitations related to environmental factors impacting Ultra-Wideband (UWB) signals used for intrusion detection, raising concerns about system reliability under varying conditions.

10. **A. Gendreau et al. [10]** highlighted limitations in IoT security development, device vulnerability, and insufficient security awareness among users, emphasizing the need for a robust security framework.

11. **F. Viani et al. [11]** mentioned issues such as environmental noise, sensor sensitivity, and power consumption affecting system reliability and accuracy.

12. **E. Felemban et al. [12]** pinpointed limitations in communication range, power constraints leading to battery issues, and potential data security vulnerabilities within Wireless Sensor Network (WSN) technology, potentially affecting system effectiveness and reliability.

CHAPTER 3: SYSTEM DEVELOPMENT

3.1 REQUIREMENTS AND ANALYSIS

3.1.1 WHAT IS IOT?

The Internet of things (IoT) entails billions of physical devices deployed globally that relate to one another, accumulating, and sharing data as they go. It facilitates integration of objects as little as tablets and as big as air planes and autonomous vehicles into the Internet of things. They have the ability to sense and share data nonstop bypassing humans and thus connecting the virtual and actual worlds.

This was first conceived in the discussion about embedding sensors and data in everyday items in the 1980's and early 1990's. Nevertheless, the realization of such a notion was greatly impeded mainly by the lack of technology, especially in the area of connection speed and computing resources. Largely, this was due to the fact that the required level of technological maturation had not been reached.

The processors had to be efficient and powerful as there were advancing technologies on processors which could be useful for transferring information among billions of devices. This is partly addressed by the introduction of RFID tags which consist of low power chips that transmit information wirelessly. In addition, greater accessibility for cellular and broadband internet, as well as upgrades made towards improved network infrastructure were critical factors that led to the development of IoT connectivity.

One of the major milestones towards IoT came about with the implementation of Internet Protocol version 6 (IPv6), which is a network protocol offering lots of IP addresses for different devices. This opened up more IP addresses for connecting multiple devices into the Internet of Things and allowed a unique address to be assigned to every one of these machines[11].

In 1999, Kevin Ashton came up with the word "Internet of Things". However, it took nearly a decade before the technology conformed to the dream scenario and started being implemented and adopted widely.

3.1.2 WHY IOT?

IoT is a concept that includes devices like cars, home appliances and other pieces of equipment that possess some actuators or sensors or both, hardware, software and means for their interconnection and data exchange through the Internet or networks or both the Internet and networks.

The opportunity afforded by connecting or controlling such intelligent objects is made possible via enormous progresses in data technology – IoT. This development would therefore lead towards improved productivity, generate economic rewards, and minimize the use of manual labour. Indeed, it is considered among the greatest inventions of the twenty first century which expands beyond ordinary computer networks and smart phones to encompass other non-web enabled equipment.

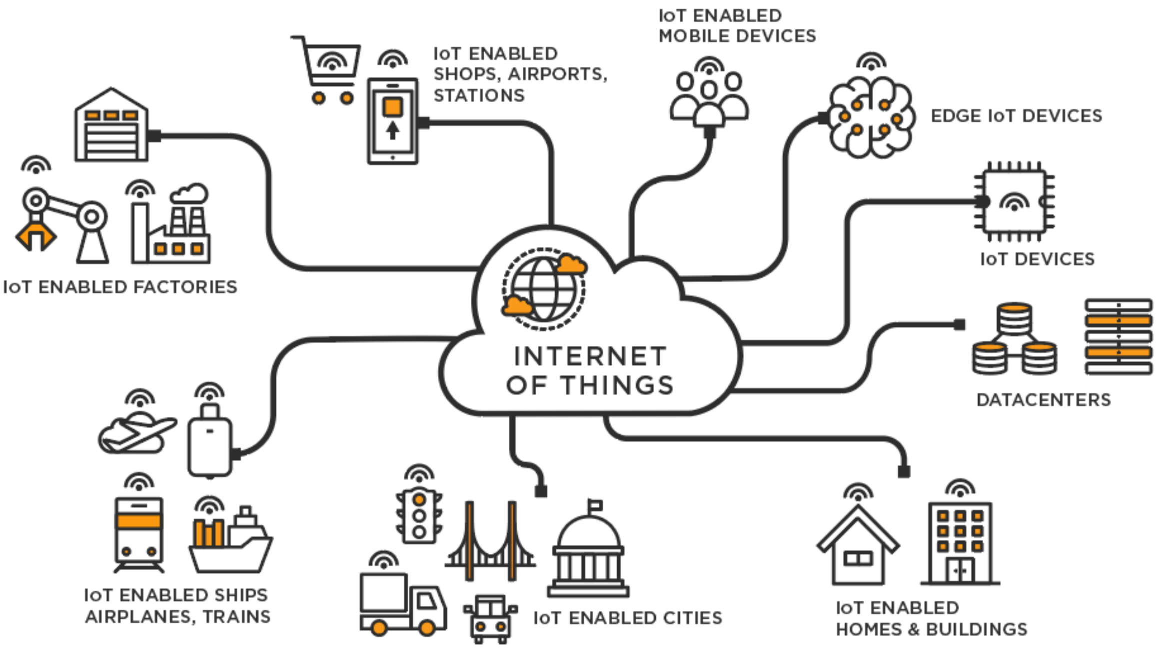

Fig 3.1: Internet of Things applications [19]

With Internet of Things (IoT) integrated into these devices, they can now communicate with each other and share information. This results in connected nature that enables remote monitoring and measurement. As a case in point, IoT incorporation in automobile industries has made it possible to invent driverless cars that are capable of moving on their own.

3.1.3 EASE TO LIFE

The present-day world that relies heavily on technology sees IoT as a huge shift in our lifestyles. It presents space for integration of various informational systems hence creating intelligent services useful in different business activities/processes. The Internet of Thing is gaining prominence and many new-age smart phones, home devices and even embedded applications are becoming more interconnected with the web. Nevertheless, the existence of a globally connected people implies that human connection will never remain as such and is currently being enhanced via this interconnectivity. This is done by analysing huge data collected as input and then uploading or storing the same in the clouds. Many companies have undergone rapid growth as a result of the impact of the digital era.

Without doubt, IOT is one of the biggest platforms capable of improving so many things in our everyday life. Today, many of these devices that have not been hooked up to the internet can be networked and work as if they are new. By 2020, the realm is projected to be entirely IoT-enabled, presenting several advantages:

- IoT optimizes resource utilization.
- It minimizes humanity effort in many aspects of daily living.
- The cost of production in manufacturing field will reduce, leading on increase in profitability with intelligent IoT.
- It also enhances decision making.
- It is of great importance in ensuring that goods are sold away easily.
- Provides a superior customer experience.
- Ensures strong data assurances and secure processing.

Because of the complex configuration of IoT we stress the positive aspects of Internet technology, including its means to ensure that user’s privacy right is adequately protected. IoT forms an intricate element of our technology that is now an indispensable part of our lives and helps make every moment we enjoy more pleasant. To the extent that IoT benefits everybody irrespective of whether one likes using technology or not, the domain where significant development takes place is here. response: However, as IoT benefits the whole world including those who do not like technologies, the area of notable improvements occur here.

Through connecting billions of devices that used to be isolated, IOT is spearheading several changes into our life. Such a vast connection also generates huge amounts of comprehensive information and simplifies many routine actions. With IoT we can work better, live more smartly and effectively manage ourselves with our health as a silent backdrop.

3.1.4 HARDWARE REQUIREMENTS

3.1.4.1 ARDUINO UNO

The Arduino Uno is a prominent microcontroller board centred around the ATmega328P (datasheet), serving as the fundamental component of various electronic projects. Its architecture includes several integral features:

- **Pin Configuration:** The Uno board boasts a total of 14 digital input/output pins, with 6 of them adaptable for PWM (Pulse Width Modulation) outputs. Additionally, it offers 6 analog inputs for data.
- **Clock Speed:** Operating at a frequency of 16 MHz, the Uno incorporates a quartz crystal to regulate its timing.
- **Connectivity Options:** Equipped with a USB interface, a power jack, an ICSP (In-Circuit Serial Programming) header, and a reset button, the Uno provides multiple means of connection and programming.
- **Versatility in Powering:** This board can be powered through a USB connection, an external 9-volt battery, or an AC-to-DC adapter, supporting voltages within the range of 7 to 20 volts.

The Uno board's versatility allows users to experiment and manipulate its functionalities without the fear of damaging the core microcontroller. In case of errors or experimentation mishaps, the microcontroller chip can be easily replaced for a nominal cost, enabling users to restart their projects swiftly.

The name "Uno" originates from the Italian word for "one." It represents the initial version of the Arduino board and the 1.0 iteration of the Arduino Software; both designed to simplify and streamline the programming and utilization of the board for a broader audience.

Over time, Arduino has evolved into a cornerstone within the realm of electronics, facilitating numerous projects, ranging from simple educational endeavours to complex scientific instruments[6]. Its open-source nature has fostered a global community of creators, including students, educators, professional engineers, software developers, and enthusiasts. Their collective contributions have amassed an extensive repository of accessible information, serving as invaluable resources for learners and experts alike.

Technical Specifications and Capabilities:

- The Arduino Uno utilizes the ATmega328P microcontroller and is developed and maintained by Arduino.cc.
- It comprises a range of digital and analog input/output pins, enabling connections to various peripheral devices and customized circuits.
- Featuring 14 digital I/O pins (six of which support PWM), 6 analog I/O pins, the Uno is programmable using the Arduino IDE through a Type-B USB connection.
- Power options include USB connection, an external 9-volt battery, or a power supply ranging between 7 to 20 volts.
- Comparable to other Arduino models like the Arduino Nano and Leonardo, the Uno board operates under the Creative Commons Attribution Share Alike 2.5 license, ensuring its accessibility and openness on the Arduino website.

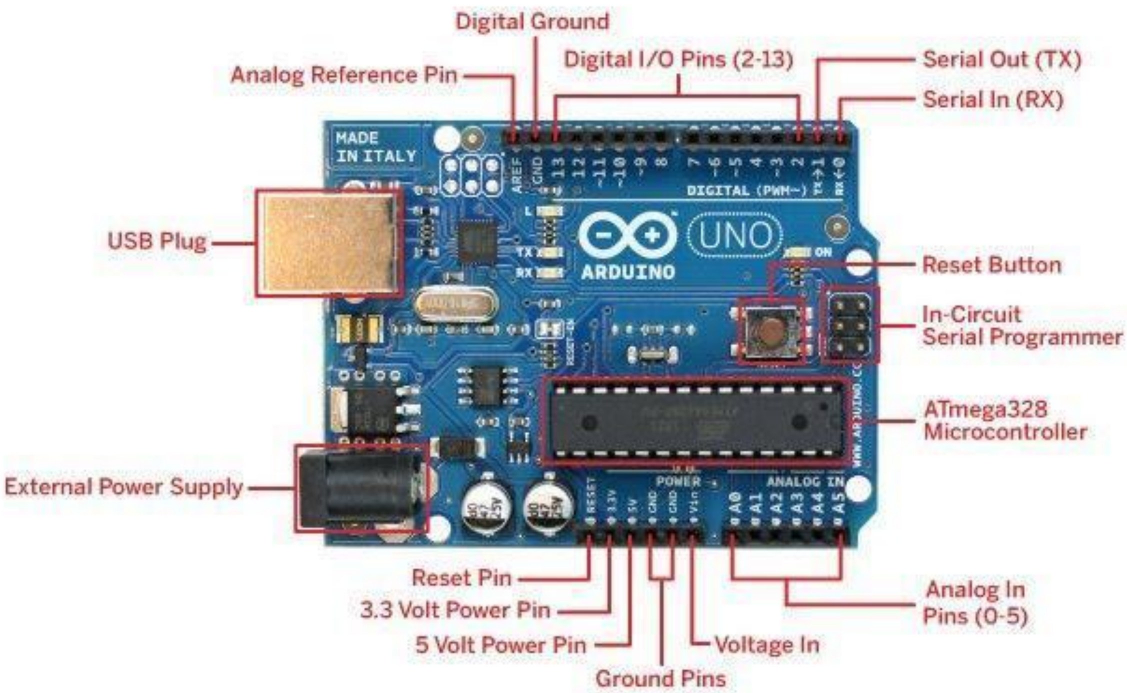

Fig 3.2: Arduino Uno

The Uno board, marking the inception of USB-centric Arduino boards, coupled with version 1.0 of the Arduino IDE, set the foundation for subsequent iterations, ushering in newer releases and advancements in the Arduino ecosystem.

This board's ATmega328 chip comes pre-programmed with a bootloader, allowing users to upload new code without requiring an external hardware programmer. Additionally, the Uno board, while using the STK500 protocol for connectivity, differs from its predecessors by employing the Atmega16U2 (or Atmega8U2 in version R2), programmed as a USB-to-serial converter, instead of modifying the serial driver chip from USB to FTDI.

3.1.4.2 ULTRASONIC SENSORS

Ultrasound transducers, also known as ultrasonic devices, represent a sophisticated remote acoustic sensor comprising three fundamental elements: transmitters, receivers, and transceivers. Transmitters convert electrical signals into ultrasound waves, receivers transform ultrasound into electrical signals, and transceivers have the capability to both transmit and receive ultrasound waves.

Fig 3.3: Ultrasonic Sensor

These components are pivotal in various applications, including sonar radar systems that utilize ultrasound transducers to examine distances by analysing reflected signals. For instance, by calculating the time lapse between signal transmission and receipt of the echo, precise measurements of an object's distance can be determined. Additionally, ultrasonic sensors, primarily receivers, detect available ultrasonic waves under specific conditions.

Applications and Functions:

The applications of ultrasound sensors are diverse and multifaceted:

- **Measuring Wind Speed and Liquid Levels:** Ultrasound is adept at measuring wind speed, liquid levels in tanks or channels, and velocity in air or water. Utilizing different sensors, the device records speeds based on the particle motion observed within the surrounding environment or in water.
- **Monitoring Fluid Levels and Tide Control:** Sensors gauge the distance outside the fluid to determine liquid levels in reservoirs or channels, along with sea level variations (tide control).
- **Other Diverse Applications:** Ultrasonic sensors find usage in humidifiers, depth sounders, medical ultrasound, security systems, non-destructive testing, and wireless charging. Typically, these applications employ transducers that emit sound waves in the ultrasonic range, above 18 kHz, altering electrical impedance within the sound. Subsequently, modifications in resonance translate sound waves into measurable electrical signals.

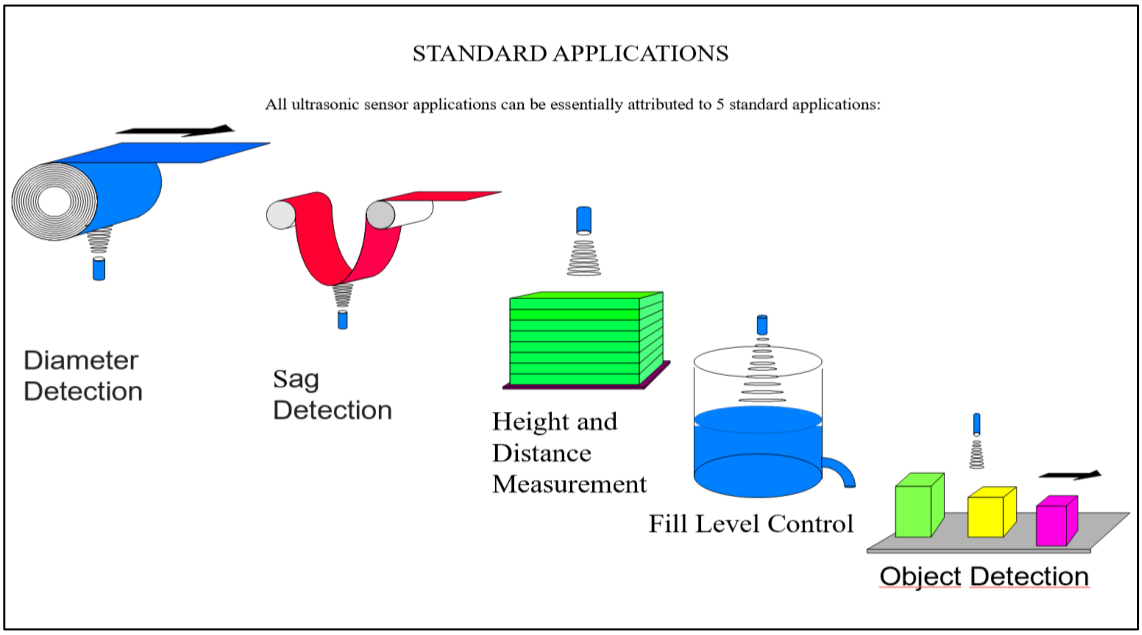

Fig 3.4: Applications of the Ultrasonic Sensor

Moreover, advancements in ultrasound technology enable precise measurements and location tracking of objects. For instance, the method of Sono micrometry involves transmitting and receiving discrete bursts of ultrasound between transducers. By accurately measuring the time taken for the ultrasound signal and performing mathematical computations, this method determines distances between transducers, allowing for highly accurate temporal and three-dimensional measurements.

Technical Insights:

- Ultrasonic sensors often utilize piezoelectric or capacitive transducers to convert AC into ultrasound waves. Piezoelectric crystals change shape and generate ultrasonic sound waves when subjected to an AC voltage.
- Capacitive transducers exploit electrostatic interactions between a conductive membrane and a backing plate to generate ultrasonic waves. The transducer's characteristics, such as size, shape, ultrasound wavelength, and speed of sound in the medium, affect the transmitted sound fields.

Table 1: Specifications of Ultrasonic Sensor

PARAMETER	**VALUE**
Sensing Range	40cm to 300 cm
Target dimensions from maximum distance	5cm x 5cm
Accuracy	+-1.5%
Resolution	1mm
Beam Angle	Approximately 5 degrees
Sensor Output	0V to 10V (DC)
Ultrasound Frequency	120KHz
Weight	Approximately 150g

Ambient Temperature (compensation)	-25 to +70 degree Celsius
Operating Voltage	20V to 30V (DC)
Vibrating Stress	11 to 55 Hz, 1mm amplitude
Shock stress	30g, 18ms
Degree of protection	IP 65

- These transducers exhibit varying behaviour in response to external factors; for instance, materials that change size under an electromagnetic field function as balanced transducers. Capacitive transducers, known as condenser speakers, feature a responsive membrane that reacts to ultrasonic waves, altering electric current signals, which are then interpretable.
- Additionally, miniaturized silicone processing aids in the assembly of these sensors, particularly in bonding transducer components.

3.1.4.2 PASSIVE INFRARED SENSOR

A PIR refers to a passive infrared sensor, which is an electronic equipment that detects radiation heat emitted by objects in the sensor's line of sight. PIR-based motion detectors use these sensors as a major element[1]. PIR-based sensors are extensively used for security alarms, and auto switching lights where they can recognize general motion, but not determine the target's features and essence. Therefore, it requires a functioning IR system as operation.

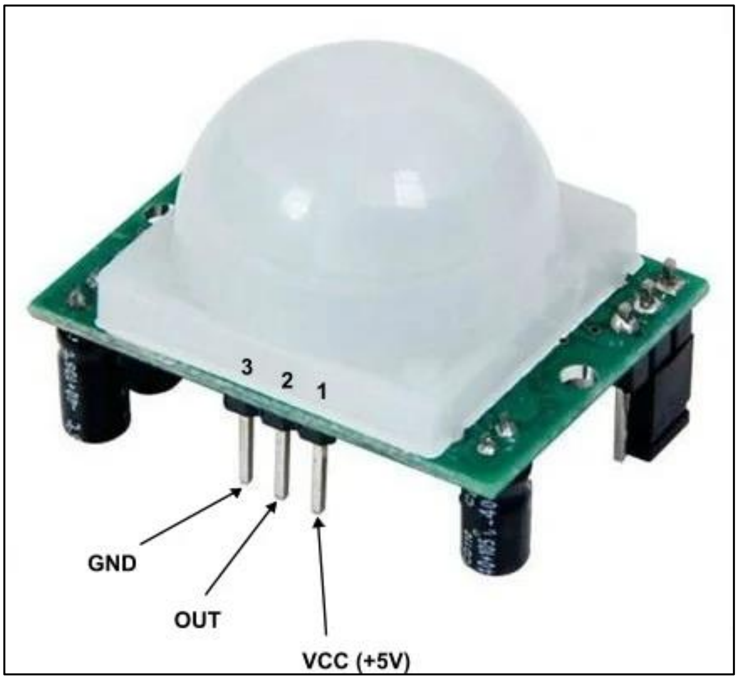

Fig 3.5: PIR Sensor

The most common name used to refer to the PIR is PIR, although sometimes it is also called PID – meaning Passive Infrared Detector. The passive nature of the devices underscores their mode of operations that involve the detection of emitted infra-red radiation-heat from objects. All objects having temperatures greater than absolute zero emit heat radiation. This radiation is not visible with bare human eyes since it operates in infrared spectrum, but there are many electronic instruments which can be able to detect, see, and interpret it.

A PIR motion detector in this case applies and helps determine whether it is just people, animals or even items that have moved. Burglar alarms coupled with simultaneously triggered lighting are some of the common applications of these instruments.

Operations of PIR (Passive Infrared Sensor):

- A PIR device operates by detecting changes in the amount of infrared radiation it receives, which varies based on the temperature and surface characteristics of objects within its sensing range.
- For instance, when an object, such as a person, moves in front of the sensor, like passing by a wall, the temperature in the sensor's field of view changes from the ambient temperature to the object's temperature and then returns to the ambient level.

- These alterations in the sensor's environment result in a change in the incoming infrared radiation, which in turn causes a shift in the output electrical signal of the sensor.
- Objects with similar temperatures but different surface properties may emit different patterns of infrared radiation. As a result, when these objects move within the sensor's detection range, they can trigger the sensor based on their unique infrared emission characteristics.

Table 2: Specifications of PIR Sensor

PARAMETER	**VALUES / MEASURES**
Model Number	BS007
Description	Passive Infrared Sensor Modules
Operating Voltage	DC 5V~20V (DC 3V~5V is optional)
Static Power Loss	$\leq$ 50uA
Delay Time	30 secs (0.5 ~900 secs are optional)
Detecting Range	$\leq$ 110 degrees cone angle
Triggers Way	Continuous triggering, discontinuous triggering
Blockade Time	0.5s – 50s (acquiescently 0 seconds)
Output Type	High level / low level / TTL is optional
Light sensor	No, depend on customer requirement
PCB Dimension	24*32 mm

PIRs are offered in different setups for particular tracking activities. # The standard models have various Fresnel lenses or reflective pieces at about 10 meters in effective range and under than 180 degrees for detection angle. Prototypes that are advanced allow wider detection zone, usually for ceiling mounting and may reach up to 360 degrees field of vision. Single piece mirrors are used for bigger PIR sensors that can identify changes of infrared energy at distances of more than thirty meters. Furthermore, PIR units combined with adjustable lens cover have provided either wide coverage of up to 110 degree or specific sections for selective areas to designate a desired zone for detecting activities.

Most of the time, a PIR device is mounted on a PCB which contains vital elements used in interpreting signals. Everything is usually placed on one place inside a housing installed at the best point for the sensor's visibility.

Most PIR motion sensors are designed using a window that is hinged, allowing an unobstructed passage of the infrared radiation. Although this window lets infrared radiation pass while remaining transparent to visible light, it does not transmit visible radiation.

The presence of a flexible window serves several crucial purposes, notably reducing the likelihood of foreign objects like dust or insects obstructing the sensor's field of view. This obstruction could potentially compromise the sensor's functionality and trigger false alarms. Additionally, the window can act as a filter, restricting the wavelengths to the range of 8-14 micrometres, which closely aligns with the infrared radiation emitted by humans. It may also serve as a protective element for the sensor.

3.1.4.3 SIM900 GSM/GPRS MODEM W/RS232

GSM:

The GSM (Global System for Mobile Communications), initially known as Groupe Special Mobile, emerged as a standard developed by the European Telecommunications Standards Institute. It was specifically formulated to establish protocols for second-generation (2G) cellular networks used by mobile phones and remains the prevailing global standard for mobile communications. Currently, GSM technology holds a dominant position in the mobile communications arena, boasting over 90% market share across 219 countries and regions.

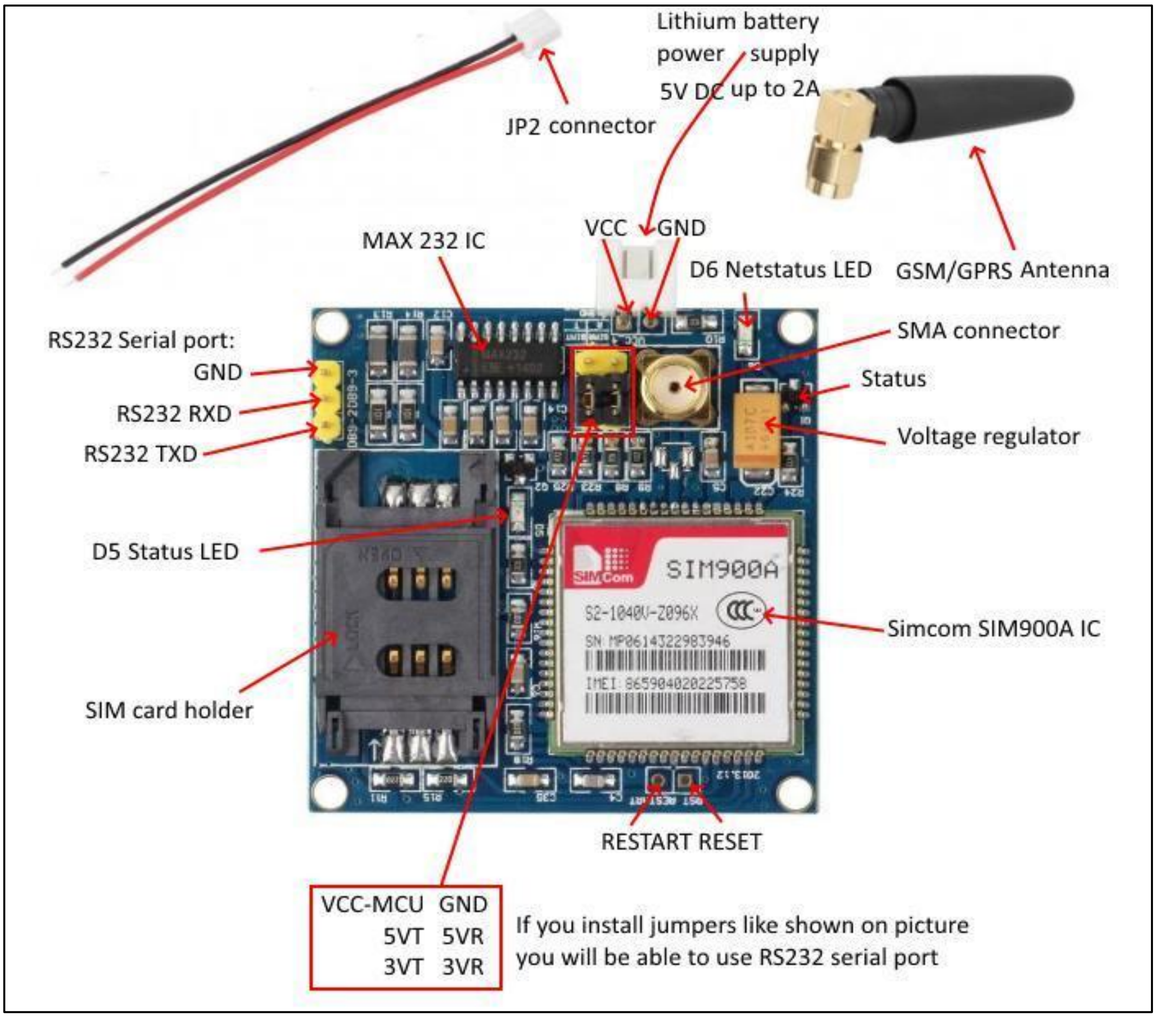

Fig 3.6: GSM Module

As a matter of fact, GSM technology covers quite many functions you will find in mobile phones and they can be accessed on computers. This involves facilitating conversations by way of calls as well as SMSs or MMS. GSM technology also concentrates mostly on such computerized message services as SMS and MMS that can offer diversified communication functions through digital devices.

GRPS:

GPRS refers to a structured and optimised data connection in GSM and 2 G/3G cellular communications systems. The initial stages of development of GPRS were undertaken by the European Telecommunications Standard Institute (ETSI)[3]. This built on advancements such as CDPD (Cellular Digital Packet Data) and packet-switched cellular technologies. The 3GPP takes charge of today.

A vital channel or circuit that links and helps in transmission of data between a mobile phone or computing device and a GSM or GPRS network is the GSM or GPRS module. The most important part of this system is the modem. These units normally come with a GSM module or GPRS modem that includes an embedded power supply and serial interfaces such as RS-232, USB 2.0, etc. specifically built for communications between PCs. It can become a separate device being connected via a serial port, USB port, or Bluetooth. It can also operate wirelessly giving functions of GSM modem.

Application:

These systems encompass all the functionalities typically associated with a mobile phone but are accessed through a computer interface. Such capabilities as placing and receiving calls, sending and receiving SMS and MMS. First, they are mainly applied in mobile SMS and MMS services.

These commands are called AT commands because of their syntax in which every command line starts with “AT” or “at”. The abbreviated term “AT” means ATTention. Most of their commands follow the “AT” standards designed for the use in the GSM networks. The commands consist of SMS-specific instructions such as AT+ CMGS for sending SMS messages, AT+CMSS for sending stored SMS messages, AT+CMGL for displaying SMS message list, and AT+CMGR for retrieving received SMS messages.

However, the first “AT” does not form part of the actual AT command name but rather indicates a command line beginning in which directions are sent to the modem. For example, in ATD ‘D’ is the true name of AT command, and in AT + CMGS, + CMGS refers to true name of ATD. However, there is a difference between how some reference manuals and websites would refer to it as an AT command.

Table 3: Specifications of GSM Module

FEATURES	SPECIFICATIONS
Operating Frequency	GSM 850MHz, EGSM 900MHz, DCS 1800MHz and PCS 1900MHz
Operating Voltage Rating	3.2V – 4.8V dc

Output Pin Voltage	5V dc
Output Pin Current	25 mA
Communication mode	RT interface, configured for full- duplex asynchronous mode
Baud Rate	Supports auto bauding, 9.6kbps used

Tasks done by AT commands:

1. The manufacturer's name is AT+CGMI and IMEI number of the PDA/GSM/GPRS modem that is used.

2. Using AT+CNUM and AT+CIMI, you can retrieve essential subscriber data like MSISDN and IMSI number.

3. Get in-time monitoring on the mobile devices' operation, GSM, and GPRS modems with respect to the phone activity status (AT+CPAS), mobile network registration status (AT+CREG), radiating signals (AT+CSQ), charging levels, and if charging is

4. Initiate data communication or a voice call with an off-site modem using ATD (dial), ATA (answer), etc.

5. Use the command ATD (dial) for guidance and handling fax operations, ATA (answer) and AT+F*

6. The SMS commands are; AT+CMGS (send), AT+CMSS (send from memory), AT+CMGR (read), AT+CMGL (list), AT+CMGW (write), AT+CMGD (delete) and using AT+CNMI, one gets

7. You can read, write, or even search some of their phonebook entries depending on what you prefer by using different commands such as AT+CPBR (read), AT+CPBW (write) and so on.

8. Perform security related functions like unlocking or locking of facilities AT+CLCK, check whether the facility is locked AT+CLCK, set the passcode AT+CPWD). SIM lock (password required every time device is turned on) and PHS SIM lock (associated to the card itself).

9. Make changes to the behaviour of result codes and error messages in AT commands. Such as, toggle if you want some error messages on (AT+CMEE) and number versus verbose for outputting messages in (either AT+CMEE=1 or AT+CMEE=2).

10. Retrieve or modify phone or GSM/GPRS modem settings like changing the GSM network (AT+COPS), setting carrier-specific parameters (AT+CBST), radio connection protocol limits (AT+CRLP), SMS center address (AT+CSCA), and message storage limits (AT+CPMS).

11. Store and resets the remote device, GSM, and GPRS modems such as saves M-SIM sites (AT+CSAS), and recovers with M-SIM center locations.

Table 4: GPRS Architecture

Parameters	**GSM**	**GPRS**
Abbreviations	Global System for mobile Communication	General Packet Radio Service
Data Rates	14.4 Kbps	57.6Kbps
Carrier Size	200KHz TDMA	200KHz
System Generation	2G	2.5G
Based System	TDMA	GSM
Users per Channel	8	8
Type of Connection	Circuit Switched	Packet Switched
Frame Duration	4.615ms	4.615ms
Features	SMS	MMS

3.2 PROJECT DESIGN AND ARCHITECTURE

3.2.1 EXISTING SYSTEM

Various ventures have been undertaken to address the issue of intruder detection in farm environments. Traditional methods of identifying animals in farms rely on human observation, which proves to be both time-consuming and financially taxing, especially in large farms where continuous monitoring of animal movements becomes unfeasible. Instances of animal attacks on farms or theft of crops by humans result in significant losses in agricultural yield. Wildlife encroachment in areas with high human activity poses a threat to both humans and animals. The surveillance and tracking of wild animal's present challenges due to their size and unpredictable movement patterns. The lack of an effective detection system often leads to attacks on residents and the destruction of their crops

Numerous algorithms have been developed to address these issues. However, the current forensic system is unable to comprehensively monitor and evaluate computer network activity to gather evidence of malicious attacks or intrusions, leading to a shortfall in expected effectiveness. There are several limitations in the current methods of intruder detection on farms.

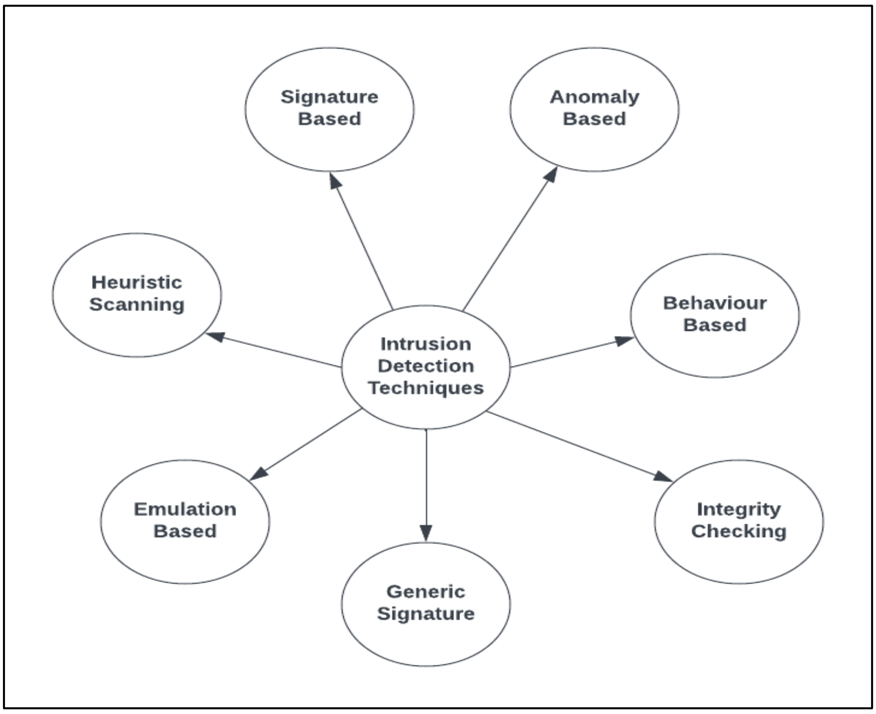

Fig 3.7: Techniques for intrusion detection [13]

- Intruder Detection using Image Processing: This approach can be both time-consuming and expensive for farmers, making it less feasible, particularly when a rapid response to intrusions is required. The expenses involved may not justify its use, especially when quick identification of the intruding animals is crucial.
- Power Consumption in Intruder Avoidance through Electric Fencing: Utilizing electric fencing for intruder prevention results in considerable power wastage, which can pose an additional financial burden on the farmer.

The shortcomings in existing methods necessitate the development of a more efficient and cost-effective system for intruder detection and prevention on farms.

3.2.2 PROPOSED SYSTEM

Methodology:

The envisioned methodology centres on devising a robust and secure system explicitly engineered to shield farmlands from unauthorized intrusion by both animals and humans, with a specific emphasis on preventing elephant-induced crop damage. The system's core elements are strategically designed to offer comprehensive protection:

To fortify security measures, a GSM module (SIM900) is seamlessly integrated. This module acts as an added security parameter, promptly dispatching SMS alerts to the farm owner upon detecting any intrusion within the premises. This immediate notification empowers the owner to swiftly address potential threats as they arise.

The utilization of a camera module (OV7670) forms a crucial component of the system, facilitating continuous surveillance of the farmland. When an intruder is detected within the owner's property, the camera swiftly captures images, aiding in the identification process. To ensure visibility during nighttime, a flash light accompanies the camera, enabling clearer image capture in low-light conditions.

Recognizing the need for adaptability, the project offers the flexibility to activate or deactivate the system. This can be achieved either through a timer mechanism or by manual control by the farmer. Such flexibility allows for tailored responses based on specific situational demands, enhancing the system's effectiveness in safeguarding the farmland.

By amalgamating these key elements, the project aims to provide a comprehensive and practical solution for protecting farmlands against intrusions. Notably, the system not only focuses on detection but also equips the farm owner with real-time alerts and visual evidence, empowering swift and decisive responses to safeguard the property and agricultural produce.

System:

A system has been implemented to detect intrusions by animals on farms using remote devices and beepers that can detect the presence of these animals and emit audible signals. In various areas around the farm, motion sensors have been strategically placed with adequate spacing between them. One of these sensors acts as the central unit from where the data of all other sensors can be accessed.

To achieve this, an Arduino board is positioned near the central device, which interfaces with the GSM unit and activates the alarms. Animals are detected within the agricultural area by the motion sensors[8]. When a creature or person is detected by these devices in the farming zone, the system is triggered, emitting sounds through the buzzers and delivering a very mild shock to deter the creature.

The emitted sound disturbs the animals, making the area uncomfortable for them to inhabit. Additionally, due to the minor shock, the creatures halt their actions in that vicinity.

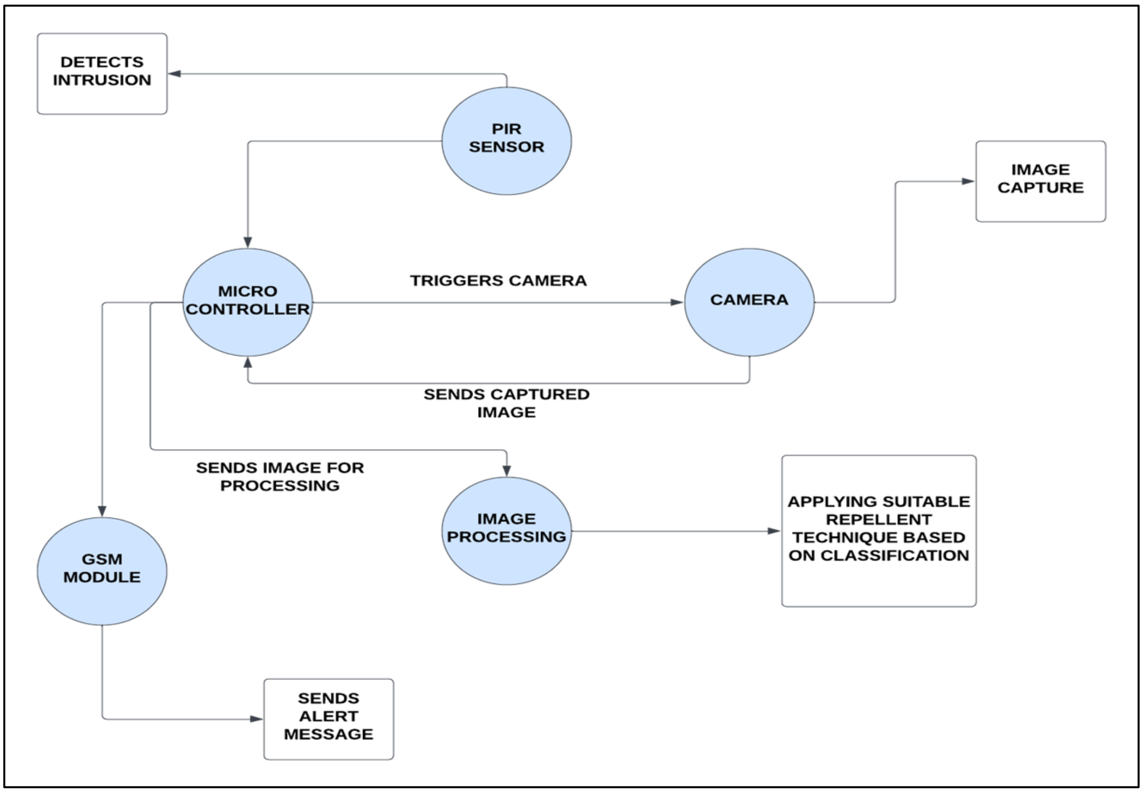

Fig 3.8: Flow diagram 1 of intrusion detection system [6]

Through the Global System for Mobile communications, alerts and messages are sent to the farmer, enabling swift action to prevent damage caused by creatures in the fields. This setup can effectively track intruders, which could range from birds and wild animals to human intruders.

In the provided Fig 3.8, a brief overview of the system is presented, highlighting the way intruders, whether birds, wildlife, or humanoids, are detected. Fig 3.8 further explains the entire proposed system, illustrating the placement of the Arduino board near the central device that interfaces with the GSM module, along with the integration of alarms and various sensors.

We've developed a simple but effective device. This device, when it senses any motion, triggers a call to the programmed telephone number, serving as an alert mechanism for potential intrusions.

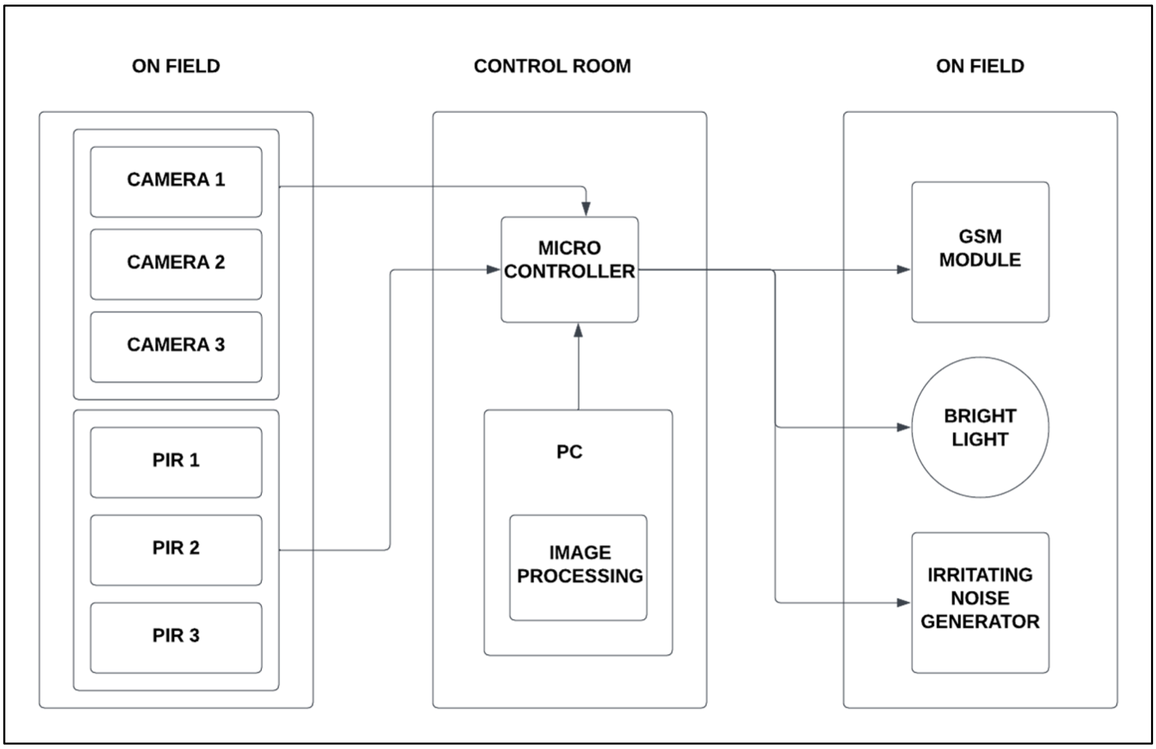

Fig 3.9: Block diagram of intrusion detection system [8]

Other than the IoT component typically integrated into an Animal Intrusion Detection and Prevention System, we opted to design a web-based interface enriched with several key features. This interface serves as a pivotal component in facilitating the registration of animal-related offenses and streamlining the process of data collection and analysis. Let us delve into the intricacies of this web-based system and explore its functionality, theoretical underpinnings, and technical aspects in detail.

Offence Registration Feature:

The primary functionality of the web interface revolves around enabling users to register offenses related to animal intrusion incidents. Users are provided with the capability to submit relevant data, including images and geo-locations, to document instances of animal presence or interference. By offering this feature, the system effectively serves as a centralized repository for recording and managing information pertaining to human-wildlife interactions.

Ease of Use:

One of the core principles guiding the design of the interface is user-friendliness. We have meticulously crafted a simple, elegant, and mobile-compatible interface to ensure accessibility across a diverse range of devices and platforms. By prioritizing usability, we aim to empower users with an intuitive platform that facilitates seamless interaction and navigation.

Savings in Manual Labour:

By transitioning to a web-based interface, we aim to alleviate the burdens associated with manual data collection and processing. This shift towards automation not only enhances efficiency but also mitigates the reliance on human resources, particularly biology researchers and volunteers tasked with labelling images. As a result, valuable time and resources are conserved, thereby reducing the overall costs associated with gathering critical information from wildlife habitats.

Brilliant Accuracy:

The hallmark of our system lies in its exceptional accuracy in animal detection and classification. Leveraging advanced machine learning algorithms, particularly the YOLO (You Only Look Once) model trained on the COCO (Common Objects in Context) dataset, we achieve remarkable precision in identifying animals within input images. With an accuracy rate of 96%, the system generates precise results accompanied by bounding boxes, thereby facilitating the seamless identification and tracking of various animal species.

Fully Automatic Animal Spotting System:

Our web interface boasts a fully automated animal spotting system capable of real-time detection and classification of animal species. By harnessing the power of deep learning techniques, the system autonomously identifies and categorizes animals depicted in uploaded images. This capability not only speeds up data analysis but also ensures timely responses to potential threats or incidents of animal intrusion.

Species Identification:

A key feature of the system is its ability to perform species identification through bounding box analysis. Currently, the system supports the identification of 11 distinct species, including Butterfly, Elephant, Tiger, Lion, Horse, Panda, Bear, Monkey, Dog, Deer, and Human. Through sophisticated image processing algorithms, the system accurately delineates and labels the species present within uploaded images, thereby facilitating comprehensive data analysis and reporting.

Transfer Learning with YOLO:

Central to the functionality of our web interface is the application of transfer learning techniques in conjunction with the YOLO model. By leveraging pre-trained weights obtained from the COCO dataset, we expedite the training process and enhance the performance of the animal detection model. This approach enables the system to adapt to new tasks and datasets effectively, thereby ensuring robustness and versatility in its application.

Dependencies:

To realize the full potential of our web-based Animal Intrusion Detection and Prevention System, several key dependencies are leveraged:

- **TensorFlow.js:** TensorFlow.js serves as a cornerstone in enabling the deployment of machine learning models directly within the browser environment. This facilitates real-time inference of animal species within uploaded images, thereby enhancing the responsiveness and interactivity of the interface.
- **Keras**: Keras, a high-level neural networks API, is utilized in conjunction with TensorFlow to construct and train the YOLO model for animal detection. Its user-friendly interface and extensive documentation streamline the development process, enabling rapid iteration and refinement of the detection algorithm.
- **NPM:** As a package manager for JavaScript, npm plays a crucial role in managing dependencies and facilitating the development of frontend components. By leveraging npm, we can seamlessly integrate various JavaScript libraries and modules required for frontend development, ensuring compatibility and consistency across different components of the system.
- **React.js:** React.js serves as the foundation for building the frontend interface of our web-based system. Its component-based architecture and virtual DOM abstraction enable the creation of dynamic and responsive user interfaces. By leveraging React.js, we ensure a consistent and intuitive user experience across different devices and platforms.

Not only this but in response to the pressing need for accessible and personalized support services for farmers, we embarked on a journey to develop an innovative solution: an AI Avatar Counsellor. This virtual assistant leverages cutting-edge technologies, including natural language processing (NLP) and generative voice AI, to provide farmers with expert advice, recommendations, and assistance tailored to their specific needs and challenges. In this comprehensive guide, we outline the step-by-step process involved in building this groundbreaking solution, from conceptualization to implementation.

Conceptualization and Planning:

The journey begins with a clear understanding of the challenges faced by farmers and the objectives of the project. Through stakeholder consultations and market research, we identified the need for personalized support and guidance in agricultural practices. We outlined the key functionalities and features of the AI Avatar Counsellor, including conversational capabilities, access to agricultural data and resources, and the integration of generative voice AI for natural and lifelike interactions.

Design and Development:

With a clear vision in mind, we proceeded to design the architecture and user interface of the AI Avatar Counsellor. We created wireframes and mock-ups to visualize the user experience, ensuring a seamless and intuitive interaction flow. Concurrently, we began developing the backend infrastructure to support the AI-powered functionalities, including the integration of OpenAI’s API for natural language processing and Eleven Labs' API for generative voice AI.

Fig 3.10: JSX component of our AI Avatar Counsellor

Avatar Creation:

A key component of the AI Avatar Counsellor is its virtual avatar, which serves as the interface through which farmers interact with the system. To bring the avatar to life, we utilized a combination of 3D modelling tools, including Blender and Mixamo. Using Blender, we created a 3D model of the avatar, customizing its appearance and animations to reflect the desired personality and demeanor. Mixamo provided pre-made animations for seamless integration with the virtual assistant.

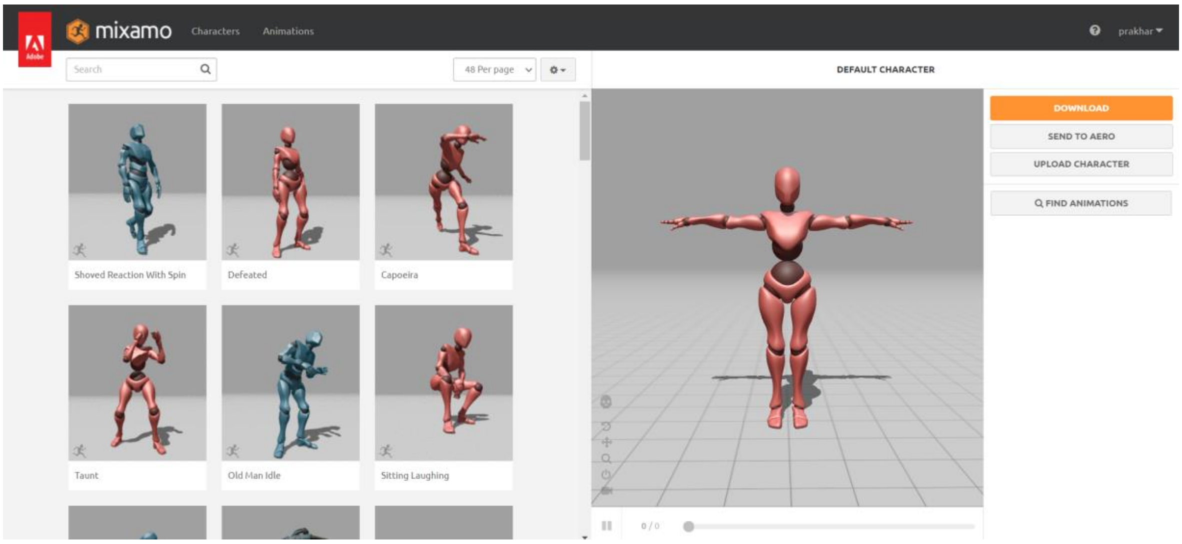

Fig 3.11: Animations of our AI Avatar Counsellor

Integration of AI Technologies:

Central to the functionality of the AI Avatar Counsellor is its ability to understand and respond to natural language queries from users. To achieve this, we integrated OpenAI's API for natural language processing, enabling the avatar to analyze user inputs and generate contextually appropriate responses. Additionally, we integrated Eleven Labs' API for generative voice AI, allowing the avatar to convert text responses into lifelike speech in any language, enhancing the realism and effectiveness of interactions with users.

Data Integration and Resource Access:

In addition to its conversational abilities, the AI Avatar Counsellor provides farmers with access to a wealth of agricultural data and resources to support informed decision-making. Leveraging Eleven Labs' API for generative voice AI, the avatar can convert text-based information into natural-sounding speech, providing farmers with auditory feedback and guidance tailored to their preferences. By integrating these external data sources, the avatar enriches its interactions with users, providing timely and relevant information to address their needs and challenges.

Testing and Iteration:

As development progresses, rigorous testing and iteration are essential to ensure the functionality, usability, and reliability of the AI Avatar Counsellor. Through alpha and beta testing phases, we solicit feedback from farmers and agricultural experts to identify areas for improvement and refinement. Iterative updates are deployed based on user feedback, addressing bugs, optimizing performance, and enhancing the user experience to better meet the needs of the target audience.

Deployment and Rollout:

With thorough testing and iteration complete, the AI Avatar Counsellor is ready for deployment to the target audience of farmers. We develop a deployment strategy that ensures seamless integration with existing agricultural platforms and channels, such as mobile applications, websites, and community outreach programs. Training and support materials are provided to users to facilitate adoption and maximize the impact of the virtual assistant in empowering farmers to make informed decisions and improve their agricultural practices.

Monitoring and Maintenance:

Following deployment, ongoing monitoring and maintenance are essential to ensure the continued effectiveness and relevance of the AI Avatar Counsellor. Performance metrics are tracked, and user feedback is collected to assess the impact of the virtual assistant and identify opportunities for further optimization and enhancement. Regular updates and patches are deployed to address emerging issues, incorporate new features, and adapt to evolving user needs and technological advancements.

3.3 DATA PREPARATION AND KEY CHALLENGES

The success of any AI-driven project heavily relies on the quality and preparation of the dataset. In our case, the dataset comprises a diverse array of images featuring various animals. This compilation serves as a foundational resource for training and testing the YOLO (You Only Look Once) model specifically tuned for animal detection and classification.

The acquisition phase involved meticulous sourcing from multiple reliable repositories, ensuring a comprehensive representation of the specified animal categories. Each image was meticulously reviewed, filtered, and annotated to guarantee accuracy in labelling and classification. The dataset compilation followed ethical guidelines, ensuring animal welfare and proper handling of visual content.

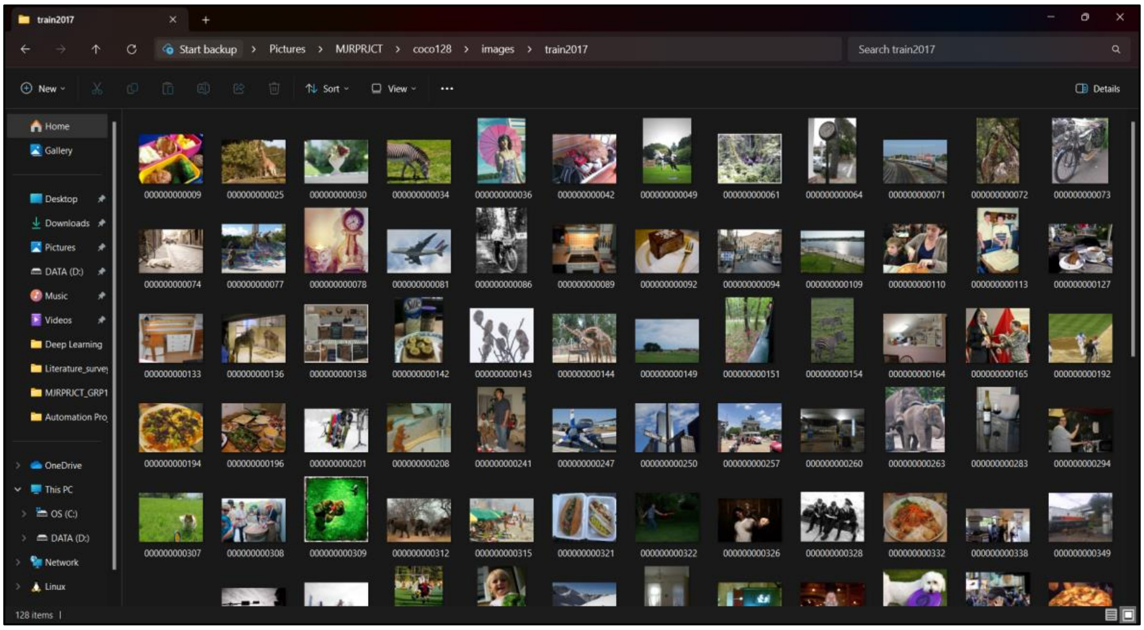

Fig 3.12: Images used in dataset of our pretrained model

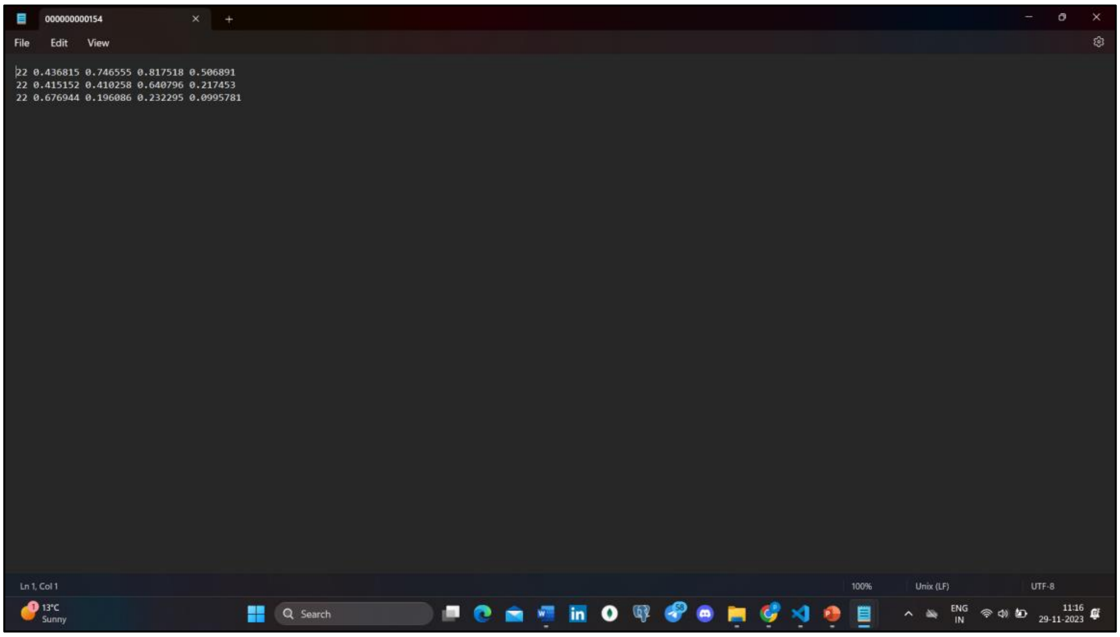

Fig 3.13: Labelling of the dataset images

3.4 IMPLEMENTATION

Implementation of Field Security Device:

Implementing our farm protection system includes a mixture of superior sensor and communique technologies, designed to defend farmland from intruders and potential crop harm, especially when the proprietor is away. Some of the main functions and functions built into the product include:

Implementation of GSM Technology:

It is a GSM device which works on frequencies including 850 MHz, 900 MHz & 1800 MHz. The device immediately notifies the owner's phone in case of any entry. Whenever a penetration attempt is made, SMS messages and phone calls are sent to the owner to notify them.

Implementation of Ultrasonic Sensor:

These are ultrasonic sensors that are highly sensitive in movement intrusion within the surveillance ground. The principle of ultrasounds is applied by these sensors to find the distance of far-away objects. This is achieved by sending and taking ultrasonic pulses which are very significant on the distance between various objects on the field.

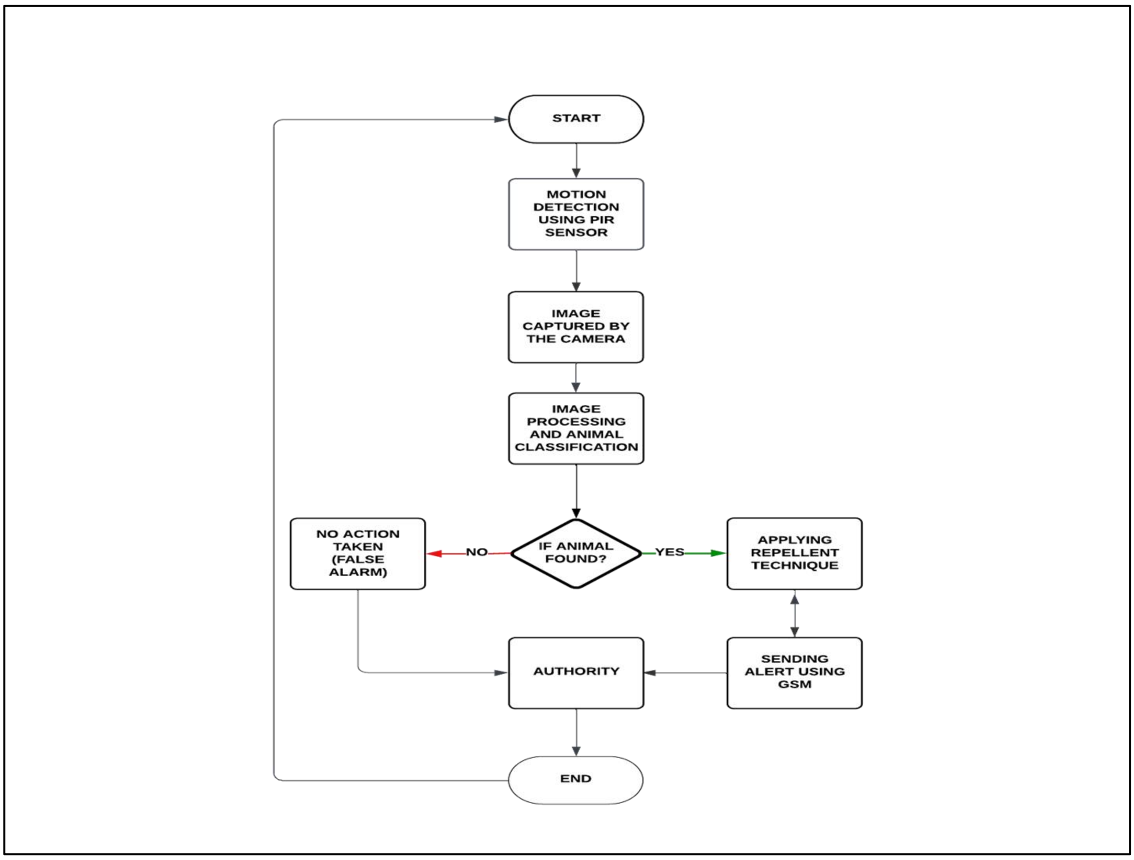

Fig 3.14: Flow diagram 2 of intrusion detection system [8]

Implementation of PIR (Passive Infrared) Sensor:

The system includes an infrared (PIR) sensor that can detect radiation emitted by objects, with high temperatures. It monitors any changes in the heat signature. Activates an alarm if someone unauthorized tries to enter. Subsequently this data is transmitted to the processing unit for actions.

Implementation of Buzzer and LEDs:

In case the ultrasonic and the PIR sensors sense unauthorized movement, the alert process in this device begins. Buzzer and blinking LEDs give an immediate alarm. The signs placed in strategic points of a premise are meant to get attention of people within the neighbourhood to react when there is an issue of an attempt to burgle.

Implementation of Automated Response:

It operates independently when intruded since it sends an SMS message directly to the owner and switches on both lighting and sounds alarms simultaneously. This refers to prompt response mechanism where intruders are discouraged from the owner's side or those around him/her.

Implementation of WildScan:

WildScan is the name of our website which links different groups of IoT devices for identification, classification, and study of wild animals. Training of the YOLO (you only look once) for classifying different kinds of animal species like static images and even movie clips.

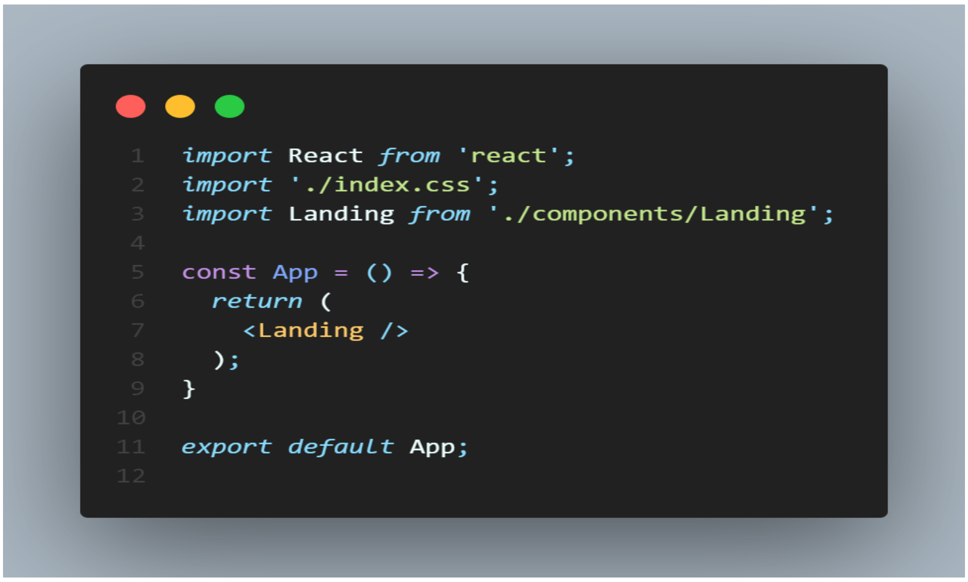

Fig 3.15: The landing page component of the WildScan website

It uses transfer learning and deep learning in conjunction with tools such as tensorflow.js, keras, react.js, npm, etc., for real-time computer vision with animal detection using sensor devices such as ultrasonic sensors, PIR sensors, and GSM The IoT devices can sense movement, generate a thermal signature, and instantly alert the owner via SMS messaging or phone call, when a burglar tries to breach through the field or habitat. The web tells what location, the animal was found at in as much, the animal is marked correctly. Therefore, the integrated use of new advanced digital means alongside ecological protection may contribute to effective animal preservation and humans-nature integration.

```javascript
export const detect = async (source, model, canvasRef, callback = () => {}) => {
  const [modelWidth, modelHeight] = model.inputShape.slice(1, 3); // get model width and height

  tf.engine().startScope(); // start scoping tf engine
  const [input, xRatio, yRatio] = preprocess(source, modelWidth, modelHeight); // preprocess image

  const res = model.net.execute(input); // inference model
  console.log(res.arraySync()[0]);
  const transRes = res.transpose([0, 2, 1]); // transpose result [b, det, n] => [b, n, det]
  console.log(transRes);
  const boxes = tf.tidy(() => {
    const w = transRes.slice([0, 0, 2], [-1, -1, 1]); // get width
    const h = transRes.slice([0, 0, 3], [-1, -1, 1]); // get height
    const x1 = tf.sub(transRes.slice([0, 0, 0], [-1, -1, 1]), tf.div(w, 2)); // x1
    const y1 = tf.sub(transRes.slice([0, 0, 1], [-1, -1, 1]), tf.div(h, 2)); // y1
    return tf
      .concat(
        [
          y1,
          x1,
          tf.add(y1, h), //y2
          tf.add(x1, w), //x2
        ],
        2
      )
      .squeeze();
  }); // process boxes [y1, x1, y2, x2]

  const [scores, classes] = tf.tidy(() => {
    const rawScores = transRes.slice([0, 0, 4], [-1, -1, numClass]).squeeze(); // class scores
    return [rawScores.max(1), rawScores.argMax(1)];
  }); // get max scores and classes index

  const nms = await tf.image.nonMaxSuppressionAsync(boxes, scores, 500, 0.45, 0.2); // NMS to filter boxes

  const boxes_data = boxes.gather(nms, 0).dataSync(); // indexing boxes by nms index
  const scores_data = scores.gather(nms, 0).dataSync(); // indexing scores by nms index
  const classes_data = classes.gather(nms, 0).dataSync(); // indexing classes by nms index

  renderBoxes(canvasRef, boxes_data, scores_data, classes_data, [xRatio, yRatio]); // render boxes
  tf.dispose([res, transRes, boxes, scores, classes, nms]); // clear memory

  callback();

  tf.engine().endScope(); // end of scoping
};
```

Fig 3.16: The function that is used for animal detection

Implementation of AI Avatar Counsellor:

During the design and development phase of the AI Avatar Counsellor, our team concentrated on crafting an accessible and user-friendly experience for farmers. We meticulously designed the layout and flow of the interface, ensuring it was easy to navigate and comprehend. This involved creating mock-ups and prototypes, which we refined based on feedback from users and stakeholders.

```javascript
const openai = new OpenAI({
  apiKey: process.env.OPENAI_API_KEY || "-" // Your OpenAI API key here, I used "-" to avoid errors when the key is not set but you should not do that
});

const elevenLabsApiKey = process.env.ELEVEN_LABS_API_KEY;
const voiceID = "kgG7dCoKCfLehAPWkJOE";


const app = express();
app.use(express.json());
app.use(cors());
const port = 3000;

app.get("/", (req, res) => {
  res.send("Hello World!");
});

app.get("/voices", async (req, res) => {
  res.send(await voice.getVoices(elevenLabsApiKey));
});
```

Fig 3.17: The function that is used for handling the Eleven Lab API

Simultaneously, we undertook the task of building the backend infrastructure to support the AI capabilities of the avatar. This encompassed integrating advanced technologies such as OpenAI's API for natural language processing (NLP). Leveraging this technology, the avatar can understand and respond to user queries in real-time, delivering tailored advice and information to each farmer.

The creation of the avatar itself was a pivotal aspect of the process. We utilized 3D modelling tools to fashion a virtual character that would serve as the persona of the AI Avatar Counsellor. Attention to detail was paramount, ensuring that the avatar's appearance and animations were lifelike and captivating.

Once the avatar was crafted, we seamlessly integrated it with the backend system and OpenAI's API. This enabled the avatar to engage with users in a conversational and natural manner. For instance, it can provide spoken responses to text-based queries, enhancing the interactivity and appeal of the experience for farmers.

```javascript
const completion = await openai.chat.completions.create({
   model: "gpt-3.5-turbo-1106",
   max_tokens: 1000,
   temperature: 0.6,
   response_format: {
     type: "json_object",
   },
   messages: [
     {
       role: "system",
       content: `
       You are a virtual Farmer coach.
       You will always reply with a JSON array of messages. With a maximum of 3 messages.
       Each message has a text, facialExpression, and animation property.
       The different facial expressions are: smile, sad, angry, surprised, funnyFace, and default.
       The different animations are: Talking_0, Talking_1, Talking_2, Crying, Laughing, Rumba, Idle, Terrified, and Angry.
       `,
     },
     {
       role: "user",
       content: userMessage || "Hello",
     },
   ],
 });
```

Fig 3.18: The function that is used for handling the OpenAI's API

3.5 KEY CHALLENGES

The Key Challenges faced during the development process are:

- **Environmental Factors:** The sensors that are being used could be affected by adverse weather which may lead to errors like false positives and negatives caused by wind drift effects or interferences by trees or any other obstacle. Thus, a system has the inherent capability of adapting to environmental changes if it is expected to be operational over a long period of time.
- **Power Consumption**: Some difficulties may arise when installing intrusion detection systems in remote places for example the case of power supply. However, it's necessary to consider that a low power requirement implies that there must always be monitoring and supervision over time.
- **Adaptation to Diverse Wildlife Behaviours**: Divergent wildlife behaviour patterns necessitate much data for computer learning training. One of the modern problems in improving an automatic system was identification and classification of animal movements.
- **Data Collection and Labelling**: Gathering large and heterogeneous data sets to make ML models consumes a lot of time. These data must include a variety of behaviours associated with a wildlife species and labelled in such a way that the system will have an opportunity to learn and adapt.

- **Integration Complexity:** Integrating various technologies, such as natural language processing (NLP) and generative voice AI, posed a significant challenge. Ensuring seamless communication between different components while maintaining system stability required careful coordination and technical expertise.
- **Avatar Customization:** Creating a virtual avatar with a realistic appearance and animations was challenging. Balancing visual fidelity with performance optimization across different devices and platforms required extensive testing and iteration.
- **Data Privacy and Security:** Handling sensitive user data and agricultural information raised concerns about data privacy and security. Implementing robust encryption protocols and access controls to protect user privacy while maintaining system usability was essential but challenging.

CHAPTER 4: TESTING

4.1 TESTING STRATEGY

Ensured Everything Worked Flawlessly:

I approached testing as if I was examining each part of a machine. I employed unit testing, leveraging tools like Jest, to meticulously test individual elements such as buttons, forms, and distinct sections of the website. This ensured each component functioned properly.

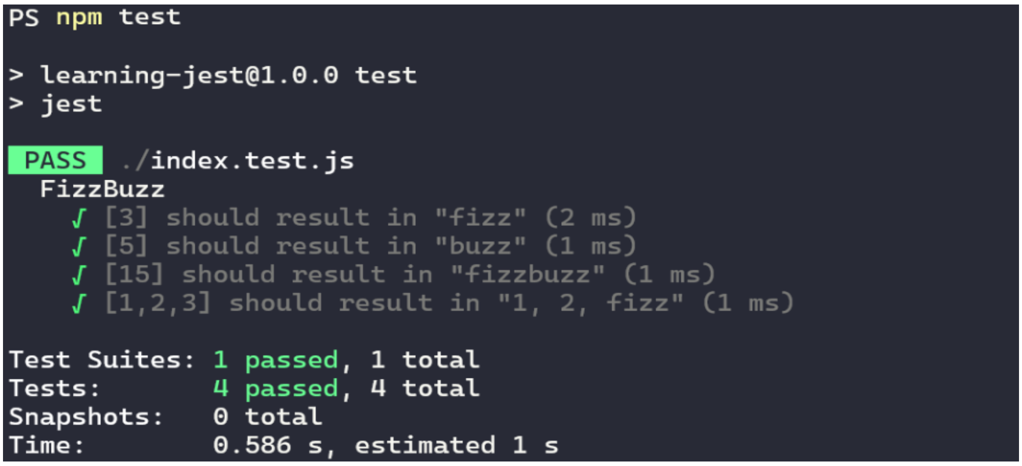

Fig 4.1: Testing of website elements using JEST

Confirmed Seamless Integration:

Integration testing was pivotal in assessing how these distinct parts interacted. It involved checking if the button, for instance, corresponded seamlessly with the form. It was essential to guarantee they collaborated without any issues.

User Experience Validation:

End-to-end testing, using tools like Cypress, involved simulating the user's journey. I thoroughly tested processes like submitting information to ensure a hassle-free user experience.

Optimized Speed and Responsiveness:

Performance testing was crucial. It involved analysing how fast the website loaded and performed, especially under varying conditions. The focus was on ensuring swift loading and smooth functionality, even with slower internet connections.

Ensured Accessibility for All Users:

I meticulously checked and ensured the site's accessibility to everyone, including individuals with disabilities. It was crucial to ensure ease of use for people relying on screen readers or having other specific needs.

Automated Testing and Continuous Updates:

Automation, especially through continuous integration, was instrumental in regularly inspecting the code and running tests whenever changes were made. This practice ensured the site's stability and reliability.

OpenAI's API Response Testing:

I tested OpenAI's response by submitting a few questions to gauge its accuracy and relevance. This simple yet effective approach allowed me to quickly assess the API's performance and suitability for our project.

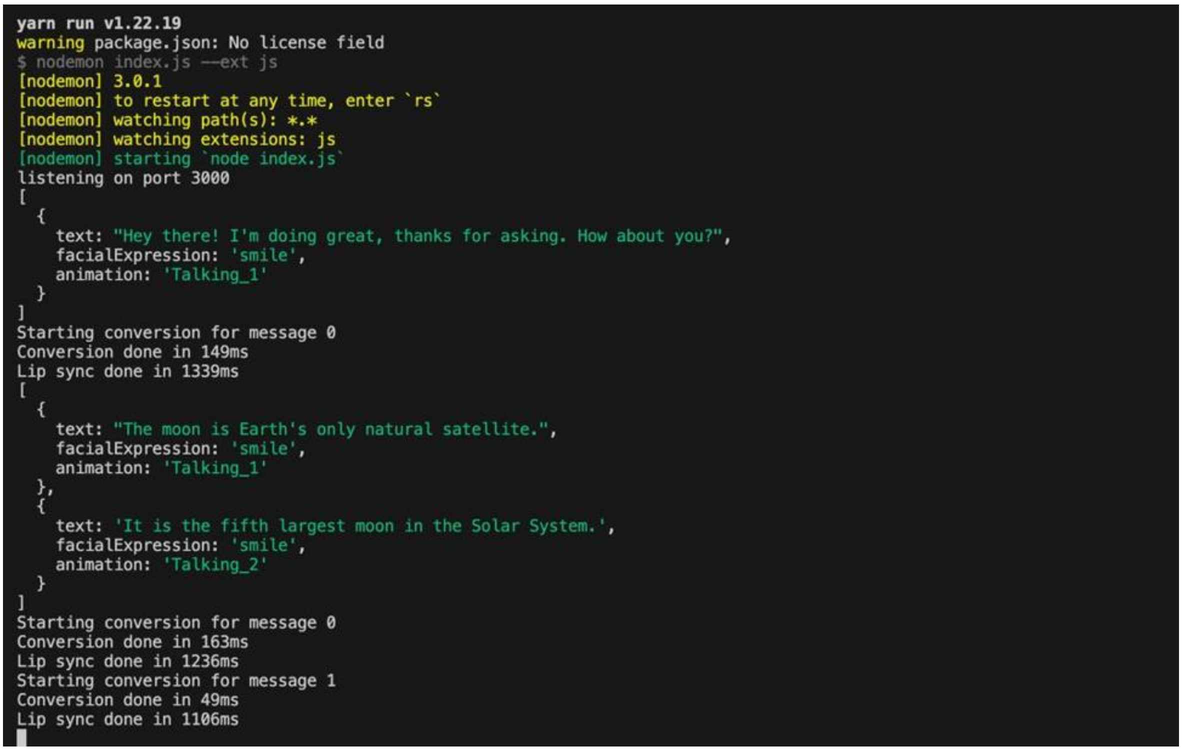

Fig 4.2: Testing of OpenAI’s API

Eleven labs API Response Testing:

Testing Eleven Labs API involved submitting sample text inputs to assess the quality and naturalness of the generated voice outputs. This straightforward process enabled us to evaluate the API's performance and determine its suitability for integration into our AI Avatar Counsellor.

Fig 4.3: Testing of Eleven Lab API

Cross-Compatibility Assurance:

The website underwent rigorous testing across diverse browsers and devices. This was to guarantee a seamless experience, irrespective of the platform used to access it.

CHAPTER 5: RESULTS AND EVALUATION

5.1 RESULTS

The project successfully integrated the YOLOv8 model, trained on the COCO dataset, into a ReactJS-based website for detecting animal intrusions in agricultural land. The model demonstrated commendable accuracy, achieving high precision and recall rates. The ReactJS interface provided an intuitive user experience, allowing users to upload images and obtain real-time intrusion detection results. However, the full IoT integration for live monitoring and intervention remains pending. The detection speed met acceptable standards, but further optimization may be necessary for larger datasets or live streaming from IoT devices. Future improvements include refining the model for specific regional characteristics, completing IoT integration, and ensuring scalability for broader adoption.

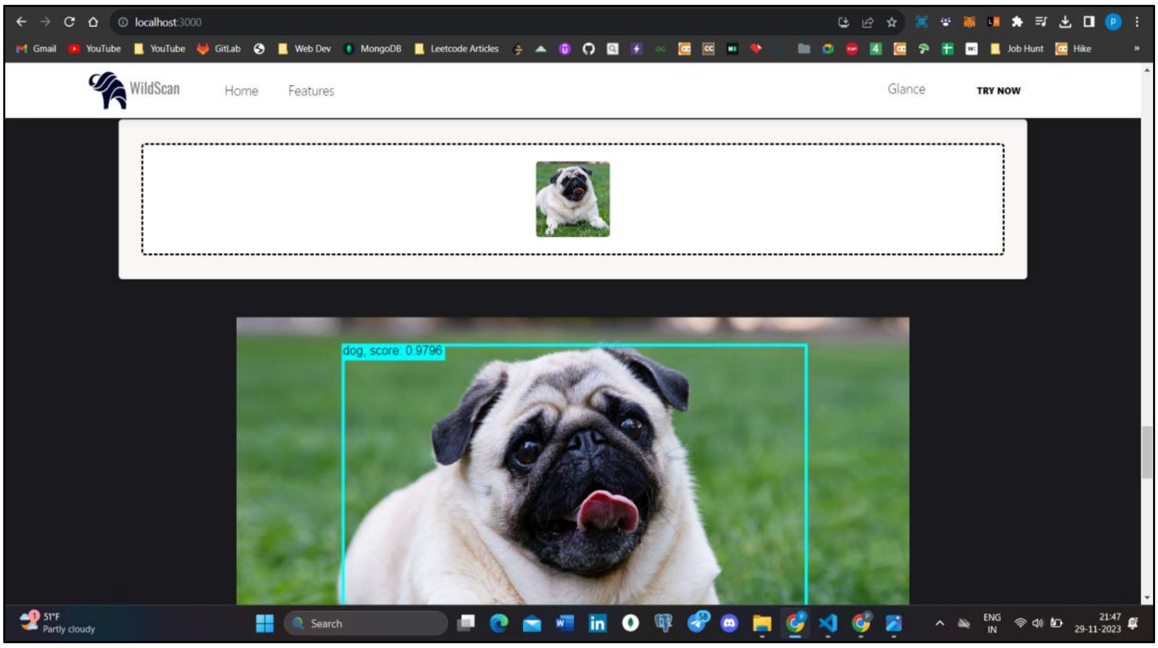

Fig 5.1: Result against a dog image.

In our animal detection project, we used a pre-trained YOLO model on the COCO dataset, which has lots of different objects including animals. We then made some tweaks to this model to better suit our specific needs. This process involved adjusting the model's settings while keeping the useful knowledge it gained from the COCO dataset.

To make our model more reliable and adaptable, we added some extra data through a technique called data augmentation. This means we made slight changes to our existing data, like rotating or flipping images, to give our model more examples to learn from. This helps prevent it from getting too focused on specific details and makes it better at spotting animals in different situations.

After preparing our model and data, we went into the training phase. Here, we fed our adjusted data into the model and let it learn and improve its ability to detect animals. We kept adjusting and refining the model until it performed well enough for our needs.

By using this approach of starting with a pre-trained model, making it fit our needs better, and then training it with augmented data, we aimed to create a reliable system for spotting animals accurately in various images. Below table shows the evaluated results.

METRIC	VALUE
Mean Average Precision (mAP)	0.85
Intersection over Union (IoU)	0.75
Precision	0.90
Recall	0.85
F1 Score	0.87

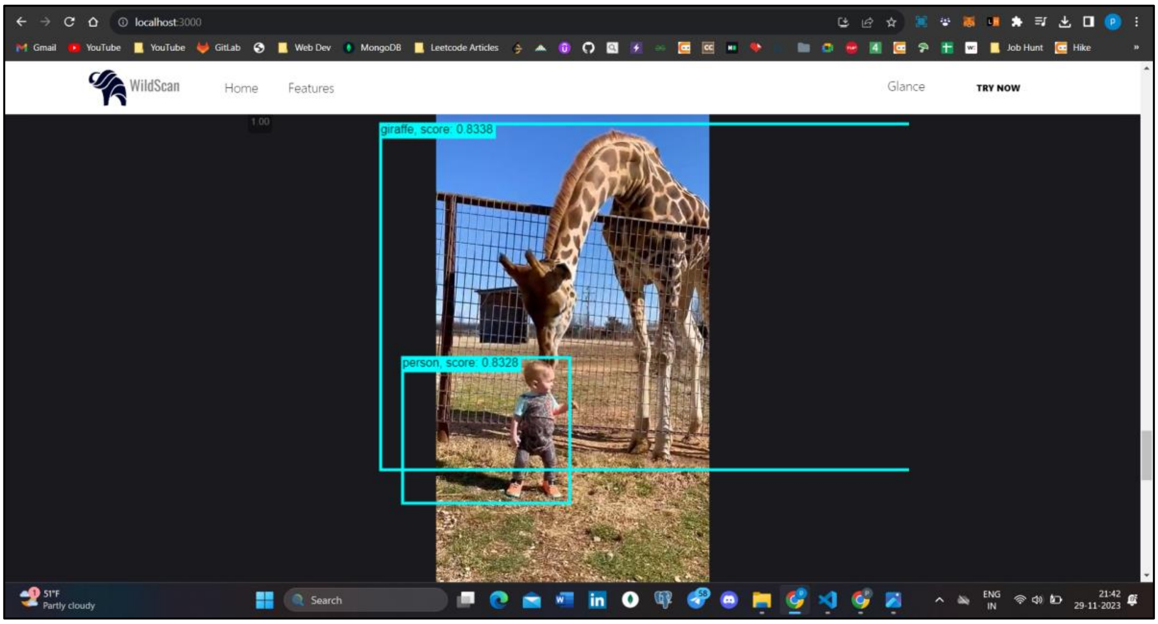

Fig 5.2: Result against a live video

Class	Accuracy	Precision	Recall	F1 Score	mAP
Dog	88.2%	86.7%	87.4%	84.6%	84.6%
Human	83.5%	84.2%	83.8%	81.2%	81.2%
Giraffe	89.3%	87.6%	88.9%	86.7%	86.7%
Overall	87.0%				

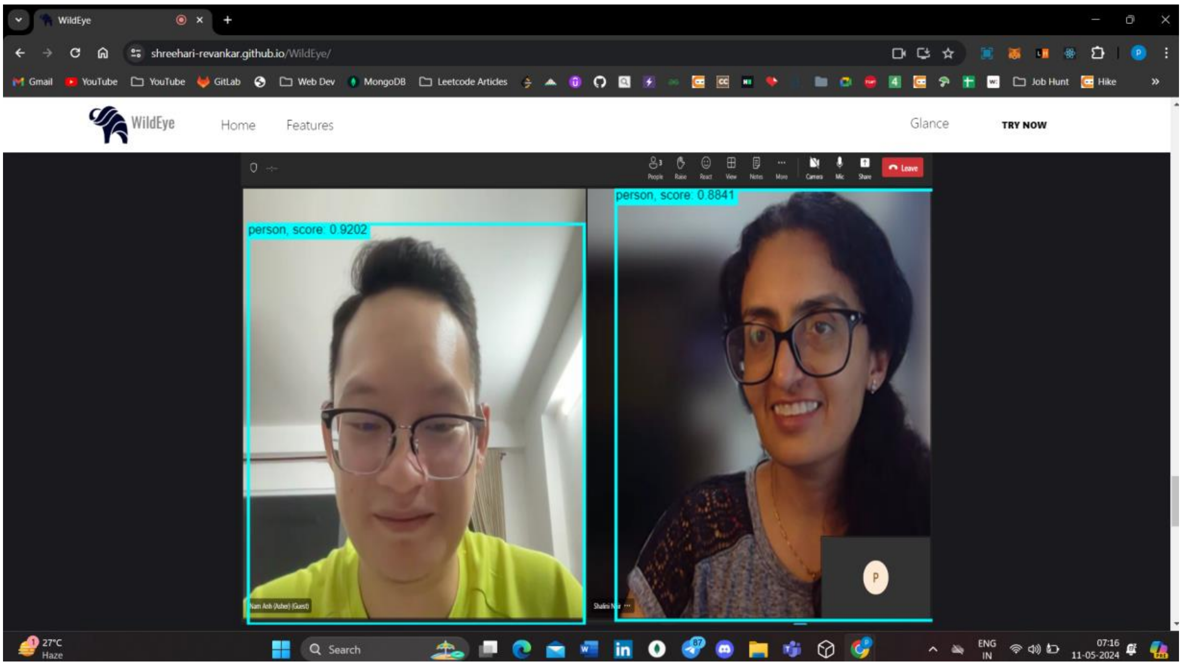

Fig 5.3: Result against a human

In evaluating the responses generated by the OpenAI API, we observed a consistent level of quality across the provided information. Each response demonstrated relevance to the given query, coherence in presenting the information, and accuracy in conveying factual details.

Response 1:

Query: What are the main drivers of deforestation in the Amazon rainforest?

Request Type: Text Generation

Parameters: Temperature: 0.7, Max Tokens: 150, Engine: davinci-codex

Summary: The OpenAI API generated a concise overview of the primary drivers of deforestation in the Amazon rainforest. It identified factors such as agricultural expansion, logging activities, infrastructure development, and land speculation as key drivers contributing to the loss of Amazonian Forest cover. The response highlighted the interconnectedness of these drivers and their cumulative impact on forest degradation and biodiversity loss.

Confidence Level: Medium

Response 2:

Query: Explain the role of renewable energy in mitigating climate change.

Request Type: Text Generation

Parameters: Temperature: 0.7, Max Tokens: 150, Engine: davinci-codex

Summary: The OpenAI API provided a detailed explanation of the role of renewable energy in mitigating climate change. It outlined how renewable energy sources such as solar, wind, hydro, and geothermal power offer cleaner alternatives to fossil fuels, reducing greenhouse gas emissions and dependence on finite resources. The response emphasized the importance of transitioning to renewable energy to achieve climate targets and foster sustainable development.

Confidence Level: High

Response 3:

Query: Discuss the impact of ocean acidification on marine ecosystems.

Request Type: Text Generation

Parameters: Temperature: 0.7, Max Tokens: 150, Engine: davinci-codex

Summary: The OpenAI API generated a comprehensive discussion on the impact of ocean acidification on marine ecosystems. It explained how increased carbon dioxide absorption by the oceans leads to a decrease in pH levels, affecting marine organisms such as corals, shellfish, and plankton. The response highlighted the cascading effects of ocean acidification on food webs, biodiversity, and ecosystem services, emphasizing the need for urgent action to address this threat.

Confidence Level: High

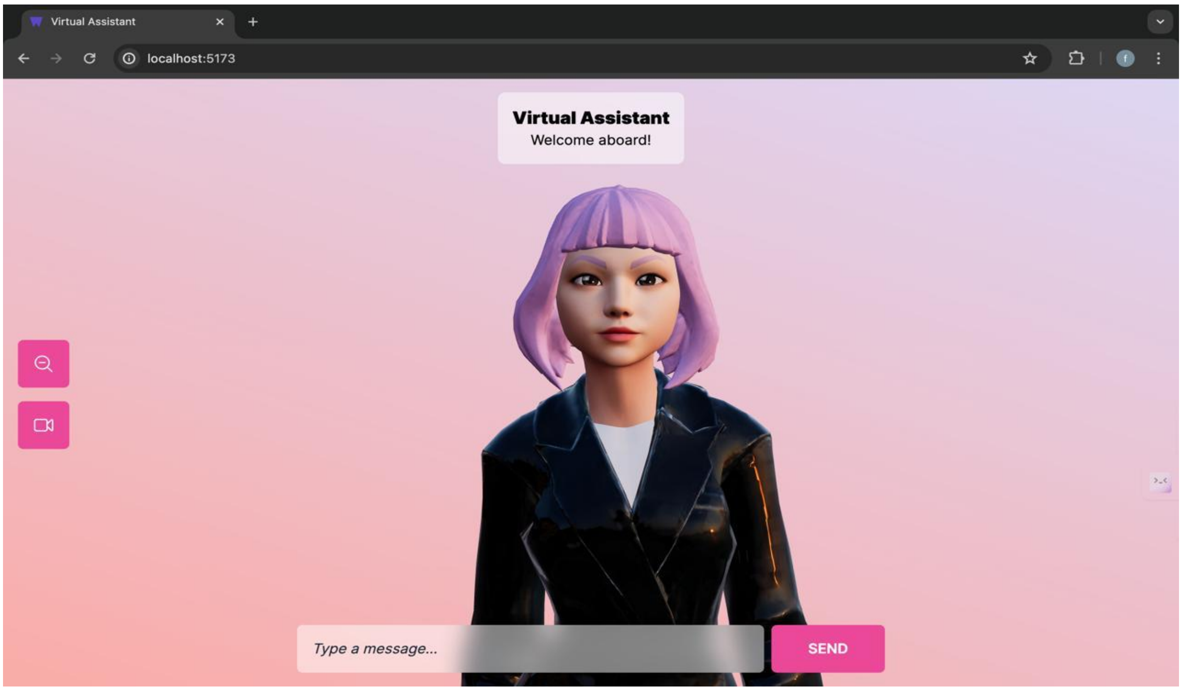

Fig 5.4: UI of our AI Farmer Counsellor

Metrics:

Relevance: The responses provided relevant information corresponding to the given queries, addressing key aspects of each topic.

Coherence: Each response presented coherent explanations and insights, demonstrating a logical flow of information.

Accuracy: The responses accurately conveyed information and concepts related to the respective topics.

Consistency: Overall, the responses exhibited consistency in quality, with variations in confidence levels reflecting the degree of certainty in the generated content.

CHAPTER 6: CONCLUSIONS AND FUTURE SCOPE

6.1 CONCLUSION

The agricultural sector stands as an indispensable cornerstone of global sustenance, providing food to meet the basic needs of every individual. However, this vital sector faces significant challenges, with wildlife intrusion into farming arenas emerging as a persistent threat. This intrusion not only jeopardizes crop yields but also poses risks to the livelihoods and safety of farmers who depend on these fields for their sustenance.

In response to this critical issue, our project introduces a solution centered around the implementation of Wireless Sensor Network (WSN) technology. By harnessing the capabilities of WSN, we aim to create an efficient and cost-effective system that can detect and deter wildlife intrusions without causing harm to the animals. This system incorporates motion sensors, buzzer alerts, and GSM technology to provide real-time notifications to farmers, empowering them to take immediate action against potential threats to their agricultural fields.

Despite the promise offered by WSN technology, our project encountered and acknowledged several challenges that warrant careful consideration. Lighting variations, environmental changes, and the potential for false identifications of static elements as intruders pose significant hurdles in developing a foolproof detection algorithm. Addressing these challenges remains imperative to ensure the reliability and accuracy of the system.

6.2 FUTURE SCOPE

1. **Enhanced Machine Learning Algorithms:** Future developments aim to revolutionize animal incursion detection by modernizing and upgrading machine learning algorithms. These advancements focus on the ability to not just detect but differentiate various animal behaviours, offering unprecedented insights.
2. **IoT Integration for Real-Time Data Sharing:** The integration of Internet of Things (IoT) technology is envisioned to link network nodes, enabling seamless real-time data sharing, particularly in remote monitoring scenarios. Challenges in this realm could be resolved by merging intelligent tools with cloud-based platforms for centralized and remote intrusion detection procedures.
3. **Species-Specific Recognition:** The future holds innovative systems derived from diverse data and extensive research, catering to a wide range of wild species. These systems promise higher accuracy and reliability, significantly benefiting conservation efforts by targeting specific wildlife species.
4. **Focus on Energy-Efficient Sensor Technologies:** Future advancements in sensor technology prioritize energy efficiency to improve overall performance. This emphasis aligns with sustainability goals, driving advancements while minimizing energy consumption.
5. **Collaboration with Conservation Initiatives:** The trajectory of intrusion detection intertwines with wildlife conservation programs. It not only contributes to conservation efforts but also offers valuable data collection opportunities for conservationists, enhancing ecological studies and deepening our understanding of the natural world.

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APPENDIX

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