UNIVERSITY of RWANDA

ACEIoT

Website: www.aceiot.ur.ac.rw
Mail: aceiot@ur.ac.rw

College of Science and Technology

AFRICAN CENTER OF EXCELLENCE IN INTERNET OF THINGS

Research Thesis Title: Enhancing Military Surveillance Capabilities through Deep Learning enabled Robot.

A research Thesis submitted in partial fulfilment of the requirements for the award of masters of science degree in internet of things: wireless intelligent sensor network.

Submitted By:

Name: WASWA John (Ref. No: 221030744)

July, 2024

AFRICAN CENTRE OF EXCELLENCE IN INTERNET OF THINGS

Research Thesis Title: Enhancing Military Surveillance Capabilities through Deep Learning enabled Robot.

A dissertation submitted in partial fulfilment of the requirements for the award of masters of Science degree in internet of things: wireless intelligent sensor network

Submitted By

WASWA John (Ref. No: 221030744)

Supervised by:

-Dr. UWITONZE Alfred

-Dr. GASHEMA Gaspard

July, 2024

CERTIFICATE

This is to certify that the" Enhancing Military Surveillance Capabilities through Deep Learning enabled Robot" final thesis is a record of the original work done by WASWA John (Ref.No: 221030744) in partial fulfillment of the requirement for the award of a Master's Degree in Internet of Things-Wireless Intelligent Sensor Networking from the University of Rwanda- College of Science and Technology through the African Center of Excellence in Internet of Things, during the Academic year 2023-2024.

This work has been submitted under the supervision of ……………… and ……………………...

Main Supervisor: Dr UWITONZE Alfred

Date: 05/06/2024

Signature :

Co-Supervisor: Dr GASHEMA Gaspard

Date: 05/06/2024

Signature:

The Head of Masters and Training

Dr. James RWIGEMA

Signature:

Date:…../……../2024

DECLARATION

I, **WASWA John (Ref.No: 221030744**) declare that the research thesis titled " Enhancing Military Surveillance Capabilities through Deep Learning enabled Robot " for the award of a Master's degree in Internet of Things- Wireless Intelligent Sensor Networking is my original work and has never been presented in any University or Institution for the same purpose.

Names: **WASWA John**

Ref: **Ref. No: 221030744**

Signature ………………………

Date: ……/……/……

ACKNOWLEDGEMENT

First of all, I would like to thank God for all the blessings, guidance and protection during my studies. My deep gratitude and acknowledgements are also expressed to my supervisors, **Dr Uwitonze Alfred** and **Dr Gashema Gaspard** for devoting their time to supervise and monitor this project. Their guidance, responsibilities, several meetings for feedback, and advice to me all helped to successfully complete this project.

Also, my sincerely appreciation goes to University of Rwanda, African Center of Excellence in Internet of Things(UR-ACEIoT) for their tremendous support. They have turned my Masters journey to the best part of my academic life Thank– you to everyone who gave me their thoughts in order to assist me in achieving this thesis'sgoals.

May God pour blessings upon them.

LIST OF FIGURES

ABSTRACT

In the modern area of warfare and defense, the need for efficient and adaptable surveillance Solutions is Paramount. This thesis leverages a fleet of autonomous and controlled robots equipped with a multitude of sensors, such as H-bridge, ultrasonic sensor, NodeMCU (ESP8266) and camera connected to a Raspberry-pi play a big role. In this thesis, the Yolov8 model as one of the state-of-the-art deep learning models to perform object detection and recognition tasks was applied. The aforementioned robots are deployed in strategic military environments for real –time surveillance and reconnaissance tasks. The core system relies on deep learning(DL) algorithms especially its YOLOV8 model to enable the system to make intelligent decisions. Through this model, the robots continuously learn and adapt their behaviors based on the environment and mission objectives. Robot for military surveillance contains some features such as, communication and coordination. Herein, after capturing the image using camera, the robot processes the image through the YOLOV8 model of deep learning. In addition, it shows and differentiate the detected objects though the identification of name, location, timestamp. It is farther controlled through the control center in real-time while dashboard displays all of data of detected objects with their attributes. This is a real-time decision patrolling specific area, tracking moving targets and reporting anomalies to the dashboard. In other words, by combining IoT and YOLOV8 model, the system offers a scalable, cost-effective and efficiency solution for military surveillance in the camp or in the field enhancing situational awareness and response capabilities. This proposed system provides a potential technology to significantly improve the effectiveness of military operations while reducing risks to realize the capabilities of the innovative approach for military surveillance. The results received indicate that the robot was capable to fully move around and it is able to detect and identify obstacles. The probability of detecting an object as human has a confidence level between 0.5-1.0-while that of other object is about under 0.5.

Keywords: Deep Learning, Robot, Military surveillance, Ultrasonic sensor, Yolov8.

LIST OF ACRONYMS AND SYMBOLS

DL: Deep Learning

IOT: Internet of Things

DC: Direct current

VCC: Common Collector Voltage

MCU: Microcontroller Unit

GND: Ground

YOLOv8: You Only Look Once

SPI: Serial peripheral interface

SDIO: Secure Digital Input Output

I2C: Inter-Integrated Circuit

UART: Universal asynchronous receiver / transmitter

IMU: International Measurement Unit

TABLE OF CONTENTS

CHAPTER 1. INTRODUCTION

In an area marked by evolving security challenges and the need for advanced surveillance capabilities, the fusion of cutting-edge technologies has become imperative. [1]The integration of the internet of Things (IoT) and Deep Learning (DL) has emerged as a promising solution to enhance military surveillance systems [2]. This introduction provides an overview of the Robot for military surveillance, an innovative paradigm that leverages IoT and DL to address the demands of military operations. Modern Military operations require a profound understanding of complex and dynamic environments. [3] Surveillance plays a pivotal role in acquiring critical information, monitoring threats and ensuring the safety and security of military Personal. Traditional Surveillance methods. [4] however are often constrained by their Static nature and limited adaptability to evolving scenarios. In response to these Challenges, the Robot for Military Surveillance offers a paradigm shift. In addition, the Integrated Internet of Things based design and Android operated Multi-Purpose Field Surveillance Robot for Military Use and the Military safety and surveillance robot with two-Way Communication have proved the promise of (IoT)-based robotics in Military applications. The IoT revolution has ushered in a new area of connectivity extends to a fleet of autonomous robots equipped with an array of sensors, transforming them into intelligent IoT devices. These robots, deployed in strategic military locations, serve as a distributed network of data-gathering agents. [5]Deep Learning for Autonomy especially using YOLOV8, its well-trained model, [6]a subset of artificial intelligence, has gained prominence for its ability to imbue autonomous Systems with the Capacity to learn, adapt and make intelligent decisions. In the Robot for Military Surveillance, DL algorithms act as the Cognitive engine, empowering the robots to autonomously navigate intricate terrains, optimize surveillance routes, [7] and respond dynamically to emerging threats. This Research is to harness the potential of IoT and YOLOV8, the model of Deep Learning to create a military surveillance System that is agile, adaptive and effectives, the system aims to optimize resource utilization and enhance operational effectiveness.

1.1 BACKGROUND AND MOTIVATION

The development of a Robot for Military Surveillance using Deep Learning (DL) is rooted in the evolving nature of military operations, [8]the emergence of advanced technologies and the need for more effective, adaptive and intelligent surveillance solutions. The background and motivation for this innovative approach can be summarized in different way such as Changing Battlefield Dynamics; For Modern Warfare is characterized by rapidly changing Battlefield Dynamics[9]. Military forces often face asymmetric threats, urban workface and unconventional tactics. These Complexities necessitate Surveillance Systems that can adapt to diverse operational scenarios. Limitations of Traditional Surveillance Methods; such as fixed camera**s** and human patrols, have limitations in terms of Flexibility, scalability and adaptability[10]. They are often static and incapable of responding quickly to emerging Treats or Dynamic changes in the Environment. The proliferation of IoT technologies has enabled the integration of sensors, Communications devices and robotics, creating a network of interconnected devices [11]. In the military context, IoT offers the potential to transform a collection of sensors into an intelligent surveillance network. DL algorithms have demonstrated the capability to enable autonomous agents to learn from the environments and make intelligent decisions, which aligns with the need for adaptable surveillance systems. Military Surveillance Systems should not only passively collect data but also analyze and respond to it [12]. A Robot for Military Surveillance equipped with DL techniques especially YOLOV8 can operate autonomous, navigate challenging terrains and make informed decisions in real time. Ensuring the security and reliability of military surveillance systems is paramount.

1.2. PROBLEM STATEMENT

Traditional military surveillance methods often suffer from limited Coverage and blinding spots in the Operational area. This limitation hampers situational awareness and increases Vulnerability to Threats that may exist outside the surveillance range; The problem statement for developing a Robot for Military surveillance using Deep Learning (DL) though YOLOV8; its well-trained model for Objects recognition can be classified in the following manners such as Fixed Cameras and manned patrols, lack the adaptability to respond swiftly and effectively to changing battlefield Conditions. They are often static, rigid and unable to autonomously adjust their surveillance strategies in real -time. In order to maintain national security, it is crucial to embrace military surveillance practices. With recent advancements in technology robotics has become an increasingly popular tool for this task. However, the existing generation of Surveillance robots exhibits weakness regarding its capacity to adapt to diverse situations and circumstances. Deep learning's practical applications within robots have exhibited considerable potential in enhancing robot's adaptability. The Implication of this finding necessitates the development of an IoT – Based military Surveillance robot that integrates YOLOV8, a Deep Learning Model into its system design to increase efficiency and enable rapid adaptation under different environments and Conditions.

1.3 Study Objectives

1.3.1 General objective

General Objective of developing a Robot for Military Surveillance Deep learning through YOLOV8 Model is to create an advanced, adaptive and efficient surveillance system that enhances the effectiveness of military operations while minimizing risks to human personal.

1.3.2 Specific Objectives

To achieve the general objective of Developing a Robot for Military Surveillance Using Deep Learning, Specific objectives that have to be achieved are as follows:

1. To assess the existing Military surveillance system and identify its weaknesses and strengths.

2. To Design and develop the physical hardware and architecture of the IoT Connected robotic agents capable of navigating and patrolling designed areas within a military camp or operational environment.

3. To Integrate a state-of-the art deep learning model such as YOLOv8, to enable real-time object detection and classification, with a focus on identifying potential threats, enemies holding weapons while ensuring reliable performance in both day and night conditions.

4. To Establish secure and reliable data transmission protocols to enable the robot to seamlessly share the captured images, detection results and other relevant data with a central command center, facilitating a real-time situational awareness and rapid response.

5. To implement a user-friendly control and monitoring system that allows military personal to remotely operate the robot, receive alerts while ensuring the system's resilience and adaptability to changing environmental conditions.

1.3 Hypothesis

The hypotheses for the study were:

1) There are no existing architectures for integration of IoT into existing Military Surveillance systems.

2) The use of IoT – connected robotic agents with Deep Learning algorithms Significantly improves the efficiency of military surveillance operations compared to traditional surveillance methods.

3) It is possible to use IoT technologies to develop areal –time Military Surveillance system.

1.4 Study Scope

The study scopes of a Robot for Military Surveillance using YOLOv8, a Deep Learning model is an interdisciplinary research area that Combines robotics, IoT, Artificial intelligence and military applications. The autonomous Robot has the capability to work in the military camp or at the field depending upon its necessity.

1.5 Significance of the Study

IoT Robot for Military surveillance Using Deep learning techniques, YOLOv8 specifically is multifaceted and extends to various aspects of military operations, technology advancement and national security.

1.6 Organization of the Study

The rest of the study is organized as follows:

Chapter 1: This chapter introduces the research thesis's background and describes the research thesis motivation. The introduction to technologies is followed by a description of problem statement that set the objective, the scope, hypothesis, significance and organization of the study for this project. The Chapter ends with a conclusion.

Chapter 2: Presents a review of related literature. This Section discusses the existing studies; highlight their strengths and limitations and also the research gaps to be addressed.

Chapter 3: Indicates the methods used for this research thesis, system design, prototype model and their parameters.

Chapter 4: Discusses on obtained results and make analysis based on graphs findings. Chapter 5: Concludes the discussion and final remarks.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This section provides a comprehensive analysis of existing studies, Research and technical articles related to Robot for Military Surveillance using Deep Learning. The review aims to identify the state-of-the-art solutions, highlight their strengths and limitations and identify research gaps that the proposed study intends to address.

2.2 Existing Robot for Military Surveillance using Deep Learning

Researchers have recently shown a lot of interest for the potential of using robots to carry out military surveillance. The development of the IoT has allowed for the better integration of robotics and sensors into military surveillance, [13] creating new opportunities. For example, Singh et al, in their study on the development of surveillance robots, they pointed out the significance of situation modeling, situation awareness, situation calculus, situation control, and situation semantics.

A literature review on “Robot Military Surveillance Using Deep Learning” Would Provide an overview of the state-of-the art in this field. It should encompass key papers, trends, Challenges and future directions related to the integration of IoT (Internet of Things) technologies, robotics, military surveillance and Deep learning.

IoT (internet of things) has revolutionized various domains, including military applications, by providing real- time data for informed decision-making. [14]Combining IoT with robotics' and Deep learning has the potential to enhance military Surveillance, making it more autonomous and efficient. This literature review discusses the key developments in this area

2.3 IoT in Military Surveillance

The Internet of Things (IoT) has found numerous applications in military surveillance and defense operations. [15]IoT technology provides the military with the capacity to collect,

Transmit and analyze data from various sensors and devices in real –time. This enables better situational awareness, more effective decision-making and improves security.

It's important to note that while IoT technology provides many benefits in military surveillance, it also raises concerns about data security, [16] privacy and the adversaries to exploit Vulnerabilities in the connected systems. As result, the military needs to implement robust security measures to protect its IoT infrastructure and data.

2.4 Deep Learning in Robotics

Deep Learning (DL) is a machine learning paradigm where agents learn to make sequential decisions by interacting with an environment Yolov8 is a state-of-the-art deep learning model for real-time objects detection used in robotics, autonomous driving and video surveillance. [17]It has found numerous applications in robotics, as it enables robots to adapt and improve their behavior through trial and error. Here's how Deep learning is used in robotics:

1. Training Robot Behavior: DL can be used to train robots to perform tasks and make decisions such us images detections and highlights in dynamic and uncertain environments using YOLOv 8; a state-o-the-art deep learning model.
2. Continuous Learning: Deep learning allows robots to continuously adapt to new situations and tasks. They can learn from their experiences and update their policies or Strategies in real-time.
3. Simulated Training: Many robotic systems are trained in simulated environments before being deployed in the real world. DL can be used to train robotics in simulators to reduce the risk of damage and accidents during the learning process.
4. Manipulation and Grasping: DL is used to teach robots how to grasp and manipulate objects. Robots can learn to pick up and move objects of various shapes and sizes, making them valuable in manufacturing and warehouse automation.
5. Human- Robot Interaction: DL can be applied to robots that interact with humans. For example, robots can learn to provides assistance in healthcare settings or guide visitors in publics space

Challenges, while DL offers tremendous potential for robotics, it also comes with challenges, such as the need for extensive training data, safety concerns during training and the transfer of learned behaviors from simulation to real World. These challenges are actively being addressed by researchers.

2.5 Integration of IoT and Robotics

The integration of IoT and robotics is transforming industries by making robots more intelligent, [17] adaptive and efficient. Integration of IoT and Robotic can integrated in different manner such as **Sensors and perception**: IoT Sensors such as Cameras, LiDAR and proximity sensors can provide robots with rich source of data about their surroundings.

Real-time Data Sharing: IoT enables robots to share real-time data with other devices, robots or control systems.

Remote Monitoring and Control: IoT Connectivity allows operators to remotely monitor and control robots.

Data Analytics and Machine Learning: The data collected from IoT Sensors on robots can be used for data analytics and machine learning. This allows robots to learn from their experiences and improve their performance over time.

Safety and Security: IoT can enhance the safety and security of robotic systems. For example, robots can use IoT data to detect and respond to safety hazards and security measures can be implemented to protect robot communications and operations

2.6 Deep Learning for Autonomous Surveillance

Autonomous Surveillance Systems Powered by DL has the potential to make real-time decisions, adapt to changing environments and efficiently monitor and respond to various security and Surveillance tasks. [18]

2.7 Challenges and Security Concerns

The integration of IoT and Robotics in the context of autonomous Surveillance presents several Challenges and Security concerns such as

1. Privacy concerns: The use of IoT Sensors and Surveillance Cameras can potentially invade individuals ‘privacy. [19] It’s crucial to implement mechanisms to protect the privacy of individuals and comply with relevant privacy regulations

2. **Data Security:** The data collected by IoT devices and surveillance Cameras is Sensitive and valuable. Securing this data from Cyber-attacks, unauthorized access is almost importance.

3. **Network Security:** Implementing robust network security measures such as encryption and access control is essential.

4. **Device security:** IoT devices can be vulnerable to attacks if not properly secured.

5. **Edge Computing Security**: Many IoT devices and surveillance systems employ edge computing to process data locally.

CHAPTER 3: RESEARCH METHODOLOGY

This Chapter describes different methodologies tools, techniques, processes and procedures that have been used to achieve the general and specific objectives highlighted in this study.

3.1 Research Process

The research process started with analysis of existing research in the field of interest for the purpose of getting a critical understanding of the field of a studied challenge as well as identifying a research problem. This has been conducted along with formulating the research topic based on the gaps identified from the literature review.

3.2 Development of AI Robot Surveillance

Firstly, the proposed robot will have the ability to navigate its surroundings and keep an eye on its surroundings without the assistance of a person, which will lower the probability of human casualties occurring in high-risk locations. Secondly, the robot will be outfitted with a variety of sensors, including camera, ultrasonic, sensor, which will let it to recognize and avoid obstacles in its route. These sensors will also allow it to detect and avoid obstacles in its path.

3.3 Embedded System Design

This section presents the embedded system level design. The system architecture is described first, and then the system design. The use case diagrams, system flow chart, and system components are shown. [20]

3.3.1 System Architecture

The main components of The Internet of Things robot to utilize for military surveillance include hardware components, Software part and Visualization Part.

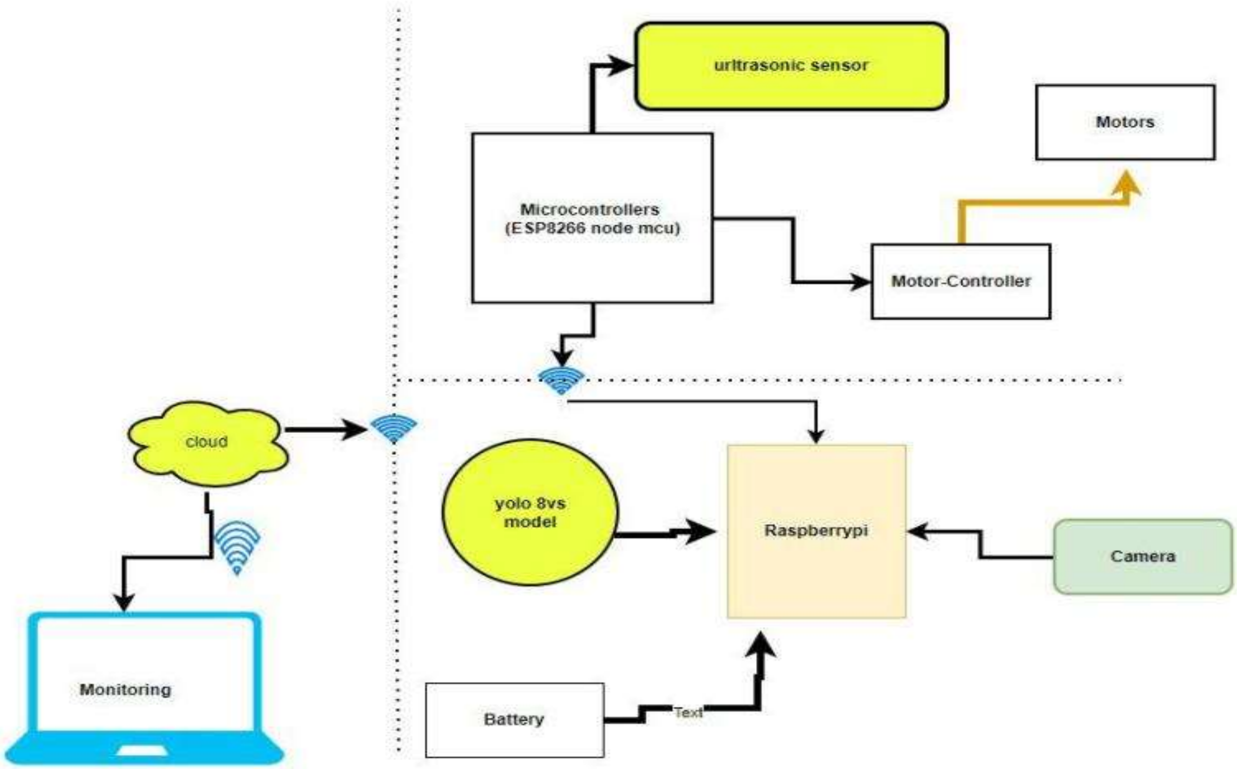

Figure 1: System architecture

The above architecture consists of camera sensor with day and night vision-enabled and connected to the Raspberry pi and use Yolov8, the state-of-the-art deep learning model which uses Raspberry Pi to transmit data to the cloud. The detected objects, what they hold and their location are real-timely detected and displayed to the dashboard. On the other hand, the ultrasound sensor on moving robot is able to detect the obstacles and has the right to turn around either right or left during its patrol. The movement of robot is activated by the motors. The robot is powered by a battery and electrical power for energy efficiency.

3.3.2. Hardware Architecture

To create a Robot for Military Surveillance using Deep Learning, numerous IoT ecosystem was applied. Those include Camera connected to Raspberry pi for capturing images, ESP8266 for wireless communication to the cloud, Robotic case for housing the Components, motors responsible for the movement of the robot, Ultrasonic sensor for obstacles avoidance and battery for energy.

3.3.3. Software Architecture

Software design is based on modules. It depends upon the programming languages applied during the development as follows:

- These modules refer to the encapsulation of data and the functions for the entire system working principle.
- On the other hand, they can refer to the package that builds the system.

3.4 System Components

The system is made up of both hardware and software components. The components have been grouped in categories based on their functions.

3.4.1 Hardware components

3.4.1.0. H-Bridge

Is a simple circuit that lets you control a DC motor to go back of forward? You normally use it with a microcontroller, such as an Arduino, to control motors. In this system the robot's motion will be managed by means of an H-Bridge.

Figure 2: H-Bridge

3.4.1.1. Ultrasonic Sensor

An ultrasonic sensor is an instrument that measures the distance to an object using ultrasonic sound waves. An ultrasonic sensor uses a transducer to send and receive ultrasonic pulses that relay back information about an object's proximity. It has four pins namely Vcc, GND, Echo and Trigger. [23]Vcc is connected to 5V supply while GND is grounded. Therefore, in this system the presence of people will be detected using the Ultrasonic sensor and IR sensor and the robot's path obstructions will be identified by the ultrasonic sensor.

Figure 3: Ultrasonic Sensor

3.4.1.2. Wireless Module (ESP8266)

ESP8266 can perform as a complete standalone system or as a slave device to a host MCU, reducing communication stack overhead on the main application processor. ESP8266 can interface with other systems to provide Wi-Fi and Bluetooth functionality through its SPI / SDIO or I2C / UART interfaces. WIFI Module is used to make communication between robot and the base station. WIFI Module also is used to control robot to move forward, backward, left and right directions.

Figure 4: ESP 8266 Wi-Fi Module

3.4.1.3. Camera sensor

The Camera is attached to microcontroller and it will capture the images and records the video and saves in the SD card present on it.

Figure 5: Camera

3.4.1.4. Raspberry Pi

In addition to being a low-cost Linux computer, the Raspberry Pi has a set of GPIO (general purpose input/output) pins that let you experiment with the Internet of Things (IoT) and control electronic components for physical computing.

Figure 6:Raspberry Pi

3.5. Software tools

Languages, Libraries, Editors and Programming tools were applied during this thesis.

3.5.1. Cloud

The storage and management of the data produced by Internet of Things devices is greatly aided by cloud computing. Cloud platform was used referring to its capability of being elastic to continuously receive, store IoT data. This cloud was developed to store Camera data, Ultrasonic and other system related data for decision making purpose. The communication of data to the cloud was enabled by the Wi-Fi.

3.6. The System Functionality

This part explains the flow both instruction and data in the system and how it functions. It also explained the data flow its function in the system. It presents the processes details of how can be implemented.

The figure below indicates an algorithm using flowchart by taking about how surveillance robot in this thesis is done. The system continues its task by detecting the presence of the person in military environment and make intelligent decision based on the collected data.

3.6.1. System Flowchart

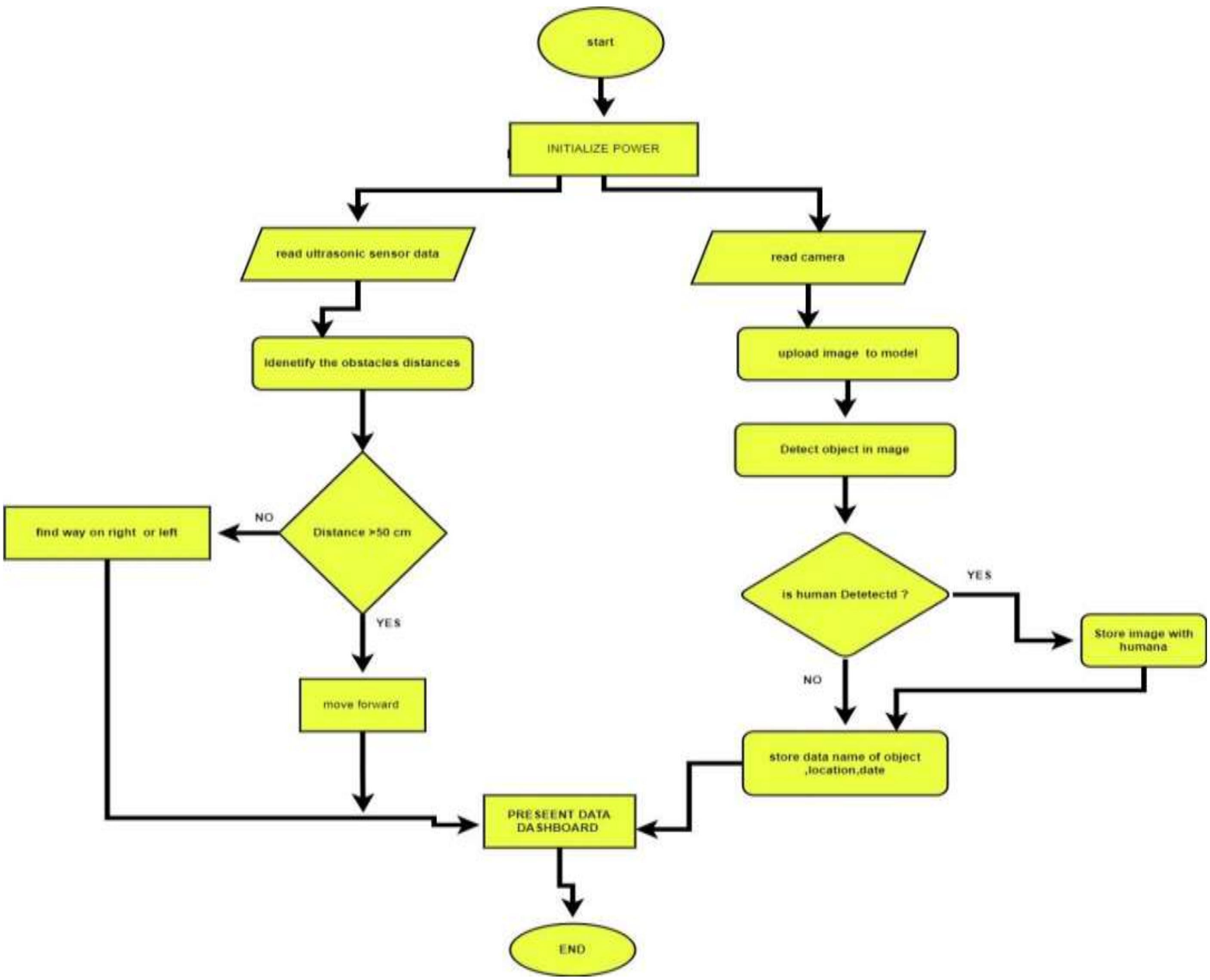

Figure 7: System Flowchart

3.6.2. Explanation of the Flowchart

This flowchart consists of the workability of the entire system where the system is powered on and the ultrasonic sensor attached in the front side of the Robot assists in the movement, detects obstacles and move forward when the obstacles are in more than 20 cm. Otherwise, the robot finds the way right or left to continue its operation of surveillance. On the other hand, when the camera which connected to the raspberry pi detects an object, it uploads the image to the YOLOv 8 model for processing. In case it identifies this objects/image as human, the information automatically is stored to the cloud as Human and what it holds. Also incase the object is not human, the information is also stored to the cloud with name, location and what it holds.

3.6.3. Functional Requirements

To be able to have a robot system for military surveillance, these functional requirements are applied:

- Patrolling the military camp or the field during military operations using camera sensor.
- Robot movement enabled by motors and ultrasonic sensor for obstacles avoidance.
- Detect image, process it and display the objects detected to the cloud and what they hold with its location in longitude and latitude coordinates using Yolov8, the state-of-the-art deep learning model.
- Analysis and visualization of data is done to the dashboard.

3.6.4. Non-functional Requirements

- Performance: the performance is based on hardware, software, connectivity, startup and storage.
- Reliability: This robot system delivers accurate and reliable data based on the set probability intervals which is of 0.5 to 1.0, the object is human and under this threshold, the object is not human.
- Availability: Th robot system is available and working 24/7 hours using day and night vision camera. It won’t turn off.
- Usability: It is used in Military settings for surveillance purpose.
- Recoverability: In case there is a damage, the robot system used for the surveillance is easy to fix.

CHAPTER 4: RESULTS AND DISCUSSION

This section describes step by steps of the system results obtained and system analysis.

The figure below shows the prototype of moving surveillance robot. This surveillance robot is made with different sensors such as H-bridge, Ultrasonic sensor, Camera and the microcontrollers such as Esp8266 and the Raspberry pi.

4.1. Robot Prototype

Figure 8: Surveillance robot

The Robots is deployed in strategic military environments for real –time Surveillance and Reconnaissance tasks. The robot is equipped with an ultrasonic sensor, a sensor, and a camera. The ultrasonic sensor connected to NodeMCU (ESP8266) is used to measure the distance between objects and avoid obstacles, the camera assists the robot in capturing images, and the sensor is used to detect the object moving together with their name, location and what they have. When the robot identifies a person, it sends a message together with the person's name, location (longitude and latitude). Our robot can also detect the type of items that a person owns using the yelov8, the state-of-the-art deep learning model. By integrating the sensors with RaspberryPi, allow the robot to make intelligent decision based on collected data, enabling it to navigate autonomously as illustrated in the figures below.

4.2. Insider Robot case

Figure 9:Insider Robotic case

The above picture shows the components which are inside the case of the robot.

4.3. Object detection and Classification

4.3.1. Object detection

For the object detection, see the figure below:

Figure 10: Object detected

In the above figure, the camera connected to the Raspberry Pi detected an object which is a person. It displayed on the dashboard the time the object is captured, the name of the object, the confidence level of 0.75 which inside the probability interval of 0.5-1.0. It displays also the longitude of 30.0861036 and the latitude of -1.9893346. The analysis report should be also downloaded from the dashboard in the form of PowerPoint.

4.3.2. Objects Classification

The figure below depicts the classification of objects detected and display them in details:

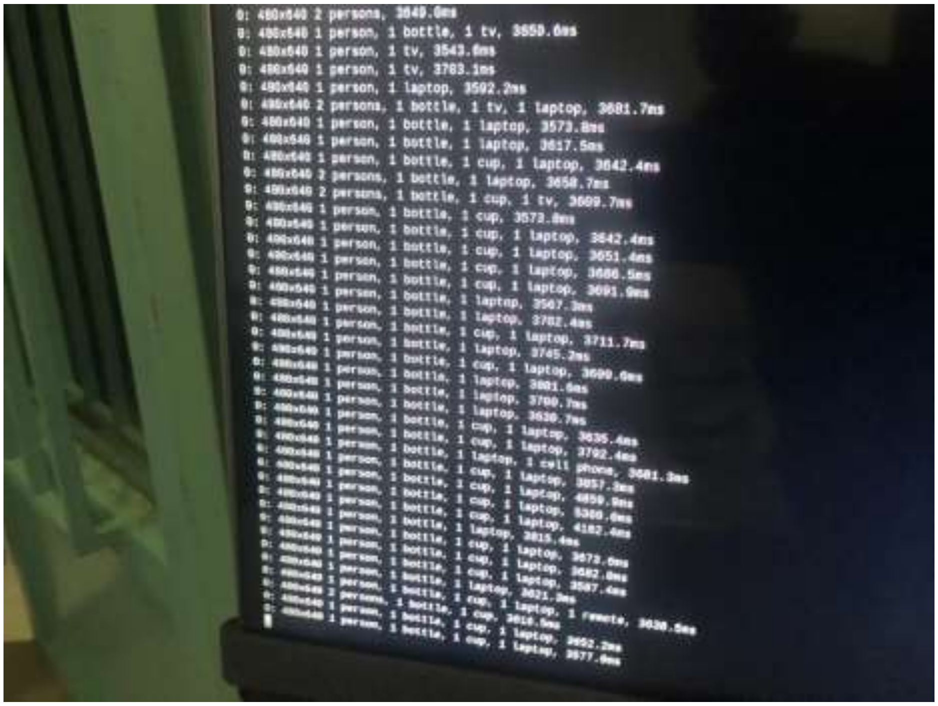

Figure 11: Objects classification

The figure above Illustrates the results of an event detected by the Robot which automatically sends notification of the occurred event and the position of the detected individual with the items hold to the person who is to the cloud.

4.3.3. The location of objects detected

The objects detected ‘location is displayed in the called model of performance as displayed in the below figure:

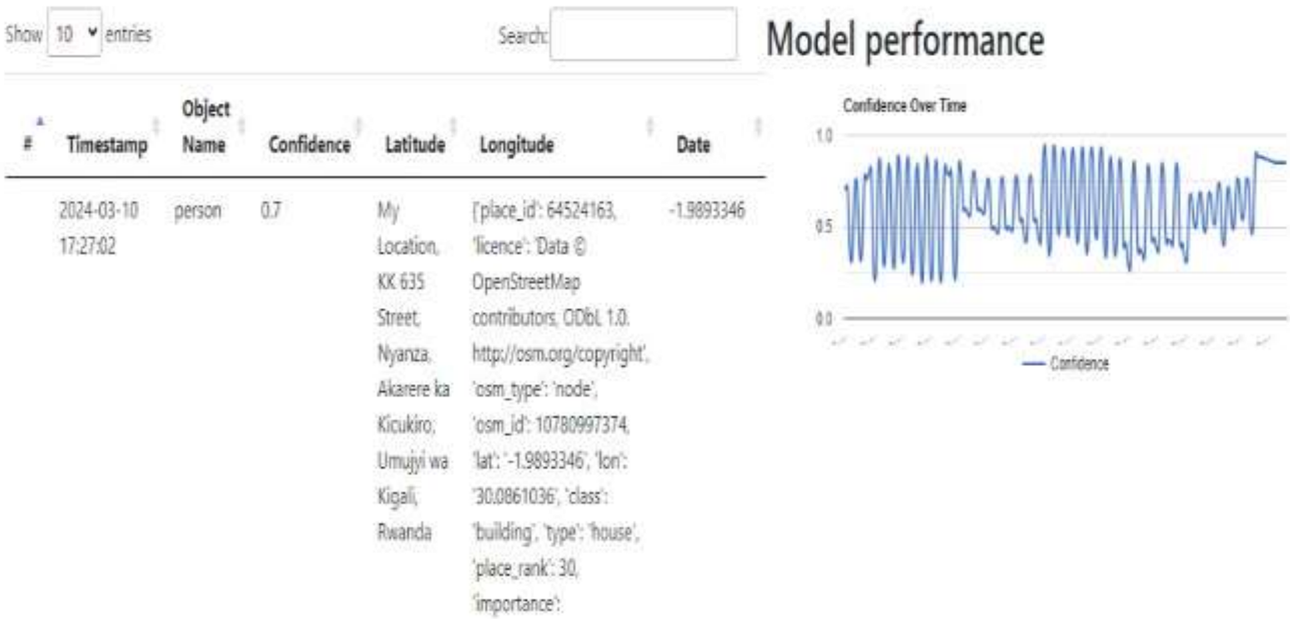

Figure 12: System's model performance

The above figure illustrates the persons detected and her or his location. This serves to demonstrate that incase a person is detected; robot is able to identify full information of detected person and display information to the dashboard. The performance of the model is demonstrated in responding to the set probability for Human or any other object detected. For Human, the probability is between 0.5-1.0 and other this interval, the object is not Human which displays also in the chart above with the hold equipment. As mentioned in the above figure, the street, district and province where the enemy is detected are also displayed.

4.3.4. Dashboard

The below picture consists of the dashboard where all of the results are displayed.

Report Data

Timestamp	Object Name	Confidence	Latitude	Longitude	Date
2024-03-10 16:28:31	person	0.42	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:31	person	0.42	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:32	person	0.27	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:32	person	0.27	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:33	person	0.46	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:33	person	0.46	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:33	person	0.45	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:33	person	0.45	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:34	person	0.38	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:34	person	0.38	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:35	person	0.38	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:35	person	0.38	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:36	person	0.47	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:36	person	0.47	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:37	person	0.33	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:37	person	0.33	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:37	person	0.36	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:37	person	0.36	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:38	person	0.33	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:38	person	0.33	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:39	person	0.38	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:39	person	0.38	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:40	person	0.36	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:40	person	0.36	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:41	person	0.36	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:41	person	0.36	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:41	person	0.75	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:41	person	0.75	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:42	person	0.75	-1.9893346	30.0861036	2024-03-10
2024-03-10 16:28:42	person	0.75	-1.9893346	30.0861036	2024-03-10

Figure 13: Dashboard

The above table is the dashboard which contains the object detected. In this case, it displays the name of the object, the timestamp, confidence level, latitude and longitude and date the object is taken.

4.3.5. Spatial Distribution of the detected objects

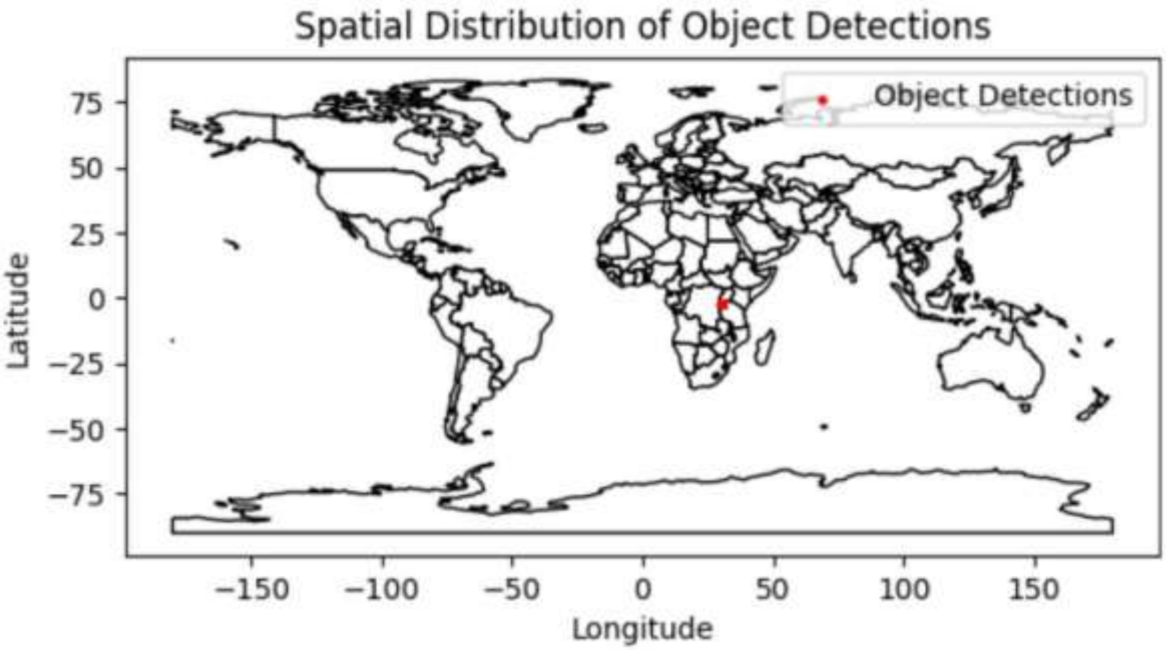

Figure 14: Spatial Distribution of Detected objects

The above picture presents the results in their spatial distribution on the map. The red dots show the location of the object in longitude and latitude representation**.** [21]

4.3.6. Detected person and what he holds

Figure 15: Person Detected

The picture above shows the person who was captured by the camera and the equipment he holds which is the cell phone in his hands. The confidence level of a person here is of 0.89 and for the cell phone is of 0.41.

4.3.7. Data Organization on the dashboard

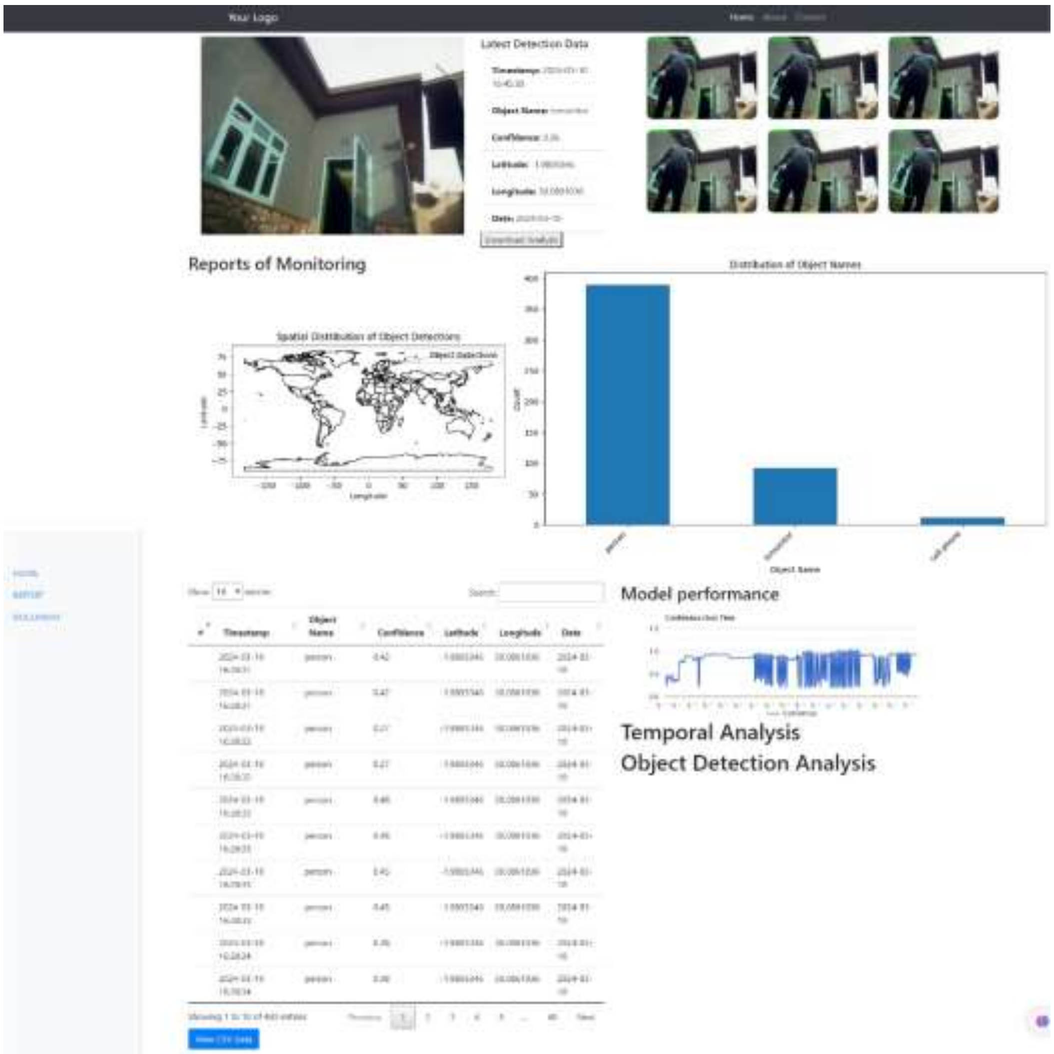

Figure 16: Data Organization on the Dashboard

The figure displays the organization of the data in the dashboard including detected objects and their visualization to be used for future research.

4.3.8. Data Analytics Time Series

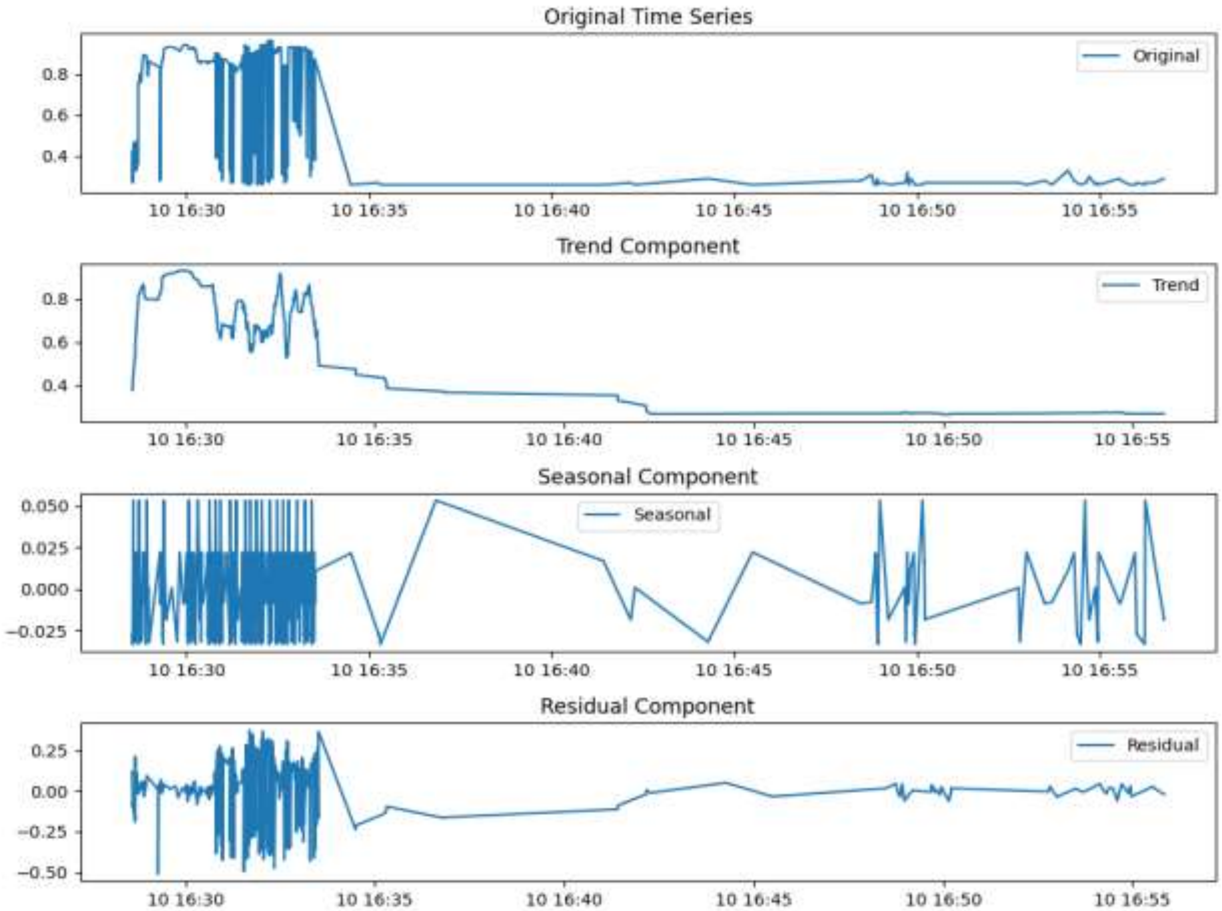

Figure 17:Data Analytics time series

The time series analysis in this figure revealed significant trends and seasonal patterns in the data. There is a noticeable increase in detections during certain periods, indicating potential areas of interest for further investigation.

Moving forward, it is important to continue monitoring the data for any emerging trends or anomalies. Consideration should also be given to improving data collection methods and refining analysis techniques to enhance the accuracy and reliability of future insights.

4.3.8. Robot control system

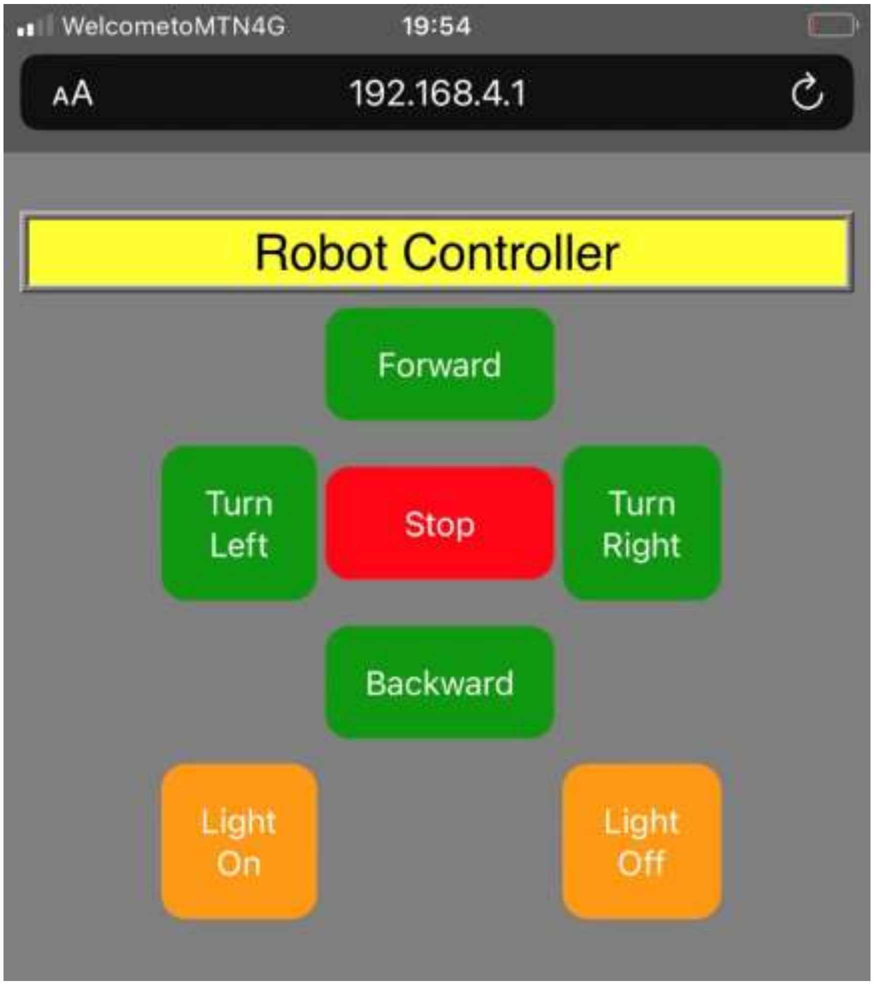

Figure 18: Robot control

The above figure consists of the system used to control the movement of the Robot in case there is a need to call it for some fixing which is connected to the portable wireless.

CHAPTER 5: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

An Enhancing Military Surveillance Capabilities through Deep Learning enabled Robot is a system that uses deep learning model to detect people and objects they hold, identifies the objects and report them with their location. The results have shown that the system works perfectly especially when it comes detecting the objects through a moving robot while using the YOLOv8 model to recognize the objects. It has also shown the high performance since the results are displayed to the dashboard for future use.

However, there are still challenges that need to be addressed. The performance of the system can be further improved by optimizing the deep learning models and incorporating more advanced techniques, such as transfer learning and ensemble learning. Additionally, ensuring the security and privacy of the Surveillance data remains a critical concern that needs to be addressed in future research.

5.2 Recommendation

Based on the finds and outcomes of a project on “Robot Surveillance using Deep Learning” the following are some recommendations for further research: Sensor Fusion: Investigate the integration of multiple sensors such as Cameras, LiDAR, and infrared sensors, to improve the overall perception capabilities of the surveillance system. Energy Efficiency: Develop energy-efficient algorithms and hardware solutions for IoT devices and robots to prolong their battery life and reduce energy consumption. User Training: Provide training and support for users to effectively deploy and manage the Robot surveillance system

REFERENCES

[1] V. B. Heidelberg, "Recognition and tracking in UAV videos," in *Springer*, 2012.

[2] I. a. P. M. K.K.Soundra Pandian Members, "Traversability Assessment of Terrain for Autonomous Robot Navigation," in *Proceedings of the International MultiConference of Engineers and Computer Scientists*, 2010.

[3] M. A. S. A. R. a. I. M. Nawi, "Path Planning Automated Guided Robot," in *Proceedings of the WoDLd Congress on Engineering and Computer Science* , San Francisco, 2008.

[4] B. J. a. G. S. Sukhatme, "“Real-time Motion Tracking from a Mobile Robot," *International Journal of Social Robotics*, Vols. Volume 2, Number 1, pp. 63-78.

[5] B. a. A. D. Wilson, "A state-based approach to the representation and recognition of gesture," in *IEEE Transactions on pattern analysis and machine*, 1997.

[6] S. A. S. K. a. G. K. M. Sathiyanarayanan, "Command Controlled Robot for Military Purpose," in *International Journal for Technological Research in Engineering*, 2014.

[7] S. A. S. K. a. G. K. M. Sathiyanarayanan, "Self Controlled Robot for Military Purpose," in *International Journal for Technological Research in Engineering*, 2014.

[8] S. A. S. K. a. G. K. M. Sathiyanarayanan, "Gesture Controlled Robot for Military Purpose," in *International Journal for Technological Research in*, 2014.

[9] U. G. V. M. Sathiyanarayanan, " Rajiv Gandhi Instititute of Technology," Unmanned Ground Vehicle, 2011.

[10] S. Kumar and P. Awasthi, "Navigation architecture for autonomous surveillance rover," in *International Journal for Technological Research in Engineering*, 2014.

[11] X. Y. a. J. Z. P. Z. Wenshuai Yua, "A new framework of moving target Detection and tracking for uav video application," in *International Journal for Technological Research in Engineering*, 2015.

[12] S. B. a. Y. Edal, "Evaluation automatic guided vehicle systems," in *International Journal for Technological Research in Engineering*, 2008.

[13] S. B. a. Y. Edal, "Evaluation automatic guided vehicle systems," in *International Journal for Technological Research in Engineering*, 2008.

[14] D. K. a. J. W. Oberholzer, "“The development and application of electronic technology to increase health, safety, and productivity in the South African coal mining industry," in *IEEE Trans. on Industry Applications,* 1997.

[15] J. B. R. M. S. &. P. Gubbi, "Internet of Things (IoT): A vision, architectural elements, and future directions. Future Generation Computer Systems," in *International Research Journal of Engineering and Technology (IRJET)*, 2021.

[16] L. A. R. A. C. S. S. Grieco, IoT-aided robotics applications: Technological implications, target domains and open issues, Computer Communication.

[17] D. S. S. D. P. F. &. Miorandi, Internet of things: Vision, applications and research challenges, Ad Hoc Networks, 2012.

[18] A. I. G. M. L. Atzori, The Internet of Things, Comput. Netw, 2010.

[19] M. B. J. C. R. D. J. E. D. G. K. H. R. J. J. M. A. P. B. S. M. T. O. Z. R. D. M. R. M. Waibel, "IEEE Robotics & Automation Magazine 18 (2)," 2011.

[20] A. P. V. &. L. D. N. Nayyar, A Comprehensive Review of Semiconductor-Type Gas Sensors for Environmental Monitoring., Review of Computer Engineering Research, 2016.

[21] S. a. P. Awasthi, "“Navigation architecture for autonomous surveillance rover," *International journal of computer Theory and engineering,* 2009,vol.1, No.3.