**BIRD DETECTION AND DETERRENCE SYSTEM**



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# **ABSTRACT**

Bird infestations continue to pose serious agricultural productivity challenges which result in heavy economic losses from damaged crops and disease spread. Traditional scarecrow methods have demonstrated limited success over time because birds develop resistance to these techniques. Small-scale agricultural producers still cannot access affordable technology-based solutions. The project featured an automated bird detection and deterrence solution using computer vision and acoustic repellent methods to tackle agricultural challenges. The ESP32 cameras provided real-time monitoring while the Arduino-based platform processed images through a YOLOv8 object detection model that was trained using 3,000 annotated images (2,750 for training purposes and 250 for testing purposes). The detection system developed with Python OpenCV and TensorFlow reached extraordinary results in a 50-epoch training period with its precision at 0.999, recall at 1.0, and mAP@50 at 0.995. The system achieved precise identification of birds amidst environmental features. A 12V rechargeable battery powered the signals to provide instant bird deterrence without the need for complex speaker systems. Future studies need to investigate solar power technologies together with edge computing improvements to enhance both system robustness and its deployment flexibility. This cost-effective intelligent system has demonstrated significant potential for safeguarding small to mid-sized sorghum farms and various crop production settings.

# **DECLARATION**

We, **Tendai Samuriwo and Ropafadzo Tabeth Kufandirori**, hereby declare that we are the sole authors of this dissertation. We authorise the **Midlands State University** to lend this dissertation to other institutions or individuals for the purpose of scholarly research.

Signature: …………………………………… Date:

………………………………………………

Signature: …………………………………… Date:

………………………………………………

# **APPROVAL**

This dissertation, entitled **“Bird Detection and Deterrence System”**  by Tendai Samuriwo and Ropafadzo Tabeth Kufandirori, meets the regulations governing the award of the degree of **BSc Honours Degree in Computer Systems Engineering** of the **Midlands State University**, and is approved for its contribution to knowledge and literary presentation.

Supervisor’s Signature: …………………………. Date: ………………………………

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First and fore mostly, we begin by giving thanks to Almighty God for His divine guidance during our entire project journey and for making this project a success

We extend sincere appreciation to Mr. Mpini for his professional guidance along with dedicated support which incorporated insightful feedback. His expertise and mentorship directed our project to success while ensuring proper execution.

We are deeply thankful to our families for providing continuous support and motivation which enabled us to finish this project. The combination of their unwavering belief in our capabilities and their moral, emotional as well as their financial support established the foundation for our strong determination and keeping our focus on high.

We extend heartfelt thanks to our colleagues, all academic staff members and technical personnel for their teamwork and valuable direct and indirect contributions toward completing this project. We experienced significant work quality improvement through their useful advice and constructive critiques along with their willingness to offer assistance.

# **DEDICATION**

We dedicate this work to our parents, whose unconditional love, constant sacrifices, and steadfast encouragement have been our foundation throughout this journey. Your unwavering belief in our abilities inspired us to overcome every challenge. To our siblings, thank you for your enduring support and motivation that carried us through demanding times. This accomplishment stands as a testament to the strength and love of our family.

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# **CHAPTER 1: INTRODUCTION**

# **INTRODUCTION**

This chapter explains the bird detection and deterrence system, describing the background of the investigation as well as the problem statement of the project. It also shows the aim and objectives of the project. Moreover, it explains the restrictions coupled with the delimitations in doing the research. The part also explains the tools and resources required for the system’s development and gives a work plan, including each phase from design to testing, as well as the justification and summary of the overall system.

# **BACKGROUND OF THE PROJECT**

Birds can cause serious damage to the agricultural sector by eating crops and lowering the yield of crops [1]. Additionally, they serve as vectors for a number of diseases and pests that can further damage crops [2]. As birds become accustomed to traditional bird deterrents, such as scarecrows, they frequently lose their usefulness over time [3]. This inefficiency shows the urgent need for innovative methods that can guarantee dependable crop protection. By instantly identifying bird movements and putting defenses in place, more sophisticated technologies like camera-based systems offer a superior approach [4]. Although real-time tracking of bird movements is made possible by these technologies, which offer a promising answer to this problem, these advancements are not without issues [4]. Because they are worried about the perceived cost, complexity, and reliability of these technologies, many farmers are unwilling to use them. Furthermore, a major flaw in the solution to the crop damage problem is that, although camera-based systems are able to identify the presence of birds, they do not deter them [5]. By offering a more efficient preventive mechanism, this study seeks to provide scalable and affordable systems that are necessary for increasing yields and minimizing economic losses.

# **1.3 PROBLEM DEFINITION**

Crops suffer damage from birds as birds eat seeds, grains and fruits. These bird invasions pose serious danger to crops, which can lead to various problems like huge yield decreases for farmers, broken plants, grain loses, spread of diseases and delayed growth resulting in increased economic losses. Scarecrows and other traditional bird repellents, are labor-intensive and often useless.

# **1.4 AIM**

To design a raspberry pi based prototype which identifies birds in a sorghum field using object recognition by ESP32 cameras and prevents birds from interfering with sorghum fields using sound technology.

# **1.5 OBJECTIVES**

* To develop a computer vision based device using the raspberry pi and ESP32 camera capable of identifying objects
* To train and validate a YOLO v8 model to classify birds from other objects.
* To scare away detected birds using alarm sounds.

# **1.6 LIMITATIONS**

Limitations are factors that may affect the validity of research results and the scope of findings [6]. These limitations reflect potential challenges in implementing the system. There are several limitations associated with implementing the bird detection and deterrence system. A major limitation is weather interference, as various weather patterns like rain or fog can make the cameras inaccurate, which lowers the system's efficiency. The device should be placed in a protected area like a shade. As time goes on, birds get used to the repellents over time. To add levels of deterrence that birds can't easily overcome, combine the detecting technology with additional deterrent measures like physical barriers [7]. Even though it is intended to be affordable, small-scale customers may still find the cost of setting it up expensive.

# **1.7 DELIMITATIONS**

Delimitations are the variables that lead the researcher to narrow the scope of the study from its potential vastness to a manageable size [8]. They can also be defined as the boundaries in which the system will operate.

This initiative focuses on small- to medium-scale usage like one acre farm and is not meant for vast agricultural plantations. The technology is not suitable for densely populated urban areas, as it can only function within a limited distance. The project will only look at eco-friendly deterrent strategies, it will not look into the use of dangerous chemicals or physical barriers.

# **1.8 DEVELOPMENT INSTRUMENTS**

Development instruments are the equipment required to develop the project. Some of the instruments include ESP32 cameras, Raspberry Pi, speakers, battery, python, YOLO v8 algorithm and Google colab.

**1.81 ESP32 CAMERAS**

ESP32 cameras are high-resolution cameras capture real-time images and videos of bird. The ESP32 camera module is known for its low cost and versatility in IoT activity. They are essential for monitoring the environment and detecting birds as they approach applications [9].

**1.82 RASPBERRY PI**

A microcontroller will control the system, activating deterrents such as sound when birds are detected. This small, powerful computer processes the images captured by the ESP32 cameras. It runs necessary algorithms, like those provided by the YOLO v8 algorithm, for real-time bird detection and identification. The Raspberry Pi also acts as the brains of the operation, controlling the system and activating deterrents based on bird activity [10].

**1.83 SPEAKERS**

These produce sound outputs to scare away birds. When the system detects birds, the speakers can play alarm sounds that birds find unpleasant, thus deterring them from the area [11].

**1.84 PYTHON**

Python is the programming language used to write the code for this project [12]. YOLO v8 algorithm distinguishes birds from other objects like leaves, drones in a detection system accurately from the camera feed especially in cases where unique movements’ patterns help in identifying birds [13]. Together, they form the software backbone of the system, enabling bird detection and triggering deterrent actions.

**1.85 BATTERY**

This provides a reliable and continuous power source for the entire system. It's crucial for ensuring that the cameras, Raspberry Pi, and speakers remain operational, especially in remote or off-grid locations [14].

**1.86 GOOGLE COLAB**

Google Colab is a cloud-based Jupyter notebook environment that allows you to write and execute Python code in the browser. It provides access to powerful hardware (Graphics Processing Unit and Tensor Processing Unit) for training machine learning models [15].

# **1.9 WORK PLAN**

A research plan is a documented overview of a project from start to finish, detailing the research efforts, participants, methods and anticipated results.

Table 1.1: Table of activities and duration

|  |  |  |  |
| --- | --- | --- | --- |
| **Task** | **Start date** | **Finish date** | **Duration (month)** |
| Project Proposal | 1 September 2024 | 30 September 2024 | 1 |
| Planning | 1 October 2024 | 31 October 2024 | 1 |
| Literature review | 1 November 2024 | 30 November 2024 | 1 |
| Design | 1 December 2024 | 28 February 2025 | 3 |
| Implementation | 1 March 2025 | 31 March 2025 | 1 |
| Testing | 1 April 2025 | 30 April 2025 | 1 |
| Documentation | 1 September 2025 | 30 April 2025 | 8 |

**GANTT CHART**

A Gantt chart is a project management tool that visually represents a project schedule over time.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| TASK NAME | DURATION (MONTHS) | | | | | | |  |
|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Project proposal |  |  |  |  |  |  |  |  |
| Planning |  |  |  |  |  |  |  |  |
| Literature review |  |  |  |  |  |  |  |  |
| Design |  |  |  |  |  |  |  |  |
| Implementation |  |  |  |  |  |  |  |  |
| Testing |  |  |  |  |  |  |  |  |
| Documentation |  |  |  |  |  |  |  |  |

**Figure 1.1: Gantt chart**

# **1.10 JUSTIFICATION**

The justification of a study is a set of reasons that explain why the study is necessary and important based on its background [16].

A more dependable method is necessary because the present bird prevention techniques, like utilizing scare craws, are frequently inefficient or time-consuming. The purpose of the project is to decrease crop losses brought on by bird damage, which is a big problem for farmers. It offers an automated bird tracking and prevention system that is inexpensive and boosts efficiency while minimizing the need for human involvement. Furthermore, the system's use of safe repellents ensures environmental compliance, conserving animals while fixing the problem. By adopting this device, farming livelihoods can be boosted, yields can be increased, and labor costs connected with traditional deterrent tactics can be minimized.

# **1.11 SUMMARY**

This chapter has provided the project's background, problem statement description, goals, and objectives for a bird detection and deterrence system. It specified the scope through its delimitations and detailed the system's limits, such as weather interference and bird adaptability. The development instruments necessary for designing the system, such as sensors and microcontrollers, were discussed. A work plan was supplied, describing each phase of the project, from design to testing. Finally, the rationale for the initiative underlined its significance in overcoming the economic and safety challenges encountered by birds in agricultural areas. The project attempts to provide a scalable and efficient solution that may be employed in a number of situations, assuring its broad utility.

# **CHAPTER 2: LITERATURE REVIEW**

# **2.1 INTRODUCTION**

This chapter introduces the literature review of the past studies carried out pertaining bird detection and deterrence. It also highlights the analysis of study or related work. The chapter identifies gaps and explores how the proposed system can address the identified issues. Moreover, feasibility analysis is done to determine if it is feasible to carry out the proposed work.

# **2.2 ANALYSIS OF STUDIES**

A literature review is a comprehensive summary of previous research on a specific topic [17]. The application of AI in various fields has seen significant advancements particularly in the detection and deterrence of birds using machine learning techniques. This review explores the existing literature on bird detection and deterrence systems on global, regional and local scale. The analysis was conducted using Google Scholar, with the search terms “bird detection”, “bird deterrence”, AND “machine learning”. The research considered articles from 2012 up to 2024**.**

The examination of the literature on bird detection and deterrence systems showcases advancements in the implementation of machine learning and artificial intelligence methods in this field. Many studies have examined methods for bird pest control in different situations. For example, an automated bird deterrent was developed using Unmanned Arial Vehicles (UAVs) [18]. To minimise agricultural damage, a study concentrated on locating and detecting birds using unmanned aerial systems (UAS) [19]. In addition, another investigation focused on the effectiveness of auditory and visual bird frightening methods while emphasizing the need for further improvement in this regard [20]. Studies have also exhibited the potential of deep learning methods for real-time bird detection. One study utilized MobileNet SSD for improved wildlife monitoring [21].

In Rwanda, an acoustic network was created to keep birds away [22]. Another development involved testing an ultrasonic bird repeller [23]. The exploration of using drones in agriculture as a bird deterrent system emphasized the role of technology in pest management. Additionally, a scarecrow that is solar powered was made, promoting eco-friendly options [24].

Another advancement in deep learning involved analyzing webcam images for bird detection which helps to monitor birds in different environments [25]. These studies jointly show growing successes, and persisting challenges in the fields of bird monitoring and deterrence that call for further research, as well as the implementation of some new technologies. Table 2.1 shows a summary of the reviewed studies.

Table 2.1: Summary of Analysed Studies

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Source** | **Country** | **Year** | **Computer Vision Technique** | **Bird Recognition Technique** |
| [18] | Pakistan | 2022 | Open CV.4.2 | Deep learning (CNN, RNN, Transformer) |
| [19] | USA | 2017 | Background subtraction | ViBe |
| [26] | USA | 2020 | AI Integration | Automated Bird Counting |
| [20] | Romania | 2023 | Not specified | Not specified |
| [21] | India | 2024 | MobileNet SSD | Real-time animal classification |
| [22] | Rwanda | 2024 | ConV1D Neural Network | Acoustic detection |
| [23] | Nigeria | 2012 | Not specified | Not specified |
| [27] | Zimbabwe | 2022 | Radar motion sensor | Not specified |
| [24] | Zimbabwe | 2023 | Not specified | Not specified |
| [28] | Cameroon | 2019 | Not specified |  |
| [29] | Nigeria | 2019 | Not specified | Not specified Not specified |
| [25] | South Africa | 2022 | Deep learning architectures (faster R-CNN, SSD) | Not specified |

# **2.3 GAPS IDENTIFIED**

The current systems for bird detection and deterrence show several gaps that need to be addressed. Firstly, the systems often focus on either detecting birds or deterring them but rarely combine both functionalities. This research aims to combine real-time detection with a variety of deterrent techniques. Additionally, many existing systems do not consider how birds might adapt over time. As birds get used to certain deterrents, the effectiveness of the current systems decreases leading to ongoing crop damage and reduced yields. This initiative seeks to address this issue by using multiple deterrent techniques such as dog barking sounds. Lastly, the cost effectiveness of the deterrent systems presents a significant challenge. Advanced technology that could eliminate these challenges can be expensive, making them unobtainable for small scale farmers that require affordable alternatives.

# **2.4 PROPOSED WORK**

The project attempts to construct a real-time detecting system for birds which will simultaneously scare them away. The system will utilize ESP32 cameras alongside the YOLO v8 object recognition technology to precisely detect birds. The technology will incorporate alarm sounds as an extra deterrent to prevent birds from becoming habituated to scare methods. The use of sound guarantees that the bird deterrent acts with more dependability and consistency. Farmers and agricultural users should be able to use the system easily because it provides an economical and effective solution.

**2.4.1 FEASIBILITY ANALYSIS**

A feasibility analysis is a methodical assessment of a project's viability and practicality that frequently includes technical, economic, social, and operational evaluations to ascertain overall feasibility [30]. The feasibility analysis of the bird detection and deterrence system looks at its operational efficacy, social impact, economic viability, and technical capabilities. In addition to cost-benefit analysis and calculations of Return On Investments (ROI), Net Present Value (ROI), and Payback Period (PP), the feasibility study evaluates the requirements for both hardware and software while accounting for stakeholder analysis and risk assessment.

**2.4.1.1TECHNICAL FEASIBILITY**

The process of assessing whether the technology and resources required for a project are available and capable of achieving its objective is known as technical feasibility. Compatibility with existing systems, technological advancements, and the degree of implementation expertise required are all taken into consideration in this evaluation [30]. The system's core consists of low-cost parts like Raspberry Pi, ESP32 cameras, and sound-based deterrents. The system increases the accuracy of bird recognition by using the YOLO v8 detection algorithm. Combining Python programming with cloud platforms like Google Colab enables powerful data analysis capabilities. Open-source technologies reduce development costs while preserving system flexibility. Because weather-related environmental factors can cause disruptions, protective measures like waterproofing and shading support the system's performance.

**2.4.1.2 HARDWARE REQUIREMENTS**

The functionality of the bird detection and deterrence system depends on its hardware components. In addition to deterrent features, the hardware components must be durable enough to withstand agricultural environmental conditions and enable real-time bird detection and data processing capabilities. Effective component integration enables the system to detect and react to bird activity with ease. The hardware specifications for the suggested system are displayed in Table 2.2.

Table 2.2: Hardware Requirements

|  |  |  |  |
| --- | --- | --- | --- |
| **Item** | **Quantity** | **Specifications** | **Comments** |
| ESP32 Camera | 2 | High-resolution, wireless, IoT-compatible | Required |
| Raspberry Pi | 1 | 4GB RAM, Quad-Core Processor, Model 4B,1.5GHz | Required |
| Speakers | 2 | Waterproof, High-Frequency output | Required |
| Battery | 1 | 12V,Rechargable | Required |
| Mounting Equip. | 1 Set | Poles, fasteners, and casings | Required |
| Laptop | 1 | Core i5, 1TB Memory, 1 GB RAM | Available |

**2.4.1.3 SOFTWARE REQUIREMENTS**

The system's software requirements play a significant role in enabling successful data processing and initiating automatic bird detection and discouragement operations. The application needs real-time image processing capabilities for bird species recognition which subsequently activates deterrent actions upon detection. Remote monitoring capabilities together with data recording operations and system update support must be included to optimize system performance over time. Table 2.3 outlines software requirements for the bird detection and deterrence system.

Table 2.3: Software Requirements

|  |  |  |
| --- | --- | --- |
| **Item** | **Specifications** | **Comments** |
| Python | Version 3.10 | Open-source software |
| OpenCV | Latest Version | Open-source software |
| TensorFlow | Latest Version | Open-source software |
| Sound Playback Software | PyGame Mixer | Open-source software |
| Arduino IDE | Latest Version | Open-source software |
| Google Colab | Cloud-based | Free trial version available |

**2.4.1.4 TECHNICAL EXPERTISE**

**2.4.1.4 TECHNICAL EXPERTISE**

The specific knowledge and abilities required to design, develop, and implement a given system or technology are referred to as technical expertise. This includes having expertise in data analysis, software development, and hardware development to ensure that the project can be completed successfully and efficiently [31]. For the bird detection and deterrence system to be successful, experts in software development, image processing, machine learning, hardware integration, and system automation are needed.

For the system to be implemented successfully, technical expertise in a variety of fields is required. Essential hardware integration skills involving knowledge of Raspberry Pi and Arduino are required for setting up and configuring ESP32 cameras and other electronic components. Professionals need to understand circuit design, power management, and sensor integration in order to maintain effective system operation in a variety of environmental circumstances.

Because it uses OpenCV for image processing tasks and TensorFlow for implementing machine learning solutions to recognize birds, proficiency in Python software development is crucial. Developers must create automation scripts that activate deterrent sounds using specialized software.

It takes fundamental knowledge of embedded systems and the Internet of Things to connect Raspberry Pi, Arduino IDE, and microcontrollers with peripheral devices. The system reliably provides real-time responses while functioning autonomously. By combining the required technologies and skills, the bird detection and deterrence system is successfully designed, developed, and deployed.

Because the development team includes computer systems engineers with expertise in embedded systems, IoT, and software development, it has access to readily available technical expertise. Existing open-source tools and frameworks make the system's implementation easier to handle and provide the expertise needed for project success.

**2.4.1.5 OVERVIEW OF TECHNICAL FEASIBILITY**

The technical viability of the bird detection and deterrence system is confirmed by the assessment of hardware requirements in conjunction with software capabilities and current technical expertise. ESP32 cameras along with Raspberry Pi and sound playback software exist as necessary components which benefit from widespread availability and comprehensive support through open-source technologies. The development team has the necessary technical skills for both implementation and maintenance of the system. Current technology supports the system's utilization of machine learning for recognizing birds and delivering automated deterrence. The system's potential operating challenges, which include power supply issues as well as environmental durability and wireless connectivity problems, can be resolved through proper design planning. Therefore, the project stands as technically feasible to build and execute using available resources and expertise.

**2.4.2 ECONOMIC FEASIBILITY**

Economic feasibility evaluates the financial viability of the project by examining the costs and expected benefits [32]. It seeks to ascertain whether the system's investment will provide enough long-term returns to be a financially viable way to reduce crop damage caused by birds. Key metrics like Return on Investment (ROI), Payback Period (PP), and Net Present Value (NPV) are used to assess financial sustainability.

**2.4.2.1 COSTS**

Costs are the monetary outlays required for a project's conception, execution, and management [30]. Knowing these expenses is essential for evaluating the project's overall sustainability and economic viability in the context of bird detection and deterrence systems.

Table 2.4: Hardware Costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Item** | **Quantity** | **Specifications** | **Cost(USD)** |
| ESP32 Camera | 2 | High-resolution, wireless, IoT-compatible | 100 |
| Raspberry Pi | 1 | 4GB RAM, Quad-Core Processor, Model 4B,1.5GHz | 50 |
| Speakers | 2 | Waterproof, High-Frequency output | 60 |
| Battery | 1 | 12V,Rechargable | 30 |
| Mounting Equip. | 1 Set | Poles, fasteners, and casings | 20 |
| Laptop | 1 | Core i5,  1TB Memory,  1 GB RAM | 0 |
| **Total** | - | - | **260** |

Table 2.5: Software Costs

|  |  |  |
| --- | --- | --- |
| **Item** | **Specifications** | **Cost(USD)** |
| Python | Version 3.10 | 0 |
| OpenCV | Latest Version | 0 |
| TensorFlow | Latest Version | 0 |
| Sound Playback Software | PyGame Mixer | 0 |
| Arduino IDE | Latest Version | 0 |
| Google Colab | Cloud-based | 0 |
| **Total** | **-** | **0** |

Table 2.6: Development Costs

|  |  |
| --- | --- |
| **Item** | **Cost/Year (USD)** |
| Hardware Cost | 260 |
| Software Cost | 0 |
| **Total** | **260** |

Table 2.7 Operational Costs

|  |  |
| --- | --- |
| **Item** | **Cost/Year (USD)** |
| Software Maintenance | 100 |
| Internet & Data Costs | 100 |
| Hardware Maintenance | 100 |
| Power Supply | 50 |
| **Total** | **350** |

**2.4.2.2 BENEFITS**

Benefits are the favorable outcomes and value that come from a project's successful completion. These benefits include, but are not limited to, financial gains, operational effectiveness, customer satisfaction, strategic positioning, and social and environmental impact [17]. Benefits can be tangible or intangible. Tangible benefits are measurable and quantifiable advantages expressed in financial terms whereas intangible benefits are non-quantifiable advantages that contribute to overall project success [33]. Intangible benefits may not have a direct monetary value. Tables 2.8 and 2.9 show tangible and intangible benefits respectively.

Table 2.8: Tangible benefits

|  |  |
| --- | --- |
| **Benefit** | **Value/Year (USD)** |
| Reduced crop damage due to birds | 500 |
| Increased yields | 200 |
| **Total** | **700** |

Table 2.9: Intangible Benefits

|  |  |
| --- | --- |
| **Benefit** | **Value/Year (USD)** |
| Improved farmer satisfaction | - |
| Enhanced environmental protection | - |
| **Total** | **-** |

**2.4.2.3 COST BENEFIT ANALYSIS**

Cost Benefit Analysis (CBA) is a systematic approach that is used to evaluate the economic feasibility of a project by comparing the total expected costs and benefits [34]. The primary goal of CBA is to determine whether the benefits of the project outweigh its costs, thereby providing a clear rationale for decision making.

Table 2.10: Cost Benefit Analysis

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **2024 (USD)** | **2025 (USD)** | **2026 (USD)** | **2027 (USD)** |
| **Costs** |  |  |  |  |
| Development Costs | 260 | 0 | 0 | 0 |
| Operational Costs | 350 | 300 | 290 | 250 |
| **Total Costs** | **610** | **300** | **290** | **250** |
|  |  |  |  |  |
| **Benefits** |  |  |  |  |
| Tangible benefits | 0 | 700 | 750 | 850 |
| Intangible benefits | 0 | 0 | 0 | 0 |
| **Total** | **0** | **700** | **750** | **750** |
|  |  |  |  |  |
| **Net Benefits / Profit** | **(610)** | **400** | **460** | **600** |

**2.4.2.3.1 RETURN ON INVESTMENT**

Return on Investment (ROI) is a financial metric used to evaluate the profitability of an investment relative to its cost. It is expressed as a percentage and helps stakeholders assess the efficiency of an investment and compare profitability of different projects [35]. ROI is crucial in determining whether the anticipated benefits of the bird detection and deterrence system justify the initial and ongoing expenditures. It is calculated using the formula below.

ROI = (net benefits /total costs) \*100

Table 3.11: Return on Investment

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **2024 (USD)** | **2025 (USD)** | **2026 (USD)** | **2027 (USD)** |
| Net Benefits | (610) | 400 | 460 | 600 |
| Total Costs | 610 | 300 | 290 | 250 |
| **ROI** | **-100%** | **133%** | **159%** | **240%** |

In 2024, there was a negative ROI of -100%. This indicates that the costs associated with the project exceeded the benefits gained from it. It also means that the money invested has not generated sufficient returns. In this case, a negative ROI is acceptable in the short term since long term benefits are anticipated.

In 2025, the ROI increases to 133%, reflecting improved performance as compared to the previous year 2024. A positive increase suggest effective operations and acceptance of the project by farmers. This trend reinforces confidence in the project’s sustainability and financial health.

A significant rise from 133% in 2026 to 159% in 2026 demonstrates a remarkable enhancement in financial returns. The positive ROI value reflects that the net benefits exceed the total costs. This upward trajectory strengthens the case for ongoing investment.

The ROI increases to 240% in 2027, indicating that the project is not only sustaining high returns but also significantly improving its profitability. This year marks the peak performance of the system in the analysis. The ROI suggests that the project is well positioned for future growth and justifies continued support from farmers and other stakeholders.

**2.4.2.3.2 NET PRESENT VALUE**

Net Present Value is a financial metric that calculates the present value of future cash flows generated by an investment, subtracting the initial investment costs. NPV helps assess the profitability of a project by considering the time value of money, which reflects the principle that money available today is worth more than the same amount in the future due to its potential earning capacity [36]. NPV is calculated using the formula below

PV = Cash Flow / (1+i) t ,

Where i is the discount factor,

t is time period in years

Table 2.12: Net Present Value

|  |  |  |  |
| --- | --- | --- | --- |
| **Year** | **Cash Flow** | **Discount Factor** | **Present Value** |
| 2024 | (610) | 1 | (610) |
| 2025 | 400 | 0.99 | 396 |
| 2026 | 460 | 0.826 | 379.96 |
| 2027 | 600 | 0.638 | 382.80 |
| **NPV** |  |  | **548.76** |

**2.4.2.3.3 PAYBACK PERIOD**

Payback Period is a financial metric that calculates the time required to recover the initial investment from the net cash inflows generated by the project. It is a straight forward measure of how quickly an investment can return its costs [37]. Table 2.12 shows the Payback Period

Table 2.13: Payback Period

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Year** | **2024(USD)** | **2025 (USD)** | **2026 (USD)** | **2027 (USD)** |
| Cash Flow | (610) | 400 | 460 | 600 |
| **Cumulative Cash Flow** | **(610)** | **(210)** | **250** | **350** |

The payback happens between 2025 and 2026.

Payback period = 2 + [(210/460) \*12]

Therefore the payback period is approximately 2 years 5 months meaning it takes 2 years and 5 months to regain our money.

**2.4.2.4 OVERVIEW OF ECONOMIC FEASIBILITY**

The economic feasibility of the bird detection and deterrence system has been thoroughly assessed through the Cost Benefit Analysis, which evaluates the financial implications of implementing the system. This analysis reveals that the anticipated benefits, such as reduced crop damage and increased agricultural productivity significantly outweigh the costs associated with hardware, software and maintenance. A positive Net Present Value (NPV) means the project is expected to generate more money than its costs, which shows it’s financially worthwhile

**2.4.3 SOCIAL FEASIBILITY**

Social feasibility analyzes a project's possible social effects by determining how well-received it is by the community and how it affects different stakeholders [38]. Public opinion, possible societal benefits, and any unfavorable effects that might result from the project's execution are all taken into account in this assessment. There are major social ramifications to the bird detection and deterrence system in agricultural fields, most of which are positive. The system has the potential to improve food security and sustain farmers' livelihoods by efficiently controlling bird populations that pose a threat to crops. By lowering the need for dangerous pesticides, this technology can encourage eco-friendly behaviors that are good for the environment and people's health. Incorporating local farmers into the system's operation and implementation can also encourage community involvement, bolstering ties within the community and encouraging sustainable farming methods.

**2.4.4 OPERATIONAL FEASIBILITY**

Operational viability looks at how feasible it is to carry out a project using the systems and procedures already in place within an organization. This evaluation determines whether the technology, staff, and training required to support the project successfully are available. It also takes into account whether the project can be seamlessly integrated without causing major disruptions and the possible impact on ongoing operations [39]. It makes sense to install a bird detection and deterrence system in agricultural areas. With little interference, the technology can be incorporated into current farming methods, enabling farmers to use sensors and automated deterrents in addition to their usual tasks. Farm employees can receive simple training that focuses on system maintenance and operation. The project's implementation can improve crop protection without causing significant disruptions by coordinating with current agricultural operations, which will ultimately increase yields and farmer satisfaction.

# **2.4.5 STAKEHOLDER ANALYSIS**

All people, organizations, or groups with a stake in a project are identified through stakeholder analysis. Understanding their responsibilities, expectations, and impact on the project's success are all part of this analysis. Project managers can create engagement plans and targeted communication strategies by classifying stakeholders according to their level of interest and impact [40]. Farmers, agricultural associations, technology companies, local communities, and environmental organizations are important participants in the bird detection and deterrence system for agricultural fields.

By shielding their crops from bird damage, farmers who are the system's main users benefit directly. Their input is essential to the functionality and design of the system. Furthermore, by offering insights into best practices and encouraging community involvement, agricultural organizations can aid in the system's adoption and represent the interests of farmers. The businesses that create and set up the detection systems are known as technology providers. By offering the required assistance and training, they play a crucial part in making sure the technology is efficient and easy to use. Additionally, people who live close to agricultural fields might be worried about the system's effects on the environment or noise levels. It's crucial to interact with them in order to resolve any problems and promote wholesome relationships. Finally, in order to preserve ecological balance, environmental organizations make sure that the deterrent techniques are humane and do not harm nearby wildlife.

# **2.4.6 RISK ANALYSIS**

Risk analysis means spotting risks that might harm a project's chances of success. It looks at both how likely these risks are and how much harm they could cause. This understanding helps project managers create plans to handle problems before they happen. To avoid potential setbacks effective risk analysis plays a key role in planning [41].

The bird detection and scare system used in farms can face different challenges like data theft bad weather and natural events, or even people refusing to use it. Hackers breaking into private data can cause privacy problems and reduce user confidence in the system. It is important to use strong cyber security tools to keep this data safe.

Harsh weather can harm hardware parts and reduce how reliable systems are. Floods, as an example, might harm detection system infrastructure, which can interrupt operations. To reduce these risks, it is essential to plan disaster recovery and system resilience.

Farmers might feel uneasy about trying out new tech because they do not know enough about it, do not understand it well, or worry about change. Offering proper training and showing how the system helps can address these worries and promote its use.

# **2.5 SUMMARY**

This chapter examines research on bird detection and deterrence, emphasizing developments in artificial intelligence and machine learning. It draws attention to significant gaps, such as the lack of systems that integrate deterrence and detection into a single solution. It also talks about how birds adapt to current deterrent techniques. The suggested system will employ various deterrent techniques and real-time bird detection using inexpensive technology. The idea's viability in practical contexts is confirmed by the feasibility study. It emphasizes how important community involvement is to its success and support of sustainable farming practices.

# **CHAPTER 3: METHODOLOGY**

# **3.1 INTRODUCTION**

This chapter highlights the methodology employed in coming up with the bird detection and deterrence system. It explains the hardware and software components involved, the system architecture together with different diagrams that illustrate the design. The chapter also focuses on process analysis which explains how activities are going to occur, algorithm design and circuit design. Additionally, the chapter discusses the approach to gathering information from users and stakeholders, ensuring the system aligns with real-world needs. Simulation results are also discussed in this chapter.

# **3.2 HARDWARE AND SOFTWARE REQUIREMENTS**

Hardware refers to the physical components of a computer system, such as processors, memory devices, and input/output devices. It is tangible, meaning it can be physically handled and seen. Hardware executes tasks and processes data based on instructions provided by software, which is the set of code and data that tells the hardware how to perform specific tasks [42] Software, on the other hand, is intangible and consists of instructions that cannot be physically touched. It interacts with users through interfaces and enables the hardware to function. While hardware requires physical upgrades or replacements to enhance performance, software can often be updated without changing hardware [43]. Examples of hardware include CPUs and sensors, while of software include operating systems and applications [44]

**3.2.1 HARDWARE COMPONENTS**

The hardware components chosen for the bird detection and deterrence system are critical for achieving real time detection and effective deterrence of birds. The main components include ESP32 cameras, Raspberry Pi, speakers, power supply and mounting equipment such as poles and casings to securely position the cameras and speakers for optimal coverage.

**3.2.1.1 ESP32 CAMERAS**

The primary hardware element is the ESP32 camera. ESP cameras are high-resolution cameras which capture real-time images and videos of bird activity. The ESP32 camera module is known for its low cost and versatility in IoT activity. They are essential for monitoring the environment and detecting birds as they approach applications [9].

**3.2.1.2 RASPBERRY PI**

A microcontroller will control the system, activating deterrents such as sound when birds are detected. This small, powerful computer processes the images captured by the ESP32 cameras. It runs necessary algorithms, like those provided by the YOLO v8 algorithm, for real-time bird detection and identification. The Raspberry Pi also acts as the brains of the operation, controlling the system and activating deterrents based on bird activity [10].

**3.2.1.3 SPEAKERS**

In order to come up with an effective deterrent technique, the system makes use of waterproof speakers that are capable of emitting high-frequency sounds. When the system detects birds, the speakers can play alarm sounds that birds find unpleasant, thus deterring them from the area [11].

**3.2.1.4 BATTERY**

The battery provides a reliable and continuous power source for the entire system. It's crucial for ensuring that the cameras, Raspberry Pi, and speakers remain operational, especially in remote or off-grid locations [14].

**3.2.2 SOFTWARE COMPONENTS**

The software components are equally important for the system's functionality and operation. Some of the key software tools necessary for the development of the project include Python, OpenCV, TensorFlow, Google Colab and lastly Pygame mixer.

**3.2.2.1 PYTHON**

Python is the programming language used to write the code for this project [12]. It chosen because of its simplicity and extensive libraries that are necessary for facilitating image processing and machine learning. It is also used for developing algorithms that enable image processing and data analysis.

**3.2.2.2 ARDUINO IDE**

The main software environment for the Raspberry Pi is the Arduino IDE. It can handle data processing tasks and program the ESP32 cameras. The Arduino IDE is selected due to its ease of use and broad library support, which makes hardware control and image processing easier [45].

**3.2.2.3 OPENCV**

OpenCV, an open-source computer vision and machine learning software library that offers a wide range of tools and functions for image processing and analysis, is one of the key libraries. The ESP32 cameras' images are captured, processed, and analyzed using it [46]. Additionally, it facilitates tasks like edge detection, filtering, and resizing, all of which are essential for getting images ready for machine learning algorithms. Because of its real-time performance optimization, it is especially useful for tasks like spotting birds as they fly through different environments.

**3.2.2.4 TENSORFLOW**

An open-source framework called TensorFlow was created by Google and is used to create and train machine learning models, especially deep learning models. It is used to implement and train convolutional neural networks (CNNs) for bird detection tasks in the context of bird detection and deterrence systems. CNNs are excellent at classifying and recognizing images, which makes them perfect for recognizing various bird species from image data [47].

**3.2.2.5 PYGAME MIXER**

For sound playback, the system makes use of PyGame mixer, which is a library that enables the triggering of auditory deterrents through the speakers upon detection [48]. Its ease of use enables straightforward integration into the detection system, providing immediate audio responses that are essential for deterrence.

**3.2.2.6 GOOGLE COLAB**

Google Colab is a cloud-based platform that allows users to develop and execute Python code in the browser, making it particularly helpful for machine learning and data analysis. It provides access to powerful hardware (Graphics Processing Units and Tensor Processing Units) for training complicated machine learning models [15]. It supports libraries like OpenCV and TensorFlow, facilitating the development and testing of algorithms before their deployment.

# **3.3 PROPOSED SYSTEM ARCHITECTURE**

The system architecture is designed to integrate the hardware and software components effectively. It consists of several layers, namely sensor layer, processing layer, action layer and data management layer.



Figure 3.1: System Architecture

**3.3.1 SENSOR LAYER**

This layer includes the ESP32 cameras that capture images of birds. The layer is responsible for capturing visual data from the environment. The cameras periodically capture high resolution images of surrounding area. They transmit captured images to Raspberry Pi. The use of two cameras allows for a wider field of view, enhancing the system’s ability to detect birds in various locations simultaneously.

**3.3.2 PROCESSING LAYER**

The processing layer, represented by the Raspberry Pi which serves as the central processing unit, analyzes the images captured in the sensor layer using machine learning algorithms to identify bird species. Making use of OpenCv, the Raspberry Pi processes incoming images to enhance features and prepare them for classification. TensorFlow is employed to run a CNN that has been trained to recognize various bird species. The model analyses the processed images and determines whether a bird is present and if present, it identifies the species. The processing layer decides whether to trigger a deterrent action based on the detection.

**3.3.3 ACTION LAYER**

Upon detection, the Raspberry Pi sends a command to the PyGame mixer to play specific deterrent sounds through the speakers. The speakers provide instant feedback to birds thus maximizing the deterrent effect. By using high frequency sounds that are unpleasant to birds, the system effectively discourages them from reaching the fields again.

# **3.4 PROCESS ANALYSIS**

The bird detection and deterrence system operates through a structured workflow represented by activity and flowchart diagrams. ESP32 cameras capture images at specific intervals and send them to the Raspberry Pi for processing. Convolution Neural Network (CNN) and OpenCV-based systems use these technologies to detect birds. After the ESP32 camera detects the bird, the Raspberry Pi starts the PyGame Mixer, which makes noise through the speakers to frighten the birds away. For effective training and testing of the CNN models, the bird species photographs as well as non-bird images are included in the datasets. Performing data preparation approaches such as picture noise reduction, normalization, and augmentation considerably contributes in constructing model correctness and robustness. The system's flowchart diagrams record the decision-making procedures starting from the picture acquisition, detection and activation of deterrents, or monitoring status.

# **3.4.1 FLOWCHART SHOWING PROCESS ANALYSIS**



Figure 3.2 Flowchart

# **3.5 ALGORITHM DESIGN**

The bird detection and deterrence system's algorithm architecture incorporates a Convolutional Neural Network (CNN) at its core to identify birds and set off the correct deterrent actions. To start, the system resizes, normalizes, and filters collected photos. This guarantees the data input stays consistent and enhances the model's accuracy. The CNN then pulls out distinctive aspects like wing shapes and movements, which allow it recognize birds apart from other things. Next, the model works out if birds are present and when needed, pinpoints their species. Once it finds birds, the system blasts a preset sound over speakers using PyGame Mixer to scare them off. The full process is written out in flowchart diagrams, from gathering photographs to categorizing them and turning on the deterrent. The team chose to employ a CNN because it can teach itself to detect different levels of features in photos making it adept at spotting birds. Here's a description of the algorithm and a flowchart explaining how the proposed system works:

**3.5.1 ALGORITHM FOR BIRD DETECTION AND DETERENCE SYSTEM**

1. Start

2. Capture image from ESP32 Camera

3. Preprocess data (a) Resize image

(b) Normalize image

(c) Data Augmentation

(d) Filter image to make sure data is entered consistently

4. Process image using OpenCV

5. Train Convolutional Neural Network (CNN)

6. Pass image through CNN model

7. Get features, find the shape of the wings and how they move

8. Identify unique patterns

9. Determine bird presence

10. Check if birds are detected

11. IF birds are detected:

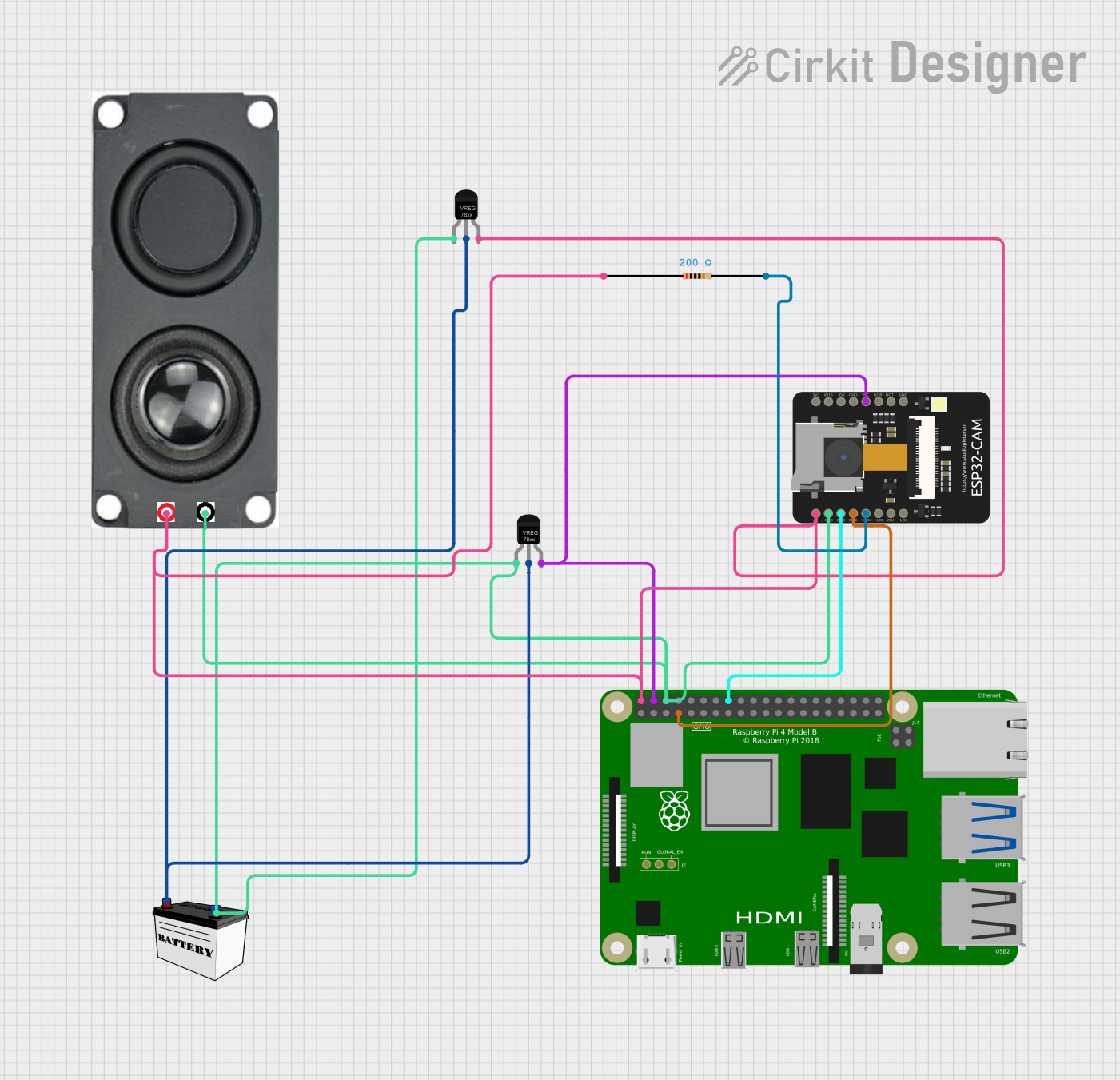
Activate PyGame Mixer to emit specific deterrent sounds through speakers

Else: Continue Monitoring

# **3.6 CIRCUIT DESIGN**

The bird detection and deterrence system's circuit design combines essential hardware components to provide smooth operation and connectivity. ESP32 cameras obtain visual data from their environment and send them to the Raspberry Pi through Wi-Fi connections for immediate processing. The Raspberry Pi uses its audio output to activate speakers which play deterrent sounds after the CNN model identifies a bird thereby driving the birds away. The entire system operates on power from a 12V rechargeable battery which guarantees uninterrupted function outside without needing external power. This circuit optimizes efficiency through reduced latency in data transmission and processing which ensures quick deterrent measures are possible. The circuit diagram below shows how ESP32 cameras, Raspberry Pi, speakers, and power supply components connect while detailing data flow and component placement for system performance optimization.

3.6.1 CIRCUIT DESIGN DIAGRAM

****

**Figure 3.3: Circuit Diagram**

# **3.7 SUMMARY**

This chapter has detailed the methodology for developing the bird detection and deterrence system, focusing on the hardware and software components, their specifications, and how they integrate into a cohesive system. It also detailed the proposed system architecture, algorithm design and circuit design. Simulation results were further discussed. The next chapter will present the results and findings from the implementation of the proposed system.

# **CHAPTER 4: RESULTS AND DISCUSSION**

# **4.1 INTRODUCTION**

This chapter presents the results obtained from the implementation and testing of the bird detection and deterrence system. It provides an overview of the testing procedures and the key performance indicators used to evaluate the system's effectiveness. It also details the performance of the system in terms of detection accuracy, deterrence effectiveness, and overall system reliability. The results are explained in depth supported by tables.

# **4.2 TEST PROCEDURES / MODEL TESTING**

**4.2.1 DATASET OVERVIEW**

The YOLOv8 model was trained and tested on 3000 images with diverse types and poses for birds. By dividing them into 2,750 training images and 250 testing images, we were able to reliably evaluate the performance of the model in the unseen condition. For better generalization, we took training pictures from different bird types,  background contexts, and lighting conditions. Therefore, robustness and applicability of model for the real-life bird detection tasks were increased.

**4.2.2 TRAINING PROCEDURE**

The YOLOv8 model completed 50 training epochs through multiple iterations of the training dataset to fine-tune its parameters. Progress evaluation required continuous monitoring of Distance from the Feature Loss (DFL), Classification Loss (CLS), and Box Loss metrics. Through a comprehensive approach, the model learned to identify specific bird features which resulted in higher detection accuracy.

**4.2.3 VALIDATION PROCESS**

The YOLOv8 model's validation process included a test dataset with 250 images which were kept separate from the training data. The validation process involved suitability checks for each image to ensure no corrupt content existed. Using a Tesla T4 GPU processing enabled efficient performance throughout the validation task for the Ultralytics YOLOv8.3.131 framework. The performance metrics Precision, recall and mean Average Precision (mAP) were calculated by comparing model predictions to ground truth annotations. Through extensive testing the detection model proved its bird localization capability while highlighting its strengths and improvement areas.

**4.2.4 PERFORMANCE METRICS**

The YOLOv8 model's bird detection performance is assessed by critical metrics. Precision, recall and mean Average Precision (mAP) serve as key evaluation tools since they reveal different detecting capabilities of the model.

Precision examines how accurate a model's positive predictions are by analyzing the proportion of real positive results among all positive predictions it makes. When a model illustrates high precision it generates minimal false positives and precisely classifies birds without mistakenly recognizing other things as birds. With a precision score of 0.999 the model displayed outstanding accuracy in its positive predictions for bird detection.

The recall evaluation of the model assures completeness by analyzing the proportion of real positives detected compared to all actual positives contained in the dataset. The model obtained 100% recall by successfully identifying all bird instances in the test set.

The mean Average accuracy (mAP) statistic improves evaluation procedures by delivering full accuracy and memory assessments across multiple IoU criteria. The model performs ideally at a 50% IoU threshold with a mAP@50 score of 0.995 and maintains constant accuracy across IoU thresholds as evidenced by its mAP@50-95 score of 0.988.

The detection model gives amazing dependability in bird detection tasks while keeping low false positive rates and lowest detection misses. The performance profile of the model exhibits its operational effectiveness in bird detection applications by illustrating how it functions across various deployment circumstances.

# **4.3 RESULTS PRESENTATION**

This section covers main loss components that act as monitoring tools for both model training advancement and learning efficiency evaluation. Understanding these performance measures is vital to accurately evaluate how effectively the model adjusts throughout training.

The Distance from the Feature Loss (DFL Loss) quantifies the distance between anticipated outputs and actual image features within training datasets. The Distance from the Feature Loss (DFL Loss) value reduces when bird feature representation becomes effective. The loss function helps steer the training process towards obtaining important properties from the target class.

Classification Loss examines how well the model assigns input data to their proper categories to determine if the object belongs to the bird class. When classification loss gets lower, the model becomes more accurate in its picture classification tasks. The metric provides key functions for differentiating bird components from non-bird components within the model.

Box Loss assesses how well the model detects bounding boxes for identified items. The metric examines the model's precision in recognizing both position and dimensions of bounding boxes in relation to the real positions of objects in images. The model obtains greater accuracy for locating specific bird placements in photos as evidenced by decreasing box loss values.

During the training stage regular observation of these loss indicators to understand their collective performance was maintained. The model shows successful learning by decreasing its loss values as it completes many training epochs. The following table summarizes the loss metrics observed throughout different training epochs:

Table 4:1 Loss Metrics over Training Epochs

|  |  |  |  |
| --- | --- | --- | --- |
| **Epoch** | **Box loss** | **Cls loss** | **Dfl loss** |
| 1 | 0,9383 | 1,233 | 1,627 |
| 5 | 1,009 | 1,325 | 1,672 |
| 15 | 0,9717 | 1,311 | 1,645 |
| 32 | 0,9175 | 1,217 | 1,590 |
| 50 | 0,5368 | 0,522 | 1,286 |

In this table, we observe a consistent decrease in all three loss metrics as training progresses. The training process shows ongoing learning and performance improvements per epoch according to the observed pattern. Analyzing these loss metrics provides essential insights into the model's training journey which guides improvements in training methods.

# **4.4 DISCUSSION OF FINDINGS**

Implementation results indicate that the YOLOv8 model achieves excellent detection performance together with dependable outcomes in bird detection tasks. With a precision score of 0.999 the model proves its remarkable ability to minimize false positives and maintain accurate bird detection. The necessity for high precision levels in biodiversity monitoring applications arises from the potential severe ecological damage that can result from species misidentification errors.

This research delivers superior results compared to earlier investigations when evaluated against established datasets. The study from India [21] revealed that MobileNet SSD performed well in real-time wildlife classification yet YOLOv8 demonstrated better precision and recall metrics and bounding box accuracy for improved model robustness.

YOLOv8 successfully identified every bird instance throughout the evaluation phase while maintaining perfect detection performance. The latest development delivers significant enhancements when compared to former background subtraction approaches like ViBe that encountered difficulties with changing backdrops [19]. YOLOv8 achieves better detection accuracy than older automated bird counting AI techniques making it essential for conducting bird population surveys and conservation work [26]

The superior performance of the model is demonstrated by top mean Average Precision (mAP) scores of 0.995 for mAP@50 and 0.988 for mAP@50–95. A stable performance across multiple IoU thresholds demonstrates its suitability in environments with different visual complexities. YOLOv8 delivers a more adaptable and complete visual detection approach relative to the ConV1D neural network which focuses on a limited acoustic range in Rwanda [22].

YOLOv8 uses cutting-edge deep learning advancements which are also present in South Africa's 2022 architecture that utilized faster R-CNN and SSD [25] unlike the outdated or unspecified models from Romania [20], Nigeria [23, 29], and Cameroon [28]. YOLOv8 surpasses these architectures in real-time detection capability and the ability to learn complex bird features from advanced datasets.

The model's learning effectiveness becomes clear through analysis of training loss metrics. The steady reduction in Distance from the Feature Loss (DFL), Classification Loss (CLS), and Box Loss throughout multiple epochs shows the model’s expertise in identifying and positioning bird features. The transformative leap in smart surveillance demonstrated by YOLOv8's data-driven precision surpasses the capabilities of basic sensor-based studies from Zimbabwe [27] and traditional scarecrow approaches [24].

YOLOv8 demonstrates exceptional bird detection performance that advances scientific research. YOLOv8 achieves improved detection accuracy alongside better localization performance and enhanced adaptability to different environments compared to previous studies. The new model represents a significant evolution in ecological monitoring because it progresses from basic visual and sensor-based methods to intelligent systems that provide improved reliability. The results align with existing deep learning research while demonstrating higher detection performance and application potential which proves this system works well in both natural and controlled settings.

# **4.5 SUMMARY**

This chapter described the outcomes of test runs and practical implementation for the bird detection and deterrent system with an Arduino Uno serving as its processing core. The system evaluation revealed moderate levels of detection accuracy along with effective deterrence capability. The next section provides an overall project summary along with research conclusions and additional study recommendations.

# **CHAPTER 5: SUMMARY, CONCLUSION, AND RECOMMENDATIONS**

# **5.1 SUMMARY OF RESULTS**

The birddetection and deterrence system achieved the objectives in a cost-effective manner by integrating YOLOv8, ESP32-CAM technology with Arduino Uno hardware. The detection model reached outstanding performance levels for precision and recall as well as mean Average Precision (mAP) metrics after processing 3,000 training images. The detection system achieved its top performance with a precision level of 0.999 and perfect recall of 1.000 and recorded mean Average Precision scores of 0.995 at mAP@50 and 0.988 at mAP@50-95.The loss metric registered higher precision levels at the conclusion of the 50th training epoch. Due to financial constraints a buzzer system was installed to serve as an inexpensive solution for deterrence. Farmers can deploy bird control systems to safeguard their crops while improving their agricultural output.

# **5.2 SIGNIFICANCE OF PROJECT**

The project created substantial agricultural developments leading to extensive social transformations. Small-scale farmers access affordable bird prevention systems to preserve their traditional lifestyles while meeting their fundamental needs. The agricultural technology system functions reliably across various conditions due to its flexible solutions.

Researchers investigated the potential of machine learning technologies to create bird control systems which would streamline farm operations while cutting operational expenses. The system update improves user interactions while concurrently boosting management operation efficiency.

# **5.3 CONCLUSION**

The system accomplished its predetermined goals by solving a fundamental agricultural issue. Modern technology combined with practical application techniques allowed agricultural users to create an effective crop protection system. The project successfully met its targets because of substantial initial cost savings along with simplified user training requirements. The system reached successful operational outcomes by modifying development processes according to user feedback.

# **5.4 RECOMMENDATIONS AND FUTURE WORK**

Research studies that will be conducted in the future demand detailed evaluations to determine key enhancements needed for bird detection and deterrence systems. The system experiences considerable performance gains when its components receive upgrades. Sensors integration enables extensive data gathering which produces larger data sets that enhance machine learning model accuracy.

For a system to be deployed successfully users need to undergo training program development. Through vital technical training, farmers learn to perform essential operational tasks on their farms. Through training courses farmers learn critical technological skills that enable them to customize applications according to their unique requirements.

Conducting field trials is also essential. Farmers study system performance metrics to determine the efficiency of their systems across different agricultural settings. Research teams achieved their greatest advancements in systems through the integration of field data and user feedback.

Through strategic financial planning organizations can enhance operational efficiency while simultaneously cutting their operating costs. New farming technologies attract small-scale farmers when they demonstrate potential financial benefits. Producers need to discover cost-efficient strategies that maintain their established production quality standards.

By monitoring hardware technology organizations can customize system update cycles based on their operational patterns. Advanced machine learning algorithms combined with high-performance hardware processors allow the Raspberry Pi platform to achieve efficient performance standards.

One needs to collect performance data from various operational environments to evaluate system adaptability. Specialists will conduct system performance evaluations within agricultural areas subject to varying weather patterns.

The use of expert sustainable farming techniques in combination with advanced support systems allows farmers to gain extra benefits.

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# **APPENDICES**

# **APPENDIX A: USER MANUAL**

**SYSTEM OVERVIEW**

This bird detection system uses an ESP32-CAM camera to monitor for birds in real-time. When birds are identified by the AI detection model, it triggers a buzzer connected to Digital Pin 9 (D9) of the Arduino board. The system features automatic 10-second activation cycles, connection recovery, and real-time status monitoring through an on-screen display.

**HARDWARE SETUP**

Begin by connecting your components:

* Wire the buzzer's positive (+) terminal to Arduino's D9 pin and the negative (-) terminal to any GND pin
* Connect the Arduino to your computer via USB cable
* Power the ESP32-CAM module and ensure it's connected to your Wi-Fi network
* Verify all connections are secure - a 100Ω resistor should be added between D9 and the buzzer if using an active buzzer

**SOFTWARE CONFIGURATION**

Install required software by opening Command Prompt (Windows) or Terminal (Mac/Linux) and running:

pip install opencv-python numpy ultralytics pyserial requests

Then modify these critical settings in the Python code:

* Set esp32\_url to match your camera's IP address (found in your router settings)
* Confirm arduino\_port matches your Arduino's connection port (check Device Manager on Windows or use `ls /dev/cu` on Mac)
* Upload the provided D9-specific Arduino sketch before running the system

**OPERATION PROCEDURE**

1. Launch the system by executing `python bird\_detector.py` in your terminal

2. The system will automatically:

* Establish connection with ESP32-CAM and Arduino
* Open a live video window with detection overlay
* Activate the D9 buzzer for 5 seconds when birds are detected
* Display confirmation messages like "D9 set HIGH - Buzzer activated" in the console

3. During operation:

* Green bounding boxes will appear around detected birds
* System status (FPS, connections, detection state) shows on-screen
* The D9 buzzer will sound only during bird presence

4. Press 'Q' in the video window to safely shut down the system

**TROUBLESHOOTING**

If the buzzer doesn't activate:

* Confirm the Arduino sketch uses `const int BUZZER\_PIN = 9;`
* Check serial monitor for "D9-HIGH-ACK" responses during detection
* Verify wiring with a simple test: Temporarily change `b'D9H'` to `b'D13H'` in `set\_pin\_high()` - the Arduino's built-in LED should light
* Ensure no competing programs (like Arduino IDE) are using the serial port

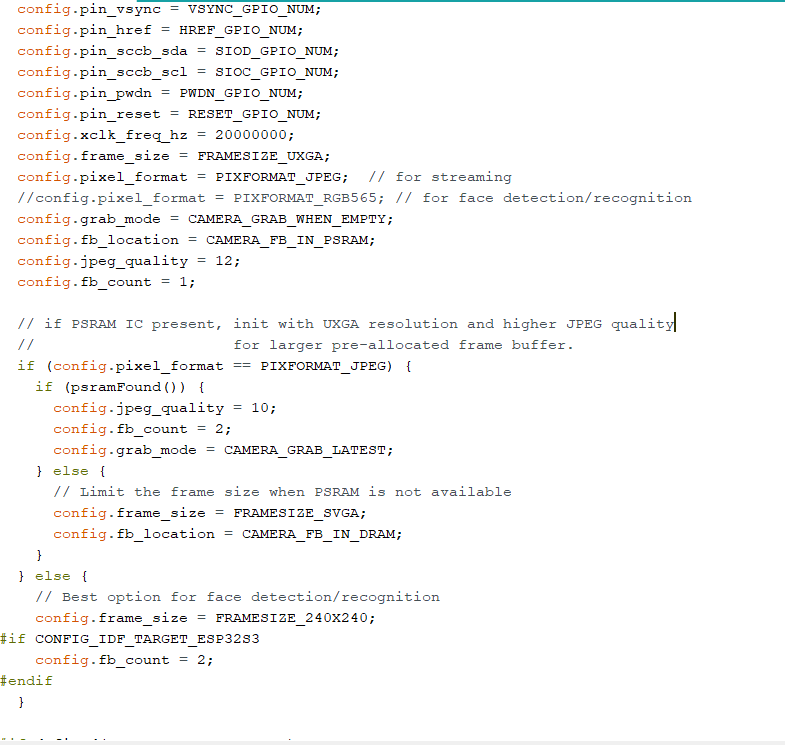
**SAFETY & MAINTENANCE**

* Place the buzzer in a weatherproof enclosure if used outdoors
* Limit continuous operation to 1 hour for passive buzzers to prevent overheating
* Clean camera lens monthly with microfiber cloth
* Disconnect power before handling wiring
* Test weekly by waving a bird-shaped object before the camera

# **APPENDIX B: CODE SNIPPETS**

Arduino IDE code for configuring and setting up the ESP32-CAM

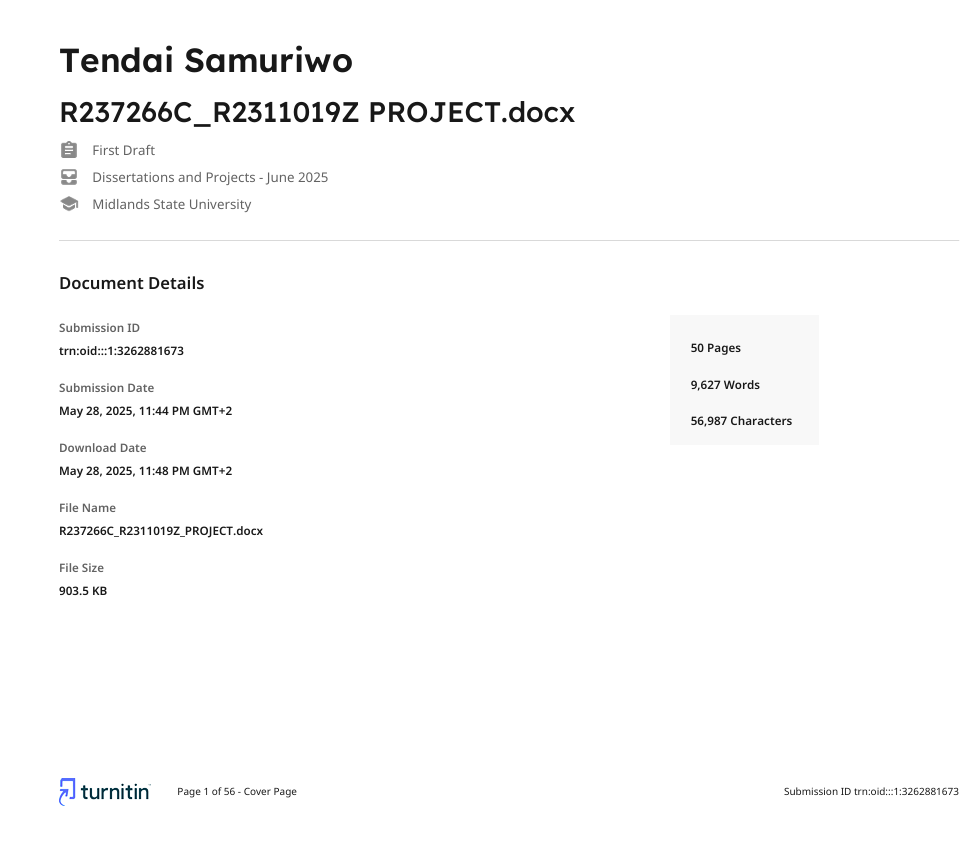


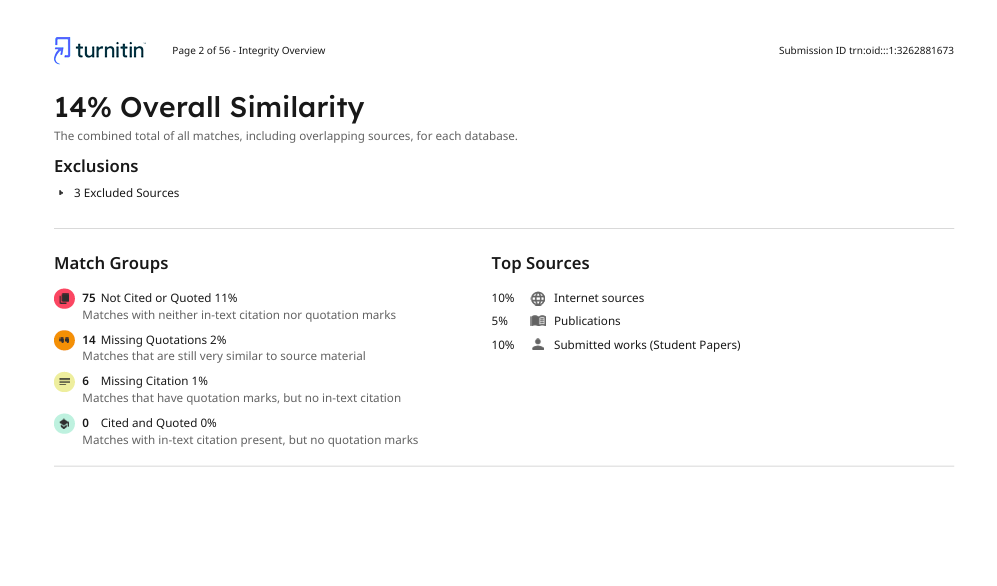






# **APPENDIX C: SIMILARITY REPORT**





# **APPENDIX D: AI WRITING REPORT**