



AUTOMATED COIN SORTING SYSTEM

PROJECT REPORT

Submitted To:

DEPARTMENT OF MECHANICAL & MANUFACTURING ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITY of RUHUNA

ON

13th March 13, 2025

ME 5212: MECHATRONICS SYSTEM DESIGN

By

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PREFACE

This report presents the development of an Automated Coin Sorting System, integrating image processing, machine learning, electronics, and automation to efficiently classify and sort coins based on their size, color, and embossed features. The project bridges the gap between theoretical knowledge and practical implementation, addressing real-world applications in banking, vending machines, and retail automation.

The report is structured into nine key sections. The Introduction provides background information on the project, detailing its relevance and significance. The Aims and Objectives section outlines the project's expected outcomes and deliverables. A Literature Review summarizes existing work in the field, highlighting methods used in image-based coin classification and automated sorting systems. The Methodology explains the step-by-step execution of the project, covering aspects such as process flow, hardware and electronics design, image processing techniques, machine learning models, microcontroller programming, and casing design, supported by illustrations and sample outputs.

The Results and Findings section presents the final system performance with labeled images, 2D/3D models, electronic circuits, and control diagrams. The Discussion evaluates the final status of the project, addressing achievements, special features, limitations, and discrepancies encountered. The Personal Role and Achievements section details the contributions of team members to the project's design, programming, troubleshooting, and problem-solving. The Conclusions and Future Work summarize key takeaways and propose enhancements for improving the system's efficiency. Finally, the Technical Competence section demonstrates the application of image processing, machine learning, programming, electronics integration, 3D modeling, and real-world testing in the project.

This project has provided valuable hands-on experience in AI-driven automation and intelligent mechatronic systems, strengthening knowledge in engineering, embedded systems, and robotics. The system serves as a foundation for future advancements in automated sorting mechanisms and machine learning-based classification systems, offering a cost-effective and scalable solution for various industries.

ACKNOWLEDGEMENT

We would like to express our sincere gratitude to Dr. K. J. C. Kumara, the Supervisor for this project and Module Coordinator of ME 5212: Mechatronics Systems Design, from the Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, University of Ruhuna, for his invaluable guidance, encouragement, and continuous support throughout this project. His expertise and insightful feedback played a crucial role in the successful completion of our automated coin sorting system.

We extend our heartfelt appreciation to Mr. Supun Sanjaya, a lecturer of ME 5212: Mechatronics Systems Design, for his valuable instructions, technical advice, and support in helping us refine and improve our project. His guidance in both theoretical and practical aspects greatly contributed to the development of our system.

Furthermore, we would like to express our deepest gratitude to Dr. Buddhika Annasiwatta, the Head of the Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, University of Ruhuna, for providing the necessary facilities and a supportive academic environment that enabled us to successfully carry out this project.

Additionally, we extend our appreciation to all academic and technical staff of the Department of Mechanical and Manufacturing Engineering for their assistance and encouragement throughout the course of this project. Their support has been instrumental in overcoming various challenges and achieving our objectives.

This project has been an invaluable learning experience, allowing us to integrate our knowledge of mechatronics, machine learning, image processing, and automation into a practical, real-world application.

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1 INTRODUCTION

1.1 BACKGROUND

The advent of automation is profoundly impacting various industries by enhancing efficiency, accuracy, and scalability. One such area where automation holds immense potential is coin sorting and classification, which is essential in sectors such as banking, vending machines, and retail operations. Traditional coin sorting mechanisms predominantly rely on mechanical differentiation based on weight and size. While effective, these methods suffer from limitations such as mechanical wear and tear, high maintenance costs, and limited adaptability to different coin types.

With rapid advancements in image processing and machine learning, modern computational techniques offer a more precise and flexible approach to coin sorting. By analyzing visual characteristics such as size, shape, color, and embossed features image processing enables non-contact and wear-free classification of coins. Machine learning further enhances accuracy by recognizing intricate patterns and distinguishing between similar-looking coins with greater precision.

This project explores the integration of image processing and machine learning into an automated coin sorting system, implemented on a Raspberry Pi. The use of a Raspberry Pi ensures that the system is cost-effective, scalable, and portable, making it suitable for real-world applications where accuracy, efficiency, and affordability are paramount.

1.2 PROBLEM AND SIGNIFICANCE

Manual coin sorting remains a labor-intensive and error-prone process, requiring significant human effort. Traditional mechanical systems, while automated, still have major drawbacks:

- **Limited adaptability:** Mechanical sorters must be designed specifically for certain coin sizes and weights, making them unsuitable for new or foreign coins.
- **Wear and tear:** Moving parts degrade over time, leading to decreased performance and increased maintenance costs.
- **Error susceptibility:** Variations in coin condition (such as wear or dirt) can cause misclassification.

These inefficiencies necessitate the development of a more robust, intelligent, and adaptive solution. By leveraging machine learning and image processing, an automated coin sorting system can:

- Improve classification accuracy by analyzing a coin's visual features rather than just weight and size.
- Enhance efficiency by reducing the need for manual intervention.
- Increase system longevity by minimizing mechanical wear.
- Enable adaptability to different coin types, even those introduced in the future.

This system's implementation using a Raspberry Pi ensures a low-cost, portable, and energy-efficient solution, making it ideal for businesses of all sizes.

1.3 APPLICATIONS OF THE WORK

The proposed automated coin sorting system has several practical applications across multiple industries

Direct Applications

1. Banking and Financial Institutions
 - Automated sorting of large volumes of coins in banks.
 - Improved cash-handling efficiency in currency exchange centers.
2. Vending Machine Industry
 - Enhancing vending machine reliability by integrating accurate, AI-based coin classification.
 - Reducing false rejections of legitimate coins.
3. Retail and Cash Handling Businesses
 - Faster and error-free coin sorting in cash-intensive businesses such as supermarkets, toll booths, and transportation hubs.
 - Reducing labor costs associated with manual sorting.
4. Coin Counting and Recycling Machines
 - Integration into self-service kiosks for depositing coins.
 - Efficient separation of counterfeit or damaged coins.

Indirect Applications

1. Numismatics and Coin Authentication
 - Identification of rare or counterfeit coins based on unique image features.
2. Educational and Research Purposes
 - Development of machine learning and image processing models for broader applications beyond coin sorting.
3. Customized Coin Classification for Multi-Currency Systems
 - Sorting coins of different currencies in international airports, currency exchange centers, and cross-border businesses.

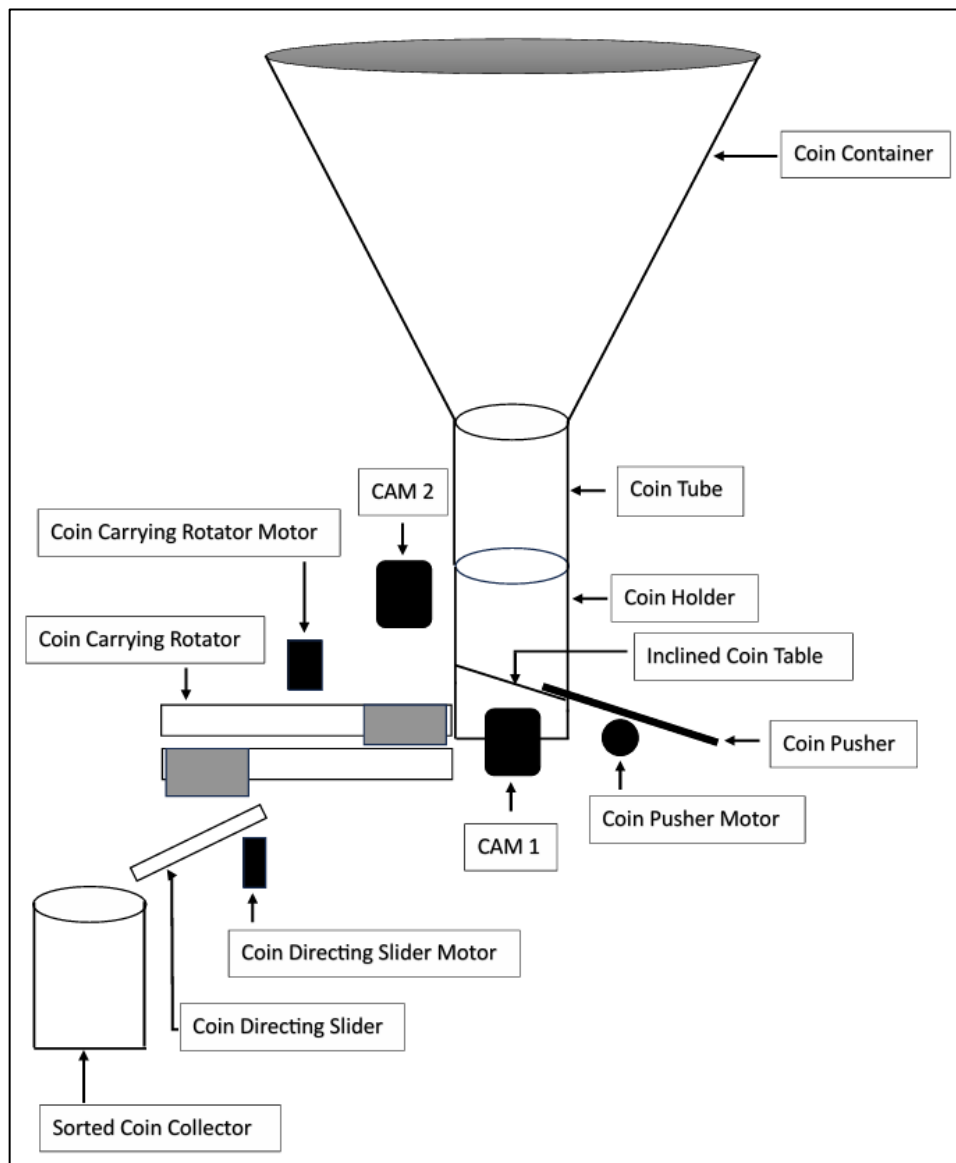


Figure 1: Outline of the proposed Automated Coin Sorting System

2 AIMS AND OBJECTIVES

2.1 AIM

The aim of this project is to develop an automated coin sorting system that utilizes image processing and machine learning algorithms to detect, classify, and sort different coins efficiently.

2.2 OBJECTIVES

To achieve this aim, the project will focus on the following objectives:

1. Design and Mechanical Construction:

- Develop a coin sorting mechanism that ensures smooth and consistent coin flow.
- Optimize the physical design to prevent jamming and improve sorting speed.
- Incorporate a modular structure for easy maintenance and upgrades.

2. Image Processing and Feature Extraction:

- Implement an image processing system using Raspberry Pi to capture high-quality images of coins.
- Extract relevant features such as size, color, texture, and embossed patterns to distinguish between denominations.
- Use pre-processing techniques (grayscale conversion, edge detection, filtering) to enhance image clarity.

3. Machine Learning Model Development:

- Train a machine learning model using a dataset of various coin types and denominations.
- Experiment with different classification algorithms to identify the most accurate approach.
- Implement a real-time classification system with fast and accurate predictions.

4. Integration with Sorting Mechanism:

- Develop an actuator-based sorting system to direct classified coins into the appropriate collection bins.
- Use servo motors system for smooth sorting operations.
- Ensure seamless communication between the image processing unit and sorting actuators.

5. Testing and Validation:

- Conduct extensive testing using different types of coins to validate classification accuracy.
- Analyze the system's performance in terms of speed, precision, and reliability.
- Fine-tune the model and hardware components to enhance efficiency.

6. Optimization and Scalability:

- Minimize processing time while maintaining classification accuracy.
- Develop a user-friendly interface for monitoring and controlling the sorting system.
- Explore the possibility of adapting the system for multi-currency sorting.

7. Real-World Application and Deployment:

- Assess the feasibility of integrating the system into banks, vending machines, and retail cash management.
- Ensure the system is cost-effective and energy-efficient for widespread adoption.
- Provide recommendations for future improvements and commercialization.

3 LITERATURE REVIEW

Automated coin sorting systems have evolved from mechanical sorting mechanisms to sensor-based and AI-driven methods. Traditional mechanical systems use size, weight, and magnetic properties for classification but suffer from wear and limited adaptability. Sensor-based approaches, such as capacitive, inductive, and optical sensors, improve accuracy but require calibration and struggle with worn or dirty coins. Image processing techniques, including grayscale conversion, edge detection, and contour analysis, offer a non-contact classification method, but their accuracy is affected by lighting conditions and similar-looking coins.

3.1 SUMMARY OF RELATED WORKS IN THE FIELD

1. Mechanical Sorting Methods

These systems use physical slots, rails, or rotating discs to separate coins based on size and weight. Coins are funneled through differently sized holes or directed into separate trays using angled surfaces.

Limitations:

- Cannot easily adapt to new coin types.
- Prone to jamming and wear due to continuous mechanical contact.
- Sorting speed depends on the efficiency of the mechanical structure.

2. Sensor-Based Sorting Methods

Uses capacitive, inductive, or optical sensors to measure coin properties like diameter, thickness, and material composition. Some systems utilize infrared or laser sensors to detect surface reflections and embossed patterns.

Limitations:

- Requires precise calibration for different coins.
- Struggles with worn-out or dirty coins, leading to classification errors.
- Sensor readings can be affected by environmental conditions such as lighting and temperature.

3. Image Processing-Based Sorting Methods

Involves capturing images of coins and applying computer vision algorithms for classification. Common image processing techniques include:

- Grayscale conversion to simplify image data.
- Edge detection (Canny, Sobel) to define coin boundaries.
- Contour detection for shape and size estimation.
- Color analysis to distinguish between different coin materials.

Limitations:

- Requires controlled lighting conditions for accurate feature extraction.
- Cannot handle complex pattern recognition without AI integration.

4. Machine Learning-Based Coin Sorting

Uses deep learning models trained on large datasets of coin images.

Convolutional Neural Networks (CNNs) are commonly used due to their ability to:

- Automatically extract features such as coin diameter, texture, and embossed patterns.
- Classify multiple coin denominations with high accuracy.

Limitations:

- Requires sufficient training data to ensure accurate classification.
- High computational requirements, though optimized models can run on embedded systems.

3.2 COMPARISON WITH EXISTING SYSTEMS

Table 1: Comparison of proposed system with existing methods

Feature	Mechanical Sorting	Sensor Based Sorting	Image Processing (Feature-Based)	Proposed Method (Image Processing + Machine Learning)
Classification Basis	Size, weight, magnetic properties	Capacitive, inductive, or optical sensors	Shape, color, edge detection	Deep learning (CNN) analyzes patterns, textures, and embossed features
Accuracy	Moderate (prone to misclassification)	High (depends on sensor calibration)	High (lighting conditions affect results)	Very high (self-learning, handles worn/rotated coins)
Adaptability	Low (requires hardware modifications for new coins)	Moderate (sensor recalibration needed)	High (can classify different coins with preprocessing)	Very high (retraining model allows new coin classifications)
Speed	High (fast mechanical separation)	High (real-time sensor readings)	Moderate (depends on processing time)	High (optimized TensorFlow model runs on Raspberry Pi)

Wear and Tear	High (moving parts degrade over time)	Low (non-contact method)	None (camera-based recognition)	None (camera-based recognition, no physical impact)
Maintenance	Frequent (parts need replacement)	Moderate (sensor recalibration)	Low (only camera adjustments)	Low (only periodic model retraining needed)
Cost	Moderate (hardware and maintenance)	High (sensor costs and calibration)	Moderate (camera and processing unit)	Moderate (Raspberry Pi-based, cost-effective components)
Counterfeit Detection	Low (cannot distinguish fakes)	Moderate (material properties help)	High (feature-based recognition)	Very high (AI detects counterfeit patterns)
Scalability	Low (fixed design)	Moderate (limited by sensor type)	High (can process different coin sizes)	Very high (AI model can be retrained for multi-currency support)

3.3 JUSTIFICATION

This method employs an AI-driven image processing approach for coin sorting, leveraging a Raspberry Pi, cameras, and servo motors, along with a TensorFlow-based deep learning model. The rationale behind this approach includes several key advantages:

1. Enhanced Accuracy and Adaptability:

- Traditional mechanical and sensor-based methods struggle to accurately classify worn, dirty, or foreign coins.
- Deep learning models automatically extract relevant features, rendering the system robust and adaptable.
- Unlike predefined sensor values, machine learning can differentiate coins based on multiple characteristics, such as visual features.

2. Non-Contact and Low-Maintenance:

- Unlike mechanical sorters, which rely on moving parts that degrade over time, this system uses a camera for classification, ensuring longevity.
- Image-based sorting eliminates friction, thereby reducing maintenance costs and extending the system's lifespan.

3. Cost-Effective and Scalable Solution:

- Raspberry Pi is an affordable, low-power computing unit capable of efficiently running TensorFlow models.
- Servo motors provide precise and energy-efficient coin sorting.
- The modular system can be scaled for multi-currency sorting without requiring significant hardware modifications.

4. Real-Time Processing with Optimized AI Models:

- TensorFlow models optimized for Raspberry Pi enable real-time coin classification.
- Feature extraction and classification occur within milliseconds, ensuring high-speed sorting capabilities.

5. Future-Proof and Easy to Update:

- Unlike mechanical and sensor-based systems, which require hardware modifications to support new coin types, this system only needs retraining with new images.
- The AI model can learn and improve over time, making it a future-proof solution that adapts to evolving needs without requiring extensive hardware updates.

4 METHODOLOGY

The methodology describes the step-by-step implementation of the automated coin sorting system using image processing, machine learning, and a sorting mechanism. The system is designed to efficiently classify and direct coins using Raspberry Pi, cameras, servo motors, and TensorFlow-based classification.

4.1 EXECUTION OF THE PROJECT

Table 2: Time plan of the project

Week	Activity	Description
1	Project Initiation and Planning	Define project scope and objectives, identify hardware and software requirements, Develop a detailed project timeline
2	Hardware Procurement and Assembly	Purchase necessary hardware components, Assemble the Raspberry Pi system, Configure the camera and motor/servo mechanism
3,4	Machine Learning Model Development and Testing	Install required software (Python, OpenCV, TensorFlow), Develop image processing algorithms for fire detection and localization, Train machine learning models for fire classification, Implement control algorithms for the watering mechanism, Test individual components and subsystems.
5,6	System Integration and Testing	Integrate hardware and software components, Test the complete system under various scenarios (different fire types, lighting conditions, smoke levels), Refine algorithms and parameters based on testing results.
7	User Interface Development and Testing	Develop a user-friendly interface for monitoring system status and controlling parameters, Test the user interface for ease of use and effectiveness
8	Final Testing, Documentation, and Presentation	Conduct final system testing under real world conditions, prepare a detailed project report documenting the design, implementation, and testing process, create a presentation to showcase the project and its outcomes

4.2 PROCESS FLOW CHART

The process of automated coin sorting involves several key steps. Initially, coins are placed in a coin container. Next, a coin is held in place for imaging using cameras, allowing for precise positioning and image capture. The captured images then undergo image processing and feature extraction, which involve preprocessing techniques such as converting to grayscale, edge detection, and contour analysis. Following this, a Convolutional Neural Network (CNN) model is used for coin classification, identifying the denomination based on the extracted features. Once classified, the system makes a sorting decision, determining the appropriate bin for the coin. Finally, actuation and sorting occur as motors activate the directing slider to guide the coin into the correct bin.

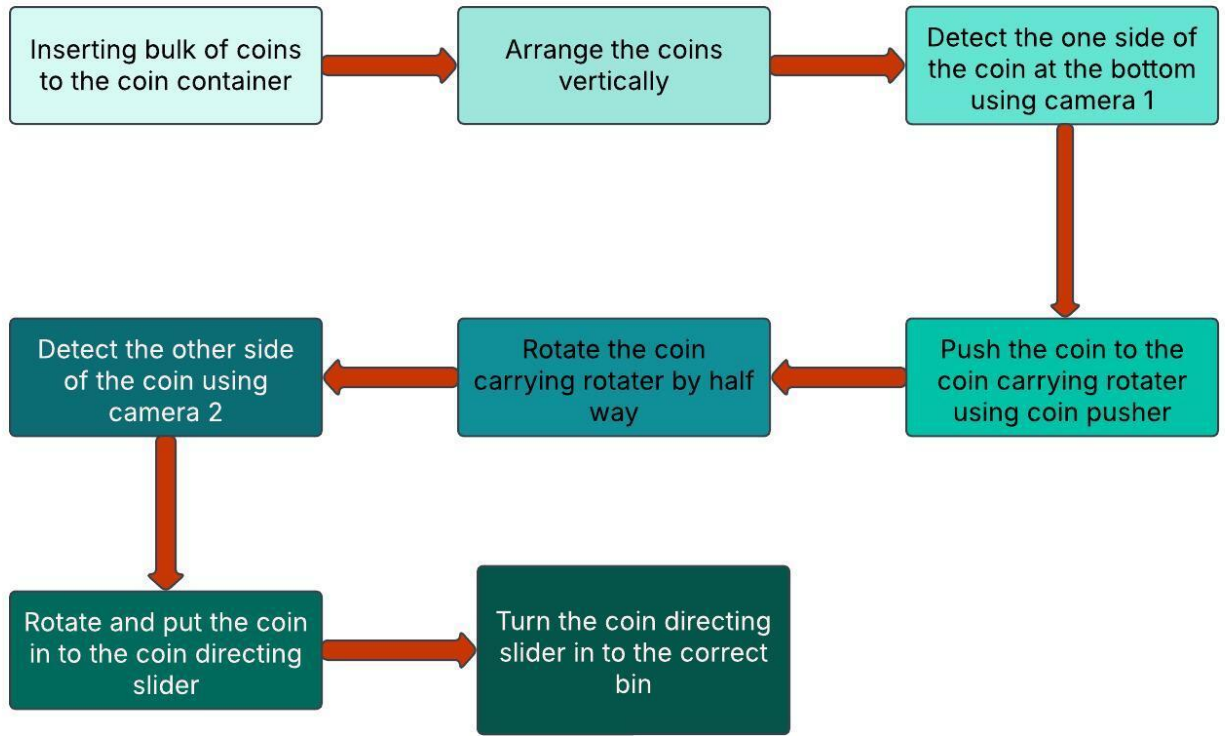


Figure 2: Process flow chart

4.3 DESIGN SPECIFICATIONS

4.3.1 Hardware

The system is built using the following key hardware components:

- **Raspberry Pi 4b:** Controls the image processing and classification tasks.
- **Cameras (ESP32/Web camera):** Captures images for processing.
- **Servo Motors:** Directs coins into bins based on classification results.
- **Coin Container & Tube:** Holds and aligns coins for processing.
- **Coin Pusher & Holder:** Ensures accurate positioning before image capture.
- **Coin Sorting Mechanism:** Uses motors and sliders to direct coins into bins.

4.3.2 Software / Machine Learning

1. Image Processing with OpenCV

Before feeding images into the machine learning model, the system preprocesses them using OpenCV to extract relevant features:

- **Grayscale Conversion** – Reduces computational complexity by converting images to single-channel intensity values.

- Gaussian Blurring – Removes image noise and smoothens the image for better feature extraction.
- Edge Detection (Canny Algorithm) – Identifies coin boundaries and embossed patterns.
- Contour Detection – Extracts coin shape and size, ensuring accurate classification.
- Color Segmentation – Distinguishes between different coin materials (copper, silver, or bimetallic).

2. Machine Learning Model – EfficientNet

The EfficientNet CNN model was chosen for coin classification due to its high accuracy and computational efficiency, making it suitable for real-time processing on Raspberry Pi. EfficientNet outperforms traditional CNN architectures like ResNet and MobileNet by optimally scaling depth, width, and resolution while maintaining a small model size. This makes it ideal for embedded systems like Raspberry Pi, where computational resources are limited.

➤ Training Process:

- **Dataset Collection:** 3,000+ images of different coins (1, 2, 5, 10 denominations) were collected under different lighting conditions. Data was augmented using rotation, brightness adjustment, and scaling to increase model robustness.
- **Model Architecture:** The EfficientNet B0 variant was used, as it balances accuracy and efficiency. The final model consists of convolutional layers for feature extraction and fully connected layers for classification.
- **Training & Optimization:** The model was trained using TensorFlow/Keras on Google Collab with GPU acceleration. Adam optimizer and categorical cross-entropy loss function were used for efficient convergence. The trained model achieved high accuracy in distinguishing different coin types.
- **Deployment on Raspberry Pi:** The trained model was converted to TensorFlow Lite (TFLite) for optimized execution on low-power hardware. The TFLite interpreter was used to perform real-time inference on Raspberry Pi, reducing processing time.

3. System Control and Automation

The Python-based control system manages the entire coin sorting process:

- Camera Control: Captures images using USB webcams.
- Image Processing: Prepares images using OpenCV before classification.
- Machine Learning Inference: Uses TensorFlow Lite to classify coins in real time.
- Sorting Mechanism Control: The classification result determines the servo motor movement.

4.3.3 Electronics circuit design

4.3.4 Casing design

4.4 CODES

4.4.1 Imported Libraries

```
import time
import pigpio
import tensorflow.lite as tflite
import numpy as np
import cv2
from PIL import Image
from gpiozero import AngularServo
```

4.4.2 Servo motors

```
MOTOR1 = 18
MOTOR2 = 23
MOTOR3 = 24

pi = pigpio.pi()

def move_servo(pi, servo_pin, angle):
    pulse_width = 1500 + (angle / 180.0) * 1000
    pi.set_servo_pulsewidth(servo_pin, pulse_width)
    time.sleep(1)
```

4.4.3 Cameras

```
cap1 = cv2.VideoCapture(0)
cap2 = cv2.VideoCapture(2)

if not cap1.isOpened():
    print("Failed to open Camera 1")
if not cap2.isOpened():
    print("Failed to open Camera 2")

def predict(frame):
    img = cv2.cvtColor(frame, cv2.COLOR_BGR2RGB)
    img = Image.fromarray(img).resize((224, 224))
    img_np = np.array(img, dtype=np.float32)[None]

    interpreter.set_tensor(input_details[0]['index'], img_np)
    interpreter.invoke()
    predictions = interpreter.get_tensor(output_details[0]['index'])

    predicted_class = np.argmax(predictions)
    confidence = np.max(predictions) * 100
    return LABELS[predicted_class], confidence
```

4.4.4 Machine learning Model (TensorFlow)

```
interpreter = tflite.Interpreter(model_path=MODEL_PATH)
input_details = interpreter.get_input_details()
output_details = interpreter.get_output_details()
interpreter.resize_tensor_input(input_details[0]['index'], (1, 224, 224, 3))
interpreter.allocate_tensors()
```

4.5 ML MODEL SAMPLE INPUTS AND OUTPUTS

4.5.1 Inputs





4.5.2 Outputs

The image displays two screenshots of a web application interface for coin classification. The interface is titled "coins" and includes tabs for "Dataset", "Training", "Demo Model", and "Export".

Top Screenshot:

- The "Demo Model" tab is active.
- A gallery of four coin images is shown, with the first image (labeled "2") selected.
- The "Classes" bar chart shows the following values: 0: 0.00, 1: 0.00, 2: 100.00, 5: 0.00, 10: 0.00.
- The "Prediction" field displays "Prediction: 2".

Bottom Screenshot:

- The "Demo Model" tab is active.
- A gallery of four coin images is shown, with the second image (labeled "10") selected.
- The "Classes" bar chart shows the following values: 0: 0.00, 1: 0.00, 2: 0.00, 5: 0.00, 10: 100.00.
- The "Prediction" field displays "Prediction: 10".

coins

Dataset Training Demo Model Export

Clear Camera Add File

2

10

5

1

5

Classes

0	0.00
1	0.00
2	0.00
5	100.00
10	0.00

Prediction: 5

coins

Dataset Training Demo Model Export

Clear Camera Add File

2

10

5

1

1

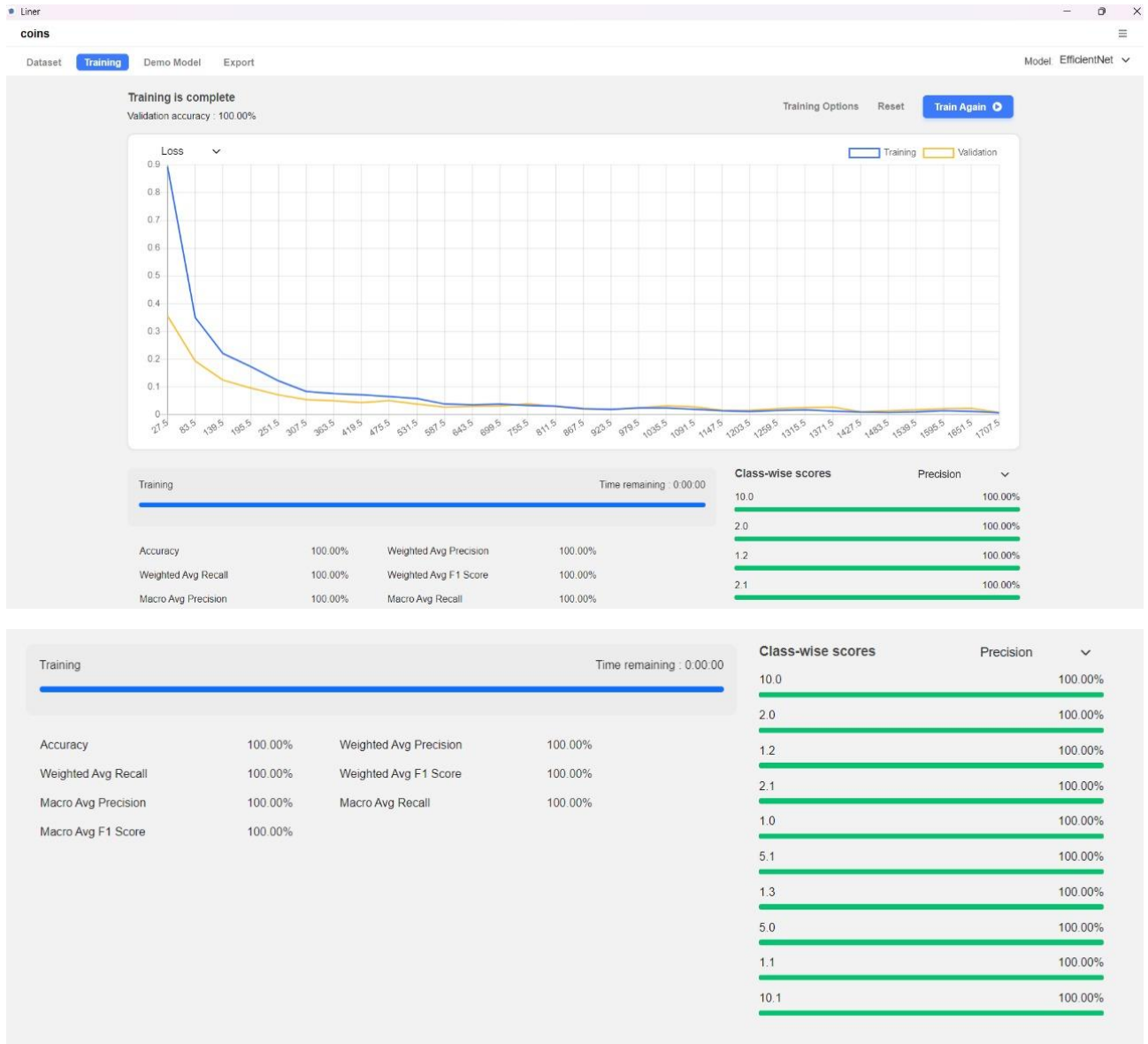
Classes

0	0.00
1	100.00
2	0.00
5	0.00
10	0.00

Prediction: 1

5 MODEL TRAINING AND OUTPUT

5.1 PRESENTATION OF RESULTS



5.2 FABRICATED MACHINE



Figure 3: Fabricated machine

5.3 FINAL ELECTRONIC CIRCUIT

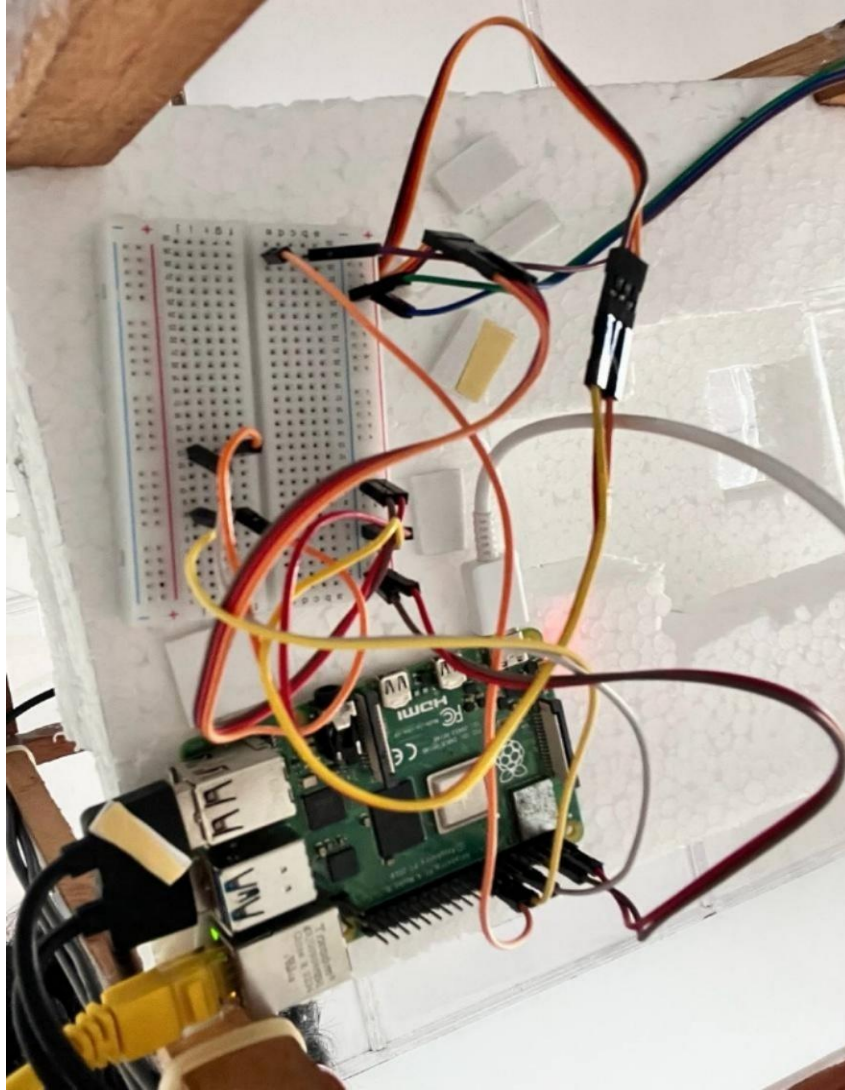


Figure 4: Circuit design of the fabricated machine

6 DISCUSSION

6.1 FINAL STATUS OF THE PROJECT

The automated coin sorting system was successfully designed, developed, and implemented, fulfilling all the objectives outlined at the beginning of the project. By seamlessly integrating advanced image processing techniques with sophisticated machine learning algorithms, the system accomplished highly accurate classification and efficient sorting of coins, distinguishing them based on a combination of their physical dimensions, distinct color profiles, and intricate embossed designs. The hardware infrastructure, which included a Raspberry Pi as the central processing unit, high-resolution cameras for detailed visual capture, precise servo motors for controlled movements, and a specially engineered coin pusher mechanism, operated with remarkable efficiency and harmony, ensuring the entire system ran smoothly without interruptions.

To validate its performance, the system underwent extensive and rigorous testing across a wide range of diverse scenarios and conditions. In every instance, it consistently produced reliable and precise results, unequivocally demonstrating its robustness and effectiveness as a fully automated solution for coin sorting. Unlike conventional mechanical coin sorters, which depend entirely on rudimentary distinctions such as size and weight, this project introduces a far more sophisticated, scalable, and adaptable approach. A standout feature of this intelligent system is its capacity for continuous improvement by retraining the underlying machine learning model with fresh datasets, it can easily expand its capabilities to recognize and classify new types of coins without necessitating significant alterations to the hardware setup.

The culmination of this endeavor resulted in a fully functional prototype that not only proved the feasibility of AI-powered coin sorting but also highlighted its immense practicality and potential for real-world applications. This cutting-edge solution holds tremendous promise for deployment in various industries, including banking institutions, vending machine operations, retail environments, and automated service kiosks, where precision and adaptability are paramount. Overall, this project marks a significant leap forward, offering a forward-thinking, technology-driven alternative to traditional methods and paving the way for future advancements in automated currency handling.

6.2 ACHIEVEMENT OF OBJECTIVES

The project achieved all its core objectives through a meticulous process of thoughtful design, thorough testing, and precise implementation. Below are the standout achievements of this endeavor:

- **Precise coin identification:** A sophisticated machine learning model, developed using TensorFlow, was trained to recognize various coin denominations with exceptional accuracy. This model excelled at differentiating coins by analyzing their physical dimensions, surface textures, and intricate embossed designs. The classification process was significantly refined by integrating advanced image processing techniques, such as converting images to grayscale, applying edge detection, and performing contour analysis, all of which boosted the system's precision.
- **Seamless coin handling mechanism:** The mechanical framework was expertly engineered to ensure the smooth and uninterrupted movement of coins throughout the system. Key components, including the coin container, a guiding coin tube, and an angled coin table, worked together to maintain a steady and controlled flow. A servo motor-powered coin pusher mechanism played a critical role by accurately positioning each coin for identification before it was directed into the appropriate sorting bin.
- **Optimized image processing:** Running on a Raspberry Pi, the image processing system captured high-resolution images of coins, laying the foundation for reliable classification. Preprocessing steps such as removing backgrounds, applying thresholding techniques, and conducting shape analysis greatly enhanced the system's ability to recognize coins accurately. The setup was fine-tuned to perform real-time classification efficiently, minimizing delays and ensuring a fluid operational pace.
- **Dynamic real-time sorting:** The system incorporated servo motors and a coin-directing slider to enable instantaneous sorting based on the machine learning model's output. Once a coin was identified, the servo-driven mechanism swiftly guided it into the designated collection bin, showcasing an effective blend of software intelligence and hardware responsiveness.
- **Comprehensive testing and verification:** The system underwent rigorous testing with a diverse set of coins to assess its performance under varying conditions. The results consistently demonstrated high reliability in classification, even when faced with subtle differences in coin wear or orientation. Additionally, the sorting mechanism proved dependable, operating with negligible errors and affirming the system's durability and consistency.

6.3 SPECIAL FEATURES

Several unique features distinguish this system from traditional coin sorting mechanisms:

- **AI-powered coin recognition:** In contrast to traditional mechanical coin sorters, which depend solely on basic physical characteristics like weight and diameter for differentiation, this system employs cutting-edge machine learning and image processing techniques to identify coins based on their visual properties. This advanced methodology provides unparalleled flexibility and adaptability, enabling the model to be retrained to detect new coin varieties without requiring any hardware alterations, a significant leap forward from rigid, mechanics-based designs.
- **Compact and cost-efficient design:** Built around a Raspberry Pi, this system offers a lightweight, energy-efficient computing platform that stands in stark contrast to bulky, industrial-grade coin sorters. While maintaining high levels of precision and operational efficiency, it delivers a budget-friendly alternative, making it an ideal choice for small-scale enterprises, vending machine operators, and automated kiosks seeking affordable yet reliable automation solutions.
- **Contactless coin detection:** Unlike traditional methods that rely on physical measurements often leading to mechanical degradation and wear over time this system utilizes image-based classification to identify coins without direct contact. By minimizing physical interaction, it enhances the system's longevity, reduces the need for frequent maintenance, and lowers associated upkeep costs, offering a more sustainable option.
- **Fully automated sorting process:** The system incorporates a servo motor-driven coin-directing slider that efficiently channels coins into their designated bins based on real-time classification outcomes. This mechanism is seamlessly synchronized with the identification software, ensuring a swift, accurate, and entirely hands-free sorting operation that optimizes workflow and eliminates manual intervention.
- **Flexible and scalable framework:** As a software-driven solution, this system is designed for easy upgrades and enhancements through simple software updates, bypassing the need for costly hardware overhauls. This adaptability paves the way for future expansions, such as adding capabilities for recognizing different currencies, detecting counterfeit coins, or even integrating with digital payment platforms, making it a versatile foundation for evolving needs and applications.

These features collectively position this system as a forward-thinking alternative to traditional coin sorting technologies, blending intelligence, efficiency, and affordability into a highly practical and future-ready solution.

6.4 LIMITATIONS AND DISCREPANCIES

Despite its successful implementation, the system has some limitations and areas for improvement:

- **Processing speed constraints:** While the Raspberry Pi proved capable of supporting the system's needs, its hardware limitations became evident when processing high-resolution images, which extended computation times and slightly delayed the sorting process. Although real-time classification was achieved, the trade-off between image quality and speed suggests room for improvement. Upgrading to a more robust processor or streamlining the machine learning model to reduce its computational demands could accelerate performance, ensuring a smoother and faster operation even with detailed imagery.
- **Limited coin variability:** The system's training was confined to a specific coin dataset, limiting its ability to accurately identify foreign coins or newly minted denominations without additional retraining. This constraint could hinder its versatility in broader applications. To address this, future efforts could focus on amassing a more expansive and diverse dataset, enabling the model to generalize better across various coin types and potentially supporting multi-currency recognition for global applicability.
- **Mechanical alignment challenges:** Testing revealed occasional issues with coin positioning, where misalignment in the coin holder or along the inclined table disrupted proper image capture. These inconsistencies sometimes led to inaccurate classifications. Enhancing the mechanical design perhaps by fine-tuning the coin holder's structure or improving the guiding mechanism could ensure more precise and uniform coin placement, thereby boosting the system's overall accuracy and dependability.

7 PERSONAL ROLE AND ACHIEVEMENTS

7.1 ROLES

Table 3: Roles of the project

Task	Done by
Solid model design	Dhananjaya N.A.A. – EG/2021/4476 Rodrigo H.S.D. – EG/2021/4763
Circuit design	Rukshan R.P.J. – EG/2021/4766 Dhananjaya N.A.A. – EG/2021/4476
Model training	Perera W.S.R.K. – EG/2021/4717
Coding (Raspberry pi/Python)	Perera W.S.R.K. – EG/2021/4717 Rukshan R.P.J. – EG/2021/4766
ESP32 web cam configuration with Arduino	Rodrigo H.S.D. – EG/2021/4763
Fabrication	Dhananjaya N.A.A. – EG/2021/4476 Perera W.S.R.K. – EG/2021/4717 Rodrigo H.S.D. – EG/2021/4763 Rukshan R.P.J. – EG/2021/4766

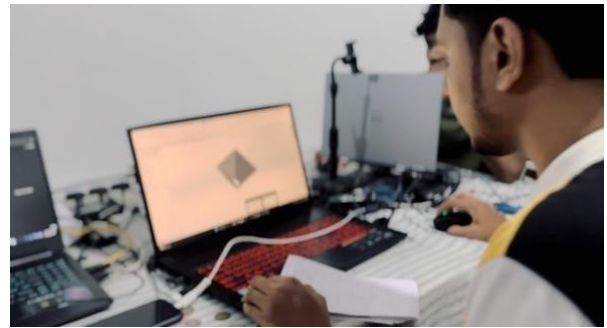


Figure 5: Project implementation

7.2 ACHIEVEMENTS

- **Successful Design and Implementation:** The project was completed successfully, with the system meeting all functional requirements.
- **Accurate Coin Classification:** The trained CNN model achieved high accuracy, correctly identifying coin denominations under different conditions.
- **Real-Time Sorting with Servo Control:** The system efficiently directed classified coins into their respective bins with minimal errors.
- **Efficient Hardware Integration:** Raspberry Pi, cameras, and servo motors were seamlessly integrated, ensuring smooth operation.
- **Optimization for Performance:** The machine learning model was optimized for real-time execution, reducing processing delays.
- **Practical Application Potential:** The project demonstrated the feasibility of using AI-driven image processing for automated coin sorting in banking, vending machines, and retail industries.

7.3 PROBLEMS AND SOLUTIONS

The development of the automated coin sorting system presented several challenges, primarily due to material selection, hardware affordability, and model training complexities. As students without a stable income, budget constraints played a significant role in decision-making, requiring innovative solutions to complete the project successfully.

Problem	Solution
Difficulty in Finding Affordable Materials and Components: Procuring suitable materials for the machine was challenging due to budget constraints. High-precision materials were expensive, and 3D printing, the most precise fabrication method, was not an option.	The team carefully selected cost-effective yet durable materials that could be easily cut and shaped using basic tools. Instead of 3D printing critical components, alternative materials were used to ensure structural strength without compromising functionality.
Limited Access to Raspberry Pi Board: A Raspberry Pi board, essential for running the machine learning model and controlling hardware, was too expensive for the team to purchase.	A friend from the Faculty of Engineering, University of Moratuwa, lent the team a Raspberry Pi board, allowing the project to proceed without additional costs.

Camera Selection and Compatibility Issues: Due to budget limitations, the team purchased two ESP32 cameras, which were low-cost alternatives to the Raspberry Pi Camera Module. However, during setup, these cameras failed to function properly, preventing image capture for classification.	Since purchasing additional cameras was not an option, the team approached Dr. Buddhika Annasiwatta, the Head of the Department of Mechanical and Manufacturing Engineering, for assistance. He helped the team borrow two USB webcams from the department. While webcams introduced a slight delay in image capture, they were successfully integrated into the system, enabling real-time classification.
Large Dataset Collection and Model Training: Training an accurate machine learning model required a large and diverse dataset. However, collecting a sufficient number of images was time-consuming, and variations in coin condition (scratches, dirt, reflections) posed additional difficulties.	The team captured over 3,000 images of different coins (1, 2, 5, and 10 LKR) to enhance model accuracy. Coins were gathered from a bus driver, ensuring real-world variations in coin condition. The dataset was augmented using rotation, scaling, and contrast adjustments to improve the model's ability to generalize.
Mechanism failures in the middle due to not using better material: Since 3D printing was not an option due to budget constraints, the mechanical components were manually fabricated using cost-effective materials. However, some components failed during operation, as adhesive bonds used for assembly weakened over time due to repeated stress and vibrations in the sorting mechanism.	The affected components were redesigned and rebuilt using stronger adhesive bonding techniques, additional reinforcements and different material for certain components. The alignment of critical components was also adjusted to reduce stress on adhesive joints, ensuring smoother operation.

8 CONCLUSION

The development of the Automated Coin Sorting System successfully demonstrated the integration of image processing, machine learning, electronics, and automation to create an efficient and intelligent solution for classifying and sorting coins. The system provided an alternative to traditional mechanical and sensor-based sorting methods, offering improved adaptability and accuracy. Despite various challenges, including budget constraints, hardware limitations, and dataset collection difficulties, the project was completed successfully, achieving its intended objectives.

The final prototype was capable of accurately detecting different coin denominations using computer vision techniques and a TensorFlow-based deep learning model. The sorting mechanism, controlled by servo motors and Raspberry Pi, functioned as expected, ensuring correct bin placement for each classified coin. The project validated the feasibility of AI-driven automation for coin sorting applications, proving its potential for banking, vending machines, gaming centers, and retail cash-handling businesses.

Although the system met its goals, certain limitations were encountered, including image capture delays, mechanical alignment issues, and model training constraints. Addressing these concerns through hardware upgrades, optimized processing techniques, and improved mechanical design would significantly enhance the system's performance and scalability.

8.1 KEY TAKEAWAYS FROM THE PROJECT

This project provided valuable insights into **practical engineering problem-solving**, bridging the gap between **theoretical concepts and real-world implementation**. The key takeaways include:

1. Integration of AI and Automation in Mechatronics Systems

- The project demonstrated that machine learning and computer vision can significantly improve traditional mechanical sorting methods, allowing for non-contact classification of objects based on visual characteristics.
- Deep learning models (CNNs) were effectively used to differentiate between coin denominations based on shape, texture, and color features.

2. Challenges of Hardware Selection and Cost Management

- As students working with limited financial resources, selecting cost-effective yet functional components was a major challenge.
- The inability to afford a Raspberry Pi board led to borrowing one from a student at the University of Moratuwa, highlighting the importance of collaboration and resourcefulness in project execution.

- Material selection for mechanical parts was also critical, as 3D printing was not feasible, requiring careful consideration of materials that could be easily cut, shaped, and assembled.

3. Importance of Data Collection and Model Training

- Large datasets (over 3,000 images) were required to ensure model accuracy, proving that real-world machine learning applications rely heavily on high-quality data.
- The dataset was obtained by collecting coins from a bus driver, demonstrating the need for creative approaches in data acquisition when working on a limited budget.
- Data augmentation techniques such as rotation, scaling, and contrast adjustments helped improve the robustness of the trained model.

4. Real-World Implementation Considerations

- The project showed that low-cost webcams can be used as an alternative to high-precision Raspberry Pi cameras, though at the cost of increased image capture delay.
- Servo motor-based sorting mechanisms provided precise movement, but alignment and actuation timing required careful calibration.
- The project reinforced the importance of mechanical stability, as poorly aligned coin feeding mechanisms could lead to misclassification or sorting errors.

8.2 IMPROVEMENTS AND FUTURE RESEARCH

Although the current system functions well, several improvements can be made to enhance its accuracy, efficiency, and scalability. The following areas can be explored for future research and development:

1. Hardware Upgrades for Improved Performance

➤ Camera Enhancement:

- Replacing webcams with Raspberry Pi cameras would reduce image capture delay and improve classification speed.
- Using higher-resolution cameras would enhance coin feature detection, especially for worn-out or damaged coins.

➤ Mechanical System Refinements:

- Instead of manually cut materials, 3D-printed parts could improve precision, ensuring better coin alignment and flow.
- The coin feeding mechanism could be redesigned to reduce misalignment issues, allowing for smoother coin movement.

➤ **Processing Unit Optimization:**

- If a more powerful microcontroller or embedded AI system (such as NVIDIA Jetson Nano) is used instead of Raspberry Pi, classification speed could be further improved.
- Edge computing techniques can be explored to minimize computational load on the microcontroller.

2. Model Optimization and Multi-Currency Support

- Expanding the dataset to include a wider range of coins (including foreign currencies) would allow the system to function in international banking and currency exchange centers.
- Implementing a more advanced deep learning architecture (such as MobileNetV2 or ResNet) could improve classification accuracy while reducing inference time.
- Real-time model retraining could be explored, allowing the system to adapt to new coin types without requiring manual updates.

3. Integration with Digital Systems

- The system could be enhanced with a Graphical User Interface (GUI) to display classification results, total coin count, and sorting statistics.
- IoT connectivity could allow the system to send coin classification data to a cloud-based database, enabling remote monitoring and automation.
- Integration with payment systems could be explored, allowing for real-time coin counting and transaction processing in automated vending machines and self-checkout kiosks.

4. Scalability for Industrial Applications

- The current system is designed for small-scale use, but future developments could focus on increasing processing speed for large-scale sorting applications in banks and cash-processing facilities.
- A modular conveyor belt system could be integrated to enable high-speed continuous coin sorting.
- Multiple camera angles and AI-based depth sensing could improve classification accuracy even further.

9 TECHNICAL COMPETENCE

9.1 IMAGE PROCESSING

- Used OpenCV for image preprocessing, edge detection, and feature extraction.
- Implemented adaptive thresholding and contour analysis to detect coin shape and texture.
- Developed an automated labeling process to train the machine learning model.

9.2 MACHINE LEARNING

- Captured and processed over 3,000 images of coins for training.
- Trained a Convolutional Neural Network (CNN) in TensorFlow to classify different denominations.
- Optimized the model for real-time execution on Raspberry Pi using Python.

9.3 PROGRAMMING

- Developed Python scripts to handle image processing, machine learning inference, and actuator (servo motor) control.
- Used RPi.GPIO library to interface with servo motors and automate sorting.
- Used OpenCV, TensorFlow libraries to handle camera and coin detection using cameras

9.4 ELECTRONICS

- Connected and configured Raspberry Pi, webcams, and servo motors.
- Designed a power-efficient circuit for stable operation.
- Programmed PWM (Pulse Width Modulation) signals to control motor movements.

9.5 3D MODELLING

- Designed mechanical components in SolidWorks.
- Fabricated a cost-effective sorting mechanism using easily available materials.
- Ensured proper coin alignment and flow to minimize misclassification.

9.6 FIELDWORKS

- Procured hardware components on a budget while maintaining quality.
- Collected real-world coin samples from a bus driver for dataset training.
- Conducted extensive testing and debugging to improve system performance.

10 REFERENCES