

GLASGOW CALEDONIAN UNIVERSITY

MEng Group Research Project

MMH723842-24-AB-GLAS

**Design and implementation of a PSD-Based
Analogue 2D Sun Sensor**

word count: xxx

by Zac McCaffery, Alexandru Belea,
Sebastian Alexander, William Kong, Nassor Salim,

Date: April 6, 2025

Contents

Abstract	5
1 Acknowledgements	6
2 Introduction	7
3 LiteratureReview	8
4 Background	9
5 Methodology	10
5.1 System Design Overview	10
5.1.1 Functional Requirements	11
5.1.2 Design Approach	11
5.1.3 System Architecture	11
5.2 Sensor Array Development	11
5.2.1 Functional Requirements	12
5.2.2 Design Approach	12
5.2.3 System Architecture	12
5.3 Signal Conditioning Circuitry	12
5.3.1 Functional Requirements	14
5.3.2 Design Approach	14
5.3.3 System Architecture	14
5.4 Enclosure Design And Fabrication	14
5.4.1 Functional Requirements	15
5.4.2 Design Approach	15
5.4.3 System Architecture	15
5.5 Data Acquisition System	15
5.5.1 Functional Requirements	17
5.5.2 Design Approach	17
5.5.3 System Architecture	17
5.6 Testing Apparatus	17

5.6.1	Functional Requirements	18
5.6.2	Design Approach	18
5.6.3	System Architecture	18
5.7	Prototype Development Lifecycle	18
5.7.1	Functional Requirements	20
5.7.2	Design Approach	20
5.7.3	System Architecture	20
6	Results	21
6.1	Sensor Characterization	21
6.1.1	Functional Requirements	22
6.1.2	Design Approach	22
6.1.3	System Architecture	22
6.2	Amplification Performance	22
6.2.1	Functional Requirements	24
6.2.2	Design Approach	24
6.2.3	System Architecture	24
6.3	Photodiode Angular Response	24
6.3.1	Functional Requirements	25
6.3.2	Design Approach	25
6.3.3	System Architecture	25
6.4	Enclosure Effectiveness	25
6.4.1	Functional Requirements	27
6.4.2	Design Approach	27
6.4.3	System Architecture	27
6.5	Data Acquisition System Evaluation	27
6.5.1	Functional Requirements	28
6.5.2	Design Approach	28
6.5.3	System Architecture	28
6.6	System Performance Analysis	29
6.6.1	Operational Constraints Identified	29
6.6.2	Environmental Factors Impact	29
6.6.3	System Stability and Repeatability	29
6.6.4	Recommendations for Improvement	29
6.7	Comparative Analysis	29
6.7.1	Breadboard vs. Stepboard Results	30
6.7.2	Iteration Improvements Analysis	30
6.7.3	Performance Against Design Requirements	30
6.7.4	Design Evolution Assessment	30

6.8	System Limitations And Considerations	30
6.8.1	Functional Requirements	31
6.8.2	Design Approach	31
6.8.3	System Architecture	31
7	Conclusions	34
8	FutureWork	35
	Bibliography	35

List of Figures

5.1	System Design Overview Flowchart	10
5.2	System Architecture Diagram	11
5.3	System Design Overview Flowchart	12
5.4	System Architecture Diagram	13
5.5	System Design Overview Flowchart	13
5.6	System Architecture Diagram	14
5.7	System Design Overview Flowchart	15
5.8	System Architecture Diagram	16
5.9	System Design Overview Flowchart	16
5.10	System Architecture Diagram	17
5.11	System Design Overview Flowchart	18
5.12	System Architecture Diagram	19
5.13	System Design Overview Flowchart	19
5.14	System Architecture Diagram	20
6.1	System Design Overview Flowchart	22
6.2	System Architecture Diagram	23
6.3	System Design Overview Flowchart	23
6.4	System Architecture Diagram	24
6.5	System Design Overview Flowchart	25
6.6	System Architecture Diagram	26
6.7	System Design Overview Flowchart	26
6.8	System Architecture Diagram	27
6.9	System Design Overview Flowchart	28
6.10	System Architecture Diagram	29
6.11	Environmental Testing Results	29
6.14	System Design Overview Flowchart	30
6.12	Overall System Performance Analysis	32
6.13	Prototype Iteration Comparison	33
6.15	System Architecture Diagram	33

Abstract

add abstract here

1. Acknowledgements

2. Introduction

Write intro here [1]

3. LiteratureReview

4. Background

5. Methodology

5.1 System Design Overview

This section provides an overview of the System Design Overview.

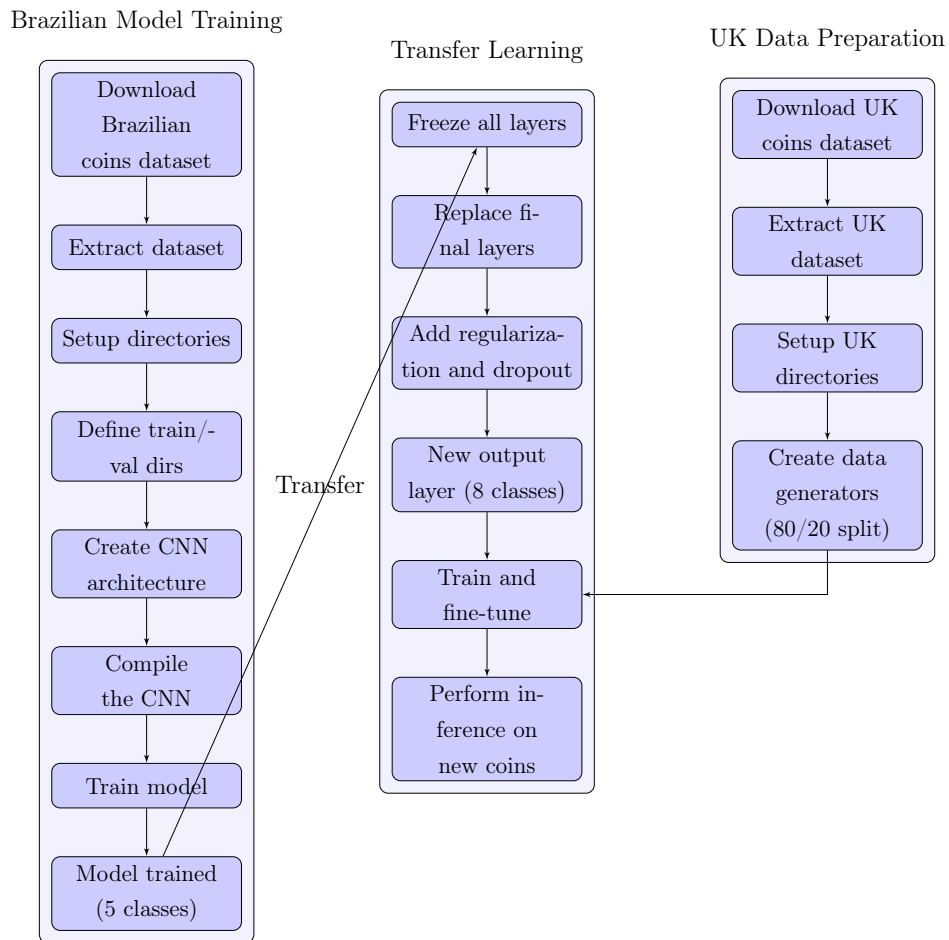


Figure 5.1: System Design Overview Flowchart

5.1.1 Functional Requirements

5.1.2 Design Approach

5.1.3 System Architecture

As shown in Figure 5.1 the system architecture consists of various components.

```
1 # Your code here
```

Listing 5.1: System Architecture Code Example

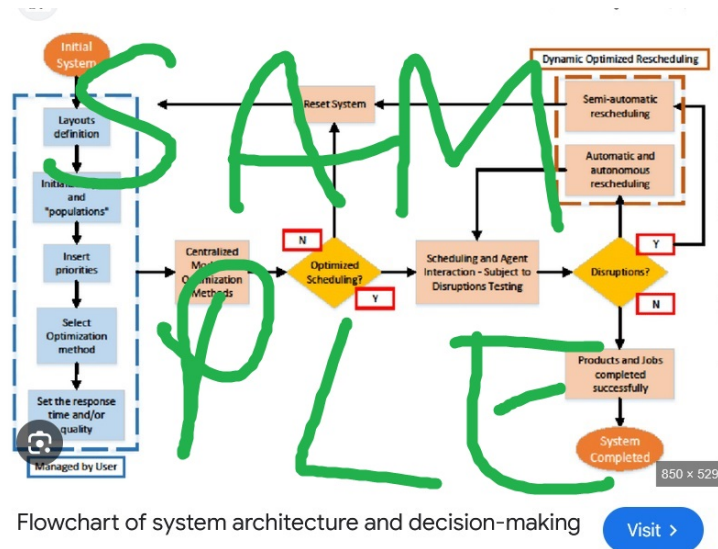


Figure 5.2: System Architecture Diagram

5.2 Sensor Array Development

This section provides an overview of the Sensor Array Development.

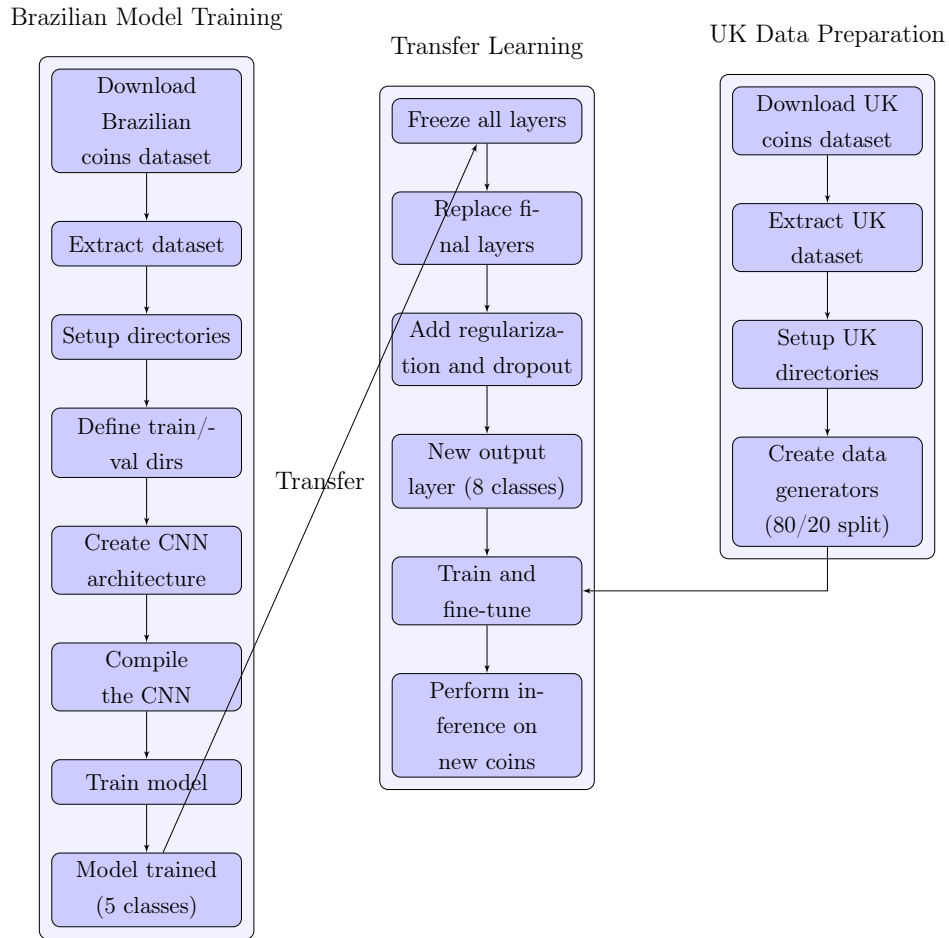


Figure 5.3: System Design Overview Flowchart

5.2.1 Functional Requirements

5.2.2 Design Approach

5.2.3 System Architecture

As shown in Figure 5.3 the system architecture consists of various components.

```
1 # Your code here
```

Listing 5.2: System Architecture Code Example

5.3 Signal Conditioning Circuitry

This section provides an overview of the Signal Conditioning Circuitry.

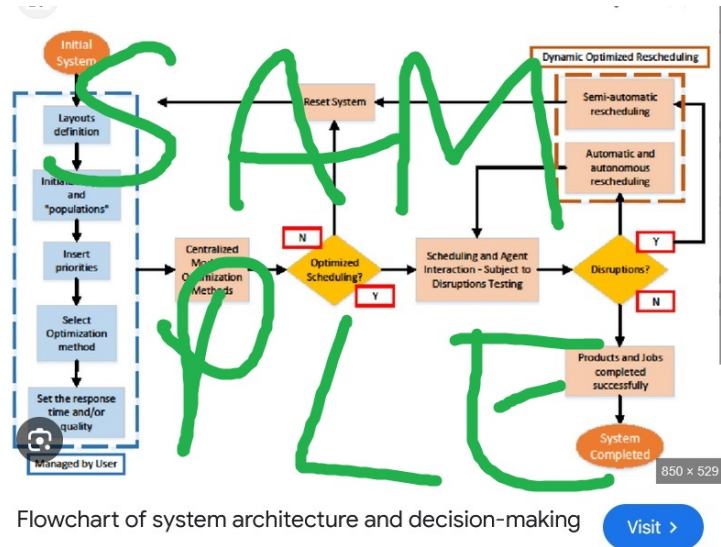
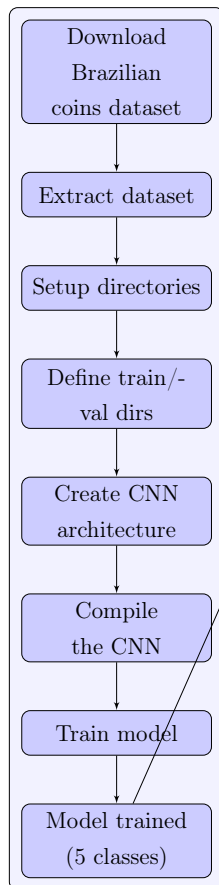
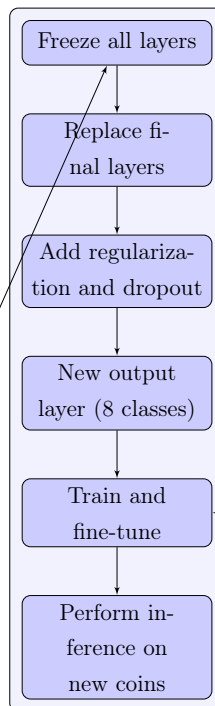


Figure 5.4: System Architecture Diagram

Brazilian Model Training



Transfer Learning



UK Data Preparation

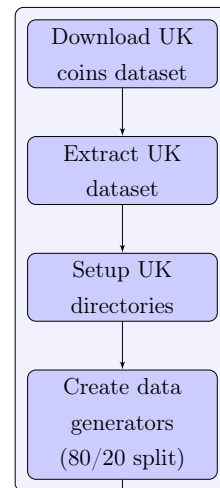


Figure 5.5: System Design Overview Flowchart

5.3.1 Functional Requirements

5.3.2 Design Approach

5.3.3 System Architecture

As shown in Figure 5.5 the system architecture consists of various components.

```
1 # Your code here
```

Listing 5.3: System Architecture Code Example

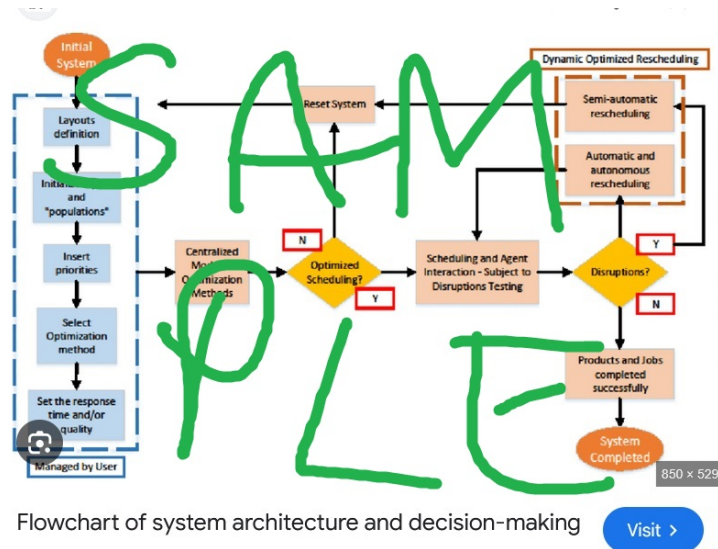


Figure 5.6: System Architecture Diagram

5.4 Enclosure Design And Fabrication

This section provides an overview of the Enclosure Design And Fabrication.



Figure 5.7: System Design Overview Flowchart

5.4.1 Functional Requirements

5.4.2 Design Approach

5.4.3 System Architecture

As shown in Figure 5.7 the system architecture consists of various components.

```
1 # Your code here
```

Listing 5.4: System Architecture Code Example

5.5 Data Acquisition System

This section provides an overview of the Data Acquisition System.

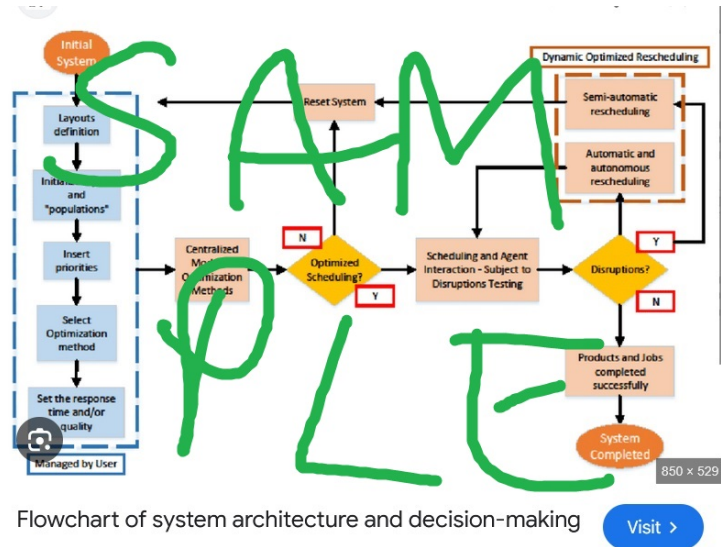
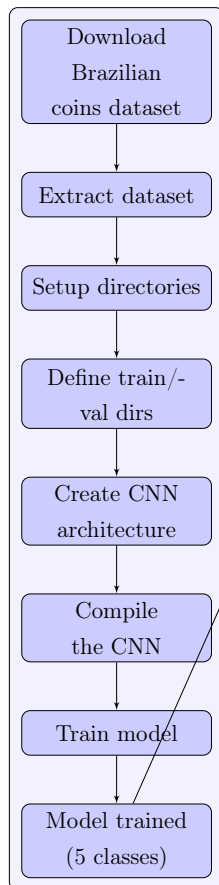
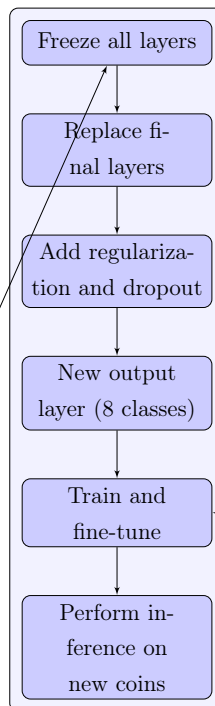


Figure 5.8: System Architecture Diagram

Brazilian Model Training



Transfer Learning



UK Data Preparation

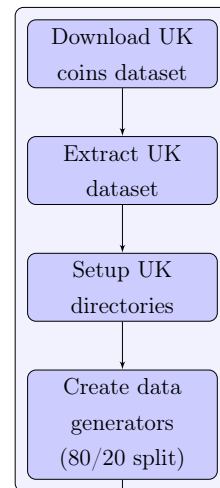


Figure 5.9: System Design Overview Flowchart

5.5.1 Functional Requirements

5.5.2 Design Approach

5.5.3 System Architecture

As shown in Figure 5.9 the system architecture consists of various components.

```
1 # Your code here
```

Listing 5.5: System Architecture Code Example

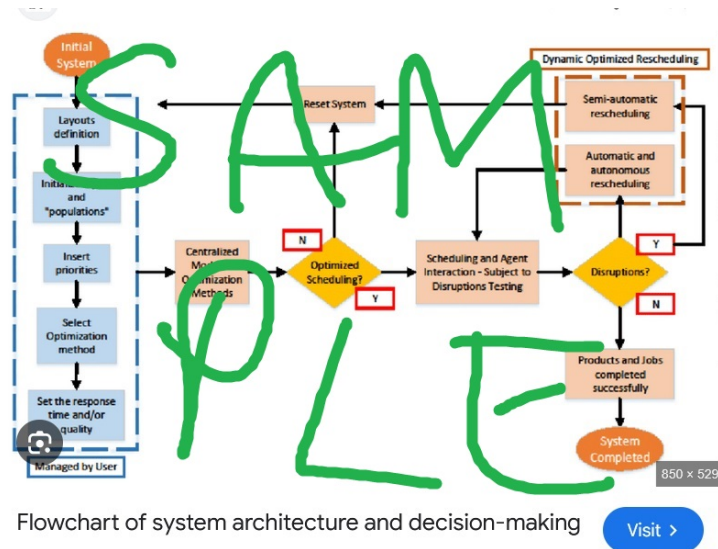


Figure 5.10: System Architecture Diagram

5.6 Testing Apparatus

This section provides an overview of the Testing Apparatus.

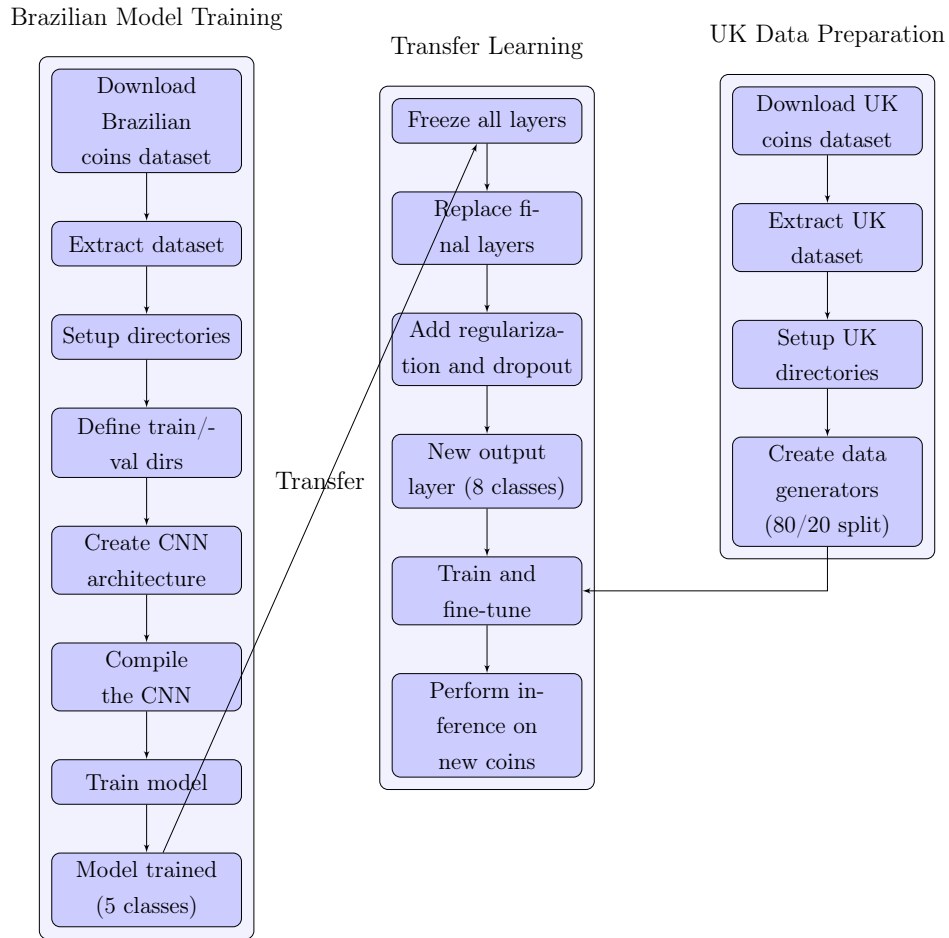


Figure 5.11: System Design Overview Flowchart

5.6.1 Functional Requirements

5.6.2 Design Approach

5.6.3 System Architecture

As shown in Figure 5.11 the system architecture consists of various components.

```
1 # Your code here
```

Listing 5.6: System Architecture Code Example

5.7 Prototype Development Lifecycle

This section provides an overview of the Prototype Development Lifecycle.

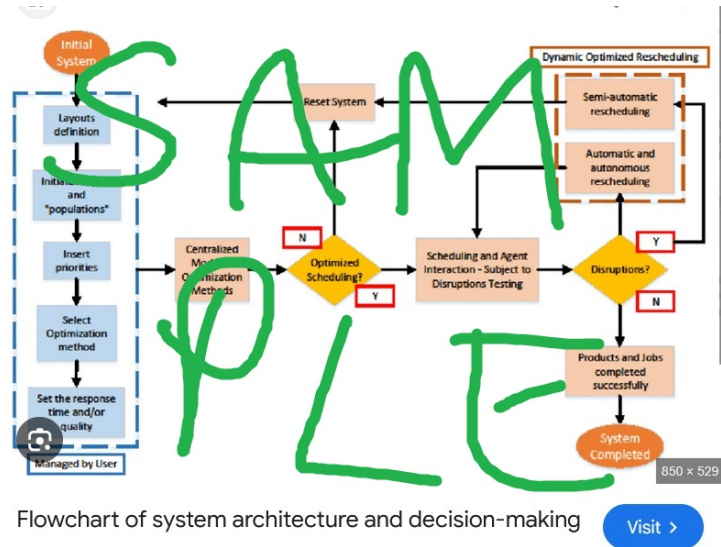
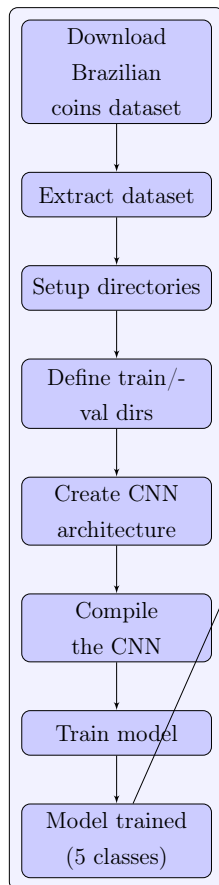
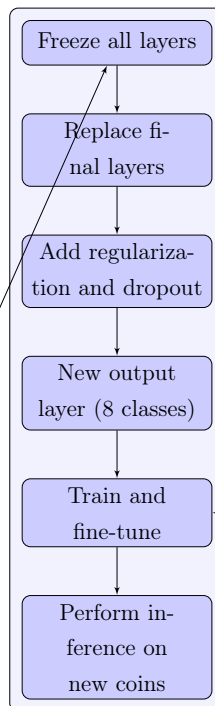


Figure 5.12: System Architecture Diagram

Brazilian Model Training



Transfer Learning



UK Data Preparation

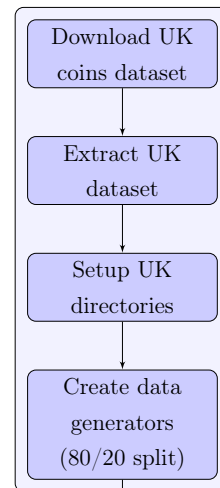


Figure 5.13: System Design Overview Flowchart

5.7.1 Functional Requirements

5.7.2 Design Approach

5.7.3 System Architecture

As shown in Figure 5.13 the system architecture consists of various components.

1 # Your code here

Listing 5.7: System Architecture Code Example

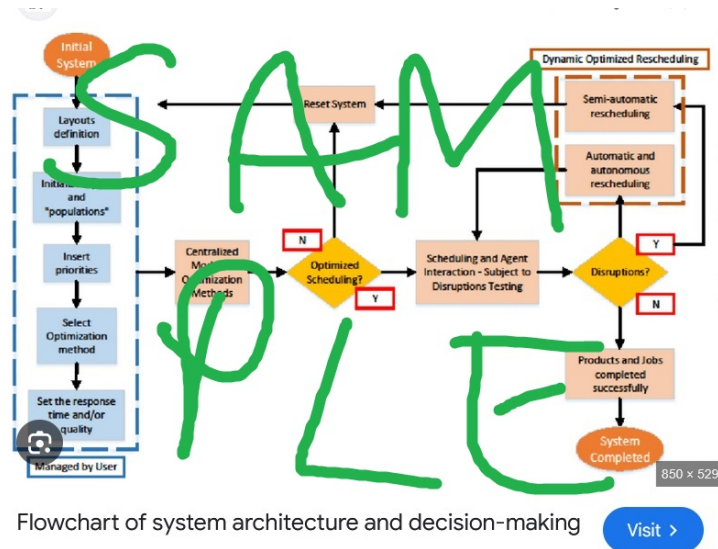


Figure 5.14: System Architecture Diagram

6. Results

6.1 Sensor Characterization

For the SensorCharacterization.tex file, you'd want to focus on the fundamental properties and performance of your photodiodes themselves, distinct from the other subsections. Here are some key elements that would belong specifically under SensorCharacterization:

- Basic Photodiode Electrical Characteristics:

- Dark current measurements
 - Junction capacitance
 - I-V characteristics in different lighting conditions
 - Spectral response profiles (sensitivity vs. wavelength)

- Individual Sensor Benchmarking:

- Performance comparison between the 4 photodiodes (matching/differences)
 - Responsivity measurements (A/W)
 - Quantum efficiency calculations
 - Detection threshold levels

- Response Linearity:

- Measurements showing linear range of the photodiodes
 - Saturation point characterization
 - Recovery time from saturation

- Temperature Dependency:

- Performance drift with temperature
 - Baseline shift measurements
 - Temperature compensation data

- Aging/Stability Tests:

- Long-term drift measurements
 - Repeatability of measurements over time

This section should focus on the inherent properties of the photodiodes themselves - essentially providing the baseline characterization data that underpins all the other analysis. The other sections then build on this foundation by examining how these sensors perform when integrated into the complete system with amplification, angular positioning, enclosure effects, etc.

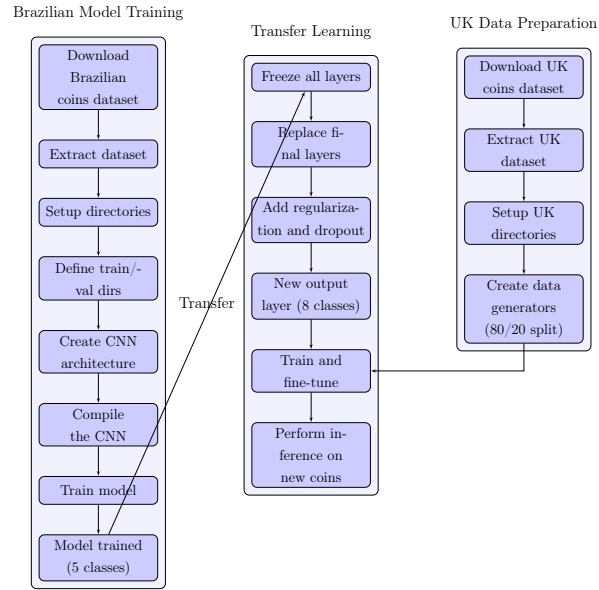


Figure 6.1: System Design Overview Flowchart

6.1.1 Functional Requirements

6.1.2 Design Approach

6.1.3 System Architecture

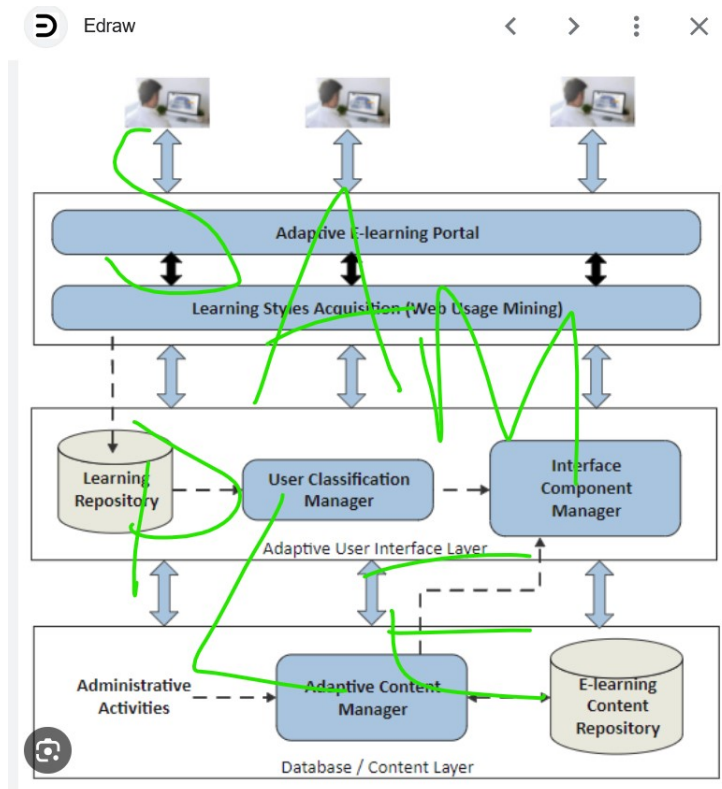
As shown in Figure 6.1 the system architecture consists of various components.

```
1 # Your code here
```

Listing 6.1: System Architecture Code Example

6.2 Amplification Performance

This section provides results of the amplifier performance.



System Architecture Diagram: A Complete Tutorial |

[Visit >](#)

Figure 6.2: System Architecture Diagram

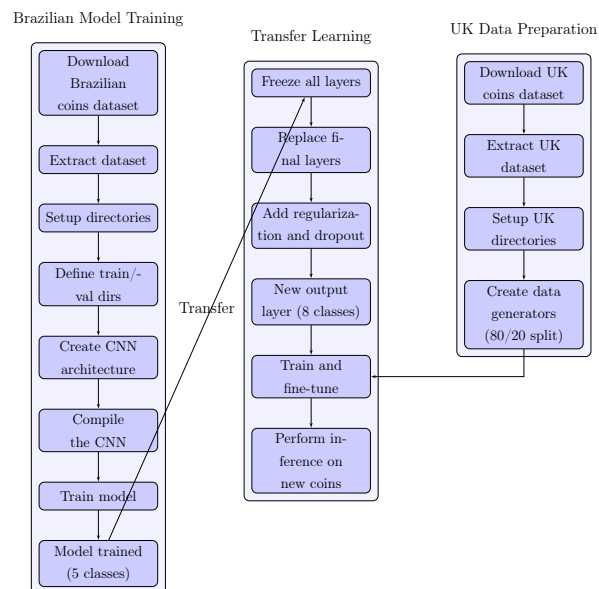


Figure 6.3: System Design Overview Flowchart

6.2.1 Functional Requirements

6.2.2 Design Approach

6.2.3 System Architecture

As shown in Figure 6.3 the system architecture consists of various components.

```
1 # Your code here
```

Listing 6.2: System Architecture Code Example

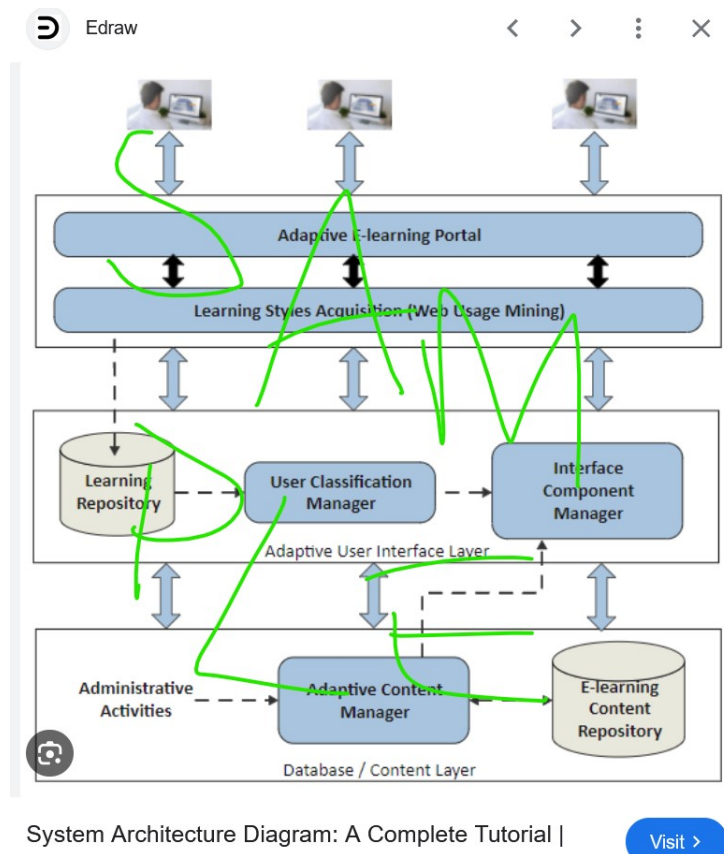


Figure 6.4: System Architecture Diagram

6.3 Photodiode Angular Response

This section discusses the results of the response of the solar sensor to angular changes of the light source.

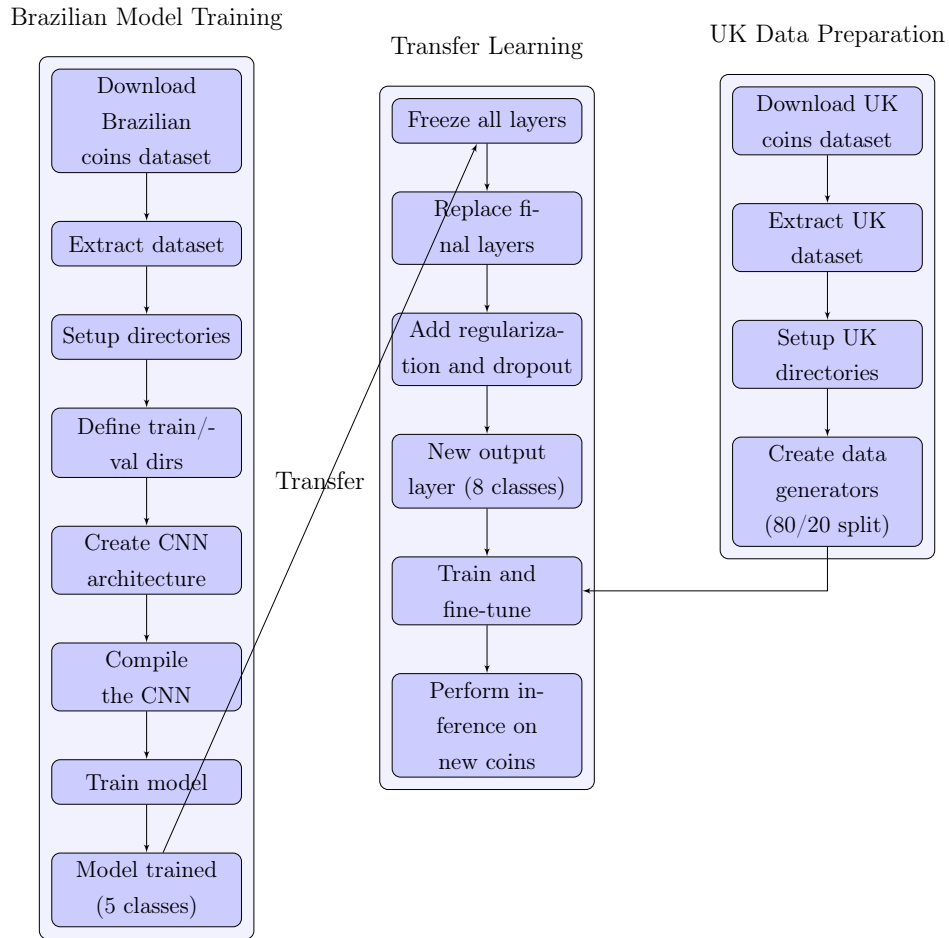


Figure 6.5: System Design Overview Flowchart

6.3.1 Functional Requirements

6.3.2 Design Approach

6.3.3 System Architecture

As shown in Figure 6.5 the system architecture consists of various components.

```
1 # Your code here
```

Listing 6.3: System Architecture Code Example

6.4 Enclosure Effectiveness

This section discusses the effectiveness of the Photodiode enclosure.

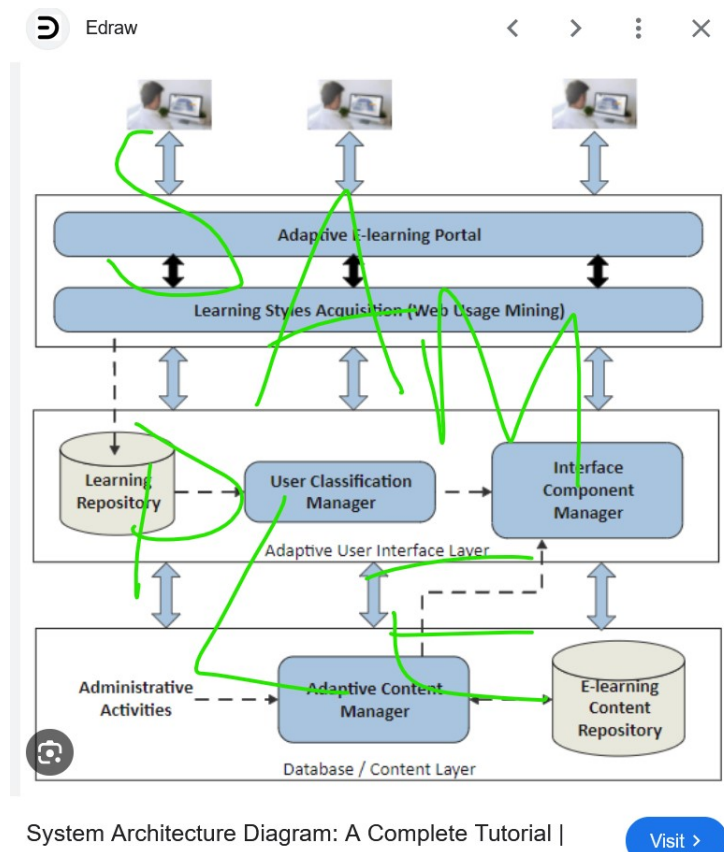
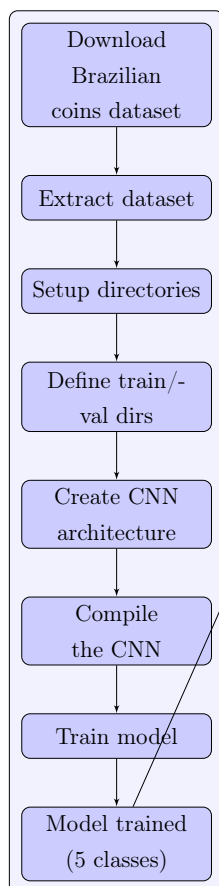
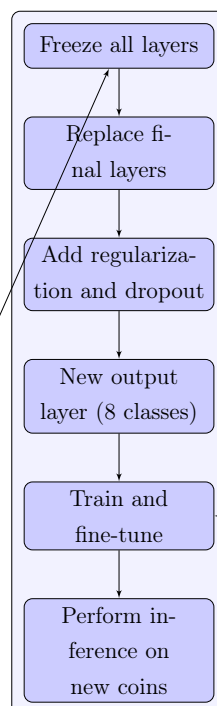


Figure 6.6: System Architecture Diagram

Brazilian Model Training



Transfer Learning



UK Data Preparation

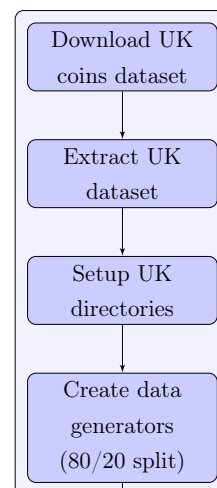


Figure 6.7: System Design Overview Flowchart

6.4.1 Functional Requirements

6.4.2 Design Approach

6.4.3 System Architecture

As shown in Figure 6.7 the system architecture consists of various components.

```
1 # Your code here
```

Listing 6.4: System Architecture Code Example

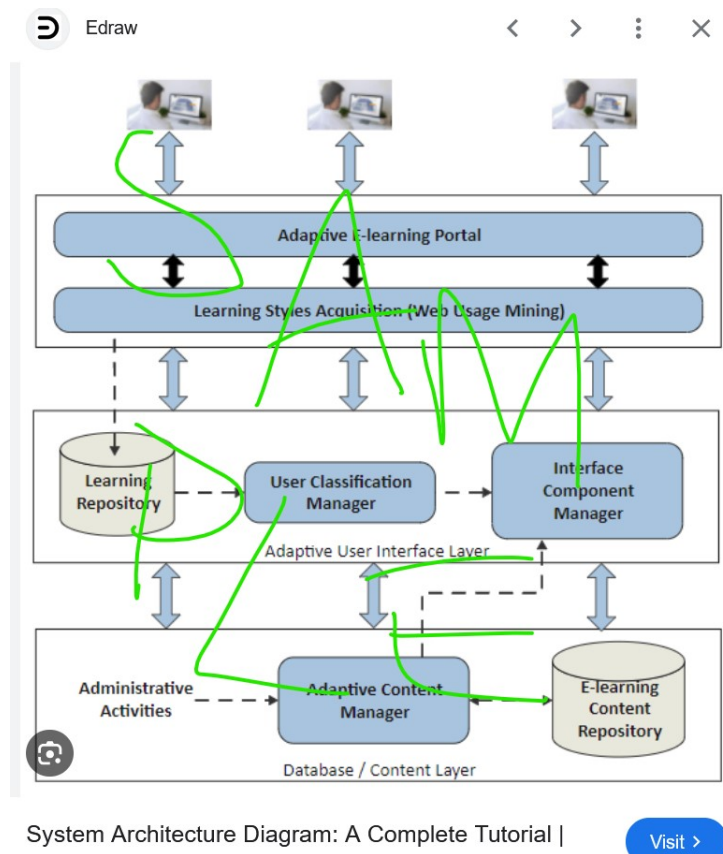


Figure 6.8: System Architecture Diagram

6.5 Data Acquisition System Evaluation

This section provides results related to the Arduino DAQ.

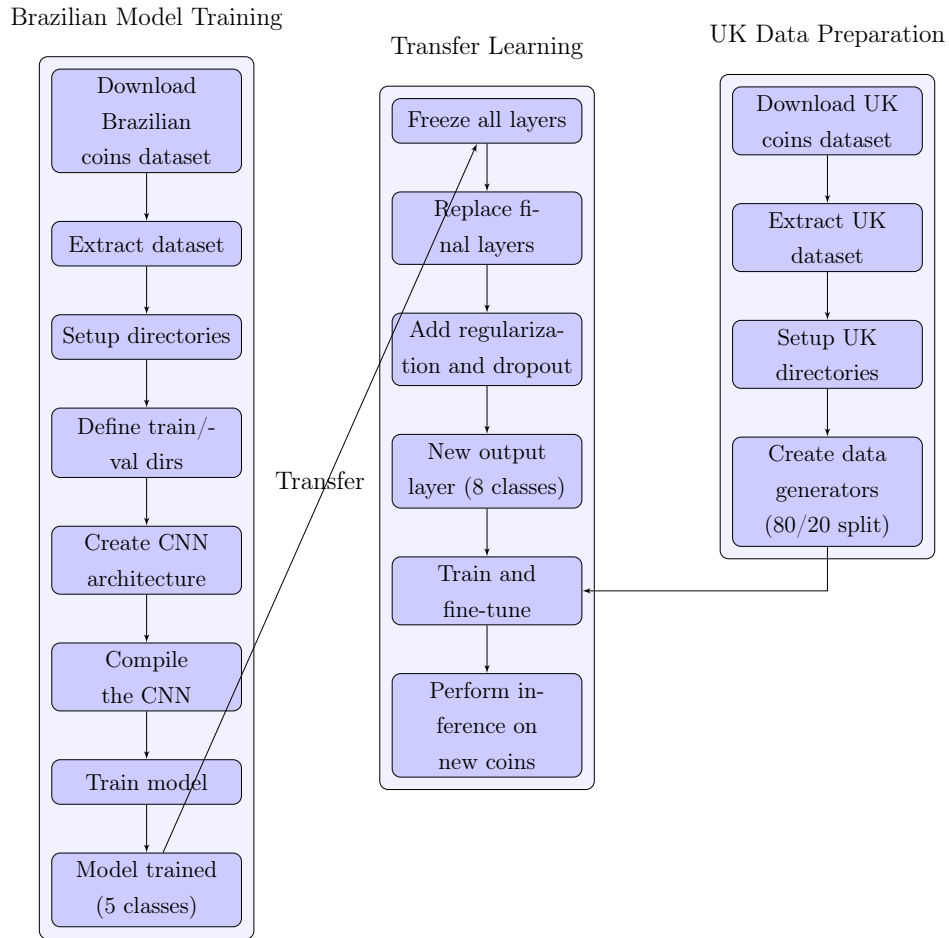


Figure 6.9: System Design Overview Flowchart

6.5.1 Functional Requirements

6.5.2 Design Approach

6.5.3 System Architecture

As shown in Figure 6.9 the system architecture consists of various components.

```
1 # Your code here
```

Listing 6.5: System Architecture Code Example

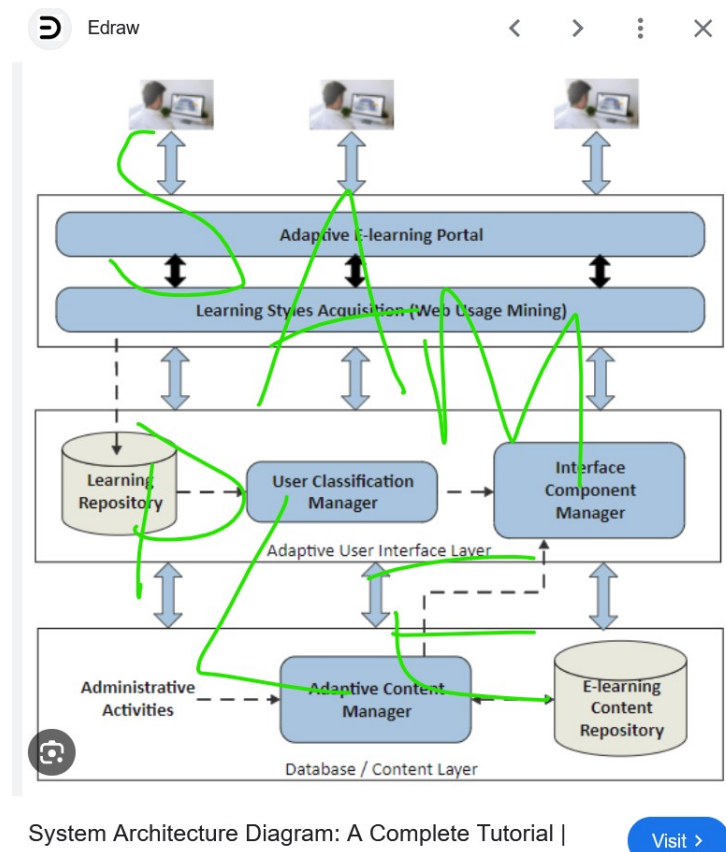


Figure 6.10: System Architecture Diagram

6.6 System Performance Analysis

6.6.1 Operational Constraints Identified

6.6.2 Environmental Factors Impact

```
1 // Environmental test results
2 // Temperature, ambient light, and vibration effects
```

Figure 6.11: Environmental Testing Results

6.6.3 System Stability and Repeatability

6.6.4 Recommendations for Improvement

6.7 Comparative Analysis

This section compares the simulation with the prototype results.

6.7.1 Breadboard vs. Stepboard Results

6.7.2 Iteration Improvements Analysis

6.7.3 Performance Against Design Requirements

The performance ...

6.7.4 Design Evolution Assessment

The what now?

6.8 System Limitations And Considerations

This section discusses the limitations and future work.

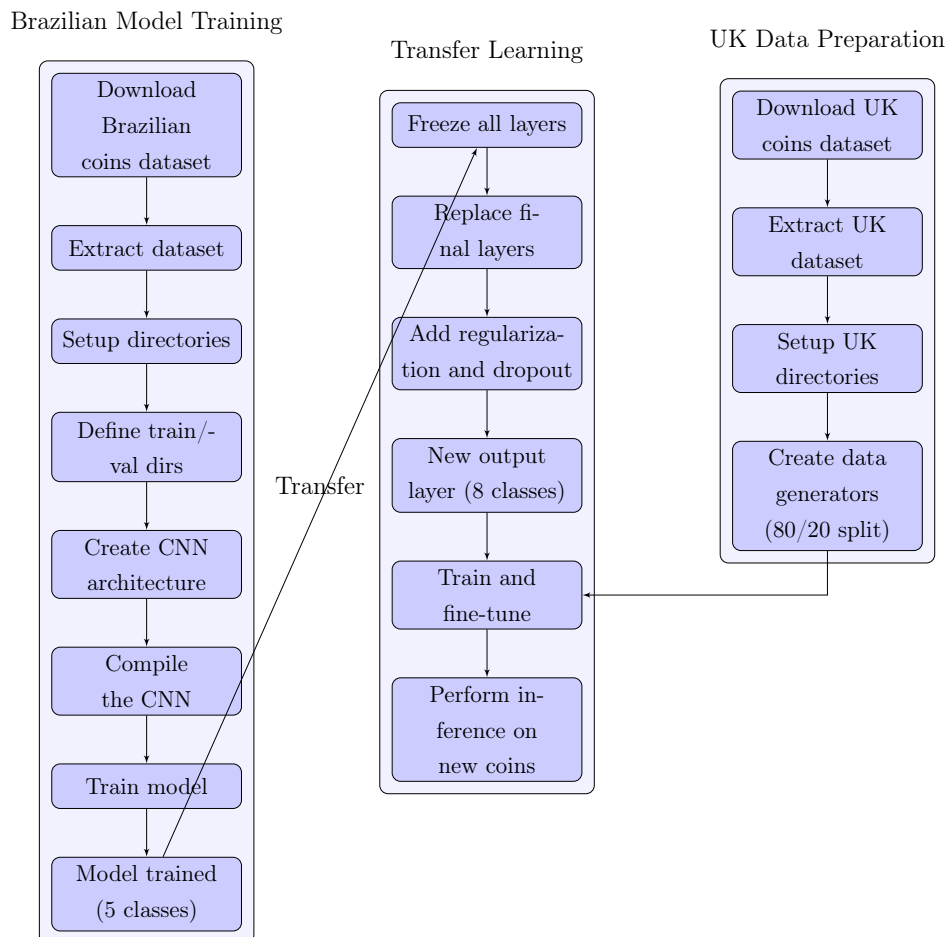


Figure 6.14: System Design Overview Flowchart

6.8.1 Functional Requirements

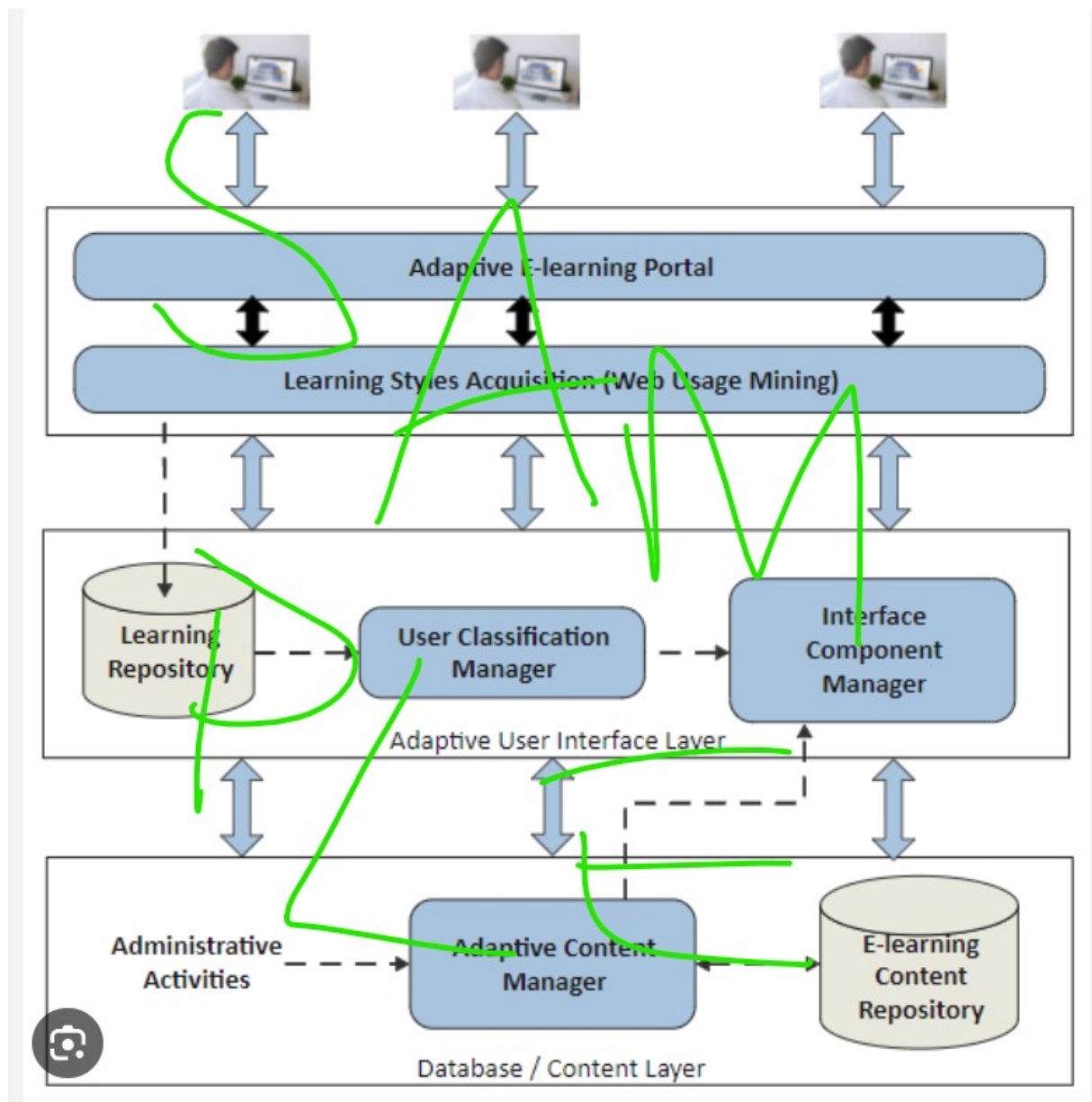
6.8.2 Design Approach

6.8.3 System Architecture

As shown in Figure 6.14 the system architecture consists of various components.

```
1 # Your code here
```

Listing 6.6: System Architecture Code Example



System Architecture Diagram: A Complete Tutorial |

[Visit >](#)

Figure 6.12: Overall System Performance Analysis

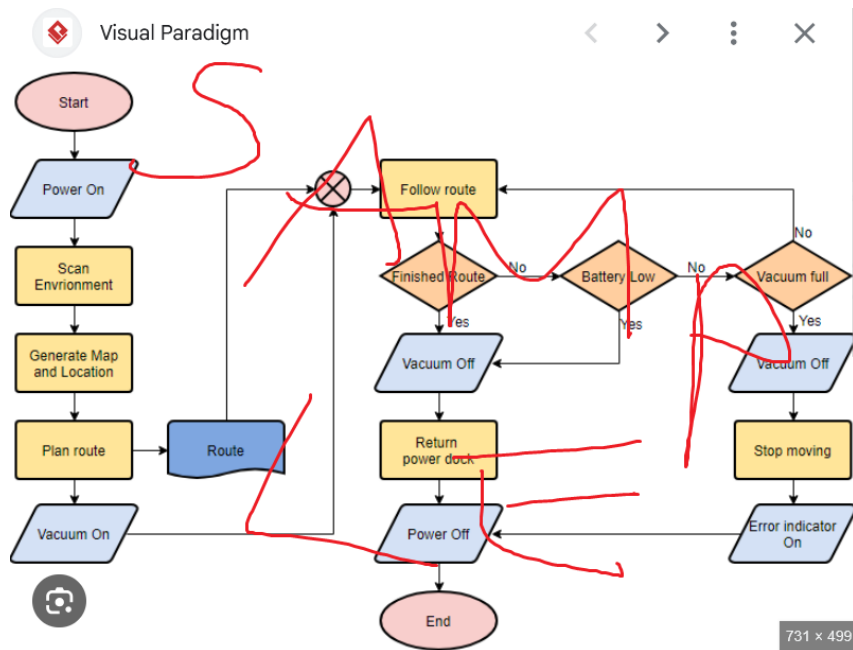
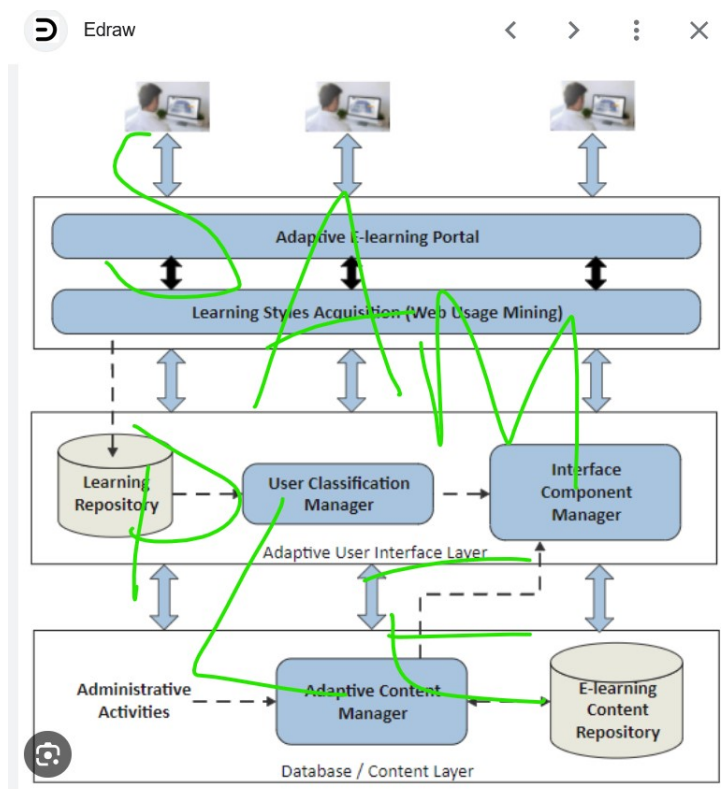


Figure 6.13: Prototype Iteration Comparison



System Architecture Diagram: A Complete Tutorial |

[Visit >](#)

Figure 6.15: System Architecture Diagram

7. Conclusions

8. FutureWork

Bibliography

- [1] A. Rosebrock. (2019, 12) Label smoothing with Keras, TensorFlow, and deep learning. [Online]. Available: <https://pyimagesearch.com/2019/12/30/label-smoothing-with-keras-tensorflow-and-deep-learning/>