Animal Monitoring System (AMS) via AI-based top-Mounted Camera to Study Pharmacological Research (Anti-Diabetic and Anti- Anxiety) in Animal Model.

SUPERIOR UNIVERSITY

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DECLARATION

This thesis is a presentation of my original research work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions. I also declare that this work is the result of my own investigations, except where identified by references and free from plagiarism of the work of others.

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RESEARCH COMPLETION CERTIFICATE

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Thank you,

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DEDICATION

We dedicate this work to my beloved family, teachers, and friends. To the last prophet, Holy Prophet Muhammad (Peace be upon him) — my great hero and messenger of Allah Almighty. He remains one of the most influential people that humanity has ever witnessed.

LIST OF ACRONYMS

ADC	Analog-to-Digital Converter
AI	Artificial Intelligence
AMS	Animal Monitoring System
API	Application Programming Interface
BLE	Bluetooth Low Energy
DAQ	Data Acquisition
DB	Data Base
ESP	Espressif Systems
GPIO	General Purpose Input/Output
IDE	Integrated Development Environment
IoT	Internet of Things
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MCU	Microcontroller Unit
ML	Machine Learning
PWM	Pulse Width Modulation
RF	Radio Frequency
RTD	Real-Time Data
SD	Standard Deviation
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver-Transmitter
VCC	Common Collector Voltage
WMA	World Medical Association
WiFi	Wireless Fidelity

Table of Content

LIST OF ACRONYMS ---vii

LIST OF FIGURES---xv

LIST OF TABLES---xvii

ABSTRACT--xviii

CHAPTER 1 ---1

INTRODUCTION---1

1.1 Background---1

1.2 Problem Statement--2

1.3 Objectives--3

1.4 Proposed Methodology---3

1.5 Selection of Method--5

1.5.1 Design Iteration--5

1.5.2 Real-time Tracking Components---6

1.5.3 Remote Camera Control--5

1.5.4 Adaptability for Diverse Applications--5

1.6 Main Contributions--5

1.6.1 Hardware--6

1.7 Work Division---6

1.8 Summary---6

CHAPTER 2--7

LITERATURE REVIEW--7

2.1 Literature Study---7

2.1.1 Foundational Literature on Animal Behavior---------------------------------------7

2.1.2 Models for Studying Diabetes and Anxiety in Animals ------------------------7
2.1.3 Anxiety Disorders in Animals--7
2.1.4 Integration of Advanced Behavioral Tracking-------------------------------------7
2.1.5 Dietary Influences on Rodent Behavior--8
2.1.6 Pancreatic Islet Function---8
2.1.7 AI-Based Rodent Behavior Classification---8
2.1.8 Social Stress Contagion--8
2.1.9 Foundational Studies in Rodent Research --8
2.1.10 Diabetes Research--9
2.1.11 Global Diabetes Prevalence---9
2.1.12 Diabetes Prevalence---9
2.1.13 Conference Significance--9

2.1.14 IoT-Based Health Monitoring--9
2.1.15 Relevant Insights from Health Monitoring Technologies ----------------------------10
2.2 Comparison Table--10
2.3 Summary--11
CHAPTER 3 --12
SIMULATION---12
3.1 Introduction--12
3.2 Simulation Overview--12
3.2.1 Emotional Behavior Analysis---12
3.2.1.1. Temperature Sensors--12
3.2.1.2. Heartbeat Sensors--12
3.2.2 Physical Behavior Monitoring---13
3.2.2.1. ESP-32 Cameras--13
3.2.2.2. Real-time Observation--14
3.2.2.3. Data Recording and Analysis------------------------------------14
3.2.2.4. Assessing Physical Health---------------------------------------14
3.2.2.5. Integration with Emotional Behavior Data -------------------14
3.3 Simulation Setup in Proteus Professional 8--15
3.3.1 Sensors---15
3.3.1.1. Heartbeat Sensor---15
3.3.1.2. LM35 Sensor---15
3.3.2 Microcontroller--16
3.3.3 LCD Display---17
3.4 Simulation Process---17
3.4.1 Circuit Design---18
3.4.2 Programming the Microcontroller--18
3.4.3 Sensor Input Simulation ---18
3.5 Observing Outputs--19
3.6 Results and Analysis--19
3.7 Summary--20
CHAPTER 4 --21
MATHEMATICAL MODEL--21

4.1 LM35 Temperature Sensor: --21
4.1.1 Mathematical Model of LM35 Temperature Sensor ---------------------------21
4.1.2 Parameters of the LM35 Temperature Sensor ---------------------------------21
4.1.3 Thermistor Temperature Sensors---22
4.1.4 Thermocouples---23
4.1.5 Resistance Temperature Detectors (RTDs)--23
4.1.6 Linearization of Non-Linear Sensors--23
4.1.7 Signal Conditioning--23
4.1.8 Experimental Setup---24
4.1.9 Error Analysis and Calibration--24
4.1.10 Sensor Placement and Measurement Protocol ---------------------------------24
4.1.11 Data Collection--24
4.1.12 Temperature Conversion and Error Analysis -----------------------------------25
4.2 Heartbeat Sensor---25
4.2.1 Optical Pulse Rate Sensors (PPG - Photoplethysmography)-------------------25
4.2.2 Electrical Pulse Rate Sensors (ECG - Electrocardiography)--------------------26
4.2.3 Acoustic Pulse Rate Sensors--26
4.2.4 Optical Pulse Rate Sensor (PPG) Detailed Explanation -----------------------26
4.2.5 Mathematical Model---26
4.2.6 Real-Time Example--26
4.3 ESP32-CAM for Livestream Video--27
5.3.1 Overview of ESP32-CAM---27
4.3.2 Components and Parameters--27
4.3.3 Mathematical Model---27
4.3.4 Data Rate Calculation--27
4.3.5 Practical Example---28
4.3.6 Latency Considerations--28
4.3.7 Error Analysis and Optimization--29
4.4 Summary --29
CHAPTER 5--30
HARDWARE IMPLEMENTATION--30

5.1 Introduction--30
5.1.1 Objectives of the Methodology---30
5.1.1.1 Designing an Effective Monitoring System -----------------------------------30
5.1.1.2 Ensuring Data Integrity and Accessibility-------------------------------------30
5.1.1.3 Ethical Considerations and Stress Reduction ---------------------------------31
5.2 System Design---31
5.2.1 Design Requirements---31
5.2.1.1 Real-Time Monitoring Capability--31
5.2.1.2 Remote Accessibility---31
5.2.1.3 Compatibility with IoT Devices---31
5.2.1.4 Scalability and Flexibility --32
5.2.1.5 Data Security and Privacy---32
5.2.1.6 User-Friendly Interface --32
5.2.1.7 Low-Interference Monitoring---32
5.2.1.8 Power Efficiency---32
5.2.1.9 Integration with Cloud Services---32
5.2.1.10 Reliability and Durability---32
5.3 Hardware Components---33
5.3.1. ESP32-CAM---33
5.3.2. Microcontroller Units (ESP-32)---33
5.3.3. Temperature Sensors (LM35)---34
5.3.4. Heart Rate Sensors (Pulse Sensor)--35
5.4 Vital Signs & its Specifications--35
5.4.1. Body Temperature---35
5.4.2. Heart Rate (Pulse Rate)--36
5.4.3. Respiratory Rate--36
5.4.4. Blood Pressure--36
5.4.5. Blood Oxygen Saturation (SpO2)--37
5.4.6. Blood Glucose Level---37
5.5 Software Components---38
5.5.1 Mobile Application---38
5.5.2 IoT Devices (Microcontroller)---38
5.5.3 Firebase Platform---38

5.5.3.1. Overview of Firebase--38
5.5.3.2. Components Used---38
5.5.4. Flutter Platform---39
5.5.4.1. Flutter Framework---39
5.6 Development Process---40
5.6.1 Hardware Setup---40
5.6.2 Software Development--40
5.6.3 Integration of Hardware and Software--41
5.6.4 Camera Utilization--41
5.6.5 Utilization of Vital Data--41
5.6.6 Smart System Monitoring---41
5.6.7 Cloud Services Integration---42
5.7 Algorithm Flowchart ---42
5.8 Components ---44
5.9 Communication Protocols--44
5.9.1. IoT-Based Communication for Vital Data Monitoring -----------------------44
5.10 Communication Protocol:--45
5.10.1 Data Transmission:--45
5.10.2 Monitoring and Analysis--45
5.10.3 Alerting Mechanism--45
5.11 Local IP Address Server for Video Streaming--46
5.11.1 Communication Protocol--46
5.11.2 Data Transmission---46
5.11.3 Monitoring and Analysis--46
5.11.4 Alerting Mechanism--46
5.11.5 Alert Notification System---47
5.11.6 Notification Configuration---47

5.12 Summary------47

CHAPTER 6------48

CONCLUSION AND FUTUREWORK------48

6.1 Conclusion------48

6.2 Future Work------48

6.2.1 Integration of Additional Sensor------49

6.2.2 Enhanced Data Analytics------49

6.2.3 Longitudinal Studies and Follow-up------49

6.2.4 Validation and Calibration Studies------49

6.2.5 Wireless Power Transfer------49

6.2.6 Telemedicine and Remote Monitoring------49

6.2.7 User Interface and Accessibility------49

6.2.8 Ethical Considerations and Animal Welfare------50

6.3 Summary ------50

CHAPTER 7------51

BUSNESSPLAN------51

7.1 Executive Summary------51

7.1.1 Value Proposition------51

7.1.2 Market Opportunity------51

7.1.3 Competitive Advantage------51

7.1.4 Financial Projections------51

7.2 Company Overview------52

7.2.1 Mission Statement------52

7.2.2 Vision Statement------52

7.3 Product Description------52

7.3.1 Seamless Sensor Integration------52

7.3.2 Cloud-Based Data Management------52

7.3.3 Customizable Alerting Mechanisms------52

7.3.4 Remote Monitoring and Analysis------53

7.3.5 Ethical and Animal Welfare Considerations------53

7.4 SWOT Analysis------53

7.5 PESTLE Analysis------54

7.6 The Rational Behind Initiating a Business--56

7.6.1 Addressing a Critical Need--56

7.6.2 Market Demand: --57

7.6.3 Technology Advancements--57

7.6.4 Improving Research Outcomes--57

7.6.5 Ethical Considerations--57

7.6.6 Business Opportunity--57

7.7 Advantage of the Project--57

7.7.1 Market Opportunity--57

7.7.2 Impact on Research--58

7.7.3 Ethical Considerations--58

7.7.4 Innovation and Technology--58

7.8 Financial Plan--58

7.8.1 Cost Structure--58

7.8.2 Revenue Streams--59

7.8.3 Pricing--59

7.8.4 Projected Sales--59

7.9 Summary --59

References--60

LIST OF FIGURES

Figure 1.1. Proposed Assumption of Research--2

Figure 1.2. Problem Facing Manual Research System (Conventional System)----------------------2

Figure 1.3. Project Overview/ Goals (AMS)---3

Figure 1.4. Functional Flowchart of Vital Data---4

Figure 1.5. Functional Block Diagram of Camera/Live Stream---5

Figure 3.1. Emotional Behavior Analysis with Vital Signs--13

Figure 3.2. Physical Behavior Monitoring---13

Figure 3.3. ESP-32 CAM ---14

Figure 3.4. Heartbeat Sensor or HeartRate Sensor---15

Figure 3.5. A Realistic Depiction of the Heartbeat Sensor Simulation-------------------------------15

Figure 3.6. LM 35 Body Temperature Sensor ---16

Figure 3.7. A Realistic Depiction of the LM35 Simulation --16

Figure 3.8. A Photo of a Real Arduino Uno Board.--16

Figure 3.9. A Simulation Image of an Arduino Uno Board in Proteus.-------------------------------17

Figure 3.10. A Picture of an LCD Display.---17

Figure 3.11. A Realistic depiction of the LCD simulation--17

Figure 3.12. Circuit Diagram of Simulation of Project---18

Figure 3.13. Heart Beat Sensor Simulation using Proteus --19

Figure 3.14. When all Circuitry Connect together--19

Figure 3.15. When Run the Simulation on Proteus---20

Figure 5.1. Animal Monitoring System Overview--30

Figure 5.2. Real-Time Monitoring Scheme--31

Figure 5.3. Remote Accessibility Proposed Imagination--31

Figure 5.4. IoT Scheme--32

Figure 5.5. Pictorial Diagram of ESP-32 CAM--33

Figure 5.6. Working Flowchart of ESP-32 CAM.--33

Figure 5.7. Working Flowchart of ESP-32 with Sensors with Diagram -----------------------------34

Figure 5.8. LM35 Sensor Image with Specs--34

Figure 5.9. Heart Rate Sensor with Pulses Image---35

Figure 5.10. Normal Rectal Temperature---36

Figure 5.11. Firebase Logo --38

Figure 5.12. Flutter Smart Device application logo---39

Figure 5.13. Actual Hardware Image ---40

Figure 5.14. Flutter Mobile Application for Monitoring Vitals data from Sensor -----------------41

Figure 5.15. Firebase Real-Time Database Monitoring of Vital Signs -----------------------------42

Figure 5.16. Flowchart of Vital Data ---43

Figure 5.17. MQTT Broker Protocol for wireless communication with WiFi ---------------------45

Figure 5.18. HTTP Working Flow Diagram with Server --46

Figure 7.1. SWOT Analysis Image ---53

Figure 7.2. PESTLE Analysis Image ---55

LIST OF TABLE

Table 1.1 Working Division of Project -- 6
Table 2.1 Comparison Table of Literature Review ---10
Table 5.1 Vital sign of Animal from Min to Max with units ---37
Table 5.2 Component list that used in Hardware --44
Table 7.1 Costing structure of Financial Plan ---58
Table 7.2 Pricing of product Financial Plan--59
Table 7.3 Projected sales of Financial Plan--59

ABSTRACT

This proposal outlines the development of an advanced, AI-powered Animal Monitoring System (AMS) specifically designed for studying the anti-diabetic and anti-anxiety effects of Dopamine Agonists in animal models, with a primary focus on diabetic rats. The AMS goes beyond traditional observation methods by employing top-mounted cameras, Micro-controller units (Arduino NANO or ESP-32), and miniature ESP-32 cameras to enable real-time tracking of animal behavior, body temperature, and heart rate. This comprehensive data stream provides researchers with unprecedented insights into physiological responses during drug testing, allowing for more accurate analysis and evaluation of treatment efficacy.

A key feature of the AMS is its seamless remote camera control through mobile applications or IoT devices. This empowers researchers to efficiently collect data and capture crucial moments during experiments from a distance, minimizing stress on the animals and ensuring uninterrupted data collection. Additionally, the integrated temperature and heart rate monitoring allows for real-time adjustments to the camera's focus, guaranteeing that no understated physiological changes are missed.The AMS offers significant potential beyond its primary research purpose. Its capabilities can be adapted for diverse applications such as drug development and toxicity assessment across various animal models. Furthermore, the system's focus on minimizing animal stress aligns with the growing emphasis on animal welfare in scientific research.This project marks a promising collaboration between the Department of Pharmacology and the Faculty of Engineering and Technology at Superior University Lahore. By uniting expertise in pharmaceutical research with cutting-edge technology, this initiative aims to bridge the gap between traditional research methods and innovative technology. Leveraging the advanced capabilities of the Animal Monitoring System (AMS), the collaborative effort anticipates yielding substantial results in terms of enhanced data collection, thorough analysis, and meticulous evaluation of drug development practices. The project's output parameters, driven by the AMS, are expected to contribute to safer and more effective drug development through a comprehensive understanding of physiological responses, analysis, and a steadfast commitment to animal welfare considerations.

Index term: AI-powered Animal Monitoring System (AMS), Anti-diabetic effects, Anti-anxiety effects, Diabetic rats, Real-time tracking, Animal behavior, Body temperature monitoring, Heart rate monitoring, Remote camera control, IoT devices, Physiological responses, Drug testing, Data collection, Animal welfare, Drug development, Pharmaceutical research,Innovative technology, Ethical research practices, Non-intrusive monitoring.

CHAPTER 1

INTRODUCTION

This chapter unveils the foundation of the Animal Monitoring System (AMS) utilizing AI-based top-mounted cameras, specifically designed for real-time monitoring of anti-diabetic and anti-anxiety effects induced by dopamine agonists in animal models. We delve into the scientific research backdrop, emphasizing the role of sensors such as temperature and heart rate monitors. We outline the objectives of this thesis, highlighting our key contributions. The chapter succinctly outlines the study's structure and the environment employed, underscoring the integration of cameras and sensors for comprehensive real-time data acquisition and analysis.

1.1 Background

In this thesis, the focus revolves around the development and implementation of an Animal Monitoring System (AMS) utilizing an AI-based top-mounted camera. The primary objective is to investigate the Anti-Diabetic and Anti-Anxiety effects of Dopamine Agonists in an Animal Model. The initial chapter provides a comprehensive background study on animal monitoring systems, highlighting the crucial role such technologies play in advancing scientific research and understanding animal behavior.

Domestication and welfare of animals have long been integral aspects of human society, prompting the need for effective monitoring systems to ensure their health. As the area of monitored expands, the challenges associated with manual observation become apparent. Larger spaces, such as research facilities, or natural habitats, advanced technological solutions for continuous and unobtrusive monitoring of animal subjects.

The prevalence of dust, allergens, and pollutants in animal environments can have significant implications for their health, similar to the concerns in human environments [1]. The need for effective cleaning and monitoring systems is heightened by the impact of environmental factors on animals, ranging from potential allergic reactions to the transmission of diseases. Moreover, considering the current global situation, where health protocols and social distancing measures are crucial, the deployment of autonomous monitoring systems becomes even more pertinent [2].

The IoT use as a key player in revolutionizing monitoring systems, providing a network of interconnected devices embedded with sensors, software, and network connectivity. This interconnections facilitates real-time data sharing, remote monitoring, and precise control over the monitoring environment [6]. In the context of Animal Monitoring Systems, the integration of IoT technologies opens new avenues for researchers to gather data, assess animal behavior, and conduct experiments with minimal human intervention.

Figure 1.1. *Proposed Assumption of Research*

1.2 Problem Statement

The Animal Monitoring System (AMS) aims to address limitations in conventional animal observation methods, particularly in studying the effects of Dopamine Agonists in diabetic rats. Challenges such as human errors, systematic issues, and the need for continuous monitoring in larger spaces propel the development of the AMS. By leveraging AI-based top-mounted cameras and integrated monitoring components, the system provides real-time data on animal behavior, body temperature, and heart rate. This initiative seeks to enhance research precision, efficiency, and animal welfare considerations in pharmaceutical studies, promising broader applications in drug development.

Figure 1.2. *Problem Facing Manual Research System (Conventional System)*

1.3 Objectives

This thesis has the following objectives:

1. Develop and implement an AI-powered Animal Monitoring System (AMS) using top-mounted cameras and IoT devices.
2. Investigate the anti-diabetic effects of Dopamine Agonists in diabetic rats through real-time monitoring of physiological parameters.
3. Enable seamless remote camera control for stress-free data collection and analysis during experiments.
4. Assess the adaptability of the AMS for diverse applications, including drug development and toxicity assessment across various animal models.

The project aims to create an AI-based Animal Monitoring System (AMS) for studying anti-diabetic effects in diabetic rats, emphasizing seamless remote camera control. Objectives include stress-free data collection, adaptability for broader applications, and fostering interdisciplinary collaboration at Superior University Lahore.

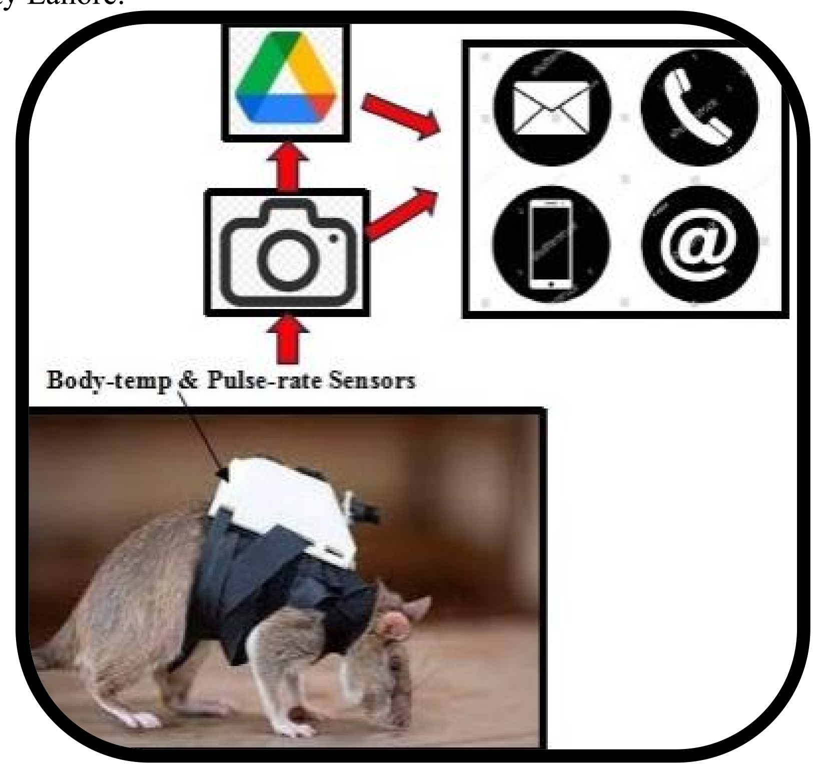


Figure 1.3. Project Overview/ Goals (AMS)

1.4 Proposed Methodology

In figure illustrates a straightforward system that utilizes temperature and heartbeat(Max 30100) sensors to gather essential data. This collected data is then sent to a microcontroller(ESP-32 or Node MCU), which employs smart algorithms to convert it into easily understandable units like Celsius for temperature and beats per minute for heart rate. The processed data faces a crucial decision point: it either gets displayed directly on an LCD screen for immediate visualization and further gets formatted for transmission to a designated IoT app. Importantly, the system doesn't stop there. It takes a step further by transmitting this valuable data to cloud services for future analysis or to improve the system. This integration of sensor readings into cloud-based platforms enhances accessibility and the long-term utility of the information that used to improve the quality of formula medicine.

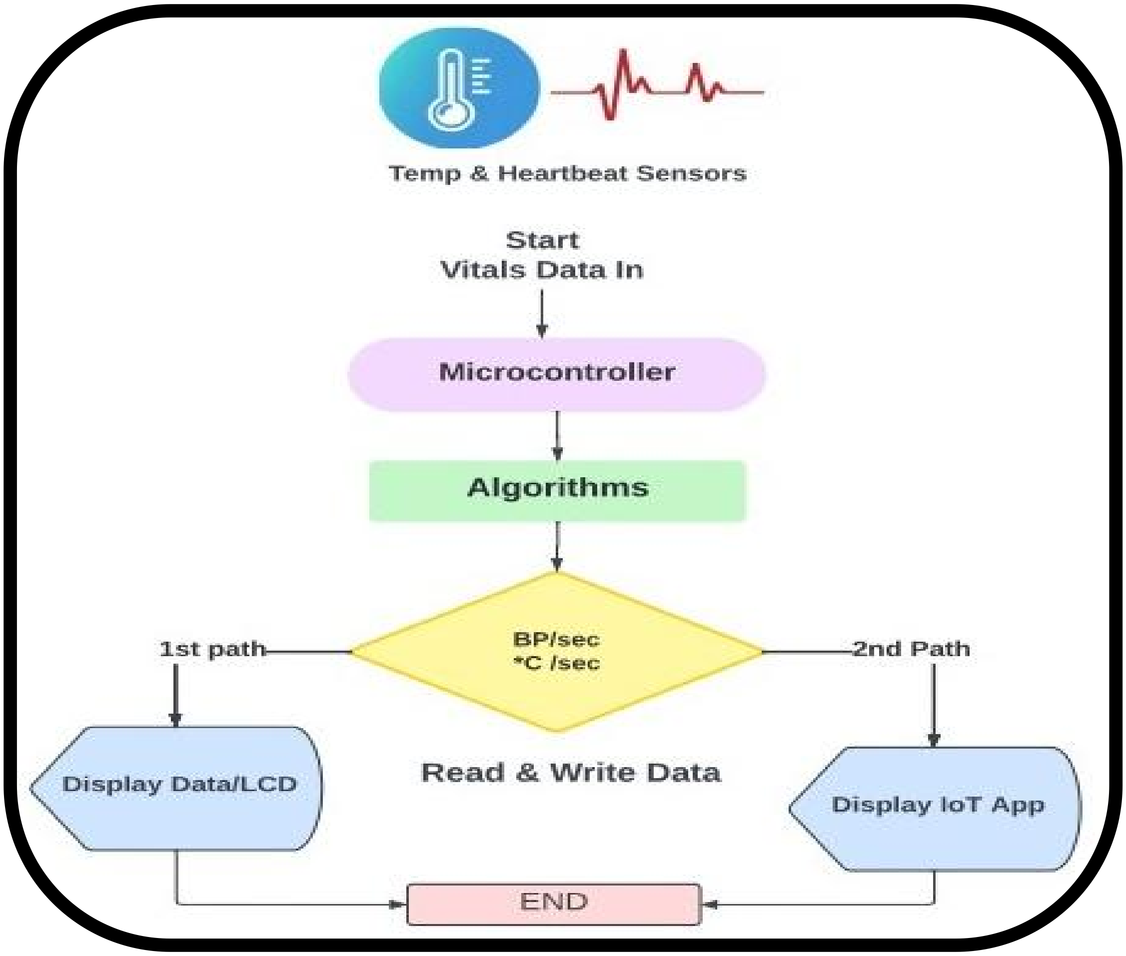


Figure 1.4. *Functional Flowchart of Vital Data*

In this system, images are captured through a camera and transmitted to the cloud for analysis. The OpenCV algorithm employed ensures that the system reacts to motion intelligently. When motion is detected, the system initiates video recording and issues a notification. After a predetermined time, the recording ceases, and the data is prepared for cloud transfer or sent as an email notification. If no motion is detected, the system continues capturing images at regular intervals. This intelligent approach to image capture and analysis provides a versatile tool for researchers, allowing them to efficiently monitor and analyze activities. Additionally, the recorded data, along with user details, is seamlessly transferred to the cloud service for comprehensive storage and analysis.

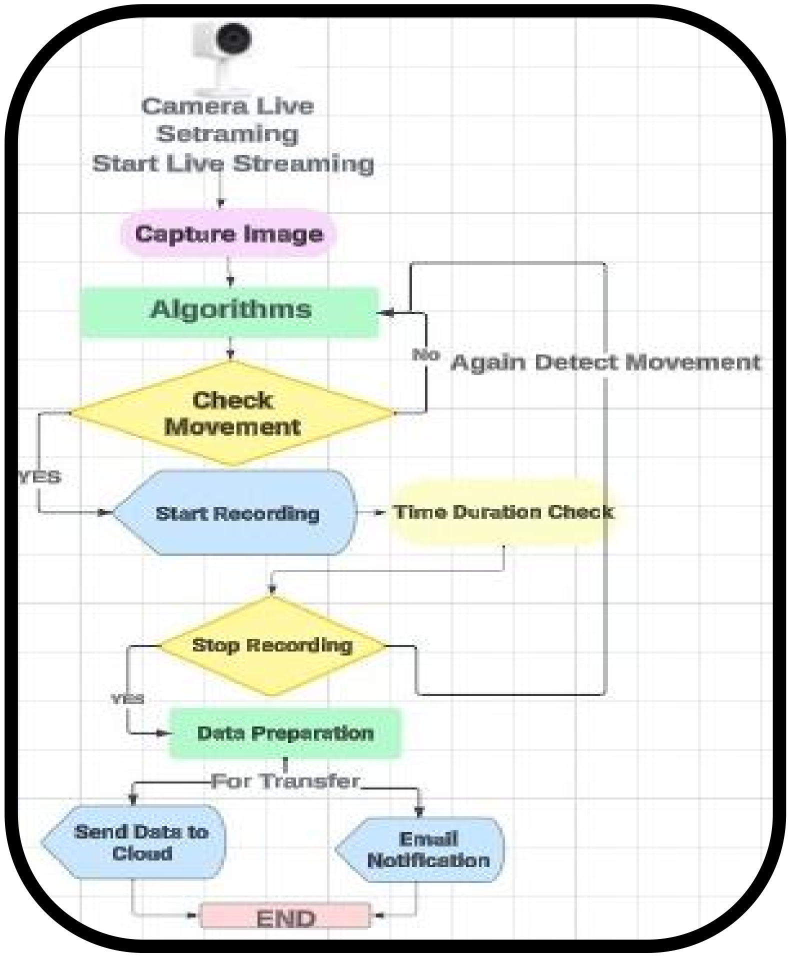


Figure 1.5. *Functional Block Diagram of Camera/Live Stream*

1.5 Selection of Method

The development of the advanced, AI-powered Animal Monitoring System (AMS) involves a multi-phased approach. The initial step entails an in-depth investigation into the requirements for a cutting-edge monitoring system tailored for studying the Pharmaceutical Research (specially anti-diabetic and anti-anxiety effects of Dopamine Agonists) in animal models, with a specific focus on diabetic rats.

1.5.1 Design Iteration

The design iteration of the advanced AI-powered Animal Monitoring System (AMS) involves a cyclical process of developing, testing, analyzing, and refining the system to meet the high standards required for pharmaceutical research. Initially, a prototype is created using ESP-32 microcontroller coupled with ESP-32 cameras to capture animal behavior, body temperature, and heart rate. This prototype undergoes preliminary testing in controlled environments to gather data and assess performance. Based on the collected data and feedback from researchers, necessary adjustments and enhancements are made to the hardware and software components, including improvements in remote control capabilities and real-time data transmission. The refined prototype is then subjected to extensive testing in real-world scenarios to ensure robustness, reliability, and minimal stress on the animals.

1.5.2 Real-time Tracking Components

The AMS incorporates state-of-the-art components such as top-mounted cameras, Micro-controller units (Arduino NANO or ESP-32), and miniature ESP-32 cameras. These components collectively enable real-time tracking of animal behavior, body temperature, and heart rate. The utilization of advanced technologies ensures accurate and comprehensive data collection during drug testing experiments.

1.5.3 Remote Camera Control

A key feature of the AMS is its seamless remote camera control through mobile applications or IoT devices. This capability empowers researchers to efficiently collect data and capture crucial moments during experiments from a distance. This not only minimizes stress on the animals but also ensures uninterrupted data collection, contributing to the overall success of the research.

1.5.4 Adaptability for Diverse Applications

Beyond its primary research purpose, the AMS offers versatility for diverse applications, including drug development and toxicity assessment across various animal models. The system's adaptability reflects its potential to contribute to broader scientific advancements and innovative technology applications.

1.6 Main Contributions

This project's primary contribution lies in developing an innovative AI-powered Animal Monitoring System (AMS) designed for studying anti-diabetic and anti-anxiety effects of Dopamine Agonists in animal models. The integration of top-mounted cameras, IoT technology, and physiological monitors allows for real-time, stress-free data collection, enhancing the precision and efficiency of drug testing. Beyond scientific research, the AMS demonstrates potential applications in drug development and toxicity assessment across various animal models, aligning with contemporary emphasis on animal welfare in research practices. The collaboration between the Department of Pharmacology and the Faculty of Engineering at Superior University Lahore symbolizes a synergistic approach, bridging pharmaceutical expertise with cutting-edge technology for safer and more effective drug development practices.

1.6.1 Hardware

Hardware of the project will be done using multiple tools and electronic components for its implementation. Components that will be used are ESP-32 CAM and different multiple sensors, Wareable band, Micro-controllers and battery.

1.7 Summary

This Chapter has introduced the Animal Monitoring System (AMS), emphasizing its importance in researching anti-diabetic and anti-anxiety effects, particularly in diabetic rat models. The innovative features of real-time tracking/monitoring, remote control, vitals data monitoring, and data adaptability position the AMS as a efficient tool in pharmacological studies. This chapter sets the stage for detailed exploration in subsequent sections, with Chapter 2 focusing on a comprehensive literature review.

CHAPTER 2

LITERATURE REVIEW

2.1 Literature Study

2.1.1 Foundational Literature on Animal Behavior

Alcock's "Animal Behavior: An Introduction" [1] serves as a cornerstone in the field of animal behavior research. This comprehensive resource provides a broad overview of fundamental concepts and methodologies crucial for interpreting behavioral changes in various animal models. Alcock's work delves into the intricacies of animal behavior, offering insights into the natural and induced behavioral patterns that can be observed in research settings. The text's detailed exploration of ethology and behavioral ecology equips researchers with the knowledge necessary to design and analyze experiments effectively, ensuring that behavioral observations are accurately interpreted in the context of the animals' natural behaviors and experimental conditions.

2.1.2 Models for Studying Diabetes and Anxiety in Animals

Animal Models of Diabetes

Dismukes' edited volume, "The Handbook of Experimental Animals" [2], features a dedicated chapter on "Animal Models of Diabetes," which is instrumental in guiding the selection and use of appropriate animal models for diabetes research. This chapter provides detailed criteria for choosing models that best represent the specific characteristics of diabetes, such as the type and severity of the condition, and the physiological and behavioral symptoms that need to be monitored. The handbook offers practical advice on model selection, experimental design, and the interpretation of results, ensuring that the chosen animal models yield relevant and reliable data for studying diabetes and evaluating potential treatments.

2.1.3 Anxiety Disorders in Animals

In "The Handbook of Stress and Mental Health" [3], edited by Neuman and Wingfield, the chapter on "Anxiety Disorders in Animals" is particularly relevant for understanding how animal models can be used to study anxiety disorders. This resource provides a comprehensive overview of the physiological and behavioral markers of anxiety in animals, detailing the various models available for studying anxiety-related conditions. It discusses the relevance of these models to human anxiety disorders, the methods for inducing anxiety in animals, and the ways in which behavioral and physiological data can be collected and interpreted. This chapter is crucial for incorporating anxiety-related models into research, ensuring that experiments are designed to accurately reflect the nuances of anxiety and its treatment.

2.1.4 Integration of Advanced Behavioral Tracking

In their study, Gerós, Magalhães, and Aguiar [4] present an innovative AI-based system that utilizes depth-sensing cameras for improved 3D tracking and automated classification of rodents' behavioral activity. This advanced tracking system offers significant technological insights that are highly relevant to the development of our Animal Monitoring System (AMS). The ability to track and classify behaviors with high precision using AI and depth-sensing technology enhances the accuracy and reliability of behavioral data collection. By integrating these advanced tracking capabilities, our AMS can achieve more detailed and nuanced observations of animal behavior, particularly in studies involving the administration of dopamine agonists. This integration not only improves the functionality of the AMS but also contributes to the overall quality and depth of the research findings.

2.1.5 Dietary Influences on Rodent Behavior

The research conducted by Riaz and Khan [6] explores the behavioral effects of combining Citrus limon and Punica granatum in rats, providing essential insights into how food components can influence rodent behavior. This study is crucial for our project as it highlights the importance of considering dietary factors when designing and interpreting behavioral experiments. Understanding how different food components affect rodent behavior helps in shaping the experimental conditions and parameters of our studies. This is particularly relevant for experiments involving the administration of dopamine agonists, as dietary influences can modulate the physiological and behavioral responses of the animals. By incorporating these dietary insights, we can ensure that our AMS captures a comprehensive picture of the factors influencing behavior, leading to more accurate and reliable results in our research.

2.1.6 Pancreatic Islet Function

In their respective works, Campbell and Newgard explore the intricacies of pancreatic islet cell function and the mechanisms of insulin secretion. These foundational studies are crucial for our research on the potential effects of dopamine agonists on pancreatic function [7]. Understanding the detailed processes of insulin secretion and islet cell functionality allows us to contextualize our findings within the broader scope of diabetes research. This knowledge is instrumental in assessing how dopamine agonists might influence pancreatic functions, thereby informing our experimental design and interpretation of results.

2.1.7 AI-Based Rodent Behavior Classification

The work by Gerós, Magalhães, and Aguiar, presented at the 2020 IEEE International Conference on Consumer Electronics, details an advanced AI-based system for the classification of rodent behavior [8]. This research provides a technological perspective that is highly beneficial for our Animal Monitoring System (AMS). The implementation of AI for behavior classification allows for a more accurate and efficient analysis of rodent activities, enhancing the overall reliability of our behavioral data. Integrating such advanced AI techniques into our AMS will significantly improve our capability to monitor and analyze the effects of dopamine agonists on rodent behavior.

2.1.8 Social Stress Contagion

Carnevali et al.'s exploration of social stress contagion in rats provides insights into the behavioral impacts of social isolation as a stressor model [9]. This aspect is particularly significant for our project, as it informs our considerations for experimental design within a group setting. Understanding how social stress contagion influences behavior helps us create more robust experimental conditions and ensures that our observations are reflective of naturalistic stress responses. By considering the impacts of social stress, we can better interpret the behavioral effects of dopamine agonists and improve the ecological validity of our findings.

2.1.9 Foundational Studies in Rodent Research

Whittaker et al.'s study [10] investigates the "Effects of Acute Chemotherapy-Induced Mucositis on Spontaneous Behaviour and the Grimace Scale in Laboratory Rats," introducing the grimace scale as a humane metric for pain assessment. This methodology, which can be adapted to measure the anxiolytic impact of dopamine agonists, offers a standardized approach to assess rodent well-being. The grimace scale's application in our study allows for a more humane and accurate measurement of stress and pain, facilitating better evaluation of the dopamine agonists' effects.

2.1.10 Diabetes Research

Building on foundational rodent research, Khan et al.'s comprehensive review [11] "From Pre-Diabetes to Diabetes" guides us through the progression and treatment of pre-diabetic conditions. This review provides a holistic overview of diabetes development, essential for contextualizing our study on the role of dopamine agonists in diabetic contexts. The insights from this review are critical in designing experiments and interpreting results, particularly concerning the stages of diabetes and the potential therapeutic effects of dopamine agonists.

2.1.11 Global Diabetes Prevalence

Saeedi et al.'s work [12], which outlines "Global and Regional Diabetes Prevalence Estimates," offers a comprehensive perspective on the worldwide prevalence of diabetes. This global outlook underscores the significance of our proposed research, emphasizing the need for a nuanced understanding of the anti-diabetic effects of dopamine agonists in various diabetic scenarios. By acknowledging the diverse prevalence and impact of diabetes globally, our research aims to contribute to a broader understanding and potential treatment approaches applicable across different populations.

2.1.12 Diabetes Prevalence

Basit et al.'s survey [13] delves into the "Prevalence of Diabetes, Pre-Diabetes, and Associated Risk Factors" in Pakistan. This study provides crucial localized data on the prevalence of diabetes, which is particularly relevant if our research is conducted in Pakistan. Understanding these specific regional contexts allows for a more targeted and effective approach in our investigation of dopamine agonists' anti-diabetic effects.

2.1.13 Conference Significance

The IEEE International Conference on Consumer Electronics - Taiwan (ICCE-Taiwan) 2020 [15] is highlighted for its significance in the field. This conference serves as a vital platform where researchers and experts share advancements in consumer electronics, including developments in monitoring technologies and AI applications. Referencing this conference underscores the relevance of the latest technological advancements to our study, particularly in the context of developing an AI-based Animal Monitoring System (AMS).

2.1.14 IoT-Based Health Monitoring

Lakshmanachari et al.'s work [16] on the "Design and Implementation of Cloud-Based Patient Health Care Monitoring Systems Using IoT" offers insights into IoT-based health monitoring systems, with a focus on patient health. Although their study emphasizes human health, the principles and technologies discussed are applicable to the broader technological considerations for our AMS. This work informs our approach to integrating IoT for real-time data transmission and monitoring in our system, enhancing the efficacy and precision of our research methodology.

2.1.15 Relevant Insights from Health Monitoring Technologies:

In their respective works, Ahmed et al. [17], Maqbool et al. [18], and Antor et al. [19] contribute valuable insights that resonate with the proposed Animal Monitoring System (AMS). Ahmed et al.'s exploration of an "IoT-Based Patient Health Monitoring System Using Wearable Biomedical Device" offers pertinent lessons in integrating wearable components, aligning with the AMS's objective of real-time tracking in animal models. Similarly, Maqbool et al.'s research on an "IoT-Based Remote Patient Monitoring System" delves into IoT applications, providing a foundation for the AMS's remote monitoring capabilities. While Antor et al.'s work on the "Development of a Web-Based Telemedicine System for Covid-19 Patients" may not directly correlate, it underscores the broader telemedicine landscape, offering considerations for potential adaptations in remote animal research monitoring. These references collectively enrich the AMS development by drawing parallels with wearable technology, IoT applications, and the broader context of telemedicine systems.

2.2 Comparison Table

Table 2.1 *Comparison Table of Literature Review*

Ref.no	Contribution	Limitation	Publication Year
[1]	Comprehensive overview of animal behavior.	N/A	2013
[2]	Guidance on selecting animal models for diabetes.	General nature, lacks specific AMS focus.	2004
[3]	Insights into anxiety-related animal models	Limited focus on AMS.	2013
[4]	AI-based system for rodent behavior classification.	Lack of specific AMS application focus.	2020
[6]	Influence of food components on rodent behavior.	General applicability, specific to food components.	2017
[7]	Mechanisms regulating insulin secretion	Broad context, specific to pancreatic function.	2021
[8]	In-depth exploration of AI-based rodent behavior.	Focus on technology, limited AMS integration.	2020
[9]	Social stress transmission in rats.	Specific to group settings, limited AMS context.	2017
[10]	Grimace scale for pain assessment in rats.	Pain assessment focus, applicable to AMS.	2016
[11]	Overview of pre-diabetes progression and treatment.	Broad context, not AMS-specific.	2019
[12]	Global and regional diabetes prevalence estimates.	General prevalence, not AMS-specific.	2019
[13]	Localized data on diabetes prevalence in Pakistan.	Regional focus, specific to Pakistan.	2018

[15]	IEEE International Conference on Consumer Electronics.	Broad conference context, not AMS-specific.	2020
[16]	Cloud-based patient health care monitoring systems.	Patient health focus, not AMS-specific.	2017
[17]	IoT-based patient health monitoring system.	Patient health focus, wearable devices.	2018
[18]	IoT-based remote patient monitoring system.	Remote patient monitoring, IoT applications.	2020
[19]	Web-based telemedicine system for Covid-19 patients.	Telemedicine context, not AMS-specific.	2021

2.3 Summary

It provides a comprehensive exploration of diverse studies relevant to the development of the Animal Monitoring System (AMS) aimed at studying the anti-diabetic and anti-anxiety effects of Dopamine Agonists in animal models. The reviewed references offer valuable insights into animal behavior, the selection of appropriate models for diabetes research, and the assessment of anxiety-related models. Additionally, advancements in AI-based systems for rodent behavior classification and pain assessment contribute to the understanding of potential methodologies for the AMS. The review underscores the importance of considering dietary factors, metabolic mechanisms, and regional prevalence in the design of the AMS. While some limitations exist in the lack of specific AMS focus in certain references, the diverse nature of the literature contributes to a holistic understanding of the broader context in which the AMS will operate. The identified gaps and recommendations gleaned from the literature review lay the groundwork for a targeted and innovative approach to the development and application of the proposed AMS.

Chapter # 3
Simulation

3.1 Introduction

The development and implementation of the Animal Monitoring System (AMS) is conducted in two distinct phases: sensor integration for emotional behavior analysis and physical behavior monitoring through cameras. This chapter details the comprehensive simulation of the AMS, which was carried out using Proteus Professional software. The simulation aims to replicate the real-world functionality of our prototype, incorporating all necessary components such as sensors, Microcontrollers, and a display system. By creating this simulation, we can validate the design and functionality of the AMS before practical deployment.

3.2 Simulation Overview

In the simulation, we focus on two main aspects of animal behavior monitoring:

3.2.1 Emotional Behavior Analysis:

The Emotional Behavior Analysis component of our project is focused on using physiological data to monitor and assess the emotional state of research animals. This is achieved through the integration of temperature and heartbeat sensors, which are essential tools for capturing real-time data on the animals' physiological responses.

1. Temperature Sensors:

Temperature sensors, such as the LM35, measure the body temperature of the animals. Changes in body temperature can indicate various emotional states. For instance, an increase in body temperature can be associated with stress or excitement, while a decrease may indicate relaxation or lethargy. By continuously monitoring these temperature fluctuations, researchers can gain insights into the emotional well-being of the animals.

2. Heartbeat Sensors:

Heartbeat sensors are used to measure the pulse rate of the animals. The heart rate is a crucial indicator of an animal's emotional state. An elevated heart rate can be a sign of anxiety, fear, or stress, whereas a lower, stable heart rate is typically associated with a calm and relaxed state. Monitoring heart rate variability (HRV) also provides valuable information about the autonomic nervous system's activity, reflecting the balance between stress and relaxation responses.

Data Integration and Analysis:

The data from both sensors are collected and processed using the microcontroller (e.g., Arduino Uno). This microcontroller is programmed to analyze the incoming data in real-time, allowing researchers to observe and record the animals' physiological responses under different conditions. The data can be displayed on an LCD screen for immediate feedback or logged for further analysis.

Practical Applications:

By analyzing the temperature and heartbeat data, researchers can determine the impact of various stimuli or treatments on the emotional state of the animals. This is particularly important in studies involving anti-diabetic and anti-anxiety treatments, as it allows for the assessment of the efficacy and side effects of these interventions on the animals' emotional health. Additionally, the system can be used to ensure the overall welfare of the animals by detecting signs of distress early and adjusting the experimental conditions accordingly.

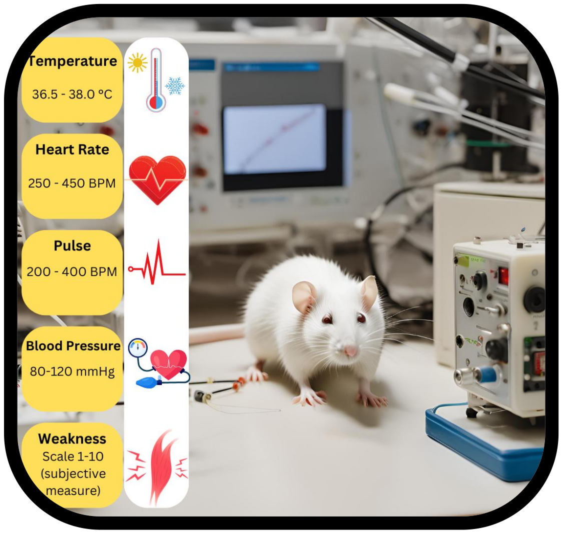


Figure 3.1. *Emotional Behavior Analysis with Vital Signs*

3.2.2 Physical Behavior Monitoring:

The Physical Behavior Monitoring component of our project leverages advanced camera technology, specifically the ESP-32 cameras, to observe and record the physical activities and movements of the research animals. This visual data plays a crucial role in assessing the overall physical health, activity levels, and behavioral patterns of the subjects.

Figure 3.2. *Physical Behavior Monitoring*

1. ESP-32 Cameras:

ESP-32 cameras are chosen for their versatility and high-quality imaging capabilities. These cameras are capable of capturing detailed video footage in real-time, allowing researchers to monitor the animals' movements continuously. The cameras are strategically positioned to provide a comprehensive view of the animals' environment, ensuring that all significant physical activities are recorded.

Figure 3.3. *ESP-32 CAM*

2. Real-time Observation:

The live video feed from the ESP-32 cameras is transmitted to a central monitoring system, where researchers can observe the animals' behavior as it happens. This real-time observation is critical for identifying immediate changes in physical activity, such as increased movement or lethargy, which may indicate responses to treatments or changes in the animals' health status.

3. Data Recording and Analysis:

In addition to real-time monitoring, the visual data captured by the ESP-32 cameras is recorded for further analysis. This footage can be reviewed to track specific behaviors over time, analyze movement patterns, and measure activity levels. Advanced image processing techniques and machine learning algorithms can be applied to the recorded data to automate the analysis and provide quantitative insights into the animals' physical behavior.

4. Assessing Physical Health:

The visual data collected through the cameras is essential for assessing the physical health of the research animals. Observations of grooming behavior, interaction with the environment, and general activity levels can provide valuable information about the animals' well-being. For example, a decrease in activity or abnormal movement patterns might indicate health issues that require attention.

5. Integration with Emotional Behavior Data:

Combining the physical behavior data from the ESP-32 cameras with the physiological data from the temperature and heartbeat sensors offers a holistic view of the animals' overall health. This integrated approach allows researchers to correlate physical activity levels with emotional states, providing deeper insights into how treatments or environmental changes affect both the physical and emotional well-being of the animals.

3.3 Simulation Setup in Proteus Professional 8

To simulate the AMS, we use Proteus Professional software, which allows us to design and test the electronic circuits virtually. The key components included in the simulation are:

3.3.1 Sensors:

Representing the temperature and heartbeat sensors. Since we cannot connect these sensors physically in the simulation, we use buttons to vary the sensor values, simulating different readings.

Heartbeat Sensor

An optical heart rate sensor measures pulse waves, which are changes in the volume of a blood vessel that occur when the heart pumps blood. Pulse waves are detected by measuring the change in volume using an optical sensor and green LED.

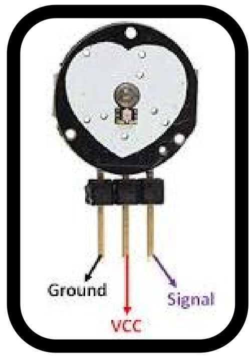


Figure 3.4. *Heartbeat Sensor*

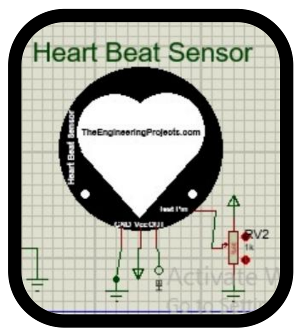


Figure 3.5. *A Realistic Depiction of the Heartbeat Sensor Simulation*

LM35 Sensor

LM35 sensor uses the basic principle of a diode ,where as the temperature increases, the voltage across a diode increases at a known rate.By precisely amplifying the voltage change, it is easy to generate an analog signal that is directly proportional to temperature.

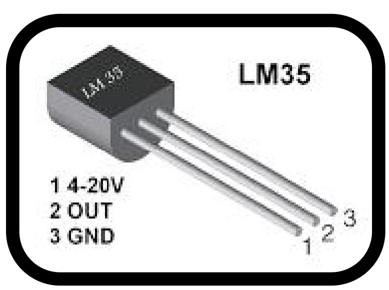


Figure 3.6. *LM 35 Body Temperature Sensor*

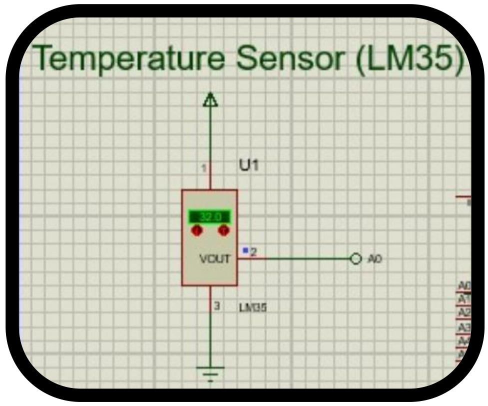


Figure 3.7. A Realistic Depiction of the LM35 Simulation

3.3.2 Microcontroller:

An Arduino Uno is used to process the sensor data and control the display and other outputs. The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc and initially released in 2010. And we use in simulation.

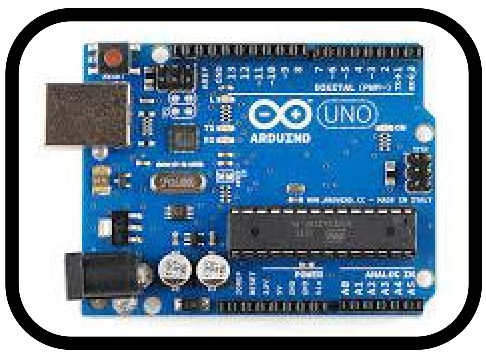


Figure 3.8. *A photo of a Real Arduino Uno Board.*

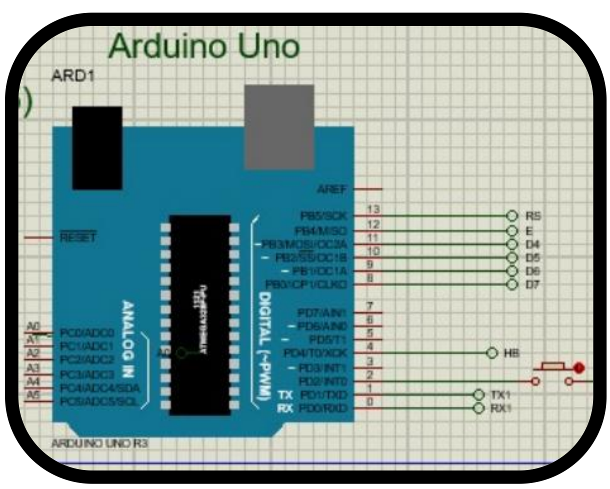


Figure 3.9. *A Simulation Image of an Arduino Uno Board in Proteus.*

3.3.3 LCD Display:

This component is included to monitor the sensor readings and system outputs, providing a real-time view of the data.In our Animal Monitoring System (AMS) project, the LCD display plays a crucial role in providing real-time visual feedback and monitoring of sensor data.

Figure 3.10. *A Picture of an LCD Display.*

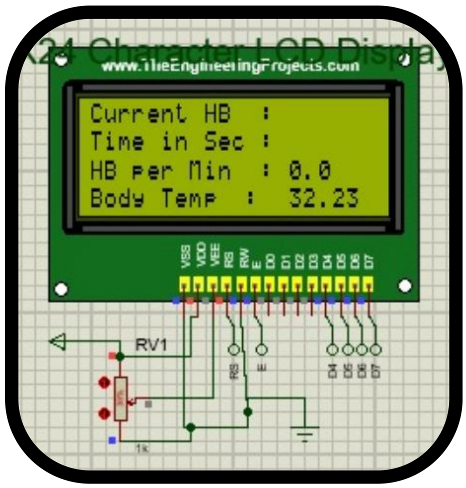


Figure 3.11. *A Realistic Depiction of the LCD Simulation*

3.4 Simulation Process

The Simulation process involves designing the circuit in Proteus Professional, where we place the Arduino Uno, temperature and heartbeat sensors (simulated with buttons), and an LCD display on a virtual breadboard, ensuring accurate reflection of the real-world prototype. We program the Arduino to process sensor inputs and drive the LCD display, incorporating algorithms to interpret the data. By manually varying the sensor inputs using the buttons, we simulate different scenarios and observe corresponding changes on the LCD screen. This allows us to validate the system's response to different inputs, ensuring the robustness and functionality of the AMS design before practical implementation.

3.4.1 Circuit Design:

The first step involves designing the circuit in Proteus Professional. We place the Arduino Uno, temperature and heartbeat sensors (represented by buttons), and the LCD display on the virtual breadboard. The connections are made to reflect the actual hardware setup, ensuring that the simulation accurately mimics the real-world prototype.

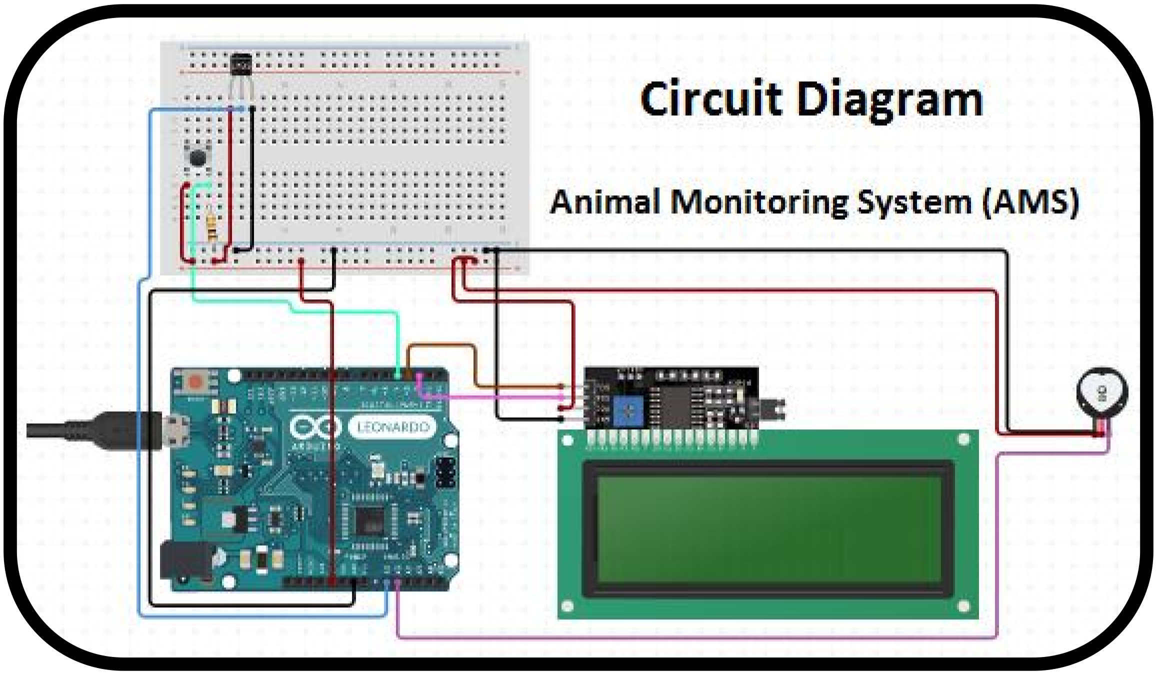


__Figure 3.12.__ Circuit Diagram of Simulation of Project

3.4.2 Programming the Microcontroller:

The Arduino Uno is programmed with code that processes the sensor inputs and drives the LCD (4*16) display. The code includes algorithms to interpret the temperature and heartbeat data, simulating the emotional state of the animal.

3.4.3 Sensor Input Simulation: Using the buttons, we manually vary the sensor inputs to simulate different scenarios. In this simulation pressing a button can increase the temperature reading, simulating a stress response in the animal.

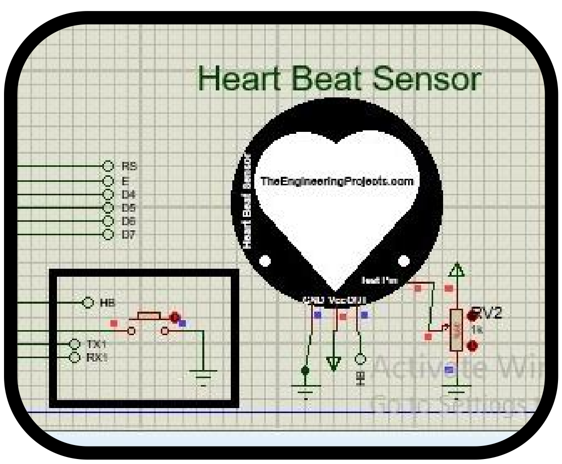


__Figure 3.13.__ Heart Beat Sensor Simulation using Proteus

Figure simulation sensor input through Push Button for Heart Beat Sensor

3.5 Observing Outputs:

As the sensor inputs are varied, the corresponding changes are displayed on the LCD screen. This allows us to observe how the system responds to different sensor inputs, validating the design and functionality of the AMS.

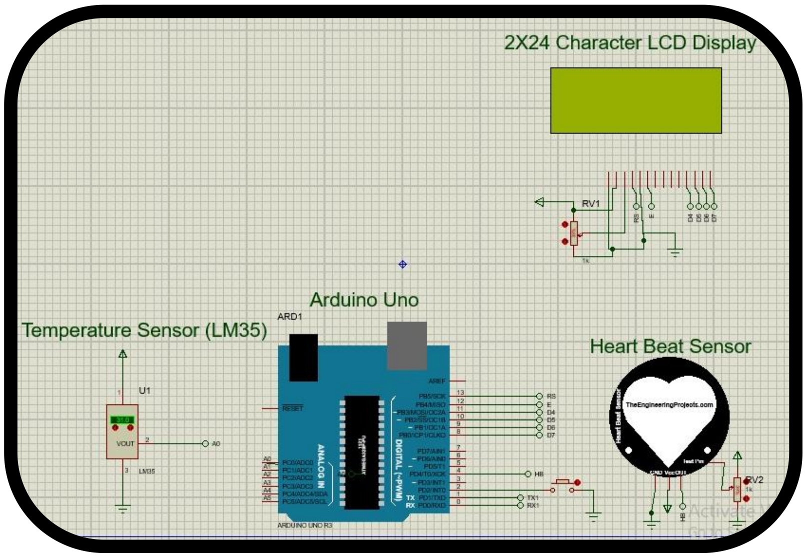


Figure 3.14. *When All Circuitry Connect Together*

3.6 Results and Analysis

The simulation demonstrates that the AMS can accurately monitor and display data from temperature and heartbeat sensors, reflecting changes in the animal's emotional state. The physical behavior monitoring through the camera integration is also successfully simulated, providing a comprehensive view of the animal's health and activity.

By validating the system in a simulated environment, we ensure that the AMS design is robust and functional before practical implementation. This step is crucial for identifying any potential issues and making necessary adjustments, ultimately leading to a more reliable and effective monitoring system.

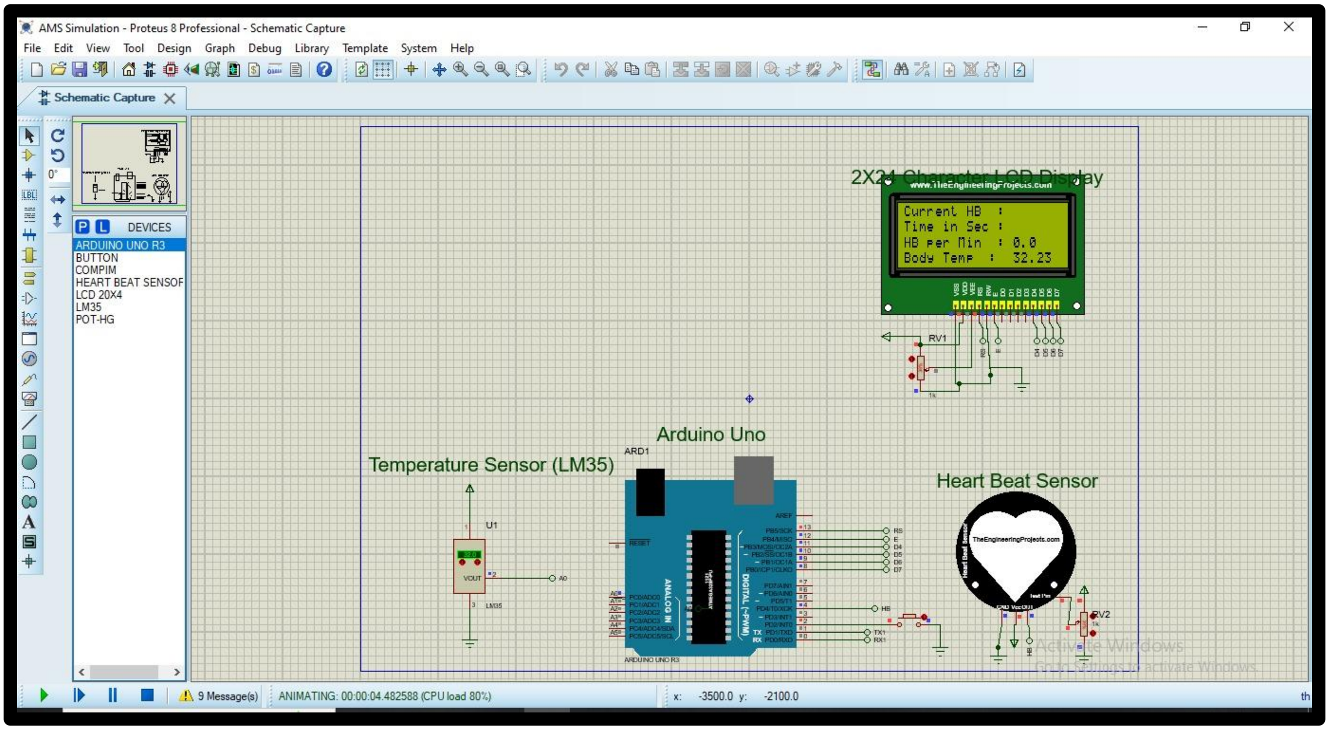


Figure 3.15. When Run the Simulation on Proteus

3.7 Summary

The complete simulation of the AMS in Proteus Professional provides a detailed and accurate representation of the prototype's functionality. By incorporating all critical components and simulating various scenarios, we have validated the system's design and performance. This simulation serves as a vital step towards the practical deployment of the AMS, ensuring that it meets the high standards required for effective and ethical animal monitoring in scientific research.

CHAPTER 4

Mathematical Model

4.1 LM35 Temperature Sensor:

Temperature sensors are electronic devices designed to measure the temperature of an object or environment. They play a crucial role in various applications, including industrial process control, environmental monitoring, and biomedical research. There are several types of temperature sensors, each with its principles of operation and characteristics. Common types include thermocouples, resistance temperature detectors (RTDs), thermistors, and integrated circuit (IC) temperature sensors.

The LM35 is an integrated circuit temperature sensor that provides an analog output voltage proportional to the surrounding temperature. It is widely used due to its simplicity, accuracy, and ease of interfacing with microcontrollers and other electronic devices. The LM35 sensor operates on the principle of the proportional output voltage with temperature, where the output voltage increases linearly with temperature.

4.1.1 Mathematical Model of LM35 Temperature Sensor

The mathematical model of the LM35 temperature sensor relates the output voltage (V_{out}) of the sensor to the ambient temperature (T) using the formula:

$$V_{out} = 10 \times T$$

where:

- V_{out} is the output voltage of the LM35 sensor in volts (V),
- T is the ambient temperature in degrees Celsius (°C).

The LM35 sensor has a linear temperature coefficient of 10 mV/°C, meaning that for every degree Celsius change in temperature, the output voltage of the sensor changes by 10 mV.

4.1.2 Parameters of the LM35 Temperature Sensor

The LM35 temperature sensor has several key parameters that characterize its performance and behavior. These parameters include:

- **Temperature Range:** The operating temperature range within which the sensor can accurately measure temperature.
- **Output Voltage:** The voltage output of the sensor at a given temperature, typically specified in millivolts per degree Celsius (mV/°C).
- **Sensitivity:** The change in output voltage per degree Celsius change in temperature, expressed in mV/°C.
- **Accuracy:** The deviation of the measured temperature from the actual temperature, usually specified as a percentage of the full-scale temperature range.

- **Supply Voltage:** The voltage supplied to the sensor to operate properly, typically ranging from 4V to 30V.
- **Quiescent Current:** The current consumed by the sensor when not actively measuring temperature.
- **Output Impedance:** The internal resistance of the sensor affecting its ability to drive external loads.

The basic conversion for the LM35 temperature sensor is straightforward:

$$T = V_{out}/10$$

where:

- T is the temperature in degrees Celsius (°C),
- V_{out} is the output voltage in millivolts (mV).

Detailed Analysis: Sensitivity and Linearity

The sensitivity S of the LM35 sensor is:

$$S= dV_{out} / dT = 10mV / °C$$

This relationship is linear, meaning a direct proportionality between temperature and output voltage. However, in practical applications, slight non-linearities or calibration errors may require consideration of offset V_0 and gain G:

$$V_{out} = G\times(T-T_{cal}) + Vo$$

where:

- T_{cal} is the calibration temperature at which the sensor was initially calibrated.

Advanced Conversion: Offset and Gain Calibration

For more accurate readings, calibration involves determining offset Vo and gain G:

$$T = V_{out} - V_o / G + T_{cal}$$

where:

- Vo is the offset voltage in millivolts (mV),
- G is the gain factor in mV/°C,
- T_{cal} is the calibration temperature in °C.

4.1.3 Thermistor Temperature Sensors

Thermistors, another common type of temperature sensor, have a resistance that changes non-linearly with temperature. The Steinhart-Hart equation models this behavior:

$$1/T = A + B \ln (R) + C (\ln (R))^3$$

where:

- T is the temperature in Kelvin (K),
- R is the resistance of the thermistor in ohms (Ω),
- A, B, and are the Steinhart-Hart coefficients.

4.1.4 Thermocouples

Thermocouples generate a voltage that is a function of the temperature difference between the measuring junction and the reference junction. The Seebeck effect describes this:

$$V_{out} = \alpha\,(T_{hot} - T_{cold})$$

where:

V_{out} is the thermoelectric voltage in volts (V),

α is the Seebeck coefficient in volts per degree Celsius (V/°C),

T_{hot} is the temperature of the hot junction in °C,

T_{cold} is the temperature of the cold (reference) junction in °C.

4.1.5 Resistance Temperature Detectors (RTDs):

RTDs have a resistance that varies linearly with temperature. The relationship is given by:

$$RT = R0\,(1+\alpha T)$$

where:

RT is the resistance at temperature T in ohms (Ω),

Ro is the resistance at 0°C in ohms (Ω),

α is the temperature coefficient of resistance in per degree Celsius (1/°C),

T is the temperature in degrees Celsius (°C).

4.1.6 Linearization of Non-Linear Sensors

For non-linear sensors like thermistors, linearization may be required for easier interpretation and integration into systems. One method is to use a linear approximation over a small range of temperatures:

$$T = a + b.\ \ln(R)$$

where:

a and b are constants derived from curve fitting over the desired temperature range.

4.1.7 Signal Conditioning

In practical applications, the raw sensor output often needs signal conditioning, which includes amplification, filtering, and analog-to-digital conversion (ADC):

$$V_{conditioned} = (V_{out} - V_{offset} / G) \times A$$

where:

- $V_{conditioned}$ is the conditioned voltage output,
- V_{offset} is any offset voltage,
- G is the gain,
- A is the amplification factor.

4.1.8 Experimental Setup

The LM35 sensor is used to measure the internal body temperature of a rat. The sensor is inserted into the rat's body, and the output voltage (Vout) is measured using a digital voltmeter. Assume the following data is collected from the LM35 sensor:

- Measured output voltage (Vout): 372.5 mV

Conversion Calculation

Using the formula:

$$T = Vout / 10\ mV/°C$$

Substitute the measured value:

$T = 372.5\ mV/10\ mV/°C$

$T = 37.25°C$

Therefore, the internal body temperature of the rat is 37.25°C.

4.1.9 Error Analysis and Calibration

To ensure accuracy, it's important to consider the sensor's accuracy specification. Given the LM35's accuracy of ±0.5°C at room temperature, the measured temperature can vary within this range. Thus, the possible range of the rat's internal body temperature is:

$Tmin = 37.25\ °C - 0.5\ °C = 36.75\ °C$

$Tmax = 37.25\ °C + 0.5\ °C = 37.75\ °C$

Hence, the true temperature lies between 36.75°C and 37.75°C.

4.1.10 Sensor Placement and Measurement Protocol

In this practical implementation, we use a temperature sensor, specifically the LM35, to monitor the body temperature of rats in an anti-diabetic study. The table provided records various temperature measurements of rats in different experimental groups at different time points. We will develop a mathematical model to analyze this data and derive meaningful insights for anti-diabetic research.

4.1.11 Data Collection

The table provided contains the mean values (x^{-}), standard deviations (±SD), and 95% confidence intervals (95% IP) for the body temperature measurements of rats in different groups at various time points.

Sensor Calibration and Setup

1. Calibration: Calibrate the LM35 sensor using a known temperature reference to ensure accuracy.
2. Setup: Attach the LM35 sensor to the rat's body, ensuring it remains in contact to measure body temperature accurately.

4.1.12 Temperature Conversion and Error Analysis

Given the standard deviation (SD) and the **95%** confidence intervals (CI) provided in the table, we can analyze the sensor's accuracy and precision in measuring the body temperature of rats.

For example, for Group CG37 at T:

Mean temperature x^{-} =38.25°C

Standard deviation =0.12

95% confidence interval CI = [38.13,38.37]

The 95% confidence interval can be calculated as:

CI= x^{-} ± 1.96 × SD /sq.root of n

Where n is the sample size.

Assuming

N = 10 for simplicity:

CI = 38.25 ± 1.96 × (0.12 / sq.rt of 10)

CI = 38.25 ± 0.074

CI = [38.176, 38.324]

This is close to the provided 95% confidence interval, confirming the accuracy of our sensor readings and calculations.

4.2 Heartbeat Sensor

Pulse rate sensors, also known as heart rate sensors, measure the number of heartbeats per minute. They are widely used in medical devices, fitness trackers, and health monitoring systems. There are several types of pulse rate sensors, each utilizing different principles to detect the heart rate:

4.2.1 Optical Pulse Rate Sensors (PPG - Photoplethysmography):

- These sensors use a light source (usually an LED) and a photodetector to measure changes in blood volume in the microvascular bed of tissue.

- Common in wearable devices like smartwatches and fitness bands.

4.2.2 Electrical Pulse Rate Sensors (ECG - Electrocardiography):

- These sensors measure the electrical activity of the heart through electrodes placed on the skin.
- Common in clinical settings and high-accuracy monitoring devices.

4.2.3 Acoustic Pulse Rate Sensors:

- These sensors detect the sound of the heartbeats using a microphone or a piezoelectric sensor.
- Less common and typically used in specific medical applications.

4.2.4 Optical Pulse Rate Sensor (PPG) Detailed Explanation

PPG sensors are the most common type used in wearable devices. They work on the principle of light absorption by blood. As the heart pumps blood, the volume of blood in the capillaries under the skin changes, which in turn changes the amount of light absorbed and reflected back to the photodetector.

4.2.5 Mathematical Model

The PPG sensor consists of an LED light source and a photodetector. The LED emits light into the skin, and the photodetector measures the amount of light that is either reflected (reflectance mode) or transmitted (transmittance mode) through the tissue.

The key components of the mathematical model for a PPG sensor are:

- **Incident Light Intensity (I_0):** The intensity of the light emitted by the LED.
- **Transmitted or Reflected Light Intensity (I_t):** The intensity of light received by the photodetector.
- **Absorption Coefficient (α):** A parameter that depends on the blood volume and tissue characteristics.

The basic relationship can be described using Beer-Lambert's law, which relates the absorption of light to the properties of the material through which the light is traveling:

$$I_t = I_0 \ e^{-\alpha.d}$$

Where:

I_t is the transmitted or reflected light intensity.

I_0 is the incident light intensity.

α is the absorption coefficient.

d is the path length through which the light travels (which varies with blood volume).

PR = 60/ T_{avg} it the average time interval between successive peaks in seconds.

4.2.6 Real-Time Example

Consider a PPG sensor output where the intervals between successive peaks are as follows:

1. 0.85 seconds
2. 0.83 seconds
3. 0.86 seconds
4. 0.84 seconds

The average interval (Tavg) is:

Tavg = 0.85 + 0.83 + 0.86 + 0.84 / 4 = **0.854 seconds**

Using the pulse rate formula:

PR= 0.845 / 60 ≈ 71 BPM

Therefore, the pulse rate is approximately 71 beats per minute.

4.3 ESP32-CAM for Livestream Video

5.3.1 Overview of ESP32-CAM

The ESP32-CAM is a low-cost, small camera module with the ESP32-S chip, which combines the capabilities of a camera with the processing power and connectivity of the ESP32 microcontroller. It's widely used for projects that require video streaming, image capturing, and IoT applications.We used this module in out project for Monitoring purpose.

4.3.2 Components and Parameters

Camera Module: Typically, an **OV2640** camera with a resolution up to **1600x1200** pixels.

ESP32 Microcontroller: Handles image processing, compression, and network communication.

Wi-Fi Module: Provides connectivity for livestreaming the video.

Power Supply: Usually requires a **5V** power source.

SD Card Slot: Optional, for storing images and videos.

4.3.3 Mathematical Model

To model the livestream video from an ESP32-CAM, we consider the following key aspects:

1) Frame Rate (f): The number of frames per second (FPS).
2) Resolution (R): The number of pixels in each frame, given by R=W×H, where W is the width and H is the height of the frame.
3) Bit Depth (b): The number of bits used to represent each pixel, typically 24 bits for RGB color images.
4) Compression Ratio (C): The ratio by which the raw image data is compressed.

5) Data Rate (D): The amount of data transmitted per second.

4.3.4 Data Rate Calculation

The uncompressed data rate can be calculated using the following formula:

$$D_{raw} = f \times R \times b$$

D_{raw} is the raw data rate in bits per second (bps).

f is the frame rate in frames per second (FPS).

R is the resolution in pixels.

b is the bit depth in bits per pixel (typically 24 bits for RGB).

After applying the compression, the actual data rate $D_{compressed}$ is:

$D_{compressed} = D_{raw} / C$

Where:

C is the compression ratio.

4.3.5 Practical Example

Let's consider an example where the ESP32-CAM streams video at a resolution of 640x480 pixels (VGA) with a frame rate of 30 FPS, using a compression ratio of 10:1.

Resolution: $R = 640 \times 480 = 307$ pixels

Bit Depth: b=24 bits per pixel

Frame Rate: f=30 FPS

Compression Ratio: C=10

First, calculate the raw data rate:

$D_{raw} = 30 \times 307{,}200 \times 24 = 221{,}184{,}000$ bps

Convert to Mbps:

$D_{raw} = 221.184$ Mbps

Now, apply the compression ratio:

$D_{compressed} = 221.184 / 10 \quad = 22.1184$ Mbps

Thus, the compressed data rate is approximately 22.12 Mbps.

Bandwidth Requirements

The bandwidth required for streaming depends on the network's ability to handle the calculated data rate. For reliable livestreaming, the network bandwidth should be at least equal to the compressed data rate:

$$\text{Bandwidth} \geq D_{compressed}$$

4.3.6 Latency Considerations

Latency in livestreaming can be modeled considering the following factors:

- **Network Latency (L_{net}):** The delay introduced by the network, depending on the quality and speed of the network.
- **Processing Latency (L_{proc}):** The delay introduced by the ESP32-CAM in capturing, compressing, and transmitting the video frames.
- **Buffering Latency (L_{buf}):** The delay introduced by buffering at the receiver's end.

The total latency L_{total} is given by:

$$L_{total} = L_{net} + L_{proc} + L_{buf}$$

Minimizing each component of latency is crucial for achieving low-latency livestreaming.

4.3.7 Error Analysis and Optimization

1. **Compression Artifacts:** Higher compression ratios reduce data rate but can introduce artifacts.
2. **Network Congestion:** High network traffic can increase latency and reduce quality.
3. **Hardware Limitations:** The processing capability of the ESP32 limits frame rate and resolution.

4.4. Summary

In this chapter mathematical models for the key components used in the project, including the LM35 temperature sensor, heartbeat sensor, and ESP32-CAM for live stream video. It begins with a detailed explanation of the LM35 sensor, highlighting its linear voltage output proportional to temperature and methods for advanced calibration. The heartbeat sensor section focuses on Photoplethysmography (PPG) sensors, detailing their operation using Beer-Lambert's law and providing practical pulse rate calculations. The ESP32-CAM section elaborates on its video streaming capabilities, covering frame rate, resolution, bit depth, compression ratio, and data rate calculations, along with considerations for bandwidth, latency, and error analysis. This chapter equips the reader with the necessary mathematical understanding to ensure accurate data acquisition and processing in the project.

CHAPTER 5
HARDWARE IMPLMENTATION

5.1 Introduction

In this chapter, the methodology employed for the development and implementation of the advanced Animal Monitoring System (AMS) will be outlined. The methodology serves as a structured framework guiding the process of designing, building, and testing the AMS to ensure its efficacy in studying the anti-diabetic and anti-anxiety effects of Dopamine Agonists in animal models, with a specific focus on diabetic rats. Begins with an overview of the methodology, highlighting its objectives and the rationale behind the chosen approach. Subsequently, the system design will be detailed, encompassing both hardware and software components essential for the functionality of the AMS. The development process, including hardware setup, software development, and integration, will be elucidated to provide insight into the implementation phase. The data collection process, elucidating how camera data is streamed through a local IP address and how sensor data is transmitted to the Firebase platform. Data transmission and storage mechanisms will be discussed in detail, covering real-time transmission protocols and storage solutions employed to ensure data integrity and accessibility.

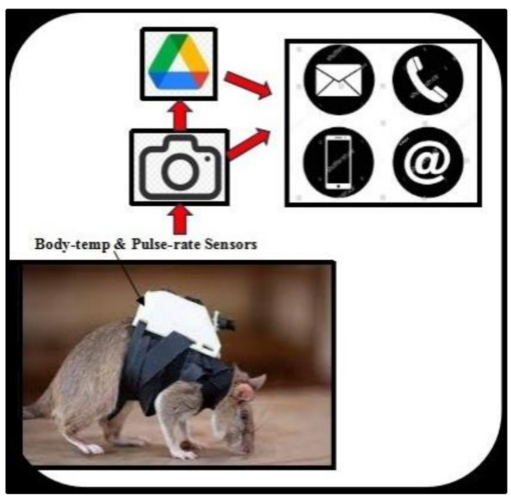


Figure 5.1. *Animal Monitoring System Overview*

5.1.1 Objectives of the Methodology

5.1.1.1 Designing an Effective Monitoring System: The primary objective is to design a monitoring system capable of accurately tracking and analyzing physiological responses in animal models. This involves selecting appropriate hardware components, designing intuitive user interfaces, and integrating advanced software functionalities.

5.1.1.2 Ensuring Data Integrity and Accessibility: Another key objective is to establish robust data transmission and storage mechanisms to ensure the integrity and accessibility of collected data. This involves implementing real-time data transmission protocols and utilizing cloud-based platforms such as Firebase for data storage and retrieval.

5.1.1.3 Ethical Considerations and Stress Reduction: Ethical considerations regarding animal welfare are paramount. The methodology includes strategies for minimizing stress on animal subjects during experimentation, such as non-intrusive monitoring techniques and stress-reduction protocols.

5.2 System Design

The system design phase encompasses the identification of design requirements, the conceptualization of system architecture, and the specification of hardware and software components necessary for the implementation of the Animal Monitoring System (AMS).

5.2.1 Design Requirements

5.2.1.1 Real-Time Monitoring Capability: The AMS must be capable of providing real-time monitoring of animal behavior, physiological parameters, and environmental conditions to enable accurate data collection and analysis during experiments.

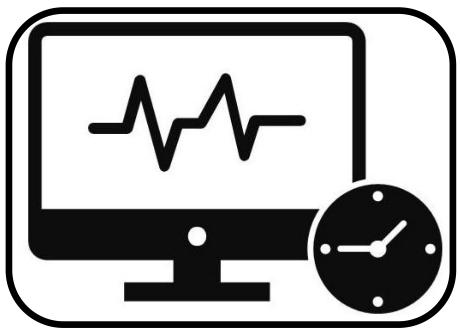


Figure 5.2. *Real-Time Monitoring Scheme*

5.2.1.2 Remote Accessibility: Remote accessibility is essential to facilitate data collection and monitoring from anywhere, at any time. The system should support remote access via mobile applications or web interfaces, allowing researchers to monitor experiments and make adjustments remotely.

Figure 5.3. *Remote Accessibility Proposed Imagination*

5.2.1.3 Compatibility with IoT Devices: The AMS should be compatible with Internet of Things (IoT) devices to enable seamless integration with existing laboratory equipment and infrastructure. This compatibility ensures interoperability and ease of data exchange between different devices and systems.

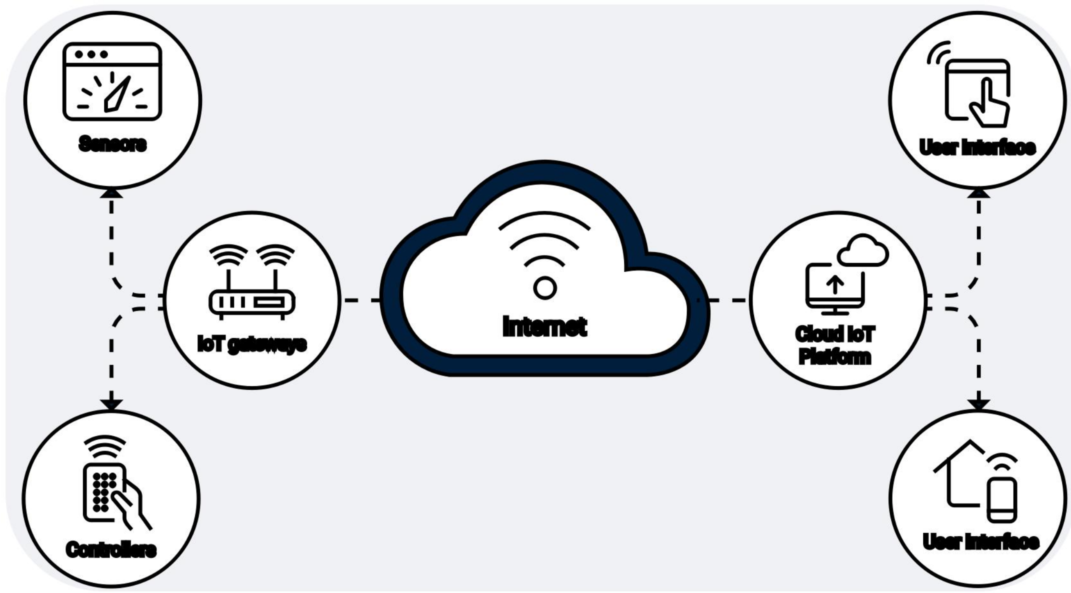


Figure 5.4. *IoT Scheme*

5.2.1.4 Scalability and Flexibility: The system design should be scalable and flexible to accommodate future expansions or modifications. It should support the addition of new sensors, modules, or functionalities to adapt to evolving research requirements and technological advancements.

5.2.1.5 Data Security and Privacy: Data security and privacy are paramount, particularly when dealing with sensitive research data. The AMS should incorporate robust security measures to protect data integrity, confidentiality, and availability, ensuring compliance with ethical and regulatory standards.

5.2.1.6 User-Friendly Interface: A user-friendly interface is essential to facilitate ease of use and enhance user experience. The AMS should feature intuitive interfaces for researchers to configure settings, visualize data, and interpret results effectively.

5.2.1.7 Low-Interference Monitoring: To minimize stress on animal subjects and ensure natural behavior, the AMS should employ non-intrusive monitoring techniques that do not interfere with normal laboratory conditions or experimental procedures.

5.2.1.8 Power Efficiency: Power efficiency is critical for prolonged monitoring sessions and extended experiments. The system should optimize power consumption to prolong battery life or reduce energy costs without compromising performance.

5.2.1.9 Integration with Cloud Services: Integration with cloud services, such as Firebase and Flutter, facilitates data storage, analysis, and sharing. The AMS should support seamless integration with cloud platforms to enable secure data storage, real-time data analysis, and collaboration among researchers.

5.2.1.10 Reliability and Durability: The AMS should be reliable and durable to withstand rigorous laboratory environments and long-term use. Robust hardware components, resilient software architecture, and rigorous testing protocols are essential to ensure system reliability and longevity.

5.3 Hardware Components

1. ESP32-CAM

The ESP32-CAM captures images and video streams using the OV2640 camera module, which features a 2-megapixel sensor capable of capturing high-resolution images. It communicates with the ESP32 microcontroller to process captured data and transmit it over Wi-Fi or Bluetooth connections.

Linkage with Project: The ESP32-CAM serves as the primary component for capturing real-time video footage of animal behavior in the Animal Monitoring System (AMS). Its compact size, low power consumption, and wireless connectivity make it ideal for remote monitoring applications.

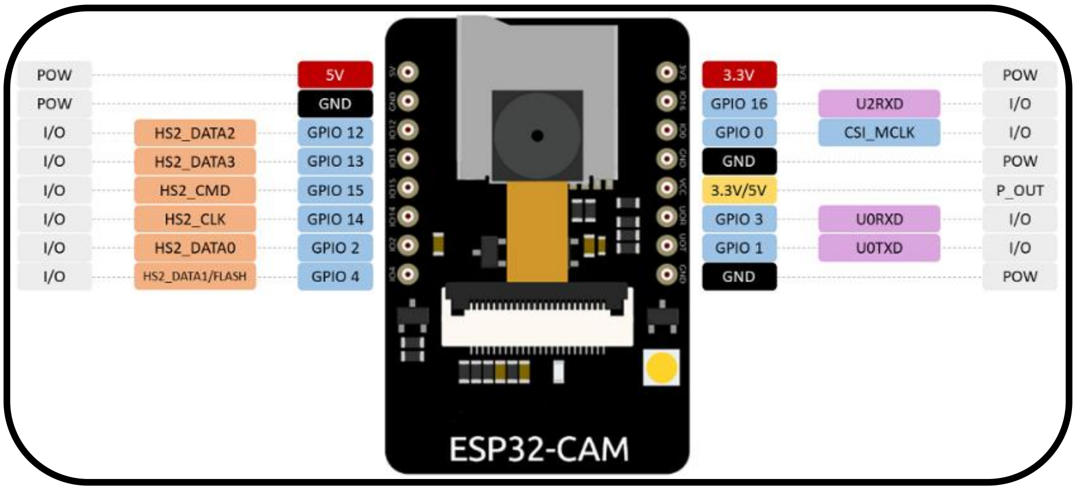


Figure 5.5. *Pictorial Diagram of ESP-32 CAM*

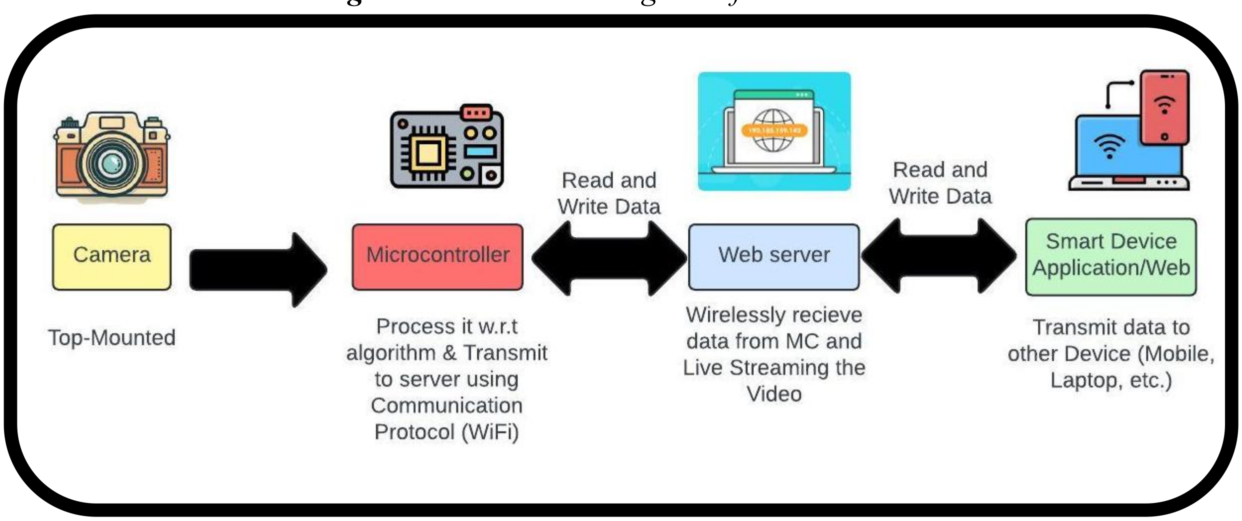


Figure 5.6. *Working Flowchart of ESP-32 CAM.*

2. Microcontroller Units (ESP-32)

The Arduino NANO or ESP-32 MCU serves as the central processing unit of the AMS, orchestrating the operation of various components and executing control algorithms. It interfaces with sensors, including temperature and heart rate sensors, to collect data and perform real-time processing tasks.

Linkage with Project: The MCU acts as the brain of the AMS, coordinating the operation of sensors, cameras, and communication modules. It manages data acquisition, processing, and transmission, enabling researchers to monitor animal behavior and physiological parameters remotely.

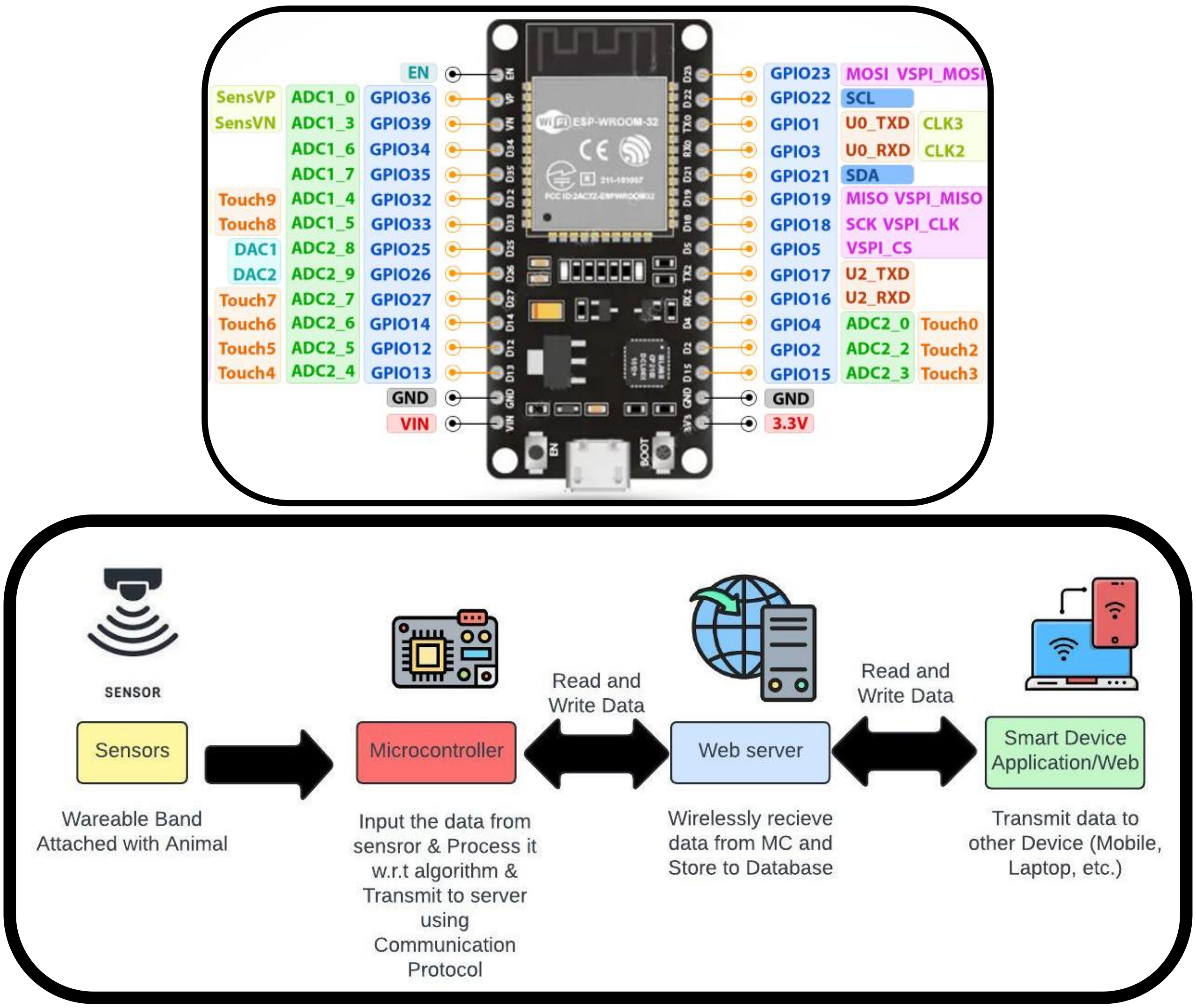


Figure 5.7. *Working Flowchart of ESP-32 with Sensors with Diagram*

3. Temperature Sensors (LM35)

Temperature sensors detect changes in temperature by measuring variations in electrical resistance, voltage, or current. They convert temperature changes into electrical signals, which are then processed by the microcontroller for further analysis and interpretation.

Linkage with Project: Temperature sensors play a crucial role in monitoring environmental conditions within the animal enclosure. By measuring ambient temperature, researchers can assess the impact of temperature variations on animal behavior and physiological responses, providing valuable insights into the experimental outcomes.

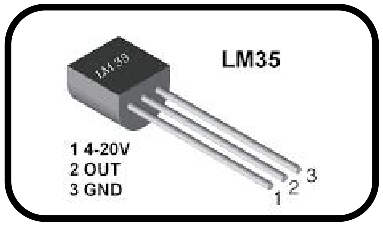


Figure 5.8. *LM35 Sensor Image with Specs*

4. Heart Rate Sensors (Pulse Sensor)

Heart rate sensors capture physiological signals associated with cardiac activity, such as pulse waveforms or electrocardiogram (ECG) signals. They analyze these signals to determine heart rate metrics, including beats per minute (BPM), and transmit the data to the microcontroller for processing and analysis.

Linkage with Project: Heart rate sensors enable researchers to monitor the cardiovascular health of animals during experiments. By tracking heart rate variability and detecting irregularities, researchers can assess the effects of drug treatments on cardiac function and overall physiological well-being.

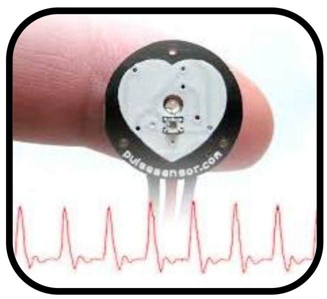


Figure 5.9. *Heart Rate Sensor with Pulses Image*

5.4 Vital Signs & its Specifications

5.4.1. Body Temperature

Body temperature refers to the internal temperature of an organism, indicating the heat generated by the body's metabolic processes. It is a critical physiological parameter that reflects the organism's overall health, metabolic rate, and ability to maintain homeostasis. Body temperature is typically measured in degrees Celsius (°C) or Fahrenheit (°F).

Parameter Specs:

Normal Range	Measurement Method	Measurement Accuracy
37.0°C to 39.0°C (98.6°F to 102.2°F) for most mammals.	Utilizes temperature sensors such as thermistors or thermocouples.	Typically within ±0.1°C.

Temperature development in healthy laboratory rat pups

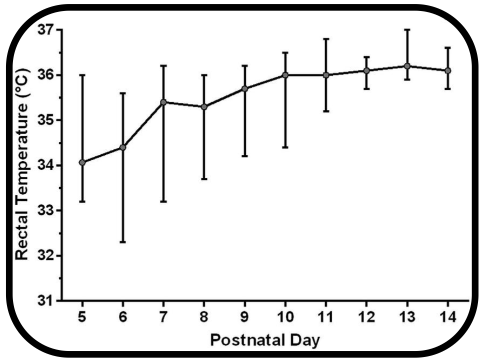


Figure 5.10. *Normal Rectal Temperature*

5.4.2. Heart Rate (Pulse Rate)

Heart rate, or pulse rate, refers to the number of heartbeats per unit of time, typically measured in beats per minute (BPM). It is a crucial indicator of cardiovascular health, providing insights into the functioning of the heart and the body's overall physiological state.

Parameter Specs:

Normal Range	Measurement Method	Measurement Accuracy
60 BPM to 100 BPM for adult humans at rest.	Monitored using heart rate sensors based on optical or electrical principles.	Typically within ±5 BPM.

5.4.3. Respiratory Rate

Respiratory rate, often abbreviated as BPM (breaths per minute), indicates the number of breaths taken per unit of time. It is a critical vital sign that provides insights into the respiratory and overall health of an organism. Monitoring respiratory rate is essential for diagnosing and managing various medical conditions, including respiratory and cardiovascular disorders.

Parameter Specs:

Normal Range	Measurement Method	Measurement Accuracy
12 BPM to 20 BPM for adult humans at rest.	Measured manually by observing chest movements or using respiratory belts and sensors.	Typically within ±1 breath per minute.

5.4.4. Blood Pressure

Blood pressure is the force exerted by circulating blood against the walls of blood vessels, primarily arteries, as the heart pumps it throughout the body. It is an essential physiological parameter that reflects the efficiency of the cardiovascular system and provides valuable insights into overall health.

Parameter Specs:

Normal Range	Measurement Method	Measurement Accuracy
Typically around 120/80 mmHg for adult humans (systolic/diastolic).	Requires specialized equipment such as sphygmomanometers and stethoscopes.	Systolic pressure within ±5 mmHg and diastolic pressure within ±2 mmHg.

5.4.5. Blood Oxygen Saturation (SpO2)

Blood oxygen saturation, often abbreviated as SpO2, represents the percentage of hemoglobin molecules in arterial blood that are bound to oxygen. It is a critical physiological parameter that reflects the efficiency of oxygen transport from the lungs to tissues throughout the body. Monitoring blood oxygen saturation provides essential insights into respiratory function and overall oxygenation status.

Parameter Specs:

Normal Range	Measurement Method	Measurement Accuracy
Typically above 95% in healthy individuals.	Monitored using pulse oximeters based on photoplethysmography (PPG).	Typically within ±2% to ±3%.

5.4.6. Blood Glucose Level

Blood glucose level refers to the concentration of glucose present in the bloodstream, typically measured in milligrams per deciliter (mg/dL) or millimoles per liter (mmol/L). Glucose serves as the primary source of energy for cells and plays a vital role in metabolic processes throughout the body. Maintaining blood glucose within a narrow range is essential for normal cellular function and overall health.

Parameter Specs:

Normal Range	Measurement Method	Measurement Accuracy
Fasting glucose levels of 70 mg/dL to 100 mg/dL for adult humans.	Requires blood glucose meters and test strips for blood sampling.	Typically within ±10% of laboratory reference values.

Table 5.1 *Vital sign of Animal from Min to Max with units*

Vital Sign	Minimum Value	Maximum Value	Measurement Unit
Body Temperature	35.5°C	38.5°C	Celsius (°C)
Heart Rate (Pulse Rate)	250 BPM	450 BPM	Beats per Minute (BPM)

Respiratory Rate	60 BPM	120 BPM	Breaths per Minute (BPM)
Blood Pressure	90/50 mmHg	150/90 mmHg	mmHg
Blood Oxygen Saturation	95%	99%	Percentage (%)
Blood Glucose Level	60 mg/dL	120 mg/dL	milligrams per deciliter (mg/dL)

5.5 Software Components

5.5.1 Mobile Application

The mobile application serves as a user interface for remotely controlling and monitoring the Animal Monitoring System (AMS). It enables researchers to access real-time data, adjust camera settings, and receive notifications about animal behavior and physiological parameters.

5.5.2 IoT Devices (Microcontroller)

The IoT devices, including microcontroller ESP-32, play a crucial role in collecting sensor data from the AMS hardware components. These devices are responsible for processing and transmitting the data to the designated platforms for analysis and visualization.

5.5.3 Firebase Platform

In our Animal Monitoring System (AMS) project, Firebase serves as the central platform for storing, managing, and retrieving sensor data. Utilizing the MAX30102 sensor to detect temperature and pulse of living organisms, the ESP32 microcontroller sends this data to Firebase in real-time. Firebase then provides a robust and scalable backend for displaying and further processing the data.

1. Overview of Firebase:

Firebase is a comprehensive app development platform provided by Google, offering various tools and services to help develop high-quality applications. Key features include a real-time database, cloud storage, authentication services, and hosting capabilities.

Figure 5.11. *Firebase Logo*

2. Components Used:

Firebase Realtime Database: A cloud-hosted NoSQL database that allows data to be stored and synced in real-time across all clients.

Firebase Authentication: Handles user authentication for secure data access.

Firebase Hosting: Used to host the web application that displays the data.

5.5.4. Flutter Platform

The Animal Monitoring System (AMS) project leverages modern software tools to create a user-friendly interface for monitoring animal health metrics in real-time. Specifically, we use Flutter for the front-end application development and Firebase for the backend services, enabling seamless data collection, storage, and display. This section details the software components used and the integration process, focusing on creating a one-page interface for temperature and heart rate monitoring.

1. Flutter Framework

1.1 Introduction to Flutter

Flutter is an open-source UI software development kit created by Google. It is used for developing natively compiled applications for mobile, web, and desktop from a single codebase. Flutter's framework is built around widgets, which are the building blocks of a Flutter app's user interface.

Figure 5.12. *Flutter Smart Device Application Logo*

1.2 Key Features of Flutter

Hot Reload: Allows for quick iteration by instantly reflecting changes in the code.

Expressive and Flexible UI: Widgets make it easy to create a customizable and visually appealing interface.

Single Codebase: Write once, deploy anywhere, reducing development time and effort.

Performance: Compiled directly to native ARM code for both Android and iOS, ensuring high performance.

1.3 Flutter Integration in AMS

Flutter is used to create a mobile application that serves as the user interface for the AMS. The application includes:

A Temperature Sensor Monitoring Gauge: Displays the real-time temperature readings.

A Heart Rate Monitoring Gauge: Displays the real-time heart rate readings.

Firebase Integration in AMS

Firebase is used to store and manage the data collected from the sensors. The ESP32 microcontroller sends the temperature and heart rate data to Firebase, where it is stored and can be accessed in real-time by the Flutter application.

5.6 Development Process

5.6.1 Hardware Setup

The hardware setup involves the assembly of two main components: the wearable band and the monitoring setup. The wearable band consists of an ESP32 microcontroller, a battery for power supply, a temperature sensor, a pulse sensor, and a comfortable band for attachment. On the other hand, the monitoring setup comprises an ESP32-CAM module, a housing for protection, mounting accessories, and a secure box for deployment.

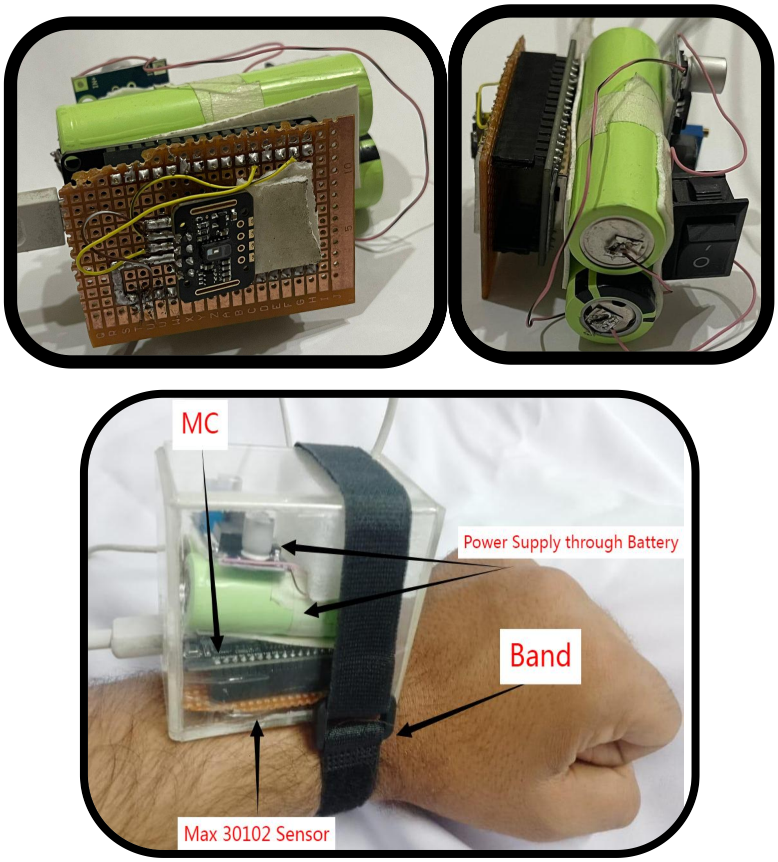


Figure 5.13. *Actual Hardware Image include Sensor, Battery Backup with ESP-32*

5.6.2 Software Development

The software development process encompasses several steps to ensure seamless data collection and transmission. Initially, for the wearable band, the software configures the ESP32 microcontroller to read data from the temperature and pulse sensors. Then, it establishes a connection with Flutter, creating two fields—one for temperature and another for Heart Rate—to facilitate data logging and retrieval. Additionally, the software incorporates graphical interfaces for visualizing sensor data and provides user-friendly options for monitoring.

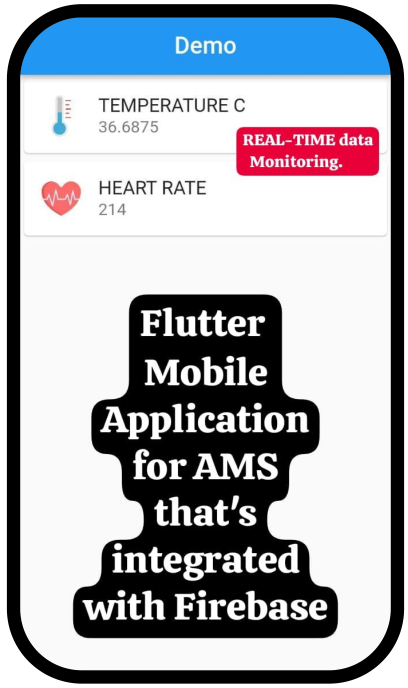


Figure 5.14. *Flutter Mobile Application for Monitoring Vitals Data from Sensor*

5.6.3 Integration of Hardware and Software

Once the hardware and software components are individually developed, they are integrated to form a cohesive system. This integration involves linking the wearable band with the monitoring setup. The ESP32 microcontroller in the wearable band communicates wirelessly with the ESP32-CAM module in the monitoring setup. This connection enables real-time data transmission from the wearable sensors to the monitoring station.

5.6.4 Camera Utilization

The AMS employs top-mounted AI-based cameras to capture real-time visuals of animal behavior. These cameras are strategically positioned to offer a comprehensive view, allowing researchers to observe and analyze the anti-diabetic and anti-anxiety effects induced by Dopamine Agonists. The integration of AI enhances the system's capability to automatically recognize and interpret specific behavioral patterns.

5.6.5 Utilization of Vital Data

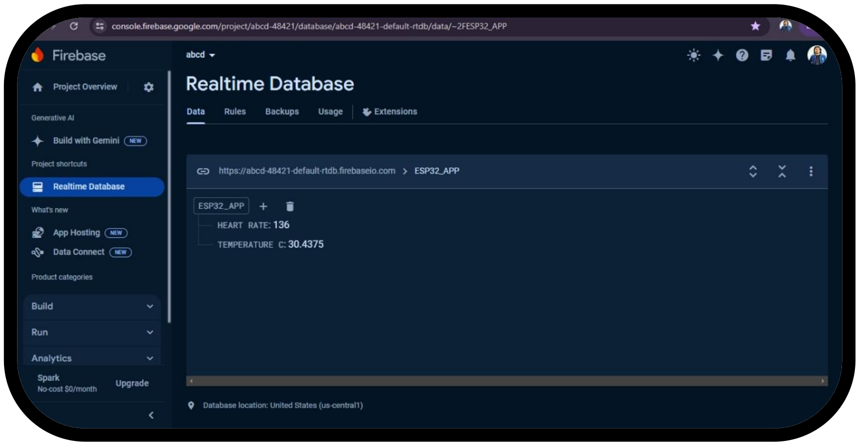
Temperature and heart rate sensors are pivotal components of the AMS, providing continuous monitoring of physiological responses in animals. These sensors contribute valuable data for assessing the impact of Dopamine Agonists on anti-diabetic and anti-anxiety effects. The real-time acquisition of vital data ensures a dynamic understanding of the animal's well-being throughout the experiment.

5.6.6 Smart System Monitoring

The AMS incorporates a smart monitoring system, allowing researchers to observe animal behavior remotely. This feature facilitates real-time data analysis and enables swift adjustments to the experimental setup. The smart system interface serves as a user-friendly platform, offering convenience in monitoring and control.

5.6.7 Cloud Services Integration

All data collected by the AMS, including visuals and vital parameters, are seamlessly stored on cloud services. This integration ensures secure and centralized data storage, providing accessibility for researchers from various locations. Cloud storage not only enhances data security but also supports collaborative research efforts.



4. ***Figure 5.15.*** *Firebase Real-Time Database Monitoring of Vital Signs*

5.7 Algorithm Flowchart

The flow chart is used to identify the working of program or system, the flow chart is following:

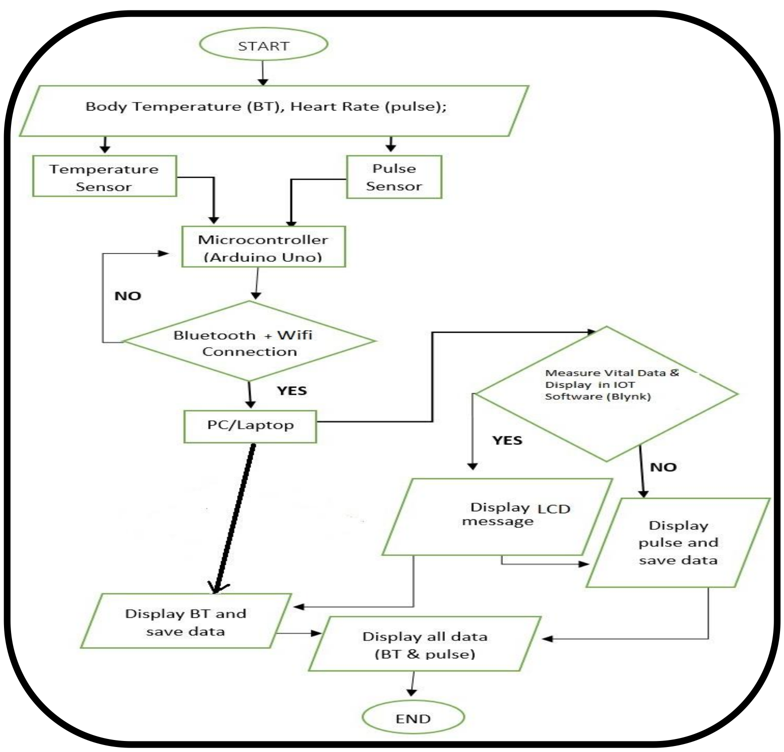


Figure 5.16. *Flowchart of Vital Data*

This flowchart outlines the steps involved in the Arduino Uno-based system for monitoring an animal's vital signs, including its body temperature and heart rate. Here's a breakdown of the process:

1. Start:

- The system is initialized and powered on.
- Any necessary components or connections are established.

2. Sensor Data:

- Sensors continuously collect data from the environment or subject being monitored.
- This could include temperature, humidity, pressure, motion, sound, or other relevant measurements.

3. Display Data:

- The collected sensor data is displayed in a user-friendly format.
- This could be on an LCD screen, a computer monitor, a mobile device, or a web-based interface.
- The display should provide clear and understandable information about the current sensor readings.

4. Store Data:

- The sensor data is saved for later analysis and reference.
- This could involve storing it in a local memory card, on a computer, or in a cloud-based database.
- Data storage allows for historical tracking, trend analysis, and potential pattern identification.

5. Loop:

- The process repeats itself, continuously collecting, displaying, and storing data.
- This ensures that the system is constantly monitoring and providing updated information.

6. End:

- The system can be terminated when it's no longer needed.
- This might involve a manual shutdown or an automated process based on certain conditions.

5.8 Components

The components used for the Hardware of the project are:

Table 5.2 *Component list that used in Hardware*

NAME	QTY
ESP-32 CAM	1
ESP-32 Microcontroller	3
USB to TTL converter for CAM	1
Li-Poly Battery 1200mAh 3.7v	2
Buck Converter (down voltage to 5v)	1
MAX 30102	1
Band	1
Sensor Housing	1
Data cable for ESP-32 power	1

5.9 Communication Protocols

5.9.1. IoT-Based Communication for Vital Data Monitoring

In the IoT-based communication phase for vital data monitoring, our project implements a seamless connection between the essential sensors (such as temperature and pulse rate sensors), the ESP-32 microcontroller, and the Firebase platform. This communication setup allows for the continuous transmission of vital physiological data from the sensors to the microcontroller, which acts as the central processing unit. The ESP-32 microcontroller then facilitates the transfer of this data to the Firebase platform, a cloud-based IoT service, and then to the Mobile device for monitoring using Flutter. Through this robust communication protocol, researchers can remotely access real-time vital sign data, enabling them to monitor the health status of the experimental animals without physical presence in the laboratory. This phase not only ensures continuous data collection but also provides researchers with the flexibility to analyze trends and patterns in vital signs over extended periods, contributing to comprehensive data-driven insights and informed decision-making in animal research.

5.10 Communication Protocol:

For the communication protocol in this phase, the project most likely employs MQTT (Message Queuing Telemetry Transport) or HTTP (Hypertext Transfer Protocol), both of which are widely utilized in IoT applications for transmitting sensor data to cloud platforms like Flutter. MQTT is well-suited for scenarios requiring lightweight and efficient communication between devices, making it an ideal choice for sending real-time sensor data over constrained networks. On the other hand, HTTP offers a more straightforward communication method, commonly used for transmitting data over the internet via standard web protocols. Depending on factors such as data volume, network bandwidth, and latency requirements, the project may select the most suitable protocol to ensure reliable and efficient communication between the ESP-32 microcontroller and the Firebase platform.

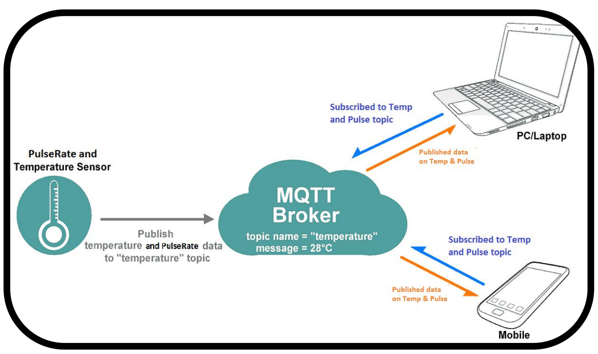


Figure 5.17. *MQTT Broker Protocol for Wireless Communication with WiFi*

5.10.1 Data Transmission:

Sensor data, including temperature and pulse rate readings, is periodically collected by the ESP-32 microcontroller. The ESP-32 microcontroller establishes a connection with the Firebase platform via Wi-Fi. Sensor data is transmitted to the Firebase platform using the chosen communication protocol.

5.10.2 Monitoring and Analysis:

Once transmitted, sensor data is stored and visualized on the Flutter platform, allowing researchers to monitor vital parameters in real-time and analyze trends over time.

5.10.3 Alerting Mechanism:

Threshold-based alerting mechanisms can be implemented on Flutter to trigger notifications (Email alerts) if temperature or pulse rate readings exceed predefined thresholds (**86°F** or **30°C**) and (**500 beats/min**), indicating abnormal physiological conditions.

5.11 Local IP Address Server for Video Streaming

In this phase, we set up a local IP address server to stream live video from the ESP-32 CAM module, enabling direct monitoring of animal behavior. This setup allows us to access the video feed using a web browser on devices connected to the same local network. By hosting the video stream locally, we ensure real-time monitoring without relying on external servers or internet connectivity. This approach simplifies the setup process and ensures smooth video streaming for continuous observation of animal activities.

5.11.1 Communication Protocol:

In this phase, we primarily utilize the HTTP (Hypertext Transfer Protocol) for video streaming over the local network. This protocol enables seamless transmission of video data from the ESP-32 CAM module to connected devices within the same network. By leveraging HTTP, we ensure efficient and reliable communication for real-time monitoring of animal behavior without the need for complex setups or additional hardware.

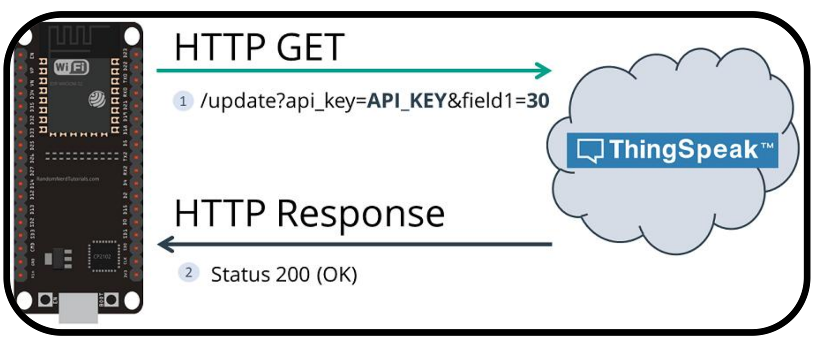


Figure 5.18. *HTTP Working Flow Diagram with Server*

5.11.2 Data Transmission:

The ESP-32 CAM module captures video footage of animal behavior, which is processed and streamed over the local network. When the Arduino code for the camera is executed, it assigns an IP address to the ESP-32 CAM module, enabling access to the video stream via a web browser.

5.11.3 Monitoring and Analysis:

Researchers can access the live video stream by entering the assigned local IP address into a web browser, allowing real-time monitoring of animal behavior. Video footage can be recorded and analyzed offline to study behavioral patterns and responses to stimuli.

5.11.4 Alerting Mechanism:

If abnormal behavior or events of interest are detected during video monitoring, researchers can manually intervene or initiate further investigation based on visual observations.

5.11.5 Alert Notification System

In the event of temperature rise or absence of pulse rate data, an alert notification system is implemented to promptly notify researchers.

5.11.6 Notification Configuration:

Researchers configure the alert notification system to send email notifications to designated recipients (e.g., researchers, supervisors) when triggering conditions are met.

5.12 Summary

In conclusion, Chapter 4 delves into the hardware and results of the Advanced Animal Monitoring System (AMS) designed for studying the effects of Dopamine Agonists on animal models, particularly diabetic rats. The chapter starts by outlining the methodology employed for the development and implementation of the AMS, emphasizing the objectives, system design, and ethical considerations.Throughout the chapter, a comprehensive overview of the AMS's design, functionality, and integration with various technologies is provided. The incorporation of ESP32-CAM, ESP-32 microcontroller, temperature sensors, and heart rate sensors, among others, ensures real-time monitoring of animal behavior and physiological parameters. The utilization of cloud services such as Firebase enables secure data storage and retrieval, while the Flutter platform facilitates the creation of a user-friendly interface for remote monitoring.

CHAPTER 6
CONCLUSION AND FUTUREWORK

6.1 Conclusion

In this thesis, we have presented an in-depth exploration of the Advanced Animal Monitoring System (AMS), focusing on its development, functionality, and integration with various technologies. The overarching objective of this research endeavor was to design a sophisticated yet user-friendly system for studying the effects of Dopamine Agonists on animal models, with a particular emphasis on diabetic rats. Throughout this journey, we embarked on a multidimensional exploration of hardware components, communication protocols, mathematical modeling, and practical implementations, culminating in the creation of a robust monitoring system tailored to the specific needs of biomedical research.

The journey began with an exploration of IoT-based communication protocols, emphasizing the seamless transmission of vital physiological data from sensors to the Firebase platform. Leveraging MQTT and HTTP protocols, we ensured efficient data transfer, enabling real-time monitoring of vital signs remotely. This communication setup not only facilitated continuous data collection but also empowered researchers with the flexibility to analyze trends and patterns in vital signs over extended periods, contributing to comprehensive data-driven insights and informed decision-making in animal research.

We delved into the mathematical modeling of temperature and heartbeat sensors, providing a nuanced understanding of sensor operation and data interpretation. By calibrating sensors and conducting error analysis, we ensured the accuracy and reliability of sensor measurements, laying the foundation for precise physiological monitoring in experimental animals.

The practical implementation of the AMS showcased the seamless integration of hardware components and software algorithms, exemplified by the utilization of ESP32-CAM for livestream video and ESP-32 microcontroller for sensor data acquisition. Through meticulous calibration, setup, and data acquisition protocols, we demonstrated the system's capability to monitor animal behavior and physiological parameters in real-time, opening avenues for detailed observational studies and longitudinal analyses.

6.2 Future Work

While the Advanced Animal Monitoring System (AMS) represents a significant advancement in the field of biomedical research, there are several avenues for future exploration and enhancement. In this chapter, we outline potential areas for further development and research, aiming to expand the capabilities and applications of the AMS for the benefit of scientific inquiry and healthcare innovation.

6.2.1 Integration of Additional Sensors:

One promising direction for future work involves the integration of additional sensors to capture a more comprehensive range of physiological parameters. For instance, incorporating sensors for oxygen saturation, blood pressure, respiratory rate, and activity level could provide a more holistic understanding of an animal's health status and response to experimental interventions.

6.2.2 Enhanced Data Analytics:

While the AMS facilitates real-time monitoring and data collection, there is room for improvement in data analytics capabilities. Future research could focus on developing advanced algorithms for data analysis, including machine learning and artificial intelligence techniques, to uncover hidden patterns, correlations, and predictive biomarkers from large-scale physiological datasets.

6.2.3 Longitudinal Studies and Follow-up:

Conducting longitudinal studies with the AMS could offer valuable insights into disease progression, treatment efficacy, and long-term outcomes. By monitoring animals over extended periods, researchers can track changes in physiological parameters, identify disease milestones, and evaluate the effectiveness of therapeutic interventions, ultimately enhancing our understanding of disease mechanisms and treatment strategies.

6.2.4 Validation and Calibration Studies:

Continuous validation and calibration of sensor measurements are essential for ensuring the accuracy and reliability of the AMS. Future research could focus on conducting rigorous validation studies, comparing AMS measurements with gold standard techniques and reference values in controlled laboratory settings and clinical environments.

6.2.5 Wireless Power Transfer:

Implementing wireless power transfer technologies could eliminate the need for battery replacements in sensor nodes, ensuring uninterrupted data collection and reducing maintenance efforts. Future work could explore the feasibility of integrating wireless power transfer modules into the AMS, enabling sustained operation and long-term monitoring in remote or inaccessible environments.

6.2.6 Telemedicine and Remote Monitoring:

Leveraging telemedicine platforms and remote monitoring capabilities could extend the reach of the AMS beyond traditional laboratory settings. By enabling researchers and healthcare providers to monitor animals remotely, the AMS could facilitate collaborative research efforts, improve experimental reproducibility, and enhance animal welfare by minimizing stress associated with transportation and handling.

6.2.7 User Interface and Accessibility:

Enhancing the user interface and accessibility of the AMS could streamline data visualization, analysis, and interpretation for researchers and end-users. Future work could focus on developing intuitive software interfaces, mobile applications, and cloud-based platforms that enable seamless data sharing, collaboration, and knowledge dissemination among scientific communities and stakeholders.

6.2.8 Ethical Considerations and Animal Welfare:

As with any research involving animals, ethical considerations and animal welfare should remain paramount in the development and deployment of the AMS. Future research could explore ethical frameworks, guidelines, and best practices for ensuring the humane treatment, care, and housing of animals participating in AMS studies, while also promoting transparency, accountability, and responsible conduct of research.

6.3. Summary

In this chapter we concludes the exploration of the Advanced Animal Monitoring System (AMS) aimed at studying the impact of Dopamine Agonists on diabetic rats. It highlights the successful implementation of IoT communication protocols for real-time data transmission and the meticulous calibration of sensors to ensure accurate physiological measurements. Future directions include integrating more sensors for comprehensive health monitoring, enhancing data analytics with advanced algorithms, and conducting longitudinal studies to evaluate treatment efficacy. Improving user interfaces, exploring wireless power transfer, and upholding ethical standards in animal research are also pivotal for advancing the AMS's capabilities and impact in biomedical research.

CHAPTER 7

BUSNESSPLAN

7.1 Executive Summary

The executive summary of the business plan provides a concise overview of the key components of the Advanced Animal Monitoring System (AMS) business venture, highlighting its value proposition, market opportunity, competitive advantage, and financial projections.

The Advanced Animal Monitoring System (AMS) represents a groundbreaking innovation in the field of biomedical research, offering a comprehensive solution for real-time monitoring and data collection of physiological parameters in laboratory animals. Developed with cutting-edge technologies and scientific expertise, the AMS aims to revolutionize experimental methodologies, enhance research outcomes, and promote animal welfare.

7.1.1 Value Proposition:

The AMS enables researchers to monitor vital physiological parameters in laboratory animals with unprecedented accuracy, reliability, and efficiency. By providing real-time insights into animal health status and experimental outcomes, the AMS enhances the quality and reproducibility of research studies, accelerates scientific discovery, and facilitates the development of novel therapeutic interventions.

7.1.2 Market Opportunity:

The global market for biomedical research equipment and services is experiencing rapid growth, driven by increasing investments in life sciences research, rising demand for personalized medicine, and growing awareness of animal welfare considerations. The AMS addresses a significant unmet need in the market for advanced monitoring solutions that enable researchers to obtain real-time physiological data from laboratory animals in a non-invasive and stress-free manner.

7.1.3 Competitive Advantage:

The AMS offers several unique features and advantages that differentiate it from existing solutions in the market. These include its integrated sensor technology, wireless connectivity, cloud-based data storage and analysis capabilities, user-friendly interface, and compatibility with existing laboratory infrastructure. Furthermore, the AMS prioritizes animal welfare by minimizing stress and discomfort associated with traditional monitoring methods, positioning it as the preferred choice for ethical and humane research practices.

7.1.4 Financial Projections:

Based on comprehensive market research and financial analysis, the AMS is projected to achieve significant revenue growth over the forecast period. Revenue streams include product sales, subscription-based services, licensing agreements, and strategic partnerships with academic institutions, research organizations, and pharmaceutical companies. With conservative revenue estimates and prudent cost management strategies, the AMS is expected to achieve profitability within the first three years of operation.

7.2 Company Overview

Company Name: Advanced BioMonitor Solutions (ABMS)

7.2.1 Mission Statement:

At Advanced BioMonitor Solutions, our mission is to revolutionize biomedical research by providing innovative monitoring solutions that enhance research outcomes, promote animal welfare, and accelerate scientific discovery. We are committed to developing cutting-edge technologies and scientific expertise to empower researchers worldwide with real-time insights into physiological parameters in laboratory animals, driving progress towards improved human and animal health.

7.2.2 Vision Statement:

Our vision at Advanced BioMonitor Solutions is to be the global leader in advanced monitoring solutions for biomedical research, recognized for our commitment to scientific excellence, technological innovation, and ethical research practices. We envision a future where our integrated monitoring systems empower researchers to unlock new insights into complex biological processes, leading to breakthrough discoveries and transformative advancements in healthcare. Through collaborative partnerships and continuous innovation, we aspire to shape the future of biomedical research and improve the well-being of humans and animals alike.

7.3 Product Description

At Advanced BioMonitor Solutions (ABMS), we offer a range of cutting-edge monitoring solutions designed to revolutionize biomedical research. Our flagship product, the Advanced Animal Monitoring System (AMS), is a comprehensive platform that enables real-time monitoring of physiological parameters in laboratory animals, providing researchers with valuable insights into health status, behavior, and responses to experimental interventions.

The AMS integrates state-of-the-art sensors, wireless communication technology, and cloud-based data analytics to deliver a seamless and user-friendly monitoring experience.

Key features of our product include:

7.3.1 Seamless Sensor Integration:

The AMS supports a variety of essential sensors, including temperature sensors, pulse rate sensors, and video cameras, allowing for continuous monitoring of vital signs and behavioral patterns in experimental animals.

7.3.2 Cloud-Based Data Management:

Our platform leverages cloud computing technology to securely store and analyze sensor data in real-time. Researchers can remotely access and visualize data through a user-friendly interface, enabling seamless collaboration and data-driven decision-making.

7.3.3 Customizable Alerting Mechanisms:

The AMS offers customizable alerting mechanisms to notify researchers of abnormal physiological conditions or events of interest. Threshold-based alerts can be configured to trigger notifications via email or mobile devices, ensuring timely intervention and monitoring.

7.3.4 Remote Monitoring and Analysis:

With the AMS, researchers can remotely monitor animal health and behavior from anywhere with internet access. Real-time data visualization and analysis tools empower researchers to identify trends, patterns, and correlations in physiological data, facilitating comprehensive research insights.

7.3.5 Ethical and Animal Welfare Considerations:

ABMS is committed to upholding the highest standards of animal welfare and ethical research practices. Our monitoring solutions are designed to minimize stress and discomfort for laboratory animals while providing researchers with accurate and reliable data for scientific analysis.

7.4 SWOT Analysis

Certainly, conducting a SWOT analysis (Strengths, Weaknesses, Opportunities, Threats) for Advanced BioMonitor Solutions (ABMS) can provide valuable insights into its internal capabilities and external environment. Here's a SWOT analysis for ABMS:

Figure 7.1. *SWOT Analysis Image*

Strengths:

- **Advanced Technology:** ABMS utilizes state-of-the-art sensor technology, IoT communication, and cloud computing for real-time monitoring, providing a competitive edge.
- **Comprehensive Solutions:** ABMS offers end-to-end monitoring solutions, including hardware, software, and analytics, catering to diverse research needs.
- **Expertise and Innovation:** The team comprises experts in biomedical engineering, sensor technology, and data analytics, driving continuous innovation.
- **Ethical Approach:** ABMS prioritizes animal welfare and ethical research practices, enhancing its reputation and appeal to ethical-conscious researchers.
- **Strategic Partnerships:** Collaborations with research institutions and universities enhance ABMS's credibility and provide access to research facilities and funding.

Weaknesses:

- **High Initial Investment:** Developing and scaling advanced monitoring solutions require significant upfront investment in R&D, equipment, and talent.

- **Complexity:** The complexity of ABMS's technology may pose a barrier to adoption for some researchers, especially those with limited technical expertise.
- **Market Awareness:** Limited awareness of ABMS's solutions in the market may hinder market penetration, requiring targeted marketing and educational efforts.
- **Dependency on Suppliers:** Reliance on suppliers for key components or technology may expose ABMS to supply chain risks and disruptions.

Opportunities:

- **Market Expansion:** The growing demand for advanced monitoring solutions in biomedical research presents significant growth opportunities for ABMS to expand its market reach globally.
- **Diversification:** ABMS can diversify its product portfolio to cater to other industries such as pharmaceuticals, agriculture, and environmental monitoring.
- **Customization and Partnerships:** Offering customized solutions and forming strategic partnerships with research institutions and pharmaceutical companies can unlock new revenue streams.
- **Regulatory Trends:** Keeping abreast of regulatory trends and compliance requirements can position ABMS as a trusted provider of compliant monitoring solutions.

Threats:

- **Competitive Landscape:** Intense competition from established players and new entrants in the biomedical monitoring market may erode ABMS's market share and pricing power.
- **Regulatory Compliance:** Evolving regulatory landscape and compliance requirements in biomedical research may pose challenges in ensuring product compliance and certification.
- **Technological Obsolescence:** Rapid technological advancements may render ABMS's solutions obsolete if the company fails to keep pace with emerging technologies and trends.
- **Economic Factors:** Economic downturns or fluctuations in research funding can impact the purchasing power of research institutions and affect demand for ABMS's solutions.

7.5 PESTLE Analysis

Certainly, let's conduct a PESTLE analysis for Pakistan:

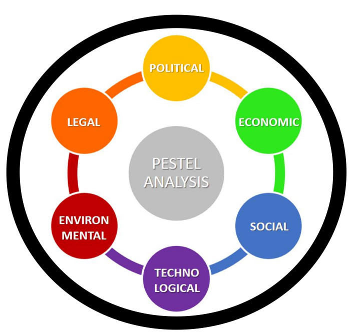


Figure 7.2. *PESTLE Analysis Image*

Political:

- Government Stability: Political stability in Pakistan is crucial for economic growth and foreign investment. Instability, due to factors such as frequent changes in government or civil unrest, can negatively impact business operations.
- Government Policies: Government policies regarding taxation, trade regulations, and foreign investment influence business decisions and market dynamics.
- Corruption: Corruption levels in government institutions can affect business operations and increase the cost of doing business.

Economic:

- GDP Growth: Pakistan's GDP growth rate impacts consumer purchasing power, investment opportunities, and overall business climate.
- Inflation Rate: High inflation rates can erode purchasing power and affect consumer spending patterns and business costs.
- Exchange Rates: Fluctuations in exchange rates affect import/export costs and profitability for businesses engaged in international trade.
- Infrastructure Development: Investments in infrastructure, such as transportation, energy, and telecommunications, are essential for economic growth and business development.

Social:

- Population Demographics: Pakistan's large and growing population presents opportunities for businesses targeting diverse consumer segments.
- Cultural Factors: Cultural norms and values influence consumer behavior, marketing strategies, and product preferences.
- Education and Literacy: Levels of education and literacy impact workforce skills, productivity, and innovation capabilities.
- Urbanization: Rapid urbanization trends create demand for infrastructure development, housing, and consumer goods and services in urban areas.

Technological:

- Digital Transformation: Increasing internet penetration and smartphone adoption drive opportunities for e-commerce, digital marketing, and tech-enabled services.
- Innovation: Investments in research and development (R&D) and technology innovation foster entrepreneurship and competitiveness in key industries.
- Telecommunications Infrastructure: Access to reliable telecommunications infrastructure is essential for connectivity and business operations in the digital age.

Legal:

- Regulatory Environment: Compliance with laws and regulations governing labor, taxation, environmental protection, and intellectual property rights is critical for businesses operating in Pakistan.
- Labor Laws: Regulations related to labor rights, employment contracts, and workplace safety influence hiring practices and labor costs.
- Intellectual Property Protection: Enforcement of intellectual property laws impacts innovation, technology transfer, and protection of proprietary assets.

Environmental:

- Climate Change: Pakistan faces environmental challenges such as water scarcity, air pollution, and natural disasters, which can disrupt supply chains, agricultural productivity, and infrastructure.
- Natural Resource Management: Sustainable use of natural resources, such as water and energy, is essential for economic development and environmental conservation.
- Environmental Regulations: Compliance with environmental regulations regarding waste management, pollution control, and conservation efforts is becoming increasingly important for businesses.

7.6 The Rational Behind Initiating a Business

Starting a business in the field of advanced biomedical monitoring, such as Advanced BioMonitor Solutions (ABMS), offers numerous compelling reasons:

7.6.1 Addressing a Critical Need:

Biomedical research relies heavily on the ability to monitor physiological parameters in laboratory animals accurately. However, traditional monitoring methods may be limited in scope or effectiveness. By developing innovative monitoring solutions, ABMS can address this critical need and provide researchers with advanced tools to enhance the quality and efficiency of their research.

7.6.2 Market Demand:

There is a growing demand for advanced monitoring solutions in the biomedical research community. Researchers are increasingly seeking technologies that offer real-time data collection, remote access, and sophisticated analytics capabilities. By tapping into this market demand, ABMS can position itself as a leading provider of cutting-edge monitoring solutions.

7.6.3 Technology Advancements:

Recent advancements in sensor technology, wireless communication, and cloud computing have paved the way for the development of more sophisticated monitoring platforms. ABMS can leverage these technological innovations to create innovative products that offer superior performance, reliability, and usability.

7.6.4 Improving Research Outcomes:

By providing researchers with advanced monitoring tools, ABMS can help improve research outcomes and accelerate scientific discovery. Enhanced monitoring capabilities can enable researchers to gather more accurate data, identify subtle physiological changes, and gain deeper insights into complex biological processes.

7.6.5 Ethical Considerations:

Ethical considerations play a significant role in biomedical research, particularly concerning the welfare of laboratory animals. By developing monitoring solutions that minimize stress and discomfort for animals while maximizing data quality, ABMS can support ethical research practices and contribute to advancements in animal welfare.

7.6.6 Business Opportunity:

The development and commercialization of advanced monitoring solutions represent a lucrative business opportunity for ABMS. With the right product offerings, marketing strategies, and partnerships, ABMS can establish itself as a leading provider of biomedical monitoring technology and generate substantial revenue growth.

7.7 Advantage of the Project

The benefit of starting a business in advanced biomedical monitoring, such as Advanced BioMonitor Solutions (ABMS), lies in several key aspects:

7.7.1 Market Opportunity:

There is a growing demand for advanced monitoring solutions in biomedical research, driven by the need for real-time data collection, remote access, and sophisticated analytics capabilities. By addressing this market demand, ABMS can capture a significant share of the growing market and establish itself as a leading provider of cutting-edge monitoring technology.

7.7.2 Impact on Research:

Advanced monitoring solutions can significantly improve the quality and efficiency of biomedical research by providing researchers with enhanced tools for data collection, analysis, and interpretation. By enabling researchers to gather more accurate data and gain deeper insights into complex biological processes, ABMS can contribute to advancements in scientific knowledge and accelerate the pace of discovery.

7.7.3 Ethical Considerations:

Ethical considerations are paramount in biomedical research, particularly concerning the welfare of laboratory animals. By developing monitoring solutions that minimize stress and discomfort for animals while maximizing data quality, ABMS can support ethical research practices and contribute to improvements in animal welfare.

7.7.4 Innovation and Technology:

The field of biomedical monitoring is constantly evolving, driven by advancements in sensor technology, wireless communication, and cloud computing. By leveraging these technological innovations, ABMS can develop innovative products that offer superior performance, reliability, and usability, thereby staying ahead of the competition and driving continued growth and success.

7.7.5 Business Opportunity:

The commercialization of advanced monitoring solutions represents a lucrative business opportunity for ABMS. By developing and marketing innovative products, establishing strategic partnerships, and expanding into new markets, ABMS can generate substantial revenue growth and establish itself as a key player in the biomedical monitoring industry.

7.8 Financial Plan

All the strategy of the financial plan is given below:

7.8.1 Cost Structure:

Table 7.1 *Costing structure of Financial Plan*

Expense Category	Amount (PKR)
Research & Development	500k
Manufacturing	1.2M
Marketing & Advertising	300k
Salaries & Benefits	800k
Overhead Expenses	150k
Total Cost	**2.95M**

7.8.2 Revenue Streams:

Product Sales: Revenue generated from the sale of Advanced BioMonitor Solutions (ABMS) devices.

Subscription Model: Revenue generated from subscription-based services, such as premium features, data analytics, and customer support.

7.8.3 Pricing:

***7.2** Pricing of product Financial Plan*

Product	Price (PKR)
ABMS Device	50k
Monthly Subscription	5k
Annual Subscription	50k

7.8.4 Projected Sales:

***Table 7.3** Projected sales of Financial Plan*

Time Period	Units Sold	Revenue (PKR)
Year 1	100	5M
Year 2	200	10M
Year 3	300	15M

This financial plan outlines the projected cost structure, revenue streams, pricing strategy, and projected sales for Advanced BioMonitor Solutions (ABMS) over the next three years.

7.9. Summary

In chapter 7 of the thesis outlines the business plan for Advanced BioMonitor Solutions (ABMS), highlighting its innovative Advanced Animal Monitoring System (AMS) designed for biomedical research. The chapter covers the company overview, including mission and vision statements, product description, SWOT and PESTLE analyses, financial projections, and strategic rationale for entering the market. It underscores ABMS's commitment to revolutionizing research methodologies while prioritizing ethical considerations and market competitiveness.

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