IoT-Vision Enabled Assistant for Epileptic Patients

Progress Report

EPI-VISION

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Chapter 1

Introduction

1.1 Graphical Abstract

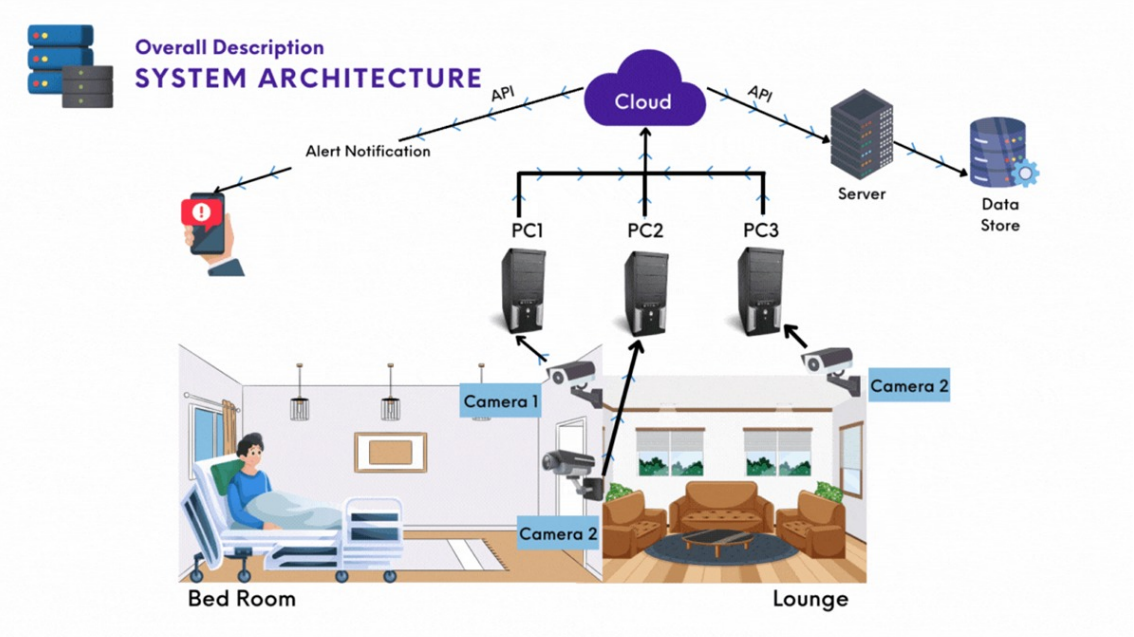

FIGURE 1.1: Overall Project

1.2 Overview of Project

IoT-Vision Enabled Assistant for epileptic patients is an innovative and comprehensive solution that aims to detect, and forecast seizures in real time to improve the lives of epileptic patients. The system uses multiple cameras to monitor patient's activities in real time for seizure detection and then send activity logs to cloud server to analyze the data where it detects any abnormal patterns that can lead to seizure. If a seizure or any of its triggers are detected, the system generates an alert and notifies the patient's family or caregivers via a mobile app.

The main objective is to detect and forecast seizures by utilizing a personalized machine learning techniques that improves the accuracy of seizure prevention using forecasting. System uses machine learning algorithms to learn activities and behavioral patterns of each patient. By using this tailored model technique, machine learning models are able to recognize and comprehend the distinct behavioral patterns of each individual patient. This helps to improve user outcomes for those with epileptic diseases and forecast their seizures.

The system has user-friendly web and desktop application which provides a high level of flexibility and convenience to patients, their family members and caretakers. The applications are simple to use, interactive and provides real time monitoring which makes it easier for caretakers to take action in case of an emergency. The system is designed to be cost-effective. It provides round -the-clock safety, comfort and assistance only when epileptic patient needs it. Hence, it reduces the burden on caretakers and nursing sector and maintains an independent, comfortable, healthy and private life of epileptic patients.

In conclusion, it is revolutionary system that uses cameras and machine learning algorithms to detect and forecast the seizures, hence improves the quality of life of the patients and caretakers. Overall this project has potential to make significant impact on the lives of millions of people suffering with epilepsy.

1.3 Background

Epilepsy is a neurological disorder/condition that causes repeated and indefensible seizures. A person can be declared epileptic if he/she has had at least two unprovoked seizures in 24 hours apart. According to World Health Organization (WHO) [11], around 50 million people with epilepsy live on the earth, making it the most common neurological disorder globally. Around 80% of the patients reside in low or middle-income countries. The general proportion of active cases (continuous seizure attacks or needs urgent treatment) is 4 to 10 for every 1000. Around 70%

people could be cured if they are properly treated. It is estimated that 5 million people are diagnosed with epilepsy every year. In high-income countries, 49 per 100,000 people get positive for epilepsy each year. Pakistan [6] has 1.5% of its total population which is about 3.3 million people, bearing epilepsy. According to the research conducted by the National Library of Medicine [7], epilepsy has quite severe consequences including lifespan shortening, excessive bodily injury, psychological and psychiatric impairment, and social disability. These consequences separate the population of epilepsy from the rest of the world.

1.4 Objectives

1.4.1 Commercial Objectives

The following commercial objectives will be achieved:

- To establish the market presence in the healthcare sector and potentially enhance the user satisfaction for sustainable growth in the revenue.
- To build brand recognition using marketing strategies.
- To foster partnerships/collaborations in the healthcare market.

1.4.2 Industry Objectives

The following industry objectives will be achieved:

- To contribute to the advancing field of healthcare technology
- To provide a framework for the practical implementation of machine learning methods in healthcare.

1.4.3 Research Objectives

- To determine and analyze existing mechanisms/solutions for seizure monitoring in epileptic patients.
- To examine the viability of the system in the detection and prevention of seizures.
- To explore and identify research gaps in the detection of epileptic seizure.
- To publish the findings in journals and present them at the international level.

1.4.4 Academic Objectives

The following academic objectives will be achieved:

- To get a deep understanding of various computer vision and machine learning algorithms used in the patient monitoring.
- To practically implement the algorithms and analyze the results.
- To provide an opportunity to the students to explore the area of healthcare technology.

1.5 Product Functions

Product functions of IoT-Vision enabled Assistant for Epileptic Patients are:

- **Seizure Detection:** System accurately detects seizures and notifies it with minimal possible delay.
- **Forecasting:** By analyzing pre and post-ictal activities of epileptic patients, system extracts behavioral patterns which help in forecasting the upcoming seizure.
- **Alarm Generation:** System generates an alarm immediately after seizure detection or observing any abnormal behavior.
- **Activity Charts:** System manages the activity charts such as food, sleep and medicine routines which ultimately helps in understanding the living pattern of patients in detail.

1.6 Scope

The IoT vision-enabled assistant targets elderly individuals suffering from epilepsy, offering real-time monitoring and assistance tailored to following motor seizures:

- Automatisms
- Clonic
- Atonic
- Myoclonic
- Hyperkinetic
- Tonic
- Tonic-clonic
- Myoclonic-tonic-atonic
- Myoclonic-atonic

The project utilizes a Bullet 2C 4MP camera installed in the patient's room, It examines various activities such as

- Drinking
- Eating
- Standing Up/Down
- Walking
- Lying
- Sitting Up/Down
- Watching Screen
- Using Smartphone
- Reading
- Entering/Leaving

These activities help in recognizing the behavioral patterns of epileptic patients. The environment of the project spans from a single room to a living room, reflecting the typical range of activities for elderly individuals.

1.7 Motivation

The development of medical expertise and a healthy lifestyle is much needed as there is exponential growth in the elderly population bearing epilepsy. Elderly epileptic patients require constant monitoring by caretakers, nurses, or family members so any emergency can be managed but this can be hectic and tiring for caretakers, costly for family, and intrusive for patients. We aim to provide an efficient, economical, and less intrusive solution to monitor epileptic patients so seizures can be detected and forecasted and then notify caretakers through the alarm. This will help lessen the burden on the nursing sector, maintain the privacy of elderly people as well as lead to economic growth.

1.8 Problem Statement

Current monitoring devices for elderly epileptic patients lack effectiveness and are intrusive(require wearables), hindering efforts to improve living standards and safety. There is a need for a cost-efficient smart system that can accurately monitor daily activities, detect seizures promptly, and provide insights to enhance the quality of life for elderly epileptic patients.

1.9 Target Audience

The application area of the project defines the environment in which the project could be deployed or could be made under the use.

- **Hospitals**
  The system could be deployed in hospital rooms where epileptic patient monitoring makes burden for nursing staff or caretakers of the patient.

- **Home**
  The system could work for the home where elderly people require assistance and are suffering from epilepsy.

1.10 Benefits

This project is aimed to detect, prevent and forecast seizures in real-time to improve the lives of epileptic patients. So, the stakeholders and caretakers can enjoy its features, and some of the benefits of the system are listed below:

- It is a comfort-oriented solution, as this system does not require any wearables.
- It is cost-effective as compared to other solutions.
- It can predict whether a seizure occurred or not with high accuracy.
- It can forecast seizures once the personalized model is trained.

1.11 Challenges

1.11.1 Challenges

- **Different Resolution**
  The resolution of IP cameras used in the project can have a significant impact on the detection of seizures. It can also affect the overall performance of the system. There are a number of factors which it can affect:

  1. Using High-resolution cameras can produce large video files, which can cause storage issues.
  2. To analyze the data also requires more processing power in real time.
  3. High-resolution cameras are also costly to use.

- **Different Lighting Condition**
  Light sensitivity may differ in the portion of the room or may differ with the time of the day. Different light sensitivity may change the meaning of the image because the camera would face difficulty in detecting the face or

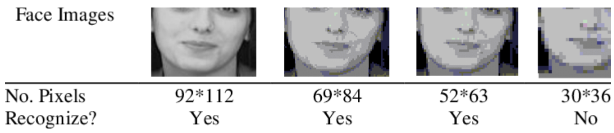

FIGURE 1.2: Effect of Resolution

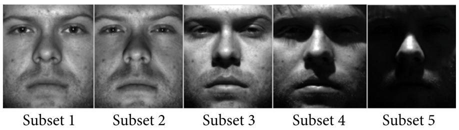

FIGURE 1.3: Face Detection in different lighting conditions

different posture of the body of the patient.

- **Occlusion**
  Occlusion frequently happens when two or more things are too close together and appear to mix or join. It reduces the amount of visual information that is available. Therefore, it can produce false results which may lead to inaccurate data. After occlusion, the system will wrongly identify the initially tracked object as a new object.

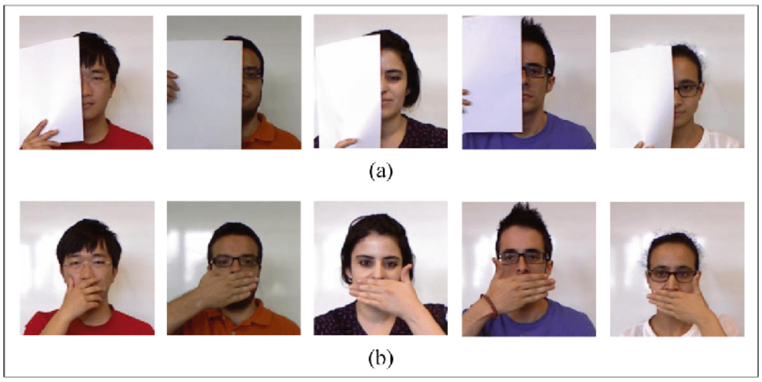

FIGURE 1.4: Occlusion in image

- **Synchronization of multiple Cameras**
  There can be multiple cameras to monitor the object such as elderly patients in our case. Synchronizing multiple cameras can be a challenging task. There can be different frame rates of cameras which makes it difficult to synchronize their video streams. Secondly, each camera has its own internal clock which can cause time drift between cameras making it difficult to align the videos. There can be network latency which can cause synchronization issues. To align the videos in real-time, high processing power is required which can be challenging.

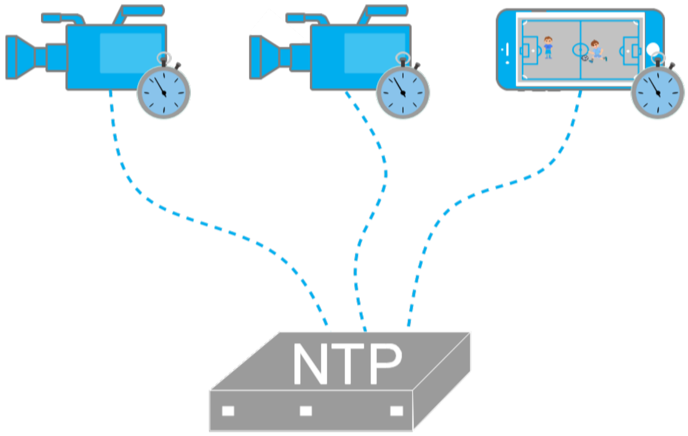

FIGURE 1.5: Syncing Multiple Camera Streams

- **Duration Variation**
  Duration variation is a crucial challenge that needs to be mentioned here. It can affect the accuracy of the model and produce inefficient results. It also creates difficulties in identifying the exact start and end times of the activities.

- **Cross-view Challenge**
  If activities are recorded from a camera, they may look different from different angles, this is a cross-view challenge faced while recording the patient activities.

- **Behaviour Modeling**
  Human behavior modeling is incredibly diverse and context-dependent, it can be changed over time due to many factors like experience, religion, ethnicity, and external influences, sometimes it also becomes subjective due to personal beliefs and emotions, collecting the data for this is challenging, and may raise many ethical concerns, therefore human behavior modeling is also a challenge.

Chapter 2

User Research Findings and Insights

2.1 User Research Findings and Insights

2.1.1 Existing Projects

Many devices are commercially available in markets for epileptic seizure detection. Most of them are sensor-based which uses sensors like accelerometer, a gyroscope, a thermometer, and electrodermal activity which detect many such activities that can help to detect seizures. EEG and Camera-based devices are also available such as Epihunter EEG headcaps, SAMi, etc.

2.1.1.1 Epihunter

Used to detect absence seizures [5]. Absence seizure is characterized by a brief, sudden loss of consciousness, often lasting only a few seconds, during which the person may appear to be staring blankly into space.

Cost: \$825.91 – \$1,515.91 inc GST

Detector Location: Scalp

FIGURE 2.1: Epihunter

2.1.1.2 Embrace 2

This device [4] utilizes accelerometer, a gyroscope, a thermometer, and electrodermal activity to detect convulsive seizure activity and communicates it to a paired wireless device which alerts designated caregivers.

Cost: The watch costs $249 and the monitoring service requires a monthly subscription, which costs either $9.90 per month, $19.90 per month, or $44.90 per month, depending on several features such as the number of caregivers to be notified.

FIGURE 2.2: Embrace 2

2.1.1.3 SAMi

SAMi [1] (Sleep Activity Monitor) is a device that is primarily designed to monitor sleep patterns and detect movements during sleep, including movements that may be associated with seizures. SAMi uses a small infrared camera that is placed near the individual's bed to monitor their movements during sleep.

Cost: Rs.114,700.00 PKR or above for different available packages.

FIGURE 2.3: SAMi

2.1.1.4 Epi-Care Mobile

Epi-Care Mobile [9] consists of sensors placed on the wrist of epileptic patients. it can easily be worn by patients both inside and outside. the sensor device is connected to an app on smartphones that can send alarms by automatically calling the caretakers of a patient for immediate assistance and also forwarding their GPS location through direct message.

Cost: £1,005.00 around 350,545 in PKR

Detector Location: Wrist

FIGURE 2.4: Epi-Care

2.1.1.5 Emfit

Emfit is a bed sensor [3], a thin-sheet device placed under the mattress that can detect GTC (Generalized tonic-clonic seizure) only.
Cost: $249.00 around 80000 in PKR
Detector Location: Under the mattress

FIGURE 2.5: Emfit

2.1.1.6 Brain Sentinel SPEAC

SPEAC [8] is used to detect GTC seizures only and can be used in the home or healthcare facilities during periods of rest (designed to detect seizures during sleep or rest).
Cost: Not Available
Detector Location: Arm (over the biceps muscle)

2.1.1.7 MedPage

It can detect tonic-clonic seizures with the help of prolonged unusual movements and will inform the caretaker for early assistance . [12]

Cost: £246.00 around 90000 PKR
Detector Location: Under the mattress

FIGURE 2.7: MedPage

2.1.1.8 AlertIt Companion by AlertIt

The Alert-iT Companion Mini is designed to detect tonic-clonic seizures and is placed between the mattress and bed base. It detects the seizure's movements and abnormal physiological symptoms that occur during seizures. It generates an alarm that can alert the caretakers by using radio pager, which has a 450m range. [10]
Cost:£248.33 around 90000 in PKR
Detector Location: Between mattress and Bed base

FIGURE 2.8: AlterIt

2.1.2 Comparison and Need of New System

So, why we still need something that can help epileptic patients to detect and prevent seizures even though these devices are available? Although these devices are available, there are many issues that can insist to propose something that can actually help patients while considering all the factors.

In [3], the results showed that users indicate that a device should be socially acceptable, as wearing a device that looks unfamiliar, visible, and intrusive may disclose their condition to others. Most of the EEG-based devices are not comfortable and also refer to instances where the device detects a seizure when no seizure is actually occurring (generate false alarms). This can happen for a number of reasons such as stress, hormonal imbalances, trauma, changes in sleep patterns etc during which changes in brain activity are not even related to seizures.

Epihunter headcap device is expensive EEG based seizure detection device compared to other devices. **Embrace2** is also expensive. It is necessary to have an active subscription to the monitoring and alerting service. There are several different epilepsy types for which the Embrace watch is not indicated, such as complex partial seizures and absence seizures. Complex partial seizures are characterized by a decreased level of awareness, with possible movements of the body, usually lasting for a few seconds. Absence seizures are characterized by a decreased level of awareness and staring spells but without involuntary physical movements.

In addition, **SAMi-like** devices have a high rate of false detection for seizures as they can detect simple movements like the movement of limbs because of restlessness may also detect as an epileptic seizure. This product is not affordable for the average person because it is more expensive than others in the market.

Other devices, like **Epi-Care Mobile**, **Emfit**, **Brain Sentinel SPEAC**, **MedPage**, and **AlertIt Companion by AlertIt**, all have some limitations. They can detect tonic-clonic or convulsive seizures by observing unusual movements using different sensors, which may generate false alarms by considering normal movements as seizure-jerking movements. This may result in disruption for patients and their caregivers. Most of them are not available in all countries, have battery limitations, and may have premium features that are not financially suitable for all epileptic patients, which can also burden their caregivers.
Many other devices with similar services and limitations are also available [2].

TABLE 2.1: Do currently marketed devices match the needs of users?

Devices	Modality	Comfort	Placement	Seizure Type	Affordable
Epihunter	EEG	×	Scalp	Absence Seizures	Expensive
Embrace 2	Sensors	✓	Wrist	Tonic-clonic Seizures	Moderate
SAMi	Camera	✓		Tonic-clonic Seizures	Affordable
Epi-Care	Sensors	✓	Wrist	Tonic-clonic Seizures	Expensive
Emfit	Sensors	✓	Under the mattress	Tonic-clonic Seizures	Moderate
SPEAC	Sensors	×	Arm	Tonic-clonic Seizures	
N/A heightMedPage	Sensors	✓	Under the mattress	Tonic-clonic Seizures	Moderate
AlertIt	Sensors	✓	Between mattress and Bed base	Tonic-clonic Seizures	Moderate

It is important to note that some devices require different subscription plans to enable premium features which can also include in the overall cost of devices.
A rough estimate of the ratio of available devices for epileptic seizure detection based on EEG, Camera, and Sensors:

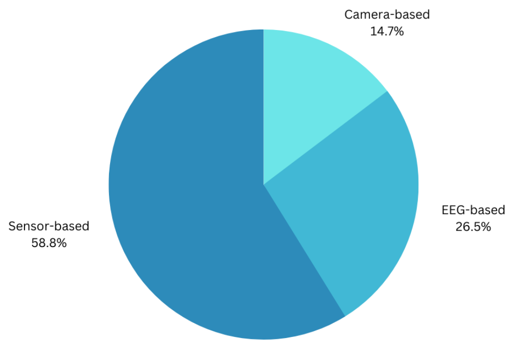

FIGURE 2.9: ratio of available devices for epileptic seizure detection

Most devices are available for people with epilepsy to monitor seizures associated with convulsive movements only. No single device exists that can forecast or prevent upcoming seizures or detects all types of seizures since different types present varying physiological and external symptoms.
Our focus is using sensor and camera-based technologies instead of relying on only one type like EEG-based or accelerometer-based devices. Sensors capture physiological signals like electrodermal activity, heart rate, and breathing patterns while cameras capture visible changes in facial expressions, body movements, etc., providing a comprehensive picture of normal and abnormal activities to forecast seizures as well as detect seizures more accurately.
Machine learning algorithms personalize the seizure forecasting and detection process considering the unique physiological characteristics of each individual user. This feature sets our project apart from others that rely on a one-size-fits-all approach resulting in a higher accuracy rate and reliable seizure detection.

Chapter 3

Ideation Process

3.1 Possible Solutions

The possible solutions can be divided into two categories:

3.1.1 Traditional Solutions

3.1.1.1 Nursing/ Caretaker Staff

Having nursing or caretaker staff present is a traditional solution for monitoring epileptic patients. These professionals are trained to recognize and respond to seizures effectively. They provide continuous monitoring and immediate assistance during seizure events, ensuring patient safety and comfort. However, relying solely on nursing or caretaker staff may not be feasible in all situations due to cost constraints or staffing limitations.

3.1.1.2 Family Members

Family members play a crucial role in caring for epileptic patients, especially in providing emotional support and assistance with daily activities. They can also help monitor the patient's condition and respond promptly to seizures. Family members are often familiar with the patient's medical history and individual needs, allowing for personalized care. However, relying solely on family members for monitoring may not be sustainable in the long term, especially if they have other responsibilities or lack specialized medical training.

3.1.2 Technological Solutions

3.1.2.1 Camera Based Monitoring

Camera-based monitoring systems utilize advanced technology to continuously observe the patient's activities and detect seizure events in real time. These systems typically employ computer vision algorithms to analyze video feeds and identify abnormal movements or behaviors indicative of a seizure. Camera-based monitoring offers the advantage of non-intrusive surveillance and can provide valuable insights into seizure patterns and frequency. However, privacy concerns and the need for adequate camera coverage in different environments are important considerations.

3.1.2.2 Sensor Based Monitoring

Sensor-based monitoring solutions utilize various types of sensors, such as accelerometers, gyroscopes, or wearable devices, to detect physiological changes associated with seizures. These sensors can be integrated into clothing, accessories, or placed in the patient's environment to capture relevant data. Sensor-based monitoring systems offer continuous monitoring without the need for direct human observation, allowing for early detection and timely intervention. However, the accuracy and reliability of sensor-based systems may vary depending on factors such as sensor placement and patient compliance.

Chapter 4

Implementation Plan

4.1 Models (Activity Recognition, Forecasting)

Timeline: June 2023 - July 2023

During this phase, the team will focus on developing robust models for activity recognition and forecasting. This involves data collection, preprocessing, feature engineering, model selection, and training. The aim is to create accurate and efficient models capable of recognizing and forecasting various activities based on input data.

4.2 Prototype Designing

Timeline: August 2023

In August 2023, the team will work on designing prototypes for both web and desktop platforms. This includes creating user interface mockups, wireframes, and user experience (UX) designs. The goal is to conceptualize the user interface and overall design of the product to ensure it meets user needs and expectations.

4.3 Prototype Implementation

Timeline: November 2023 - February 2024

During this phase, the team will implement the prototypes using selected technologies such as PyQt5, Django (djNGO), and Flutter. PyQt5 will be utilized for desktop application development, Django for web application development, and Flutter for mobile application development. The focus will be on translating the design concepts into functional prototypes with basic functionality.

4.4 Test Greater Models

Timeline: March 2024 - May 2024
In this phase, deep neural network models will be extensively tested and optimized for performance and accuracy. Various training techniques, hyperparameter tuning, and model architectures will be explored to enhance the models' capabilities. The objective is to ensure that the models deliver reliable and precise activity recognition and forecasting results.

4.5 Testing in Actual Environment

Timeline: June 2024 - July 2024
During this phase, the developed prototypes and models will undergo testing in real-world environments. User acceptance testing (UAT) will be conducted to gather feedback from users and identify any usability issues or bugs. The goal is to refine the product based on user feedback and ensure its readiness for deployment.

4.6 Marketing Plan

Timeline: August 2024
The marketing plan will be developed in August 2024 to promote the product effectively. This includes identifying target markets, defining marketing strategies, creating promotional materials, and planning marketing campaigns. The aim is to generate awareness and interest in the product among potential users and stakeholders.

4.7 Deployment of Product

Timeline: September 2024
The final phase involves deploying the product for public use. This includes setting up servers, configuring databases, ensuring scalability and reliability, and releasing the product to the target audience. The focus will be on delivering a seamless user experience and providing ongoing support and maintenance as needed.

Chapter 5

Prototype

The Prototype includes two main things which will act as an interface, a desktop application that will be used for streaming data processing and and managing all the models. Secondly, a web portal that will be a user interface for the end user of the product. Some snapshots of the prototype are included as follows:

5.1 Desktop Portal

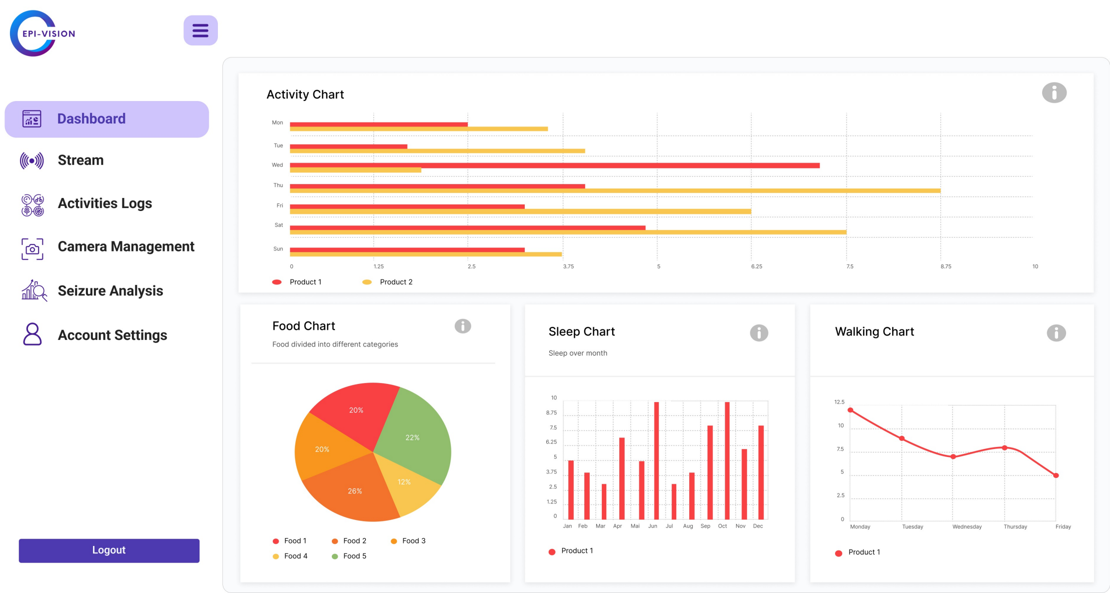

FIGURE 5.1: Dashboard

5.2 Web Portal

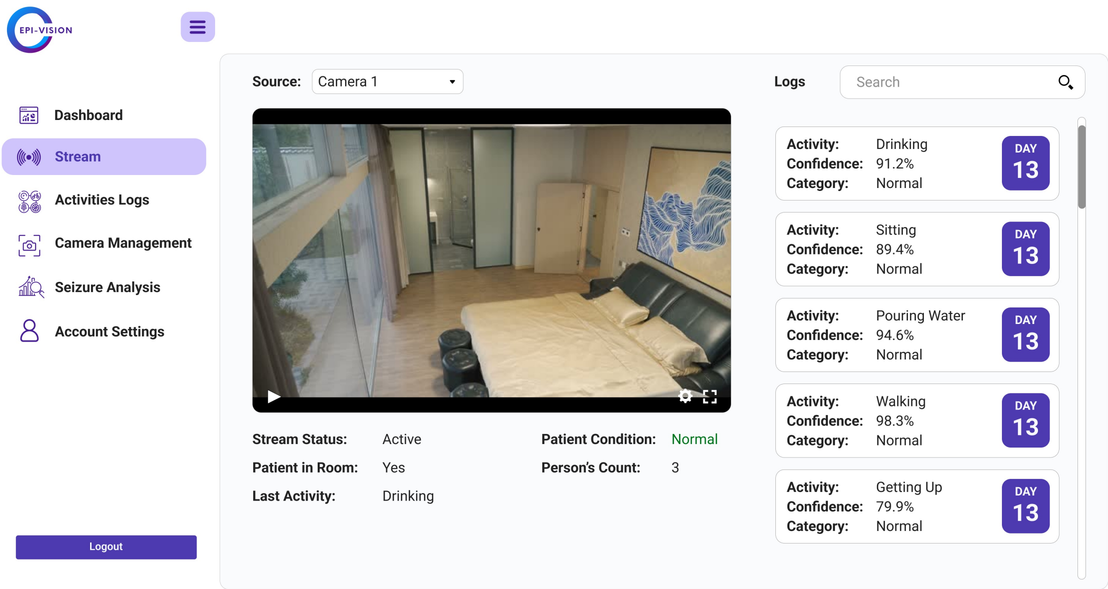

FIGURE 5.2: Stream

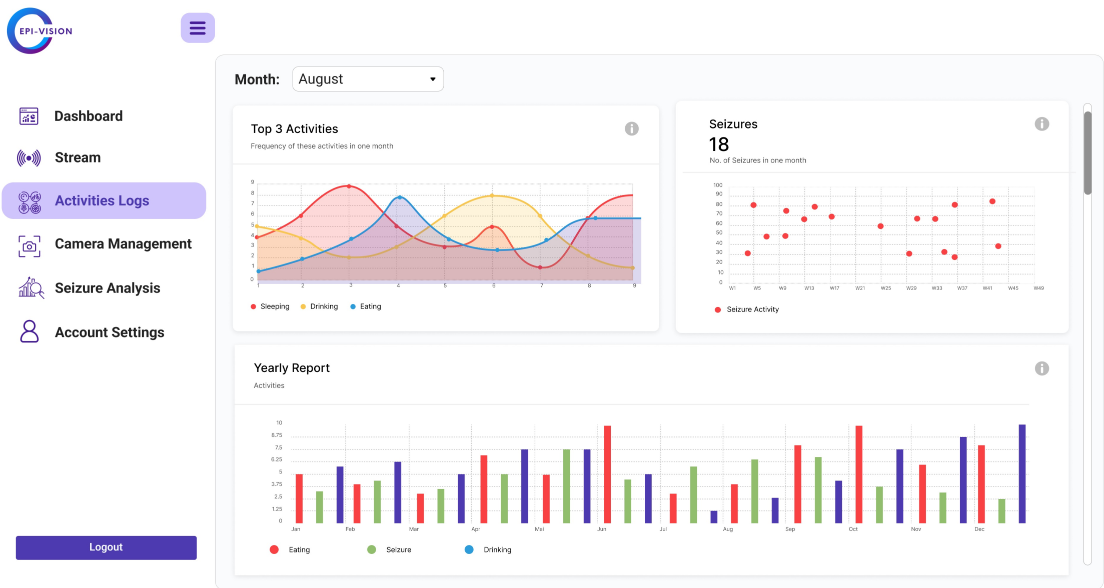

FIGURE 5.3: Activities/Charts

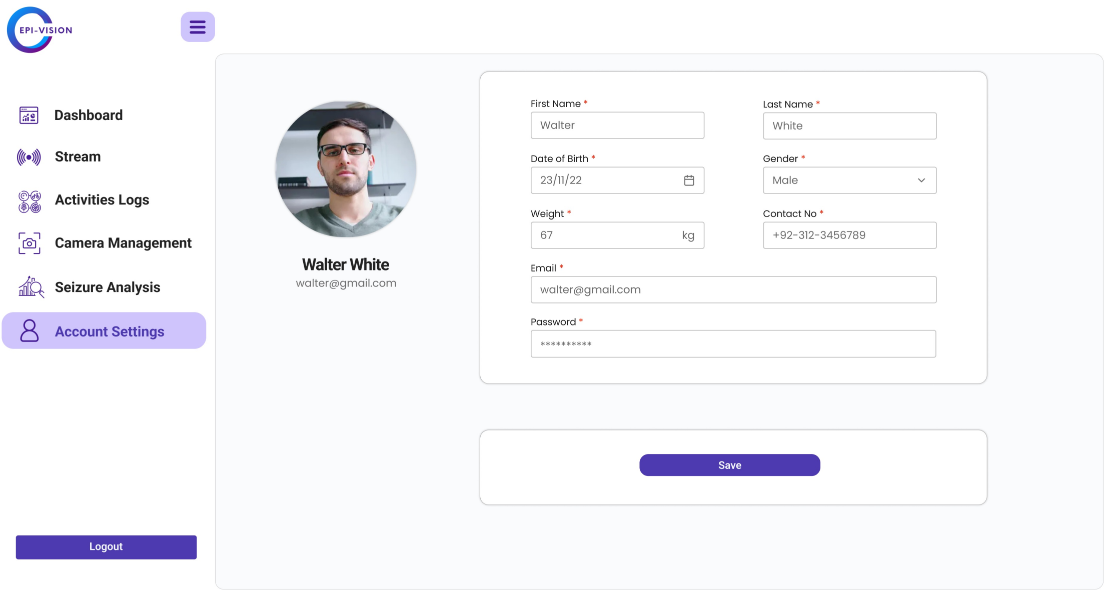

FIGURE 5.4: Profile

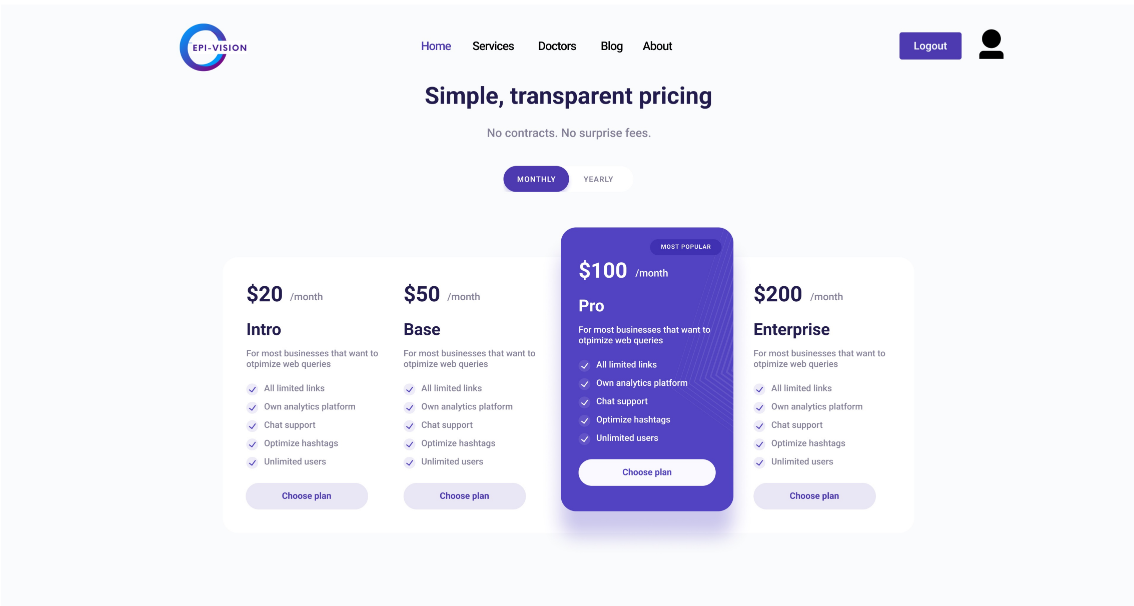

FIGURE 5.5: Pricing Plans

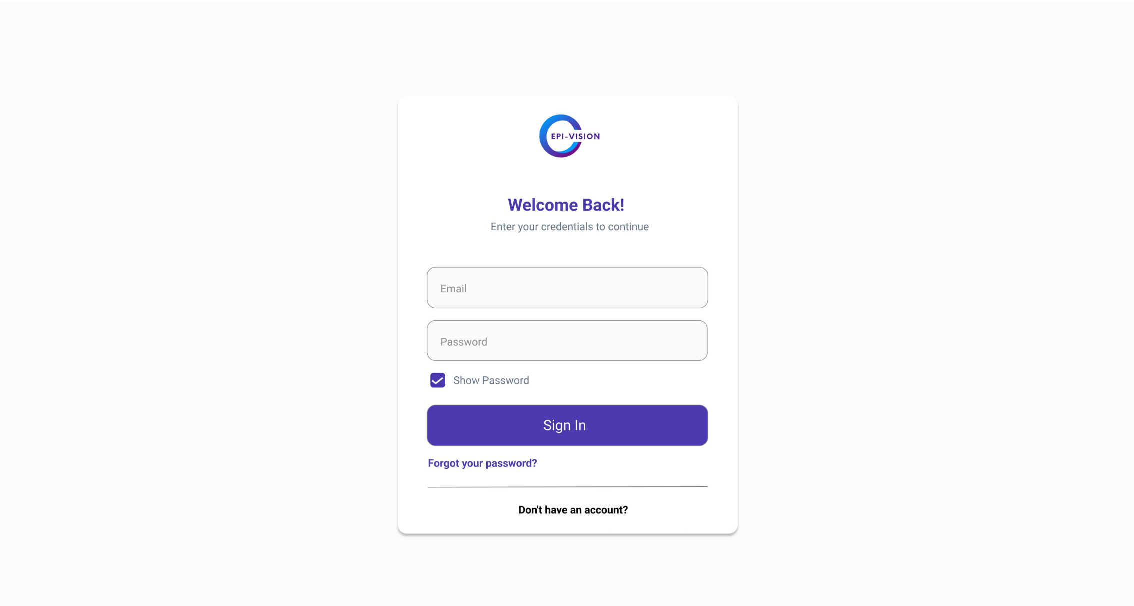

FIGURE 5.6: Sign In

Chapter 6

The Potential Impact of the idea

6.1 Impact of Project on SDGs

The Sustainable Development Goals (SDGs) aim to transform our world. They are a call to action to end poverty and inequality, protect the planet, and ensure that all people enjoy health, justice, and prosperity. It is critical that no one is left behind. Government of Pakistan has prioritized SDGs into three levels which will enable Pakistan to join the league of upper-middle class countries by 2030.

FIGURE 6.1: Sustainable Development Goals

Our solution mainly promotes or focuses on SDG 3 and SDG 10. The question that now emerges is how, out of all the Sustainable Development Goals, our solution supports SDG 3 and SDG 10. How our strategy reduces inequality while promoting health and well-being.

Sustainable Development Goals 3

- Our solution ensures healthy lives and promotes well-being by providing remote monitoring for epileptic patients so that they can maintain their health without any concern for additional medical expenses.

- It reduces the extra burden on caregivers by generating alarms in serious cases which can also prevent serious injuries by providing timely assistance.

Sustainable Development Goals 10

- It eliminates inequality and helps epileptic patients who have lack of resources in terms of health and well-being by providing them with a cost-effective solution.

- All the SDGs are interrelated by promoting goal 3 and goal 10, it can also help in promoting other Sustainable Development Goals like poverty.

Chapter 7

Conclusion

In conclusion, IoT-Vision Enabled Assistance for Epileptic Patients is a system that provides monitoring to epileptic patients. It uses IoT vision (camera) technology to capture the daily activities of the patient. A personalized model works behind the video-captured data of the patient and predicts abnormal activity (seizure) of the patient before time.

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