Sensing, ArtiFicial intelligence, and Edge networking towards Rural Health monitoring (SAFE-RH)

D2.3

Old Homes Monitoring Pilot

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Abstract

In rural areas of Pakistan, healthcare infrastructure is generally underdeveloped and lacking in contemporary tools and technologies. Especially, elderly people living in those areas face challenges due to lack of awareness and their physical, financial and support limitations. Furthermore, social ties and community relationships are often closer and more tightly knit than in urban areas. However, this can also mean that when an elderly person loses a spouse, friends, or family members, they may experience significant social isolation and loneliness. This can have a negative impact on their mental and physical health, leading to depression, anxiety, and other health issues. More than 40% of elderly population is having anxiety and depression issues but do not have direct access to psychologists, doctors and medical professionals-who often prefer to stay in urban regions, thus the elderly population in rural areas become more vulnerable. If an elderly people needs to travel to a hospital or clinic for specialized medical care, they might need transportation that has accommodations like a wheelchair ramp. Yet, given the scarcity of resources in rural areas, it can be challenging to locate such transportation. Even if transportation is available, it can be a significant expense for elderly people who may be living on a fixed income or limited budget. The cost of transportation, along with the cost of medical care itself, can be a significant financial burden for many elderly people and their families. The lack of access to advanced medical care in rural areas can also have serious health consequences for elderly people.

It is important to consider the cultural and social context in Pakistan when making decisions about caring for elderly family members. The social setup in Pakistan not recommends and is not favourable to move elderly parents or family members to old homes or hospitals and then left unattended, but rather then leaving them alone and unattended it is also important to ensure that they receive proper care and attention. This project addresses the aforementioned issues pertinent to elderly population in rural areas by linking them with medical experts available all around the world through user friendly system where patient can get appointment and discuss health issues on call with the doctor remotely according to availability of doctor and monitor their health by using IOT healthcare sensors.

1. Introduction

The Old Homes Pilot Project is a groundbreaking initiative aimed at using cutting-edge technology to improve the health and wellbeing of senior citizens. Modern machine learning methods are integrated into this pilot project at the Capital University of Science and Technology (CUST) in order to anticipate and prevent major health problems like fall and stroke, which are common among the senior population. The initiative aims to improve older individuals' quality of life by utilizing advanced predictive algorithms and data from many health monitoring devices to deliver tailored care and timely interventions.

1.1. Rationale

As the world progresses toward remote health monitoring for real-time and rapid diagnosis of health disorders, remote healthcare becomes an active research and development area. It can be divided into several categories, all of which refer to the use of technology to monitor patients outside of the hospital settings. There are manifold benefits of remote health monitoring, including early detection and prevention of diseases, continuous monitoring of the patients, cost reduction, especially the traveling and hospitalization costs, and more accurate creation of patients' health records. Remote health monitoring targets various sub-groups like the elderly, infants, and pregnant women. All these target groups require continuous monitoring and support. However, it is essential to appreciate various perspectives to develop an efficient remote health monitoring system that can serve the purpose.

SAFE-Rural-Health is a remote health monitoring system that aims to provide healthcare services in rural areas of Pakistan. The system focuses three target groups or scenarios, that is, Maternal, Infanct and elderly people. These groups have been assigned to different partner universities to work on. The CUST has been assigned "elderly people" target group, that is, those with the age more than 60 years. The Pilot provides a place for elderly people where they can be medically examined, they can stay/take rest and also are being monitored continuously. The project utilizes cutting-edge technologies such as big data, machine learning, intelligent sensing, the internet of things, and smooth communication to handle the complex problems associated with remote health monitoring.

Old homes monitoring in Pakistan typically involves a range of services, including medical care, personal care, and social support. Old homes in Pakistan often face challenges in providing quality care and support to their residents. With the aging population increasing in the country, it has become essential to find ways to improve the quality of life for elderly residents in these facilities. Remote health monitoring is one such solution that can help ensure the well-being of these residents while also reducing the burden on caregivers. Remote health monitoring uses technology to track a person's health status and provide alerts or notifications when there are changes or concerns, like, fall, stroke or general change in the physical well-being of a person. This can be especially helpful for elderly residents who may have chronic health conditions that require monitoring and management. In old homes, remote health monitoring systems can be set up to monitor vital signs such as heart rate, blood pressure, and oxygen saturation levels. These systems can also track daily activities such as sleeping patterns, eating habits, and medication management. Caregivers can then review this data and take necessary action if there are any concerns.

Using remote health monitoring in old homes can also help reduce the risk of falls and other accidents. Wearable devices such as smartwatches and fitness trackers can provide real-time alerts if a resident falls or experiences any sudden changes in activity levels. In addition to improving the quality of care for elderly residents, remote health monitoring can also help reduce healthcare costs. By providing early interventions and preventative care, the need for emergency medical interventions can be minimized, which can result in significant savings for both the resident and the facility.

Overall, implementing remote health monitoring in old homes can significantly improve the quality of life for elderly residents in Pakistan. By using technology to track their health status and provide early interventions, residents can receive better care and support, while caregivers can be more efficient in providing their services. In some cases, technology such as sensors and remote monitoring systems may also be used to provide additional support , like, report on general health condition of the person and help to keep older adults safe and comfortable in their homes. The aim is to facilitate patient access to knowledgeable physicians in remote places, lower the number of repeat hospitalizations and visits for chronic illnesses, lower the death rate from inadequate or delayed medical care, and provide patients with comfort while seeking medical advice.

1.2. Objectives

The Objectives of old homes monitoring pilot consist of:

1. **Quality of life:** To improve the quality of life for elderly by using technology to track their health status and provide early interventions.
2. **Health Surveillance:** Regular monitoring of vitals signs, medication adherence and symptoms remotely to detect any health issues or deviations from the baseline, enabling timely intervention and preventive care.
3. **Support for Caregivers:** Providing caregivers, whether family members or healthcare professionals, with real time information and alerts about the elderly patients' health status.

1.3. Expected impacts

The expected impacts of old homes monitoring pilot consist of:

1. **Improve the quality of life for elderly :** Improve the quality of elderly people by using remote health monitoring
2. **Reduced healthcare cost:** By preventing hospital admissions and emergency room visits through early detection and intervention, the system can lead to cost saving for both patients and healthcare systems.

1.4. Anticipated Outcomes

The Old Homes Pilot Project aims to achieve several key outcomes. These anticipated outcomes include:

1. Improve access to the healthcare personnels,. i.e. doctors and paramedics.
2. Reduce the rate of hospital readmission for chronic disease patients through remote monitoring.
3. Access to the wide range of medical experts world wide.

2. Description of the Pilot

According to the World Health Organization (WHO), elderly people are defined as individuals who are 60 years of age or older. Because they commonly have physical, mental, and emotional illnesses, elderly people frequently have difficulty performing fundamental everyday tasks. To make their lives easier and maintain their quality of life, they require the right facilities and technologies. Old homes monitoring pilot focuses on setting up a pilot project to significantly improve the quality of old people by use of remote healthcare monitoring. The goal of the project is to solve new research issues in the creation of non-invasive wearable and non-wearable sensors that can offer critical measurements about elder users in addition to sending out emergency alerts in cases like fall or extended periods of inactivity. A security middleware layer has been designed to address the interaction between the various levels, including the sensor tier, edge/fog components, and the cloud. This layer makes it possible for multi-vendor devices to communicate effectively and efficiently while also acquiring and processing smart data. The design and interaction of the two tiers: fog and cloud, is an open research question, where the design has to determine the priority of each task, and where it is performed, based on criticality, privacy issues, complexity to guarantee security and reliability. Finally, artificial intelligence (AI) and machine learning (ML) are emerging technologies that have been widely accepted to be the next key technology in network performance enhancement. Through training in e-commerce and ICT, health workers and patients will be trained to use latest tools of communication. The Figure-1 The Figure 1 below presents the architecture of SAFE-RH Old Home Pilot.

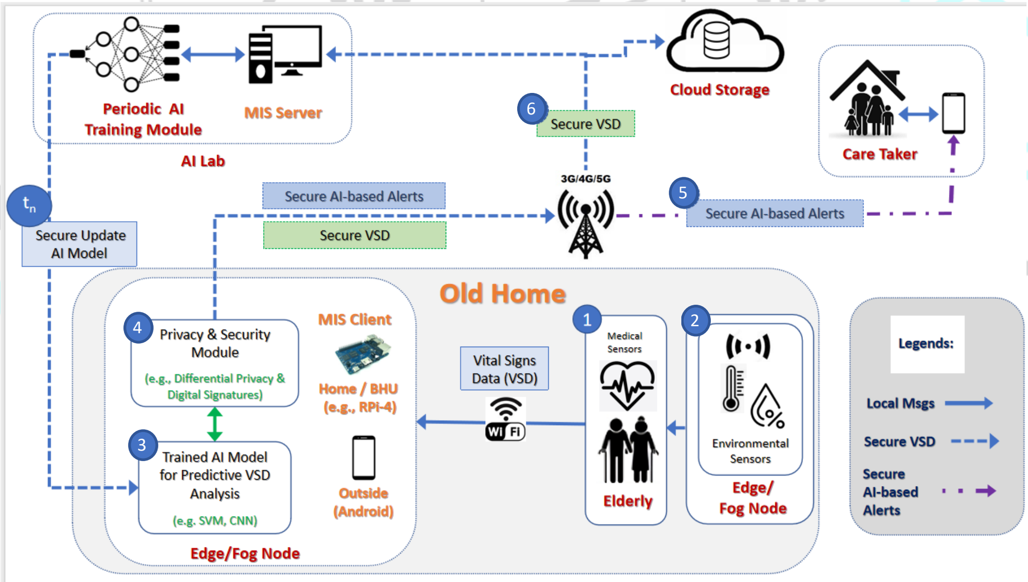

Figure-1 Architecture of SAFE-RH Old Home Pilot

The larger box below titled “Old Home” represents Old Home Pilot. At this place, elderly people are being monitored with two types of sensors. Box 1 shows the medical sensors that capture different readings. Here, we are continuously capturing temperature, pulse rate and motion (from accelerometer and gyroscope) through a smart watch that the elderly person is putting on his/her wrist. Other than that, there are multiple smart medical devices that can be applied when required capturing different readings, like weighing scale for weight, glucometer for blood glucose, Oximeter for heart rate and oxygen level and blood pressure device. These devices capture readings of the elderly person and send data to Edge/Fog node through Wi-Fi.

Other than Fog node that captures medical readings, there is another Fog node, labeled 2, in the Old Home that handles the data from environmental sensors. We are using sensors for room temperature, humidity and light control. Environmental sensors are continuously monitoring the readings, and transferring data to the relevant Fog node where different parameters are set to control the environment. For example, if there is no movement for a certain duration in the room and the light is on, then the light is turned off. Likewise, the humidity sensor captures the humidity of the room after a defined interval, if the humidity level of the room falls below a set level, then the humidifier is turned on and water vapors are sprayed in the room to maintain the humidity level. The third sensor is the temperature sensor that is sending temperature reading to the Fog node, if the temperature raises from a set level then the AC is turned on which automatically turns off after setting the temperature. The box 3 in Figure 1 shows the ML models deployed on the Fog node, that are activated to generate alarm in the critical situations as explained in section 3. Since, the SAFE-RH is handling medical data of persons, maintaining the security of the data is very critical. For this purpose, box 4 shows the security mechanisms that are applied to the data while transferring among different components of the system.

Data after passing through the Fog node and security node (boxes 2 and 3) moves to the AI lab and cloud at the same time. At cloud data is placed for storage to be used later on. In the AI lab, the ML models are evaluated to trace any drift in the models. If the concept drift is traced in the models, then the ML models are retrained using current data, and these re-trained models are then deployed on the Fog node in the old home.

This description briefly explains the architecture of old home pilot. Description of the equipment and scenarios is given in the following sub-sections: .

2.1 Process of setting up pilot activities

This section provides an overview of the foundational activities, key components, and specific module setup required to launch the pilot successfully.

A. Management Information System (MIS) of SAFE-RH

The SAFE-RH system is a healthcare delivery method that utilizes technology to providepatient care outside of traditional clinical settings. The system includes specific technology that enables electronic transmission of information between patients and physicians, and provides e- consultation. The main goal of the SAFE-RH MIS is to facilitate smart learning processes for paramedics, patients, doctors, care takers and incorporate technology such as the MIS to allow them to add or delete patients, schedule or cancel appointments, generate relevant content or tests, and prepare for challenging situations using virtual reality-based technologies. Additionally, the system enables stakeholders i.e. doctors, patients, paramedics and care takers to communicate remotely. The SAFE-RH MIS web application links different stakeholders and smart IOT devices. Information is exchanged between devices and stakeholders through MIS. For each user type, there are different functions of SAFE-RH MIS. To access the SAFE-RHMIS, users must log in and log out when finished. The system is supported by AI component where Raspberry Pi server serves as a fog node for AI models. Patient/paramedic attaches device with patient and adds a device name on MIS, real time data is then fetched from sensors and the general details of patients are fetched from MIS to the fog node where the complete record is passed through the AI models and the result is predicted. Sensors are continuously generating data and sending to the fog device installed in the facility. Fog node is processing the data and generates alarm in case of any emergency situation, otherwise data is forwarded to technology lab and to the cloud server.

B. Elderly module

The case study at CUST is the elderly people, those with the age more than 60 years. The Pilot provides a place for elderly people where they can be medically examined, they can stay/take rest and also are being monitored continuously. For this purpose, the Pilot includes devices that can control the environment, like temperature and light, the devices that can take their vitals' reading and transfer to SAFE-RH MIS for recording and also the fog-devices that host the AI model are also examining the vitals of elderly people to detect any emergency situation, like Stroke or Fall Detection.

For this purpose, multiple smart devices have been purchased, integrated and deployed at the Pilot. Initially pilot was implemented in a research lab at CUST, after things got matured, the Pilot has been shifted to the Dispensary *Figure-1* that exists inside CUST, and later pilot will be transported to a proper old home.

Figure-2 SAFE-RH Old Home Pilot

In the following, equipment acquired for the Old Homes Pilot of SAFE-RH at CUST are given in *Table-1* and *Table-2*.

Table 1: SAFE-RH Old Home Equipment

Sr. #	Name	Description
1.	L-Serial Smart Gateway	WI-FI+BLE5.0 support available and it will send data through MQTT protocol
2.	Smart Watch	Send data through Bluetooth Low Energy (BLE)
3.	Samsung Watch 6	To get the heart rate, temperature, ECG, Accelerometer and Gyroscope data from sensors through Wifi.
4.	Pulse Oximeter	To get Fingertip Pulse and Oximeter data through BLE
5.	Blood Glucometer	To get the blood glucose data through BLE
6.	BP Monitor	To get the systolic and diastolic data through BLE
7.	Weight Monitor	To get the Weight data through BLE

The table 2 below outlines the environmental equipment used in the Old Homes Pilot Project.

Table -2: Environmental Equipment

Sr. #	Name	Description
1.	ESP32 Micro Controller	Used to receive data from pi perform operations and send signal to relay
2.	Single Channel Relay	Used to receive data from ESP32 and perform the action according to signals received.
3.	PIR Motion Sensor	Detect Motion and send signals and sends signal to gateway.
4.	Temperature and Humidity Sensor	Detect temperature and humidity and sends signal to gateway.
5.	Environmental Gateway	Receive data from sensors and send to raspberry Pi.

An overview of the supporting equipment used in the Old Homes Pilot Project is given in table-3 below. These components facilitate the development, deployment, and operation of the health monitoring system. Additionally, the data fetched from the server is utilized for various purposes beyond the old homes.

Table-3: Supporting Equipment

Sr. #	Name	Description
1.	Laptops: hp notebook probook 450 g8 intel core i7, 512 GB SSD harddrive, DDR4 160GB, 2GB graphic card.	Provided to MIS development team
2.	Multi Media: panasonic multimedia projector: PT-LB306, multimedia projector screen: 6*6, cables	To be used for the training sessions to be conducted at the training venue, placed in Conference room
3.	Server Machine	To store MIS data and to train the AI models, placed in server room
4.	Raspberry Pi 4	Imported, To be used as fog node
5.	SMS Facility	SMS to be generated from MIS for the stakeholders
6.	Domain- SAFE-RH-mis.com	Domain acquired for hosting project MIS
7.	Businessvps- SAFE-RH-mis.com	MIS deployed successfully and is being used by multiple stakeholders

C. Use Cases

In the context of rural healthcare and modern technology, Two distinct scenarios illustrate the application of advanced medical information systems: the "Old Home" setting and the "Online" system. Each use case demonstrates how technology can be leveraged to enhance patient care, whether through traditional in-person visits or through digital platforms.

i. Old Home

Old home is a facility that has been specifically created for elderly people. Where they are provided a supportive environment and attention; where they can spend their time in a quality way. The Old Home proposed in SAFE-RH also has got the access to a Medical Information System (MIS) that stores the personal and medical data about the elderly persons living there. The personal information, such as name, age etc., and medical data includes different health related data taken by doctor or paramedic or data scanned through scanners, including heart rate, blood pressure, and ECG readings, using wearable sensors. An AI system analyzes this data for signs of health issues like strokes. The Old Home includes several patient beds for those requiring extended observation or treatment. Upon arrival, staff at old home registers the patient by filling out a form with essential information such as name, gender, marital status, father's name, age, address, CNIC, and phone number.

After registration, the staff books an appointment with the doctor. The system then displays the patient's details and various forms, including General Examination, Current Illness, and Previous Diseases. The staff enters general vitals such as body weight, height, BMI, body temperature (in Fahrenheit), pulse, oxygen saturation and respiration rate and attaches IoT devices to the patient and binds the device by adding the device id on MIS. These devices collect the patient's vitals and transmit the data to a gateway device at the old home and stores it in the patient's account. The doctor can view all the data entered by the staff. During the visit, healthcare providers review data, discuss any AI-generated alerts, and conduct a thorough examination. This integrated approach ensures that the patient receives personalized, timely care, enhancing the early detection and management of potential health problems.

ii. Remote monitoring Scenario

In a remote health monitoring system, a patient resides in a remote location and receives checkups from a doctor through an advanced Management Information System (MIS). This system facilitates comprehensive and continuous health monitoring, allowing healthcare providers to assess the patient's condition and deliver timely care remotely. The integration of various sensors, data transmission technologies, and AI-driven analytics ensures that the patient’s health is closely monitored, even from far away.

In a remote monitoring scenario, health data is collected by various sensors, including blood pressure monitors, oximeters, glucometers, weight monitors, and fall detection sensors, which are placed on or near the elderly person. These sensors continuously monitor the patient's vitals and send the data to a monitoring gateway. The gateway device aggregates the collected data before sending it to a cloud server and stores the health data. An API facilitates communication with the database, allowing for data retrieval as needed.

MIS contains the patient's information, such as name, age, and medical history. Meanwhile, dynamic health data, such as heart rate, blood pressure, glucose level and ECG readings, are continuously monitored at or at home using wearable sensors.

Additionally, machine learning models that are deployed on fog node can be used to analyze activity and behavior data to predict potential health issues or emergencies. The prediction module communicates with the cloud server to access the health data and make predictions. Some of the static general attributes of patient i.e. gender, age etc. are fetched from MIS. Continuous real time values of BP and glucose are coming from the sensor that are attached with the patient in home. After that, a complete record is then passed through the AI/ML model that are deployed on fog node and prediction is made. Analytic software which is MIS can then be used to analyze the health data and identify any patterns or abnormalities. This information can be used to trigger alerts or notifications for healthcare professionals or family members. Users can also access their health data through a user device, such as a personal computer. This allows them to monitor their own health and receive notifications about any changes or concerns. Patients can also upload their reports, prescription etc.

3. Prediction Models

Two AI models have been deployed on fog node that are:

3.1. Stroke Prediction in Elderly Persons using Remote Health Monitoring

Stroke prediction involves using machine learning models to analyze patient data and predict the likelihood of a stroke, allowing for early intervention and improved patient outcomes. This predictive approach leverages various health metrics and patient attributes to identify individuals at high risk of experiencing a stroke.

Stroke prediction model is being developed by using an Electronic Health Record (EHR) dataset from Kaggle (https://www.kaggle.com/datasets/fedesoriano/stroke-prediction-dataset), consisting of 43,401 records with one output class (stroke) and 11 input attributes, shown in *Figure-2*. After excluding the patient ID, the dataset is pre-processed to handle missing values by replacing them with the mean BMI value and encoding categorical attributes numerically, shown in *Figure-3* .

id	gender	age	hypertension	heart_disease	ever_married	work_type	Residence_type	avg_glucose_level	bmi	smoking_status	stroke
9046	Male	67	0	1	Yes	Private	Urban	228.69	36.6	formerly smoked	1
51676	Female	61	0	0	Yes	Self-employed	Rural	202.21	N/A	never smoked	1
31112	Male	80	0	1	Yes	Private	Rural	105.92	32.5	never smoked	1
60182	Female	49	0	0	Yes	Private	Urban	171.23	34.4	smokes	1
1665	Female	79	1	0	Yes	Self-employed	Rural	174.12	24	never smoked	1
56669	Male	81	0	0	Yes	Private	Urban	186.21	29	formerly smoked	1
53882	Male	74	1	1	Yes	Private	Rural	70.09	27.4	never smoked	1
10434	Female	69	0	0	No	Private	Urban	94.39	22.8	never smoked	1
27419	Female	59	0	0	Yes	Private	Rural	76.15	N/A	Unknown	1
60491	Female	78	0	0	Yes	Private	Urban	58.57	24.2	Unknown	1
12109	Female	81	1	0	Yes	Private	Rural	80.43	29.7	never smoked	1
12095	Female	61	0	1	Yes	Govt_job	Rural	120.46	36.8	smokes	1
12175	Female	54	0	0	Yes	Private	Urban	104.51	27.3	smokes	1
8213	Male	78	0	1	Yes	Private	Urban	219.84	N/A	Unknown	1
5317	Female	79	0	1	Yes	Private	Urban	214.09	28.2	never smoked	1
58202	Female	50	1	0	Yes	Self-employed	Rural	167.41	30.9	never smoked	1
56112	Male	64	0	1	Yes	Private	Urban	191.61	37.5	smokes	1
34120	Male	75	1	0	Yes	Private	Urban	221.29	25.8	smokes	1

Figure-3 Data Attributes

id	gender	age	hypertension	heart_disease	ever_married	work_type	Residence_type	avg_glucose_level	bmi	smoking_status	stroke
9046	1	67	0	1	1	2	1	228.69	36.6	1	1
51676	0	61	0	0	1	3	0	202.21		2	1
31112	1	80	0	1	1	2	0	105.92	32.5	2	1
60182	0	49	0	0	1	2	1	171.23	34.4	3	1
1665	0	79	1	0	1	3	0	174.12	24	2	1
56669	1	81	0	0	1	2	1	186.21	29	1	1
53882	1	74	1	1	1	2	0	70.09	27.4	2	1
10434	0	69	0	0	0	2	1	94.39	22.8	2	1
27419	0	59	0	0	1	2	0	76.15		0	1
60491	0	78	0	0	1	2	1	58.57	24.2	0	1
12109	0	81	1	0	1	2	0	80.43	29.7	2	1
12095	0	61	0	1	1	0	0	120.46	36.8	3	1
12175	0	54	0	0	1	2	1	104.51	27.3	3	1
8213	1	78	0	1	1	2	1	219.84		0	1
5317	0	79	0	1	1	2	1	214.09	28.2	2	1
58202	0	50	1	0	1	3	0	167.41	30.9	2	1

Figure-4 Encoded Labels

A. Handling Class Imbalance

To address the class imbalance, where only 783 records indicate a stroke, the Synthetic Minority Oversampling Technique (SMOTE) is applied for balancing the dataset. SMOTE works by generating synthetic samples for the minority class (stroke) by interpolating between existing minority class samples. This approach balances the dataset by increasing the number of stroke records, which helps improve the performance and robustness of the predictive models.

B. Feature Selection

Feature selection is conducted using the selectKBest technique, which identifies the most significant attributes for stroke prediction. The selectKBest technique ranks features based on their statistical significance, selecting the top features that contribute the most to the target variable. The features identified as most significant include age, heart disease, average glucose level, hypertension, marital status, and smoking status.

C. Classifiers Employed

Multiple classifiers, including Decision Tree, Random Forest, SVM, and XGBoost, are employed with different training/testing split ratios.

i. Decision Tree:

A Decision Tree classifier works by splitting the dataset into subsets based on the most significant attribute at each node. This process continues recursively, creating a tree-like model of decisions. Decision Trees are easy to interpret and visualize but can be prone to overfitting, especially with complex datasets.

ii. Random Forest

Random Forest is an ensemble learning method that constructs multiple decision trees during training and outputs the mode of the classes (classification) or mean prediction (regression) of the individual trees. It mitigates the overfitting problem of individual decision trees by averaging multiple trees, thus improving predictive performance and robustness.

iii. Support Vector Machine (SVM)

SVM classifiers work by finding the hyperplane that best separates the classes in the feature space. It is particularly effective for high-dimensional spaces and cases where the number of dimensions exceeds the number of samples. SVMs can handle linear and non-linear classification through the use of kernel functions.

iv. XGBoost

XGBoost (Extreme Gradient Boosting) is an advanced implementation of gradient boosting for supervised learning. It focuses on model performance and computational efficiency. XGBoost builds multiple trees sequentially, where each tree corrects the errors of the previous one. It supports regularization, which helps reduce overfitting, and offers superior performance and speed compared to other classifiers.

The best results are achieved with the XGBoost classifier using a 70/30 split ratio where shows superior performance using both the original four and the newly selected six features. Overall, the methodology successfully preprocesses the data, selects relevant features, and employs effective classifiers to enhance predictive accuracy for stroke, with XGBoost delivering the best results. XGBoost model is deployed on fog node for further processing.

D. Deployment on Fog Node

Once the model is trained, it is deployed on a fog node for real-time monitoring. Blood glucometer and BP monitor devices are attached to the patient to continuously collect real-time health data. The fog node acts as an intermediary device that aggregates data from these sensors and processes it locally before sending it to the cloud.

Binding the fog node device involves associating the sensors with the patient's profile in the Medical Information System (MIS). The attributes of the patient, such as name, age, and gender, are fetched from the MIS. The continuous real-time values from the sensors, such as blood pressure *figure-4* and blood glucose *Figure-5*, are combined with these static attributes to create a comprehensive health record. This record is then passed through the trained model to make predictions about the patient's stroke risk.

E. Alert System

The prediction results are transmitted back to the MIS server, which analyzes the data and generates alerts if any health risks are detected. The MIS server then sends alerts to the caregivers, healthcare professionals, or other stakeholders to enable timely intervention. The alert system ensures that potential health issues are promptly addressed, enhancing patient care and monitoring in remote settings.

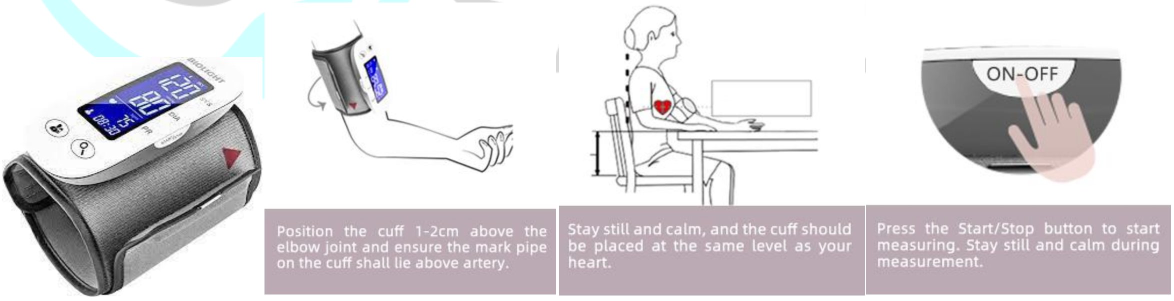

Figure-5 Blood Pressure Monitor

Figure-6 Blood Glucometer

3.2. Fall Detection

The development of a fall detection model initially utilized the K-Fall dataset (https://sites.google.com/view/kfalldataset?pli=1), leveraging accelerometer and gyroscope data from sensors mounted on the lower back. While the model demonstrated high accuracy during training, it encountered significant performance issues when deployed on a fog node and tested with real-time data from a wrist-worn S6 watch, shown in below *Figure-7.* These issues were primarily due to differences in sensor positioning and data compatibility, as movement patterns captured by wrist-worn devices differ from those recorded at the lower back.

A. Data Collection and Synchronization

To tackle the above challenges, we collected our own dateset from the watch, using data from different subjects. A timer app is implemented to ensure precise synchronization of data collection between the watch and the fog node, facilitating accurate alignment of timestamps. The collected data was then pre-processed to match the format. Feature engineering was employed to calculate the magnitudes of the accelerometer and gyroscope data, providing a single, orientation-independent measure of movement.

B. Model Training and Validation

A new LSTM model was trained using the synchronized and pre-processed data. The model was validated using a portion of the real-time data to ensure it generalized well to real-world conditions. Through rigorous evaluation and hyper-parameter tuning, the model achieved an impressive accuracy of 91%. This optimized model was then deployed on the fog node for real-time testing.

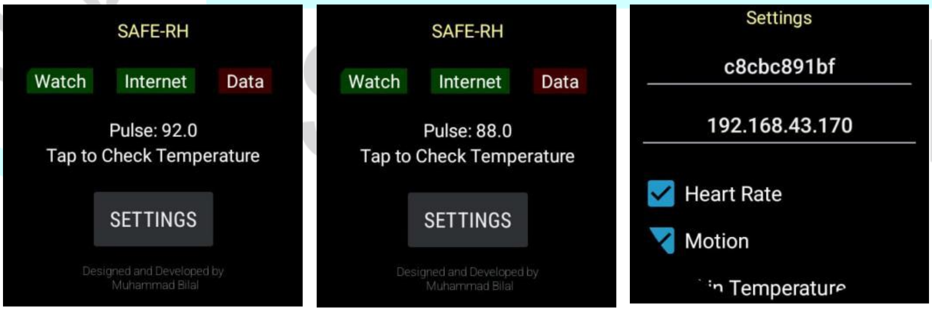

Figure-7 Samsung S6 Watch

C. Real-Time Deployment and Continuous Improvement

In real-time deployment, the model effectively processed the incoming data from the wrist-worn watch and demonstrated reliable fall detection, generating alerts when a fall was detected. This approach, which included meticulous data synchronization, robust preprocessing, and advanced feature engineering, ensured that the fall detection model could adapt to the wrist-worn sensor data, maintaining high accuracy and reliability in real-world applications.

The following diagram, *Figure-8*, illustrates the system architecture for fall detection, emphasizing the data collection and communication process using MQTT protocol.

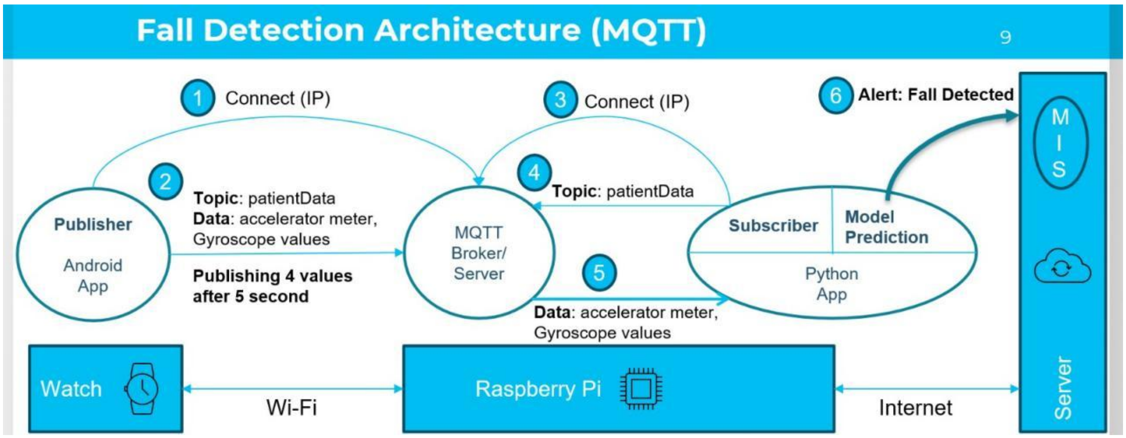

Figure-8 Fall Detection Architecture Diagram

Here's a breakdown of the architecture:

i. Publisher

- Device: Android App (installed on a watch)
- Task: Connects via IP, collects data from accelerometer and gyroscope sensors, and publishes this data under the topic "patientData".
- Frequency: Publishes 4 values every 5 seconds.

ii. MQTT Broker/Server

- Acts as an intermediary that receives the data from the publisher.
- The broker/server forwards the data to subscriber interested in the "patientData" topic.

iii. Subscriber

- Python Application running on Raspberry Pi 4.
- Connects via IP and subscribes to the "patientData" topic to receive the data.
- The data received includes accelerometer and gyroscope values from s6 watch.

iv. Model Prediction on Fog node

- The Python application processes the incoming data and formats it according to the model's requirements, then passes the formatted data to the trained model on the Raspberry Pi to make fall predictions shown in *Figure-9.*
- If a fall is detected, it sends an alert.

v. Alert System

- An alert indicating a fall is detected and sent to a Management Information System (MIS).

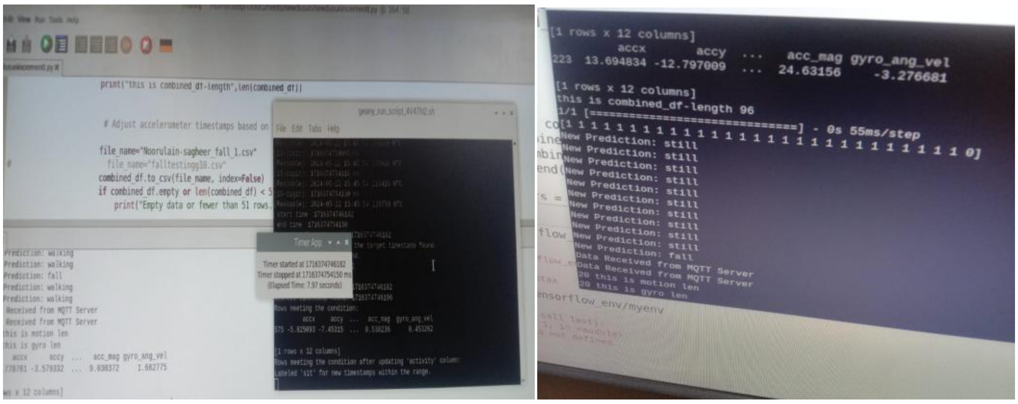

Figure-9 Fall Prediction on Fog Node

Continuous learning mechanisms are suggested to further refine the model's performance over time, adapting to changes in user behavior and ensuring sustained accuracy and efficacy in detecting falls.

3.3. Environment sensors

The Environmental Control Module for the Old Home Pilot is designed to enhance comfort, safety, and energy efficiency within residential spaces. This module integrates three primary environmental aspects: motion detection, temperature regulation, and humidity control. Following *Figure-10* shows the functionality and operational procedures of each component within the module.

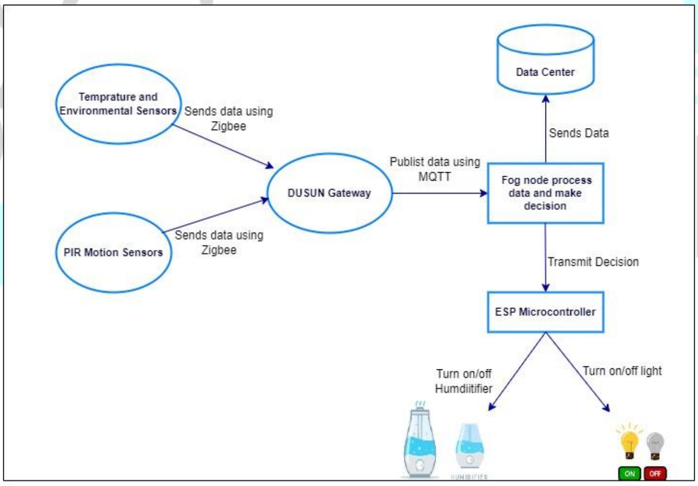

Figure-10 Environmental System

3.3.1 Sensors Types

The motion detection system aims to ensure efficient lighting management within the premises, conserving energy while providing convenience to the residents. When motion is detected by the sensor as someone enters the room, the lights are automatically turned on. The lights will remain on for a duration of 3 minutes. If, within the initial 3-minute period, further motion is detected, the timer resets, and the lights stay on for an additional 3 minutes from the last detected motion. If no motion is detected after the initial 3-minute period, the lights will automatically turn off to conserve energy. The motion detection system utilizes passive infrared (PIR) sensors to detect movement. These sensors are strategically placed to cover the entire area of the room, ensuring reliable detection and operation. The PIR motion sensors send data using Zigbee to the DUSUN Gateway, which then publishes data using MQTT to the fog node for processing and decision-making. The decision is transmitted to an ESP micro-controller that controls the lights.

The temperature regulation system maintains a comfortable temperature within the Old Home Pilot, optimizing for energy efficiency and resident comfort. If the temperature rises above 25°C, the air conditioning (AC) system is automatically activated to cool the environment. The AC continues to operate until the temperature drops to 20°C. Once the temperature reaches 20°C, the AC will automatically turn off to prevent over-cooling and save energy. Temperature sensors are placed in key locations within the premises to ensure accurate readings. The AC system is integrated with these sensors to allow for automatic control based on real-time temperature data.

The humidity control system maintains optimal humidity levels within the Old Home Pilot, ensuring comfort and preventing issues related to too high or too low humidity levels. If the humidity level falls below 30%, the humidity control system (referred to as the "Humidity-fire") is activated to increase moisture in the air. If the humidity level exceeds 50%, the humidity control system is turned off to prevent excess moisture, which could lead to discomfort or potential mold growth. Humidity sensors are deployed throughout the premises to provide accurate readings. The Humidity Fire system, possibly a humidifier or similar device, is controlled based on the sensor data to maintain the desired humidity range.The data from the sensors is sent to the DUSUN Gateway, which publishes it to the fog node for processing. The fog node's decisions are transmitted to the ESP micro- controller, which can turn on or off the humidifier based on the humidity levels.

4. Implementation of Old Home Pilot

Old Home Pilot Implementation

In this section, the deployment and demonstration of Old Home Pilot has been mentioned. The old home pilot was initially tested and deployed at a research lab in CUST where it was developed as well. Once it was found to be in consistent state, the CUST team deployed the system in dispensary of the university, where a paramedic is available during the day time, and further testing and usage of the system was performed there. The following pictures in *figure-11* show the inauguration and working of the old home pilot in CUST.

Figure-11 Inauguration of Old Home Pilot at CUST

The pilot was demonstrated at two Rural Health Centres (RHU) near Bahawalpur. One RHC is Khutrhi-Bangla and other at Khanqah Sharif. At both places, the project was explained to the local staff who took much interest in it. The system was demonstrated at both places and was appreciated by the medical staff and patients both. They showed interest in the proper deployment of the system there, which needs negotiations with the Government officials. Figure-12 below shows few pictures of the RHCs demonstration.

 

Figure 12 Demonstration of Old Home Pilot and RHQs near Bahawalpur

The demonstration at all rural health centres went very well and it was established that the SAFE-RH system is really needed in the rural area and it can help in improving the health support of the people living there.

5. Mapping Anticipated Outcomes

In the following, the mapping between anticipated outcome have been mapped with the features that are provided by the Old Home Pilot.

Anticipated Outcome	Relevant Feature(s) Supported
Improve access to the healthcare personnels	- Elderly person (EP) can access doctors and paramedics online from remote areas at any time. - EP can schedule consultations at any time, ensuring continuous access to healthcare. - Doctors can provide diagnoses and prescribe medications remotely, ensuring timely intervention and treatment.
Reduce Rate of Hospital Readmission for Chronic Disease Patients	- Old Homes Pilot Project utilizes AI models for stroke prediction and fall detection to achieve the goal of reducing hospital readmission rates for chronic disease patients by enabling timely interventions and proactive healthcare management.`
Access to the wide range of medical experts world wide	- Patients can have virtual consultations with specialists from different parts of the world using MIS, accessing expertise that may not be available locally.

The mapping above clearly shows that the anticipated outcomes have been achieved through functionalities provided in MIS and through the relevant medical equipment purchased for this purpose. The hardware and MIS have synched well to provide an integrated system.

6. Conclusion

This document presented the Old Home Pilot in detail highlighting conception, objectives, architecture, components and implementation details. The architecture is flexible in the sense that it is in working position with certain components, but further components cab be added when and if required. For example, currently certain medical and environmental sensors are working in the Old Home Pilot, however, later if we like we can add further smart devices to get other signals, like ECG. Secondly, the fog node, presently, contains stroke prediction and fall detection models, but we can deploy more models on the fog node. This gives flexibility to the system and it may become more useful in future.