Maintaining Independence, Ensuring Safety

IoT and AI for Assisted Living

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PRESENTATION FLOW

- OBJECTIVES
- RATIONALE
- LITERATURE REVIEW
- PROJECT ARCHITECTURE
- PROJECT PLAN
- PROJECT ASPECTS

OBJECTIVES

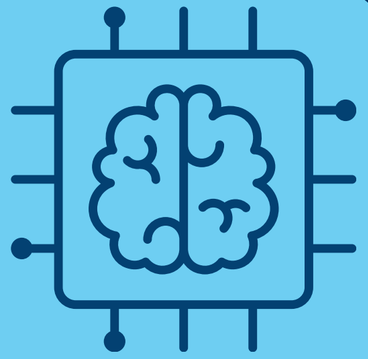
1

Create a IoT and AI system to assisted living

2

8 devices - 5 sensors 3 actuators

3



AI to learn routines and flag anomalies

4

Privacy first design

5

App for caregivers and family members

6

Continuous monitoring

RATIONALE

DEMAND FOR ASSISTED LIVING SOLUTION

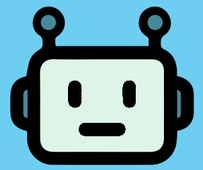
- Aging population
- Shortage staff
- Requires continuous oversight


LIMITATIONS OFF CURRENT SOLUTION

- Cloud dependencies
- Use of wearable devices
- Alert fatigues


VALUE OF IOT SENSOR NETWORKS & EDGE AI

- Real time, unobtrusive monitoring
- Low latacing processing
- Privacy protection
- Early intervention




UNIFIED CLOUD BACKEND FOR RELIABILITY & ACCESSIBILITY

- Secure central access
- DB store long records
- Cross platform, intuitive access
- Easy scalability


LITERATURE REVIEW

EXISTING SOLUTIONS

- STACKCARE [1]
- SECOM SMART WELLNESS [2]
- TAKING CARE SENSE [3]
- HOME ASSISTANT [4]
- APPLE HOME KIT [5]
- AMAZON ALEXA TOGETHER [6]

ACADEMIC ARTCILES

- BENEFITS AND BARRIERS ASSOCIATED WITH THE USE OF SMART HOME HEALTH TECHNOLOGIES[7]
- AN AIOT-ENABLED AUTONOMOUS DEMENTIA MONITORING SYSTEM[8]
- THE ROLE OF SMART HOMES IN PROVIDING CARE FOR OLDER ADULTS[9]
- MOTION & POWER SENSORS VITAL FOR WELL-BEING[10]
- ADOPTION DEPENDS ON PRIVACY & USABILITY[11]
- SMART HOME PLATFORMS INTEGRATE IOT DEVICES WITH MOBILE APPS[12]
- CROSS-PLATFORM MOBILE APPLICATION GENERATION WITH A MODEL-DRIVEN APPROACH[13]
- THE INTERNET OF THINGS HEALTHCARE MONITORING SYSTEM BASED ON MQTT PROTOCOL [14]
- REAL TIME WIRELESS HEALTH MONITORING APP[15]
- APPLICATIONS OF SMARTPHONES FOR HEALTH[16]
- COMMERCIAL SMARTPHONE-BASED DEVICES AND SMART APPLICATIONS[17]
- DEVELOPMENT OF AN IOT BASED HEALTH MONITORING[18]

KEY FINDINGS

Passive Monitoring

Standardized Communication Protocols

Increasing use of AI

Mobile Integration

GAPS

Singular Central Hub

Inconsistent Data Handling

Technology driven

Privacy first designs

PROJECT FOCUS

Optimization of AI routine learning

Multi-sensor data processing

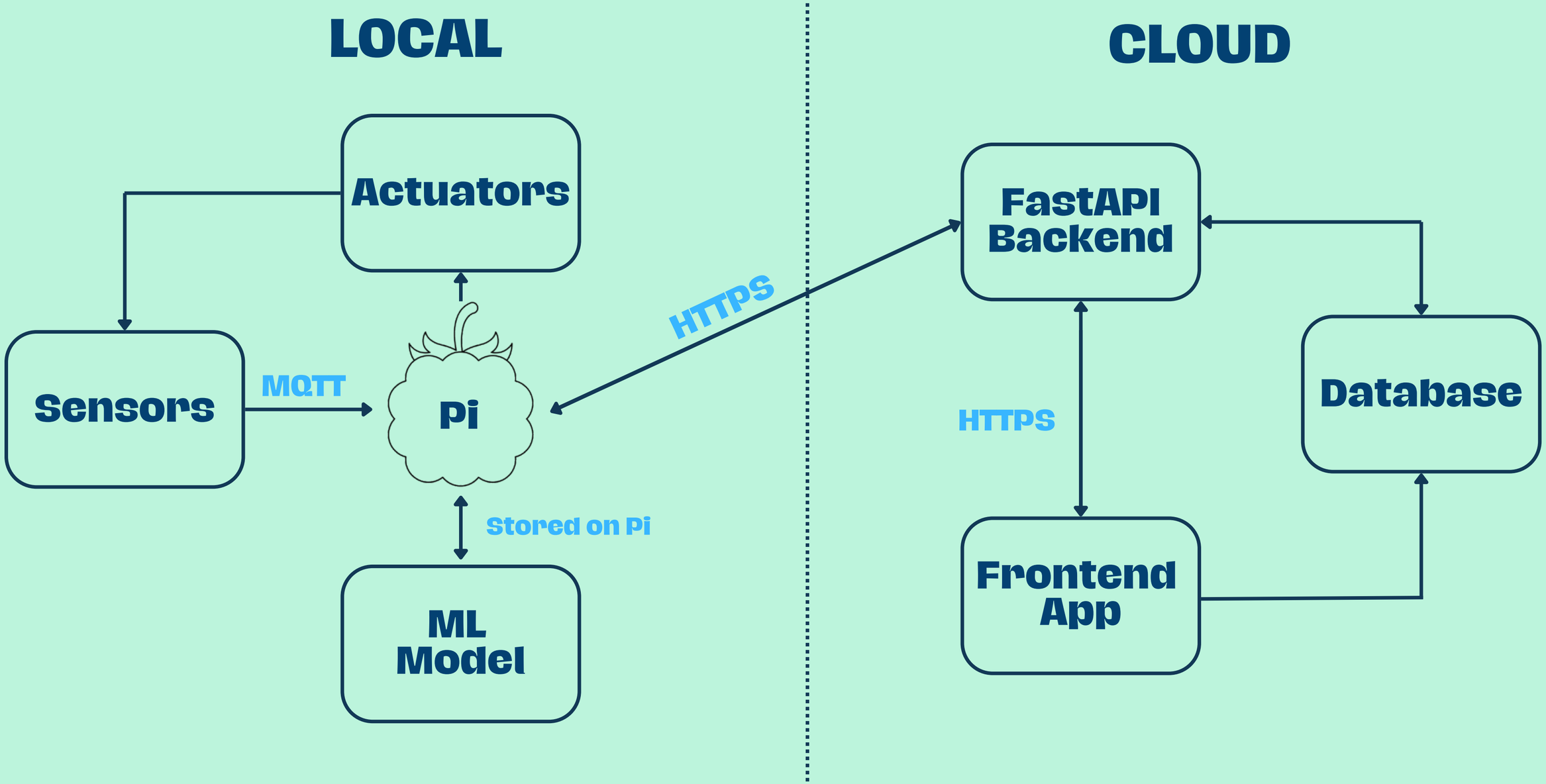
Privacy First Design

Effiency

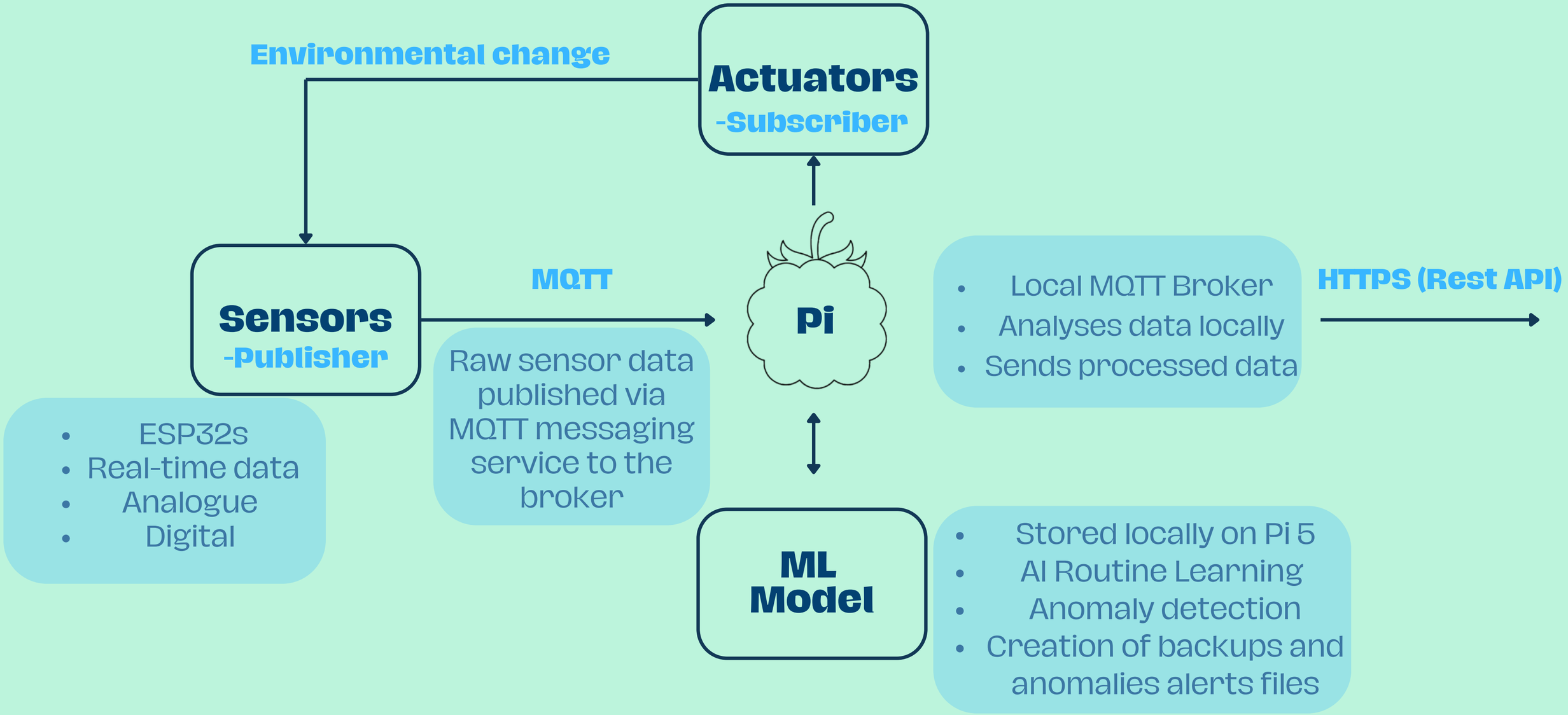
Cost - No Subscriptions

Response to Healthcare Sector Needs

PROJECT ARCHITECTURE



LOCAL


Environmental change
Actuators
-Subscriber
Sensors
-Publisher
MQTT
Pi
HTTPS (Rest API)
ML Model
ESP32s
Real-time data
Analogue
Digital
Raw sensor data published via MQTT messaging service to the broker
Local MQTT Broker
Analyses data locally
Sends processed data
Stored locally on Pi 5
AI Routine Learning
Anomaly detection
Creation of backups and anomalies alerts files

CLOUD

- Deployed by Render
- Acts as Web Server
- Provides REST API endpoints for App

FastAPI Backend

MongoDB Protocol

Database

Stores Back-up of routine, long term sensor data

HTTPS

Actuator info & routine changes

HTTPS

From Pi

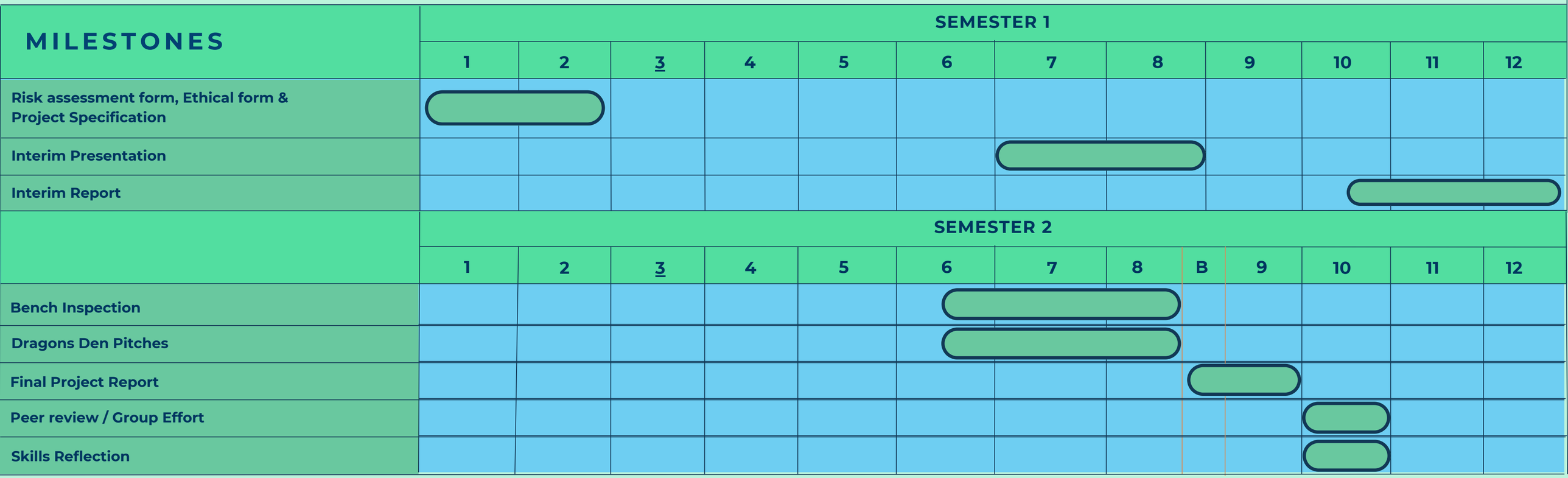
Processed data from Pi

Allows carer to access data and alerts

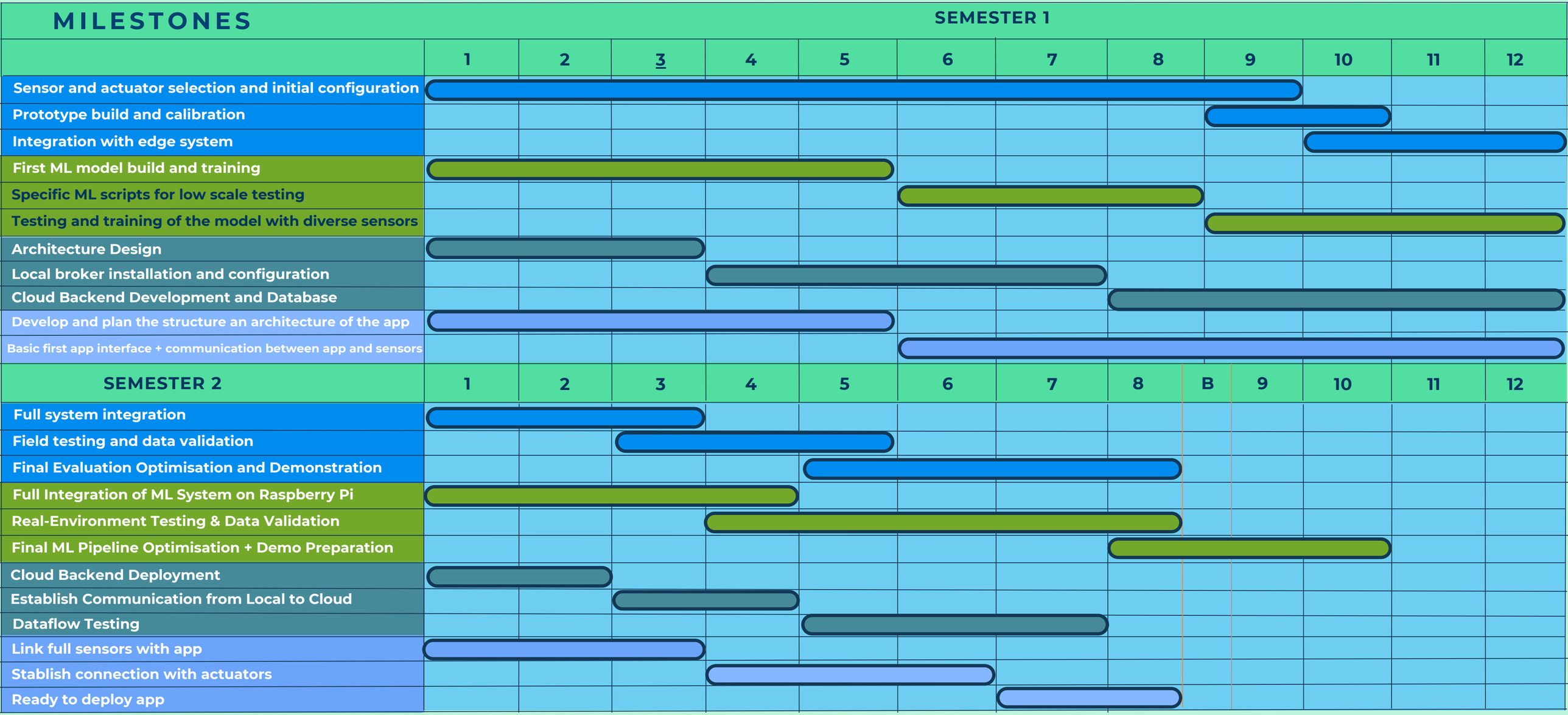
Frontend App

Sensor info, Alerts & routine changes

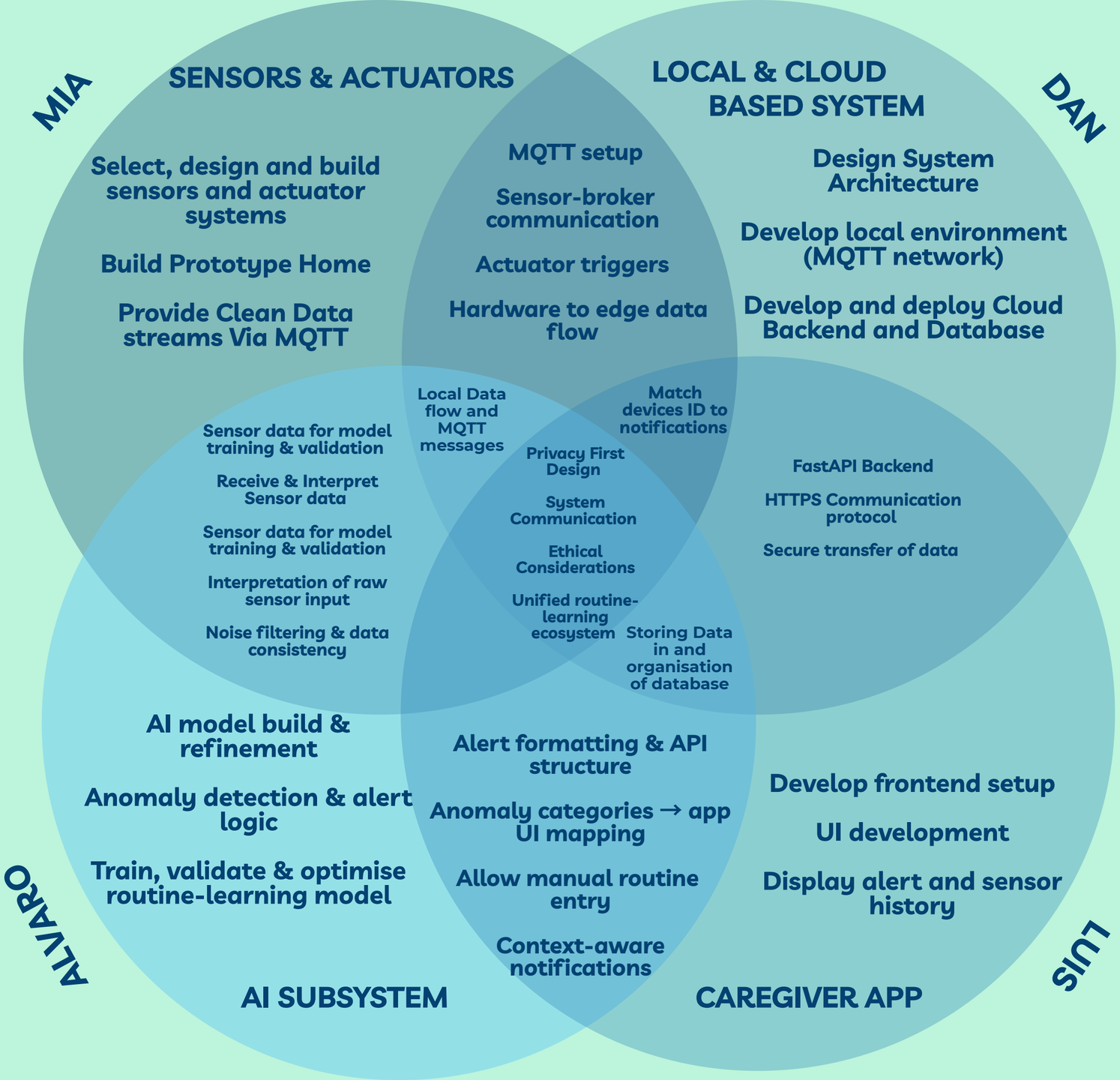
PROJECT PLAN



PROJECT PLAN



PROJECT PLAN



AIMS

- Configure Local MQTT Broker on Raspberry Pi
- Establish reliable local data transfer
- Design and Deploy FastAPI Backend on Render
- Configure Cloud System
- Integration of Local and Cloud based systems

DAN

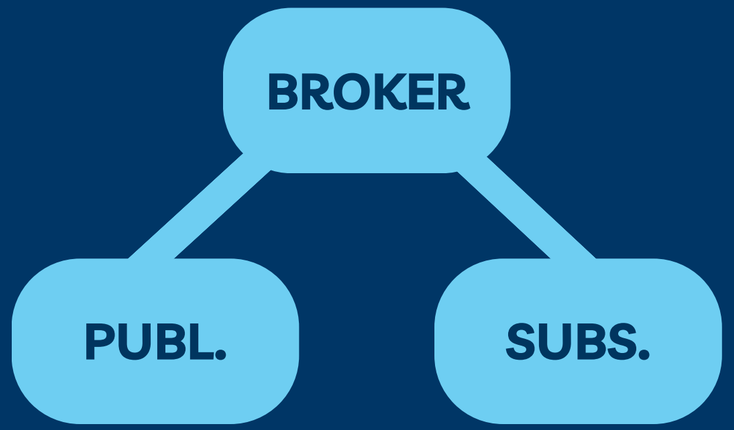
BACKGROUND THEORY

MQTT

Message Queuing Telemetry Transport

Short range, low-latency data exchange

Lightweight, publish/ subscribe protocol

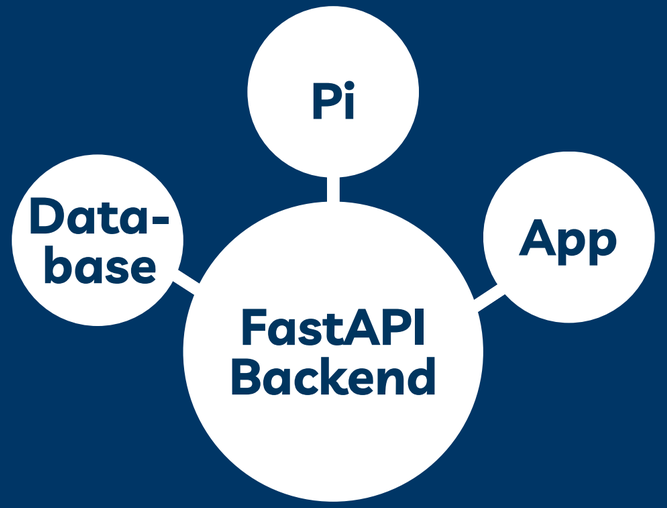


FastAPI Framework

Web framework for building APIs with Python

Handles multiple requests efficiently

Simplifies integration with databases



DAN

BACKGROUND THEORY

Render

Cloud hosting platform

Deploys web applications from GitHub

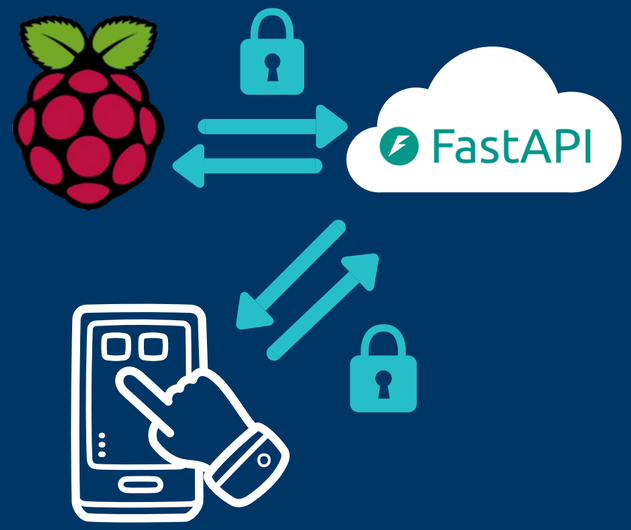
Offers built in HTTPs

HTTPS

Hypertext Transfer Protocol Secure

Encrypted data transfer method

Pi → Request → Server
Server → Response → Pi

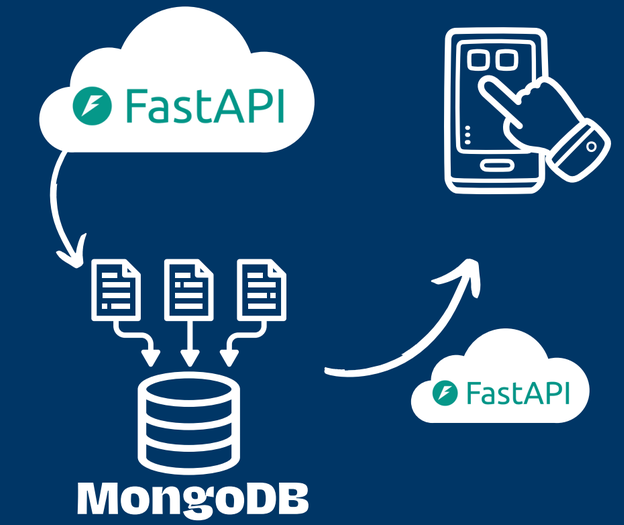


Cloud Database

MongoDB Atlas Accessible via FastAPI

Document based, cloud database

Stores sensor data and system logs securely



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METHOD

ARCHITECTURE DESIGN

- Local/ Cloud architecture
- Communication Protocols

LOCAL NETWORK SETUP

MIA

- Install and configure MQTT broker on Pi
- Connect ESP32 sensors via Wi-Fi

PYTHON EDGE SERVICE

MIA

- MQTT subscription to handle data/ control actuators
- Connect local components

ALV.

CLOUD BACKEND DEVELOPMENT

- Create FastAPI endpoints
- Connect MongoDB Atlas for cloud storage

LUIS

CLOUD DEPLOYMENT

- Deploy FastAPI backend to Render
- Configure environment and HTTPS access

LUIS

INTEGRATION AND TESTING

ALV.

- Link Pi to Cloud via HTTPS
- Verify successful flow of data

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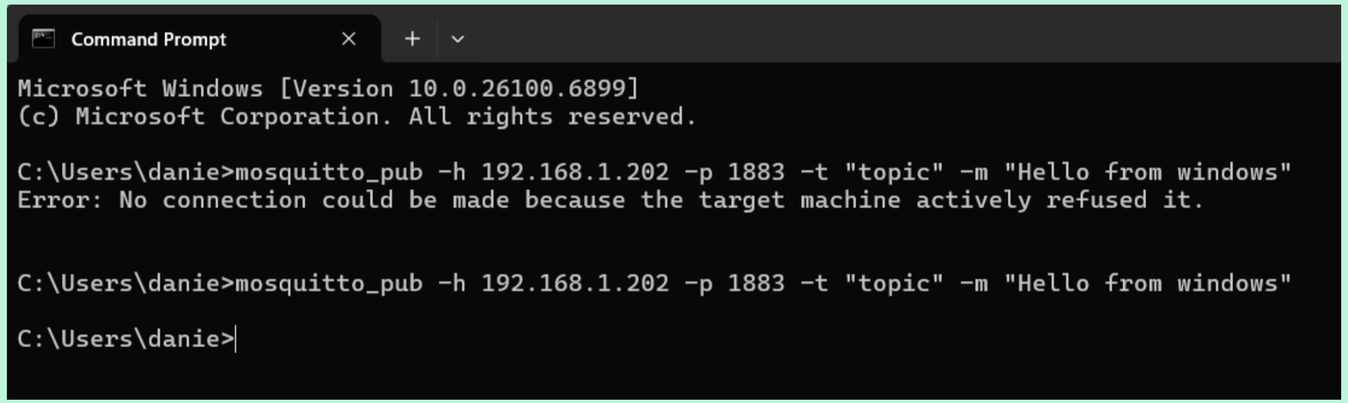
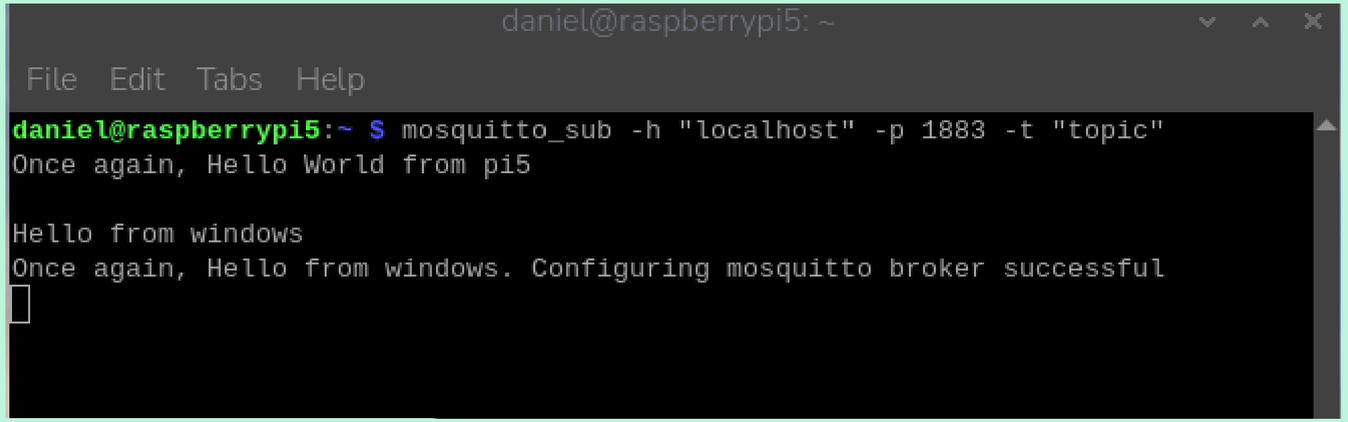
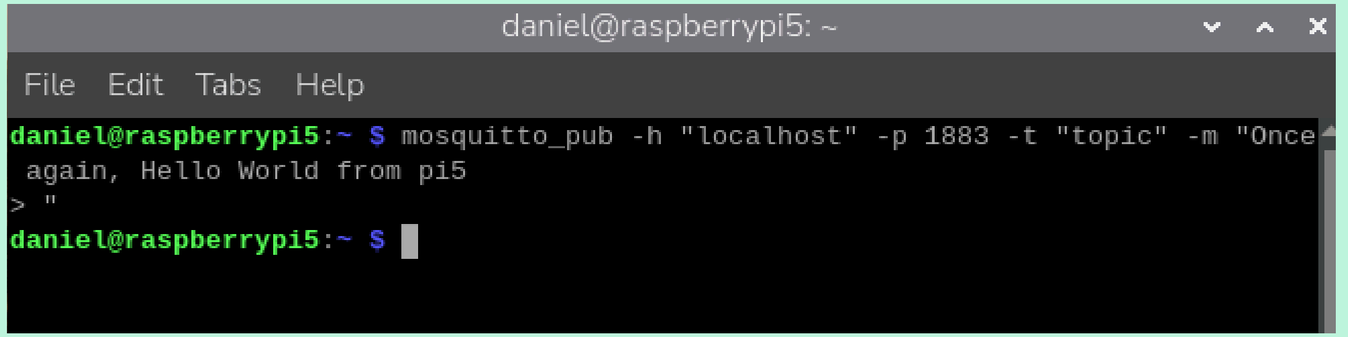
RESULTS



Windows Device acting as Publisher

MQTT Subscriber receiving published message





Successful MQTT communication using Pi as Broker

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DISCUSSION

- Local MQTT Broker Configured and Tested
- Final Design choices made and system architecture complete
- Begin testing local MQTT communication with sensors and ML Model
- Begin deployment of FastAPI Backend with online database

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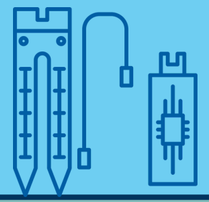
AIMS

MIA

Design and Implement a sensor-actuator network



Use at least 8 devices (5 sensors, 3 actuators)

Real-time communication

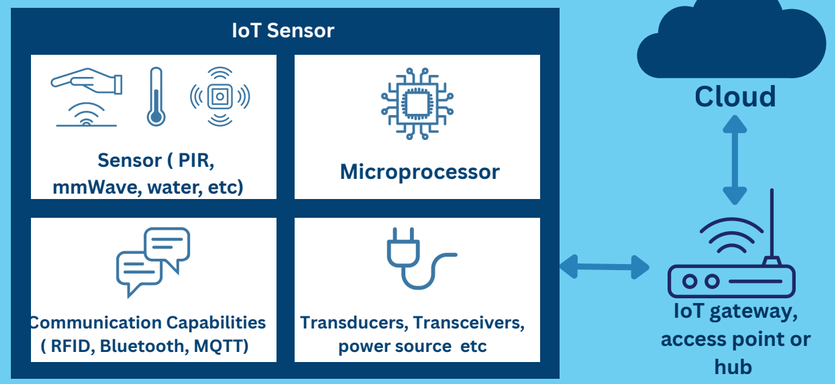
Ensure support for AI routine learning and anomaly detection

Maintain privacy first, safe and fault tolerant operation

BACKGROUND THEORY

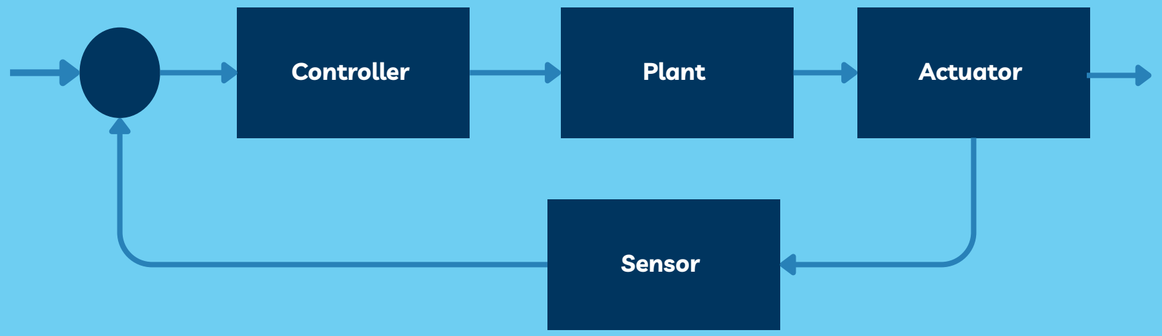
MIA

IOT SENSING



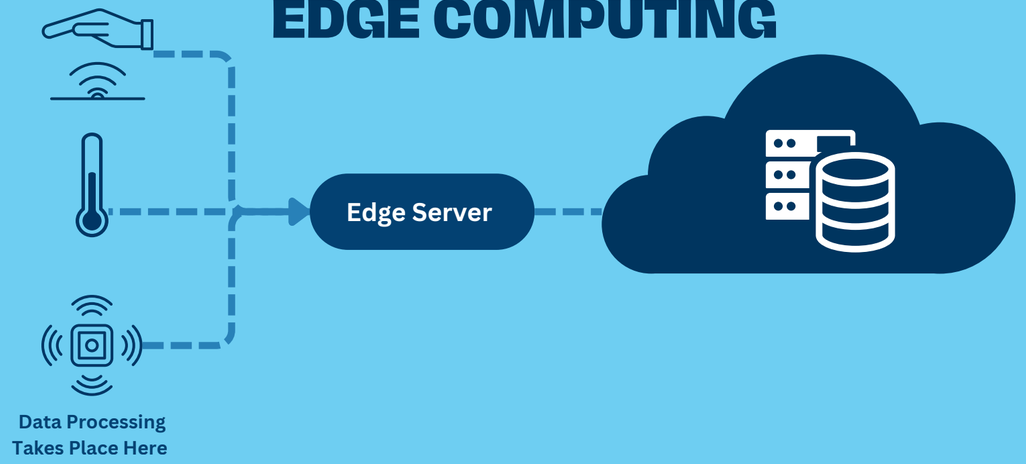
Adapted from ScienceDirect(2002) - IoT in Smart healthcare systems[19]

CLOSED LOOP CONTROL



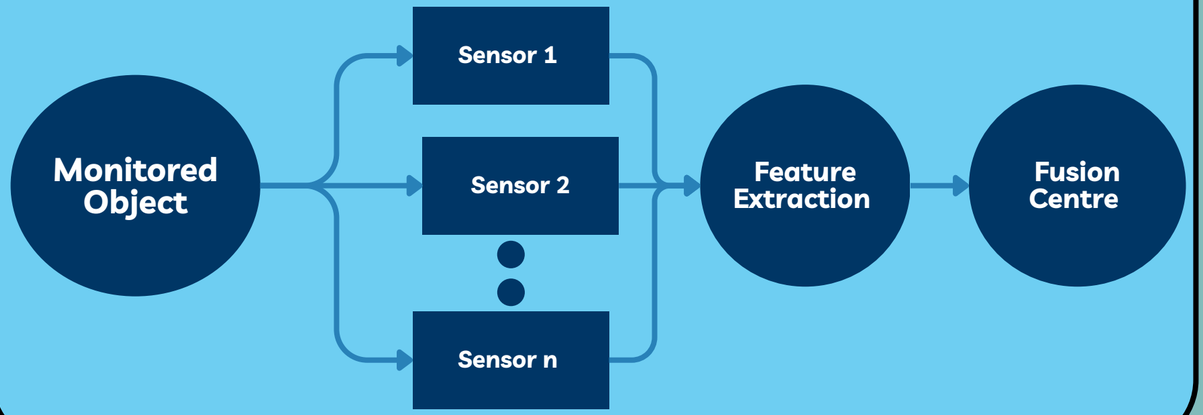
Adapted from CEL(2023) - Open Loop vs Closed Loop Control [20]

EDGE COMPUTING



Adapted from Digi International (2023) - Edge Computing Solutions [21]

MULTI-SENSOR FUSION



Adapted from IEEE (2023) - Survey on Multi-Sensor Fusion Techniques [22]

METHOD

MIA

HARDWARE
- Research, Design and Selection Circuitry
- ESP32 Boards

Dan Alvaro

COMMUNICATION
- Arduino IDE
- MQTT Topics
- Raw Data

Dan Alvaro

INTEGRATION
- Raspberry Pi 5 Broker
- Local Processor

TESTING
- Arduino IDE
- MQTT Explorer

PROTOTYPE
- Small Scale Environment Testing
- Iterative Improvement

Dan Alvaro Luis

FULL SCALE
- Implement Full Scale System Testing
- Evaluation

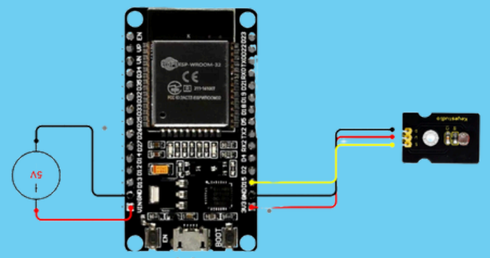
Dan Alvaro Luis

RESULTS

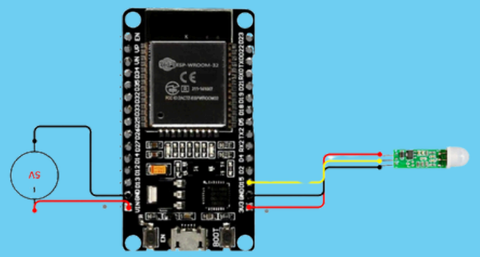
MIA

SENSORS

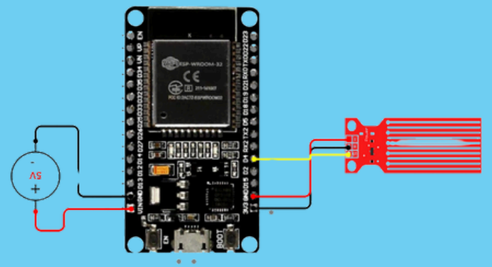
mmWave



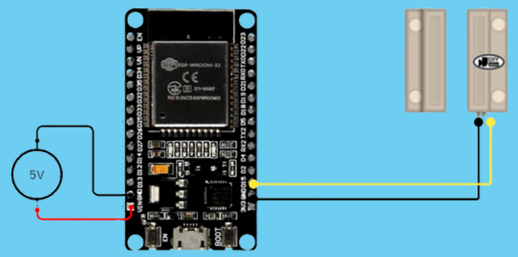
PIR



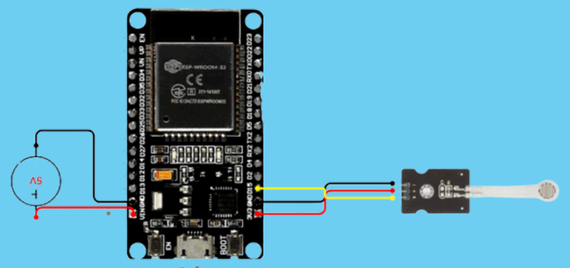
Water



Reed

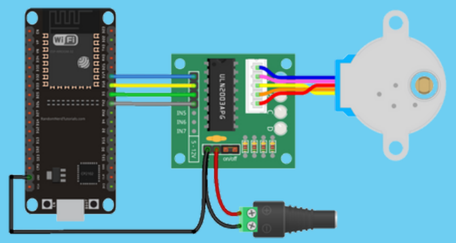


Pressure

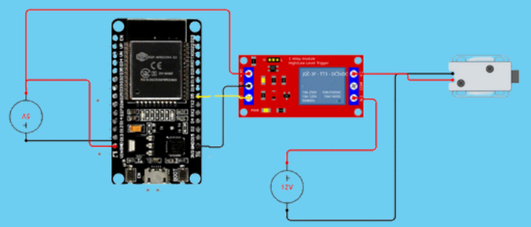


ACTUATORS

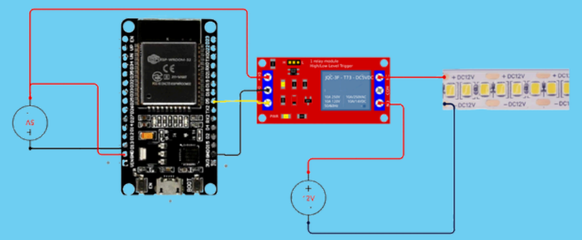
BLDC



Solenoid Lock



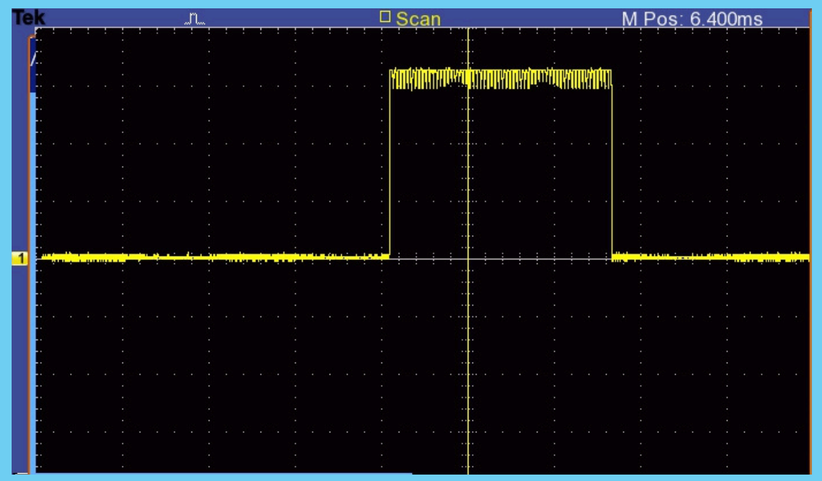
LED



RESULTS

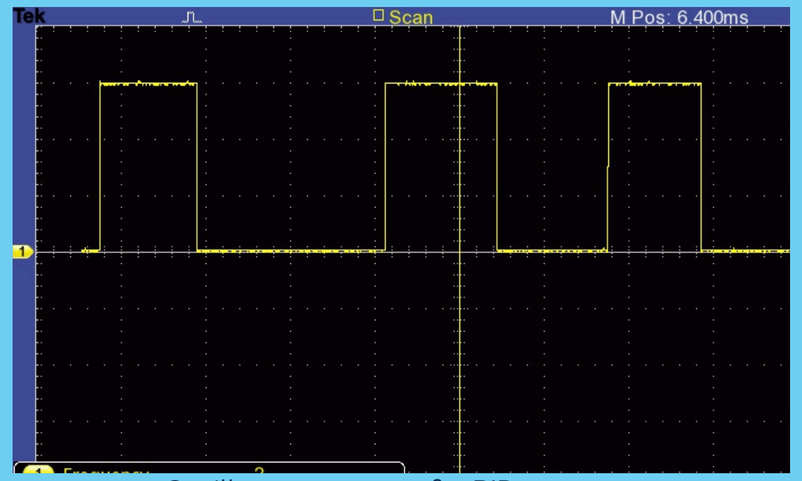
MIA

mmWave



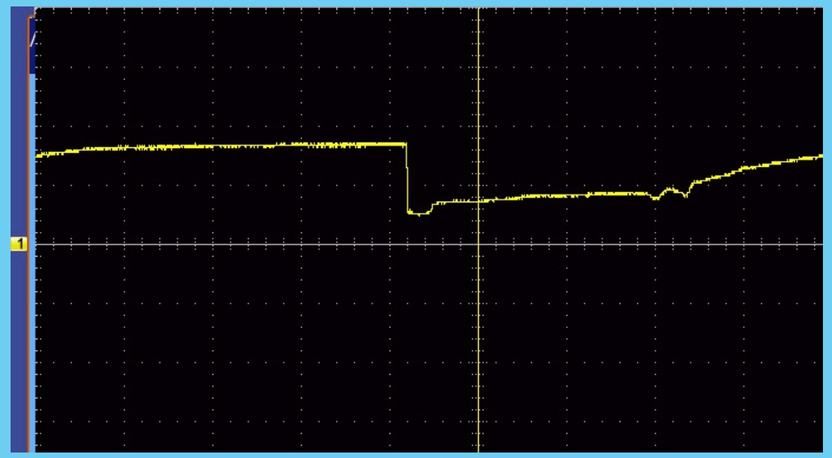
Oscilloscope output for mmWave sensor

PIR



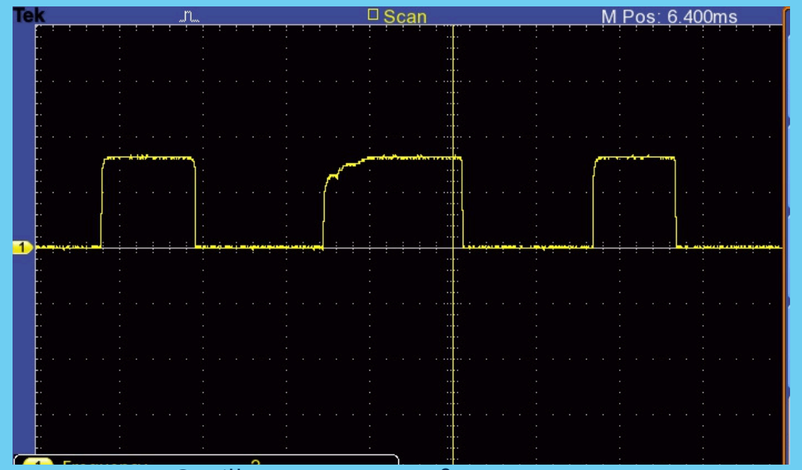
Oscilloscope output for PIR sensor

Water



Oscilloscope output for water sensor

Pressure

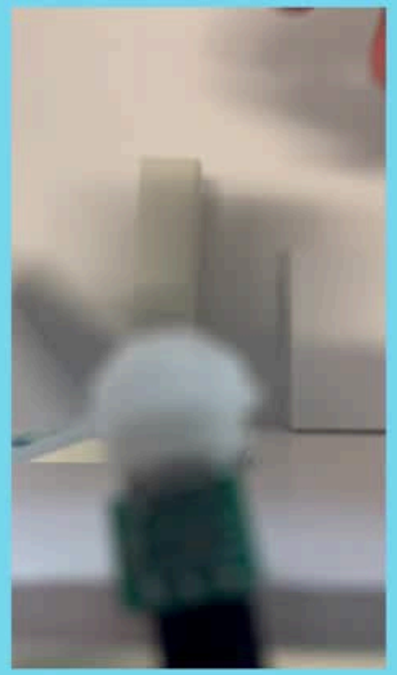


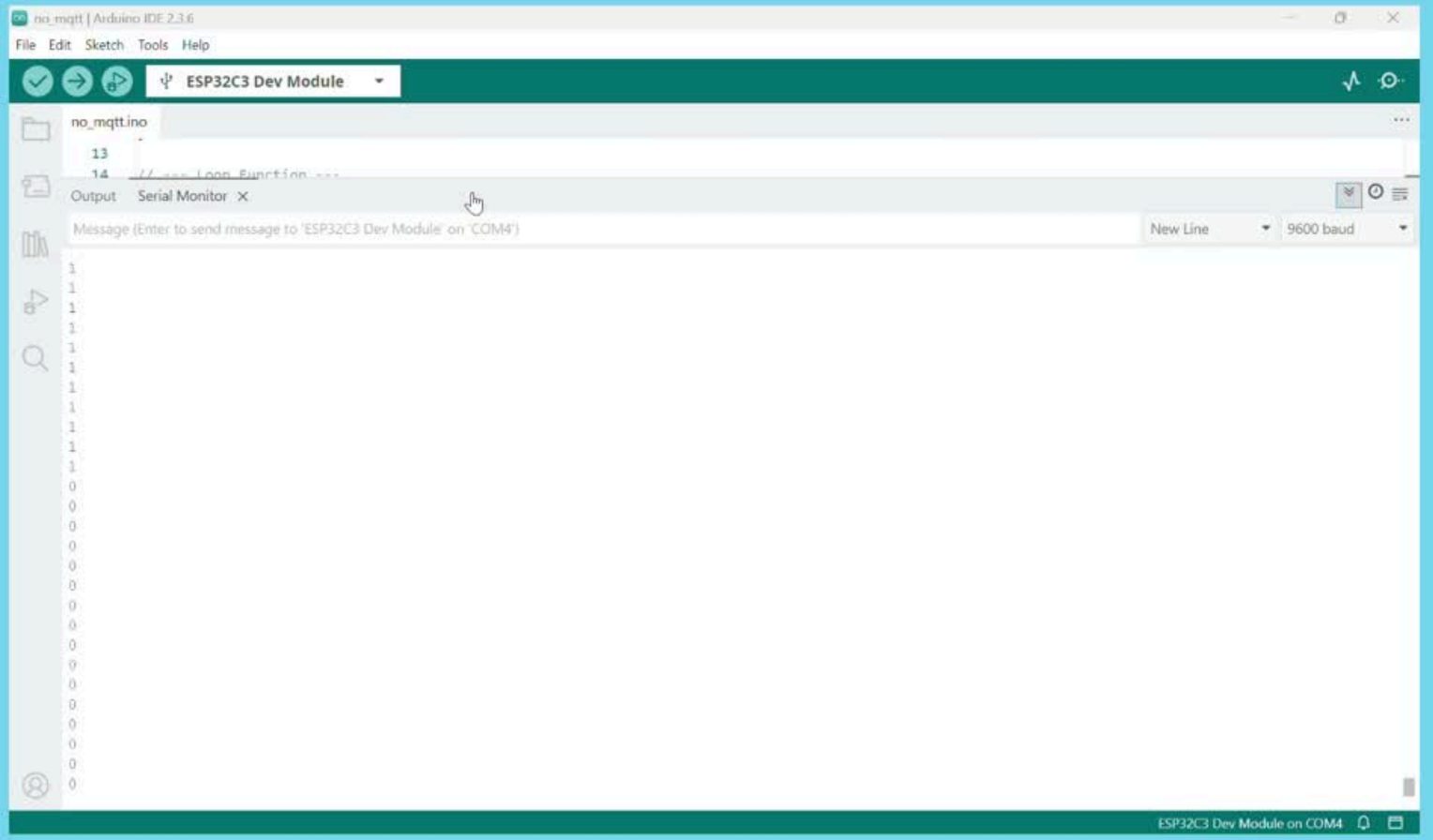
Oscilloscope output for pressure sensor

RESULTS

MIA

PIR

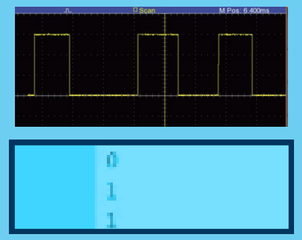




DISCUSSION

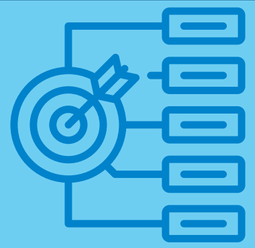
MIA

Subsystem meets early performance aims



Hardware validated

Iterative Developement



Contributes towards subsystem aims and project objectives

NEXT STEPS

Implement MQTT

Actuator circuits

Begin short term AI routine-learning

AIMS

DESIGN AND IMPLEMENT A LOCAL ANOMALY DETECTION PIPELINE

INTEGRATE MACHINE LEARNING WITH REAL-TIME IOT DATA STREAMS

ENABLE PERSONALIZED CONFIGURATION AND ADAPTIVE RETRAINING

GUARANTEE LOW LATENCY AND PRIVACY-PRESERVING ANALYTICS

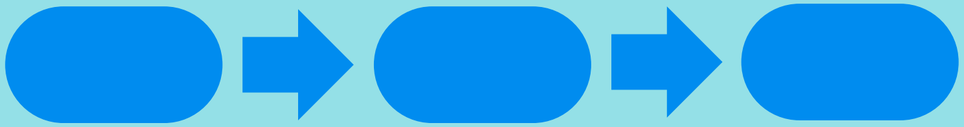
PROVIDE RELIABLE ALERTING AND CLOUD RELAY

BACKGROUND THEORY

EDGE COMPUTING PRINCIPLES

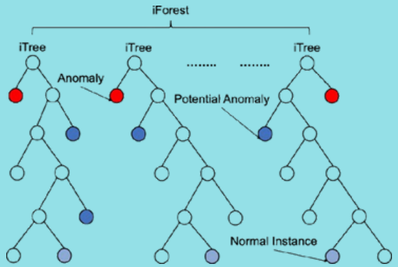
Brings computation closer to sensors, reducing latency and data transfe

AI PIPELINE INTEGRATION



The data passes through preprocessing, model inference, and alert generation

ANOMALY DETECTION IN IOT SYSTEMS



Isolation Forest model identifies deviations from learned normal behaviour

PRIVACY-FIRST MODEL

Processing stays local, preventing sensitive data from leaving the home

PERSONALISED CONFIGURATION VS DATASETS

Each installation adapts to individual routines instead of relying on generic datasets

METHOD

Local Data Flow Setup
Subscribe to MQTT topics (pressure, motion, temperature, ...) and store readings locally

Training Mode
Train Isolation Forest model on normal routine data using configurable parameters

Normal Mode (Inference)
Detect anomalies from incoming data stream; apply rule-based checks for validation

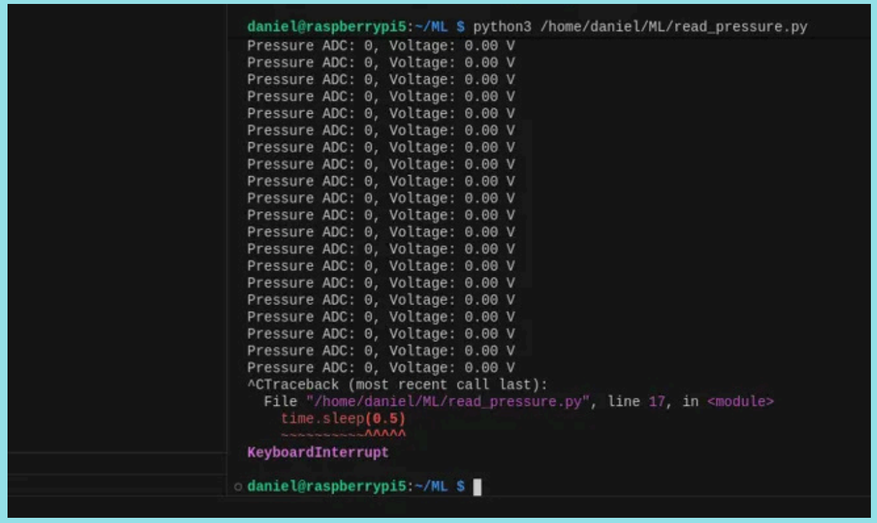
Logging and Alert Generation
Record each event with timestamp, type, and confidence in JSON format

API Integration
Send periodic backups (.pkl, .json) and anomaly reports to cloud via FastAPI

Testing in Real Setup
Pressure sensor tested in a house-replica setup; validated alert accuracy and stability

RESULTS

REAL-TIME PRESSURE SENSOR INPUT



ANOMALY DETECTION FROM PHYSICAL SENSORS

Progress: [ ]
NIGHT | 29.8s | Pressure: 1023 | ✅ Bed: occupied
========== ✅ DEMO COMPLETE!
========== 💾 Raw data saved:
data/demo_raw_20251112_161528.json 💾 Anomalies saved: data/demo_anomalies_20251112_161528.json 💾
Summary saved: data/demo_summary_20251112_161528.json 📊 TEST SUMMARY ----------
- Total Samples: 150 Anomalies Detected: 5

RESULTS

MANUAL TRAINING+ ANOMALIE DETECTION THROUGH REAL SENSOR DATA

```
Detection Options:
 1. Quick test (2 minutes)
2. Standard monitoring (10 minutes)
3. Extended monitoring (30 minutes)
4. Continuous monitoring (until stopped)
Select option (1-4): 1🎯 Starting real-time anomaly detection...
Press Ctrl+C to stop
Running for 2 minutes
Pressure: 0 | State: empty | Detections: 0 | Anomalies: 0
Pressure: 0 | State: empty | Detections: 0 | Anomalies: 0
Pressure: 12 | State: empty | Detections: 0 | Anomalies: 0
Pressure: 0 | State: empty | Detections: 1 | Anomalies: 0
Pressure: 534 | State: occupied | Detections: 1 | Anomalies: 0
Pressure: 1023 | State: occupied | Detections: 2 | Anomalies: 0
Pressure: 1023 | State: occupied | 🌙 Sleep Time | Detections: 3 | Anomalies: 0
Pressure: 987 | State: occupied | 🌙 Sleep Time | Detections: 3 | Anomalies: 0
Pressure: 0 | State: empty | 🌙 Sleep Time | Detections: 4 | Anomalies: 0
```

```
🚨 ANOMALY DETECTED! [HIGH]
Score: -0.542
Unusual patterns:
- is_sleep_time: 1.0 (z-score: 2.31)
- occupancy_rate: 0.1 (z-score: -2.45)
- pressure_mean: 45.2 (z-score: -2.18)
Pressure: 0 | State: empty | 🌙 Sleep Time | Detections: 5 | Anomalies: 1
Pressure: 15 | State: empty | 🌙 Sleep Time | Detections: 5 | Anomalies: 1
Pressure: 1023 | State: occupied | 🌙 Sleep Time | Detections: 6 | Anomalies: 1
Pressure: 1015 | State: occupied | 🌙 Sleep Time | Detections: 6 | Anomalies: 1
Pressure: 998 | State: occupied | Detections: 7 | Anomalies: 1Pressure: 456 |
State: uncertain | Detections: 7 | Anomalies: 1
🚨 ANOMALY DETECTED! [MEDIUM]
Score: -0.387
Unusual patterns:
- state_changes: 8.0 (z-score: 2.67)
- pressure_std: 412.3 (z-score: 2.04)
Pressure: 1023 | State: occupied | Detections: 8 | Anomalies: 2
Pressure: 1023 | State: occupied | Detections: 8 | Anomalies: 2
Pressure: 0 | State: empty | Detections: 9 | Anomalies: 2
[... continues for 2 minutes ...]
⚠️ Detection stopped by user
📊 Session Summary:
```

DISCUSSION

SUBSYSTEM MEETS EARLY AI OBJECTIVES

INTEGRATION VALIDATED

ITERATIVE DEVELOPMENT

CONTRIBUTES TOWARDS SYSTEM AIMS

NEXT STEPS

COMPLETE FULL MQTT LIVE STREAM CONNECTION

IMPLEMENT MODEL RETRAINING TRIGGER FOR LONG-TERM ADAPTATION

EXPAND TESTING WITH ADDITIONAL SENSORS (MOTION, TEMPERATURE, DOOR)

SUPPORT REAL-TIME ALERTS THROUGH THE MOBILE INTERFACE.

AIMS

Develop a flutter based mobile app

Enable HTTPS Communication

Display alerts, and sensor summaries

Allow manual routine entry

Mantain privacy first, fault tolerant design

LUIS

BACKGROUND THEORY

FLUTTER FRAMEWORK & CROSS-PLATFORM DESIGN

- FLUTTER SDK & MATERIAL 3
- FAST PROTOTYPING
- RAPID TESTIG

FASTAPI & HTTPS COMMUNICATION

- FAST ARCHITECTURE
- DIO LIBRARY
- TLS ENCRYPTION

LOCAL CACHING & OFFLINE-FIRST STRATEGY

- DRIFT SQLITE
- APP SYNCS WITH BACKEND
- DATA PERSISTENCE

USER FEEDBACK LOOP & HUMAN-IN-THE-LOOP LEARNING

- ADD NEW ROUTINES
- FEEDBACK PIPELINE
- JSON – DB – ML

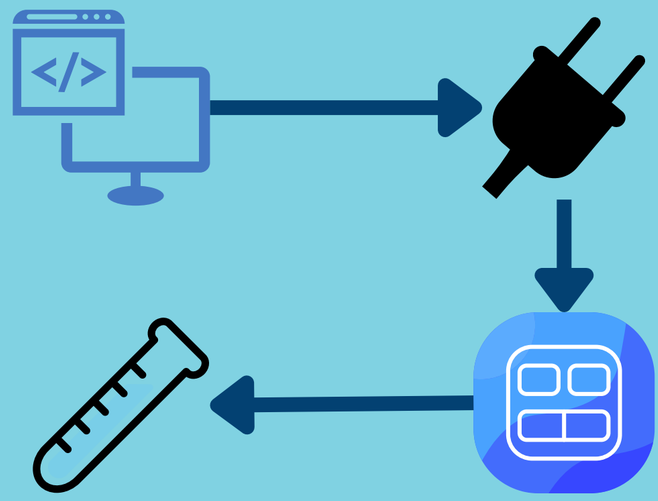
LUIS

METHOD

API DESIGN
- Fast API endpoints
- GET, POST, alerts

FRONT SET-UP
- Flutter SDK
- Visual studio
- Android studio

CONNECTION TESTING
- HTTPS request
- Postman verification



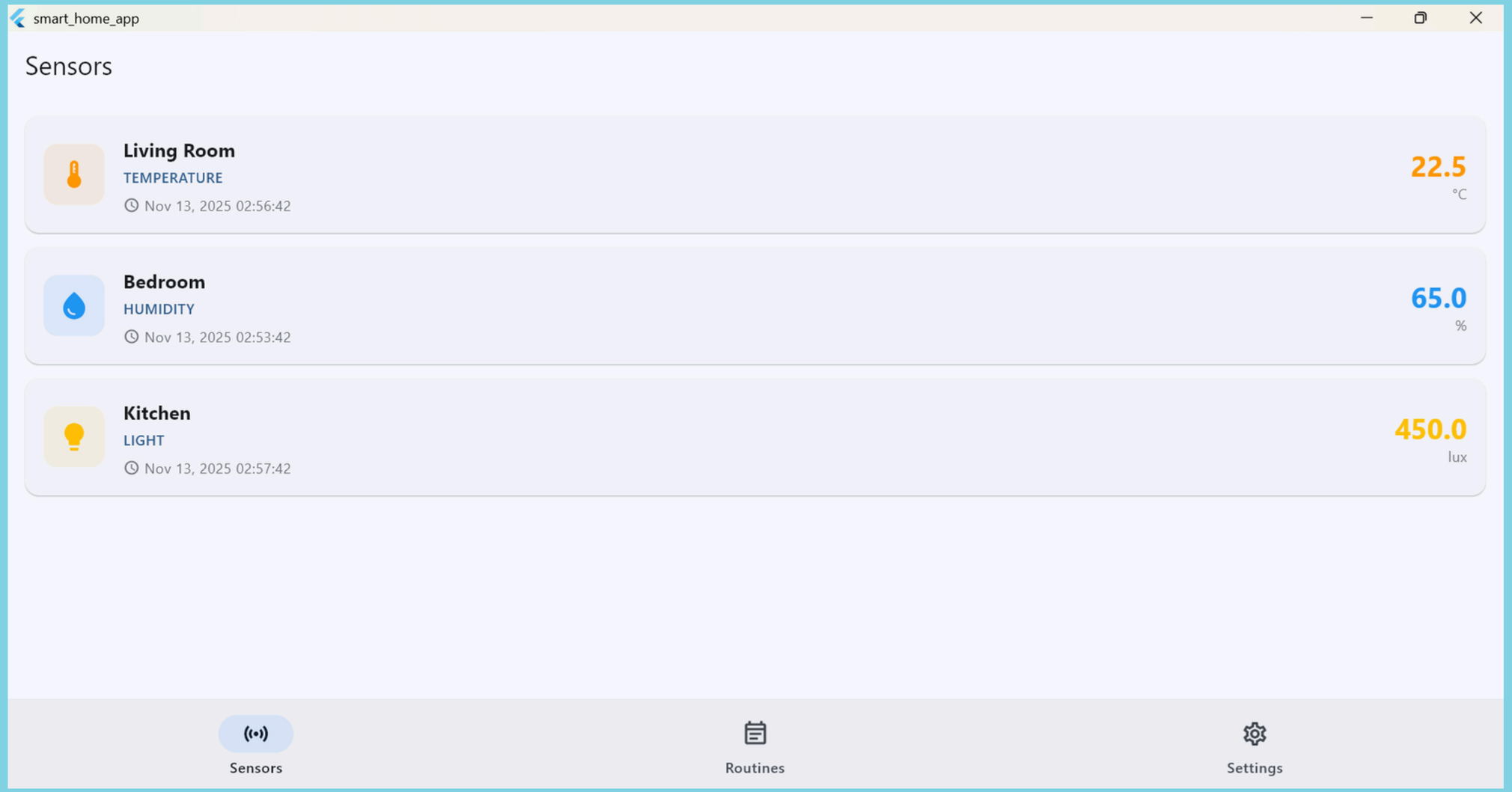
UI DEVELOPMENT
- Taps development

INTEGRATION
- Connect fast API + DB through HTTPS

INTERATION & TESTING
- Debug on emulator
- Test connectivity
- Offiline mode

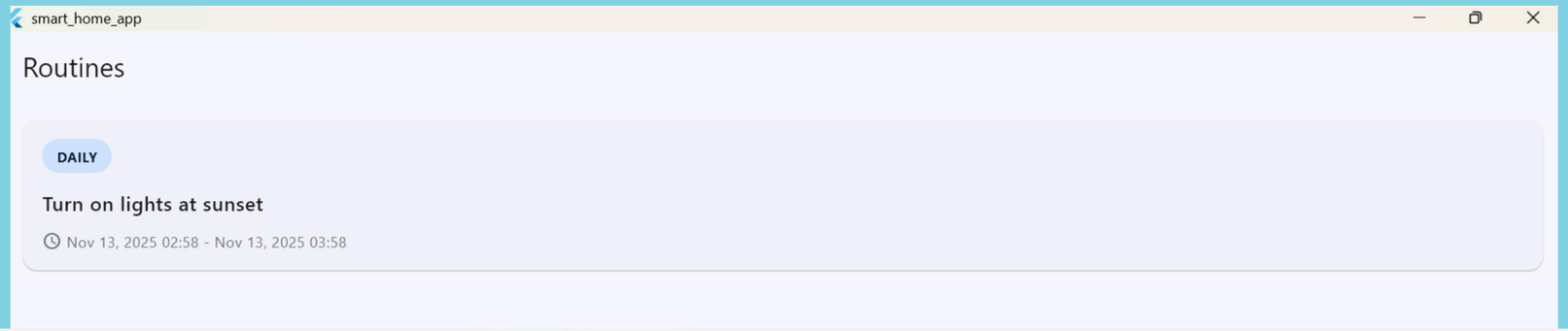
LUIS

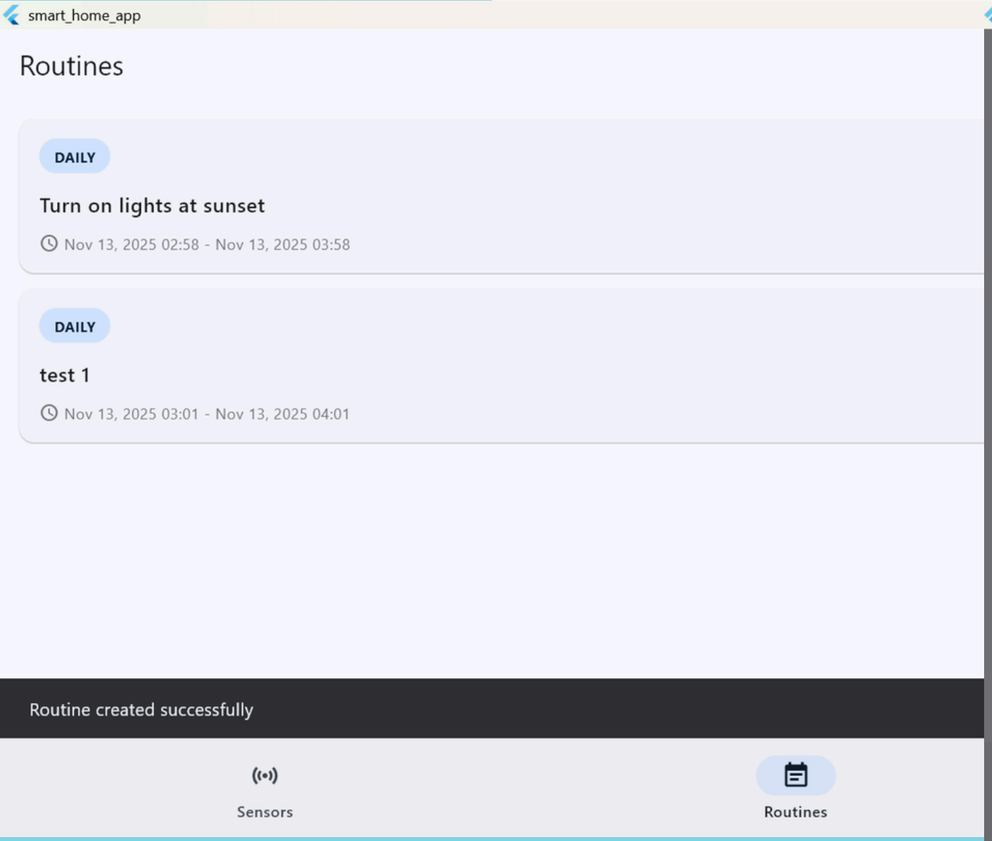
RESULTS



LUIS

RESULTS


smart_home_app
Routines
DAILY
Turn on lights at sunset
Nov 13, 2025 02:58 - Nov 13, 2025 03:58


smart_home_app
Routines
DAILY
Turn on lights at sunset
Nov 13, 2025 02:58 - Nov 13, 2025 03:58
DAILY
test 1
Nov 13, 2025 03:01 - Nov 13, 2025 04:01
Routine created successfully
Sensors
Routines


smart_home_app
Routines
DAILY
Create New Routine
Scope
Daily
Description
Start Time
2025-11-13 03:01
End Time
2025-11-13 04:01
Cancel
Create
Sensors
Routines
Settings

RESULTS


smart_home_app
Settings
Logged in as
test@test.com
App Information
Version
1.0.0
Build
Development
State Management
Riverpod
Navigation
GoRouter
MQTT Configuration
MQTT features will be available in a future update
Sensors
Routines
Settings

DISCUSSION

RELIABLE COMMUNICATION

SECURITY

SYSTEM INTEGRATION

USER INTERACTION

LUIS

MIA

DAN

MQTT setup

Sensor-broker communication

Actuator triggers

Hardware to edge data flow

Local Data flow and MQTT messages

Match sensor ID to notifications

Sensor data for model training & validation

Receive & Interpret Sensor data

Sensor data for model training & validation

Interpretation of raw sensor input

Noise filtering & data consistency

Privacy First Design

System Communication

Ethical Considerations

Unified routine-learning ecosystem

FastAPI Backend

HTTPS Communication protocol

Secure transfer of data

Storing Data in and organisation of database

Alert formatting & API structure

Context-aware notifications

Anomaly categories → app UI mapping

Allow manual routine entry

ALVARO

LUIS

SUMMARY

WE ARE PROGRESSING STEADILY TOWARDS SUBSYSTEM OBJECTIVES

CORE COMPONENTS AND CONCEPTS HAVE BEEN DESIGNED

TEAM COLLABORATION IS STRONG, WITH CONTINUOUS CROSS-SUPPORT BETWEEN ROLES

NEXT STEPS FOCUS ON INTEGRATION, OPTIMISATION, AND FULL END-TO-END TESTING

TOGETHER, WE ARE MOVING TOWARDS A FULLY FUNCTIONAL ASSISTED-LIVING SYSTEM

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