INFORMATICS INSTITUTE OF TECHNOLOGY
In Collaboration with
ROBERT GORDON UNIVERSITY ABERDEEN

Multimodal Fall Detection System For Elderly Persons

Group 20 Project Proposal Document by:
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1.0 Introduction

1.1 Chapter Overview

This chapter outlines the application's fundamental requirements, focusing on data collection and functional aspects influencing core functionality. It details techniques like questionnaires and interviews, discussing their procedures, pros, and cons. Use case diagrams illustrate actor interactions with the system, while stakeholders and their affiliations are identified. Lastly, functional and non-functional requirements are listed to define the application's essential needs.

1.2 Rich Picture

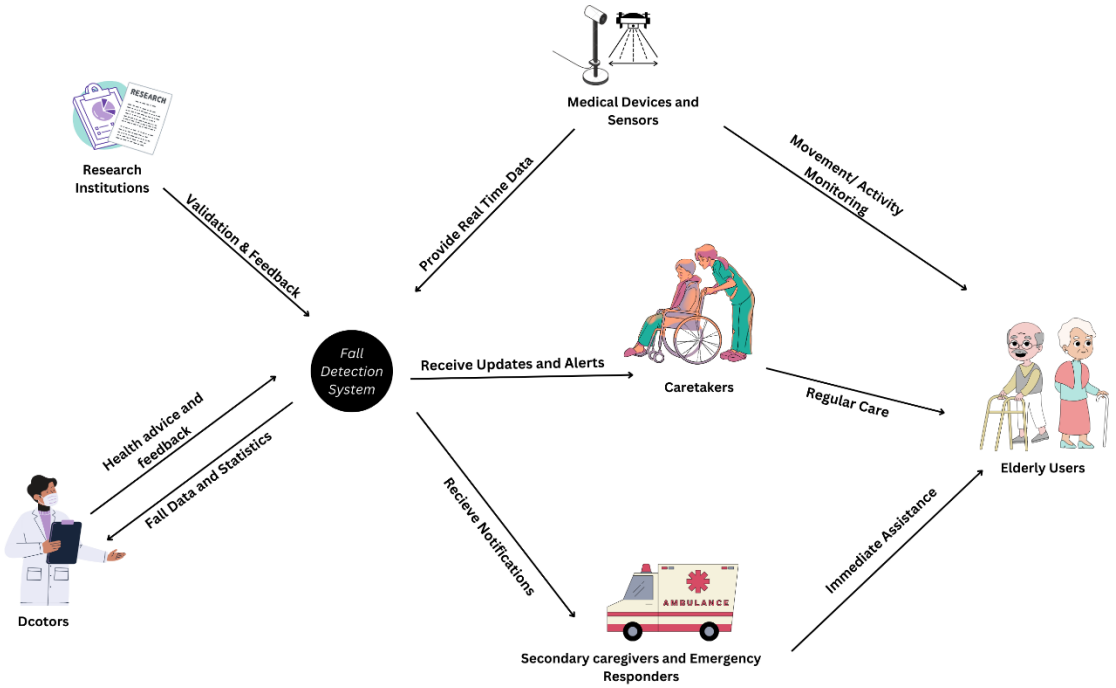


Figure 1: Rich Picture

1.3 Stakeholder Analysis

Regarding the stakeholder analysis segment of this chapter, the following Onion model lists out how a stakeholder is involved in the development of the system:

1.3.1 Onion Model

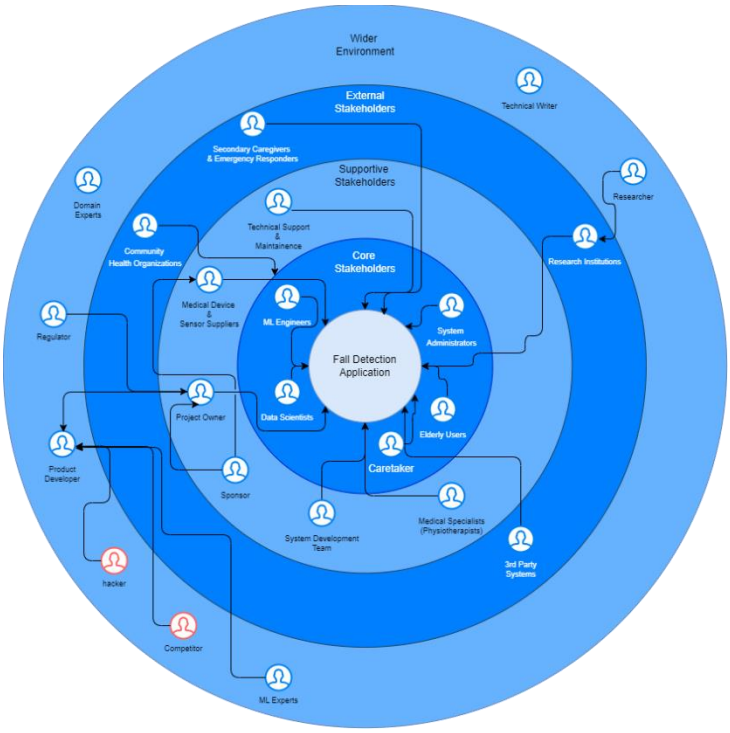


Figure 2: Onion Model

1.3.2 Onion Model Content

Stakeholder	Role in system	Contribution/ Benefit
ML Engineers, Data Scientists	Operational/ Functional maintenance	Design the process in developing a system to analyse potential falls while maintaining its functionality/accuracy and providing newly found data into data pools utilized within the machine learning model for better accuracy
System Administrator	Operational Administration	They assist with deploying the application and configuring it to fit in different environments
Caretaker	Support Provider	They provide insights into how to look after elders while taking care of them while the system is being implemented
Elderly Users	Main User	They act as the main user of the system while providing it with new training data (actively)
Technical Support & Maintenance	Project/ Application Functional maintenance	They help maintain the system if ever it were to fail while managing false positives and functional failures
Medical Device & Sensor Suppliers	Peripherals Provider	They provide the system with affordable options for the peripherals utilized in the system
Project Owner	Functional Beneficiary	Owner of the fall detection system
Sponsor	Functional Beneficiary	Fund the project through sponsors such that it can be developed further

System Development Team	Project/ Application Developers	Further develops the application to negate false positives while increasing the overall accuracy
Medical (Physiotherapist)	Health Advisors	Provide the system with advice over how to better detect falls and what parameters are to be considered in doing so
Secondary Caregivers & Emergency Responders	Medical Support Advisors/ Responders	Respond to emergencies in case a fall were to occur
Community Health Organizations	Ethical/Medical Constraint Advisors/ Responders	Regard ethical constraints the application may occur in terms of privacy and help administer solutions to it while constantly updating the systems database of constraints, etc
Research Institutions	Knowledge Contributors	Validate the accuracy of the system by carrying out recursive tests and provide evidence-based insights into the systems designs, aligning it more with real world needs
3rd Party Systems	Functional beneficiaries	Enhance system functionality by allowing it to connect with other platforms (e.g., emergency services, health records) for seamless data exchange and quick response.
Technical Writers	Operational Support	Support usability by developing clear, accessible documentation for stakeholders, including users, caregivers, and developers
Researcher	Knowledge Contributor	Improve accuracy by validating the system's algorithms, analysing effectiveness, and providing evidence-based insights for iterative improvements, they further the projects scope as well to experiment with new functions
ML Experts, Domain Expert	Expert	Enhance fall detection accuracy through improved algorithms, reducing false positives/negatives and optimizing system performance while ensuring the application caters to real world needs in actual healthcare scenarios
Competitor	Negative Stakeholder	Develops an application that directly contrasts our application
Hacker	Negative Stakeholder	Finds vulnerabilities within the system, accesses them and then reports them to the system project owner such that they are notified of a breach of privacy/functionality
Product Developer	Developer, Operational Maintenance	Ensure the system is user-centred, incorporating practical features and achieving alignment with stakeholder needs and compliance standards.
Regulator	Quality Regulator	Ensures that the application stays within healthcare-based application standards while improving patient safety, data privacy, and legal compliance. This boosts system credibility and user trust

Table 1: Onion Model Stakeholder Descriptor

1.4 Selection of Requirement Elicitation Techniques/Methods

1.4.1 Analysis of Requirement Elicitation Methodologies

Requirement elicitation involves various methods to define a system's needs. This section evaluates the advantages and disadvantages of common approaches and outlines the techniques applied to develop our fall detection system.

1.4.1.1 Observing Existing Systems and Literature Review

Studying existing systems and reviewing literature provides insights into current fall detection technologies, highlighting areas for improvement.

Advantages	Disadvantages
Provides a foundational understanding of fall detection systems.	Reviewing research papers and solutions can be complex.
Helps identify feature gaps and focus on patient safety.	May lack real-world data for targeted demographics or use cases.

Table 2: Advantages & Disadvantages of 1.4.1,1

1.4.1.2 Surveys & Questionnaires

Effective for gathering input from elderly patients, caregivers, and potential users, providing a broad understanding of user needs.

Advantages	Disadvantages
Reaches a wide audience and captures diverse insights.	Responses may vary in quality or misunderstand questions.
Time-efficient and straightforward for analysis.	Limited to predefined questions, missing nuanced experiences.

Table 3: Advantages & Disadvantages of 1.4.1.2

1.4.1.3 Interviews

Interviews with medical professionals, caregivers, and patients provide detailed insights into critical requirements and user perspectives.

Advantages	Disadvantages
Allows for detailed follow-up and clarification.	Time-intensive and limits the number of respondents.
Offers unique qualitative insights.	Some interviewees may struggle to articulate requirements.

Table 4: Advantages and Disadvantages of 1.4.1.3

1.4.2 Requirement Gathering Methods Selected

A combination of methods ensures comprehensive, accurate requirements:

- **Structured Interviews**: Gather expert insights from medical professionals on fall risks and conditions.
- **Closed-Question Questionnaires**: Collect feedback from elderly patients on fall experiences and needs.
- **Unstructured Interviews**: Capture caregiving experiences and real-world challenges from caregivers.
- **Structured Questionnaires in Physiotherapy Clinics**: Collect consistent data on patients' fall risks and histories.

This balanced approach integrates qualitative insights and quantifiable data, enabling the development of a user-centred, reliable fall detection system.

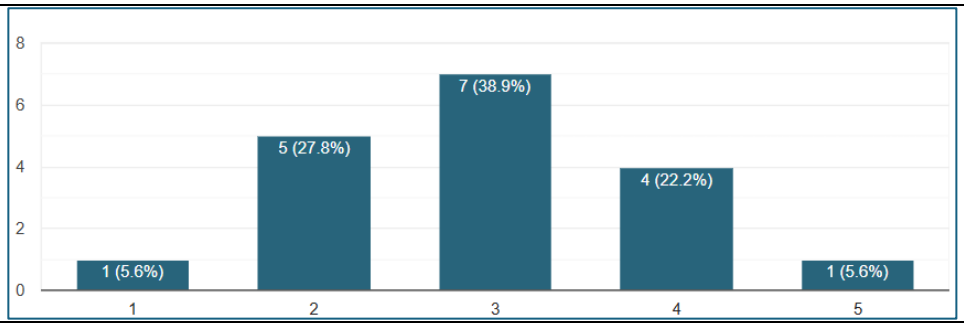
1.5. Discussion of Results

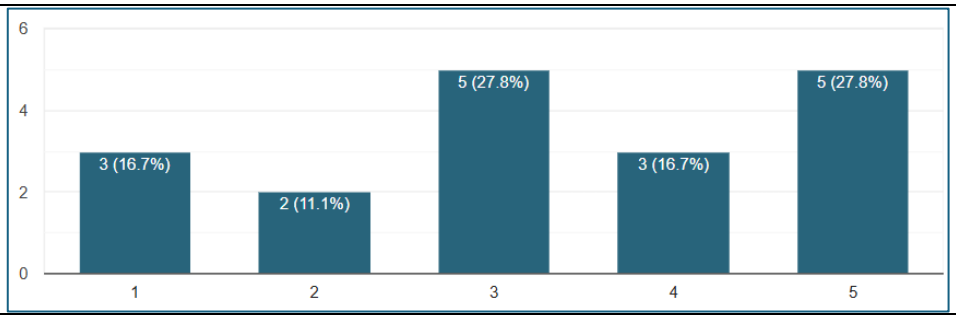
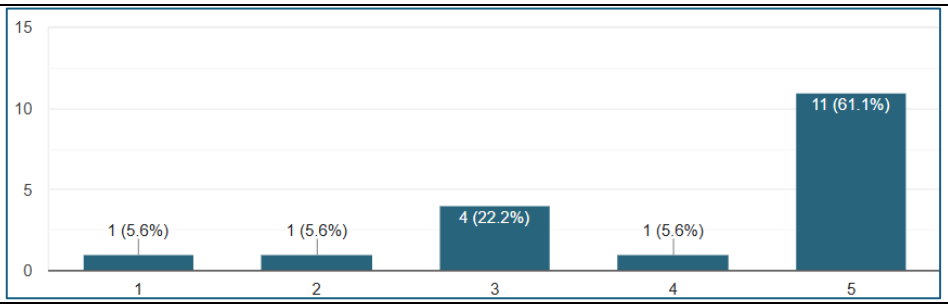
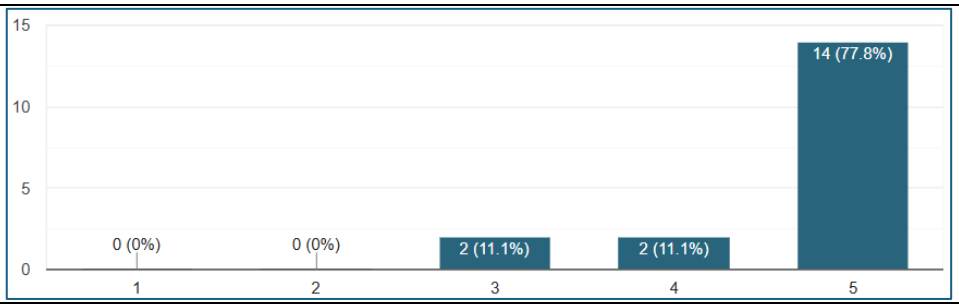
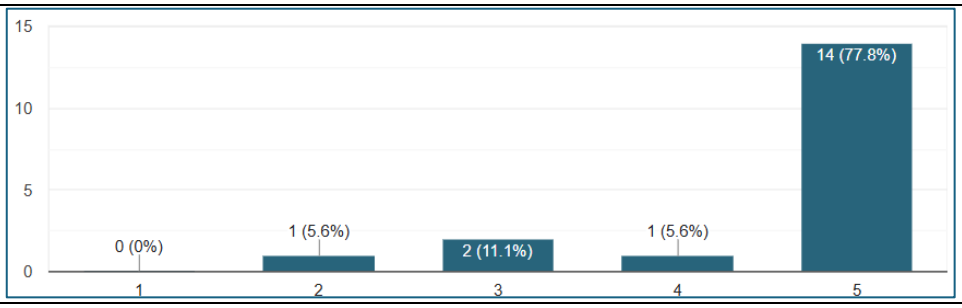
Table 5: Interview Results with the Physiotherapist at National Hospital Sri Lanka

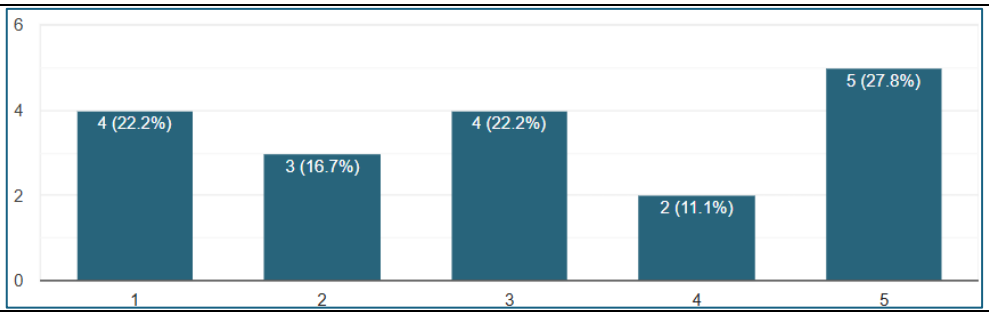
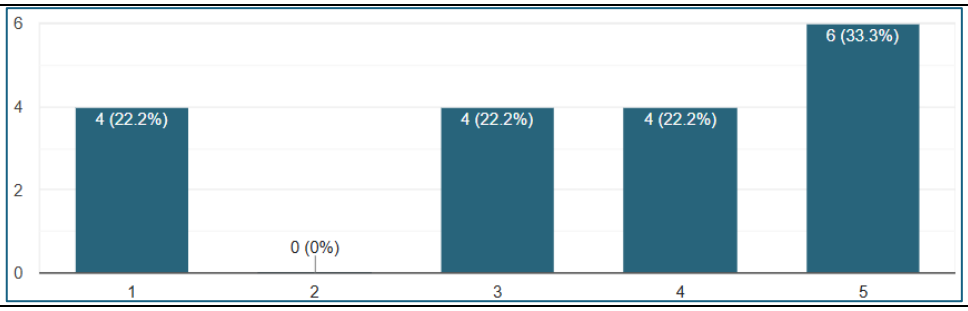
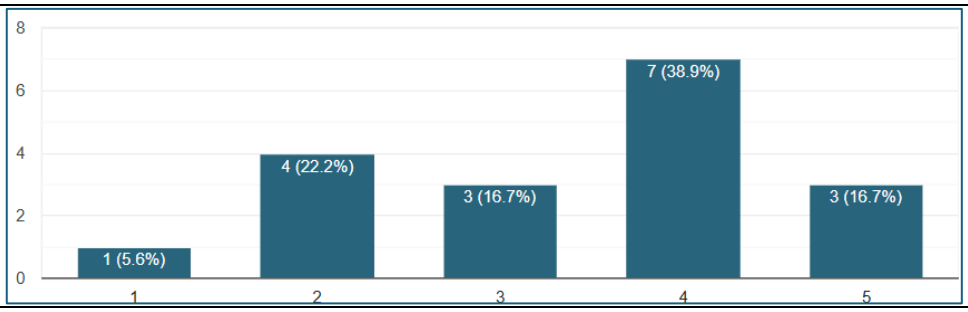
Question	Question Aim	Finding	Conclusion
1.Where on body is a good location to fix an accelerometer and gyroscope for accurate fall detection?	Determine the optimal location for device placement for reliable fall detection.	It was found that placing the device on the stomach is more fitting given the fact that the centre of gravity is normally located there and easily traceable	Placing the device on the stomach is ideal for accurate fall detection.
2.What health conditions or diseases might make a patient more vulnerable to falls?	Identify health conditions that increase fall risk.	Necrosis, Vascular disease, sudden drops and rises of blood pressure, loss of body mass, postural hypertension, joint issues, arthritis, neurological diseases, skeletal deformities.	Understanding these conditions helps target at-risk patients for fall prevention.
3.How quickly should the alert be sent, and should this response time vary based on individual patient conditions or be a standard time frame?	Establish an optimal alert response time to prevent falls.	In general, make it such that the application detects that a person is in the projected process of falling at least 2~3 minutes before they fall such that they may be told to take a seat.	Implementing a pre-fall alert system may effectively reduce the risk of injuries
4.If a patient receives an alert that they are about to fall, can they typically stabilize themselves in response to this alert?	Assess whether patients can respond to pre-fall alerts effectively	In imminent falls, patients can't stabilize themselves easily, but they can be notified to take preventive actions such as sitting down or getting low to the ground immediately.	Alerts can enable patients to take safer positions, reducing injury risk.
5.What assessments or tests do you use to evaluate a person's risk of falling?	Identify reliable fall risk assessment tools.	Physiotherapists calculate the risk of falling using fall risk scales - Berg Balance Scale, the Timed Up and Go test, and the 10-Minute Walk Test	These provide a standardized measure of fall risk for clinical use.
6.Can blood pressure be considered as a good factor for finding fall risk?	Evaluate blood pressure changes as indicators of fall risk.	Blood pressure is not a key factor for falls, but in sudden changes (drops or rises) falls can occur due to dizziness, loss of balance or fainting.	Looking for sudden blood pressure changes should be

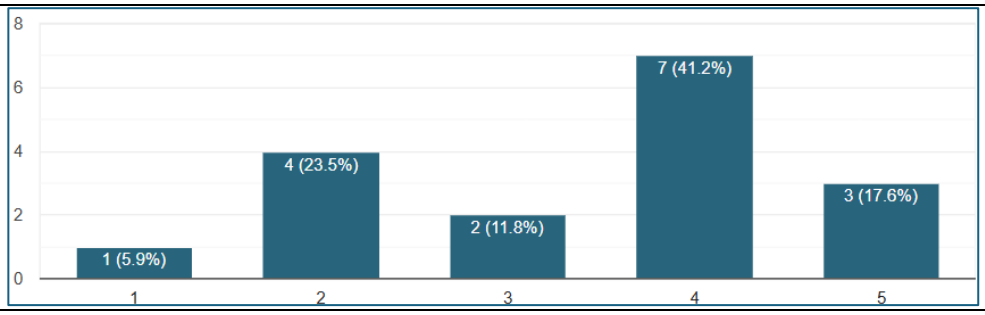
			done rather than just high or low.
7.What additional health conditions contributes to falls, such as sudden drops in blood pressure?	Identify other conditions that may lead to falls.	Conditions like high blood pressure, low blood sugar levels, and heart attacks can also lead to falls.	Blood sugar and heart attack monitoring is not possible due to resource limitations
8.What privacy concerns should we consider, and from whom should we obtain consent?	Ensure compliance with privacy and ethical requirements	Patients consent should always be taken. The patient must always be aware of the device.	Following privacy protocols protects patients' rights and trust in the system.
9.In terms of placing a blood pressure monitor on the body, where can be an appropriate place?	Determine the optimal location for monitoring blood pressure.	Wrist is a good position, because the skin in that area is thin and arteries and veins going in that area is easily identifiable from outside.	Wrist placement should be done for accurate blood pressure monitoring.
10.How do you think our system could benefit patients, especially older adults?	Evaluate potential patient benefits of the system.	very good product for elders and patients with risk of fall. Falls cause injuries, bone fractures, get bedridden, head injuries that will lead to death. This can minimize most of them if alerted before falling.	Early fall alerts may reduce recovery time and improve patient outcomes.
11.Do you have any suggestions for improving our system?	Get suggestions to improve fall detection effectiveness.	Consider identifying elderly patients with specific conditions and directing them toward physiotherapy support.	Personalized recommendations improve system's effectiveness for at-risk patients.

Table 6: Results from the elderly individuals/patients from the National Hospital

Understanding their Needs and Experiences	
Question 1	**How often do you feel unsteady or at risk of losing balance during your daily activities?**
Question Aim	To assess the individual's perceived risk of falls during their daily routine.
Observation	 Responses mostly range from 2 to 4, indicating a moderate sense of unsteadiness.
Conclusion	Many respondents occasionally feel unsteady, suggesting some awareness of fall risks but not extreme concern.
Question 2	**How much extra support do you feel you need for specific activities?**
Question Aim	To understand the level of assistance the individual requires for various tasks.

Observation		Ratings are mixed, with some participants rating it low (1-2), while others lean toward moderate or high (4-5).
Conclusion	The need for additional support varies widely, reflecting individual differences in physical capabilities and confidence.	
Gauging Expectations for the System		
Question 3	**How important would it be to you to receive an alert if you were at risk of a fall?**	
Question Aim	To evaluate the importance of a fall detection and alert system to the individual.	
Observation		Most responses are rated 5, highlighting high importance.
Conclusion	The majority consider fall alerts crucial, reinforcing the system's relevance.	
Question 4	**How comfortable would you feel if someone (like a family member or neighbour) were notified in case of a fall?**	
Question Aim	To determine the individual's openness to external intervention during a fall incident.	
Observation		Responses show strong agreement (mostly 5).
Conclusion	Participants are highly comfortable with notifying others, emphasizing the importance of involving caregivers or family.	
Question 5	**If you couldn't reach someone right away in an emergency, how useful would you find a system to automatically request help?**	
Question Aim	To assess the perceived utility of an automated emergency response system.	
Observation		Almost all responses rate this at 5.

Conclusion	There is strong support for automated emergency assistance, validating the system's utility.
Understanding Comfort Levels with Technology	
Question 6	**How comfortable are you with using technology devices?**
Question Aim	To gauge the individual's familiarity and ease with technology usage.
Observation	 Responses range from 1 to 5, with a mix of very low and very high comfort levels.
Conclusion	There is a divide in technology comfort, suggesting the need for user-friendly designs and possible training for some users.
Question 7	**How concerned are you about privacy when using a monitoring device?**
Question Aim	To understand privacy concerns related to monitoring systems.
Observation	 Ratings vary between 1 and 5, with a tendency toward moderate concern (3-4).
Conclusion	Privacy concerns are significant for some participants, requiring attention to data security and transparency.
Understanding Comfort Levels with Wearable devices	
Question 8	**How comfortable would you be with wearing a lightweight device every day?**
Question Aim	To evaluate the willingness of the individual to wear a device consistently.
Observation	 Responses are varied, with a lean toward moderate to high comfort (3-5).
Conclusion	While most respondents are open to wearing devices, there may still be some resistance or need for adaptation.
Question 9	**How frequently would you be willing to wear a device during the day?**
Question Aim	To understand the individual's preference for device usage frequency.

Observation		Most responses range from 2 to 5, showing varied preferences.
Conclusion	Most respondents are willing to use the device frequently, but some might only use it part-time.	

1.6 Summary of Findings

Findings	Literature Review	Questionnaire	Existing Systems
Optimal device placement on the body	X	X	
Health conditions affecting fall risk	X	X	
Importance of pre-fall alert systems		X	
Privacy concerns in monitoring systems	X	X	
Variability in fall assessment tools	X		
Lack of focus on multi-factor detection	X		X

1.7 Context Diagram

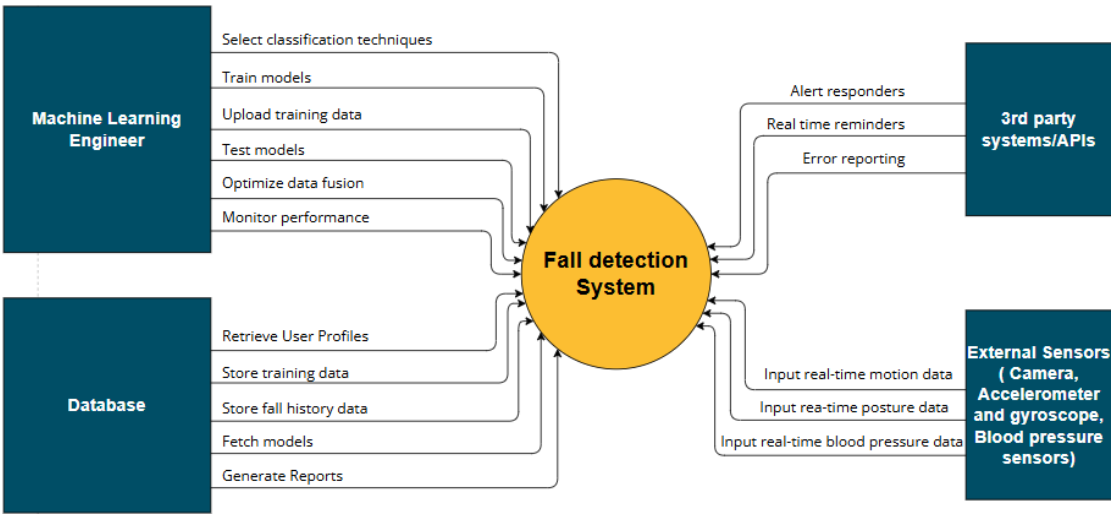


Figure 3: Context Diagram

1.8 Use Case Diagram

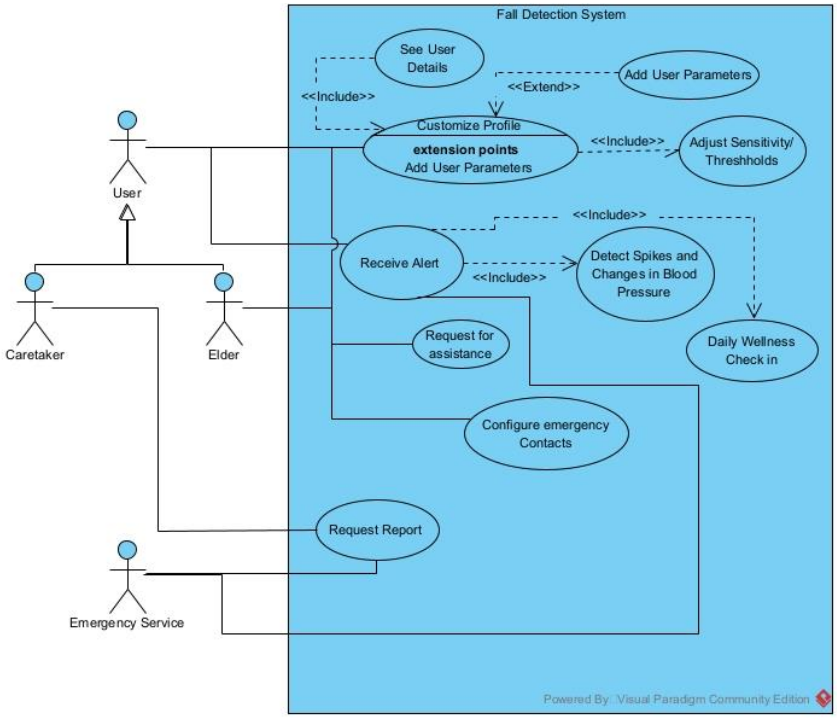


Figure 4: Use Case Diagram

Use Case ID	UC01
Use Case Name	Customize Profile
Description	Customize and view user profiles, registering details and adjusting thresholds
Actors	User (Caretaker, Elder)
Pre-conditions	User must log into the system with valid credentials
Main-Flow	1.User Customizes Profile 2.User adjusts the thresholds of certain parameters (eg: age, height, BMI 3.Add new parameters such as bone density, past conditions, etc 4.User profile is then stored in the system 5.User can view profile to identify causes of symptoms/behaviour.
Alternative Flow	-
Exceptional Flows	User fails to login, loop back to the start of UC01

Table 7: UC01 Description

Use Case ID	UC02
Use Case Name	Receive Alert
Description	User receives fall alerts (caretaker, emergency service, or elder alert to rest/exercise)
Actors	User (Caretaker, Elder), “Emergency Service”
Pre-conditions	A user profile must exist (UC01)
Main-Flow	1.An elderly individual is in a risk of falling

	2.System alerts for erratic movement and blood pressure spikes. 3.Elderly individual performs exercises for self-assessment. 4.The relevant authorities are alerted in case they are in risk of a fall
Alternative Flow	Instead of receiving an alert for a negative factor, it may just be to remind the user to carry out their "daily wellness checks in"
Exceptional Flows	The system fails to alert the user so proceeds to contact another individual

Table 8: UC02 Description

Use Case ID	UC03
Use Case Name	Request for assistance
Description	Elder may press the emergency button to alert authorities.
Actors	Elder
Pre-conditions	A user profile must exist (UC01)
Main-Flow	1.The elder experiences some difficulties in walking 2.System device contacts authorities as a precaution.
Alternative Flow	-
Exceptional Flows	In case the system doesn't work through a manual activation, the systems automated facilities will alert the relevant authorities

Table 9: UC03 Description

Use Case ID	UC04
Use Case Name	Configure emergency contacts
Description	The user can set up emergency contacts in the system.
Actors	User (Caretaker, Elder)
Pre-conditions	A user profile must exist (UC01)
Main-Flow	**1. System** shows the "Emergency Contacts" setup screen in settings. **2.User** selects the option to add a new emergency contact. **3.System** prompts the user to enter contact details (e.g., name, phone number, relationship). **4.User** enters the emergency contact information and confirms the entry. **5.System** verifies the format of the contact information (e.g., valid phone number). **6.System** saves the new contact and displays a confirmation message. **7.User** repeats steps 2-6 to add additional emergency contacts if needed.
Alternative Flow	The user could modify an existing contact or remove one
Exceptional Flows	Invalid contact information, database connection error, maximum contacts reached

Table 10: UC04 Description

Use Case ID	UC05
Use Case Name	Request Report
Description	Elevated users can request performance reports (weekly, bi-weekly, etc.).
Actors	"Emergency Service", Caretaker
Pre-conditions	-
Main-Flow	**1.Actor** navigates to the "Reports" section within the system.

	2.System displays available report options (e.g., weekly, bi-weekly, monthly). **3.Actor** selects a desired report type and specifies a time period. **4.System** retrieves data for the selected time frame and compiles the report. **5.System** generates the report and displays it to the actor in a viewable format. **6.Actor** reviews the report and may choose to download or print it.
Alternative Flow	Request a custom time period-based report
Exceptional Flows	No data available for selected period, Report generation timed out due to error, insufficient access rights

Table 11: UC05 Description

1.9 Functional Requirements

The functional requirements of the application are listed down below (they cover the fundamental needs of our application for it to be considered as a useable system):

Priority Level	Description
Critical	Core functionality/feature of the application, cannot function without it
Moderate	Not mandatory, but is considered as a requirement
Non-Important	Out of scope requirements

Table 12: Priority Definitions

ID	Requirement And Description	Priority
FR01	**Real-Time-Fall Detection –** Always analysing the potential of a fall using the sensors and the camera accurately.	Critical
FR02	**Automated Alerts before a fall occurs and after -** The system must be able to alert the relevant authorities if a user is in risk of a fall or has fallen such that they will respond immediately to the issue	Critical
FR03	**Posture Detection -** The application should be able to detect the posture of a person to detect the persons pre-fall poses.	Critical
FR04	**Blood Pressure Monitoring -** The system must be able to accurately and actively measure the users blood pressure to know if the user might experience a loss or gain in blood pressure	Critical
FR05	**Activity Monitoring -** Track the daily movement of the user to actively being traced and monitored by the system (e.g. see if they're standing, walking or in an idle position)	Moderate
FR06	**Periodic Health Check Reminders -** Constantly or time to time reminding the user to take self-assessments for them and the caretakers to understand their health status. Besides that, the user may be instructed to take a seat to keep them safe.	Critical
FR07	**Long-Term-Data Storage -** Storing historical health data (posture, blood pressure, fall events) to track trends and to generate insights over time.	Moderate
FR08	**Emergency Contact Setup -** The system should enable the user to setup emergency contacts (such as authorities in areas close to them) for them to respond to a fall or potential fall immediately	Critical

FR09	**Battery Level Alerts -** The system should be able to alert the user of low battery levels so in those cases, user can be advised to stay in an idle position (in a controlled space) until the device is ready to be used again.	Critical
FR10	**User Profile Customization -** The caretakers should be able to develop profiles for the user (elder) that take into consideration their age, height, weight, previous conditions.	Moderate
FR11	**Environmental Monitoring Integration** - The system may optionally amend the sensors for room temperature or humidity to provide a safer living environment for users in isolated settings	Non-Important
FR12	**Weekly Health Reports -** The system should be able to generate reports on the users' movements for the week to specify if they have been moving around in an irrational manner such that it might suggest that the user is experiencing fall inducing symptoms	Moderate
FR13	**Manual Emergency Button -** Provides a button for users to manually trigger an alert if they feel at risk of falling or are experiencing a health issue.	Critical
FR14	**Educational Content on Join health -** Includes access to information and tips on joint health, fall prevention, and exercises for improving stability and balance.	Non-Important

Table 13: Functional Requirements Table

1.10 Non-Functional Requirements

The non-functional requirements establish the quality and operational standards for the fall detection system, emphasizing reliability, real-time performance, and data security to ensure it effectively supports its critical functions.

ID	Requirement and Description	Priority
NFR01	**Reliability and Responsiveness**: The system must accurately detect falls and give alerts with minimum of false positives or negatives immediately.	Critical
NFR02	**Performance and Efficiency**: The immediate detection and sending alerts should be done with optimized usage of power for wearable devices.	Critical
NFR03	**Usability and Accessibility**: The interface has to be user-friendly. Needs to have accessible designs (visually impaired people)	High
NFR04	**Security and Data Privacy**: Sensitive data must be handled with privacy standards, which limits access to authorized personnel.	Critical
NFR05	**Scalability and Interoperability**: System should be able to support additional users, sensors, and devices without the need of significant changes.	Moderate
NFR06	**Maintainability**: The codebase should be able to be easily maintained, by allowing for easy updates, bug fixes and future enhancements.	High

Table 14: Non-Functional Requirements Table

1.11 Chapter Summary

To summarize, this chapter covered the fundamental and core requirements of the fall detection project as it listed out all the findings of the study, the functional/non-functional requirements, the use cases, requirements elicitation techniques and the stakeholder analysis to cover the potential contributors to the system (and its development).