Indoor Positioning and Fall Detection System Without Wearables

Fall Detection and Posture Tracking

Group D

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by

Group D

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Abstract

In the past decades, the workload and the pressure on medical personnel has been growing to an unprecedented peak. This is partly due to the ageing population and the increasing capabilities to be independent at an older age, increasing the age people enter nursing homes. This paper focuses on a novel way to detect incidents that could occur in the daily life of the elderly. Unlike most systems already proposed by others, there will be no use of wearable positioning sensors and the system is implemented on an Single Board Computer (SBC). This thesis report is one of a set of two reports discussing the final implementation of the system.

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Abbreviations and Acronyms

Notation	Description	Page List
FSM	Finite State Machine	6
SBC	Single Board Computer	I
TBI	Traumatic Brain Injury	2

1 Introduction

As people age, their bodies undergo a range of changes that increase the likelihood of health and safety incidents. For example, a loss of muscle mass and brittle bones can make falls more dangerous, while decreased reaction time can make it harder to avoid falls altogether. Older adults are also at greater risk for heart attacks and epilepsy, which can have serious consequences even when there is no fall involved. In addition to these immediate threats, there are also more gradual risks to consider. For example, Alzheimer's patients may forget to use the toilet or shower, or may even neglect to eat or drink. Mental health conditions such as depression and anxiety are also common among older adults, who may be dealing with social isolation, grief, and other challenges [1].

Due to the rapidly ageing population, the need for medical staff keeps increasing. Unfortunately, there is a shortage of medical staff. Therefore, there are situations where there is no timely assistance for the elderly who have fallen or injured themselves. This may cause heavier injuries or even death. Additionally, the shortage of medical staff increases the workload on the current nurses. To alleviate the high workload, a smart system to detect falls and other anomalies is developed. The use of this system in care facilities or hospitals will decrease the workload on the medical staff. The nurses will be notified when an incident happened to an elderly. Hence, the nurses do not have to check up on the elderly every now and then. This will leave more time for other tasks. The incident detection systems are not only useful in nursing homes or hospitals but also for the elderly living alone. When an elderly living alone falls or injures themselves, they might not have the ability to call for help. With an autonomous incident detection system, the system will call help for them.

According to the United Nations Development Programme [2], the number of elderly people (people aged 65 or older) in the world was 702.9 million and is projected to reach 1548.9 million by 2050. This 120% projected increase in population will lead to increased medical costs for elderly treatment. Looking at the numbers, it is obvious that in order to be better prepared for the future some measures have to be taken. One measure that will be focused on in this project is fall detection, with the idea that quick response to falls will eliminate complications due to 'long lie' falls, reducing medical costs, reducing the workload on medical staff and increasing the quality of life of the elderly. However, one thing to note is that unlike most work done in this field [3]–[5], this project will focus on incident detection without wearable sensors.

The proposed problem has an emphasis on non-wearables because of several reasons [6]: The elderly might forget to put them on or break them. Wearables need to be charged, which is a nuisance and can be forgotten. The aesthetics of these devices are often disliked because it looks like medical device which reminds them of their mortality. It should not draw attention to the user or single them out as a patient. Wearing them could be uncomfortable, especially during the night while sleeping. Maintaining wireless connections can be confusing and annoying. When the connection is lost, it needs to be re-calibrated. Let us get into more detail about what kinds of incidents can be observed and detected.

1.1. Falls with Delayed Assistance

Falls are very common among elderly people. According to multiple sources [7]–[9], 30-40% of people aged 65 and older are estimated to experience a fall at least once a year. These falls can have major implications both for the health of the elderly and for the medical costs. In the United States, the total direct medical costs for fall-related injuries among older adults in 2008 were US$23.3 billion, and the fall-related costs were reported to be US$1.6 billion in the United Kingdom[8].

Falls also have a much higher risk of causing serious injury for the elderly compared to younger people. Approximately 1 in 10 elderly falls result in a serious injury, such as a hip fracture, other fracture, subdural hematoma, other serious soft-tissue injuries, or head injury [9]. Other sources also state that 5-10% of elder falls lead to serious injuries like fractures [10] or Traumatic Brain Injury (TBI) [11]. It is also worth mentioning elder falls account for approximately 10-15% of visits to the emergency department [8], [9].

Due to the severity of most fall-related injuries and the recovery speed of elderly people, hospital stays end up being quite long. Not only are the recovery times long, but most patients also require physiotherapy which further increases the treatment costs. What makes the situation even worse is that approximately half of the elderly people are not able to get up on their own after a fall [12]. These 'long lies' can lead to complications such as dehydration, rhabdomyolysis, pressure sores/pressure ulcers and pneumonia [12]. These complications not only reduce the quality of life of the elderly, but they also require more treatment in the hospital.

Falls can happen in different formats, some of which can be hard to detect. When somebody falls, they try to stop this from happening; they might try to grab objects around them to stabilize or lean against a wall. There are also cases which look like a fall but actually are regular behaviours that are to be expected. The elderly might be doing yoga or physiotherapy exercises which require one to lie on the floor. This means that all fall and non-falls are going to have different positions, speeds and accelerations, thus traditional thresholding will not suffice. The success of the system hinges on its capability to change dynamically, it needs to have the ability to adapt to every scenario and situation. This is where machine learning comes into play. Smart use of this rapidly expanding field can enable the system to detect falls.

1.2. The Distinction Between Alerts and Alarms

Different incidents require different approaches to handle them. For example, a patient not eating for a day requires less attention than a patient undergoing cardiac arrest. Although both are important, there should exist a distinction in severity. This is the reason why the system processes incidents as either an alert or as an alarm. The difference between an alert and an alarm can metaphorically be described as the difference between sending an e-mail or calling by phone: an email can be responded to after a few hours or even a day, while a phone call is required if an immediate response is needed.

- An alert is a relatively unsubstantial incident. It is important to let the caretaker know that these incidents have occurred, but the time to reach the caretaker is less important. The caretaker can decide whether or not an intervention is necessary.
- An alarm is a drastic incident. It is of the utmost importance for an alarm to reach a caretaker as soon as possible. In the medical field, every second counts; it could be the difference between life and death. It is required that a notification is sent out towards the caretaker when an alarm is set off.

The system can later be expanded to detect more incidents.
The system overview is given in chapter 4. The experimental setup for validation of the full system is discussed in ??). As of the day of handing in this report, the validation of the full system has not been performed, so its results are not included in this report. The paper finishes with a conclusion and discussion in Chapter 8.

A detailed description of the requirements is given in Appendix ??. The deployment requirements and directory structure of the controller are given in Appendix ??.

2 Background Information and Previous Research

Many solutions have already been proposed to address this issue. Some are based on wearable devices, whereas others are completely autonomous. The wearable systems rely on the user wearing or holding a certain device. Autonomous systems do not require the user to hold or wear anything. Instead, the user is being monitored by a sensing device. This chapter will briefly discuss a few of the existing solutions proposed by others.

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Project Requirements

3.1. Existing System

The existing system already runs various other processes in the background, which means that any functionality added by this project needs to be carefully balanced with the other processes to ensure everything can run concurrently without delays. Thus, the primary objective of the project is to develop a robust and efficient system that can detect incidents, such as falls, unusual behaviours or other critical situations that commonly occur among the elderly population, without impacting the performance of the existing infrastructure and processes. The system must be designed to quickly identify these incidents and relay the information to caretakers. This enables them to respond swiftly and potentially save lives.

3.2. Scope

The requirements of the added functionality designed for this project are described in this section. To note, mandatory requirements are strictly required, while trade-off requirements are of lower priority, but would improve the system. Additionally, the requirements are categorized into functional and non-functional requirements. Non-functional requirements specify the constraints of the system, while functional requirements specify the attributes the system must have. The requirements are explained in more detail in Appendix ??.

Mandatory Requirements

- Non-Functional Requirements:
- Functional Requirements:

Trade-Off Requirements

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Software Level Sensor Fusion

4.1. Incident Categories

The implementation of the Finite State Machine (FSM) will ensure that the system will not waste limited resources. It portrays a clear view of the inner workings of the system and can easily be expanded. The FSM

4.2. Packaging and Sending the Data

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Fall Detection and Posture Tracking

5.1. Introduction

This section discusses the two incidents that are detected: falls and pressure injuries. As the average person spends approximately one-third of their life in bed, this area is a highly concentrated area for pressure injuries resulting from a lack of posture changes.

The chapter is structured as follows. The requirements are discussed in Section 5.2. The validation through a protocol containing different scenarios is described in 5.5. Finally, the results of the experiment are discussed in Section 5.6.

5.2. Technical Requirements

See below the technical requirements for the camera and its control system.

5.2.1. Mandatory Requirements

5.2.2. Trade-off Requirements

5.3.

5.3.1. Implementation Procedure

This section discusses the implementation of the process for developing a machine learning model described above.

5.3.2. Testing

5.4. Module Implementation

This section will present and explain the implementation of the complete fall detection and posture tracking module. To keep the flowchart clear, some parts of the functionality are split into sub-modules which will be discussed individually. The complete module will be discussed afterwards.

5.4.1. Sub-modules

5.5. Validation Protocol

All scenarios should be performed with the following requirements:

- Subjects of interest should either be relatively old or try to mimic the movement patterns of the elderly.
- The room should emulate a standard room as specified in the scenario.
- The timer for posture tracking for pressure injuries is set to fifteen seconds[i].
- Each scenario is tested during the day and during the night (or in a darkened room).

[i] See previous footnote

The possible scenarios are:

5.6. Results

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System Integration

Now that every module has been described and designed, it is time to discuss the integration of the full system.

6.1. Combining Modules

Implementing all the different modules without carefully considering the time-sensitive aspects of said modules will make the system inefficient and likely to give inaccurate results.

6.2. Finite State Machine Transitions

6.3. Testing and Validation

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System Results

In this section, the performance of the system as a whole is discussed. As the separate modules have already been tested, only system-wide metrics are discussed here. During testing, two key metrics came to light:

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Future Work