OxfordAQA International

International Extended Project Qualification (9695)

Example response 1

For teaching from 2023 onwards
For assessment from 2024 onwards

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Introduction

This guide includes a student's project that has been assessed by a senior examiner using the International Extended Project Qualification (9695) criteria. You can see the EPQ Assessment Objectives used to score the project below, including the weightings in % and a raw score (in brackets) per Assessment Objective.
Please see page 57 for the detailed breakdown of how this project was graded for each Assessment Objective for the International EPQ (9695) qualification, including a final mark given out of 60 and the senior examiner's commentary.
Please note this project was originally assessed using different Assessment Objectives and weightings, hence why some annotations and comments reflect this.

Assessment Objectives

Please note this project was originally assessed using different Assessment Objectives and weightings, hence why some annotations and comments reflect this.

- **AO1**: **Selection of topic**

  Identify and select an area of interest, devise aims and objectives and establish a working title using a selection of appropriate sources.
  ***Weighting* =** 10% (6)

- **AO2 Planning, monitoring and developing**
  Produce a project plan which incorporates a time schedule and monitor progress against objectives.
  ***Weighting* =** 20% (12)

- **AO3**: **Demonstration of research skills**
  Research, select, organise and scrutinise a range of information and resources, justifying the selection of any secondary and primary sources used.
  ***Weighting* =** 20% (12)

- **AO4**: **Analysis and application of research**
  Implement the project plan, analyse the findings of the research and arrange these findings into a Project product with references and bibliography. Include a conclusion and communicate outcomes in both a report and a presentation.
  ***Weighting* =** 40% (24)

- **AO5: Evaluation of product, process and self**
  Evaluate the strengths and weaknesses of the project process (including review of own learning arising from it) and product.
  ***Weighting* =** 10% (6)

Example response 1

Title

To what extent is the motion sensor of a phone accurate for fall detection?

Response

Please turn over to see Example response 1

Moderator Standardisation

Summer 2023

L3 Extended Project Qualification

Project 1

Please note this project was originally assessed using different Assessment Objectives and weightings, hence why some annotations and comments reflect this.

Please see page 57 for the marks and commentary awarded for the International EPQ 9695 qualification.

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Record of initial ideas

To be completed by the candidate
This page records initial meeting(s) with your supervisor to agree your project ideas. Additional pages can be submitted if more than one idea has been explored.

My idea(s) for topic/title

To what extent is the motion sensor of a phone suitable for fall detection?

Other ideas: possibly to create an artefact in the form of a video game.

My ideas for research and development of my project

The idea is to study the feasibility of using gyroscope and accelerometer data of a mobile phone in fall detection.

The data will most likely be acquired through primary research. A mobile application will be developed to acquire the raw data of the sensors and save it in a format suitable for investigation, for example, a 'csv' file. As for secondary research, the website Kaggle offers a wide range of datasets relating to this project and will be used to get more data.

This project will involve looking at and analyzing the data, exhibiting any patterns found, and whether it would be possible to differentiate between several phone motion. For example, the motion of a phone when someone is falling over or the motion during daily activities. A variety of tests will be carried out to collect the data in different actions, falling motions and environmental conditions.

Fall detection algorithms will be developed using Python based on the collected data to evaluate effectiveness.

Another idea is to create a video game using the Unity game engine. This was used because it is open sourced and has great material to help starting game developers build their first game. The content of the game have not yet been decided.

My summary of the comments and advice from my supervisor

My supervisor and I talked about the purpose of the projects and why have I chosen the ones I did.

For the first idea, we talked about how to make the primary research ethically sound, ensuring it was both accurate and safe for the participants. We also discussed more ways of finding and including secondary data sources. Lastly, changes to proposed titles were mentioned, to try and make it more specific to the purpose of the project.

For the second idea, we discussed brief details about the game, for example, what group of people it was targeted at (children, teenagers, ...), how I was going to make the game, what it was going to include and so on. We also compared this idea with the previous to help me choose between the two.

Modifications I have made as a result of my discussion with my supervisor

As a result of the discussion with my supervisor, I have chosen to go with my initial idea of seeing whether I can detect a fall using a mobile phone. This was because I believe it has more real-world use than simply making a game. Also, it would allow me to implement data science skills I had learnt prior to doing an EPQ. Similarly, I think doing a 5000 word dissertation would help more at university level.

I have also made a few clarifications and changes to the chosen project idea, as well as adding more details about various areas, mentioned below:

Firstly, regarding the purpose of the project: with an aging population, more elderly people are living by themselves, independently. Therefore, if they were to have an accident and fall over, they may be unable to call for help. The project is to see how reliable the sensors in a mobile phone are, when detecting if someone is falling/has fallen over (it is possible to detect if someone is falling over with phone sensor data as there are various downloadable apps online). Benefits include the protection of the elderly, and assurance of their safety for their family members. More research will be done on the benefits of fall detection in other areas (besides for the elderly).

Secondly, the primary research and data collection for this project must be ethical. To ensure that no harm is done, I will ask a group of Judokas to be participants. Although it may be unfair to choose people from a certain 'social group', their background in Judo and other martial arts will help prevent them from being hurt when falling over. Of course, a detailed risk assessment will be given along with proper methods of falling over, that will ensure their safety. The participants will be made fully aware of how and what the data will be used for. The data collection will be done on gym mats that have been created to absorb the majority of the impact, minimizing the amount of harm that could be inflicted. Originally, the idea was for them to fall onto grass to make the data as accurate and realistic as possible but this was considered to be too dangerous. The consent of the participants will be necessary to make this research ethically sound. To collect enough data, the participants will likely be required to fall with a variety of motions, each motion a number of times (currently, 3 times is the chosen amount but this number is not for definite). The entire collection process will be supervised closely, and participants will be able to stop whenever they want. Their personal information will not be disclosed in the research paper. Alternatively, a different option to collect the data is to attach the phone to another object of similar size to that of an average human, and push it to simulate the motion of someone falling over. However, it is likely that data collected this way will be inaccurate, and therefore, this is only an alternative option.

Similarly, secondary research has been considered. Initially, most of the data will have come from primary research, with a few being taken from a database website called Kaggle. However, after the discussion with my supervisor, I have decided to be slightly more reliant on secondary research for data regarding information on things such as the population of the elderly and the amount of people who use phones (instead of the actual sensor data being used). Similar papers about fall detection may also be mentioned, to verify the reliability of the primary research and data analysis. A Word document will be created to store any referenced sources. To make sure any secondary research used is accurate and reliable, they will be taken from reliable sources such as papers from Google Scholar and if possible, will be checked against other sources.

Lastly, the title will be changed to ' To what extent is the motion sensor of a phone suitable for fall detection of the elderly?' for now, to make the purpose of the project more clear.

Date 19/11/2021

Part A: Candidate proposal

To be completed by the candidate

Working title of my Extended Project.
Present the topic to be researched in the form of a short statement/question/hypothesis with clear focus.

To what extent is the motion sensor of a phone suitable for fall detection of the elderly?

- my initial resources will be

AO2 - detailed research, data analysis

To conduct the primary research, a mobile application is needed to collect and save the phone's sensor data. For its creation, the programming language C# and an open-source extension called Xamarin will be used. As for the analysis of the data, the programming language Python has been chosen along with many of it's data science libraries such as Pandas, NumPy and MatplotLib. Microsoft Visual Studio 2019, and Spyder are the IDEs (Integrated Development Environment) that will be used to create the app and analyse the data respectively.

Published papers and online articles will be the main references for secondary research. These will be collected from reliable sources such as Google Scholar and will be peer reviewed with similar papers to ensure the information is trustworthy. Books and journal articles may be used but will probably be less prominent since this topic is relatively new and research is still being conducted.

Other forms of resources include phones and willing participants for the data collection process along with items necessary to ensure they are safe i.e. Judo crashmats.

- the courses of study or area(s) of personal interest to which the topic relates

AO1 - strategies to meet stated objectives

This topic requires a significant amount of coding, which I have a bit of experience doing, by studying Computer Science and participating in online courses. There are 2 reasons this particular topic was chosen.

Firstly, I wanted to try creating a mobile application. This required me to learn a new programming language as well as learn how mobile applications worked - backend, frontend interactions, etc...

Secondly, I wanted to do some data analysis, to implement some of A-level math's statistics and explore the world of Machine Learning.

- my intended product

I am going to produce a 5000 word article.

AO2 - analysis data

For primary research, an app will be created allowing me to access and record the gyroscope and accelerometer data of a phone. The app should display a real-time numerical and graphical visualization of the motion sensors, as well as saving it in an accessible file.

The article will be a report of how well the motion sensor data can determine whether someone has fallen. It will include how the data was collected/analyzed, and the result will be compared with secondary research sources to establish the reliability.

AO2 - appropriate link

Provide details of the courses that you are currently studying

Part B: Supervisor's comments on candidate proposal

To be completed by the supervisor
Please comment below on the validity and feasibility of the candidate proposal (Part A) as an Extended Project

	Supervisor's comments
Indicate the relation to, and development/extension outside of, the main course(s) of study or interest	Although P studies coding in one of his A-Levels, this is not the purpose of his EPQ project and so he will not be at risk of dual accreditation. Although he is using coding to develop an application to detect fall data, his project focus is on the ability to use this application to detect falls in the elderly, and the effectiveness of this in doing so. P will need to get a final check from his IT teacher to go ahead with this idea.
Comment on the suitability of the proposed initial sources and research base	P has decided to do primary research as part of his EPQ - this is considered suitable for the project proposed. He has also shown a good understanding so far of suitable and reliable sources that he aims to use in his report.
Confirm that the project is feasible in the proposed timescale and/or indicate any potential difficulties that may prevent the candidate from meeting the assessment objectives	The proposal is considered feasible in the time frame given provided that P starts the primary research process as soon as possible. He will need to hand in a research proposal to his supervisor/coordinator before he can begin this process to determine any risks associated with his idea.

Indicate the expected format of the project product that will be submitted for assessment

☒ Research based written report

☐ Artefact (for example prototype, model, artwork, scientific investigation, creative writing) plus written report

Is the project a contribution to a group exercise? ☐ YES ☒ NO

If Yes, confirm that there is a defined individual contribution by the candidate ☐ YES ☒ NO

List the **other** group members below.

Date 15/01/2022.

Part C: Centre coordinator's approval of candidate proposal

Supervisor's name

To be completed by the centre coordinator

If you are acting as both the Centre coordinator and the supervisor, please seek counter signature from a senior colleague

Centre coordinator's comments on the feasibility and acceptability of the proposal (parts A & B) as an Extended Project

This project shows that P is thinking widely about the application of his knowledge from his A Level in Computing. Although P will be coding for his app at the start of his project, it is the application of this work that he is exploring and, as such, there is no overlap with his A Level studies. It will be a worthwhile and interesting project, as long as he builds on the suggestions regarding research from his supervisor.

☒ Approved

☒ Approved subject to the implementation of the centre coordinator's recommendations

☐ Resubmission required

Centre coordinator's name

Date 03/02/2022

Planning review

To be completed by the candidate
This page records your outline plan once your proposal has been approved.

My next steps in planning, researching and deadlines that I will set myself. What I intend to do, by when, what resources I will use and how I will implement the recommendations of the centre co-ordinator (where appropriate).

AO1 - organisation skills

Now that my coordinator and supervisor has had a look at the primary research proposal, I plan to carry out the experiment as soon as possible. Since the mobile application being used to collect the sensor data has been created and tested, I will only need to find willing participants and get them to carry out the experiment.

AO2 - analyse data

Once a sufficient amount of data has been collected, I plan on moving to the analysis stage immediately. At first, this requires me to look at the data mathematically, to spot anomalies, or patterns. However, the bulk of the analysis process will be done using programming and Python's data science libraries such as Pandas and NumPy. I am also hoping to implement Machine Learning processes to accurately predict a fall from new input data. More research on the possible mathematical and programming techniques will be done once the data has been collected and the analysis process begins.

My summary of the comments and advice from my supervisor

Me and my supervisor agreed that the main focus currently is to collect the data needed for primary research. Since the experimental method has been finished and checked to make sure it was ethically sound, I now need to create a consent form to ensure that I have proof that proper consent has been given by any participants. We discussed what the consent form should include (mentioned below), and a debrief will be given to the participants once they have finished the experiment.

Modifications I have made as a result of my discussion with my supervisor and/or the comments from my centre coordinator

AO3 - decision making.

After the meeting with my supervisor, no changes will be made to the experimental method or the question of the paper. However, I will now need to write a consent form and a debrief before I can start the experiment for primary research.

AO3 - appropriate data

The consent form will include the purpose of the experiment, telling the participants what they have signed up for, tell them how the data will be collected and what they are expected to do, as well as reminding them of the precautions made to ensure the experiment is safe. Moreover, details on how the data will be used and how their identity will be kept confidential will be given. The consent form will collect some data about the participants such as (but may not be limited to) their age and gender - more details about the sample.

A debrief will be handed to the participants, giving them the option to withdraw their data if they wanted to.

Date 09/02/2022

Mid-project review

To be completed by the candidate

This page records your outline plan when you have completed your research.

Is my project following my original plan? How has my plan developed?

My project is following the original plan in terms of content. It remains as addressing how effective data from a mobile phone is at fall detection. An introduction and literature review has been written. The next part of the write-up will be methodology.

However, there is currently a delay in collecting sensor data and conducting the experiment. Firstly, I was unaware you had to write an experimental proposal, to make the project ethical so a few hours were spent on that. Similarly, another few hours were spent, making the questionnaires (on Google Forms) for the participants of the experiment to fill in, giving their consent. Also, updates to my phone's operating system meant the app no longer worked - the way the app saved data was deprecated, so another method needed to be found. As a result, some time was needed for the redevelopment of the app.

AO3 - problem solving.

Although, at the time of writing this, the experimental proposal, questionnaire and app redevelopment has been completed.

My summary of the comments and advice from my supervisor

AO3 - appropriate changes

My supervisor and I talked at great length about the title of the project. At that point, it was 'To what extent is the motion sensor of a phone suitable for fall detection of the elderly?'. After discussing the plans and content of the project, the title was deemed unsuitable and needed slight adjustments. These will be mentioned later in the modifications section below.

AO2 - data analysis

We then talked about what the project is trying to determine, so how should data be represented and analysed. Currently, it is agreed that I should collect primary research and see how accurate it can be by trying different algorithms and comparing it with different fall detection methods.

AO2 - selection of relevant research

Lastly, me and my supervisor touched briefly on the structure of the latter half of the paper, so what should be included in the discussion and conclusion section - comparisons with other data and papers, what could be improved with the research and any new advancements on the subject. I was also told more data about the UK was needed, to make it less generalized. Most of my data was global statistics.

Modifications I have made as a result of my discussion with my supervisor at this stage

AO3 - development of the initial title.

AO1 - clear identification of topic to be investigated

I will be changing my title to 'To what extent is the motion sensor of a phone accurate for fall detection'. The 'of the elderly' part of the title was removed because the project itself focused more on the data collected from the phone, its implications, and accuracy/usefulness, rather than how this could affect the elderly or vulnerable people. Also, the word 'suitable' has been changed to 'accurate' because I found it somewhat misleading. I thought that different people had different definitions of the word 'suitable'. For example, data could be suitable if it can differentiate between a dropping of the phone and a fall, but not accurately detect when a fall has happened. Since this word is quite broad, I changed it to 'accurate'. The discussion regarding the title was quite lengthy. I mentioned that at an EPQ course I attended (with the University of Leeds as part of their Reach for Excellence programme), they said the title should be as niche and narrow as possible, and taking away 'the elderly' would broaden my project. However, at the end, it was agreed that mentioning it would mean the title strayed away from the actual purpose of the project, so it would be best removed

AO3 - appropriate reasons for change.

AO1 - monitoring project against objectives

Another change being made would be a slight change of content in the introduction. More statistics will be given about falls in the UK rather than globally, to show the impact it is having on the NHS.

AO2 - relevant research

My final title and agreed form of project product

Title: 'To what extent is the motion sensor of a phone accurate for fall detection?'

Form: Extended Essay

My planned next steps to complete my project

The immediate next step is to collect primary research. Most required resources regarding safety and confidentiality has been written and approved by my supervisor. I only need to write the debrief and find participants to conduct the experiment.

I will also need to analyse the data using various different methods and potentially, machine learning algorithms. I will need to research this area further, and am intending to do so once I have collected the necessary data.

As for the essay, I will be steadily continuing writing and editing it, for now, implementing the change in the introduction. I have already discussed what subjects to write for the next few subheadings - results and discussion.

Date 20/04/2022

Project product review

To be completed by the candidate

This page records the (near) completion of your project product. Outline the successes, failures, additions and/or changes you made as you followed the plan in your mid-project review

Did my project follow my revised plan (from the mid-project review)?

The immediate next steps after the mid-project review was to collect and analyse primary data. The collection process went smoothly and quickly - each participant took roughly 8-12 minutes and no participants were injured. All participants were given a debrief to explain how their data was being used and reminded them of their right to withdraw their data.

After that, I had to analyse the data. This took the estimated time of around 3-4 weeks due to complications in data processing and creating/finding a learning algorithm. However, the analysis step did not take too long which allowed me to finish my first draft before the deadline. I would say that I planned relatively well, I distributed time effectively between writing and analyzing/collecting data for this project.

Throughout my EPQ, there were slight changes to my plan. First, I had two ideas: a 5000 word dissertation and an artifact in the form of a game. After discussing it with my supervisor, I decided the dissertation was the better option since it had real-world applications and would be more helpful once I'm at university. There were also changes to the title to make it as precise as possible. During the starting phase, there was some confusion about how I should assess and evaluate the results of my analysis but after discussing it with my supervisor, we concluded that the results were to be compared with similar papers and its similarities and differences elaborated further.

Other changes involved how the data was processed. Initially, I planned to compare multiple machine learning algorithms but after doing further research, I found it very difficult to find and implement different algorithms, especially with unlimited data. Luckily, I did find one which I used for the analysis in this project. Also, because I didn't have enough time to optimize any algorithms, it would be an unfair to compare the performance of each algorithm. Another change is the removal of secondary data. This was due to the time constraint and the fact that I did not have full control over how that data was collected. For example, for some datasets found, there were no descriptions of how quickly the participants moved or how they fell. Therefore, I removed secondary data from the analysis.

Although there were changes throughout, my Gantt chart and plan had accounted for this meaning I was able to meet all deadlines.

My summary of the comments and advice from my supervisor at this final stage

Me and my supervisor reviewed the assessment criteria, which allowed me to assess whether I think they have been met. We discussed the possibility of adding appendices and an abstract. We then finally discussed how the presentation is to be organized and its content.

Modifications I have made as a result of discussion with my supervisor at this final stage
Do I need to do anything else to complete my product?

After discussing with my supervisor, I have decided to include an abstract in my dissertation. However, I must be cautious since I am very close to the maximum word count of 5000. The abstract will include a brief summary of my project and my findings and will allow my dissertation to look more professional and scientific. I will then proofread my dissertation for any grammatical errors or inconsistencies.

Another next step is to start planning my presentation.

Date 06/09/2022

Presentation record part A

To be completed by the candidate
This page records your presentation and its preparation.

Planned format of my presentation (eg timing, audience, use of visual aids, slides, use of notes, etc.)

I will be doing a stand-up presentation with the support of PowerPoint slides to explain my project and findings to the audience. The audience will be other Year 12s who likely have no knowledge about this subject. Therefore, my presentation needs to be simple yet informative to not make the content too difficult to understand making it become boring.

I decided to not use handouts of graphs or tables because it doesn't contribute much to the audience's understanding and I believe a large image on the board is sufficient. Also, it may be a hassle to keep on needing to flick through the images, and since many graphs look similar, it may confusing at times.

I will be holding short notes containing facts and statistics. It will also help me maintain the structure of the presentation, and remind me of the contents and order of each slide. I will not be reading entirely off a script because of its lack of flexibility and from past experience, the audience tend to quickly get bored.

Planned content of my presentation

For my presentation, I plan on mentioning the following topics:

- Introduction: welcoming audience and brief explanation of title. I will also explain why I started this project.
- Problem: I will give some statistics related to falling and explain why it is a problem. The content includes who it mainly affects (the elderly) and financial and mental impacts related to falling.
- Objective: what I was wanting to find, whether a phone can detect a fall.
- Methodology: how I collected and analysed the data.
- Results: a brief explanation of my findings and concluding the presentation.

Modifications I have made as a result of rehearsal and/or discussion with my supervisor

After speaking with my supervisor, I have realized that I needed to have more information relating to feedback and reflection. There will be extra slides relating to what I have learnt from doing an EPQ and what I would've done differently.

Date 06/07/2022

Presentation record part B

To be completed by the supervisor
Record and comment below on the delivery of the presentation

	Supervisor's record/comments
The nature of the audience (include numbers of staff, students and others present)	The audience was made up of several staff members, including supervisor and the student support manager of the Sixth Form team. Other Sixth Form students were also present in the audience.
The nature of the presentation (include use of notes, use of display items, and use of presentation software)	Visual PPT slides used to present, along with notes to support ideas and delivery
Comment on the content and delivery of the presentation (for example clarity of ideas, structure of presentation, pace, engagement with audience)	gave a very confident delivery of his presentation. He reviewed his objectives and explained them with clarity to the audience, as well as results found in his primary research. engaged very well with the audience, maintaining eye contact and interacting very confidently, including during the Q&A.. He had good eye contact throughout, not relying on notes and the PPT slides to read.
Comment on the response of the candidate to questions that demonstrated understanding and grasp of the project and/or its production. **Give examples of questions asked and answers given.**	There was a Q+A session with the audience after the presentation, in which demonstrated an excellent grasp of the questions asked. He was comfortable to clarify questions if needed. When asked 'What was the biggest challenge faced when doing your primary research?' he answered 'Analysing the data afterwards, as it relied on finding an algorithm to do the analysis. As many areas of my topic are new areas of research this was something that was difficult to overcome'. When asked how he overcome this obstacle, he replied that he did this through resilience - using trial and error. See other examples of Q&A attached.

Date 12/07/2022

EPQ Presentation – 6th July 2022

Supervisor Q&A

Question	Candidate response
Biggest challenge in research?	Analysis of data AO4 - evaluation of implementation ↳ finding an algorithm to analyse ↳ New area of research so difficult to overcome.
What have you enjoyed most?	After doing a course on computer science (optional), I was able to apply what I had learned in practice. AO4 - candidates own learning
Were there any resources you didn't use? Why?	focused on primary research as I didn't have full control of the secondary sources - some of them may not have been compatible with my aims AO2 - selection of resources. Application of resources linked to aims

Question	Candidate response
If time was not an issue, would you use secondary sources?	This would depend on what kind of data was available, but would most likely be less desirable than more primary data. AO2 - Selection and evaluation of resources
Are there any notions that occur outside or what you examined & how would this assect your conclusion?	Yes, extreme notions & other similar activities fall outside the scope & would most likely reduce the accuracy. AO4 - evaluation of strengths & weaknesses of data.

EPO Presentation – 6th July 2022

Question	Candidate response
What was your methodology?	Specific requirement for participants : they had to do judo so that they could fall without hurting selves. Consent forms signed. 2 ppts. Asked to : walk up and down, walking and falling forwards, walking and falling backwards, walking and falling left or right (ppt choice) and walking and dropping phone. Did each motion 3 times, resulted in 30 data sets.
Did you find a reason that smart watches were more accurate	Secondary data used on smart watches. They had roughly 10 x more data set. To hypothesise, my algorithm was not optimised and would need more data sets to be able to accurately predict the motions.
	AO4 - evaluation of weaknesses & strengths of data gathered

knows his topic well (notes for supervisor).

nerves shown through body language.

Compared accuracy to other possible options

↳ would have liked this to have been more in depth.

Q. Is there a reason that smart watches were more accurate than phones?

What was his methodology?

Can see his passion and knowledge on the subject shining

Summary and reflection

To be completed by the candidate

This page records your summary, reflection and evaluation when you have completed your project product and given your presentation.

Some questions you may wish to answer in this section include, what have I learned from completing this project? What new knowledge or expertise have I enjoyed or found valuable? What are the strengths and weaknesses of my project (including planning and organisation)? What skills have I improved? What changes would I make if I undertook such work again? What advice would I give to others undertaking such a project?

For my EPQ project, I wrote a 5000 word dissertation about whether fall detection can be implemented on a phone. I'd learnt many things throughout the process:

Firstly, writing the dissertation itself. This was the first time I had written an extended essay of this kind. Therefore, initially, there were lots of confusion about the formality of the writing and its content. However, after several discussions with my supervisor, this problem became less prominent and eventually negligible towards the end. In addition, I have learnt how to properly reference which I believe is a key skill in future works that I may do, as well as proofreading and going back to edit sections while staying consistent with content and avoiding repetition.

Other new skills I had picked up along the way include the ability to read scientific papers and articles, and familiarize myself with Google Scholar. I believe I am now much more capable of finding related resources that may support or contradict my idea and understand them/use them in my writing. Similarly, since I did primary research, I am much more aware of the health, safety and ethics requirements related to performing an experiment. For example, making a consent form and writing an experimental method among other things.

I was also able to develop skills such as communication. I was able to convey my ideas effectively to my supervisor, and explain what I had trouble with or how I intended to resolve a problem. Furthermore, I think I had improved my time management skill significantly. Although it wasn't spectacular, especially towards the start, I was able to create an effective Gantt chart and stuck to it which allowed my to comfortably meet all deadlines.

Lastly, a valuable skill I think I improved was my presentation making and performing skills. Prior to doing the presentation, I was very nervous standing and speaking in front of crowds. Previous presentations ended in a bored audience. However, after speaking to my supervisor on how to avoid this, I was much more confident and had a better understanding of slide contents and how it should be performed. I opted for pictures and tried my best to give clear and concise explanations on the topic I chose, especially since it is quite specialized and arguably advanced. I think this presentation was successful. I felt more confident going into and during the presentation, as well as answering questions from the audience at the end. Some even came up and said it was 'good' and 'interesting'.

Doing an EPQ not only gave me the chance to learn how to write dissertations, it allowed me to test some data analysis skills I acquired by doing an online course a few years prior. Also, I had a chance/reason to create a mobile application using code (which allowed me to collect sensor data). The EPQ gave me an opportunity to explore more areas in my field of interest - computing. I intend on studying computer science or electronic engineering at university. These subjects include research work as well as practical applications which the EPQ has prepared me for. Moreover, after attending open days and taster sessions, they also seem to require lots of presentations, which once again, the EPQ has given me a preview of what it would be like.

My final product was the 5000 word dissertation, where I first explored the idea of fall detection and why it would be helpful before going onto explaining the experimental method and the results of the data analysis. I also compared my results with other papers'. Given the amount of time I had and my lack of experience analyzing data, my results were suboptimal. If I had more time, I would have tried to collect significantly more data as well as optimize my detection algorithm. Compared to other research, the accuracy rate of my algorithm was lower but that was to be a given. The results of my project may contribute to research in healthcare and prevention of falls, especially for people in lower income countries, as it tries to prove that phones can be an affordable implementation of fall detection.

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I think my main weakness was time-management. I had started the project without much of a plan, and only a rough idea of what I was going to do. I thought I would be able to estimate how long each section of the project took to complete, but this assumption was false. Therefore, there was very little progress until a few months in, when I decided to make a Gantt chart. This created a rigid structure that I stuck to, making the project much more organized. However, this lack of initial time management had consequences. Firstly, I had planned to implement multiple Machine Learning algorithms but couldn't do so due to lack of time for research and implementation. Similarly, time for data analysis was limited so the results from this project could potentially be not optimal. Also, if I had more time, I could have collected more data or process secondary data which could've improved the performance of my algorithms. As a result, if I had organized my time more effectively at the start, the results from the paper would likely have improved. I would likely try to improve my data analysis skills and understanding of machine learning in preparation for the data analysis stage. This would also improve the performance of the results.

Another weakness I had was the writing itself. At first, there were many filler words which took up the word count. I quickly ran out so I had to edit the paper and get to the point more quickly, removed unnecessary work. Obviously this wasted time supporting my previous comment on time-management.

Although difficult at times, I found the experience I had and the skills I'd developed throughout my EPQ valuable. The journey was interesting and new and definitely wasn't smooth or easy. If I were to do the project again, I would likely plan my time a bit better. This would allow me to focus on different areas such as how well different algorithms did at detecting falls, or create an artifact that implemented a fall detection system. Also, I would be more prepared so the planning would be more detailed, and writing the dissertation (if there was one) would take less time. I would likely keep the topics related to technology since it is my area of interest and will be most beneficial for university.

If I was asked for advice on how to do an EPQ effectively, my first advice would be create mind maps to explore ideas. Make a mind map of a general subject, for example, computer science or English etc, and create branches on possible project ideas. This allows you to visualize the potential research ideas, and allows you to keep track of them. Another advice would be to make a Gantt chart, do it as soon as you have your idea, and in as much detail as possible. This prevents procrastination and gives you an idea of how long things should take. Another advice is to be confident during the presentation. It's not as bad as it seems, especially once you've done a year's worth of research on it. Lastly, spread the writing of the dissertation out thoroughly into small, manageable chunks. Not only does this make writing the dissertation less boring, the dissertation itself would be to a higher quality since you would have more time in between to think and ponder on how to write/explain an idea.

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2022

To What Extent is the Motion Sensor of a Phone Accurate for Fall Detection?

Abstract

Falling is a major problem world-wide, and its impact on health services will become increasingly predominant as the population increases. This paper investigates whether a phone can accurately detect falls based on its sensor readings, to act as an effective and affordable implementation of fall detection. Accelerometer and gyroscope readings were collected from the phone's built-in sensor via a specially built application. Mathematical and computational approaches (thresholds and machine learning respectively) were applied to the data to classify whether it was fall or not fall. Experimental results found that phones produced relatively high accuracy rates but could not match that of competing fall detection methods such as IMU devices and smart watches. This paper concludes by expressing phones have the potential to be an alternative method of fall detection and suggests optimizing algorithms and applying it to more data to better represent its performance.

1 Introduction

1.1 Problem

According to the World Health Organization, falling is the second leading cause of 'unintentional injury deaths' worldwide [1]. It is estimated that every year, 684000 people die from falling over (globally), with adults aged 60 and above being at a significantly greater risk. Around one-fifth of the UK's population is aged 65 and over [2], putting it on the forefront of the problem. Although not all falls are fatal, many are still life-threatening, with a plethora of reasons why this may be the case. Falling can lead to broken bones, damaged ligaments and tendons which may take time to heal, or potentially, leave the person with a permanent disability. It can also lead to brain injuries or damage vital internal organs. The person may also be affected psychologically; they may lose confidence or feel as if they can no longer live independently.

Similarly, falling can come with financial issues, especially in cases where individuals must pay for their healthcare (in countries such as Canada or USA). They must pay for any medications, equipment or surgery needed to prevent a fall as well as those that came as a result. In 2015, the total medical costs associated with falls came to a total of more than $50 million in the United States alone [3].

With the total population expected to continue rising by 1.0% per year [4], and the elderly population to double by 2050 [5], this problem will become ever more prominent and therefore pose a greater stress on health services internationally.

1.2 Literature Review

There are many ways of preventing a fall, ranging from developing daily habits such as tying shoelaces, and mopping up spillages, to strength and balance training. However, as advancements are being made, many people turn to technology.

The phone is the most commonly used and owned piece of technology with desktop Personal Computers coming in second. 53.5 million people in the UK own a smartphone, making it roughly 80% of the population [6]. Globally, the number of people who own a phone is expected to rise as the younger generations age and lower income countries become more developed. Therefore, it may be an easy-to-use, inexpensive way to implement fall detection.

That is not to say, the phone is the only possible method. Other technologies can be used, for example, watches or wearable IMU (Inertial Movement Unit) devices. Like the phone, these use gyroscopes, and accelerometers to measure movement and likely uses a machine learning algorithm to detect when/if a person has fallen over. Fitbit and Apple watches are commonly used. However, the fall detection feature on these have mixed reviews, with Apple stating that their watches 'cannot detect all falls' [7]. Moreover, there is the case of False Positives, where the watch reports a fall that never occurred. This mistake could be due to sudden movements of a person's hand (or elsewhere on the body in the case of IMUs). With time, the effectiveness of fall detection features will improve, as technological advancements are made in both the sensors as well as the detection methods.

Similarly, cameras can be used to track movement and detect if a person has fallen over based on its visual input. It can also record what caused the fall and how the person fell. Because cameras are not portable, this method is mostly implemented in areas where there is a high concentration of people who are likely to fall, for example, an elderly home or a hospital.

The main drawback to the mentioned options is the cost. A (sometimes large) financial investment is needed, which many cannot afford – a smart watch can cost hundreds of pounds. Since most people

already own a phone, little to no investment is needed making it the much more affordable alternative.

A technological approach will be the most effective and efficient method for data analysis. This could mean using a program to visualize the data in the form of a graph or chart and proceeding to analyse it using code. There is a wide variety of programming languages capable of this. However, it is widely accepted that Python is the go-to language, as it has many libraries and extensions such as Pandas and NumPy (among many others), specifically built for the task. It also has a strong background in machine learning and artificial intelligence, with over 60% of developers using and prioritising it for development [8].

There are many papers dedicated to fall detection, exploring different areas of the subject, as it is a prominent problem [9] [10] [11]. For example, existing 'pre-impact' apparatus, indicators and algorithms has been reviewed by Hu and Qu for their performance and sensitivity [9], to help prevent a fall or minimize the effect. These can help activate 'on-demand fall injury prevention systems' such as inflatable hips as suggested by the paper. Before proposing future research directions, the writers also summarized the limitations of current designs. One such limitation is current technology – wearable sensors are susceptible to noise, context-aware systems (such as cameras or a device which tracked fluctuation of radiofrequency) are expensive and requires high computational power. Another is limited external validity – actual fall data is hard to acquire so most fall data are collected from simulations, potentially making them inaccurate, unrealistic.

Similarly, Khan and Hoey surveyed the availability of data [10] used to train supervised machine learning algorithms. They produced a taxonomy, which categorised distinct types of accessible data, independent of sensors used or selection methods. Their paper explained different techniques which may be used for different types of data – labelled, semi-labelled and unlabelled data, or when there is an insufficient amount. For example, an algorithm may detect a fall by sensing anomalies instead of looking at sensor reading patterns, in the case of training data absence. It also notes that implementing thresholds on sensor readings may be inexpensive but is hard to generalize across different people and is therefore inaccurate. Like the previous article, it agreed that realistic fall data is hard to acquire, thus has reduced availability or incomplete datasets (semi/unlabelled) making it hard to process. Moreover, the paper concluded by discussing open research problems and potential future research such as a 'standard framework to evaluate different detection methods.'

D. Miguel et al looked at making a low-cost, 'camera-based fall detection system' [11]. A camera is used to track a person, modelling their movement data in real-time and applying it to a machine learning algorithm. The system can potentially have an alert feature, which will notify a user via a text message if a fall is detected and whether the subject has recovered. Their product had success, with a detection rate of 'greater than 96%'.

Huynh et al [12] optimized a fall detection algorithm that used both accelerometer and gyroscope readings from an IMU. According to their paper, when using accelerometer alone, algorithms had to trade sensitivity for specificity. This means although algorithms could correctly detect a fall with high accuracy, they were not very sensitive so larger movements were needed for the detection to trigger. Specificity of accelerometer-only algorithms ranged from 88% to 94% but had sensitivity of around 85%. Their algorithm implemented the gyroscope which contributed to detecting falls and resulted in both high specificity and high sensitivity, of 96.3% and 96.2% respectively.

Ge and Xu [13], compared the result between using static and adaptive thresholds. Thresholds define a region where a specific type of data should be, for example, walking. If the data exceeds the region,

it is classified as something else, for example, falling. Static thresholds stay constant regardless of the pattern of data, while adaptive thresholds change in accordance with the data. Their study found (using data from a mobile phone) that adaptive thresholds had a higher performance, with an accuracy increase of around 2% to 5%. Another paper, by Ren and Shi [14], proposed static thresholds were inflexible, and also implemented adaptive thresholds in their study, concluding with similar results.

This paper will be trying to determine how effective a mobile phone is at fall detection, based on readings from the device's built-in sensors: gyroscope (measures orientation and angular velocity) and accelerometer (measures acceleration). The primary data will be collected by a mobile application that can both access and record the reading from the sensors. Then, a mathematical and technological approach will be used for analysis. This will be further detailed in the next section of the paper.

2 Methodology

In order to perform this study, experiments will be carried out to collect the accelerometer and gyroscope data. Then, various methods were employed to differentiate between motions based on the pattern of the data.

2.1 Application Used

A mobile application was developed for participants to easily collect fall data. Figure 1 displays how the application looked on the phone used for the experiment

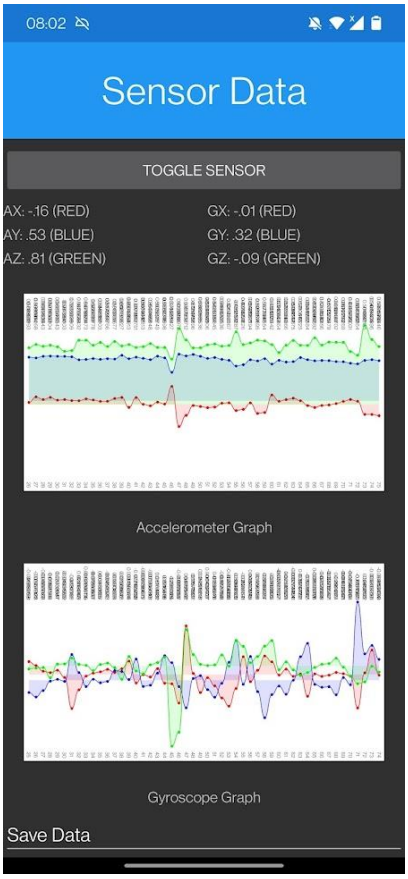

Figure 1

A button at the top will allow participants to turn the sensors on and off. Accelerometer and gyroscope readings were shown beneath the button to two decimal places. There were also graphs visualizing the sensor data in real-time. This gave the participants a rough idea of how the data looked. It also

indicated whether the sensors had been turned on, if there was no change in the graphs or the sensor readings, then the sensor had not yet been turned on. The very bottom part of the app allowed participants to change the name of the file that data was saved to – a new file was created for each new file name.

Sampling rate of the application was 14Hz.

2.2 Experimental Setup

The environment was fixed, and the phone position was kept constant throughout, so only the motion performed affected the sensor readings.

There were two participants, with initials BD and TV, performing the experiments, independent from one another. They were both male, aged 16 and 13 respectively, and both came from Leeds. Participants performed a set of five motions – normal walking, falling forwards, backwards, to the side and dropping the phone.

Each motion was repeated three times producing a total of 30 datasets. Before starting, participants were given a briefing about what they were required to do, what and how the data was collected, how it was going to be used and the precautions taken place to ensure their safety and confidentiality. The full procedure is attached in the appendix.

2.3 Ethics

2.3.1 Participants

Although this experiment tried not to target participants from a single demographic, it was important that they could withstand the impact of falling over multiple times. Therefore, only those who have had at least 6 months experience in Judo was to partake in this experiment. They would have thoroughly practiced 'Ukemi' or 'breakfalls' – this included forward, backward and side breakfalls. These techniques were utilized throughout each process to minimize the impact of falling over and ensured participants remain physically unharmed. Moreover, they fell onto gymnastics mats for the same reasons previously mentioned. Participants were able to take a break of up to 10 minutes between each motion and could stop the experiment before completion if they wished (if this was the case, their data would be deleted as it was not fit for analysis).

Participants' parents were given details about the experiment and permission for it to be carried out was granted.

2.3.2 Process

During Motion 4, falling to the side, participants placed the phone in the opposite pocket to the side that they were falling on. This was so the phone does not bridge between their body and the mat, potentially harming the participant or breaking. To keep the results consistent, participants needed to keep the phone on this same side throughout all motions, so they declared which side they were going to fall onto before conducting the first process.

2.3.3 Confidentiality and Consent

To be involved in the experiment, participants needed to fill in a Consent Form on Google Forms, sent to them via email. They needed to state their age, gender, and the city they lived in. They also needed to confirm that they have read the information sheet about the experiment and understood the risks associated with it, as well as provide consent.

The identity of each participant was kept anonymous throughout the experiment and analysis. To do this, they were only addressed by their initials, and their data was/will not be shared. At the end of

the experiment, participants were given a debrief explaining how their data was going to be used and informed them that they had the right to withdraw their data at any time.

2.4 Data Analysis

The collected data was initially studied by manually visualizing it. After this, two methods of fall detection were developed. The first was to implement thresholds. If the data exceeded a region or set of regions, it was to be detected as a fall.

Another method was using a classifier, a machine learning algorithm which categorized data into groups depending on their structure and characteristics, for example, grouping the data into 'fall' or 'not fall'. The proposed algorithm was a Convolution Neural Network (CNN) – a Deep Learning algorithm based on a model of the visual cortex [15]. The purpose of the algorithm was to differentiate images of distinct topics from one another. It took the image as an input, assigned weights, or biases to different parts, and classified the image based on its features.

3 Results

The accelerometer measures the acceleration of the phone with respect to gravity, so the Earth's gravitational pull is always influencing the phone's sensors. Values are usually represented in terms of g in three axes (x, y, z), fixed with the phone. As the phone's orientation change, the measured data will be changed accordingly.

The gyroscope measures the rate of rotation around a particular axis of the phone. Gyroscope sensors are not affected by the Earth's gravitational pull since gravity does not act at an angle.

There were two participants, TV and BD, producing a total of 30 datasets from 5 different motions.

Section 3.1 shows the results of acceleration data only, while Section 3.2 shows both data.

3.1 Accelerometer Only

3.1.1 Visualization

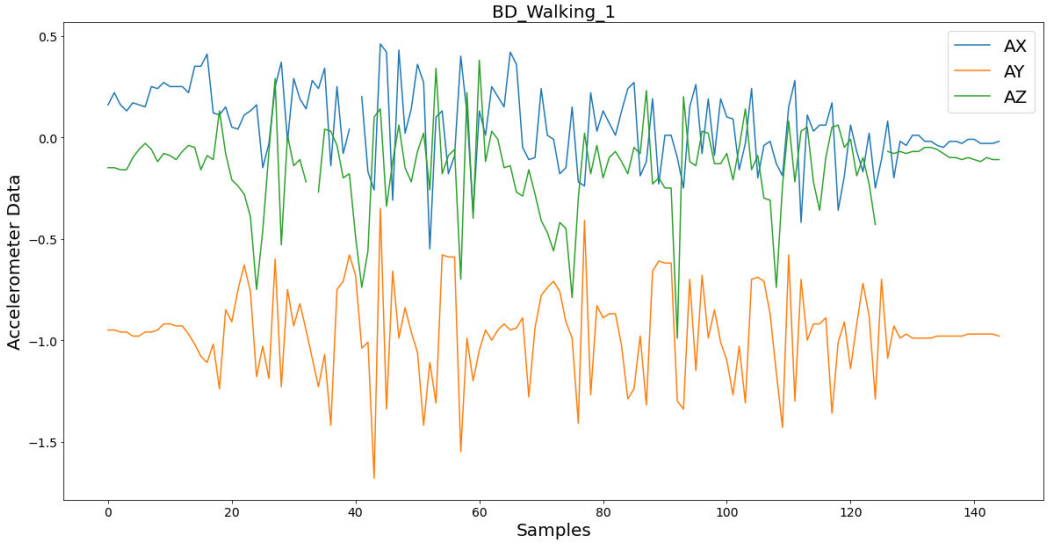

Figure 2

Figure 2 shows the three-axis accelerometer data of Participant BD walking. The x-axis represents the sample index. The walk took approximately 10 seconds, at a sampling rate of 14Hz, which resulted in approximately 140 samples. The line AY fluctuated around -1 rather than 0 because the phone's y-

component was aligned with the force of gravity but facing the opposite way. As the participant moved their leg to walk, the acceleration changed accordingly.

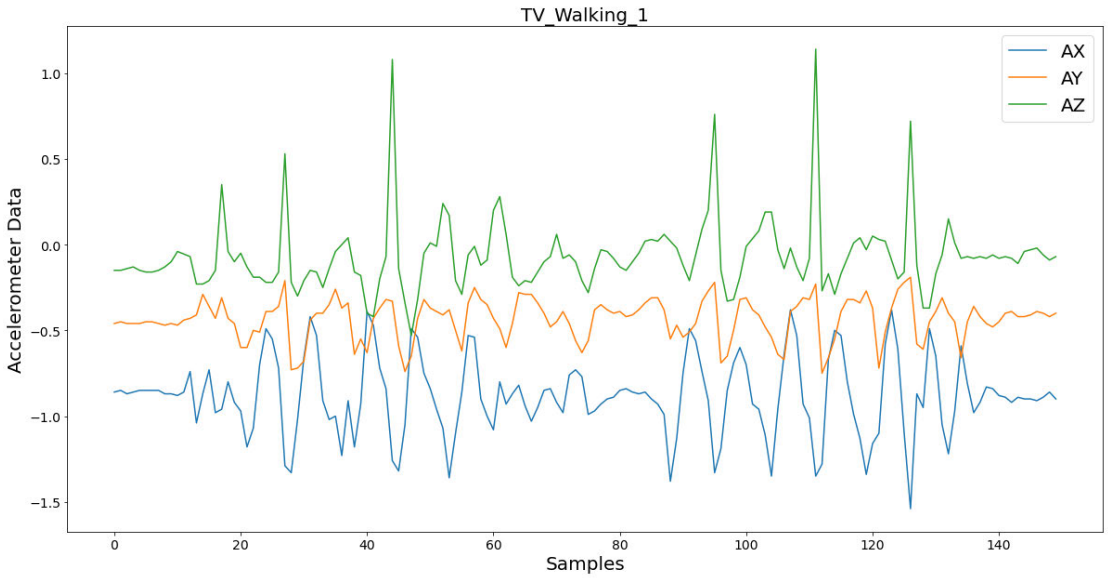

Figure 3

Figure 3 displays the walking data from Participant TV. The data was linearly interpolated at several locations due to gaps in the original data. Between Figure 2 and Figure 3, the walking patterns of the two participants were different. This may have been due to a combination of the size difference between the participants, their walking habits and/or their clothing, participant TV wore looser clothing.

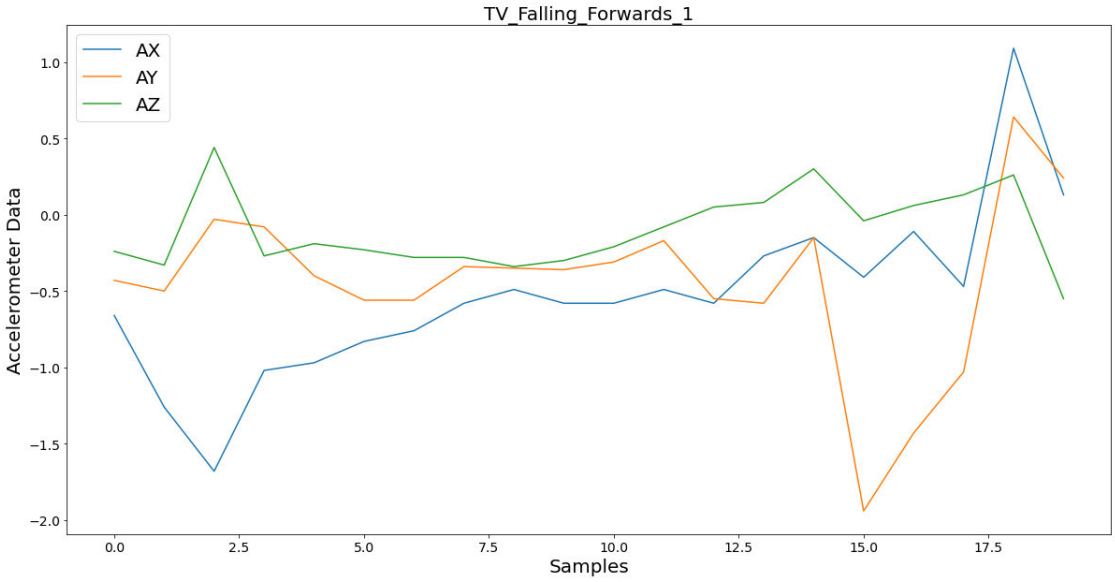

Figure 4

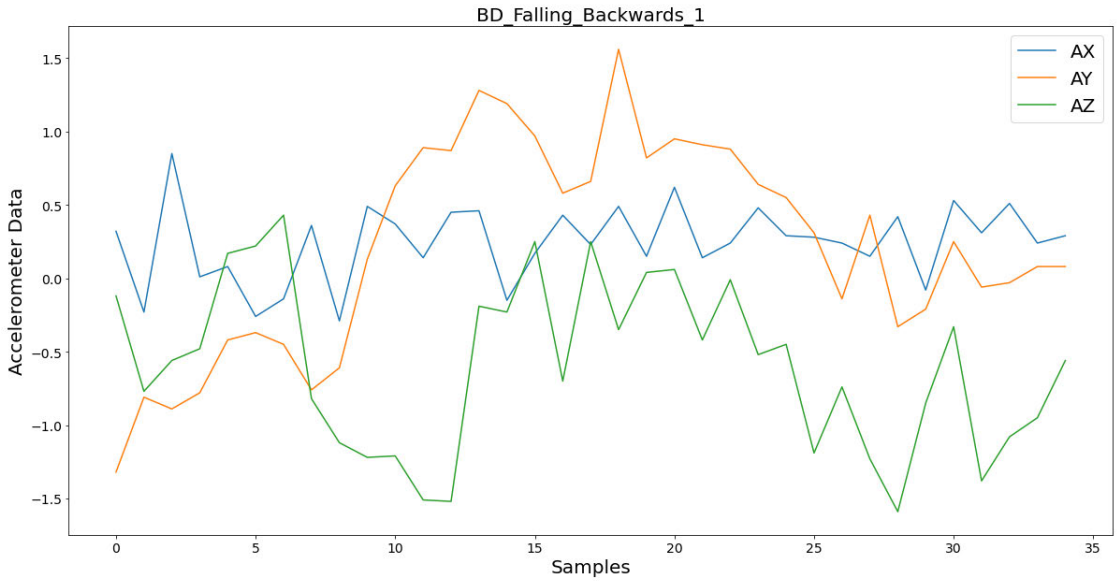

Figure 5

Figure 4 shows the data of Participant TV falling forwards. The motion lasted around 1.2 seconds so approximately 20 samples were produced. Different ways of falling produced different accelerometer patterns but they followed the general trend of staying relatively flat before spiking suddenly. For example, Figure 5 shows participant BD falling backwards. It obeyed the observation, but its peak was wider than Figure 4's and AY had a positive change rather than negative. Spikes were to be expected since the participant would accelerate quickly before hitting the ground when they fall over.

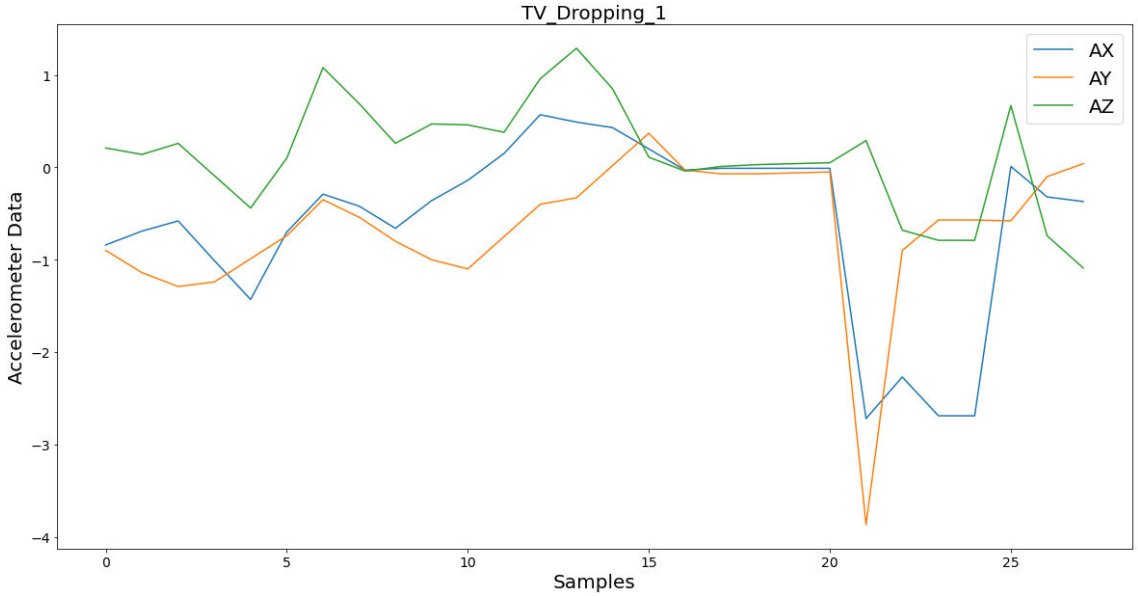

Figure 6

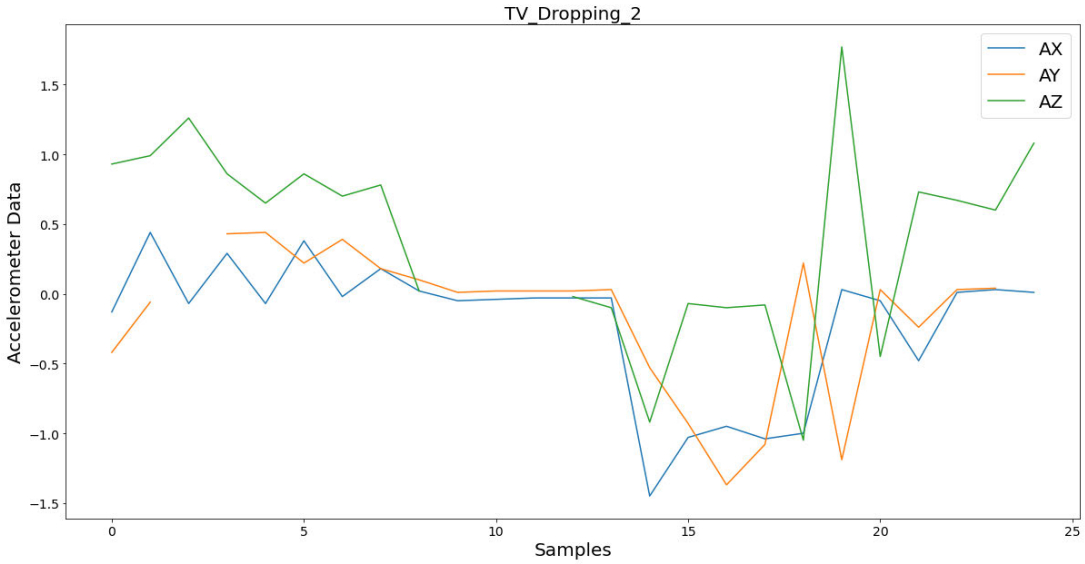

Figure 7

Figure 6 shows Participant TV dropping the phone, which had a similar pattern to Figure 4 – lines staying flat before spiking. This motion lasted roughly 1.5 seconds so approximately 30 samples were collected. The way the phone was dropped and the way it bounced greatly influenced the accelerometer reading. For example, Figure 7 shows another dropping pattern by the same participant. The pattern was mostly similar to Figure 6, besides the AZ spike, suggesting the phone had bounced.

3.1.2 Thresholding Method

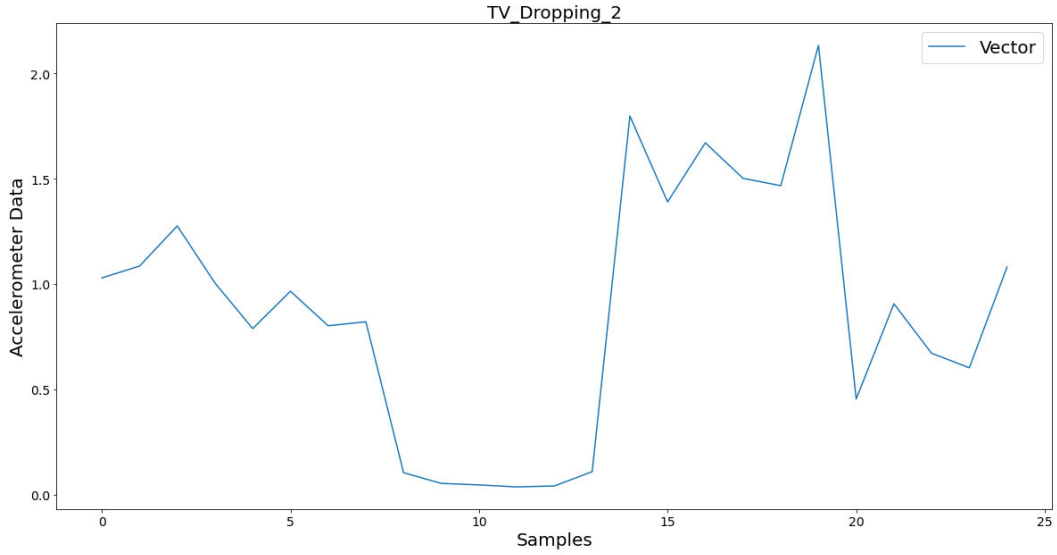

Figure 8

The three axes were combined to find the magnitude of the acceleration vector by using the equation below:

$$|R| = \sqrt{(AX)^2 + (AY)^2 + (AZ)^2}$$

Figure 8 shows the absolute magnitude of acceleration of Figure 7. Based on studying the data, a threshold of 1.8g was set. This value was found by trial-and-error and chosen because it returned the

greatest accuracy rate. If the data exceeded the threshold, it would be categorized as a fall. Not all detections were correct, so the results will be shown on a confusion matrix.

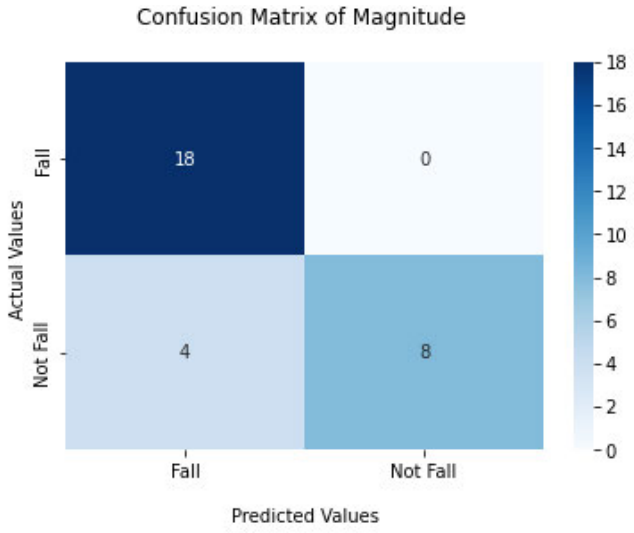

Figure 9

Figure 9 is a confusion matrix made using the threshold value. It shows the matches between detections and the actual motion. The best accuracy rate (falls detected as falls and not falls detected as not falls) was approximately 87%. In all 4 incorrect detections, dropping the phone was classified as falling.

3.1.3 CNN

In this section, a machine learning algorithm was implemented [16]. All datasets were combined with axes still separated and given a label corresponding to their motion. 75% of the data was used for training while 25% for testing, resulting in 7 datasets used for each motion.

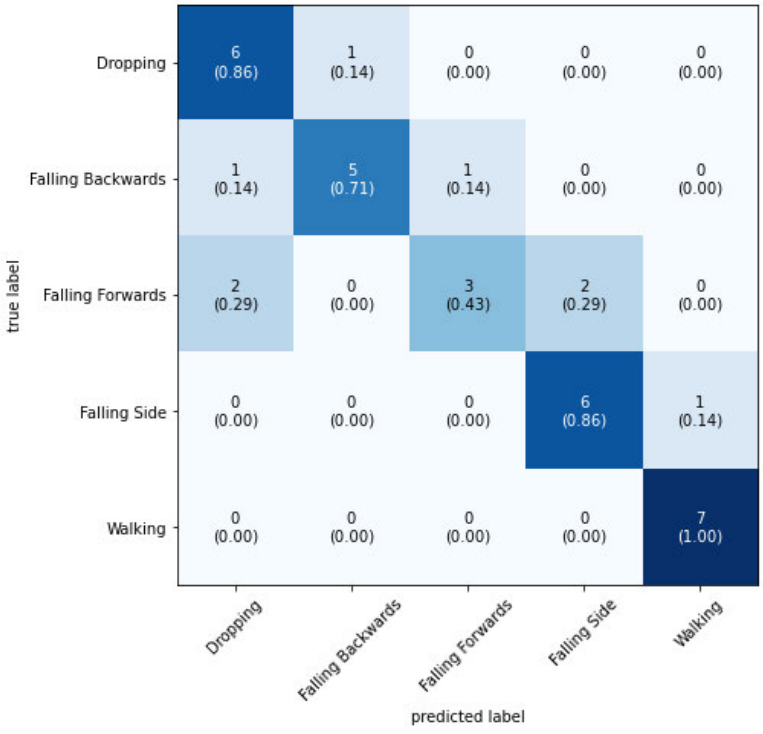

Figure 10

Figure 10 is a confusion matrix showing the results of the machine learning algorithm. The y-axis represents actual values while the x-axis represents detected values. The algorithm correctly detected different types of motions on most occasions. For example, the walking motion was correctly detected every time. However, there was some confusion between falling forwards, dropping the phone, and falling sideways. Overall, the accuracy rate was 86% when differentiating between fall or not fall and 77% when differentiating between types of falls.

3.2 Accelerometer and Gyroscope

3.2.1 Visualization

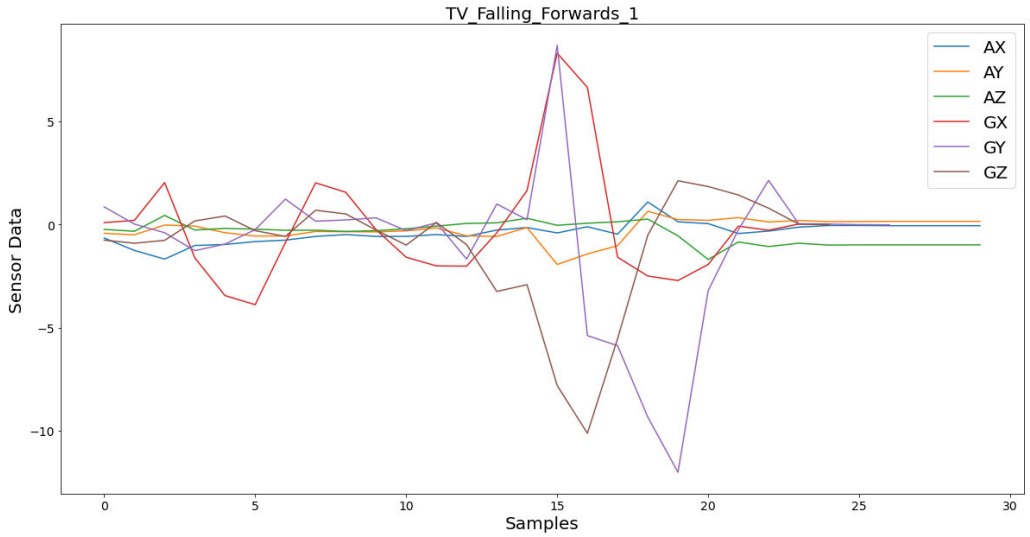

Figure 11

Figure 11 shows the pattern of Participant TV falling forwards, same as Figure 3, but this time, including the readings from the gyroscope. The large spikes indicated when the participant had fallen over. These had a similar timestamp to the spikes of the accelerometer data.

3.2.2 Threshold Method

The same equation was used to combine the gyroscope axes to find the magnitude of the gyroscope vector. Figure 12 shows the absolute vector of the accelerometer and gyroscope data on one graph.

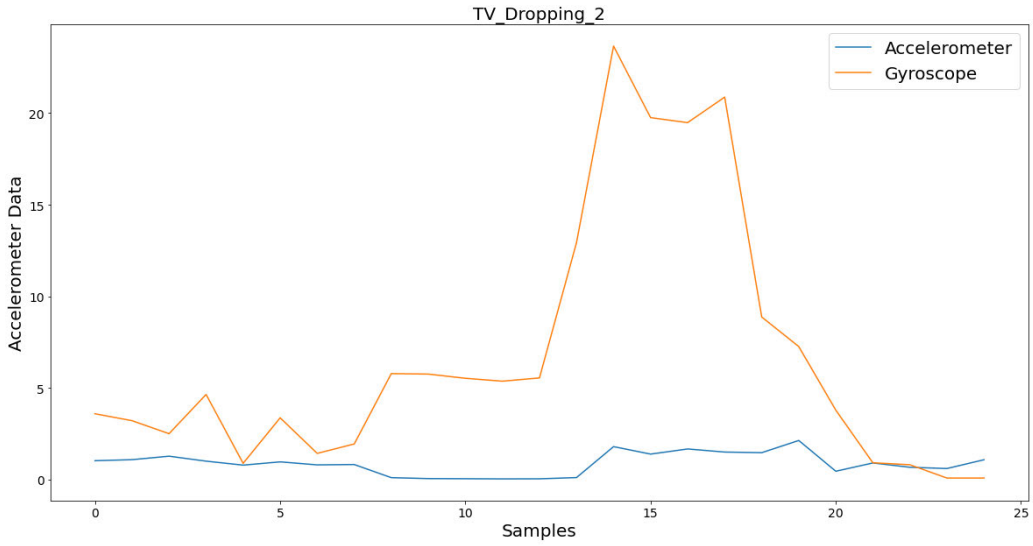

Figure 12

Thresholds of values 1.8g and 8 were set for accelerometer and gyroscope data respectively. These were found by trial and error and were chosen as they gave the highest accuracy rate which stayed constant at 87%. The program made the same wrong detections, with four dropping datasets detected as falling.

3.2.3 CNN

The pre-processing method and machine learning algorithm in Section 3.1.3 was used in this section, but datasets containing both accelerometer and gyroscope data will be used for training and testing, with a 75% to 25% split respectively.

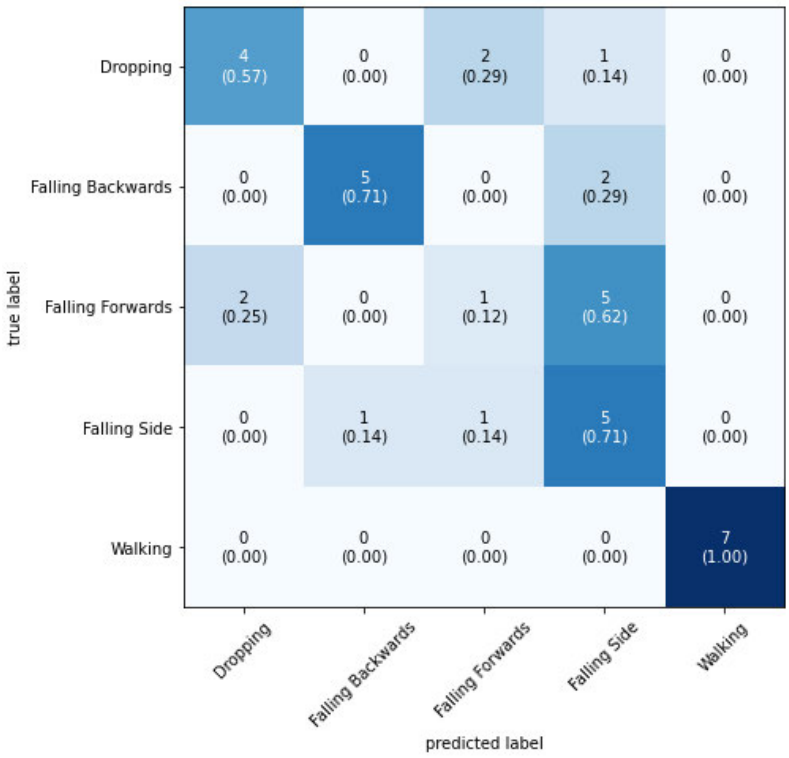

Figure 13

Figure 13 is a confusion matrix showing the results of the machine learning algorithm with both sensor data as input. The algorithm detected most motions with relative success but struggled to differentiate between different types of falls. In particular, falling forwards was consistently thought to be falling sideways. Overall, the accuracy rate of detecting fall or not fall remained at 86% but when required to detect the type of fall, accuracy fell to 61%.

4 Discussion

This study investigates whether the accelerometer and gyroscope data of a phone can be used for fall detection. In this study, two participants carried out experiments to collect the data which was analysed to see how well a computer program could differentiate between fall and not fall.

4.1 Data Processing

The data collected consisted of accelerometer and gyroscope readings in terms of g, plotted against time. Before being analysed, unnecessary data such as the 5 second start/finish indicators, where the axes stayed flat, and any data before and after this region were removed, as to not affect the

detections made by the threshold and/or confuse the learning algorithm. There are other methods of indicating when the collection process had stopped. One way would be to do it remotely and allow the experiment conductor to remotely start and stop the sensors from another device. Doing this would save time since data would not need to be removed manually.

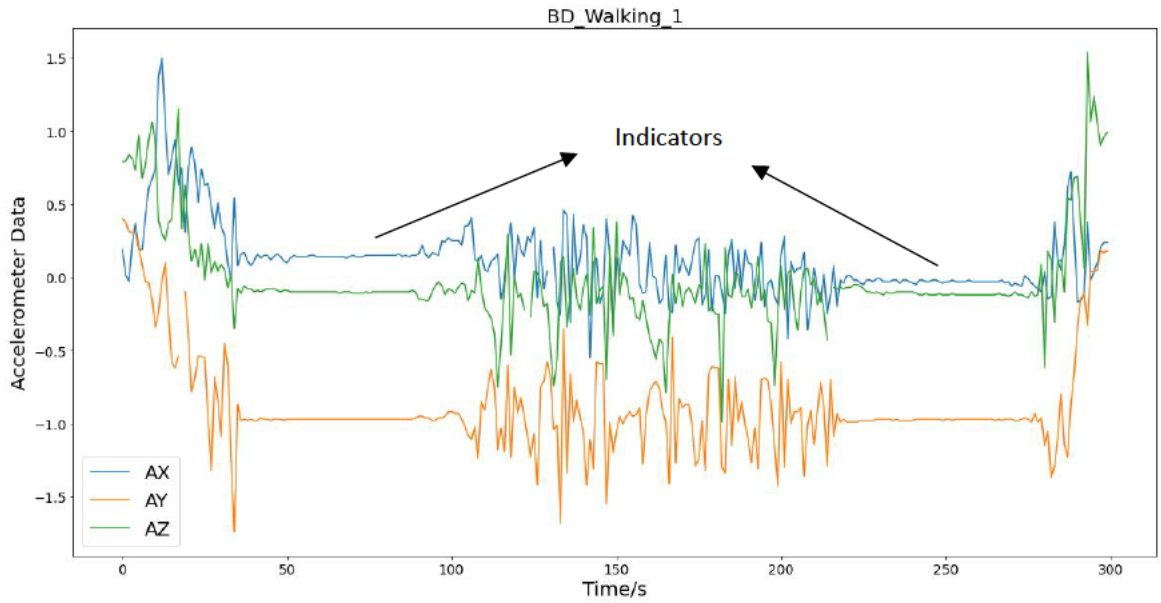

Figure 14

There were some gaps in the data, examples circled in Figure 15. This did not greatly affect detections made by the threshold but did significantly reduce the performance of the learning algorithm, which detected one motion for all test data and resulted in an accuracy rate of 20%. Gaps were likely a result of the phone's sensors not being real time, so if the CPU received a task with higher priority, it would postpone collecting the data until it finished its current task, leaving blank spaces where the data continued to change. Specialized sensors such as IMUs do not suffer from this problem since they collect data in real-time, so new data is regularly recorded every few milliseconds. Gaps were linearly interpolated to remove them – two adjacent datapoints were connected using a straight line. Although this may not have been the most precise method, it was the quickest and easiest to implement and did not greatly affect the result as gaps were quite rare. Most datasets had no gaps with few having one or two. Alternatively, a better method would be to optimize the application to allow sensors to consistently record data regardless of CPU activity.

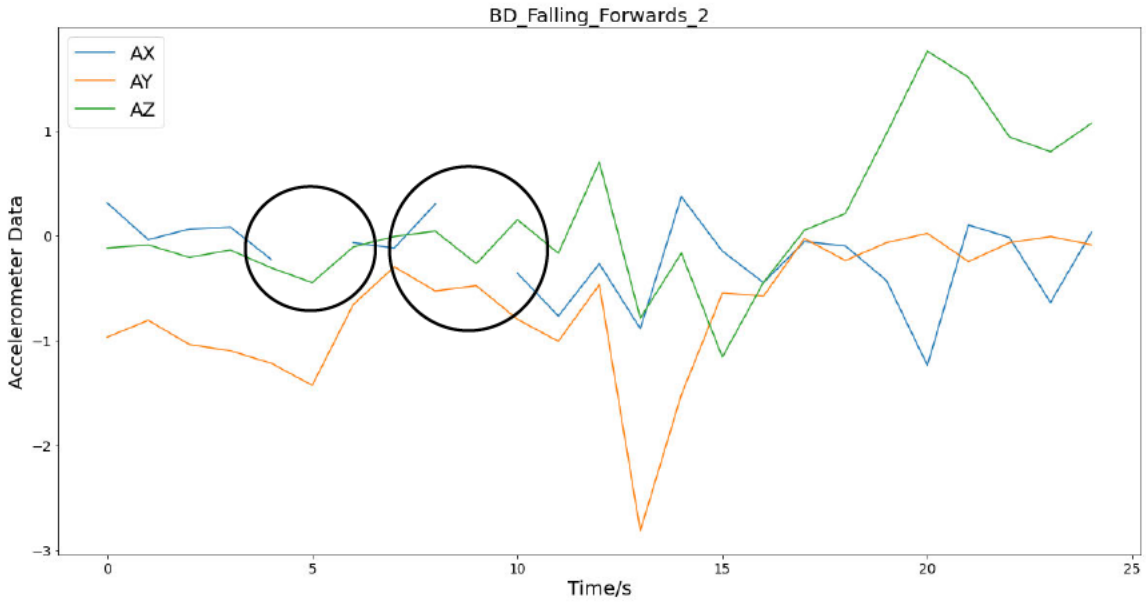

Figure 15

Only the datapoints of when the participants were falling/dropping the phone was captured, to reduce the influence of walking data prior to these motions. As a result, they had much less datapoints than the walking motion. This led to the machine learning algorithm outputting biased detections, in favour of the motion with the most datapoints (walking). Therefore, the number of datapoints of all motions were made to match the motion with the least number of datapoints, which happened to be falling forwards.

4.2 Data pattern

The data pattern of each motion differed visually. For example, Figure 3, which showed accelerometer data of participant TV walking, had a rhythmic pattern, with data constantly fluctuating by 0.5g to 1g, while Figure 4, showed the same participant falling forwards, and had significant spikes in all axes. This was strong evidence that the phone's orientation was dependent on the motion.

Data patterns also differed throughout repeats although visually, much more discrete. This was clearest between Figure 6 and Figure 7; both showed the accelerometer data of participant TV dropping the phone. The axes of both figures spiked by different amounts. How the phone was dropped greatly influenced the data. For instance, if the phone landed on its side, it bounced, which generated multiple spikes that decreased in magnitude over time. However, if the phone landed flat, it did not bounce and only one spike was produced. Similarly, if the phone was dropped with a rotational force, its pattern would be different to if it was dropped with no external force applied. It would be difficult and unrealistic to make repeats exactly identical. Instead, having 'human errors' and inconsistencies in this case would allow algorithms to better generalize over a wider variety of possible motions.

Participants involved also influenced the pattern of data. Participant BD was much larger than Participant TV and wore tighter clothing. Subsequently, although the time frame was very similar, Participant BD's walking data, Figure 2, had peaks closer together than Participant TV's walking data, Figure 3. The effect of the participant's size and choice of clothing had no obvious visual correlation to the difference in falling and dropping data, as the data of those motions varied among repeats. Again, it would be unrealistic to choose participants of a certain size and/or limit their choice of clothing as this would make the data less generalized.

4.3 Threshold Result

Two methods were developed to detect falls, the first was to set thresholds. If the data exceeded the threshold, it was classified as a fall. Thresholds were found using a trial-and-error method, firstly by studying a small sample of datasets before applying the threshold to every dataset and adjusting it accordingly until maximum accuracy was reached. When both accelerometer and gyroscope data was used, this method achieved an accuracy rate of 87%. Participant TV was much smaller than Participant BD meaning although they performed the same sets of motions in the same environment, the shapes of the data were very different. The same threshold was implemented across datasets of both participants and its performance was identical, meaning the accuracy of this method is not dependent on the user's size. Accuracy rate of using accelerometer data only, matched that of using both accelerometer and gyroscope data. This suggested that additional gyroscope data did not contribute to the effectiveness of the data and/or method.

The static thresholds method was unable to differentiate between different types of falls. Manually applying different thresholds for each motion was not a viable method since it would have been too time consuming and impractical – it was unlikely to scale well as the amount of data increased. This agrees with Ren and Shi's study [14], that static thresholds were inflexible. As results by Ge and Xu's study suggested [13], adaptive thresholds would be more suited to fall detection.

4.4 Machine Learning Result

The second method of fall detection was using a Convolutional Neural Network (CNN). The machine learning algorithm would classify input data into groups based on its shapes and characteristics. As data size grows, thresholds would likely be less effective as it would have to be implemented over a larger variety of patterns. The opposite is true for a machine learning algorithm, more data means more training allowing it to spot indicators of a fall more accurately. Furthermore, using machine learning would save time as thresholds need to be found and set manually. Using accelerometer data only, the CNN was able to correctly differentiate between fall and not fall with 86% accuracy, similar to setting thresholds. The CNN was also able to differentiate between the types of falls, with 77% accuracy. This suggests that the machine learning algorithm was more flexible than the static threshold. Potentially, it may be able to adapt to a phone being located elsewhere, for example, being held in the user's hand rather than placed in their pocket.

When using data from both sensors, the CNN's accuracy of differentiating between fall and not fall stayed at 86% but when asked to differentiate between the types of falls, accuracy fell to approximately 61%. This further supports the idea that gyroscope data does not help improve accuracy. However, this idea conflicts with the research found by Huynh et al [12], who argued that gyroscope data contributed greatly to fall detection, especially its sensitivity. The difference could be due to Huynh's study having had significantly more data, with the involvement of 27 participants in comparison to 2 for this study. Therefore, their machine learning algorithm had much more training and testing. Moreover, their algorithm was optimized for using both accelerometer and gyroscope readings while the algorithm for this study was developed for accelerometer only. With low amounts of data, the inclusion of gyroscope readings may have made it too complex for this study's algorithm, so the gyroscope data was not fully utilized.

4.5 Limitations

The following limitations can be found in this study.

Currently, the sampling rate of the application is 14Hz which could be increased to give more samples for each motion, especially motions with a short time frame such as falling and dropping the phone.

Increasing the sampling rate would also mean the collected data's pattern is a closer match to the actual pattern of movement. There would be less values missing, some of which may be important, for example, the maximum value of a spike, which was crucial when thresholds were used. Gaps in the data were linearly interpolated, potentially making it unrealistic as it may not have been the value at that sample point.

The amount of data collected and analysed in this study was quite low in terms of variety and volume. High intensity motions such as jogging, running, and jumping could have been included to see whether the methods used in this study would be able to differentiate between them and the current motions – walking, falling forwards, backwards, to the side and dropping the phone. The number of participants for this study was two, which could be increased to give a larger volume of more inclusive data. Participants of this study had different builds but were both male and lived in Leeds, which cannot be used as a generalization of the UK population. The inclusion of more data and a more optimized machine learning algorithm would mean falls would be detected with better accuracy.

This study agrees with prior research on realistic fall data being hard to obtain. For example, participants fell onto gymnastic mats to minimize the impact. This may have had an effect on the pattern of data, as gymnastic mats provide a different interaction to grass and/or hard ground. Similarly, when people drop their phone, they usually pick it up instantly so the pattern of data for dropping the phone would be different to the one found. This idea was neglected in this study.

5 Conclusion and Further Research

Fall detection is an essential area of research in elderly care and global health and is becoming more important as the population ages. This study aimed to see whether the built-in accelerometer and gyroscope sensors of a mobile phone was suitable for fall detection. Setting thresholds was the first method implemented and achieved an accuracy rate of 87%. A machine learning algorithm was the second method of fall detection and achieved an accuracy rate of 86% but was also able to consistently detect the type of fall. These results were found from 2 participants performing 5 motions, repeating each one 3 times resulting using 30 different datasets.

Similar studies using IMU devices produced detection with accuracy rates exceeding 95%. Typically, those studies had between 20 to 30 participants and a sampling rate of over 20Hz. They had significantly more optimized machine learning algorithms as well as data for training and testing. For future works, this study suggests scaling the experiment to collect more data from a phone and optimizing current learning algorithms to find the maximum detection accuracy that can be produced by data from a phone's motion sensors. The results will better determine whether a phone can be as effective as alternative technologies such as IMUs and context-aware systems.

Considering the limited amount of data, results from this study suggest phones can provide an inexpensive and easily accessible method of fall detection with relative reliability, which can be improved by further research. This will predominantly benefit the elderly, who are most susceptible to falling. An application could be made that constantly monitors sensor data and calls a family member or the health services if it detects a fall. Therefore, with minimal financial investment, the elderly can be confident that there would quickly be support if they were to fall.

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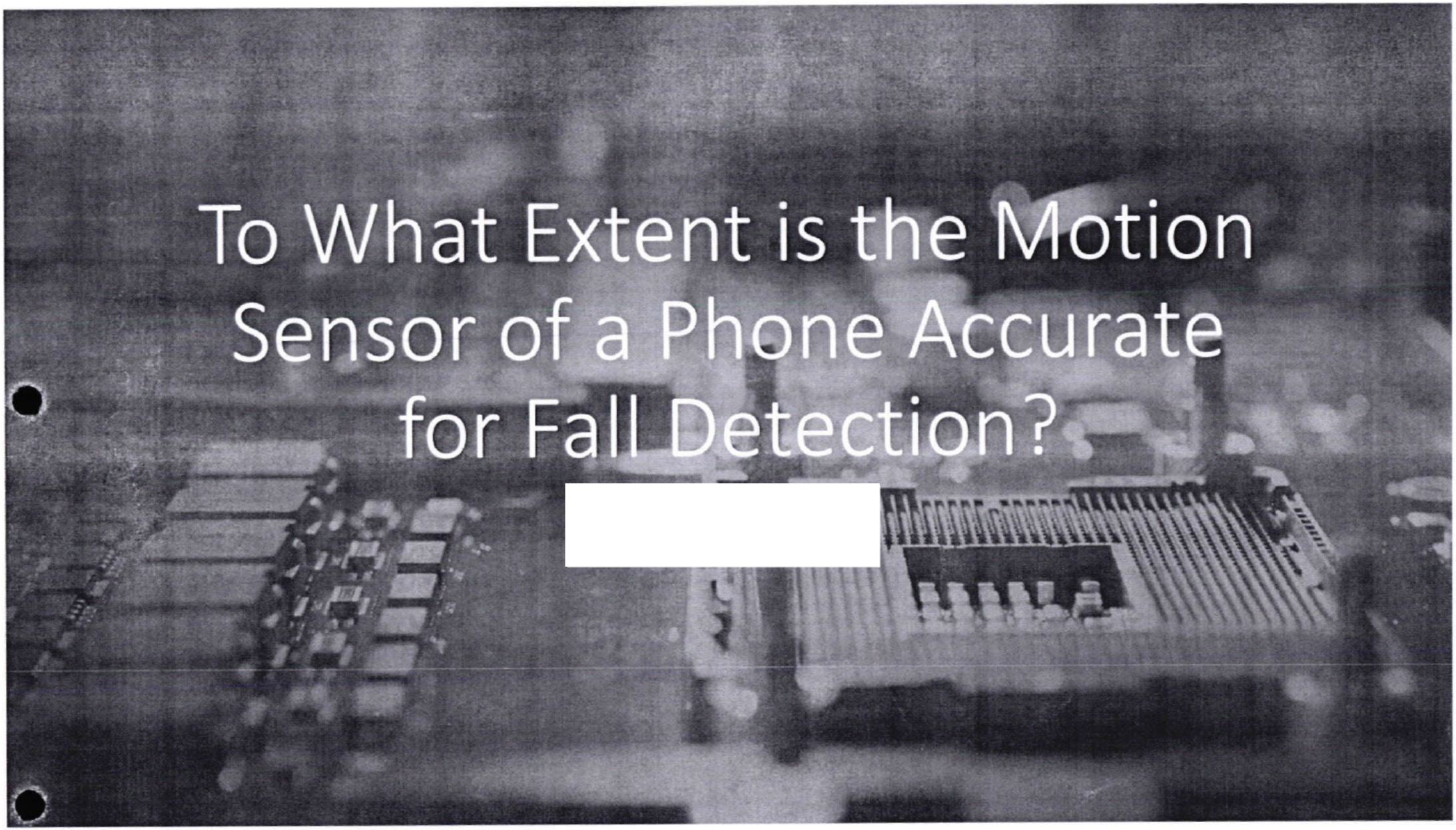

To What Extent is the Motion Sensor of a Phone Accurate for Fall Detection?

Consequence of falling

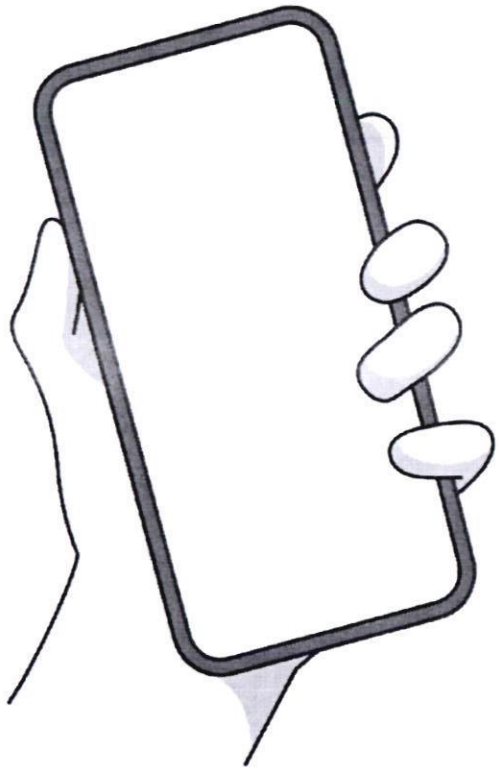
Causes Death

Mainly affects elderly

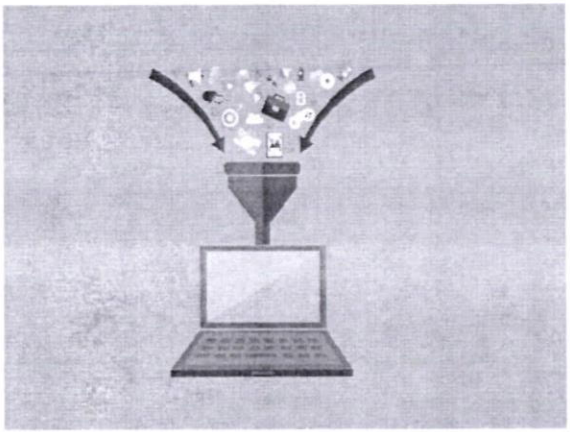
Mental impact

Financial impact

A cheaper alternative?



Objectives

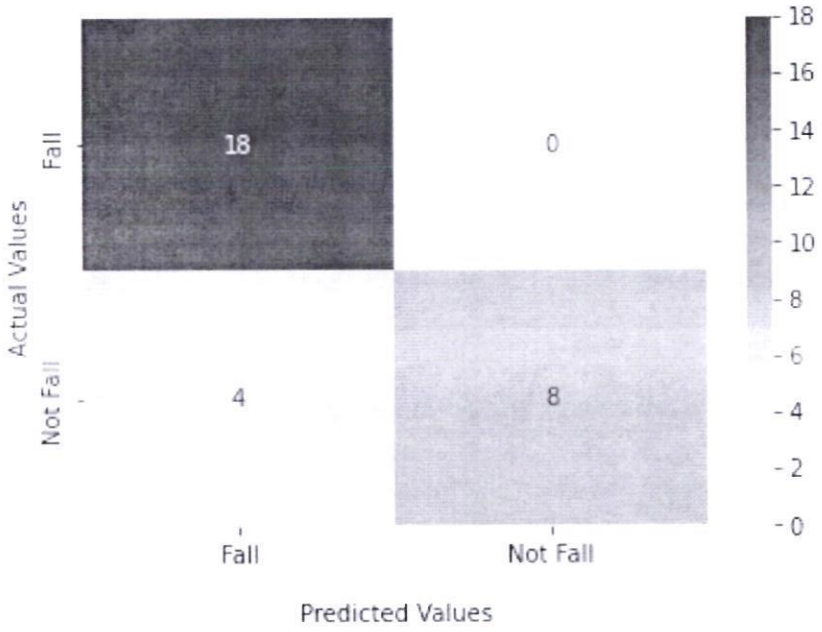


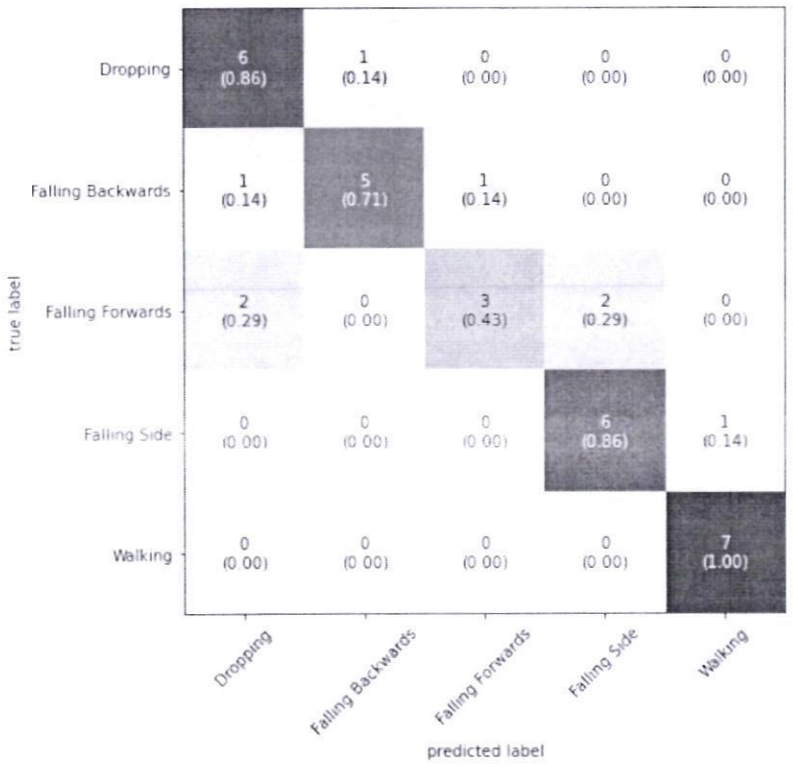
Collect Data

Analyse Data

Write Dissertation

The Results


Actual Values
Fall
Not Fall
18
0
4
8
Fall
Not Fall
Predicted Values
18
16
14
12
10
8
6
4
2
0


Dropping
Falling Backwards
Falling Forwards
Falling Side
Walking
true label
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1 (0.14)
0 (0.00)
0 (0.00)
0 (0.00)
1 (0.14)
5 (0.71)
1 (0.14)
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2 (0.29)
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3 (0.43)
2 (0.29)
0 (0.00)
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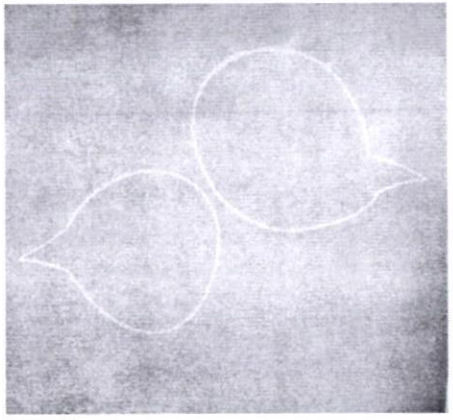
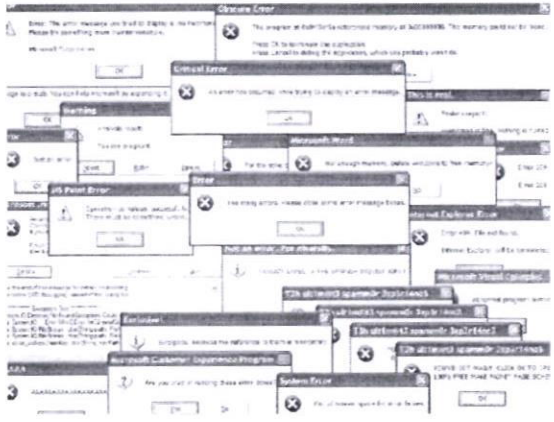
6 (0.86)
1 (0.14)
0 (0.00)
0 (0.00)
0 (0.00)
0 (0.00)
7 (1.00)
Dropping
Falling Backwards
Falling Forwards
Falling Side
Walking
predicted label

Review of Performance: The Good



Communication

Self-disciplined



Resilient

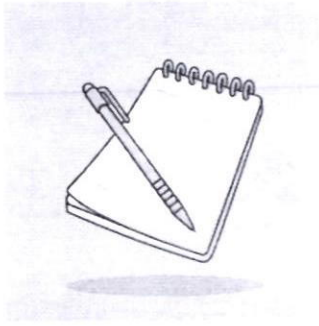
Review of Performance: The Bad

Time management

Preparation

What I've learnt from EPQ

Research skills



Dissertation Writing

Helps with University

7 Appendix 1 – Experimental Method

7.1 Aim:

The aim is to collect a sufficient amount of gyroscope and accelerometer data, enough to effectively analyse and produce a machine learning algorithm that can detect a fall, based on real-time input from the sensors.

7.2 Resources:

- Phone with Data Collection App
- Participants
- Gymnastics Mat
- Stopwatch

7.3 Process:

The participant(s) will be given a briefing on the safety precautions taking place, what they are meant to do, what data is being collected and how the data will be used before the data collection process begins. The number of participants will range from 1 to 5 and each data collection step will be repeated 3 times by each participant. This is to ensure that a sufficient amount of data is collected and minimizes the impact of anomalies. Any delays mentioned below will be recorded by a stopwatch (this data does not need to be saved).

1. The participant(s) receive a phone with the Data Collection App pre-installed. They then open the app and turn on the sensors, allowing data to be collected. The phone will be placed in their trouser pocket for the duration of the test. There will be a 5 second delay before the phone is put into their pocket and the beginning of the data collection process, to mark the start of each process.
2. Motion 1 will be ‘normal walking’. (After the 5 second wait), the participant will walk 3 meters forward as naturally and comfortably as they can. They will stop, turn around and return to the original starting point. They will then wait another 5 seconds, this time to mark the end of the process. Finally, the participant will take the phone out of their pocket and turn off the sensors. This will also save the data at the same time.
3. Motion 2 will be ‘falling forwards’. Similar to before, the participant will walk 3 meters forwards, this time, they will stop and instantaneously fall over in the direction of travel. A soft object may be placed on the ground to simulate them tripping over more accurately. They will rest on the ground motionless for 5 seconds to mark the end of the process. Then, they will stand up, and turn off the sensors, saving the data.
4. Motion 3 will be ‘falling backwards’. Once again, the participant will walk 3 meters forward, stop, but instead of falling forwards, they will fall backwards. They will stay there for 5 seconds before standing back up and disabling access to the sensors, also saving the data.
5. Motion 4 will be ‘falling to the side’. The participant will walk 3 meters, stop, and fall to the left or right. It is recommended that they fall onto their dominant side, as this will make it easier to ‘breakfall’, however, this choice is up to them. Once they have fallen, the participant will lay there for 5 seconds before standing up and turning off the sensors, saving the data.
6. Motion 5 will be ‘dropping the phone’. This is the last data collection process. The participant will walk 3 meters, stop, take the phone out of their pocket, and raise it up so that their elbows are at 90 degrees, forearm parallel to the ground. Once they have reached

this position, they will instantly drop the phone and let it stay on the ground for 5 seconds, before picking it up and doing the usual ending procedure.

7. Datasets will be saved in the following form:
   CandidateInitials_MotionNumber_RepeatNumber.

7.4 Reliability and Validity:

To make the primary research valid, the data collection will be following the basic scientific method.

Control variables are constants, variables that are unchanged throughout the process. In this experiment, the control variables include the sensors used to collect the data, the distance the participant(s) walk, the way they walk, the position of the phone and the surface at which they fall onto. This ensures that the dependent variable is only changed by the independent variable and no other factor. In other words, the data collected is only changed by the motion of the participant(s), and how they fall.

Repeating the experiment will make the data more reliable, remove anomalies and produce more data points for the machine learning algorithm.

7.5 Safety and Ethics:

To ensure the safety of the participant(s), the following procedures will be taking place:

1. The participant(s) must be able to withstand repeated falls, therefore, anyone participating in this experiment will require a background in Judo and have completed the basic gradings that cover 'Ukemi', or Judo falling techniques. These include forward breakfalls, side breakfalls, and backward breakfalls. These techniques will be used in the falling process to make sure the participant(s) are unharmed. Moreover, they will have had lots of experience doing this as it's the most basic element of this martial art.
2. The participant(s) will be falling onto gymnastic mats, to minimize the impact of each fall, and the possibility of them hurting themselves.
3. During the collection process where participant(s) fall to the side, the phone will be placed in the opposite pocket to the direction of the fall. This is so they do not land on it and hurt themselves or break the phone. For example, if the participant chooses to fall to the right, they will put the phone in their left pocket, and vice versa. During falls backwards and forwards, the participants can put the phone in pockets on either side, but this must be consistent throughout the repeats.
4. The participant(s) can take a break of any amount of time in between each data collection process and may stop whenever they wish. The data of any participant who chooses to stop before completing the experiment will not be used.
5. The identity of the participants will remain anonymous. To ensure this is the case, the name of the dataset that they record during the experiment will only include their candidate number and/or their initials.
6. The usage of their data and the involvement of the participant(s) will only proceed if they have given consent and met the conditions mentioned above.

8 Appendix 2 – Consent Form

Experiment Consent Form

You have been invited to partake in an experiment. The purpose of this experiment is to record the motion of a phone when someone has fallen over. Your participation in this experiment is completely optional, and you may choose to withdraw at any point.

Beginning the experiment, you will be given a mobile phone running a data collection application. You will then be required to turn on and off the app accordingly (more detail in the experimental method), while conducting the following range of motions: normal walking, falling forwards, falling sideways, falling backwards, and dropping the phone.

For your safety, you are required to be of age 16 or above and need to have had at least 6 months experience of Judo to participate. This experiment will be conducted on gymnastics mat to minimize the impact of the falls. You can request to take a 2-minute rest between each data collection process. The experiment will likely take no longer than 10 minutes, excluding any breaks.

The data collected will be from the sensors of the phone, and mainly numerical. It will be analysed and used to detect when a fall may have occurred. Your participation in this experiment will be kept completely confidential, along with any other relevant information. To do this, only your initials will be used to identify your corresponding dataset, no data will be shared, and will be deleted once the analysis is complete. As mentioned before, you are able to withdraw from the experiment if you wish, if this is the case, any data that had been collected will be deleted, as it is incomplete and unsuitable for analysis. If for any reason you wish to withdraw your data after you have completed the experiment, you may do so, and the data will be deleted.

If you agree to participate in the experiment, please fill in the form below:

* Required

1. Your initials *

Enter the first letter of your first name followed by the first letter of your surname.

2. Age *

_____

3. Gender *

Mark only one oval.

- Male
- Female
-
- Prefer not to say
- Other: _____

4. Home *

The city that you are currently living in

_____

5. Confirmation *

Check all that apply.

- [ ] I have read the information sheet above and consent to the usage of my data.
- [ ] I understand the risks associated with this experiment and the safety precautions being taken.

6. Date of completion *

Please answer in the following format: DD/MM/YYYY

7. Signature of Confirmation *

9 Appendix 3 – Debrief

Thank you for participating in this experiment.

The purpose was to collect readings of the built-in accelerometer and gyroscope sensors from the phone you were given. The data you collect will be analysed to see whether or not it is accurate enough for fall detection. The results of this study will primarily help the elderly who are most susceptible to falling. I am wanting to see if a phone can be a reliable, inexpensive, and easily accessible implementation of fall detection.

The task given to you was/will be the task given to other participants in this experiment.

The data you collected from this experiment and provided in the consent form will be kept anonymous and confidential. It will only be identified using your initials and will not be shared or distributed. If for any reason you wish to withdraw your data, you can do so within a month of the experiment. Your data will be immediately deleted in response.

If you would like to contact me, please email:

Once again, thank you for taking part.