Application for Human Movement Analysis Based on Pose Estimation

Project Proposal with Literature Review

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1. Introduction

Deep learning has revolutionised the advancement of today's technology, being a main subject of intense media hype with its world-changing development (Chollet, 2017). Mentioned in a book illustrated by Prof Aly Farag, deep learning can be defined as "inference of model parameters for decision making in a process mimicking the understanding process in the human brain"; or, in short: "brain-like model identification" (Hassaballah & Awad, 2020). Through the human eye, visual information can be processed and dissected semantically, extracting meaningful features from line-segments, to shape and so on from videos or images (Zhang, 2010). The development of deep learning has given rise to computer vision which enables machines to interpret information in a way that mimics the way a human brain processes visual information. A few key scenarios that put heavy emphasis on computer vision include recognition, visual tracking, semantic segmentation, image restoration, image classification and many more (Chai et al., 2021).

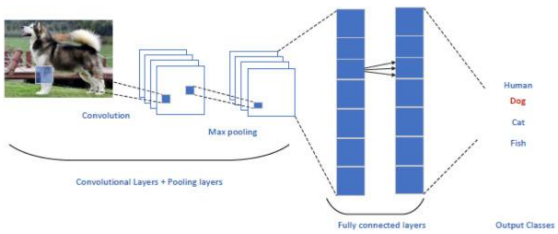

Fig. 1: CNN architecture for image classification. (Chai et al., 2021)

As per our project topic, our focus is on computer vision in human movement analysis specifically in the sports domain. There exists a range of measurement tools available to analyse athletic performance, injury mechanism, prevention and rehabilitation, or obtain metrics that might aid in any shape or form. Motion capture systems are optical systems consisting of cameras to obtain full-body capture for the tracking of active and passive markers on human joints. Wearable technology is an alternative approach with a range of different types of sensors (Adesida et al., 2019). Despite the high accuracy of these systems, they often require extensive set-up confined to laboratories, costly and possibly invasive. This sparked an interest in our team to develop a more accessible application to carry out kinematic analysis through computer vision.

A general framework for human movement analysis consists of three major components: Human Detection, Human Tracking and Behaviour Understanding. Human detection is the beginning of nearly every vision-based motion analysis system. It is the segmentation of regions that corresponds to humans from the rest of the image; Object tracking that comes after human detection involves object matching in consecutive frames, preparing data for pose estimation and action recognition; Behaviour understanding emphasises a lot on deep learning techniques in computer vision to produce high-level descriptions of actions and interactions (Wang et al., 2003).

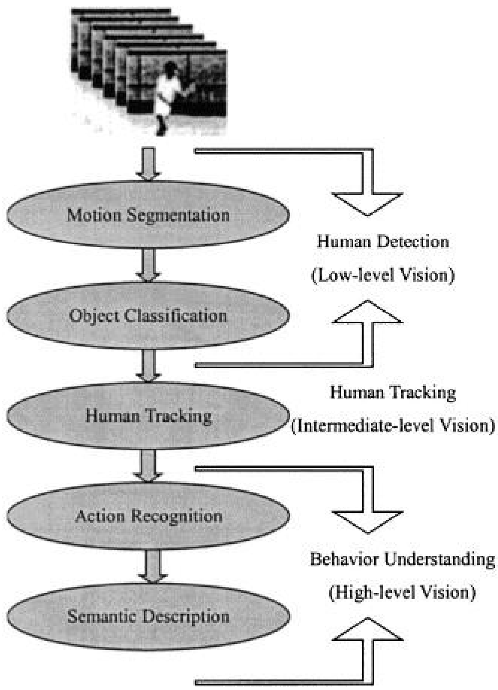

Fig. 2: General framework for Human Motion Analysis. (Wang et al., 2003)

The end goal of our project is to successfully develop a mobile application to analyse human movement on mainly weightlifting exercises. The key technology to our system would be pose estimation which involves the estimation of joint locations of a human body from videos or images (J. Wang et al., 2021).

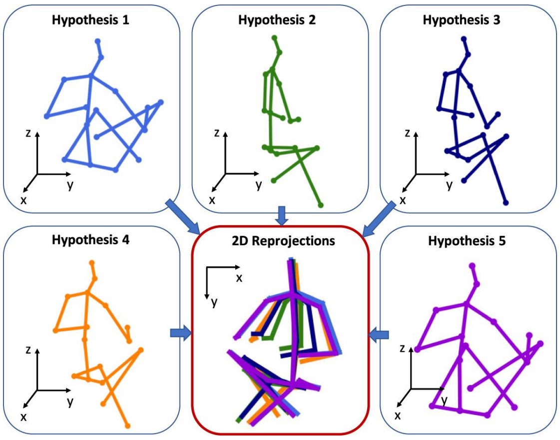

Fig. 3: Illustration of pose estimation. (J. Wang et al., 2021)

This application would function as an AI coach, providing feedback on exercises to ensure productivity, and prevention of injuries. An essential component to this project would be the availability of datasets on the accuracy of form for different exercises such as deadlifts, barbell squats etc. More extensive research on the determining factors of whether an exercise is carried out in the right form is required in order for us to acquire the ground truth by comparing these measurements and metrics with those that are obtained through utilising the motion lab in Monash.

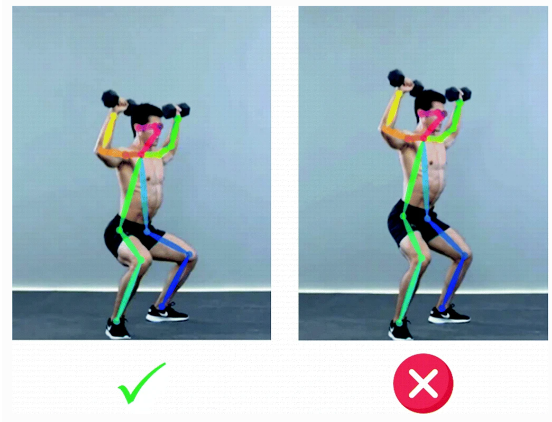

Fig. 4: Intelligent fitness trainer system based on pose estimation. (Zou et al., 2019)

2. Literature Review

2.1 Evolution of Computer Vision

Advancements of Computer Vision dates all the way back to the 1970s. Figure 5 is a rough timeline consisting of some of the more active and prominent topics of research in computer vision (Szeliski, 2022).

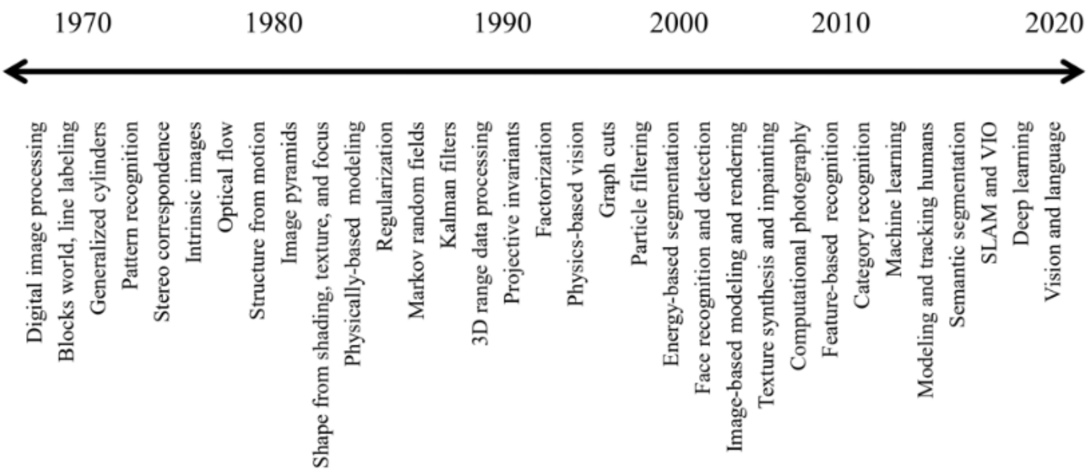

Fig. 5: Some of the most active topics of research in computer vision according to a rough timeline. (Szeliski, 2022)

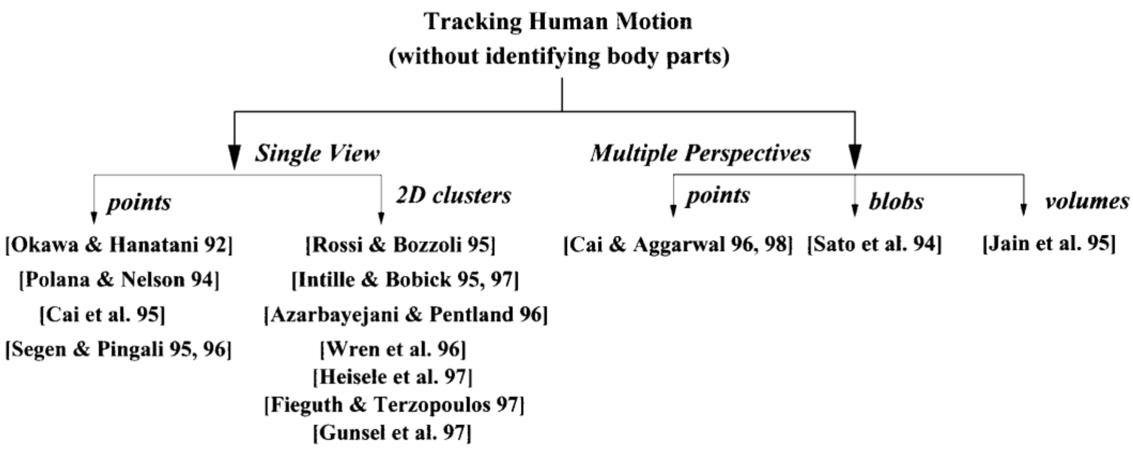

Fig. 6: Past research on tracking of human motion without using body parts. (Aggarwal & Cai, 1999)

The development of computer vision from back then till now heavily depended on one framework proposed for the basis of vision, considered as an information-processing system, and that is The Marr Paradigm. This gave rise to research conducted in artificial intelligence, digital computers, cybernetics and information theory (Jolion, 1994).

As loosely paraphrased, there are three levels to a visual information processing system (Stevens, 2012):

1. **Computational Theory**
   To know the desired outcome, and the limitations and constraints of the computation task at hand on the problem.

2. **Representations and Algorithms**
   The representation of input, output and intermediate information and the utilisation of different algorithms to achieve the desired outcome.

3. **Hardware Implementation**
   The mapping of algorithms and representations onto hardware. On the contrary, hardware limitations and constraints can be used as a guideline for the choice of representations and algorithms.

The Marr's Paradigm continues to have its influence on the development of computer vision today due to the emphasis on the multi-level analysis and understanding of the computational principles of vision.

2.2 Computer Vision for Human Movement Analysis

Human movement analysis with Computer Vision typically involves 4 major processes: Human Motion Analysis, Tracking, Pose Estimation, and Recognition.

2.2.1 Human Motion Analysis

Human motion is usually depicted as the movement of limbs and hands. There are two main methodologies that follow a general framework consisting of feature extraction, feature correspondence and high-level processing. The difference between the two methodologies is in establishing the feature correspondence between consecutive frames (Aggarwal & Cai, 1999).

2.2.2 Tracking

Tracking in this context is defined as "establishing coherent relations of the subject and/or limbs between frames" (Aggarwal &

Cai, 1999b). Three main components of tracking are as followed:

1. **Figure-Ground Segmentation**
   Figure-ground segmentation can be based on either temporal or spatial data.

The Various Characteristics and Subclasses of Figure–Ground Segmentation Approaches

Temporal data		Spatial data	
Subtraction	Flow	Threshold	Statistics
Two images Three images Background	Points Features Blobs	Chroma-keying Special clothes IR	Pixels Blobs Contours

Fig. 7: Figure-Ground Segmentation Approaches (Aggarwal & Cai, 1999b)

2. **Representation**
   There are two types of representations: Object-based and Image-based.

The Various Types of Data Representations

Object-based	Image-based
Point Box Silhouette Blob	Spatial Spatio-temporal Edge Features

Fig. 8: Types of Data Representations (Aggarwal & Cai, 1999b)

3. **Tracking over Time**
   This is the effort to identify objects of different representations in consecutive frames. The complexity of the scene and the subject becomes one of the constraints in the performance of this task.

2.2.3 Pose Estimation

Pose estimation techniques entail tracking and calculating the human skeleton while the subject is moving. This directly takes into account human motion analysis for the detection and segmentation of the subject along with the tracking of the subject. It can either be a preprocessing step or an active part in a tracking algorithm dependent on the context.

The most common and widely-known aspect of pose estimation is the use of a human model. Pose estimation is divided into 3 classes (Aggarwal & Cai, 1999b):

1. Model-free
2. Indirect Model Use
3. Direct Model Use

Before going briefly into each of these classes, according to the ChatGPT-generated text when prompted with “What is a *priori model*?”, it refers to a model or hypothesis that is formulated or developed based on prior knowledge, assumptions, or theoretical considerations. It is a deductive approach where the model is constructed before any observations or experiments are conducted. (OpenAI, 2023)

The **model-free** class covers the approaches where no priori models are used. Some sort of model is built instead to represent the pose, some of these pose representations include points, simple shapes, stick figures, and boundary boxes.

Indirect model use indicates the usage of priori models as a reference or look-up table as guides to extract information for interpretation of measured data. Typically pose is represented by the head, hands, limbs or a rough description of the human body.

Direct model use on the other hand suggests that a priori model is used directly as the model to represent the observed subject. A human model will significantly expand the capacity to effectively manage occlusion and the integration of different kinematic limitations into a system. The human model is represented by its number of joints and connecting bones.

2.2.4 Recognition

Recognition can be said to be the post process in the attempt to achieve the final or long term goal of a motion capture system. It classifies the motions into one of several types of actions such as walking or running (Aggarwal & Cai, 1999b).

Static Recognition uses the approach of comparing "known information" to the system with the current image. It deals with spatial data frame by frame. These "known information" include templates, postures, normalised silhouettes and so on.

Dynamic Recognition utilises temporal characteristics.

- *Low-level recognition* is to recognize whether the human is walking or performing a certain action in the scene. It is typically based on spatio-temporal data.

- *High-level recognition* is based more on pose estimated data. One of its methods includes the usage of Hidden Markov Models (HMM) (Czúni & Nagy, 2020) and neural networks. The main objective for high-level recognition is to identify the action itself.

2.3 Rationale

2.3.1 Need for Computer Vision in Sports

Information Technology has been very deeply intertwined with various fields, let alone the sports industry. Technology in sports is not only utilised in the enhancement of one's performance, it is integrated into evaluation systems for assisted decision making in either sports training or competitions as well. [18]

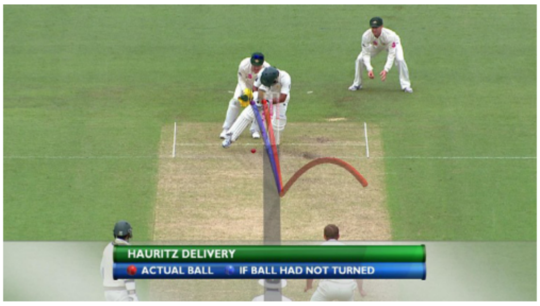

Fig. 9: Analysis and Prediction of cricket ball motion. (Thomas et al., 2017)

With the advancement of computer vision, it already plays a vital role in the world of sports today, from sports analysis for broadcast to training and coaching (Thomas et al., 2017). Specific to our project, we are looking into the integration of computer vision into kinematic analysis.

There already exist a few examples of application of computer vision to sport performance, one of them being video-based motion analysis systems. However one of the major drawbacks of said system besides its cost, is that it is time consuming to record the videos manually while also keeping in mind the accuracy of the coordinates of the joints and other points important for the analysis. With this being said, real-time analysis is not established (Liebermann et al., 2002).

2.4 Conclusion

Despite the breakthroughs in the application of technology for sports performance enhancements, these methods remain to be either rather costly, require extensive set up or may be perceived to be invasive for users. This is where computer vision comes into play.

Our proposed system heavily focuses on pose estimation, and deep learning with computer vision. The reason being the frameworks that we will be looking into using to implement the pose estimation part of the system includes two out of the four main processes of human movement analysis which are human motion analysis and tracking.

3. Project Management Plan

3.1 Project Overview

Our team will concentrate on enhancing and growing the size of a curated dataset, supplying realistic data including various human poses, and making sure the data is of good quality in order to develop a highly accurate real-time human pose analysis system.

All project team members will be given guidelines and managed with the use of project management tools and software. The various key activities, such as the project management deliverables and the product-related deliverables established in each iteration of our Agile sprints, will be broken down into small tasks for our team to execute. The project manager is in charge of ensuring that the team's work is on schedule, hence a number of tools linked to project management will be used, including:

- a risk register.
- meeting minutes
- budget report
- gantt chart

The technical lead would choose the project's technical course, which included implementing the model in code and defending the hardware and software requirements as necessary to achieve the project's requirements. To guarantee that the deliverables produced are of a high standard and meet the needs of the project's stakeholders, Quality Assurance is in charge of developing a thorough test strategy.

3.1.1 Current major milestones

The key accomplishments our team has made so far during the first semester are listed in the list below.

Project management related:

- Team Formation
- Kickoff Meeting
- Scope Statement
- Requirement Traceability Matrix
- Case Studies
- WBS (work breakdown structure)
- Project Plan Presentation
- Final Project Proposal

Product related:

- Literature Review
- Understanding the pose estimation models
- Preliminary Training
- Visualise preliminary model’s outcomes
- Our system's graphical user interface
- Look into potential contributions to the field.
- Plan for product testing

3.2 Project Scope

3.2.1 Project deliverables

Our project deliverables may be divided into two distinct, independent categories: those connected to project management and those linked to products. By the project's conclusion, these deliverables will be submitted. The complete list of deliverables is as follows:

Project management related deliverables:

Initial Phase:

1. Kickoff Meeting: Get to know the group's members and learn more about the project's needs.
2. Business case: Describe the motivations behind starting the project.

3. Case study using project management methodology: Investigate and evaluate the most appropriate project management techniques for our project.

Planning Phase:

1. Product schedule timeline: Arrange the tasks to be finished by the deadline.
2. WBS: Define the tasks and break down the project's scope.
3. Scope statement: Specifically outline the project's deliverables as well as the specifications and features of the final product.
4. Budget report: Calculate the project's overall cost.
5. Project Initial Concept and Design: A high-level illustration of the project's salient characteristics and significant outputs.

Executing Phase:

1. Minutes meetings: Highlight the major points from each meeting.
2. Resource allocation and management for the project: Assign and oversee the project's resources.

Monitoring & Control Phase:

1. Project status report: Review project expenditures, evaluate team output, and address bottlenecks.
2. Individual journal entries: Describe the project's tasks and offer critical thoughts.

Closing Phase:

1. Final Project Report: The completed project proposal includes all relevant conceptual, technical, and managerial information.
2. Final Project Presentation: Key points from the project proposal are presented orally.

Product related deliverables:

1. Instant feedback on workout form and technique in real time to assist users in maintaining appropriate posture and preventing injuries. Visual signals, verbal instructions, or a combination of both might be used to provide this feedback.
2. An intuitive and well-designed user interface that makes it simple for users to communicate with the AI trainer. This can include options for choosing an exercise, monitoring progress, and receiving tailored recommendations.
3. The AI trainer must be accessible via a mobile app that users can download to their smartphones or tablets. This provides for flexibility and convenience for accessing exercises and monitoring progress while on the move.
4. Ensuring that user data is safely stored and guarded, following privacy laws, and putting in place the necessary security measures.

3.2.2 Product characteristics and requirements

The team has determined what is inside and outside the project scope, as well as the pertinent assumptions needed for implementation and the restrictions & limits that are involved, in order to prevent sidetracking.

In scope:

1. Enhancing, fine-tuning, and expanding the dataset for the pose movement analysis model.
2. Obtaining the advice of specialists to make sure the system complies with

current data security and privacy regulations.
3. Enhancing the model's performance and accuracy while fine-tuning its architecture without overfitting the carefully selected dataset.

Out of scope:

1. Personal AI trainers shouldn't give medical advice or make diagnoses of patients' problems. Users should speak with medical specialists if they have specific health concerns.
2. Dietary guidance and nutrition: While broad nutritional recommendations may be given, a personal AI trainer cannot offer detailed nutrition planning or dietary advice.
3. An AI-based personal trainer is not a replacement for qualified physical therapy. Users with unique rehabilitation needs or injuries should see licensed professionals for advice.

Limitations / Constraints:

1. Accuracy and generalizability of the AI trainer can be affected by the quantity, calibre, and variety of training data.
2. The team's access to underlying technologies may have an impact on the system's functionality and performance.
3. Regulation compliance is often a requirement when handling sensitive user data and offering adequate data protection safeguards.

Functional & Non Functional requirements

Table 7 in the appendix include the list of functional and nonfunctional requirements..

3.2.3 Product user acceptance criteria

The project supervisor's user acceptance criteria have been defined and are represented as user stories in Table 14 of the appendix. These are the specifications that our system must meet in order to meet the project's objectives.

3.3 Project Organisation

The team's organisational structure, along with each member's title and job description, are shown in Figure 9. Dr. Raveendran is in charge of the team, which includes a project manager, technical lead, and quality assurance.

The primary duties of each project job are as follows:

1. Project Manager: Prepare the communication guidelines, assess the risks, and constantly update the schedule.
2. Technical Lead: Establish the project's technical course.
3. Quality Assurance: Maintain documentation, and make sure the deliverables are of good standard.

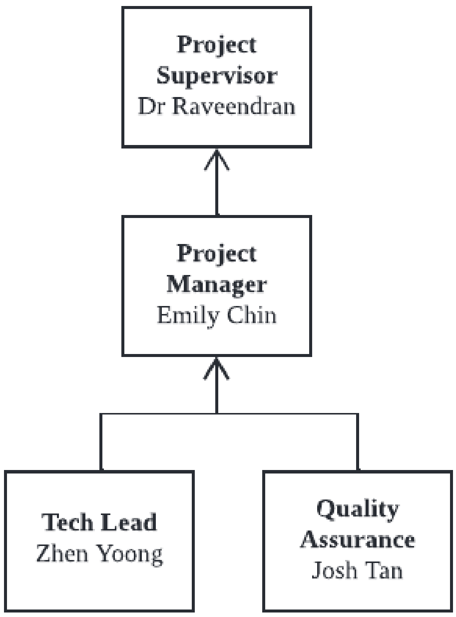

Fig. 9: Team Structure

3.3.1 Process Model

We frequently need to adapt to new models and concepts since the human movement analysis model is strongly related to the quickly developing fields of computer vision and machine learning. Additionally, because our project aims to suggest and put into practise a novel solution, there is little precedent for what we are about to do. As undergraduate students with little experience carrying out projects and even less experience in the field of movement analysis, this project is rife with uncertainty.

Since the majority of us are unfamiliar with these ideas, it is inappropriate to make every decision before putting it into practise.As a result, we want to break the project up into multiple rounds so that we may repeatedly implement and evaluate changes to the algorithm. We will continuously experiment to increase the accuracy of our model, and with each iteration, a final product with these modifications will be released.

Therefore, it is expected that project requirements would change during the project to match current technology and shifting limitations. Fortunately, in situations of high volatility, the agility of the Agile methodology really shines, allowing us to incorporate cutting-edge techniques into the project as we go while still continuously engaging with our project managers and incorporating their comments into the remaining iterations.

As a result, the agile process paradigm will be used to handle this project.

3.3.2 Project Responsibilities

Each member's specific responsibilities are carefully specified in a Responsible, Accountable, Consulted, Informed (RACI) matrix (Table 6) during the planning process to prevent conflicts brought on by misaligned expectations.

3.4 Management Process

3.4.1 Risk Management

Risk management looks at the connection between risks and the possible effects on a company's strategic goals. A company must allocate resources to avoid, monitor, and regulate the effects of adverse events while optimising the impact of positive ones in order to minimise risks. The best ways to detect, investigate, and manage serious risks are determined by using a systematic, all-encompassing, and integrated approach to risk management.

The group chose to use the **SWOT** (**Strengths, Weakness Opportunities, and Threats**) **analytical method** for identifying risks. We will be able to handle unanticipated or anticipated threats and fix them before they become significant issues with the use of the SWOT analysis, which will help us identify and deconstruct the positive and negative risks of our project. It aids in examining the current situation and better comprehending the differences between the present and future plans. Strengths are internal components that contribute to goal success, whereas weaknesses are internal components that obstruct goal achievement. Opportunities are advantageous outside elements that help provide a competitive edge. Threats, on the other hand, are outside forces that serve as obstacles or pose a risk to one's aims.

To list any potential hazards that can exist during the project execution phase, a **risk register table** will also be prepared. There will be other implicit risks in addition to the primary ones that could be recognised and managed at the beginning of the project planning phase. These risks could only be examined and assessed throughout each development sprint. As a result, the risk register is continually updated and entails calculating the likelihood that a risk event will occur as well as ranking risk events according to their importance and consequences.

The project manager must make sure that everything in the risk register is current in order to manage and monitor the risk event. For each risk occurrence, a risk owner will be assigned to one of the team members, including the supervisors. As a result, the individual chosen is in charge of keeping an eye on and reducing that particular risk, and updating the team if any adjustments are necessary.

The following information is included in the risk register:

- Rank of the risk
- Risk title
- Description of the risk
- Category which each risk falls under
- Root cause
- Risk trigger
- Potential responses of the risk
- Risk owner
- Probability of the risk occurring
- Impact of the risk
- Status of the risk
- Score of the risk

The following scales are used to indicate the likelihood of the risk happening:

1. Very low (1)
2. Low (2)
3. Medium (3)
4. High (4)
5. Very high (5)

The effect of the risk on our project is quantified using the following scales:

1. Very low (1-2)
2. Low (3-4)
3. Medium (5-6)
4. High (7-8)
5. Very high (9-10)

The risk register is located in the appendix section (Table 8)

3.4.2 Stakeholder Analysis and Communication Plan

All internal parties participating in or impacted by a project within a firm are referred to as stakeholders. Identifying each stakeholder and their expectations is essential, especially when such expectations and needs can conflict with one another or with the project's fundamental needs. Therefore, before starting the project, a thorough review is needed to identify the important stakeholders and their needs. Perform a stakeholder analysis based on each stakeholder's interest in and influence over the project for the best method of gaining this level of information.

Supervisors: The supervisors receive the project's deliverables. They have the authority to alter the requirements and establish the user acceptance standards. They have a significant impact on the project and are really engaged in it.

Project team members: The individuals in charge of carrying out the project's main operations and generating the deliverables. Section 3.3 of this report lists the several separate positions and the duties of each individual. The project team members are highly engaged and have a significant influence.

Teaching team: By keeping an eye on the project's present condition and management development, they continue to be actively involved. They are really interested in the project and have a lot of influence on it.

The project's stakeholders analysis and stakeholder management matrix can be found in the appendix.

3.4.3 Monitoring and Controlling Mechanisms

Communication matrix and task allocation

For each assignment and deliverable, all of the tasks were fairly distributed among the team members. All team members participated in the analysis and selection of the project management methodologies throughout the planning phase and added to the overall business case. In order to review the project goals and collect the information needed to establish the project scope, we convened a kickoff meeting with our supervisors.

Everyone worked together to complete the paperwork required for our project's initial phases before we got into the technical side of things. Josh completed the scope statement and the requirements traceability matrix, Zhen handled the literature reviews and product characteristics, and Emily was in charge of completing the risk analysis, identifying the key constraints, and making recommendations regarding the direction to take with regard to our final deliverables.

All team members were obliged to research the most cutting-edge methods in the industry in order to have a deeper grasp of the project. In order to discuss our results with the team at our internal meetings, our team had established deadlines for reviewing the study papers. Our technical lead, Zhen, is tasked with doing research on enhancing and fine-tuning the architecture of our pose estimate analysis model after evaluating the skill sets and talents of each team member. The project manager, Emily, is in charge of concentrating on the project management specifics as well as the primary data and data processing tools employed. Josh, our quality assurance specialist, is currently designing our project's user interface and quality assurance testing strategy.

The appendix part contains a communication matrix that takes into account communication between all stakeholders. It provides an illustration of the usual communications that will take place for all pertinent stakeholders during the project. It provides an illustration of the usual communications that will take place for all pertinent stakeholders during the project. The types of communication the team will employ for internal and external contact with the project managers. The parameters of each communication channel, including the purpose of the communication type, the medium used, and the anticipated frequency of connecting with the audience, are presented in order to build effective communications for this project. The communication matrix table also included a list of the anticipated outputs for each sort of communication.

Monitoring Progress

Project monitoring and control is one of the most important components of management. Every team member has to be informed of the project's progress, where it is in relation to the original plan, if deadlines are met, and whether funds are being properly handled, among other things. We think that open communication within the team may increase trust and promote productive collaboration. As a result, the project team has internal meetings to reach decisions and incorporate often obtained data. As a consequence, there is no information compartmentalization and every member's perspective is taken into account when the team is working on the project.

Iterations of this project are being carried out, and we will contribute new features or improve the model that was used in the earlier iterations. In order to track the project's progress, the stakeholders must be included in every iteration. Therefore, we will have a stand-up meeting with our supervisors every week to give an update on our most recent progress and present our ideas for the current iteration. At the conclusion of each sprint, a sprint review and sprint retrospective will be held to incorporate everyone's comments into the subsequent iterations, continually improve from the present state, and confirm that we are on the correct track to meet the targeted milestones. By grading the tasks and reports we provide, the teaching staff will also keep an eye on our development.

Review and Audit Mechanisms

To guarantee the high quality of the deliverables created during the project, a number of review and audit processes are used. According to their priority, the authority making decisions, and the anticipated duration for each problem's resolution, potential project difficulties are divided into four groups. As a result, the team members will be able to communicate with the responsible party more efficiently by using the issue register that has been added to the appendix section.

Our quality assurance team will create test cases and carry out code reviews for our model that have been produced prior to deployment to make sure that all software deliverables are up to grade. To evaluate the faults found in each sprint, quality assurance should perform a rigorous technical review during the code review sessions. This could help to alleviate the burden of debugging and the associated technological costs. Although the project managers are not required to be present for this meeting, they must evaluate the documentation or change logs that were created following the meeting in order to offer input and confirm that the proper procedures were followed.

We would use GitHub as our project's version control system for the implementation of the code. Each team member who makes code contributions can push to their own branches, which the quality assurance department will then examine. Each team member will be able to work on assigned tasks without impacting the source code or previously approved code thanks to the branches, which are preserved in Git by versions. Before merging to the main branch for deployment, this is done to confirm the code quality. Every modification made and the previous iteration of the code are transparently archived and recorded by Git. The team members may quickly obtain the most recent version by simply pulling the new modifications into each particular branch they are currently using if the reviewed version is updated in the main branch.

All written materials, such as meeting minutes, risk registers, and user acceptance criteria, will be kept up to date on Google Drive, a cloud-based file storing and synchronisation service created by Google. Through the team's shared drive, all team members will be able to view and access the most recent or earlier versions of the documents.

3.5 Schedule and Resource Requirements

3.5.1 Schedule

To guarantee that resources are used effectively and that tasks and milestones can be finished on time, a project must be appropriately planned. The project must be finished before the end of Semester 2 2023 (late November 2023) and will take at least six more months to complete, according to our calculations and plans. To prepare for the project's six-iteration schedule, the project team members have specified the responsibilities that will be assigned to each role. A four-week period will be used to complete each iteration. To attain at least 70% accuracy in our posture estimation movement analysis model, the project team members will concentrate on enhancing and fine-tuning our model. At the conclusion of each iteration, a review will be performed to make sure that everything is operating as intended. In order to make sure that project activities are completed on schedule, our team has opted to employ a gantt chart, a work breakdown structure, and a kanban board.

3.5.2 Work Breakdown Structure

For our project, a work breakdown structure is necessary to help divide the work into smaller, more manageable tasks that are precisely stated in a well-defined framework. Figure 17 depicts the WBS as it was most recently modified during the current iteration. As we move through the project's subsequent iterations, we will make changes when additional action items or deliverables are discovered. The tasks and deliverables for each phase are represented in the WBS as children of the branch for that phase.

3.5.3 Gantt chart

To keep track of all the tasks and show the timetable for each one, a Gantt chart will be utilised. The **Appendix** section's Gantt Chart displays the schedule of our current sprints. Using Jira, a project management application, we can easily see the individual in responsibility of each assignment and all forthcoming task deadlines for each sprint. By finishing each deliverable, we may evaluate the project's flow since the Gantt chart shows all task dependencies (GRANT, 2021). Due to unanticipated events, our team needs the Gantt chart, which might be created as the project moves forward. The first two sprints have seen the majority of key tasks and deadlines for project planning and design completed.

3.5.4 Kanban Board

A key tool for visualising and setting up cooperation is the Kanban board (Barnard, 2019). The columns display a number of tasks, with the cards corresponding to the elements that are currently in development. The jobs are organised into columns, and each column shows how each activity is progressing. By limiting work in progress and implementing regulations relevant to the team, a Kanban board may improve the consistency of the project's workflow, assess the current state, predict, and avoid future problems. Our team's Kanban board is shown in the **appendix** section.

3.6 Resource Requirements

3.6.1 Personnel & Computer time required

A project manager, a technical lead, and a quality assurance are the three tasks and duties we have assigned to each team member as part of the project personnel. Each role's duties were already covered in section 3.3. We divided up the duties and responsibilities based on our unique skills. Each team member must commit at least 30 hours per week to this project in order to finish it on time, including attending meetings, doing research, and putting the concept into practice.

3.6.2 Hardware Requirements

Processor	AMD Ryzen 9 5950X
Graphics	NVIDIA GeForce RTX 2080 (8 GB GDDR6)
Memory	64GB
Storage	SK Hynix PC401 NVMe 1.5TB (512FB x 3)

Table 1: Hardware Specifications

3.6.3 Software Requirements

Operating System	Ubuntu 20.04.2
Programming Language	Python 3.11.0
Integrated Development Environment	Visual Studio Code
Debugger	Visual Studio Code built in debugger
Prototype and Experimentation Platform	Jupyter Notebook

Package and Environment Manager	Anaconda 4.8.0
Remote Desktop Software	AnyDesk 7.1.0
Database	Oracle SQL
Repository Host	GitHub
Testing	PyTest 7.1.0

Table 2: Software Specifications

3.6.4 Maintenance Requirements

Communication Platform	Whatsapp and Zoom
Project Planning	Jira
Version Control System	Git

Table 3: Project Management Tools

4 External Design

4.1 User Interface

The essence of the project lies in the user interface of the application. In order to enhance user experience, it is important to ensure that a user-friendly interface is implemented with an improved usability. Below are the features that will be supported by this UI:

4.1.1 Sign Up / Login

Users are able to register for an account that can be personalised to them. On top of that, due to data privacy reasons, this has to be established as users' personal information and images / videos are collected.

4.1.2 Select Exercise

Prior to everything, users are required to select the type of exercise that they are looking to obtain feedback for, ie. Deadlift, Barbell Squat or Bicep Curl. The reason being each of this exercise corresponds to a different predictive model which takes in different sets of parameters.

4.1.3 Importing Videos

Users are given the option to either:
- Import pre-recorded video footage
- Import live video stream

Video will be then converted into a suitable format before going through the preprocessing stages to extract important features that will be passed into the predictive model.

4.1.4 Displaying the Detection Results

The detection results will be a combination of real-time metrics such as number of repetitions, angles between body joints, classification of form etc. Joint points of the body will also be displayed as part of the result. (see fig. 11)

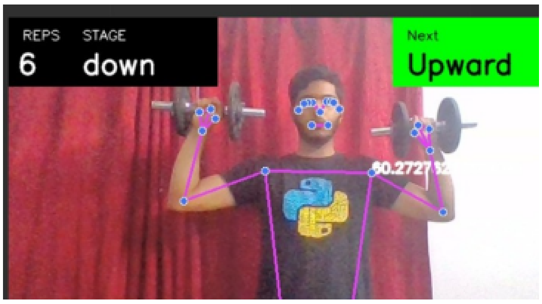

Fig. 11: Example of displayed metrics. (Saleem et al., 2023)

4.1.5 Video Playback

There are a few considerations to include a few different components to achieve video playback support:
- The basic media control buttons such as Play, Pause, Stop, Fast Forward, Rewind and a progress bar.
- The progress bar will have a slider that allows the user to go to the timeline of

the video that they desire. Live video streams will have this enabled as well, with a feature where if the user slides all the way to the right, it will continue streaming the live footage instead of playing back previous frames.

4.1.6 Previous Footage

Users are allowed to download the analysed footage or playback previous resulting footage.

4.2 Training Datasets

The training datasets obtained are very critical in our project as it determines the performance of our application. Our team has decided on two main methods to obtain these training data:

1. **Open-source datasets**
   As our topic of interest is rather niche, there are some difficulties when it comes to having complete datasets consisting of the coordinates of the joints and other useful parameters that are labelled / classified into different classes such as valid or invalid. However we have managed to scavenge the internet for some usable datasets, one of them being from Kaggle (Aboosalih, n.d.).

2. **Manual datasets**
   In the case where we are not able to obtain sufficient datasets for the model training, we will be manually annotating either images or the metrics obtained from Monash Motion Lab. We will be classifying the data according to reviewed and verified information on proper form for each exercise. This will be further elaborated in the later parts of this proposal.

5.0 Methodology

5.1 Programming Languages

5.1.1 Main Language

The development landscape is dominated by many languages.

Python is a general-purpose, versatile, and widely used language with extensive libraries and frameworks. Furthermore, Python provides us with access to a large community of developers and has plenty of resources that we could utilise.

Another alternative is the R programming language. R is a statistical programming language that is primarily used for statistical analysis and data visualisation. Still, packages and libraries such as Keras, imager, and OpenCV, to name a few that are available for R for machine learning and computer vision.

The programming language that we decided to use is Python. This is mainly because of the pose estimation and computer vision libraries for Python such as OpenPose, OpenCV, and MediaPipe that we have decided to implement for our project.

5.1.2 Application Development Language

The programming we will be using for the application development part of the project will be Java. Since we are developing the application on an Android mobile device, thus our choice was limited to either Kotlin or Java. With our previous experience in Java, we decided to ultimately use Java supposed to be Kotlin even though Kotlin is the preferred language for Android development (Chebbi, 2019).

5.2 Data Collection

The procedure for gathering data will be discussed in this section. First, we require pre-recorded videos of an individual doing the specified exercise. At the moment, for this project, we are doing form analysis on three free-weight exercises, which are: dumbbell bicep curls, barbell squats, and deadlifts (barbell). More exercises are to be added when possible. Each exercise has particular requirements for the individual to perform to achieve the correct form (To be explained in the section below).

Two kinds of videos will be utilised, online datasets and our own pre-recorded video. A combination of both kinds of videos will help our classification model to be able to predict for both amateur and professional gym goers. The online videos we use will be those with perfected form and posture, while our own pre-recorded videos will focus on amateur or non-perfect but good enough form.

5.2.1 Bicep Curl Requirement

The following list serves as a guideline: (Jimenez, 2023)

1. Feet placement is about hip-width apart.
2. Bend at the elbow while lifting the weight for the dumbbells to approach the shoulders.
3. Dumbbell is raised to eye or forehead level.
4. Elbows must remain tucked in close to the body.
5. This exercise can be done either standing or sitting.

5.2.2 Barbell Squat Requirement

The following list serves as a guideline: (Catina, 2000)

1. Bar placement should be approximately 1-3 inches below the anterior deltoid.
2. Feet placement should be slightly wider than shoulder width.
3. The lifter should descend leading by the hips rather than the knees.
4. The lifter's shin should be perpendicular to the floor while descending.
5. Lower legs should remain straight while descending.
6. Knee joints must be kept directly over the foot while descending.
7. Heels should be flat on the floor throughout the entire duration of the lift.

5.2.3 Conventional Deadlift Requirement

The following list serves as a guideline: (Holmes, 2020)

1. Feet placement is approximately the same as the shoulder width.
2. When grasping the bar, the grip on the bar should be slightly wider than shoulder width.
3. Setting up for initial pull, the pelvic girdle should be in line or slightly below the knees.
4. Back should be flat and at roughly a 45 degree angle to the floor.
5. While lifting the bar, knee joints and the hip are extended simultaneously.
6. It is important that the back is kept as flat as possible as the movement progresses.
7. The lifting movement is completed when the bar reaches mid-thigh.

5.2.4 Extract Data from Videos

From the videos, we can capture the body points or landmarks of the individual performing the exercise using the pose estimation model. For each exercise, there will be several classes that represent a certain movement represented and the coordinates of the landmarks called features. The captured values of the landmarks and their corresponding class will be represented in a CSV (Comma-Separated Values) file to be used for training the classification model. A sample of the written CSV shown in Table 4 has the class of 'up', which means the current state of the individual is lifting the weights, and the coordinates of each landmark on the body are represented in x, y, and z (3D).

	A	B	C	D	E	F	G
1	class	x1	y1	z1	v1	x2	y2
2	up	0.563296	0.655078	-1.08445	0.999918	0.586314	0.590396
3	up	0.431742	0.09826	-0.48646	0.999994	0.439272	0.076063
4	up	0.432213	0.098868	-0.42034	0.999995	0.441326	0.076329
5	up	0.428958	0.100337	-0.44594	0.999995	0.437421	0.077496
6	up	0.423288	0.100925	-0.45429	0.999995	0.431886	0.078125
7	up	0.418819	0.100918	-0.45323	0.999995	0.427296	0.078175
8	up	0.416131	0.100898	-0.43925	0.999995	0.424226	0.078231
9	up	0.410799	0.093365	-0.41117	0.999994	0.418566	0.072375
10	up	0.409648	0.088704	-0.41349	0.999994	0.417956	0.068382
11	up	0.410847	0.08683	-0.37178	0.999993	0.419283	0.065551
12	up	0.411054	0.086099	-0.34665	0.999993	0.420208	0.06448

Table 4: Sample CSV representation of data

We have two approaches to classify the action class for training. We will do manual annotation or we splice the video being fed to only show the specific action.

5.3 Pose Estimation

Several real-time pose estimation frameworks and systems are available, but we have decided to use OpenPose. "OpenPose is a library for real-time multi-person keypoint detection and multi-threading written in C++ using OpenCV and Caffe" according to OpenPose's GitHub readme and was developed by researchers at Carnegie Mellon University.

	OpenPose	PoseNet	MoveNet
Detection Parts	Body, Foot, Hand, Face	Body, Part of face	Body, Part of face
Detection No.	Many	One	One
Key-points	137	17	17
Operation	Real-time	Real-time	Real-time
Method	Bottom-up	Top-down	Bottom-up

Table 5: Specification of OpenPose, PoseNet, and MoveNet

Table 5 shows the specifications of OpenPose compared to other famous real-time pose estimation models such as MoveNet and PoseNet. OpenPose supports 137 key body points, which is significantly more than both MoveNet and PoseNet. This also means that OpenPose can track the body in greater detail compared to the other two. Additionally, OpenPose is the only model capable of estimating the poses of multiple persons due to it utilising a multi-stage CNN architecture.

5.3.1 OpenPose Model Architecture

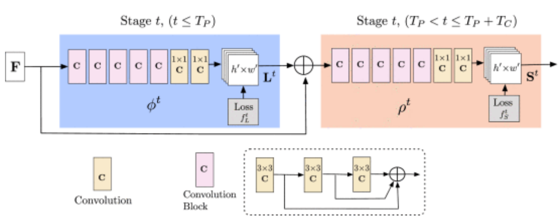

Fig. 12: OpenPose Model Architecture

Figure 12 depicts the architecture of OpenPose, which is a multi-stage convolutional neural network (CNN) where the first set of stages predicts affinity fields that encode part-to-part association (blue coloured), while the last stage predicts detection of confidence map (beige coloured). Each state's prediction and corresponding image features are concatenated for each subsequent stage.

5.3.2 Concerns

Our main concern about using OpenPose is that it doesn't support either Android or iOS. This is due to OpenPose being built with Caffe, a deep-learning framework.

This doesn't mean that porting it is impossible. We can use a GitHub repository to convert Caffe models to TensorFlow to obtain OpenPose's model files equivalent in TensorFlow. TensorFlow is a machine learning framework developed by Google, and it supports both Android and iOS, which allows us to use OpenPose's model on mobile devices.

5.3.3 Alternative

An alternative that we could use, if porting OpenPose into mobile is not feasible, is MediaPipe. MediaPipe Pose is a single-person pose estimation framework, developed by Google. Both MediaPipe and OpenPose have similar levels of accuracy, efficiency, and flexibility.

Thanks to its widespread usage and research advancements, OpenPose boasts a renowned community and extensive documentation. Meanwhile, Google-produced MediaPipe similarly benefits from a robust network of content and resources, including comprehensive documentation and numerous examples to simplify the development process.

Currently, at alpha version 0.10.0, there remains potential for issues to arise within Mediapipe's framework, and forthcoming modifications implemented within its API may lead to unforeseeable complications; developers are optimistic about providing stable APIs by version 1.0 nonetheless.

5.4 Classification Model

A classification model acts as an intelligent program that employs pre-existing knowledge to classify diverse data into distinct categories or classes. By analysing traits, features, or characteristics of a dataset carefully, the model allows it to accurately classify any given data into its relevant cluster group with ease.

Utilising a classification model, allows our system to recognize whether the individual is currently at a certain state, be that 'up' and 'down', which implies the weights are lifted up and not lifting respectively, or other action class we will decide to categorise later on during our data collection.

We currently have no idea which form of classification machine learning model would perform best for our dataset given that we have not started data collecting. Hence we propose training and testing various classification models, then selecting the one that comes with the greatest evaluated metrics and implementing it in the final product.

The classification models we chose are: Support Vector Machines (SVM), Random Forest, Convolutional Neural Networks (CNN).

5.4.1 Support Vector Machines

Support Vector Machines or SVM are originally designed for binary classification problems, where there are only two distinct classes. Our objective is to use SVM for multi-class classification, and we can do that by using approach such as “One-versus-All” (OvA) or “One-vs-Rest” (OvR) and “One-versus-One” (OvO). The OvO strategy is more suitable for small to moderate sized datasets. We decided to use the OvA strategy, because OvA is usually used when the number of classes are considerably large, which is true for our dataset where numerous classes representing coordinates of landmarks (each in x, y, and z) and multiple action classes are employed.

5.4.2 Random Forest

Random Forest can be used as a multi-class classifier without modifications. Using Random Forest as one of our classification models is great because we won’t deal with any alteration or adjustments, and be able to immediately train and test.

5.4.3 Convolutional Neural Network

Convolutional Neural Network or CNN is a type of neural network commonly used for computer vision tasks, like image classification. CNN has excellent performance on image-related tasks, but it is not limited to just image classification tasks, they can also be used for general multi-class classification. We will test CNN’s effectiveness by training it in two ways, using our CVS dataset as a multi-class classifier, and using our videos.

5.4.4 Model Training and Evaluation

From the dataset we have gathered and classified, we will do an 80-20 split to create a train and test dataset respectively. The training dataset will be used to fit the classification model, while the test dataset will be inputted into the model to evaluate its performance.

The evaluation metrics we will be using to measure the performance of our model are:
- Accuracy: The number of test cases correctly classified, or the overall correctness across all classes.

$$Accuracy = (TP+TN)/(TP+TN+FP+FN)$$

- Precision: Determines correctness of classification for a specific class.

$$Precision = TP/(TP+FP)$$

- Recall: The number of positive cases correctly identified for a specific class out of the total number of positive cases

$$Recall = TP/(TP+FN)$$

- F1 Score: merges precision and recall into a single metric, it provides a balanced measurement of the model's performance for a specific class.

$$F1Score = 2 * ((precision * recall)/(precision + recall))$$

5.5 Proposed System

The system starts with the user selecting which exercise they want to do. A camera will capture the user doing the exercise and at the same time, the pose estimation model will run in real-time to detect the landmarks and their current coordinates. Those coordinates will then be inputted into a classification model, trained with our dataset, which will tell the current action of the user.

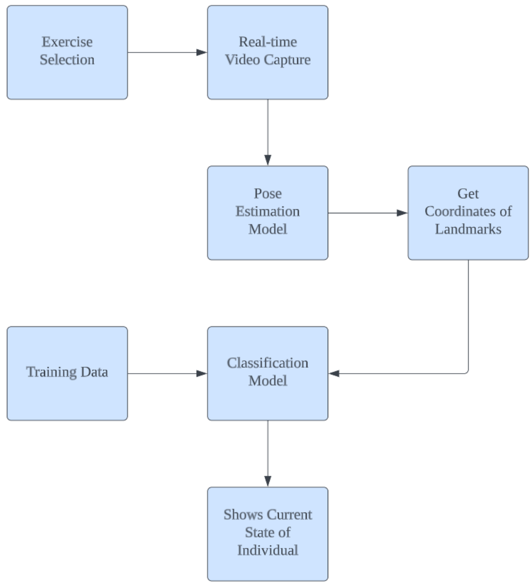

Fig. 13: High-level System Data Flow Diagram

5.3 Data management

5.3.1 Entity Relationship Diagram

To fulfil the requirements of the project, data flows in multiple formats through our human movement pose estimation system from one entity to another. In Figure 15, an entity relationship diagram is displayed. shows the connections between each data object in the database of the system.

5.3.2 Database

Database systems are a crucial component of computing systems because they enable the efficient and safe management of enormous volumes of data. Users may access, modify, create, and systematically save data with this tool.

The Oracle Database will be used to store the acquired data. The justification is that since we are more comfortable with the interface than we would with alternative database systems. We are moving our project forward utilising the agile technique.

6 Test Planning

Ensuring that the software application's functionality complies with the demands of the project's scope. Prior to delivering the minimal viable product to the project stakeholders, the team will do thorough testing on it in order to maintain the quality of the software design and to reduce the number of defects. The team's quality assurance department will be in charge of conducting the tests.

6.1 Test Coverage

The functional requirements that must be tested, the test cases that should be used to test them, and the software components concerned are all listed in the test coverage, or overall test plan. The HOI model, the database, and the software programme that encircles the model and database are the three main parts of our application that it will cover. It is generated from the user acceptance criteria.

The team's test coverage is displayed in table 12.

6.2 Test Methods

Unit testing, integration testing, and system testing will be performed as discrete phases of the test, with the scope of the test expanding with each stage. Every modification made will always be followed by a quick automated regression test to see how it will affect the current system and prevent error propagation.

The complete, open-source and free testing module, pytest which has an intuitive GUI, will be used to implement the tests. The system's adjustments in response to the shifting requirements will be incorporated into the test procedures through updates.

6.2.1 Unit Test

Unit testing's goal is to find and fix mistakes as soon as possible. The tiniest testable components of the software programme are isolated at this point and independently checked for functionality. The development team can do this in order to identify the issues' cause and repair them before they spread to other systems.

The development approach will adhere to the Agile software development framework and use the test driven design technique that was first proposed in the extreme programming software design paradigm. The team will start by creating unit test cases that fail, then go on to writing the bare minimum of code to pass the test cases. Only after that does the code reworking step begin, improving the programme architecture without changing the behaviour of the unit.

Each time an update or new component is added to the system, unit testing will be carried out regularly; thus, the test cases must be very lightweight in terms of time and space needs, and overlapping test cases will be avoided wherever feasible.

The development team will have to closely abide by the single responsibility concept in the software design due to the nature of unit testing. Instead, valuable debugging time will be saved, allowing the team to concentrate on developing the model.

6.2.2 Integration Test

Integration testing is done to find any issues that can appear when many units are merged and handled as one in order to make sure the changing requirements are included into the programme.

The bigger software entities will be assembled from the pieces and tested as a whole. The team will test the data transmission between the modules and replace any missing modules with dummy programmes. If an integration error is found, the development team will be notified so that a repair can be made, and the functionality will then be tested again. Until there are no more integration failures in the application, this procedure is repeated.

In order to ensure that all atomic units are functionally sound, integration testing is only carried out following the unit testing phase.

We will implement all components at once and test them out as a single unit. Because our application is so tiny, we can solve the mistakes right away, which gives us more time to enhance the performance of the model.

6.2.3 System Test

Every part of the system is tested to make sure it functions as a whole. By determining if the software satisfies the relevant user stories and functional requirements, the team will test the product's functionality from the user's point of view.

At this step, performance testing will also be done to ensure that the software application is effective enough to reflect the real inferencing performance of the model without bottlenecking it.

7. Conclusion

In summary, the goal of our research is to create a system for analysing human movement in the context of weightlifting workouts. The system utilises computer vision techniques, specifically pose estimation, to capture the body points or landmarks of individuals performing the exercises. The captured data is then used to train a classification model that can predict the current action or state of the user.

The proposed system follows a high-level data flow, where the user selects the exercise, the camera captures the user's movements, the pose estimation model detects landmarks, and the classification model predicts the user's current action. The system aims to provide real-time feedback and guidance, helping individuals improve their exercise form and prevent injuries.

Overall, this project combines the power of computer vision, machine learning, and mobile technology to create an intelligent system for human movement analysis in weightlifting exercises. By leveraging these technologies, we aim to empower individuals with personalised coaching and support, enhancing their overall fitness experience.

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9. Appendix

	Project Manager	Technical Lead	Quality Assurance	Project Supervisor
Identify requirements	R	A	A	C
Project scoping	R	A	A	C
Meeting minutes	R	I	I	I
Task delegation	R	I	I	I
Communication matrix	R	A	A	C
Risk assessment	R	A	A	C
Risk mitigation	R	A	A	C
Methodology	I	R	A	C
Project schedule	R	C	C	C
Timesheet	R	A	A	I
Project proposal	R	A	A	I
Dataset curation	I	A	R	C
Model training	I	R	A	C
User interface	I	R	A	C
Database	I	R	A	C
Version control	I	R	A	I
Code review	I	A	R	C
Test plan	I	A	R	C
Test cases	I	A	R	C
Testing	I	A	R	I
Presentation	R	A	A	I
Prototype Demo	R	A	A	I
Post-mortem	R	A	A	C

Table 6. RACI matrix

ID	Requirements (Functional or Non Functional)	Assumptions or/and Customer Needs	Category	Source	Status
001	High detection and classification accuracy that is reasonable	The client demands that the model identify movements with at least 70% accuracy.	Performance	Project manager	Open
002	Inference speed	The client requires the model to receive input and recognise aggressive behaviour in the video at or above 15 frames per second.	Performance	Project Manager	Open
003	In real time, the AI model can identify and analyse user postures	The client requires immediate feedback and direction to continue using good form and technique while exercising.	Functional	Project Manager	Open
004	Prevents unauthorised access to data	To ensure that only those with permission may access the data, the client wants the system to guarantee the security and privacy of the data processed.	Service	Project Manager	Open
005	The model must maintain constant accuracy in a range of illumination situations	The model's accuracy will be evaluated using data that was collected under various lighting circumstances, including daylight, low light, and various coloured lights.	Quality	Project Manager	Open

Table 7. Requirements Traceability Matrix

No.	Rank	Risk	Category	Root Cause	Triggers	Potential Responses	Risk Owner	Probability	Impact	Status	Score
1	4	Team member unavailability	Project Management	Unexpected circumstances/illnesses such as being infected by Covid-19/Accidents/Familial Problem	Member report their situation to team	Informing the teaching team about the situation, readjusting workload distribution and schedule to accommodate for two team members instead of three.	Project Team	3	10	Open	30
2	8	Supervisor cannot be reached or busy	Schedule	Supervisor having other responsibilities	The supervisor not attending to messages or emails sent by the team	Informing supervisor beforehand (regardless if the email/message is read) and meet with supervisor in their office	Project Manager	3	5	Open	15
3	5	Lack in computational capability when training the model	Technical	The model requires more than expected computational power for maximum results	Training the model takes a lot of time or keeps on stopping/crashing	Utilising cloud computers or purchasing newer computers/parts by requesting and acquiring budget	Technical Lead	3	8	Open	24
4	3	Insufficient dataset	Technical	There are insufficient videos that we can utilise which contain all the required information we needed to train the model	The model performs badly	Using online datasets and filtering them by only taking those with our specified requirements	Project Team	3	9	Open	32
5	2	Classification model fails to produce expected output	Technical	The model used is not the best choice for our type of classification or insufficient training data fed	The model performs poorly based on the evaluation metrics when using the testing data	Changing the type of classification model used or adding new/more training data	Quality Assurance	4	9	Open	36
6	6	Pose estimation model fails to capture required landmarks	Technical	Due to the orientation/view or quality of the individual's camera	The pose estimation model fails to recognise specific limbs on the individual	Train the model with videos that capture different perspective when an exercise is performed	Technical Lead	3	7	Open	21

7	1	Mobile device performance issue	Technical	The mobile device we are using to test the prototype of our application may not be able to handle the deployed model due to performance limitations	The mobile device takes too much time to process	Optimising the classification model alongside adjusting the pose estimation model to be able to perform on lower powered devices	Quality Assurance	5	9	Open	45
8	7	Unable to complete project on time	Project Management	Unable to finish each task required in the project scope due to wrong estimation of time needed or lack of understanding when dealing with task	Project schedule inaccuracy and mismanagement or bad planning	Rearrange schedules and utilising different project management tools which are better suited to our team	Project Manager	2	10	Open	20

Table 8. Risk Register

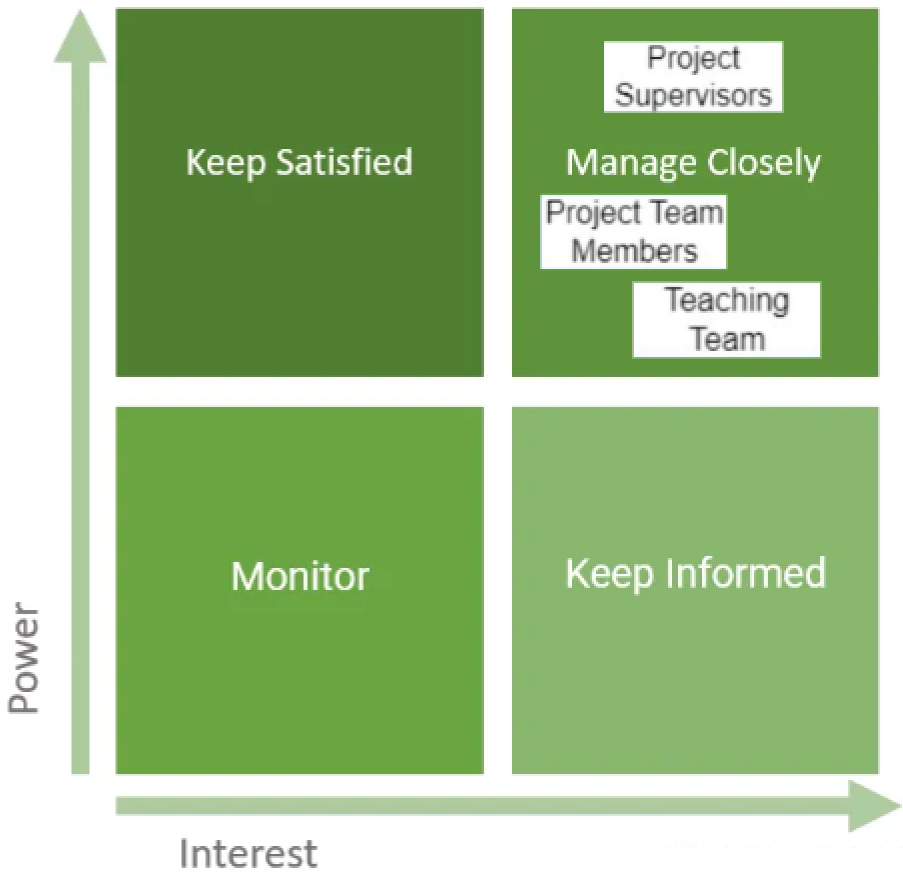

Fig. 14: Stakeholder Management Matrix

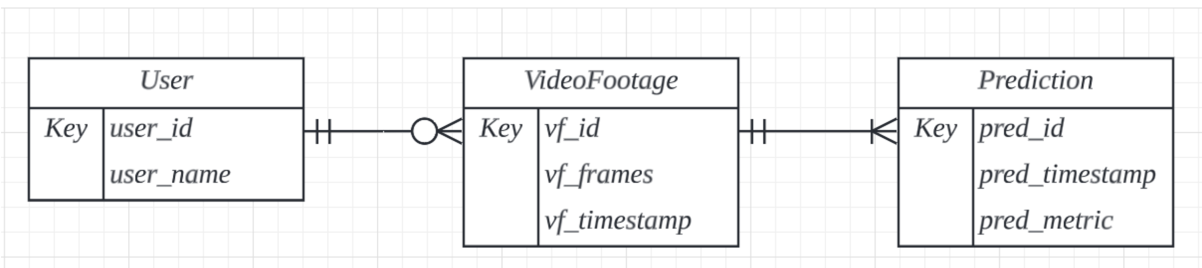

Fig. 15: Entity Relationship Diagram

Communicati Type	Objective of Communication	Communication Channel	Frequency	Stakeholder Present	Deliverable
Update on Task Progression	- Update and monitor each member's performance on each job	Whatsapp	Daily	Project team members	-
Stand Up Meeting	- Update on the sprint's development - Check to see whether the current sprint's deliverables have been met	Zoom	Weekly	Project team members, project supervisors	Meeting minutes
Retrospective	- Analyse if the project's goals were attained - Talk about the team's performance and strategies to do better.	Zoom	End of each sprint cycle	Project team members	Meeting minutes
Project Review	- Review the project plan and talk about the following action item for the following iteration	Zoom	End of each sprint cycle	Project team members, project supervisors	- Updated product backlog - Updated project plan

Table 9. Communication Matrix

Stakeholder	Interest	Impact	Contributions
Supervisors	High	High	- Monitor the team's development - Specify the project's needs and provide the team feedback after each iteration
Project team members	High	High	- Make sure the product is implemented and of good quality - Assure that the stakeholder's requirements are satisfied

Table 10. Stakeholder Analysis

FIT3161 - Computer Science Project Part 1
Meeting Minutes
Group 11

Date & Time : 30/5/23, 4:30pm - 6:00pm

Location : Zoom Meeting

Objective : Project Proposal Direction

Attendance : Emily Chin, Zhen Yoong, Josh Tan

Agenda Items:

1. Application use case and implementation
    - We decided to use different type of models for each exercises performed providing real time feedback
    - For example we want a user interface that inputs a real time video and shows users their repetition count and posture correctness.
2. APA citation format for our proposal
    - We decided to use APA 7th for our proposal
3. Questions to ask
    - What kind of classification models should we use?
4. Next meeting TBC.

Responsibilities:

PIC	Tasks
Josh Tan	Complete methodology
Zhen Yoong	Complete project management and test methods
Emily Chin	Complete literature review, exercise requirements and external design

Fig. 16: Meeting Minutes

Decision-Making Power	Occurs When
Project Manager	Issues with the project management procedures that will impact the project's schedule.
Technical Lead	Technical development issues that will impact how the software deliverables are implemented.
Quality Assurance	Issues with the production of all deliverables of a certain standard.
Project Supervisor	Issues with a significant influence on the project's deliveries that will have an impact on its success.

Table 11, Issue Register

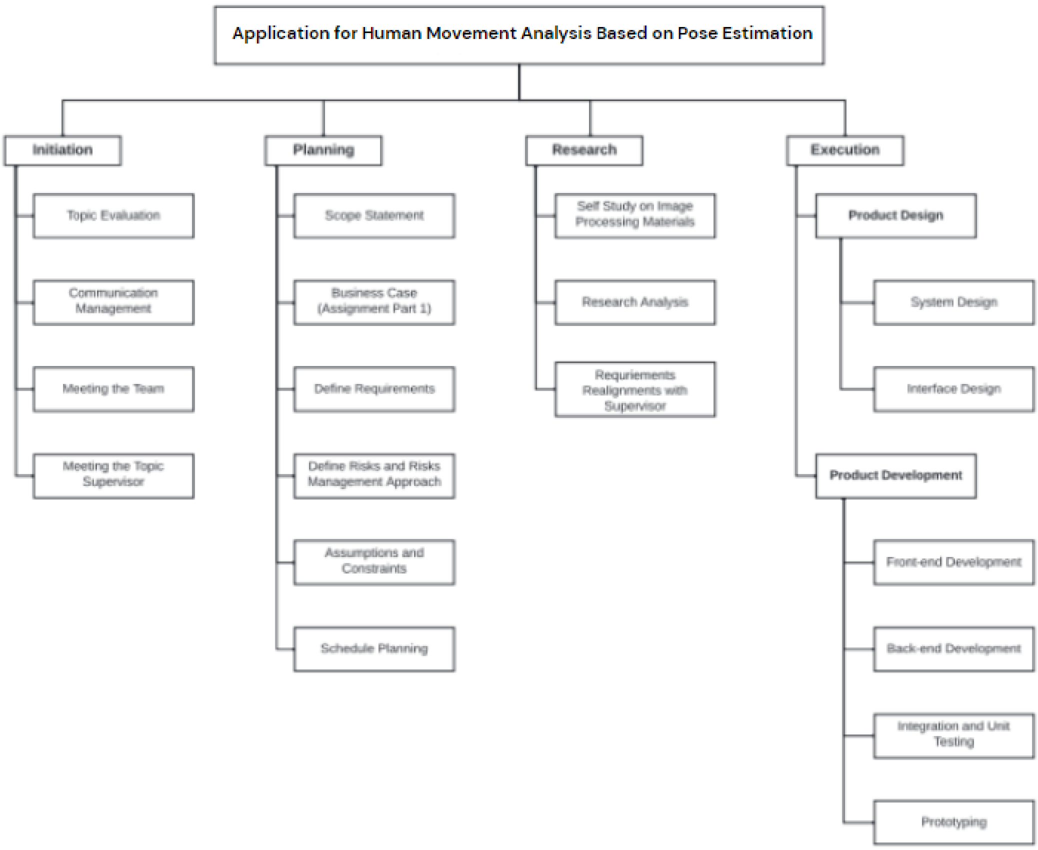

Fig. 17: WBS

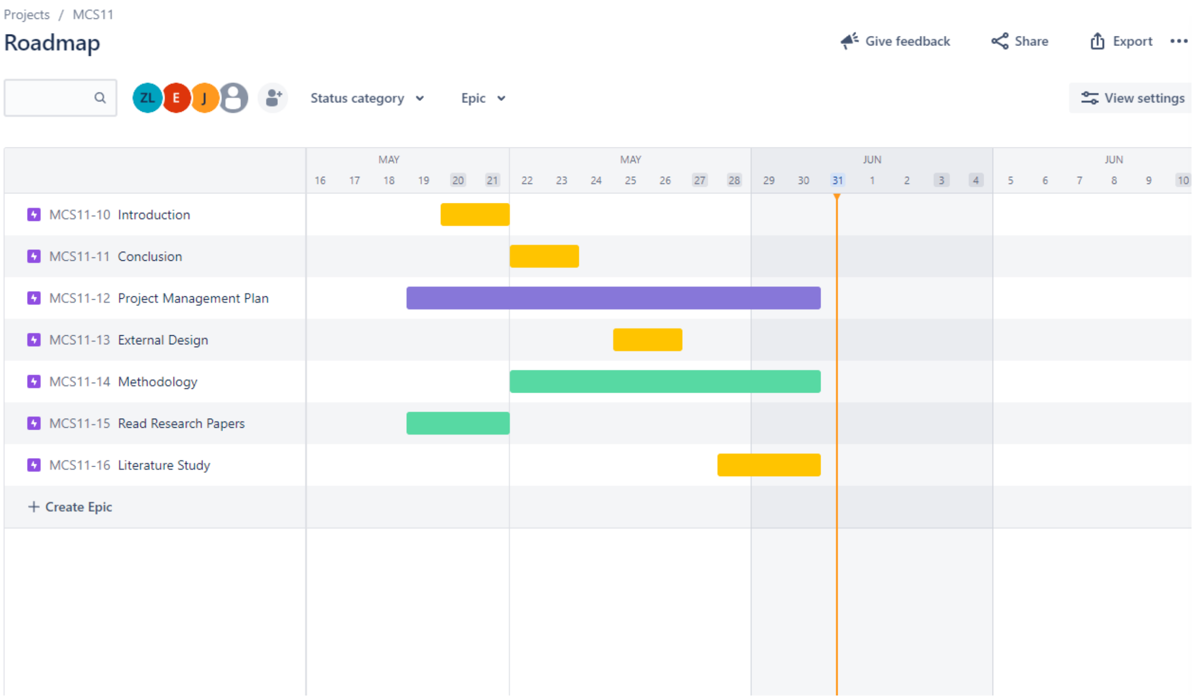

Fig. 18: Gantt Chart

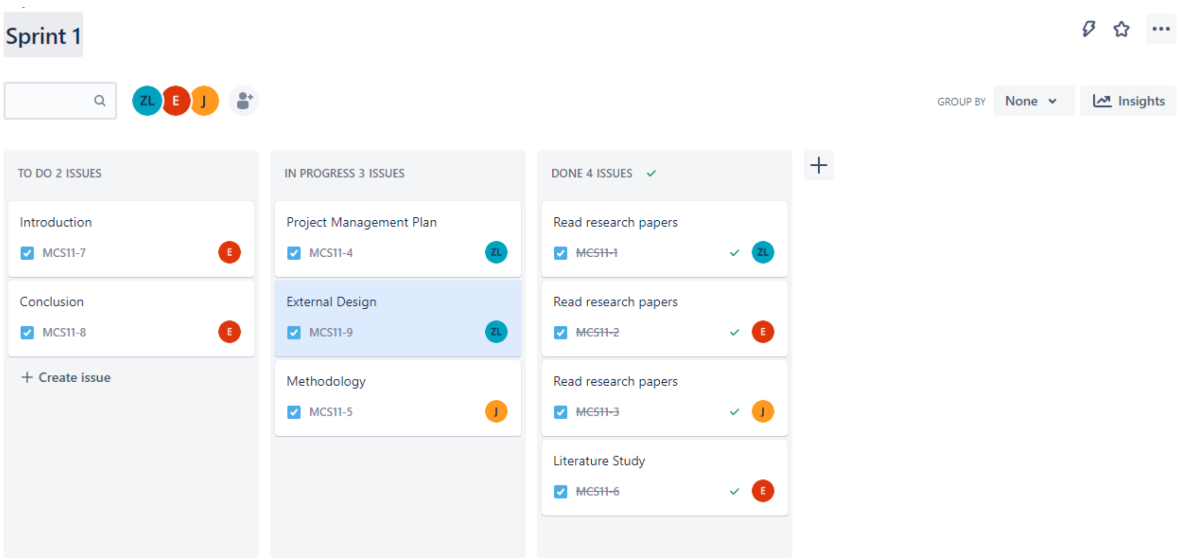

Fig. 19: Kanban Board

Criteria ID	Test Case UD	Test Description	Testing Stage	Components Involved
001	001	Test to see if CRUD operations are supported by the database.	Unit test	Database
001	002	Check to see if the user can log in using personal information; unauthorised persons are not permitted access to the programme.	System test	UI, database
001	003	Verify the UI's ability to connect to and communicate with the database.	Unit test, integration test	UI, database
002	004	Verify whether importing live video feeds from the app is possible for the user.	Unit test	Application back end
003	005	Check to see if the model can accurately predict the user's workout form in the video.	Unit test	Model
003	006	Check to see if the UI can show metrics relating to the user's exercised movement.	System test	UI, application back end, model
004	007	Check to see if the application can save analysis findings in the database.	Integration test, system test	UI, database
005	008	Check to see if the application allows for the smooth playback of video.	Unit test	UI

Table 12, Test Coverage

Front Cover Sheet	JT
Introduction	ZY
Literature Review	EC, ZY
Project Management Plan	EC, ZY
External Design	ZY
Proposed Methodology	JT
Test Planning	EC
Conclusion	JT
References	EC, ZY, JT
Style and Presentation	JT

Table 13, Team Contribution Annex

ID	User Story	Acceptance Criteria
001	As a user, I would like access to be restricted through a login process.	User credentials are adequately encrypted to withstand any assaults, and users may log in to the system without any problems.
002	As a user, I would like to be able to import live video feeds.	The system can take the majority of common data forms, and users may input live video format.
003	As a user, I would like to see the outcomes of the movement analysis detection.	Using the model, the system can forecast movement form accuracy. Its outputs, which include significant parameters pertaining to the workout movement, will subsequently be visualised over the live video.
004	As a user, I would like to use the application to play back the video.	Smooth video playback is supported by the application.
005	As a user, I would like to use the application to access previous analysis findings from the system.	The system properly supports CRUD operations and stores the analysis results in the database.

Table 14, User Acceptance Criteria