



Proof of Concept Presentation

ENSC 405W - Company 5



eye-bex



Introduction to Rock Climbing



- Climbing gym walls have a collection of rocks that form routes. Typically each route is distinguished by a unique colour from its neighbors.
- The challenge of a route is for a member to only use rocks of that colour to traverse from the low starting holds to top finish hold.
- Climbing gyms employ route setters whose responsibility is to design new routes to replace the old routes.



Our Purpose

- Designing routes that are accessible and interesting for all heights is the most difficult job in the climbing gym, and all gyms aspire to it.
- We are going to use a mounted camera system to record climbers and process data to provide feedback to route setters through a web app.
- Our feedback will help in mentoring new route setters and improve the current setting team by providing quantifiable data.



Business Case



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Market Analysis

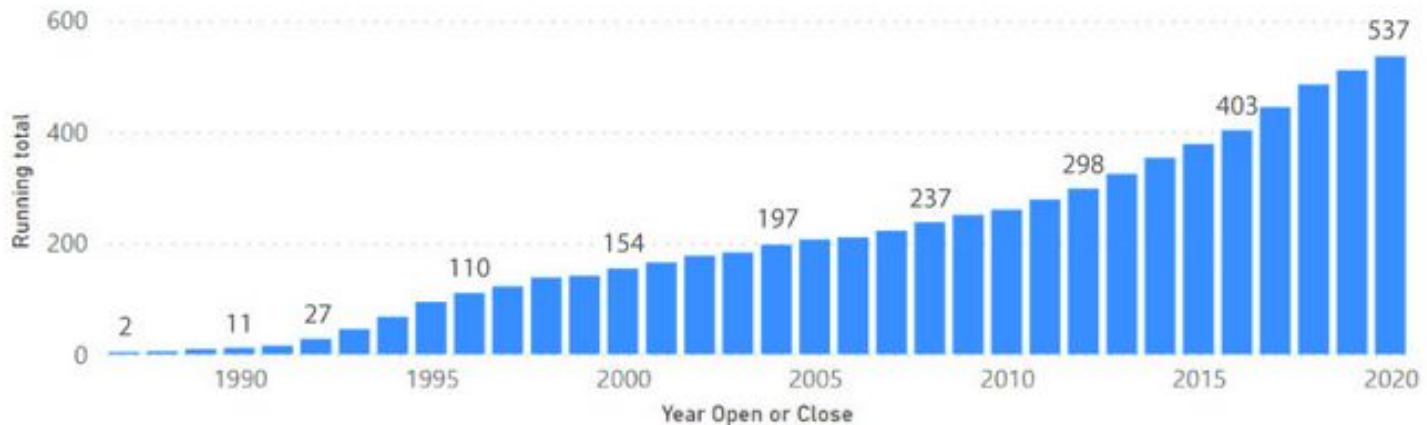


- As of 2020 there are 123 climbing gyms in Canada, and 537 climbing gyms in the United States. [1]
- Since 2011, the percentage growth year-on-year has been at least 5% and shows no signs of slowing down. [1]
- The popularity of the sport is benefitting from recent exposure on a global scale:
 - The sport made its debut at the 2020 Summer Olympic games in Tokyo in 2021.
 - Free Solo, a National Geographic documentary about a climber's conquest of the El Capitan without a rope won an Academy Award.
- Our product benefits the climbers by offering an avenue for social contact and physical activity which has been lacking through the pandemic.



Net U.S. Climbing Gym Growth

Running total by Year Open or Close



Ideal Customer



A testimonial from David Murray, owner of The Hangout Climbing Gym



Competition Analysis

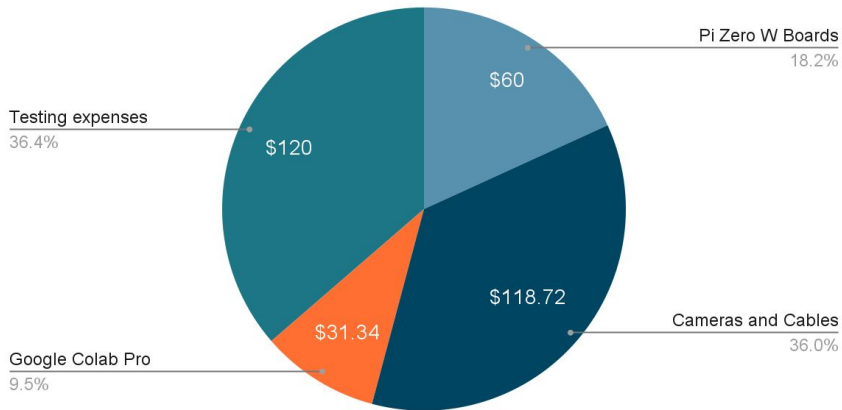
- No other solutions provide automated feedback on any wall.
- There were no direct competitors identified in our online research online or our consultation with industry professionals
- Existing phone apps such as Stokt and Beta Direct are user-focused, operate on manual input from climbers, and focus on qualitative user-sourced data.
 - Stokt requires gyms to opt in and manually submit pictures of their training walls. Climbers then have the option to manually enter climbing routes and their feedback.
 - Beta Direct requires manual input of walls from user photos and manual selection of rocks in a route. The overall functionality is similar to Stokt.
 - Manually data entry produces samples biased towards experienced users that want to participate on the app.
- Clients expressed firmly that they would not adopt any application that required manual input by their staff and increased their workload.



Cost and Financing

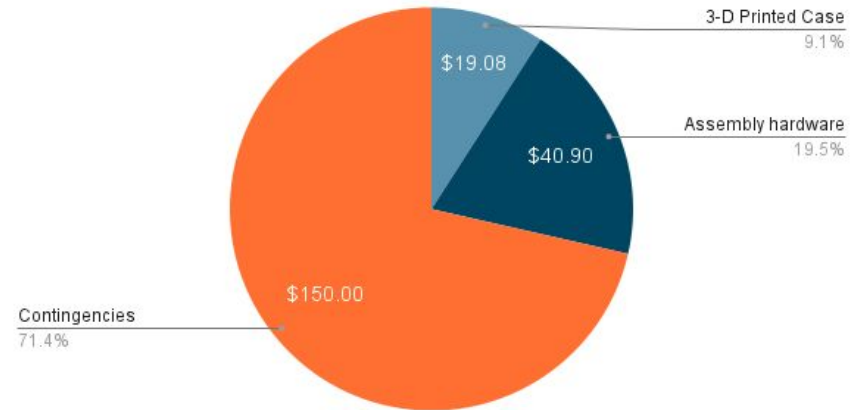
Proof of Concept Cost Breakdown

Total Cost: \$361.41



Functional Prototype Cost Breakdown

Estimated total cost: \$209.98



Technical Case



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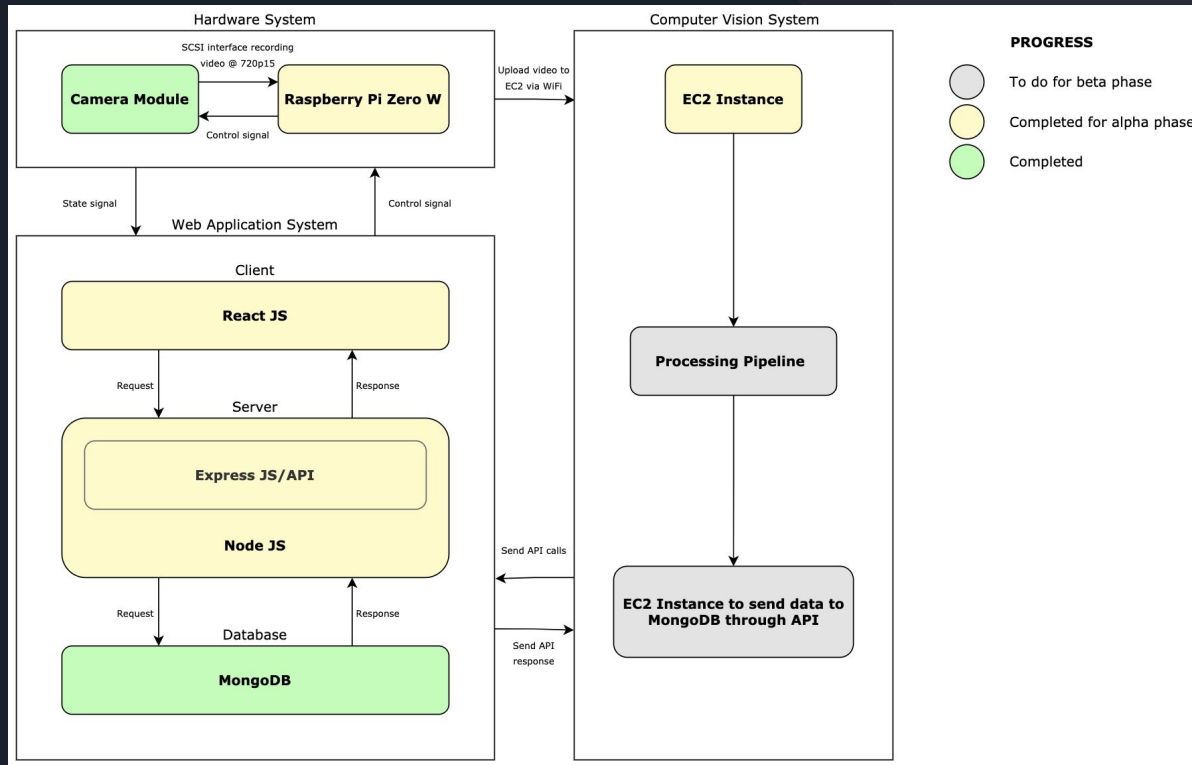
Main functions

- Hardware system will automatically record, convert and upload climbing footage wirelessly to AWS cloud
- Computer vision system will use footage to:
 - Identify and organize the rocks into separate routes by colour
 - Process each climbing attempt
 - Detect climber's heights and climbing statistics
 - Write results to database
- Web app system will process packaged data from the database and display in a user-friendly manner to the dashboard.



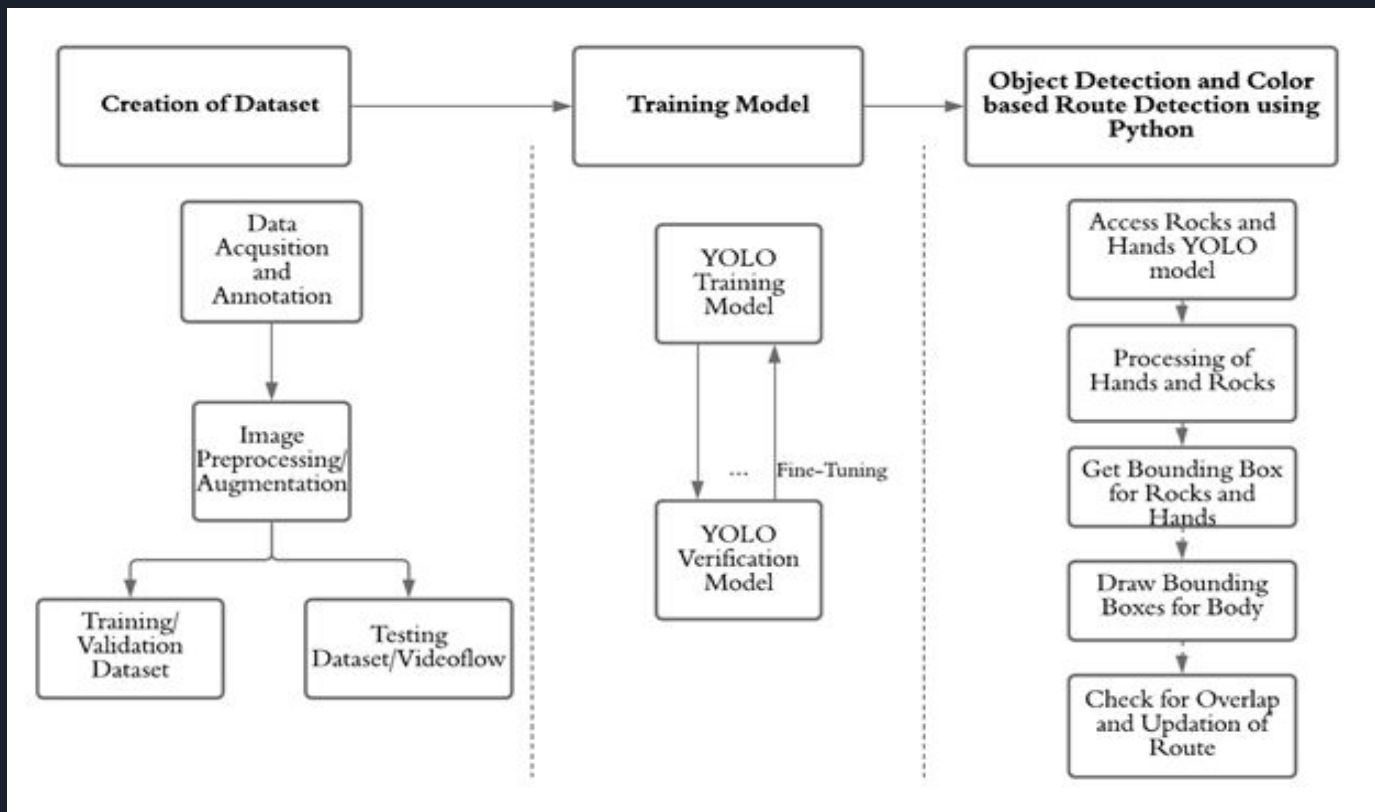


System Overview



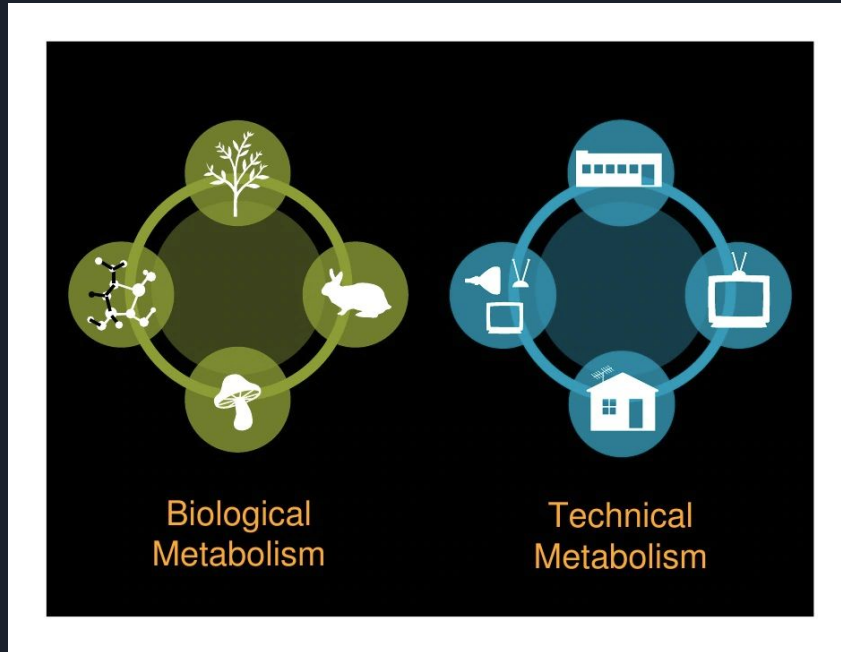


Computer Vision - Dataflow





Cradle-to-Cradle Design



- Modular design allows for replacement of any broken component
- Using PLA filament for 3D printed mount
 - Durable and biodegradable
- Microcontroller and camera module can be repurposed if needed.
- Electronics recycling can be done through Electronic Recycling Association



Engineering Standards

- CAN/CSA-ISO/IEC/IEEE 12207:18 - Framework for software life cycle processes [2]
- CAN/CSA-ISO/IEC 26557:18 - Tools and methods of variability mechanisms for software and system [3]
- ISO/IEC TR 12182:2015 - Systems and software engineering - Framework of categorization of IT systems and software, and guide for applying it [4]
- IEEE/ISO/IEC 14764-2006 - ISO - Software Life Cycle Processes Maintenance [5]
- IEEE/ISO/IEC 23026-2015 - Systems and software engineering - Engineering and management of websites for systems, software, and services information[6]
- CSA C22.1-18 - Canadian Electrical Code, Part I safety Standard for Electrical installations [7]



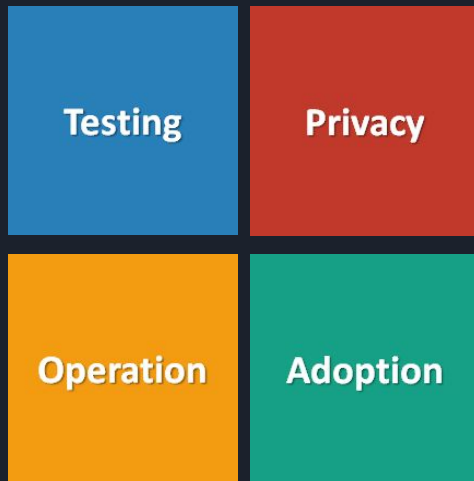


Changes in scope and design

- On-device processing vs cloud processing
 - Cloud processing is more scalable to the gym's needs for processing
 - Cloud processing facilitates installing additional cameras for cheaper and is more sustainable
 - On-device processing forces a larger physical footprint which may deter potential clients
- Prioritizing accessibility after client meetings
 - Based on feedback from the a client our statistics are now focused on embracing the accessibility of climbs for all heights, rather than limiting all climbing styles
- Data visualization
 - Asked industry professionals which data points they wanted to be collected and the best way to present it



Risk Analysis and Mitigation



There are 4 main risks we considered:

1. Testing
2. Privacy
3. Operation
4. Adoption



Risks - Testing

Testing	Privacy
Operation	Adoption

Risk

Device may be over-optimized to suite particular types of climbing walls

Mitigation:

Continue building our list of climbing gym contacts so that we can test our device in differing real-world scenarios



Risks - Privacy

Testing	Privacy
Operation	Adoption

Risk:

There may be privacy concerns about video being recorded and stored in servers which are hosted in the United States

Mitigation:

Having climbers sign a waiver for the storage of their climbing data in another country, and prevent access of video by any person outside of the admin



Risks - Operation

Testing	Privacy
Operation	Adoption

Risk:

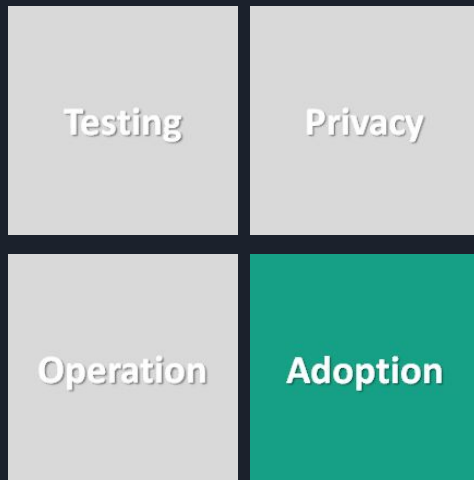
The computing servers may go down during operation of system

Mitigation:

Ensure a potential 48 hours worth of backup space on device and automatically update web server of multiple failed uploads



Risks - Adoption



Risk:

Low adoption rates from gyms

Mitigation:

Constant and thorough client consultations and potentially offering a pilot run to gyms to let them see how the product will work



Technical Design Exploration Research: Hardware



Microcontroller

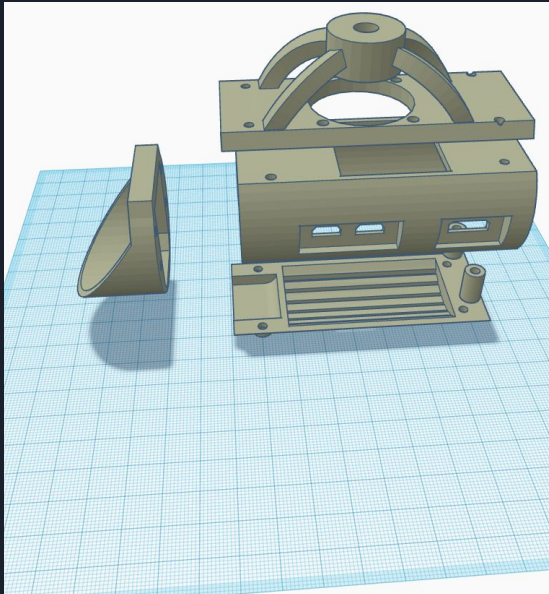
- The Arduino Nano 33 IoT, Raspberry Pi 4B, and the Pi Zero W are all capable of controlling a camera, uploading a video and automation through a script
- The Pi Zero W was selected because of its small physical footprint and affordability, as well as its familiar Linux based operating system

Camera

- Several Pi camera modules were considered. None of the specialized lenses for IR video, wide angle, fisheye, or ultra high resolution offered any advantage for our immediate needs
- The Pi Camera V2 is able to record 1080p video at 30 fps, which exceeds our base requirement of 720p resolution and 15 fps at the most affordable price point amongst Pi camera modules



Technical Design Exploration Research: Hardware



Housing

- The Eye-bex casing design is required to be lightweight, mountable, and provide space for output status LEDs
- The casing should support screw mounting to the wall, and provide access to all necessary input ports
- A 3-D printable design was selected for affordability, ubiquity, and customizability
- Using biodegradable PLA filament the 110.44mm x 44.2mm x 57.65mm housing weighs 47.7g



Technical Design Exploration Research: Computer Vision

Object Detection Options

- FR-CNN, SSD and YOLO are the most popular choices for object detection
- YOLO 3 and 4 versions were chosen considering its speed, accuracy, availability of documentations and projects online

Motion Tracking Options

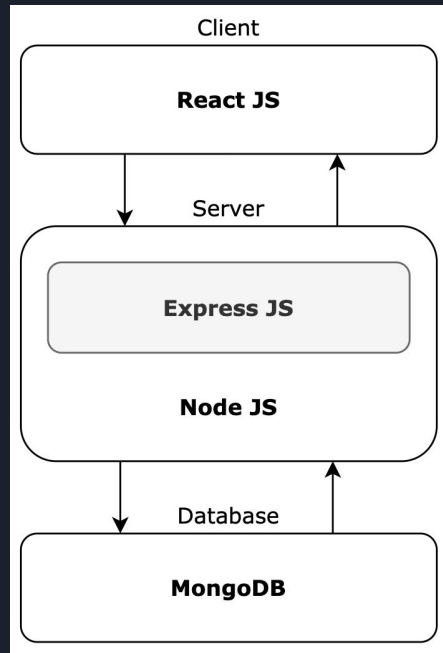
- Motpy and Deep Sort are the two options considered for motion tracking
- Motpy is a library that works well with YOLO to smoothen out the bounding boxes and would help with the jittery results

Cloud Services Options

- For cloud processing we looked into AWS, Google cloud, Oracle cloud and IBM cloud
- We wanted affordability, ease of use, high performance and online resources and we felt AWS would be right choice



Technical Design Exploration Research: Web App



Frontend

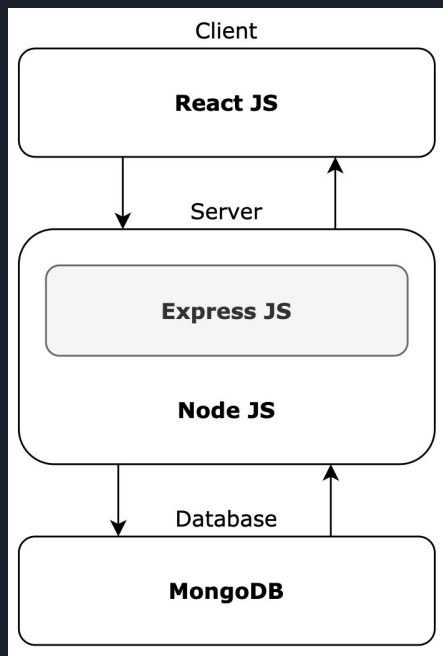
- Among frontend frameworks, the most popular ones are React JS, Angular JS and Vue JS
- We were looking for a suitable framework that would suit the needs of a single page web application, have good documentation with a lot of online resources

Server Side

- The server side options were mainly divided by Python-based web development frameworks (Django and Flask) and Node JS which is a JavaScript-based framework
- We felt it to be more restrictive to use Django as it uses a MTV pattern in website structure and also is designed for relational databases



Technical Design Exploration Research: Web App



Database

- Our other options were PostgreSQL and MySQL databases, which are relational databases
- These are heavily supported databases but we felt it didn't offer the flexibility we needed as it would require us to build the database schema at the start

Deployment

- Besides Heroku, we also considered AWS, an Infrastructure as a Service (IaaS), which means there are many services that can help in almost every situation
- The downside of using AWS is that it is quite complicated to set up and requires someone experienced in development operations to get things going



Feedback considered

Accessibility of Climbs

- Based on the feedback from the climbing gym manager in Duncan, we have focused on embracing the accessibility of climbs for all heights, rather than limiting all climbing styles

Image Augmentation to boost the performance of detection

- Feedback from TAs were considered for increasing the data size and improving the detection result
- Imgaug library in Python was used for multiple processing of images

Motpy for tracking

- For motion tracking we are considering a library called motpy that gives more consistent tracking results



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Climbing's First
Automated Data
Acquisition and
Visualization System

Testing



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Testing





Hardware Tests

Test Description	Expected Outcome	Results
Connectivity to WiFi	The module is able to connect wirelessly to a WiFi network	Tested on various networks, module has 100% connection rate
Connectivity to EC2	The module can convert and upload a 15 minute long chunk of video to the EC2 server in less than 15 minutes with a 2.5Mbps uplink	Transfer completed in under 11 minutes using The Hangout Gym's Wi-Fi
Video Recording Quality	The video recorded by the module should be 720p 15fps, with enough focus to recognize and process height stickers	Manual tests successfully records 720p 15 fps and recognizes 75% stickers placed. Plan on increasing sticker size to raise detection rate
Video Upload Stress Test	Able to record, convert, store and upload for 48 hours of footage	Transfer completed and video was found on EC2, 27.08GB of data



Computer Vision Tests

Test Description	Expected Outcome	Results
Validate rock object detection	Trained model is able to detect rocks from varied, diverse images with an mAP (mean Average Precision) > 0.5	YOLO successfully detected rocks from diverse images with an mAP of around 0.71
Validate correct object detection of hands	Trained model is able to detect hands from varied, diverse images with an mAP (mean Average Precision) > 0.5	Successful detection of hands in YOLO with an mAP of around 0.71
Validate color classification of rocks	Classified rocks from analysed videos match the manual color classifications with no more than 5% error	Successfully classified color rocks with a rate of 95.28%

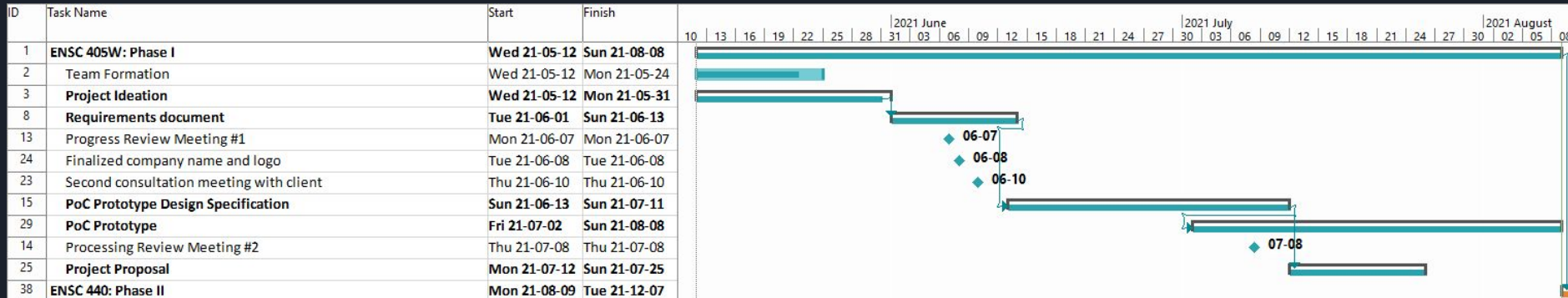


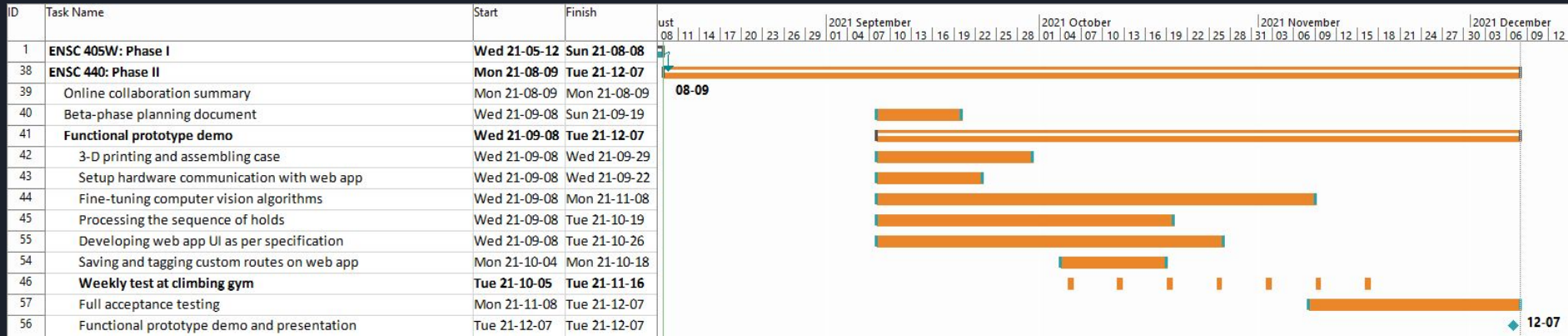
Web App Tests

Test Description	Expected Outcome	Results
Validate UI elements using white box testing	The <code><Card /></code> component can be rendered with or without a title property	<ul style="list-style-type: none">• With the help of testing tools like Jest and Enzyme to render UI components.• We were able to validate that internal elements of React components + methods have the expected output
Manual testing web app behaviour	Each item in the <code><SideNav /></code> component redirects to the corresponding page	<ul style="list-style-type: none">• As a part of the code review process, developers have to provide manual testing instructions that can be performed on a review app to verify functionality.• Found that each stub page was rendered correctly



Project Schedule







Team reflections

- Client and industry focused approach is important
 - As engineers, it is easy to get swayed by technicalities without prioritizing the needs of the client and the industry
 - Being an expert in engineering does not correlate to being an expert in any other field
- Flexibility in team roles
 - On a small team, the absence of a proper hierarchy allows for collaborative work with one another and being flexible in the team's roles
 - Fluid roles allows for redistribution of human resources to meet the immediate demands of the project
- Structured meetings
 - An agenda allows for efficient communication of key items and saves time
 - Action items provide accountability for weekly tasks and maintaining schedule



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Q&A