June 13th, 2021.

Eye-bex

Craig Scratchley
School of Engineering Science,
Simon Fraser University,
Burnaby, BC
V5A 1S6

Re: ENSC 405W Requirement Specifications for Eye-bex by Eye-bex Inc.

Dear Dr. Scratchley,

Please find the requirement specifications document for Eye-bex Inc's first product, Eye-bex. This document was created according to the ENSC 405W's course instructions. The Eye-bex is a route setter's best friend in an indoor climbing gym. It provides significant data about the popularity, reliability, and difficulty of the routes that have been set and are in use by a gym's climbers. It does this through a camera system that uses intelligent computer vision to analyze the climbers and report back to the route setter through a web dashboard.

This document serves the purpose of outlining the requirements that the team has set for the product in an ordered and organized manner. It includes requirements that will be showcased at the proof-of-concept demo as well as the prototype demo in the future. The document consists of hardware, physical, software, economic as well as non-functional requirements and a high-level system overview.

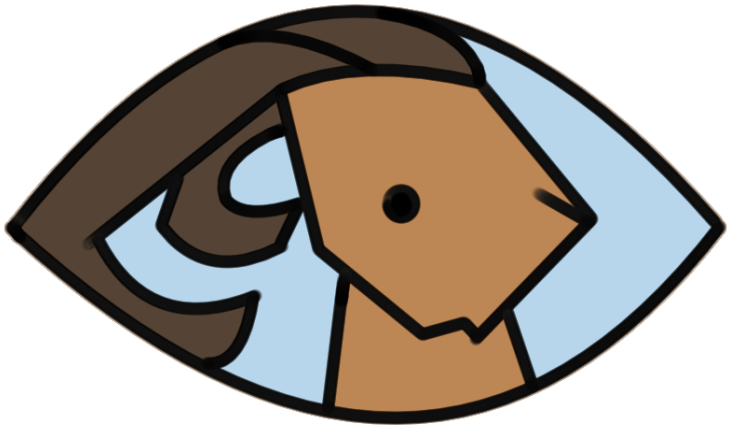
Eye-bex Inc. is a team of 7 engineering students from different disciplines ranging from Computer to Systems Engineering. Our members are Amritha Raj K.R, Arsenen Gervacio, Benjamin Martin, Kay Arellano, Nitish Mallavarapu, Takunda Mwinjilo and Yogesh Mundhra.

Thank you for taking your time to read the Eye-bex requirements specification document. Any questions or comments regarding the document can be sent to our Chief Communication Officer, Yogesh Mundhra at ymundhra@sfu.ca.

Best Regards,

Benjamin Martin

Benjamin Martin,
Chief Executive Officer,
Eye-bex Inc.



EYE-BEX INC.

EYE-BEX REQUIREMENT SPECIFICATION

JUNE 13, 2021

Company 5:

Amritha Raj K.R
Arsenen Gervacio
Benjamin Martin
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Abstract

Indoor rock climbing has become a popular choice of physical activity for people of all ages. Since climbers have varying skill levels and body types, climbing gyms employ route setters who are responsible for building enjoyable yet challenging routes. These routes are usually determined by a route setter's own intuition and expertise which may not be enough to satisfy a diverse group of climbers. To assist route setters with this task, our company will be developing Eye-bex: a camera-based system that utilizes computer vision to track activity in climbing gyms and provide new metrics for route management.

The Eye-bex system can simply be mounted to view the targeted climbing wall and track the movement of a climber and their interaction with certain holds. It can then analyze this data to provide feedback on different routes which gyms can access through our web application that will display the data Eye-bex has processed. The following document will provide our motivation for Eye-bex, a high-level overview of the system and outline the requirements that have been set by our team.

Table of Contents

Changelog

Version number	Description of change	Date made	Made by
1.0	Initial document	13th June 2021	Entire team

List of Figures and Tables

1. Introduction

1.1 Overview

Eye-bex is developing a solution using computer vision to assist climbing gym route setters. Traditionally, route setters have designed routes with no measured data on how routes are utilized by climbers. Although route setters can practice their creativity in designing, their only way to gauge the use of a particular route is either personal experience or observation. Eye-bex presents a solution that can observe the climbers and provide key insight into the response of the climbing community in climbing a route. The feedback enabled using Eye-bex's intelligent computer vision can influence future route setting, providing a new metric for route management based on statistics.

Figure 1: A climber attempting a bouldering route

Rock climbing has grown in popularity around the world, to the extent that it is now an Olympic sport [1]. Though it dates back decades to climbing actual mountains with specialized equipment [2], it has recently been modernized. With the advent of the climbing gym, climbing is done safely indoors regardless of weather conditions and local proximity to mountains. The availability of rock climbing has not only empowered enthusiasts but also created a fitness opportunity accessible to all ability levels. In the past decade, the number of climbing gyms in Canada has tripled while interest in this modern sport continues to grow [3]. With the end of the COVID-19 pandemic in sight, people are looking for physical activities, as well as social activities, and rock climbing is at the intersection of both.

1.2 Background

There are two popular forms of indoor climbing: sport and bouldering. Sport climbing involves high walls that require ropes, harnesses, and other safety equipment, to ascend and descend unharmed. Bouldering has walls low enough that the routes can be climbed without ropes, instead providing a soft mat for climbers to land on when they fall. As an alternative to challenging climbers to possess the endurance to complete a sport route, boulder routes present a shorter but more difficult sequence of moves that encourage creativity. In both forms of indoor climbing, a route is the term used to describe a collection of rock holds members are allowed to use in a specific climb. In indoor climbing the set of climbing holds are marked with a start hold and a finish hold. The challenge to the climber is to traverse from the beginning to the end placing their hands and feet only on the rocks of the route, or the flat wall.

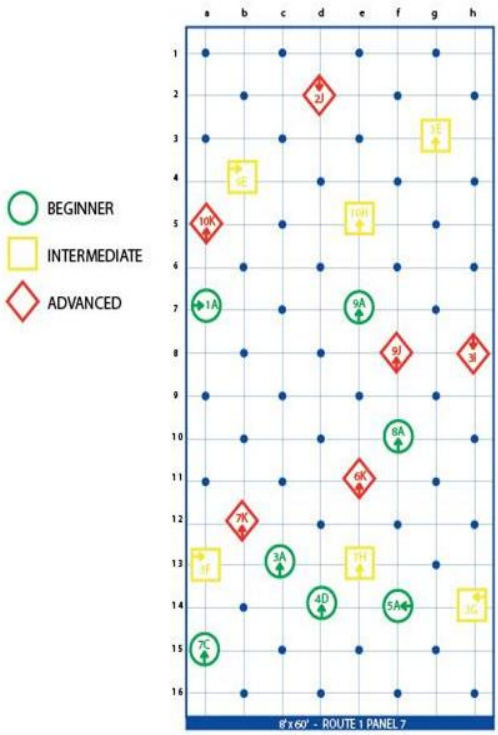

Figure 2: Example of a route setting plan with different route difficulties

To offer challenging yet rewarding climbing experiences to all levels of the community, gyms employ specialists whose job is designing routes. A key aspect of a quality route is that it presents multiple opportunities for climbing by different body types. To design a route for all gym members to participate with is the greatest difficulty a route setter faces. It is essential to the health of the gym that the climbs be accessible for both recreation and competition. One of the main draws of climbing as a fitness activity is the social aspect, and inclusiveness in route design enables sharing the experience of climbing as a group. Inclusiveness also builds a community where members can feel welcome. During competitions, accessibility of climbs is necessary to the fairness of the event.

2. High-Level System Overview

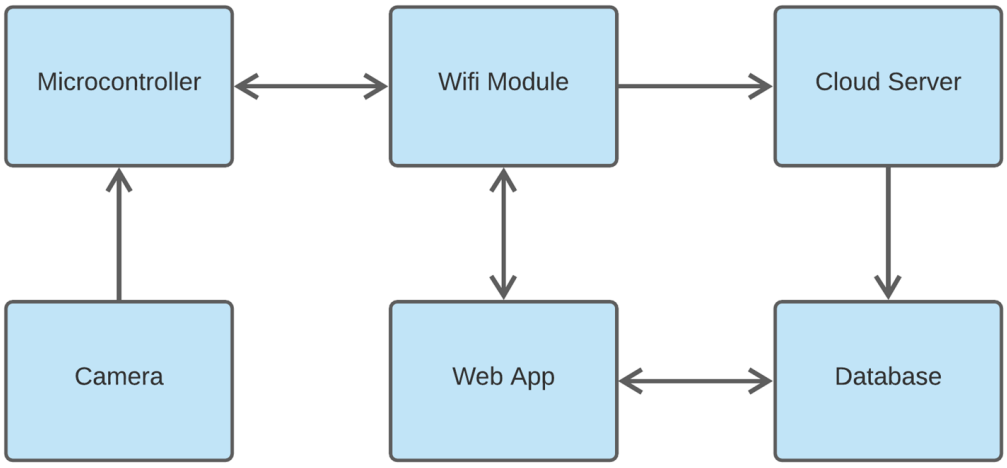

Figure 3: High level system diagram

2.1 Camera

The singular camera will be the only video input to the Eye-bex device. It will have a FOV that covers the entire bouldering wall. The placement of the camera will be adjustable in terms of where it can be mounted and what angle it is pointed at.

2.2 Microcontroller

The microcontroller will be used to provide initial configuration settings for the Wi-Fi network as well as sending status about the Eye-bex device and handling control signals from the web application. The most important job of the microcontroller will be to send the captured frames from the camera to the cloud server.

2.3 Wi-Fi Module

The Wi-Fi module will be attached to the microcontroller, which will allow for network configuration via a serial interface through USB when connected to a PC. It will be responsible for all wireless communication between the Eye-bex device and both the cloud server and web application.

2.4 Cloud Server

Images from the camera will be sent to the cloud server where all computer vision processing happens. This allows for easy scalability and removes any potential memory constraints from doing on-device processing. The cloud server will then store all processed data to the database.

2.5 Web App

The web app will provide a UI for the route setters to view previously processed data about their routes. It will also provide a way to control the actual Eye-bex device itself and see its status. Lastly, since user authentication is required to access the web app, users will also be provided with account management features.

2.6 Database

Tables in the database will include encrypted user authentication information, Eye-bex device information, and processed data. Queries can be made by the web application to retrieve information and display it to the user. Only database administrators from Eye-bex Inc. will have access to the database.

2.7 Requirement Classification Convention

This section outlines the convention used for labelling and numbering specific requirements.

R-**X**.**Y**.**Z**.{**a**}/{**b**}

where the **R** is a constant for all requirements listed and **X**, **Y** and **Z** are used for section, subsection, and sub-subsection, respectively. The letter **a** represents the requirement is intended for the alpha or proof-of-concept. These will be demonstrated at the ENSC 405W demo. The letter **b** is to indicate that the requirement is for the beta or prototype stage.

3. Physical Requirements

The physical requirements detail the tangible aspects of the device and its components. Weight and size were chosen for it to be easily and securely installed with a small footprint on the wall of the climbing gym. Incidentally, the mounting requirements were derived with the size and weight of the device in mind. Although the device would be out of reach of any climbers it needs to function in the environmental conditions of the climbing gym which include high chalk levels, increased humidity, and varying temperatures.

The distance at which the camera captures the wall requires a high-resolution but not high frame rate as climbing is a methodical process and slow-paced. The camera positioning requirements account for the maximum height of bouldering walls to be 20 feet. Given that the device needs no intervention from the user once mounted, we opted for socket/wall power as opposed to battery. A Wi-Fi module provides the versatility to position the device at the gym's convenience. For the robustness of the device, the only accessible outward facing ports are a microUSB port and a barrel jack port for power. This microUSB port is used only to set up the wireless connection when initializing the device. The calibrating stickers need only be identifiable by the device without interfering with climbing.

3.1 Weight and Size

[R-3.1.1.b] - Eye-bex must weigh less than 1 kilogram

[R-3.1.2.b] - Eye-bex casing must be less than 15 cm wide

[R-3.1.3.b] - Eye-bex casing must be less than 15 cm tall

[R-3.1.4.b] - Eye-bex casing must be less than 15 cm deep

3.2 Durability

[R-3.2.1.b] - Eye-bex must operate in the range of 10 - 35 Degrees Celsius

[R-3.2.2.b] - Eye-bex must operate in environments up to 60% humidity

[R-3.2.3.b] - Eye-bex must operate in environments up to 500 µg/m3 of hydrated magnesium carbonate hydroxide (climbing chalk).

[R-3.2.4.b] - Eye-bex must be contained in a single plastic case containing the camera and all necessary circuitry

[R-3.2.5.b] - Eye-bex case must be secured by screws and only opened for repair purposes.

3.3 Camera

[R-3.3.1.a] - Eye-bex's camera must capture colour video

[R-3.3.2.a] - Eye-bex's camera must capture at least 30 fps video

[R-3.3.3.a] - Eye-bex's camera must capture at least 720p definition

[R-3.3.4.a] - Eye-bex's camera must capture video from ground level to 20 feet in height

3.4 Power

[R-3.4.1.b] - Eye-bex must be socket powered or hybrid socket-powered with battery back-up.

[R-3.4.2.b] - Eye-bex's camera must be powered by the microcontroller

[R-3.4.3.a] - Eye-bex must be powered through a barrel jack port

[R-3.4.4.a] - Eye-bex must have a microUSB port to allow for setup to wireless network

3.5 Mounting

[R-3.5.1.b] - Eye-bex must be mountable on walls

[R-3.5.2.b] - Eye-bex must be mountable on ceilings

[R-3.5.3.a] - Eye-bex must be mounted at an angle where all rocks in the field-of-view of the camera are visible

[R-3.5.4.a] - Eye-bex must be mounted such that the camera is in landscape orientation

3.6 Data Storage

[R-3.6.1.a] - Eye-bex must contain an internal microSD port for storage of video and processed data

3.7 Communication

[R-3.7.1.a] - Eye-bex must be able to communicate via USB port with a host computer to change device settings

[R-3.7.2.a] - Eye-bex must have Wifi-5 compatible networking chip

3.8 Calibration Sticker

[R-3.8.1b] - Calibration Sticker must not interfere with climbing

[R-3.8.2b] - Calibration Sticker must cleanly remove from wall

[R-3.8.3b] - Calibration Sticker must be able be clearly distinguishable from rocks

4. Firmware Requirements

The firmware requirements reflect the need for differing security levels during device set-up and user interaction. Since the device has a USB port that is accessible, we would like to ensure robustness.

4.1 Setup & Configuration

[R-4.1.1.a] - Eye-bex must detect when a USB connection is made to a PC

[R-4.1.2.a] - Eye-bex must generate a prompt to configure network settings

4.2 Security

[R-4.1.3.b] - Eye-bex must have different configuration profiles for security

5. Software Requirements

For Eye-bex to be functional it must be able to detect, segment, and track all relevant objects. The image analysis subsection details identification of key events, as well as the necessary statistics to record that satisfy the client's needs, which were obtained through consultation with route setters. Eye-bex's web app has the purpose of conveying all important data in a manner intuitive to users with a simple interface that does not require additional training. The database requirements were chosen carefully to move the storage away from the device and onto a secure cloud.

5.1 Image Capturing

[R-5.1.1.a] - Eye-bex must be able to identify unique climbers

[R-5.1.2.a] - Eye-bex must be able to track unique climbers

[R-5.1.3.a] - Eye-bex must detect hands and feet

[R-5.1.4.a] - Eye-bex must segment hands and feet

[R-5.1.5.a] - Eye-bex must track hands and feet

[R-5.1.6.a] - Eye-bex must detect rocks

[R-5.1.7.a] - Eye-bex must segment rocks

[R-5.1.8.a] - Eye-bex must classify rocks by colour

[R-5.1.9.a] - Eye-bex must identify routes by rock colour

[R-5.1.10.a] - Eye-bex must identify start and finish holds marked by stickers

5.2 Image Analysis

[R-5.2.1.a] - Eye-bex must differentiate between hovering over and hand/foot placement on a rock by seeing if the climber remains within the bounding box of a hold for longer than 2 seconds

[R-5.2.2.a] - Eye-bex must increment the number of attempts on a route when two hands are placed on the starting holding.

[R-5.2.3.a] - Eye-bex must determine a successful attempt when two hands are placed on the final hold for at least one second

[R-5.2.4.a] - Eye-bex must track the number of daily attempts

[R-5.2.5.a] - Eye-bex must track the number of successful daily attempts

[R-5.2.6.a] - Eye-bex must track the order of the rocks used for successful daily attempts

[R-5.2.7.a] - Eye-bex must determine a climber's height

[R-5.2.8.a] - Eye-bex must aggregate data by climber height bins

[R-5.2.9.a] - Eye-bex must have results available by 23:59 PST daily

5.3 Web App

[R-5.3.1.b] - The web app must support authentication

[R-5.3.2.b] - The web app must have account management

[R-5.3.3.a] - The web app must display the climbing wall

[R-5.3.4.a] - The web app must display color-coded routes on the wall

[R-5.3.5.a] - The web app must display aggregated statistics for individual routes

[R-5.3.6.a] - The web app must display the number of daily attempts

[R-5.3.7.a] - The web app must display the number of successful daily attempts

[R-5.3.8.a] - The web app must display the order of the rocks used for successful attempts

[R-5.3.9.a] - The web app must display a spread of climbers' heights for successful attempts

[R-5.3.10.a] - The web app must have a recalibration button

[R-5.3.11.a] - The web app must have controls for system up-time

[R-5.3.12.a] - The web app must be able to display images of previously constructed route

[R-5.3.13.b] - The web app must be able to create custom tags for images of previously constructed routes

[R-5.3.14.b] - The web app must be able to set custom flags on saved images of previously constructed routes

[R-5.3.15.b] - The web app must be able to filter images of previously constructed routes by custom tags

[R-5.3.16.a] - The web app must provide feedback on recording status

[R-5.3.17.a] - The web app must provide feedback on data processing status

5.4 Communication

[R-5.4.1.a] - Eye-bex must be able to communicate via USB with an application protocol to change device's wireless connection settings

[R-5.4.2.a] - Eye-bex must be able to communicate with the web UI via a network protocol

5.5 Database

[R-5.5.1.b] - The database must be large enough to support all Eye-bex units

[R-5.5.2.a] - The database must store all processed route data

[R-5.5.3.a] - All data in database must be timestamped

[R-5.5.4.b] - All data must contain identifier of device which collected the data

[R-5.5.5.b] - The database must be normalized to at least 2NF

[R-5.5.6.a] - The database must store previously constructed routes by photograph

[R-5.5.7.b] - The database must store encrypted user credential information↡

6. Economic Requirements

For Eye-bex to be successful it must be affordable for our target market. Below are requirements centered around the economic aspects of Eye-bex including a targeted price range and expected lifespan of the device.

6.1 Sale Price

[R-6.1.1] - Eye-bex must be sellable for less than $1500

6.2 Life Expectancy

[R-6.2.1] - Eye-bex must have a minimum life expectancy of 3 years

7. Non-Functional Requirements

Below are the non-functional requirements for Eye-bex to enhance our customers' experience. These requirements focus on the overall operation of our system as a whole rather than the specific functionality of our system.

7.1 Usability

[R-7.1.1.a] - The web app must have intuitive UI for accessibility

[R-7.1.2.a] - Eye-bex must be physically installable in under 45 minutes

[R-7.1.3.a] - Eye-bex’s net must be configurable in under 10 minutes

7.2 Security

[R-7.2.1.b] - The web app must only work for valid login credentials

[R-7.2.2.b] - Eye-bex must include an associated username and password for each unit

7.3 Portability

[R-7.3.1.a] - The web app must work on Google Chrome

[R-7.3.2.a] - The web app must work on Firefox

[R-7.3.3.a] - The web app must work on Safari

[R-7.3.4.a] - The web app must work on Microsoft Edge

7.4 Performance

[R-7.4.1.a] - The web app must respond to a query for displaying UI components within 500 ms

[R-7.4.2.a] - The web app queries to database should be within 500ms

[R-7.4.3.a] - The web app must display statistics within 3 seconds

[R-7.4.4.a] - Device should have at least 16GB of onboard storage

[R-7.4.5.b] - Device should be able to automatically restart software after power outage

8. Engineering Standards

Keeping in line with standards is key to any product, Eye-bex included. Eye-bex will be following the standards set by CSA, IEEE, and ISO. Below are the specific standards for our software and electrical components the Eye-bex must follow.

8.1 Software Standards

CAN/CSA-ISO/IEC/IEEE 12207:18 - Framework for software life cycle processes [4]

CAN/CSA-ISO/IEC 26557:18 - Tools and methods of variability mechanisms for software and system [5]

ISO/IEC TR 12182:2015 - Systems and software engineering - Framework of categorization of IT systems and software, and guide for applying it [6]

IEEE/ISO/IEC 14764-2006 - ISO - Software Life Cycle Processes Maintenance [7]

IEEE/ISO/IEC 23026-2015 - Systems and software engineering - Engineering and management of websites for systems, software, and services information[8]

8.2 Electrical Standards

CSA C22.1-18 - Canadian Electrical Code, Part I safety Standard for Electrical installations [9]

9. Sustainability and Safety

9.1 Sustainability

We are aiming to have Eye-bex be sustainable and eco-friendly; To do so we aim to follow a Cradle-to-Cradle design. We want the materials we use to be recyclable as shown in Table 2 below. To further reduce the footprint of our product we will also take extra considerations in how it should be built such as having replaceable parts and allowing for down time to reduce the amount of power it uses.

Part/Component	Material	Method of Disposal
Camera	Electronics	Electronics recycling program
Microcontroller	Electronics	Electronics recycling program
Mount	Metal	Municipal recycling program
Casing	Plastic	Municipal recycling program
Battery	Alkaline	Electronics recycling program

Table 1: Part Material Composition and Method of Disposal

9.2 Sustainability Requirements

[R-9.2.1.b] - Eye-bex must have an efficient life cycle

[R-9.2.2.b] - Eye-bex must have replaceable parts

[R-9.2.3.b] - Eye-bex must allow for variable operating time to save power

9.3 Safety

[R-9.3.1.a] - The case of the product must not contain sharp edges to avoid injury

[R-9.3.2.a] - Eye-bex must not exceed 35 degrees Celsius

[R-9.3.3.a] - The operating voltage of the Eye-bex must not exceed 5 V

[R-9.3.4.a] - Eye-bex must produce noise less than 70dB

[R-9.3.5.a] - Eye-bex must have no exposed wiring

10. Test Plan

Due to the use of computer-vision, many of the tests will need to be supervised or conducted by human testers. Should reliable standards for testing be identified, these acceptance tests will be automated using the following standards.

Purpose	**Test Description**	**Acceptance Criteria**
Validate Physical measurements	Measure each of the physical properties (height, width, depth, weight, etc.)	Device should be meet physical requirements up to 10% error of the expected values
Validate correct segmentation of hands	Provide 10 standard videos of multi-ethnic climbers for 5 seconds of climb, ad check that hands and feet are segmented correctly	Compare with both eye-tracking as well as potentially using existing tested segmentation algorithms to ensure all hands and feet are correctly segmented
Validate rock segmentation from video	Provide 5 standard videos of climbing walls of increasing rock numbers. First 5 seconds are unobstructed, then the next 5 seconds are obstructed. See if software correctly identifies rocks throughout video	Compare with both eye-tracking as well as potentially using and existing tested segmentation algorithms to ensure all rocks on the wall are correctly segmented
Validate color classification of rocks	Provide 10 standard videos of climbing walls of increasing rock numbers. First 5 seconds are unobstructed, then the next 5 seconds are obstructed. See if software correctly classifies routes by their color	Compare classified results with known route patterns for each video. No more than 5% of rocks should be misclassified

Validate Hand and feet tracking for climbers	Provide 10 standard videos of multi-ethnic climbers for 5 seconds of climb, ad check that hands and feet are tracked correctly throughout video	Use eye-tracking to confirm each hand and foot is successfully being tracked through video
Validate data transfer to WebUI	Use automated tests to provide standard data sets to software to transfer to WebUI. Ensure WebUI receives data when network connection is stable	The automated test passes successfully under or within a 10% error of the expected latency for the connection speed
Validate WebUI UI elements	Run automated UI tests on all elements to ensure they are performing as expected within the specified latency	UI test passes on each UI element under or within a 10% error of the specified latency
Validate Querying speed	Run automated tests to run 10 queries of a dummy database of expected Beta size. Check to see that all queries return the correct data within the required latency	Automated test passes on each query under or within a 10% error of the specified latency
Validate Statistics representations	Use automated test to provide sets of raw data to with known statistics output and ascertain statistics are calculated correctly	Ensure all statistics are calculated within a 5% error of the expected values

Table 2: High Level Acceptance Test Plan for Proof of Concept

11. Conclusion

With Eye-bex, our company will assist climbing gyms in recognizing new metrics for route management using a data driven approach. Backed by computer vision, Eye-bex is a tool that can be added to a route setter's workflow to gain insight in how well climbers interact with climbing routes. This can be done by monitoring hand and feet placement on certain holds, recording the number of daily attempts and more. To set up Eye-bex for success, our company defined requirement specifications which address different aspects of our product. While stating the hardware, firmware, and software requirements of Eye-bex, we also define the non-functional requirements that pertain to the qualities of our system. We also share the engineering standards that our company will uphold which combined with the test plan provided, allows us to describe the best practices for engineering excellence. Additionally, we set sustainability and safety requirements to minimize our environmental footprint as well as ensure that users of Eye-bex are protected from possible harm. To further classify our deliverables, we specify the completion of each requirement either in the alpha phase or the beta phase, which ends in August 2021 and December 2021, respectively.

12. Glossary

2NF: Second Normal Form

Attempt: An event where a user places both hands on the start hold with their feet on the wall.

Bounding box: an imaginary rectangle that serves as a point of reference for object detection and creates a collision region for that object.

Cheating: Skipping or avoiding the difficult section of the route against the intentions of the setter.

Classification: The process of predicting a specific class, or label, for something that is defined by a set of data points.

Cradle-to-Cradle: A design standard used to measure sustainability, focusing on recycling and circular economy.

PC: Personal Computer

PST: Pacific Standard Time

Route: A collection of rock holds that form a challenge for members to traverse from a designated starting hold to a designated finish hold using only the rocks in that collection. Modern routes are typically designated a color to distinguish them from one another.

Route Setter: An employee of a climbing gym responsible for setting new routes.

Segmentation: The process of dividing an image into different regions based on the characteristics of pixels to identify objects or boundaries.

Serial Interface: Acts as a communication interface between two digital systems that sends data over a wire

Successful Attempt: An attempt that ends with the user placing both hands on the finish hold for at least one second.

USB: Universal Serial Bus

13. References

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