Phase 2 Report: Design Review

Sports Vision Pro
Team #13

A Report
Presented to
The Department of Electrical & Computer Engineering
Concordia University

In Partial Fulfillment
of the Requirements
of ELEC/COEN 490

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ABSTRACT

"Sports Vision Pro" leverages cutting-edge wearable technology to enhance hockey fans' experience and improve player safety. This system integrates a lightweight helmet-mounted camera and sensors to provide a real-time first-person view of the game, alongside player biometrics like heart rate and position tracking. The live data is processed and broadcast through a VR or smartphone app, offering audiences an immersive perspective complete with a HUD displaying player metrics. Prioritizing player safety, the device monitors high-impact collisions and stress levels, alerting medical teams when necessary. Combining robust engineering with innovative design, this project bridges the gap between sports technology and audience engagement while ensuring player well-being. This report covers the reviewed design documentation for the project at the end of Phase 2 of the Capstone process.

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1.0 - DESIGN SPECIFICATIONS REVIEW

1.1 - Updated Objectives

Problems being addressed:

[P1] Hockey player health monitoring and safety

[P2] Hockey player performance data collection and statistics

[P3] New immersive experience for fans from hockey player's POV

Goals:

[G1] Stream a live audio-visual feed from hockey players' POV

[G2] Measure hockey player velocity and acceleration metrics throughout the game

[G3] Track player position and movement throughout the game

[G4] Show hockey player stress levels using heart rate analysis throughout the game

[G5] Develop an application for VR goggles and/or smartphone showing the player livestream with HUD including player metrics

Deliverables:

[D1] Helmet system with a camera and microphone for live feed of player POV, sensors for player biomonitoring transmitting by WIFI, and position tracking system.

[D2] Computer server application that stores the data and live stream from the helmet system and broadcasts it to the end user

[D3] VR goggle and/or smartphone application for viewing the player's livestream and data

1.2 - Updated Functions

Helmet System:

The helmet system will be a device that can be strapped onto the helmet of the hockey player. It will include a central microcontroller for acquiring, processing, and transmitting player data to a remote server. The helmet system will also include: a camera and microphone for the live stream to show the hockey game from the player's point-of-view; an IMU for measuring the player speed and acceleration for performance monitoring and detecting sudden harmful collisions or impacts; a heart rate sensor to quantify the player's stress levels and excitement; a radio frequency transmitter for detecting the player position using time-of-flight trilateration techniques and several base stations placed around the hockey rink; and a WiFi module so that the helmet system can transmit all this data to a server for storage and broadcasting to the end user.

Computer Server:

The server running on a nearby computer will be an application capable of saving the incoming data from the helmet device as well as broadcasting it live to the end user. It will combine the audio and visual input into a live stream along with a Heads-Up-Display (HUD) overlay that gives details about the player speed/acceleration, stress levels according to their heart rate, and a mini-map with their current position on the rink using data from the trilateration.

VR Goggles/Smartphone App:

This application is for the end user, who will be able to view the livestream of the hockey player's POV from the server with the HUD showing the player's performance metrics and the minimap with the player position. The app will allow the user to select from available players to spectate, and bonus features could include on-demand replays of exciting plays during the game.

1.3 - Updated Requirements

1.3.1 - Functional Requirements

[FR-01]	Live stream video feed from a helmet camera to a server
[FR-02]	Live stream audio feed from a helmet microphone to a server
[FR-03]	Measure acceleration and velocity of hockey player and transmit it to a server
[FR-04]	Track player position and transmit it to a server
[FR-05]	Measure player heart rate and transmit it to a server
[FR-06]	Server stores recording of live audio-video stream
[FR-07]	Server stores player acceleration, velocity, position, and heart rate
[FR-08]	Server assesses player stress levels
[FR-09]	Server overlays player metrics and stress levels onto live audio-visual feed
[FR-10]	Server broadcasts live feed with overlay to the end user

1.3.2 - Non-Functional Requirements

[NFR-01]	Helmet should be CSA-certified and not expired
[NFR-02]	Helmet system is resistance to impact shocks
[NFR-03]	Helmet system is waterproof
[NFR-04]	Helmet system is not too big or heavy
[NFR-05]	Helmet system is easy to setup and use
[NFR-06]	Helmet system is comfortable for the player
[NFR-07]	Helmet system has a button to turn device on/off
[NFR-08]	Helmet system Button to turn streaming on/off for player privacy
[NFR-09]	Live stream should be viewable using VR goggles and/or smartphone app

1.4 - Updated Design Specifications

Based on the customer's needs and environmental constraints, we have listed the following parameters to be addressed in consideration of our project design.

Table 1: Customer Specifications (revised)

#	Description/ Parameter	Test Conditions	Value			Unit
			Min	Typical	Max	
1	Work in a hockey rink **temperature** environment	Indoor Hockey Rink	-12		50	Celcius (°C)
2	Work in a hockey rink **humidity** environment	Indoor Hockey Rink			70	Percent (%)
3	Transmission Range	(1)	65			Radius (m)
4	Video Resolution	any	1280x720			Pixels (p)
5	Framerate	(1)	30	60		Frames per second (fps)
6	Latency	(1)			200	Milliseconds (ms)
7	Shock tolerance that won't damage the device	< 1.0 ms			20	Acceleration (g)
8	Continuous Operating Time	(1)	180			Minutes (min)
9	Mass	(1)			200	Gram (g)
10	Location tracking accuracy	(1)			2	Meter (m)
11	Vital accuracy (Heart rate)	(1)			25	% error
12	Rotation Sensing	(1)	15			% error
13	Acceleration sensing	(1)	15			% error

The difference between customer specification and final design specification is to show what the achievable value and parameters the design can achieve while respecting the given constraints including time, budget, and physical limitations. Then the comment section explains the reason why value modification is made and approval for the change from customers.

Table 2: Final Design Specifications (revised)

#	Description/ Parameter	Test Conditions	Value			Unit	Comment
			Min	Typical	Max		
1	Temperature (Ambient)	Indoor Hockey Rink	-12		50	Celcius (°C)	
2	Ingress Protection	(1)	6/6			IPX/Y	This level of protection meets humidity specification
3	Transmission Range	(2)	65			Meter (m)	It is achievable by placing several receiver modules on the edge of the rink
4	Video Resolution	(1)	800x600			Pixels (p)	To test the system concept, the initial design will be based on low resolution camera. If the system worked, the design would go back to 1280x720.
5	Framerate	(1)	20			Frames per second (fps)	To test the system concept, the initial design will be based on low frame rate camera. If the system worked, the design would go back to 30 fps.
6	Latency	(1)			400	Milliseconds (ms)	The range may affect

							the video transmission latency, a higher bar will help to investigate how the distance affects latency.
7	Shock tolerance that won't damage the device	< 1.0 to 5.0 ms				20	Corrected approximate range at which players can receive impact
8	Continuous Operating Time	(1)	180 Or 300			Minutes (min)	This is about power requirement, the system will work on a 5V system, and an appropriate battery and power supply module will be chosen. And the device may have several states, here we assume idle state and normal operational state.
9	Mass	(1)			250	Gram (g)	Battery weight must count in the design
10	Location tracking accuracy	(1)			2	Meter (m)	
11	Vital accuracy (Heart rate)	(1)			25	% error	
12	Rotation Sensing	(1)	15			% error	
13	Acceleration sensing	(1)	15			% error	

Normal Test Conditions:

1) Testing should occur at standard indoor sports facility temperatures, around 20-22°C with 60-70% humidity, with moderate noise levels and radiation levels, and less than 2 meter change in height and altitude.
2) IP is based on the presence of ice shavings from skating activity, droplets of water from melting ice, sweat generated by players, and exposure to liquid splashes during typical celebration, the helmet must be tested for water ingress of these real world scenarios.
3) Continuous operating time is based on typical processing rate, MCU temperature, communication range, framerate, data rate, battery efficiency of our chosen design.
4) Dimensions are based on NHL regulations as per International Ice Hockey Federation (IIHF) Standards. Variations may apply for non-NHL venues.
5) Based on common vapor barrier materials, insulation materials, and other building materials used to build roofs. Variations may apply for different venues.

Progress Update

To implement position tracking for our system, we used signal strength (RSSI: Received signal strength indicator) and signal triangulation methods in one dimension by using 2 esp32, Raspberry Pi, and a Wi-Fi router developing board. Figure 2 illustrates the conceptual approach.

System Overview

Beacons and Player Node: A minimum of three beacons (Beacon 1, Beacon 2, and Beacon 3) are strategically placed around the wifi router.

Distance Calculation:

Using RSSI, the system converts the signal strength to distances.

Trilateration: With the known coordinates of the three beacons and calculated distances for calibration, the final position of the player is determined by solving a system of linear equations.

Testing Results are shown in figure 0.

Procedure:

Signals were sent from the Raspberry Pi to the ESP32 devices to simulate distance measurements.

Basic trilateration was implemented to calculate the position of the simulated "player."

Outcome:

The test successfully demonstrated that trilateration could estimate the position of a moving object within an indoor hockey rink.

Limitations: While the system concept worked, it meets the specified 2-meter accuracy requirement. The error is +/-1.5 meters, and we did not have enough distance to make more measurements on the same floor since we were heading to different rooms with different paths of loss values.

The following photos show the code and measurement reading from a computer.

The other progress is listed in the design review, more specifically, triangulation position system principle explanation, and the sub-system flow for different components.

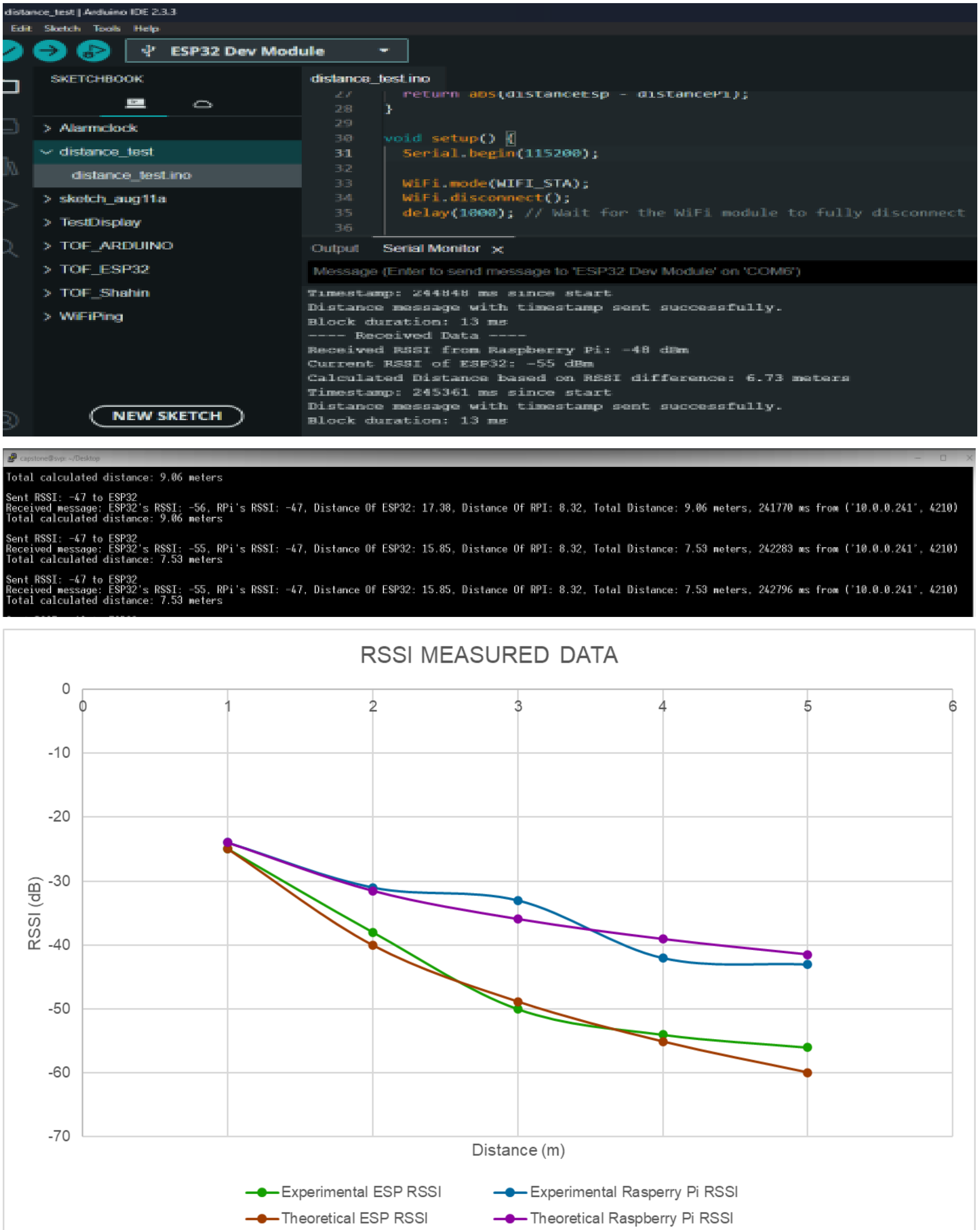


Fig 0: Using RSSI and triangulation positioning method to measure distances.

2.0 - DESIGN REVIEW

2.1 - System Block Diagram

Block Diagram of the Helmet System:

The following block diagram in *Fig 1* represents the components of the Helmet system. There are several input sensors including the camera, microphone, Inertial Measurement Unit, and heart rate sensor which gather data on the player. The RF transceiver module will be used to send pulses to beacons located around the hockey rink to use signal trilateration and time-of-flight techniques to implement the player position tracking (see next page for trilateration diagram). All data collected by the sensors will be processed by the microcontroller and transmitted to a computer server through WIFI, and the server will both store the data and broadcast the live stream to the end user application.

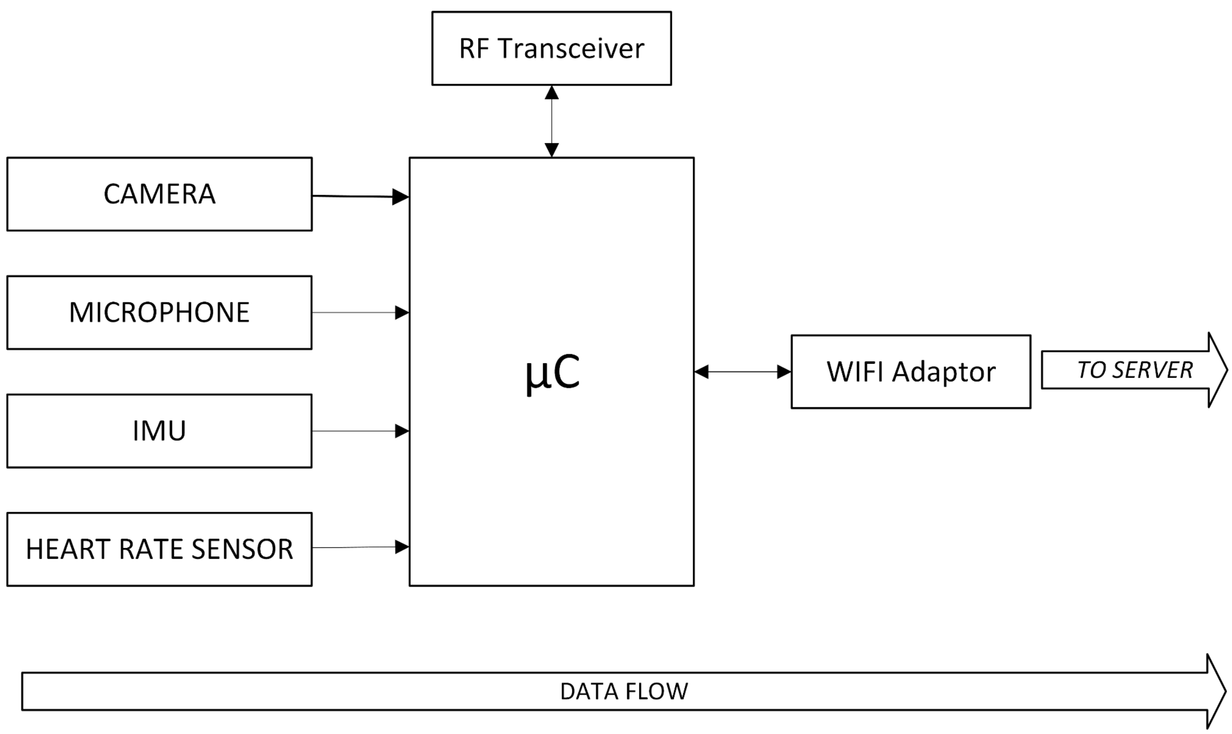


Fig 1: Block diagram of the Helmet System.

Position Tracking using Trilateration Technique:

Position tracking for our system will be implemented using time-of-flight and signal trilateration. *Fig 2* below shows how this process will work. A minimum of three beacons will be placed around the hockey rink (represented by the filled circles). Next, the helmet system of a player (yellow triangle) will send out pulses and calculate R1, R2, and R3 from each beacon by converting the time-of-flight of the pulse into a distance measurement. Once the distances R1, R2, and R3 are obtained, the player is somewhere along the circles of the respective radii, and by using the known position of each of the beacons and solving the system of linear equations the final position of the player can be determined.

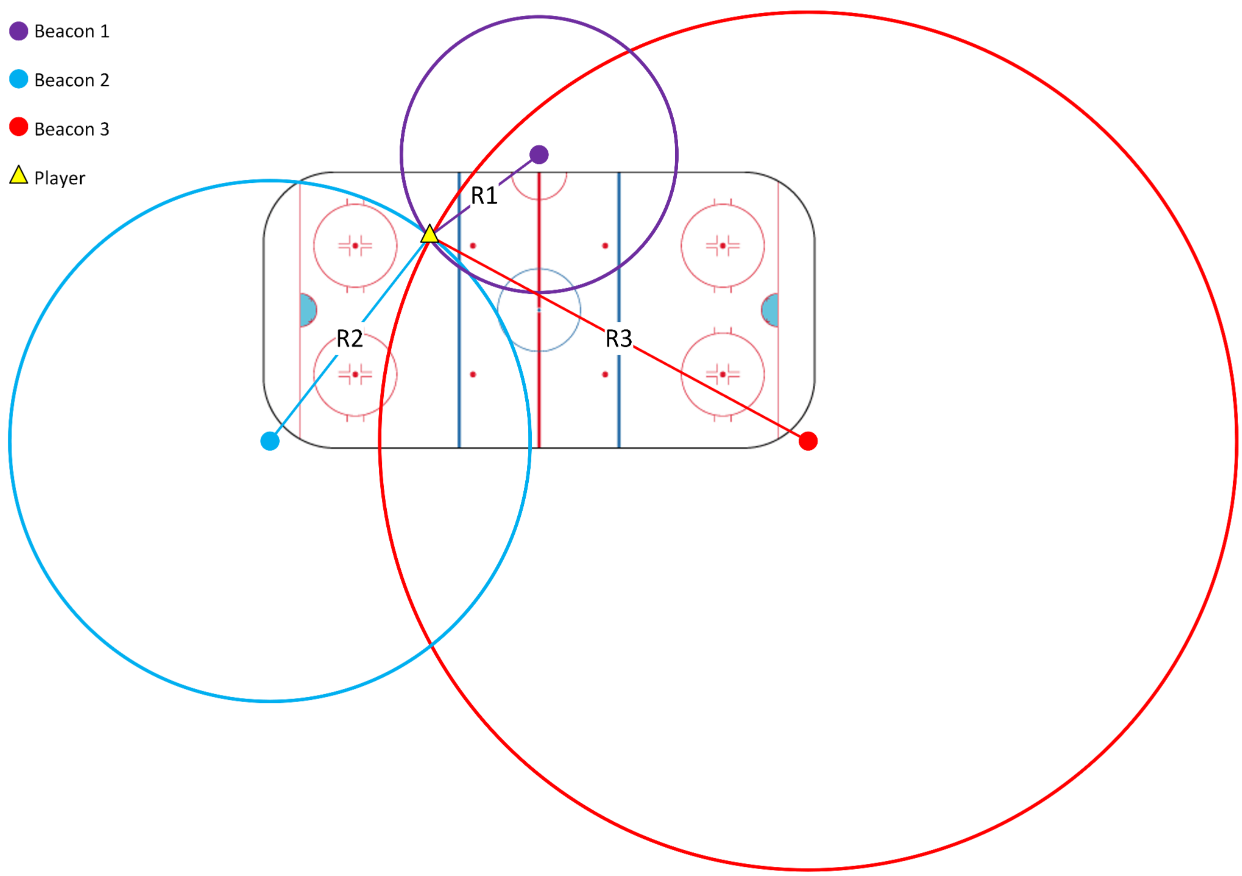


Fig 2: Position tracking using signal trilateration.

2.2 Flowcharts of the Design

<u>Video and Audio Acquisition:</u>

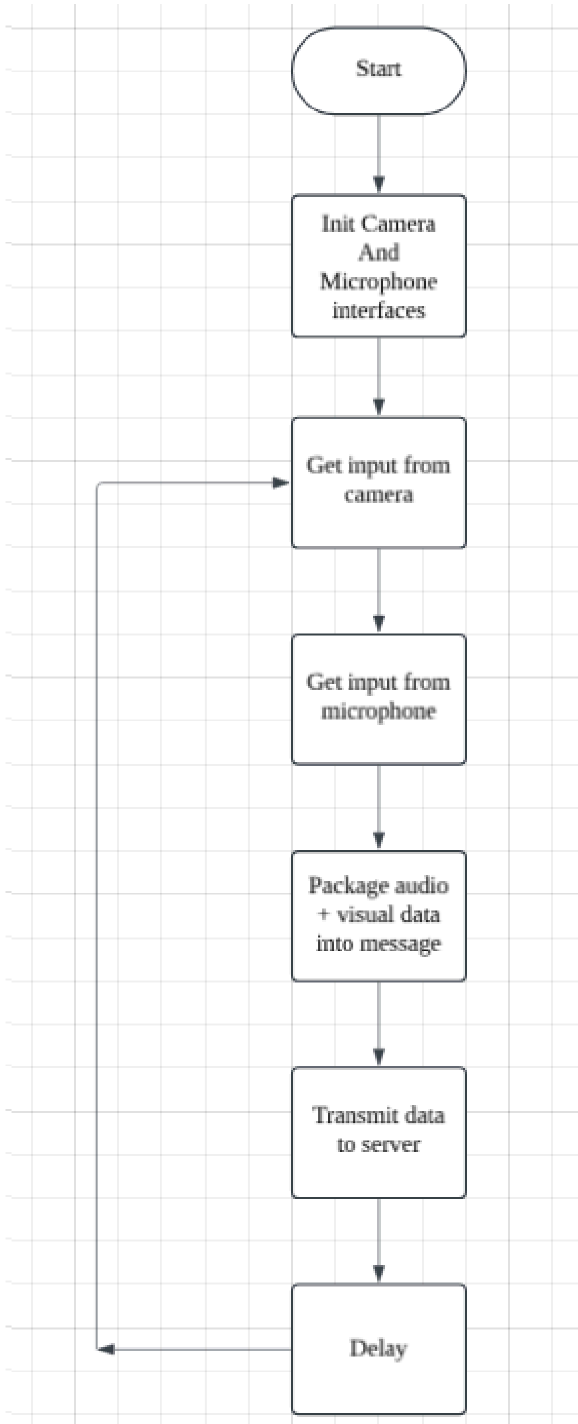
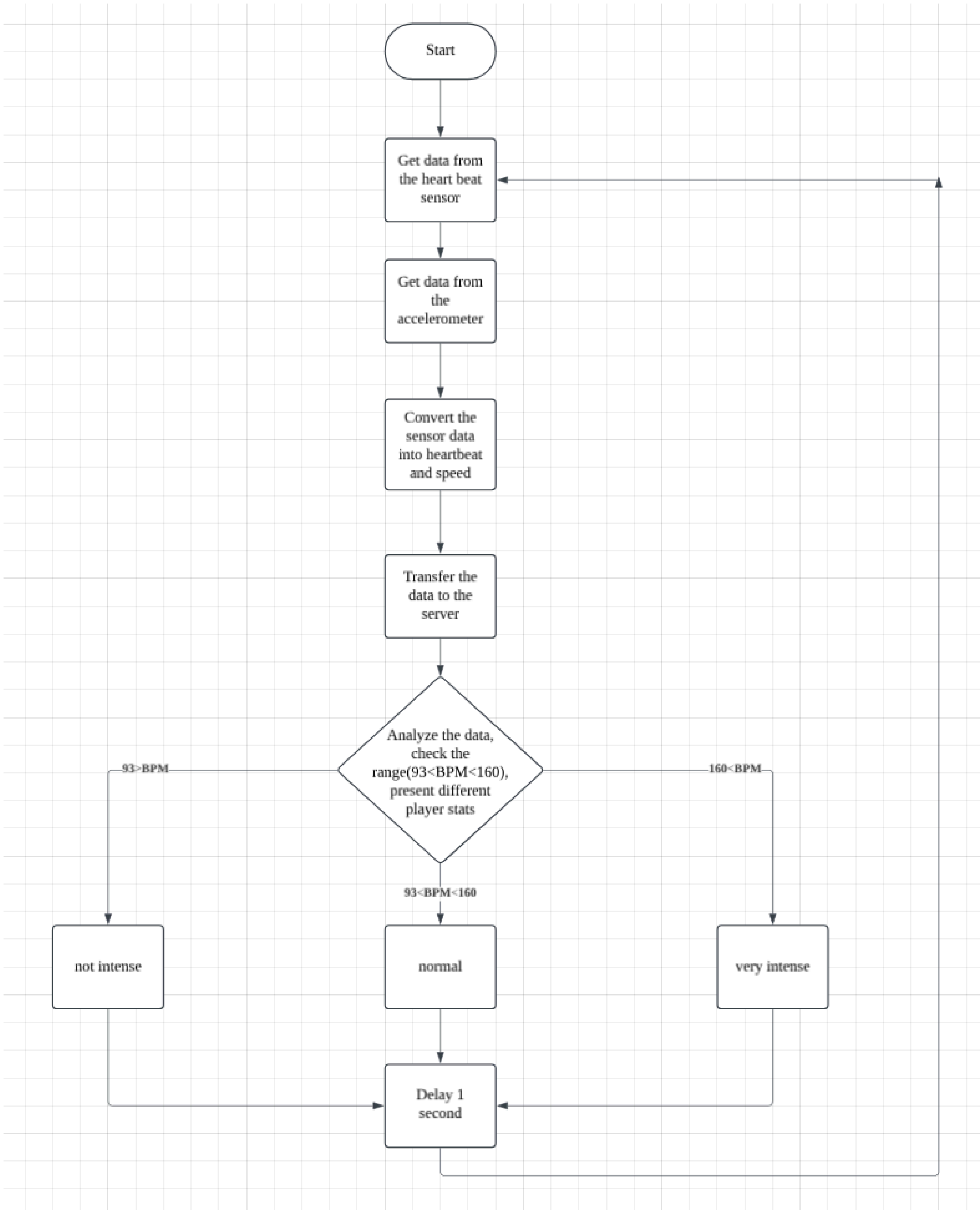


Fig 3: Flowchart V/A

Heart Rate and IMU Sensors Acquisition:



Trilateration Positioning System:

3.0 - ALTERNATIVES

For this project, considering the hockey stadium's dimensions :

NHL (National Hockey League) Standard:

-Rink Size: 200 feet (61 meters) long x 85 feet (26 meters) wide.

-Corner Radius: 28 feet (8.5 meters).

-Area: Approximately 17,000 square feet (1,580 square meters).

-Seating Capacity: Typically between 15,000 to 20,000 audiences.

IIHF (International Ice Hockey Federation) Standard:

-Rink Size: 197 feet (60 meters) long x 98.4 feet (30 meters) wide.

-Corner Radius: 28 feet (8.5 meters).

-Area: Approximately 18,000 square feet (1,670 square meters).

-Seating Capacity: Typically between 10,000 to 18,000 audiences.

The main signal transmission method we have chosen for this project is via wifi through a wireless adapter. However, there are many alternative solutions for position tracking systems.

For Triangulation:

1: *least important* **- 5:** *most important*

Table 3: Triangulation alternatives

Methods of Triangulation	Frequency Range	Distance	Bandwidth	RSSI	Cost	Total
Weights:	4	5	3	2	3	
GPS	1.1 – 1.6 GHz Score: 3	- Global coverage. -Accuracy depends on receiver capability and environmental factors. Score: 5	-24 MHz -22 MHz -25 MHz Score :1	Indoors: -125 to -100 dBm (weak) Outdoors: -70 to -50 dBm (strong) Score: 2	-Low to moderate ($50–$200 for receivers). Score: 3	53
UWB 1000	6.5 – 8 GHz Score: 5	-Indoor: 10–30 meters (33–98 feet). -Outdoor: Up to 200 meters (656 feet). Score :4	-Up to 27 Mbps. Score :4	-70 to -50 dBm in short-range indoor applications Score :5	-Moderate to high ($100–$300 for modules). Score: 2	68
WiFi Wireless Adapter	2.4 – 2.5 GHz Score :3	-Indoors: 45 meters (150 feet). -Outdoors: Up to 90 meters (300 feet). Score: 3	-25 Mbps (single stream). Score :4	-Indoors: Typically -70 to -50 dBm. Score: 3	-Low to moderate ($50–$200). Score: 3	54
Infrared (IR)	-300 GHz to 430 THz Score: 5	- Indoors: Up to 30 meters (98 feet). Score : 4	Not applicable	Not applicable	Low to moderate ($50–$200 per setup). Score: 3	Not applicable

From the total score, the best option would be the UWB1000 for triangulation estimation.

Score explanation:

Frequency range:

UWB-1000 (6.5 - 8 GHz) - Score: 5

Reason:

-Provides high level of accuracy for tracking fast-moving players and pucks.

-Works excellently in enclosed arena settings with metal structures and seating.

-Can track multiple players simultaneously with minimal interference.

GPS (0.1 - 1.6 GHz) - Score: 3

Reason:

-Signal strength significantly weakens inside the arena structure.

-Limited accuracy indoors makes it secondary to UWB.

-Signal reception may be inconsistent with metal roof structures.

WiFi Wireless Adapter (2.4 - 2.5 GHz) - Score: 3

Reason:

-The 2.4 GHz band faces interference from spectators' devices .

-Signal reflection from metal structures and ice surfaces creates multipath issues.

-Not fast enough to track high-speed plays accurately.

Distance:

GPS - Score: 5

Reason:

-Global coverage ensures continuous positioning reference.

-Provides absolute positioning across the entire 60m × 30m rink area.

-Important for integrated tracking systems between multiple venues.

-Serves as a reliable backup system.

UWB-1000 - Score: 4

Reason:

-Indoor range of 10-30m requires careful sensor placement.

-Multiple sensors needed to cover 60m length.

-Range adequate for precise positioning within the play area.

WiFi Wireless Adapter - Score: 3

Reason:

-Single access point can theoretically cover most of the rink.

-However, effective range reduced by:

+Dense crowd of 10,000-18,000 people.

+Metal structures and ice surface interference.

Bandwidth:

UWB-1000 (Up to 27 Mbps) - Score: 4

Reason:

-Can handle high-frequency position updates for fast-moving players (skating speeds)

-Sufficient for tracking multiple players simultaneously on the 60m × 30m rink

-Supports additional data like player acceleration, direction changes.

-Bandwidth allows for:

+Real-time position updates

+Multiple sensor data integration

+Low latency tracking essential for sports analytics

WiFi Adapter (25 Mbps single stream) - Score: 4

Reason:

-Good capacity for multiple device tracking.

-Sufficient for basic position data transmission.

-Can handle player tracking data across the 1,670 square meters.

-However:

+Shared bandwidth with spectator devices.

+May experience congestion in crowded arena.

GPS (24/22/25 MHz) - Score: 1

Reason:

-Lower bandwidth but still functional.

-Sufficient for basic positioning data.

-Limited by:

+Lower update rates.

+Less precise for rapid movements.

+Cannot handle high-frequency position updates.

RSSI (Received Signal Strength Indicator) :

UWB-1000 (6.5 - 8 GHz) - Score: 5 (Highest)

Reason:

-Optimal RSSI range for indoor arena environment.

-Strong and consistent signal strength (-50 dBm) perfect for precise tracking.

-Signal strength maintains well across the 60m × 30m rink because less affected by:

Metal structures in the arena

Ice surface reflections

Dense crowd interference

-Provides reliable tracking even in:

High-traffic zones

Player collision situations

<u>WiFi Adapter (25 Mbps single stream) - Score: 3</u>

Reason:

-Similar RSSI range to UWB but with limitations:

-Good signal strength for basic tracking

-However, signal quality affected by:

Huge amount of spectators' devices (if too many audiences) and it may cause network congestion and interference from other WiFi networks

-Signal strength varies more across the 1,670 square meters. It may need multiple access points for consistent coverage.

<u>GPS (24/22/25 MHz) - Score: 2</u>

Reason:

-Significantly weakened indoor signal:

-Very poor indoor signal strength (-125 dBm)

-Major limitations in arena environment:

Signal severely attenuated by building structure

Unreliable for precise tracking

Insufficient for professional sports applications

Cost:

GPS (24/22/25 MHz) - Score: 3

Reason:

-Cost considerations

-Relatively affordable per unit

-Established technology

-Multiple receivers needed for indoor coverage

Additional costs for:

Signal amplifiers for indoor use

Integration hardware

Installation throughout the 1,670 square meter arena

Low maintenance costs in long term

Readily available replacement parts

WiFi Adapter (25 Mbps single stream) - Score: 3

Reason:

-Similar cost range but different considerations:

-Multiple access points needed for full coverage

-Infrastructure costs include:

Network switches

Cabling

Backend servers

-Dual-use benefits:

Can serve spectator internet needs

Supports venue operations

Integrates with existing systems

Shared infrastructure reduces effective cost

<u>UWB-1000 (6.5 - 8 GHz) - Score: 2</u>

Reason:

-Higher unit cost but justified by:

-Superior indoor performance

-Additional costs include:

Mounting hardware

Calibration equipment

Professional installation

Summary:

For precision and low latency, UWB1000 remains the top choice for tracking players and pucks. Infrared offers high accuracy for short-range tracking but requires line-of-sight and careful setup. WiFi provides broader coverage and cost efficiency, making it a practical alternative. GPS is unsuitable for indoor use but could complement other methods for outdoor auxiliary tracking.

Table 4: Batteries alternatives

Battery	Capacity	Power	Life	Temperature	Efficiency	Cost	Total Score
Weight	2	3	4	3	3	4	95
Lithium Iron Phosphate (LiFePO4)	-Energy density of 90–160 Wh/kg. (long-term usage) Score: 4	-3.2V nominal for a single cell. -6.4V for two cells. Score: 2	-2,000 to 5,000 charge cycles. Score: 4	-From -20°C to 60°C. Score: 5	-High efficiency (~90%) Score: 4	High: From $20 to $100 per cell Score: 1	61
Supercapacitors	5–10 Wh/kg (for short bursts of power) Score: 1	-high output (5V–12V) Score: 4	-Unlimited charge and discharge cycles. Score: 5	-From-40°C and up to 65°C. Score: 5	-Extremely high (~98%) Score : 5	Moderate: $10 to $30 per module. Score: 2	72
Solid-State Batteries	-300–500 Wh/kg. Score : 5	-3.7V–7.4 V nominal Score: 4	-2,000 to 5,000 charge cycles. Score: 4	-From-30°C to 60°C. Score :5	-Extremely high (~98%) Score :5	High: $100 to $500 per cell. Score: 1	72
Nickel-Cadmium (NiCd)	-40–60 Wh/kg. Score :3	-1.2V per cell; multiple cells are required Score: 1	-Long, with 1,500 to 2,500 charge cycles Score :4	-From -20°C and up to 60°C. Score :5	-Moderate (~70%), with some energy losses. Score 1	Low: $5 to $15 per pack. Score: 5	63
Nickel-Metal Hydride (NiMH)	-50–80 Wh/kg. Score :4	-Each cell provides 1.2V Score :1	-500 –1,000 charge cycle Score :4	-From-10°C to 45°C. Score: 3	-Moderate (~70–80%) Score :2	Low: $5 and $20 per pack. Score : 5	62

Lithium-Ion (Li-ion)	-5,000–30,000 mAh. Score: 4	-Standard 5V Score: 5	-500 –1,000 charge cycles Score :4	-From: 0°C and 45°C Score: 4	-High (~90%). Score :4	Moderate $20 to $100 Score : 4	79

From the total score, the best option would be Li-on battery for battery.

Lithium Iron Phosphate (LiFePO4)

Compatibility: Fully compatible with ESP32 and Raspberry Pi when paired with voltage regulators.

Maintenance: Low, thanks to its long cycle life and robust construction.

Supercapacitors.

Compatibility: requires a regulator for stable operation with ESP32 and Raspberry Pi.

Maintenance: Minimal, with almost no degradation over time.

Solid-State Batteries

Compatibility: Fully compatible with ESP32 and Raspberry Pi via voltage regulators.

Maintenance: Low, as this is cutting-edge technology designed for durability.

Nickel-Cadmium (NiCd).

Compatibility: Compatible with ESP32 and Raspberry Pi through multi-cell setups and regulators.

Maintenance: High, as the toxic materials require careful handling and disposal.

Nickel-Metal Hydride (NiMH)

Compatibility: Compatible with ESP32 and Raspberry Pi when using multi-cell setups and regulators.

Maintenance: Moderate, requiring occasional reconditioning to maintain performance.

Lithium-Ion (Li-ion)

Compatibility: Plug-and-play compatibility with USB ports of ESP32 and Raspberry Pi

Maintenance: Moderate, as frequent recharging is necessary.

4.0 - DEVELOPING THE SOLUTION SELECTED

Based on our specifications and requirements, we have outlined the following design for our solution.

Hardware Solution:

Camera:

For the camera that was chosen, we selected the OV2640 due to its convenient adapter module, its compact size and compatibility with the ESP32-S3. It supports resolutions up to 1600x1200 pixels , making it ideal for capturing high-quality videos during gameplay while also ensuring a clear, wide-angle view.

Microphone:

The TLV320ADC3100 is a low-powered stereo ADC designed for clear audio capture, featuring automatic gain control and noise filtering. It supports I2S audio interfaces, making it easy to integrate with the ESP32-S3. Mounted near the mouth, it enables voice communication or captures environmental audio during gameplay.

IMU:

For the IMU (Inertial Measurement Unit), we chose the WT901. This model is a 9-axis IMU offering precise motion tracking and impact detection with integrated acceleration, gyroscope, and magnetometer sensors. It communicates with the ESP32-S3 via UART or I2C and is programmed to detect high-impact forces, ensuring accurate monitoring of head impacts. For the hockey player, this will ensure a precise detection of the collision speed considering all potential head collisions.

Heart Rate Sensor:

For the heart rate sensor, we consider the MAX30102 This is a compact sensor designed for wearable devices, measuring heart rate and SpO_2 using photoplethysmography (PPG). Its integrated LEDs and noise-cancellation algorithms ensure reliable health monitoring. It’s placed near the chin strap or temple for optimal skin contact during play. With a good secure placement, this sensor will allow the system to detect any abnormality of the player heart rate as well as collecting heart rate data for potential future use.

Position Trilateration:

For the trilateration, we’ve decided to adopt the Time-of-Flight method to measure the real time location of the player, this is because using other common alternatives such as the signal strength of a router has far too many drawbacks. One of those major drawbacks include inaccurate measurement of position, this is because of how signals behave when encountering a different medium between the transceiver of an MCU and a Wi-Fi router.

Microcontroller:

The ESP32-S3 WROOM is the central hub that will be managing all the sensors and components. It supports Wi-Fi for data transmission which will allow us to continuously transmit our livestream onto the server, it’s very energy efficient giving the design enough time to run during an entire match, it has multiple I2C channels for interfacing with the sensors. It also has an 80 MHz clock frequency which allows it to compute tasks at high speed. The ESP32 also has a simple to use programming interface thanks to its USB OTG features.

Software Solution:

Our software solution will utilize a scheduler with specific tasks so that each functionality will be encapsulated into its own thread, thus performance and timing necessary for each feature of our project will be satisfied.

Video Task:

This task will be responsible for acquiring the live video feed. The frequency of this task will be according to our frame rate chosen for our video feed. With a framerate of 30 fps for a decent playback, this task will have to execute every 33 milliseconds. High priority should be given to this task so that others will not preempt it and cause video quality issues.

Audio Task:

This task will be responsible for acquiring the live audio feed. Audio should be sampled at a rate of 44.1 kHz for a decent quality. With a 44.1 kHz sampling frequency, the period of this task should be 22.7 microseconds. This can be a soft deadline however, as the audio feed is secondary to the video feed and missing a sample here or there will not be detectable to the human ear. Thus this task can have a lower priority than the camera task but should still be higher than the other non-critical tasks.

IMU Task:

This task will be responsible for acquiring the acceleration and velocity of the player from the IMU. While not requiring an especially high or low frequency, the IMU data should be polled at a rate between 100 Hz to 1 kHz to account for rapid changes in the player speed or acceleration. To be able to capture this fast change in directions, we will consider a frequency closer to 1 KHz and so this task should have a period of around 1 millisecond. Therefore it can have a low priority and soft deadline since it is less crucial than the audio and video tasks.

Heartbeat Sensor Task:

This task will be responsible for acquiring the heartbeat data from the sensor. Since the heart rate will vary greatly depending on the exertion and stress level of the player, this can be a sporadic task that uses interrupts. The heart rate sensor chosen can be configured to produce an interrupt when a beat is detected, and the microcontroller can use its timer/counter to measure the time elapsed between each successive beat to find the heart rate. Therefore this can be an interrupt-driven task that runs as needed.

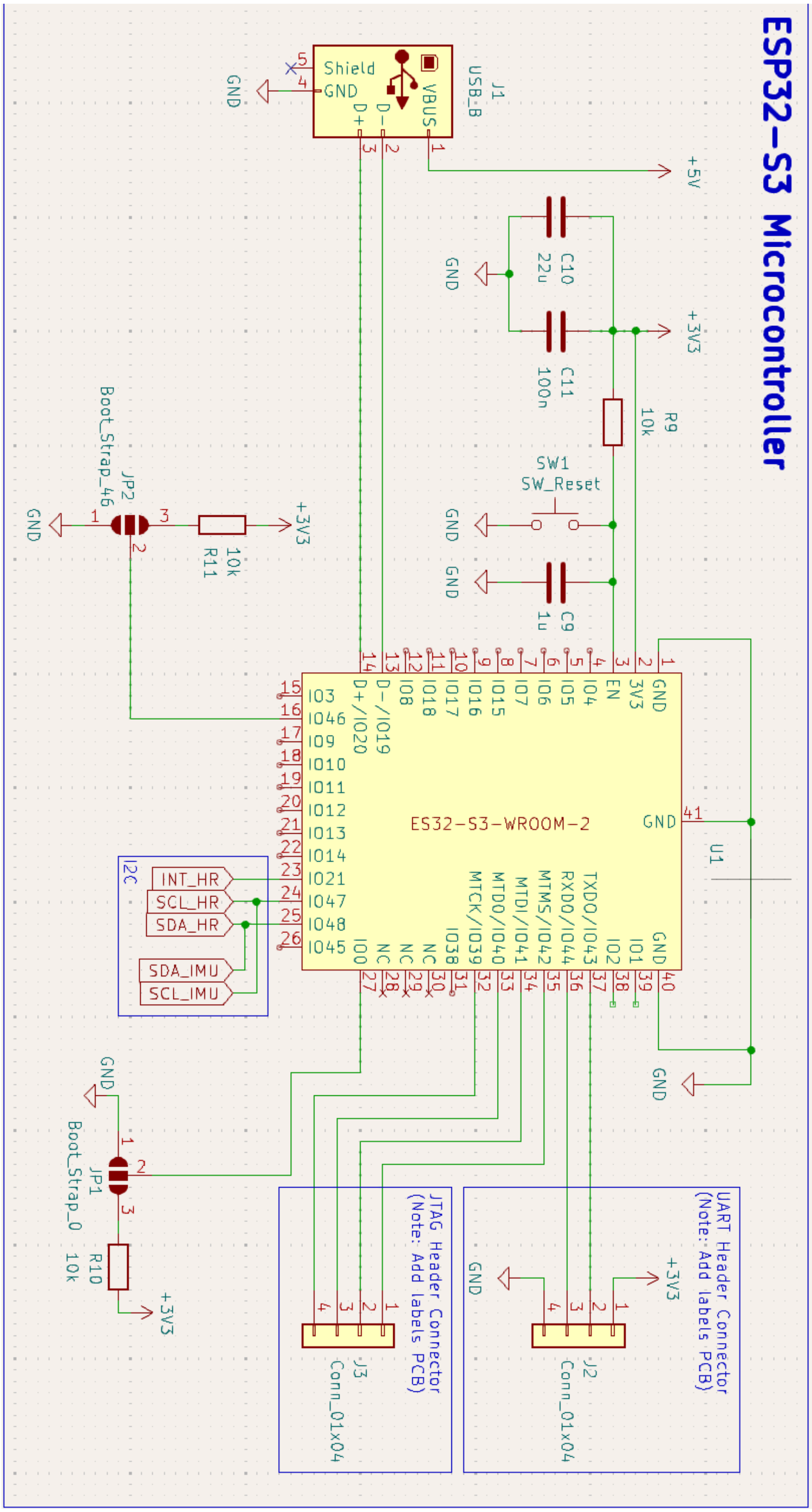
Position Tracking Task:

This task will be responsible for tracking the player position using the signal trilateration technique. A hockey player typically moves at a speed of 5-7 m/s and can have brief bursts of speed of up to 10-15 m/s. To make sure that player movements are accurately tracked, this task can be executed at 20 Hz such that if the player is moving at a speed of 15 m/s the maximum error in position will be under 1 m (1/20 * 15 = 0.75m accuracy). Therefore this task can have a period of 50 milliseconds with a medium priority compared to the video and audio tasks.

Data Transmission To Server:

This task will transmit all acquired data (video, audio, IMU, heartbeat, and position) to the server in real-time. Video and audio will be transmitted in chunks every 100 milliseconds, while sensor data (IMU, heartbeat, position) will be sent every 500 milliseconds. This task will have medium priority to ensure timely transmission without interrupting high-priority tasks like video and audio acquisition. It will adjust dynamically based on network conditions to avoid packet loss and ensure smooth data flow to the server.

Figure: Partial Schematic of Design



5.0 - DESIGN DEVELOPMENT

Prototyping Phase:

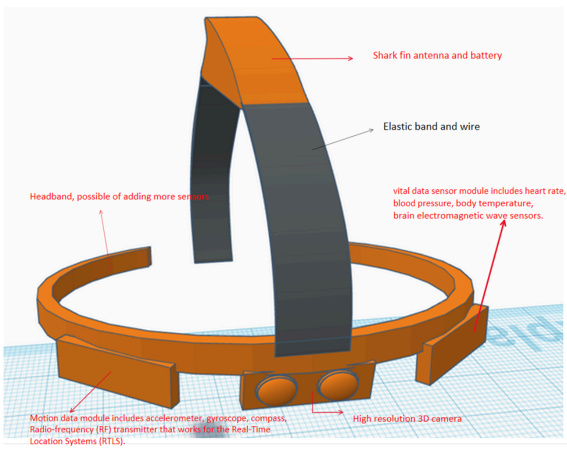
Inputs: Player Video/Audio, Heart Rate, Speed/Acceleration, Position on the Rink

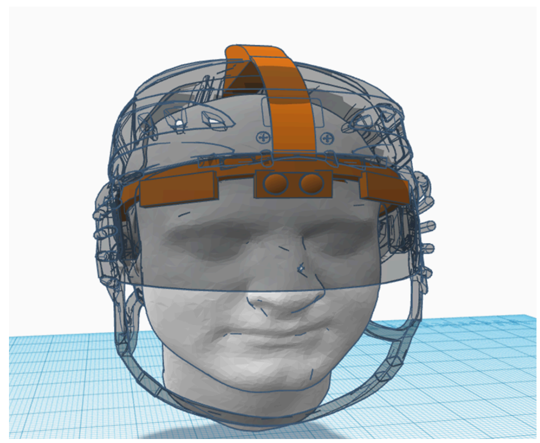
Outputs: Transmitted live stream to the server, and then to end user including HUD with player position and biometrics, real time alerts for high impact collisions or abnormal heart-rates, post game analysis

Formulation:

The image below shows a mockup of the user experience from the VR and smartphone app. The live stream of the player POV is shown, with a HUD showing player heart rate and a minimap with the player position on the rink. Screen effects can be applied when there is a collision detected by the IMU unit, like a reddening of the screen.

The following images show a 3-D mockup of the Helmet System. The microcontroller and PCB is housed in the fin at the top alongside a battery as a power supply. The camera and microphone will be attached near the forehead, to give the best representation from the player's point of view. The heart rate sensor must be in contact with the player's forehead in order to be able to capture their heart rate, while the IMU can be housed anywhere on the device and still be able to detect player velocity and acceleration.





Power Consumption:

Component	Working Current	Working Voltage
Camera (OV264)	300 mA	5V
IMU	25 mA	3.3V
Heart Rate	10 mA	3.3V
DWM1000	200 mA	3.3V
Total	535 mA	
Target Battery Capacity	**For 3 hours we need at least 2000 mAh**	

6.0 - UPDATED SCHEDULE

Table 5: Original Schedule

Event	Deadline/Time
Phase 1 (Selection and Planning) ● Project selection and team formation ● Group Meeting ● Group Meeting with Professor WeiPing Zhu ● Group meeting ● Proposal Completed ● Project Approval by Supervisor ● Group meeting ● Meeting with Space Concordia ● Group meeting ● Phase 1 presentation	 September 6 September 8 September 10 September 11 September 15 September 16 September 29 October 1 October 5 October 7
Phase 2 (Design) ● All group meeting plan ● Final Design Approval ● Software Acquisition ● Hardware Acquisition ● Phase 2 Report Submission ● Phase 2 Presentation	ALL TBD Phase 2 report and presentation will be held on end of November to beginning of December
Phase 3 (Prototype) ● All group meeting plan ● Begin Prototype Implementation ● Testing and Troubleshooting of Prototype ● Phase 3 In lab-demo	ALL TBD from January to February in 2025
Phase 4 (Final Product) ● All group meeting plan ● Final design implementation ● Verification and testing ● Phase 4 In-Lab Demo ● Phase 4 Report Submission ● Phase 4 Final Poster Presentation	ALL TBD from March to April in 2025

Table 6: Updated Schedule

COEN 490

Sports Vision Pro

Group 13

The 1st of every month	Phase 1
Phase 2	Phase 3 expected
Phase 4 TBD	

2024 Phase 1 & 2

Task Descrption	Starting Date	End Date	Days to complete	Progress
Phase 1				
Project selection and team formation	2024-09-06	2024-09-06	1	100%
Group Meeting	2024-09-08	2024-09-08	1	100%
Group Meeting with Professor WeiPing Zhu	2024-09-10	2024-09-10	1	66%
Group meeting	2024-09-11	2024-09-11	1	100%
Proposal Completed	2024-09-15	2024-09-19	5	100%
Project Approval by Supervisor	2024-09-16	2024-09-16	1	100%
Phase 1 Report	2024-09-28	2024-10-05	8	100%
Group meeting	2024-09-29	2024-09-29	1	100%
Meeting with Space Concordia	2024-10-01	2024-10-01	1	100%
Group meeting	2024-10-05	2024-10-05	1	100%
Phase 1 presentation	2024-10-05	2024-10-07	3	100%
Phase 2				
Group Meeting	2024-10-07	2024-10-07	1	100%
ELSEE aspects PowerSlide	2024-10-16	2024-10-26	11	100%
Group Meeting	2024-10-17	2024-10-17	1	100%
Group Meeting with Professor Christopher Trueman	2024-10-18	2024-10-18	1	100%
ELSEE Presentation	2024-10-28	2024-10-28	1	100%
Block Diagram Desgin	2024-11-02	2024-11-03	2	100%
Flow Chart	2024-11-02	2024-11-03	2	100%
Group Meeting with Professor Dmitry	2024-11-04	2024-11-04	1	100%
Phase 2 Report	2024-11-10	2024-11-23	14	100%
kicad schematic	2024-11-16	2024-11-22	7	100%
Group Meeting	2024-11-22	2024-11-22	1	100%
Group Meeting	2024-11-23	2024-11-23	1	100%
Phase 2 presentation powerpoint	2024-11-24	2024-11-25	2	100%

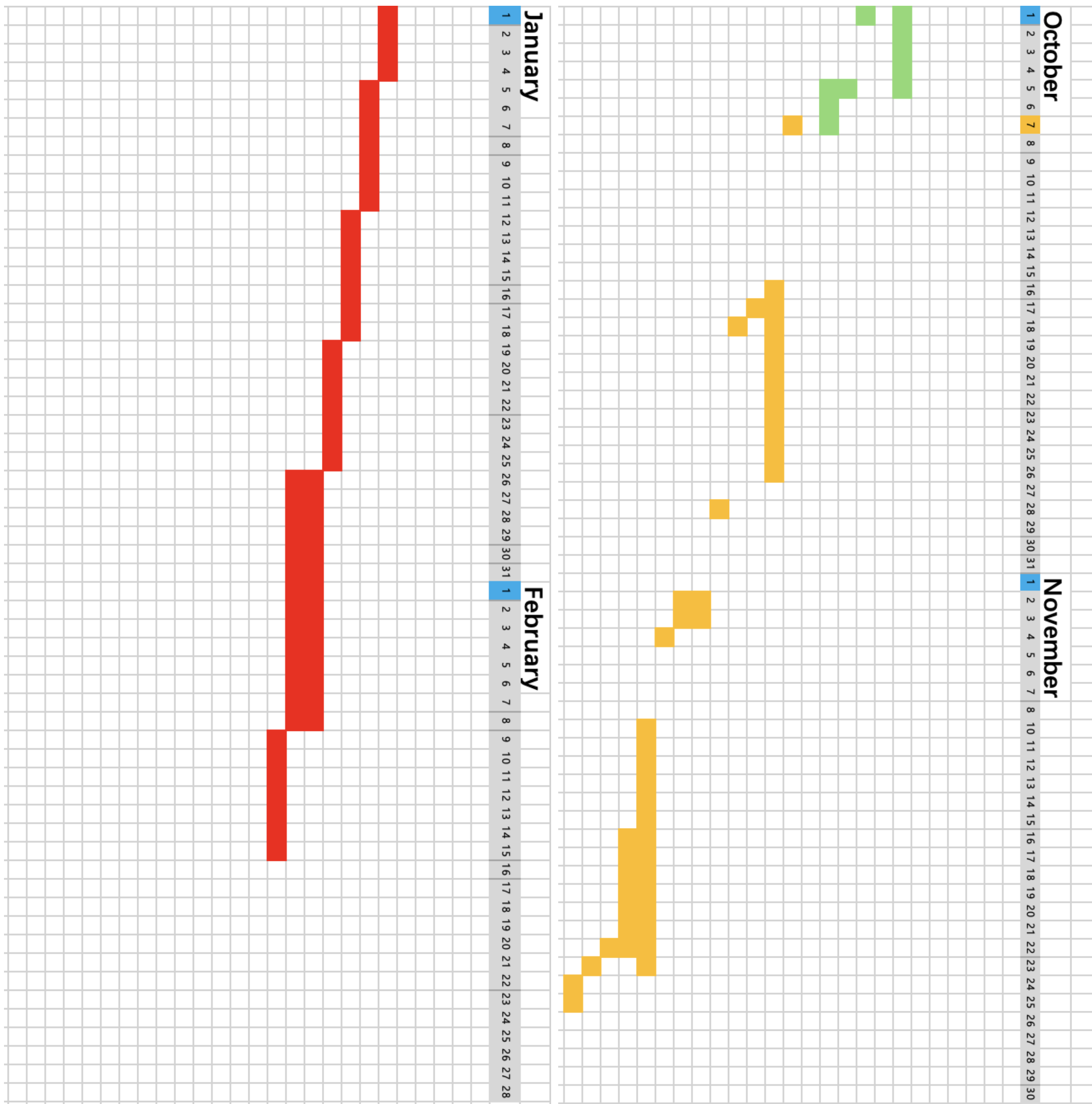
September: 6 7 8 9 10 11 12 13 14 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30

2025 Phase 3 & 4

Task Descrption	Starting Date	End Date	Days to complete	Progress
Phase 3				
Test and Prototype Video and Audio acquisition	2024-12-01	2024-12-07		
Test and Prototype IMU and heart rate sensors data acquisition	2024-12-08	2024-12-14		
Test and prototype Tracking System	2024-12-15	2024-12-21		
Test and prototype transmitting data to server	2024-12-22	2024-12-28		
Test and prototype broadcasting stream from server	2024-12-29	2025-01-04		
Test and prototype android app	2025-01-05	2025-01-11		
Test and prototype VR goggle app	2025-01-12	2025-01-18		
Test and prototype all above functions together	2025-01-19	2025-01-25		
Design complete circuit	2025-01-26	2025-02-08		
Create PCB layout	2025-01-26	2025-02-08		
Create and validate Bill of Materials	2025-02-09	2025-02-15		
Phase 3 Demo	TBD	TBD		
Phase 4				

TBD

December: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31



Our team has a little bit of problems with time management. To fix this issue, we have blocked off time for Phase 3 tasks to make sure we will stay on track and complete the prototyping in a timely manner. By assigning 1 week intervals for testing and prototyping each feature we plan to implement in the final device, we will make sure to spend enough time on every aspect of the project while allowing time at the end to merge all the functionality into one application. The final circuit schematics and PCB will be filled in as each feature is designed.

APPENDIX A - ELSEE ASPECTS

Task 1: Identify stakeholders

- Athletes
  - Ranking: Very high
  - Description of Stakeholder:
    - Athletes are the ones who will be collaborating with and directly affected by this design, especially with the VR headband and sensors that monitor vital signs.
  - Desired Feature:
    - Replays and vitals over the course of a season
  - Description of Feature:
    - This feature gives players a closer view of their performance, endurance, and accuracy for future improvement.
- Sports Fans and Audiences
  - Ranking: Very high
  - Description of Stakeholder:
    - Fans and audiences are the primary consumers of the VR experience and the largest group of people for the engagement of implementing this technology.
  - Desired Feature:
    - Real-time broadcast of a player's point of view via mobile apps or VR headset.
  - Description of Feature:

        - This feature gives viewers a more immersive experience by allowing them to see the game from a perspective of their favorite players, bringing them closer to the action and enhancing their engagement.
- Sports Teams and Leagues
    - Ranking: High
    - Description of Stakeholder:
        - Teams and leagues are directly involved as they own the games and players, and they would be key in implementing VR technology for fan engagement and player safety.
    - Desired Feature:
        - Data and analytics of present and past games.
    - Description of Feature:
        - This feature includes obtaining large sets of data of each individual player's performance on the hockey rink over the course of an entire hockey match.
- Sports Broadcasters and Media Networks
    - Ranking: Medium to high
    - Description of Stakeholder:
        - Different from traditional broadcastings, sports broadcasters might need to get used to a brand new point of view. They are not the direct beneficiaries of this technology, but this could improve their broadcasting experiences.
    - Desired Feature:
        - Multiple broadcast angles and player viewpoints.

- Description of Feature:
  - This feature enables broadcasters to switch between different player perspectives, enhancing storytelling and giving audiences an exclusive view.
- Sponsors and Advertisers
  - Ranking: Low to Medium
  - Description of Stakeholder:
    - Sponsors and advertisers will have opportunities to engage with fans in new ways, such as immersive ads.
  - Desired Feature:
    - Interactive ad placement within VR environment and mobile apps.
  - Description of Feature:
    - This feature allows sponsors to place unobtrusive, interactive ads that appear within the VR environment and through companion mobile apps, providing brands with increased visibility across multiple platforms.

Task 2: Listen to the Stakeholders

- Ethical[1]
  - Sites exist for streaming sports events for free, not distributed by a licensed television network
  - Rights to the game are held by sporting league, legal broadcast must have contract with the sporting league
  - Illegal to broadcast games without contract, unethical but not illegal for the

viewers

    - Must be sure to obtain proper authorization to broadcast sports stream, to not put users in unethical situation of watching something illegal

- Legal[2]
    - Broadcasting Rights and Licensing (exclusivity, contracts between leagues and broadcasters)
    - Intellectual Property (protection of content with copyright laws)
    - Geoblocking and Territorial Restrictions (content distribution laws differ depending on area, access may be restricted)
    - Regulatory Compliance (betting, advertising, content regulations for different regions)
    - Consumer Rights and Access (subscription models, service availability, monopoly by dominant streaming platforms, disclaimers for data collection)
- Social[3]
    - Social Anxiety (Feeling pressured to engage or perform socially)
    - Comparison Issues (Feelings of inadequacy or low self-esteem)
    - Disconnection (Feeling isolated/lonely, lack of depth of face-to-face connection)
    - Over-Reliance on Virtual Interactions (Diminished value of in-person interactions)
    - Potential for Toxic Behavior (Sometimes negative, trolling/hostile comments)
- Environmental[4]
    - High Energy Consumption (Significant energy for streaming, big carbon footprint)

    - Data Centers’ Impact (Energy-intensive, greenhouse gas emissions)
    - Infrastructure Inefficiencies (Unnecessary energy usage and waste)
    - Growing Demand (Challenges for mitigating carbon emissions)
    - Lack of Awareness (Users’ ignorance, hard to promote more sustainable practices)
    - Environmental Regulations (Environmental impacts not adequately addressed by regulations, gaps in accountability for streaming providers)
- Economical/Entrepreneurial[5]
    - High Competition (Unsustainable pricing wars, negatively impact profitability, service closures)
    - Cost of Content Acquisition (Broadcasting rights/producing original content can strain financial resources)
    - Revenue Instability (Shifting viewer habits means traditional revenue models like advertising/subscription fees may become less reliable, creating uncertainty)
    - Dependency on Subscription Models (Risky to depend on subscription revenue, market is saturated and consumers could choose to cut back on multiple subscriptions)
    - Investment in Technology (Significant start-up investment for high-quality technology)
    - Potential for Market Saturation (Oversaturated market leads to less returns)

Task 3: Learn from the Experts

- Data Ownership
    - Hudl Focus [6] has a wide angle camera that live streams the entire stadium

during the game. The camera is very automated and can easy upload the video through wifi or mobile data to their server.
    - The Product Owner decides who gets a copy (must be users on their service).
    - Opponents get shared video automatically through the account.
    - The way they address data ownership and privacy is to respect data ownership, allowing organizations to maintain control over the video content. This sets a precedent for privacy standards in sports technology, which could be applied to our 3D camera project. Ensuring clear data control and privacy.
- Environmental Approach
    - GoPro [7], as a recognized leader in action camera technology, provides an excellent reference for incorporating environmental sustainability into high-performance camera design.
    - GoPro uses recyclable materials that are also durable on their packaging, simplifying the package material.
    - Donate and support environment protection and restoration organizations.
    - GoPro also minimizes energy consumption in their products, which is essential for portable devices. This effort is particularly relevant in wearable technology for sports, where battery life and lightweight power solutions are key.
- Data Security
    - To address video streaming cybersecurity concerns, DJI [8] security features for their latest enterprise drones are impressive examples of data protection practices.
    - AES-256 Encryption for Data Transmission. DJI uses AES-256 encryption for its OcuSync communication system, the highest level of AES encryption, to prevent

man-in-the-middle attacks and unauthorized access to drone video feeds.

- DJI enables security codes for SD card encryption and provides a "Clear All Device Data" option.
- Data Sanitization Options. DJI's one-tap "Clear All Device Data" feature shows a proactive approach to data sanitization, where sensitive information can be wiped securely and swiftly. Implementing a similar data-clearing function for our 3D sports camera would add a layer of cybersecurity by allowing teams to clear footage and sensitive data after each session, thus minimizing data exposure risks.

APPENDIX B - LIFE-LONG LEARNING ASSESSMENT FORM

Your name and ID:

- Guanfeng Wu
- 40165181

a. In your Capstone project so far, what additional knowledge and skills did you need other than the prerequisite courses?

To complete the project, I had to gain expertise in wearable technology, signal trilateration for position tracking, and integrating hardware like the ESP32-S3 microcontroller. I also needed knowledge in real-time data processing, embedded systems programming, and VR application development.

b. How did you acquire the knowledge that you needed to complete the project?

I acquired the required knowledge through independent research, studying online tutorials, referencing documentation for specific components, and collaborating with teammates. Guidance from professors and insights from similar projects were also instrumental.

Your name and ID:

- Haoyu Wang
- 40216511

a. In your Capstone project so far, what additional knowledge and skills did you need other than the prerequisite courses?

I gained knowledge about infrared and trilateration positioning methods, and finally we decided to use the trilateration positioning method to track the position of players on the arena. Besides, I also gained research skills while completing the report.

b. How did you acquire the knowledge that you needed to complete the project?

I acquired the knowledge from the website that introduced the positioning methods such as WikiPedia and the official website of NHL.

Your name and ID:

- Rongmin Gan
- 40068816

a. In your Capstone project so far, what additional knowledge and skills did you need other than the prerequisite courses?

There is a lot of additional knowledge for me other than the prerequisite courses, due to our project involves a bunch of hardware, so there is a lot of knowledge such as, IMU connected arduino uno wifi rev2, NHL hockey knowledge and method of triangulation camera with machine vision to track, the triangulation alternatives between WiFi Wireless Adapter, UWB 1000, GPS, Infrared (IR).

b. How did you acquire the knowledge that you needed to complete the project?

Basically, I search for that knowledge online by google, Youtube or AI.

Your name and ID:

- Shahin Khalkhali
- 40057384

a. In your Capstone project so far, what additional knowledge and skills did you need other than the prerequisite courses?

I believe that completing an advanced technical analysis course would have been highly beneficial. Additionally, I found a need for knowledge in embedded systems programming, sensor integration, and real-time data processing, as well as skills in project management and effective team communication.

b. How did you acquire the knowledge that you needed to complete the project?

I acquired the necessary knowledge through independent research, online tutorials, and documentation for specific hardware components like the ESP32-S3 and its peripherals. I also collaborated closely with my team, leveraging peer learning, and consulted with professors and industry experts to address technical challenges.

Your name and ID:

- Tien Vu
- 40044988

a. In your Capstone project so far, what additional knowledge and skills did you need other than the prerequisite courses?

-3D modeling, finding and reading research papers, extensive teamwork, knowledge and experience for different project components.

b. How did you acquire the knowledge that you needed to complete the project?

-Google and Concordia databases help me with finding research paper, Udemy help me learn fusion 360. My friends and peers help guiding me to learn new and important knowledge for the project.

Your name and ID:

- Samson Kaller
- 40136815

a. In your Capstone project so far, what additional knowledge and skills did you need other than the prerequisite courses?

One of the biggest concerns for our project was figuring out how the player position tracking will be implemented. We considered several options, including signal trilateration, machine vision using AI, or tracking IR LEDs on the players using an IR camera. None of these things are covered in my COEN curriculum. Also, we made a start at designing the circuit schematic and PCB for our project, but I have not had any courses in PCB design, and I was surprised to learn how complicated it is to make a schematic. The most important part was to look at the datasheets for the IC chips we are using (Heart Rate sensor, IMU, etc) and if it was a good datasheet, the typical hardware connections would be describe and we could use them to design our own circuit and PCB while making sure each IC had the components it needed to work.

b. How did you acquire the knowledge that you needed to complete the project?

By searching for articles online, watching youtube tutorials of similar projects, and also getting in touch with students who already had the necessary skills so they could give me pointers on how to proceed.

APPENDIX C - INDIVIDUAL CONTRIBUTIONS

Guanfeng Wu:

I actively contributed to various aspects of the design, development, and testing phases. My key contributions include:

Camera selected and analyzed the initial results of video resolution and frame rate , ensuring they met the minimum requirements for proof-of-concept.

Researching specific UWB chip that is suitable for the indoor position system.

Documentation and design review, setup of schematics in Kicad, to support the project presentation and report.

Haoyu Wang:

Did necessary research on the infrared positioning method. Contributed on completing the alternatives, flowcharts, Appendix A - ELSEE aspects, adjusting references, and helped with overall documentation and formatting.

Rongmin Gan:

Research on methods of triangulation in the following area: Frequency Range, Distance, Bandwidth, RSSI, Cost. Score and compare the device of GPS, UWB 1000, WiFi Wireless Adapter, Infrared (IR), explains the device's score in that certain area. Do the schedule of time and task, and do the Gantt Chart.

Shahin Khalkhali:

Worked on the revision of the customer and final design specifications, and how to include different test conditions. Did physical testing of the ESP32's and Raspberry Pi's RSSI relating to another course. Did research on different modules for deciding our choice in hardware including the UWB1000, UWB3000, camera modules, and microcontrollers. Design the schematic for the upcoming phase.

Samson Kaller:

Using feedback from Dmity, I updated the project Objectives, Functions and Requirements. I worked on the System block diagram and description of the position tracking using trilateration technique. I help come up with drafts flowchart versions to help other team members create the final flowcharts. I filled in the Software Solution part of the section Developing the Solution Selected. I was also assigned to do some initial testing and prototyping of the heart rate sensors, and created a small scaled down version of our project, where the data from the heart rate sensors was capture with and ESP NodeMCU, transmitted to a small python server I was running on my laptop, and stored in a log file on the computer using socket programming and a TCP/IP client/server combination. I also did research for the ELSEE task 2 part.

Tien Vu:

Researching on different alternatives for the triangulation location method and battery. Contributing on the completion of the alternative, contingency plan, and some smaller parts of the reports. Researching and learning 3D modeling via a Fusion 360 course on Udemy. Contribute a small flowchart.

APPENDIX D - REFERENCE

[1] "Sports Streaming: An Ethical Dilemma for Cedarville Students", *Campus News*, 2014 https://cedars.cedarville.edu/2014/11/sports-streaming-an-ethical-dilemma-for-cedarville-students/

[2] "Over-the-top sport: live streaming services, changing coverage rights markets and the growth of media sport portals", *Sage Journals*, 2019 https://journals.sagepub.com/doi/full/10.1177/0163443719857623

[3] "Viewing sports online together? Psychological consequences on social live streaming service usage", *ScienceDirect*, 2020 https://www.sciencedirect.com/science/article/abs/pii/S1441352319302700

[4] "The Carbon Footprint of Streaming Media: Problems, Calculations, Solutions", 2022 https://www.sfu.ca/~lmarks/downloads/files/Marks%20and%20Przedpe%C5%82ski,%20The%20Carbon%20Footprint%20of%20Streaming%20Media.pdf

[5] "Streaming the game: How the rise of digital platforms is changing sports consumption" , *pwc*, 2021 https://www.pwc.com/us/en/industries/tmt/library/sports-streaming-platforms.html

[6] https://www.hudl.com/products/focus/faq/fixed

[7] https://gopro.com/en/ca/info/corporate-social-responsibility/environmental-sustainability

[8] https://www.heliguy.com/blogs/posts/data-security-with-dji-enterprise-drones/#:~:text=A%20guide%20to%20data%20security%20on%20DJI%27s%20most,encryption%2C%20Cloud%20API%2C%20and%20SD%20Card%20AES%20Encryption