# Deliverable D

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# Abstract

*This document will demonstrate each of our team member's concepts for all three subsystems. Team members will then produce three functional solutions based on features from each member's concepts. A decision matrix then evaluates each of those concepts based on every design criteria provided in deliverable C. Thanks to the decision matrix, one design concept will be put forth as the most viable option accompanied with detailed explanations.*

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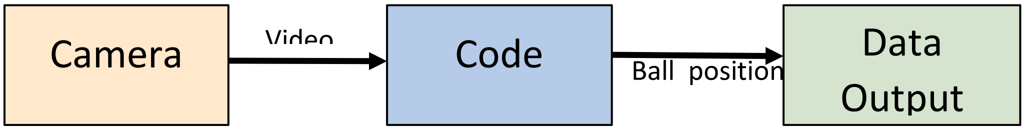
# 1 Introduction

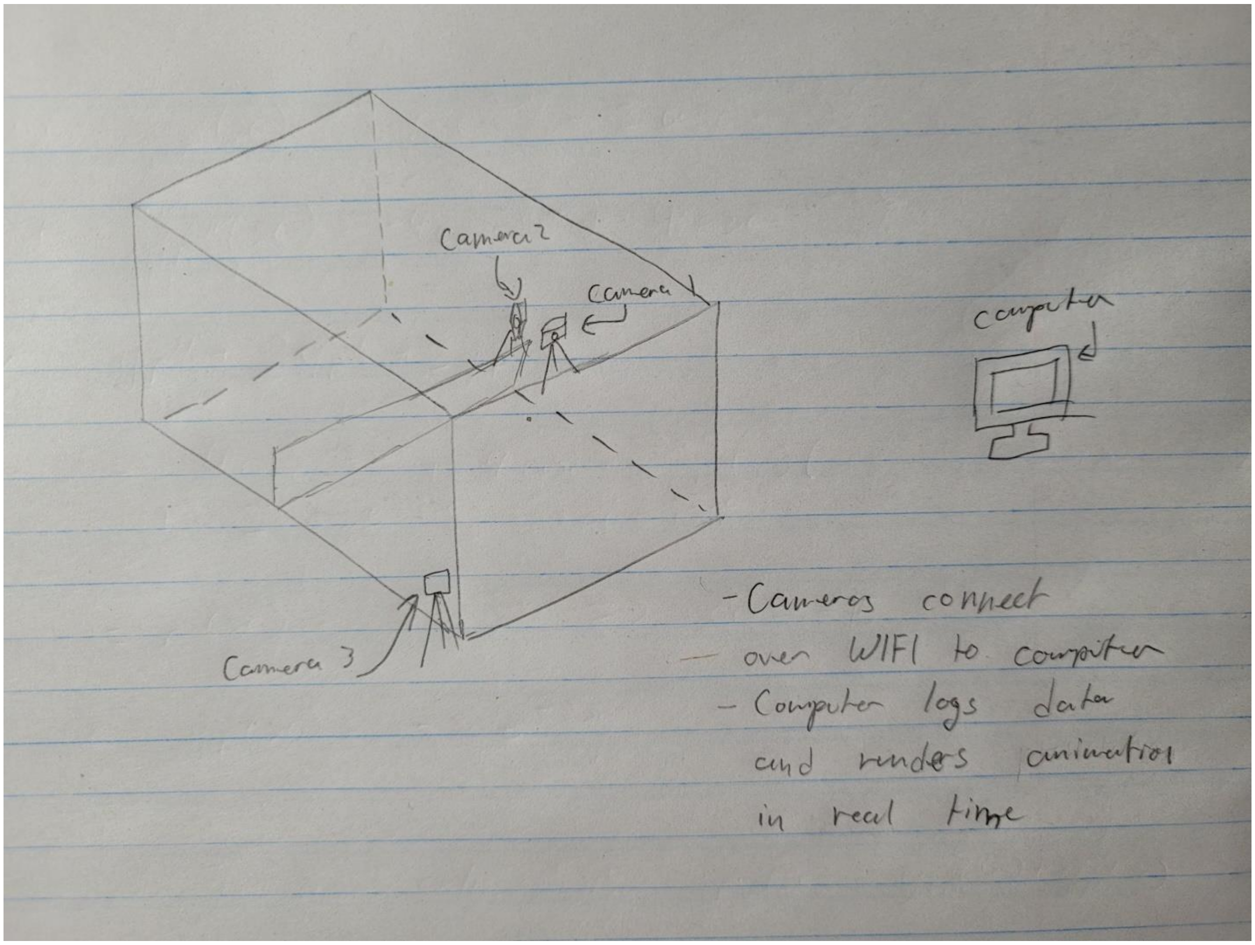
Based on the prioritized design criteria, technical benchmarking and problem statement a solution with 3 subsystem is made. Subsystem 1 consists of a hardware system that captures the images of a video of the ball in real time position in the court. Subsystem 2 consists of a code on a computer which detects the ball image on the video and measures its position on a 3D plane. Subsystem 3 consist of a 3D virtual padel court on which accurate position, velocity, trajectory and angle of the ball will be displayed.



You should clearly define the boundaries between those subsystems, so that conceptual designs for each subsystem are inter-changeable.

# 2 Subsystem 1: Hardware

## 2.1 McQueen Zhao

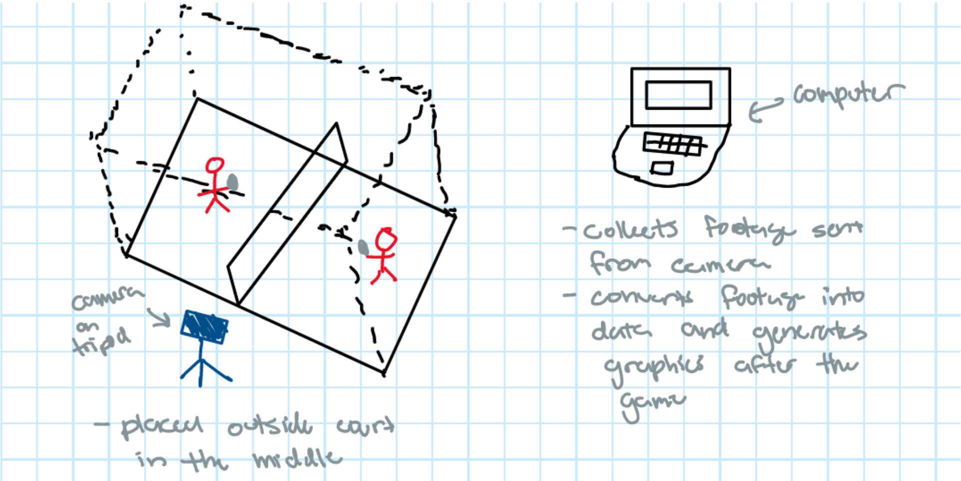


- Cameras connect over WIFI to computer
- Computer logs data and renders animation in real time

3 cameras (smartphones with Wi-Fi) are positioned as shown in order to have full coverage of the court. They wirelessly communicate the video data to the computer. All 3 cameras and the computer are located outside of the court to prevent interfering with gameplay and damage.

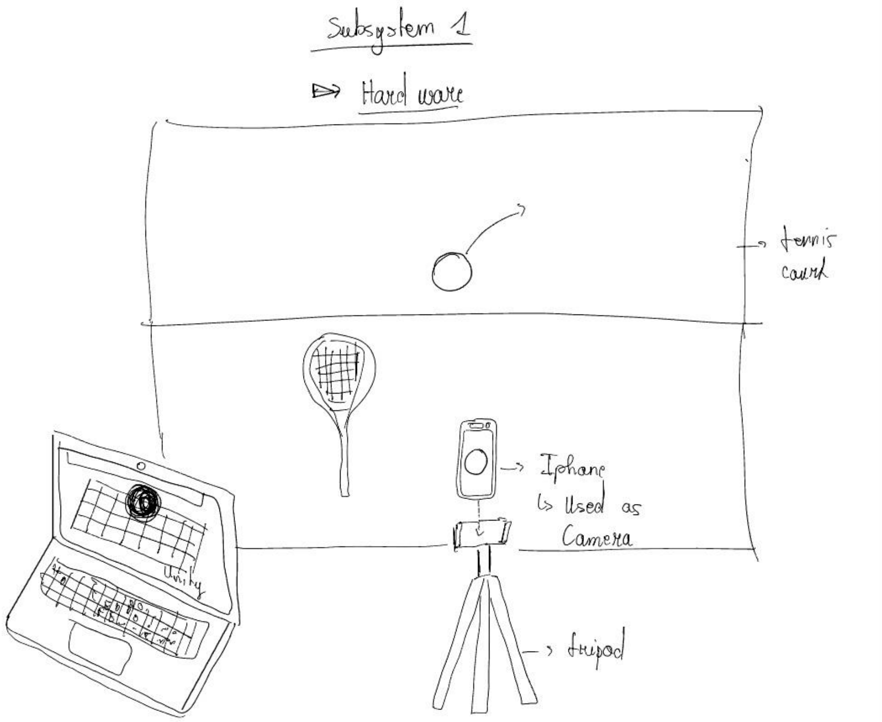
## 2.2 Anastasia Kalatcheva

The 1 camera (iPhone) would be placed on a tripod outside the glass walls of the court in the middle. It will record footage of the game. After the phone will send the footage to a computer which will process the data given and do calculations as well as render the graphics.

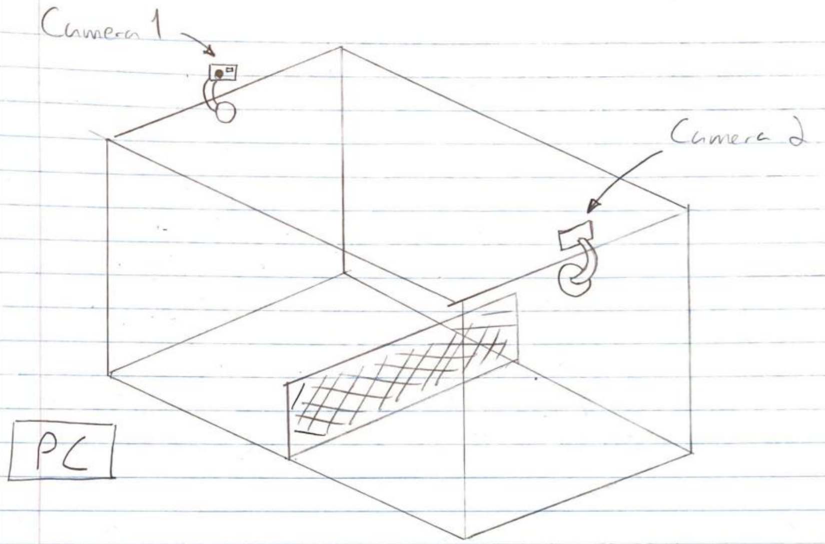

computer
- collects footage sent from camera
- converts footage into data and generates graphics after the game
camera on tripod
- placed outside court in the middle

## 2.3 Kenza Tiendrebeogo

**Note 15 Oct 2022**
15 Oct 2022 at 15:21



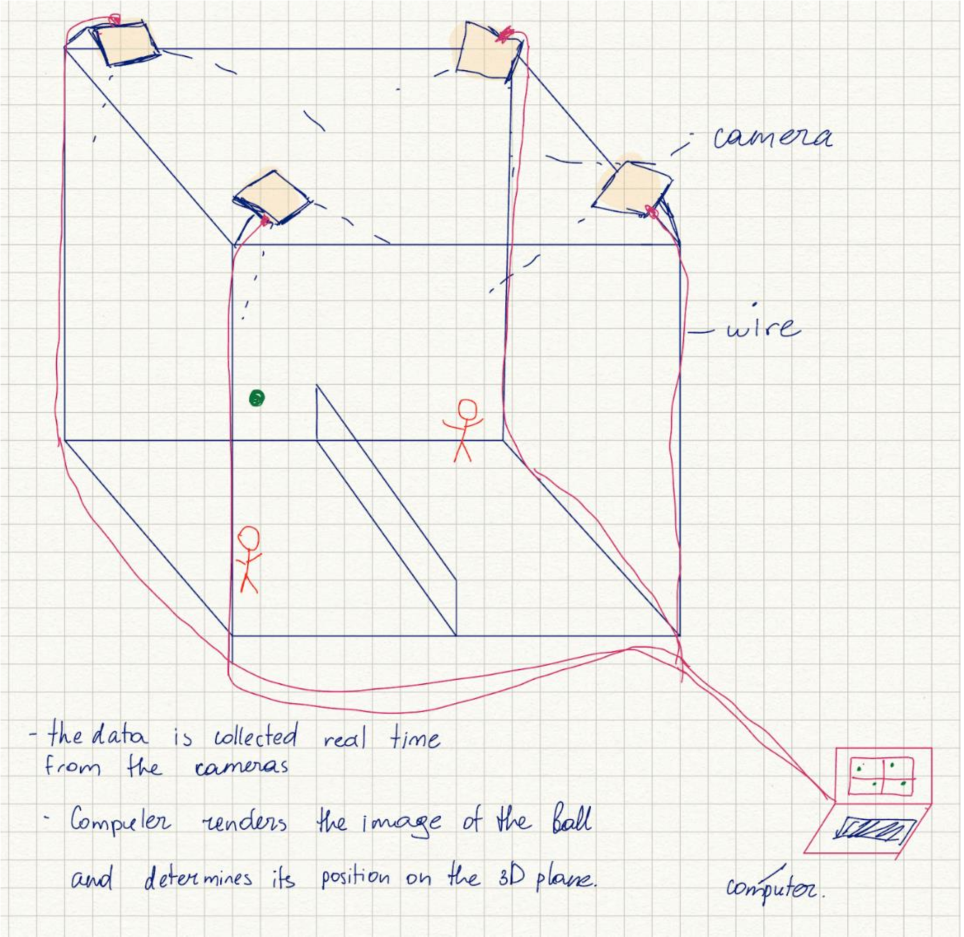
## 2.4 Matthew Waite



- → Cameras mounted on wall using suction cups.
  - ↳ Above glass for unobstructed view
  - ↳ Each end for maximum court coverage
- → Cameras connected to PC for real-time rendering
  - ↳ Collects data

2 cameras mounted on each side of the court, above plexiglass for unobstructed view, using suction cups. Cameras provide input for real-time rendering on PC.

## 2.5 Anna Kim

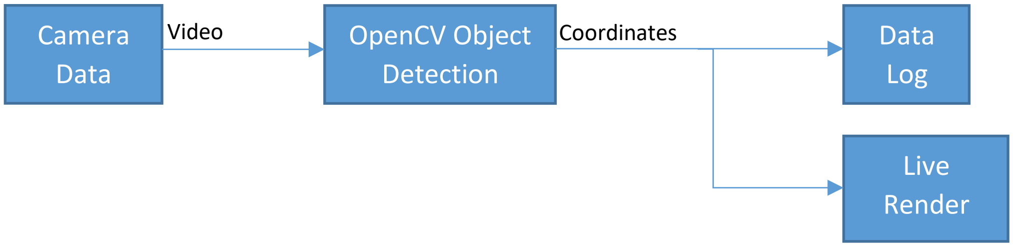


- the data is collected real time from the cameras
- Computer renders the image of the ball and determines its position on the 3D plane.

4 cameras installed on the corners of the pedal court walls. They transform information through the wire to the computer. The cameras' location allows them to capture accurate position of the ball in the 3D plane. Also, each camera is turned at an angle to capture the location of the ball as it hits the wall. Each camera captures an image of the floor and of its corresponding 2 walls on the opposite side. Therefore, as the ball hits the wall its position can be determined accurately on both walls and the court and the trajectory can be predicted as angle of elevation can be seen. However, for now we will use only one camera to capture the position of the ball for the test. According to the problem statement, the customer wants inexpensive and easy to set up solution. So instead of cameras, customer can use their phones to be set up on the corner/ corners depending how many phones they have. The cameras are not as easy to set up because it requires climbing the ladder. Also, the cameras are not placed on the ground, so it will not interfere with the game because the players may exist the court, to hit the ball inside the court.

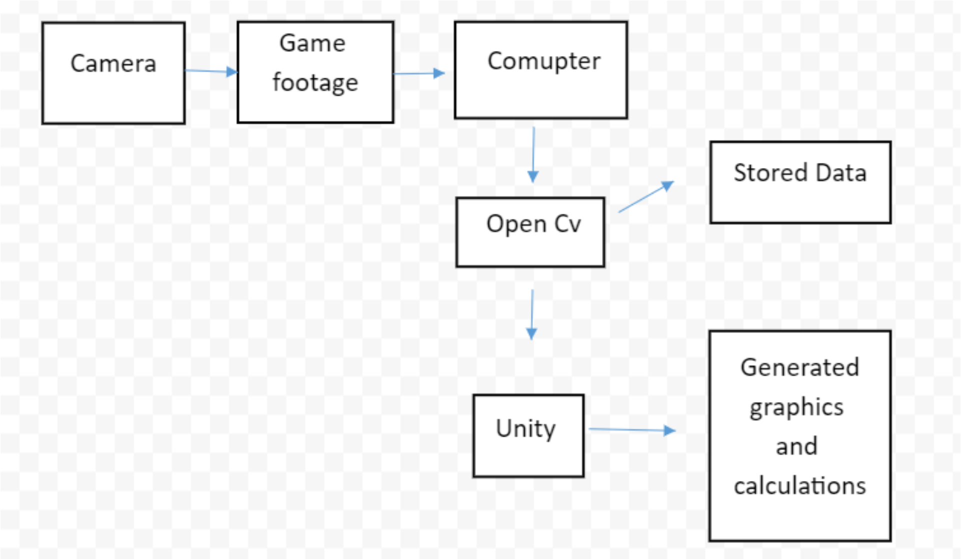
# 3 Subsystem 2: Motion capture

## 3.1 McQueen Zhao



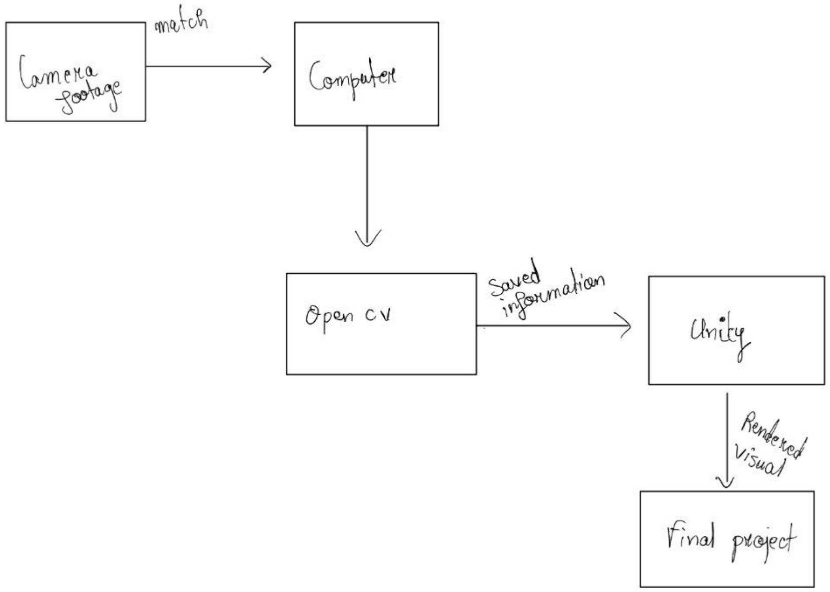
OpenCV uses its object detection features to identify the coordinates of the ball from the camera feeds and outputs those coordinates to a data log and a live render.

## 3.2 Anastasia Kalatcheva

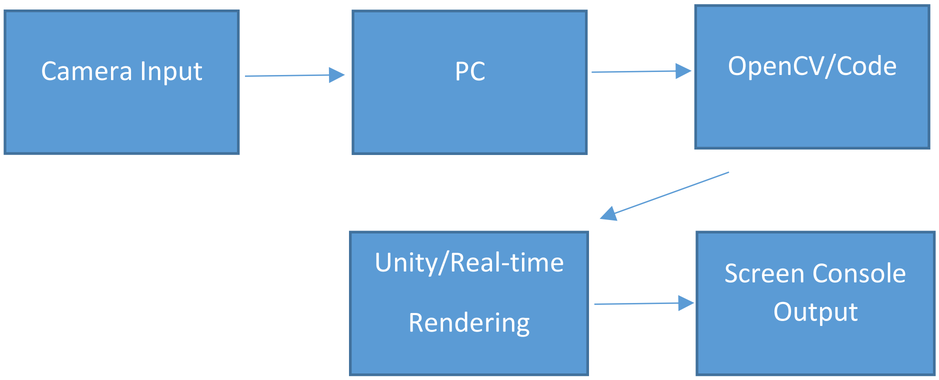


The camera would capture the game footage that would then be sent to the computer where Open CV would detect the ball and generate the coordinates of where the ball was during the game. These coordinates would then be used in unity to generate the 3d graphics of them game as well as the calculations like force and velocity of the ball.

## 3.3 Kenza Tiendrebeogo



## 3.4 Matthew Waite



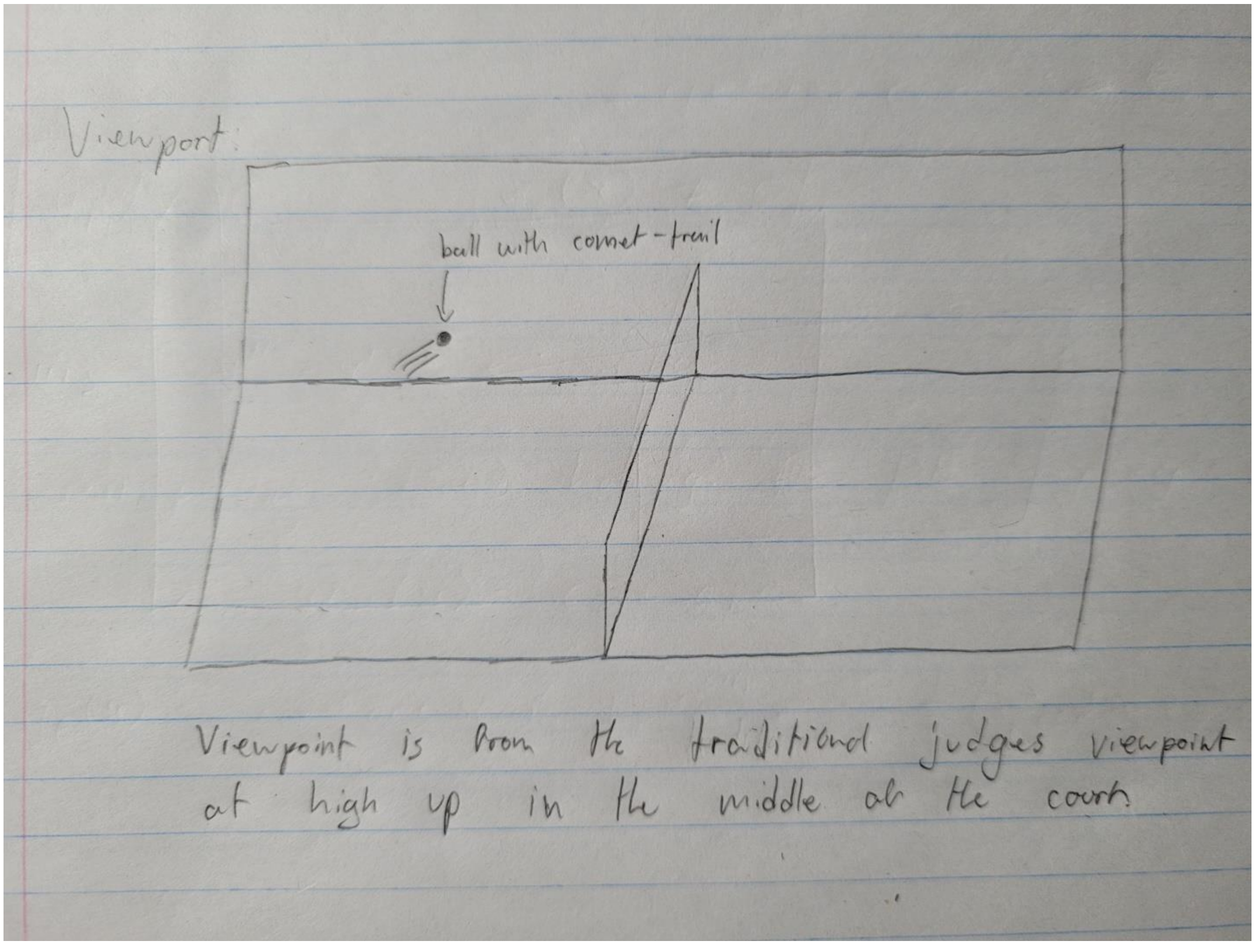
Input data is collected from the cameras and sent to the PC. Unity then uses the code created to provide a real-time rendering for the user as an output.

## 3.5 Anna Kim

For this subsystem, OpenCV will be used to detect the ball which will measure its coordinates in the 3D plane. The detection system will detect the all-round shapes on the field, instead of colour detection. The measurements of the ball position every second will be stored and calculated in the separate file to find object's speed, angle and force. The code will be made using Python and unity. Using unity, we will create virtual space to show position of the ball and all its calculated parameters.

# 4 Subsystem 3: Rendering/ Presentation

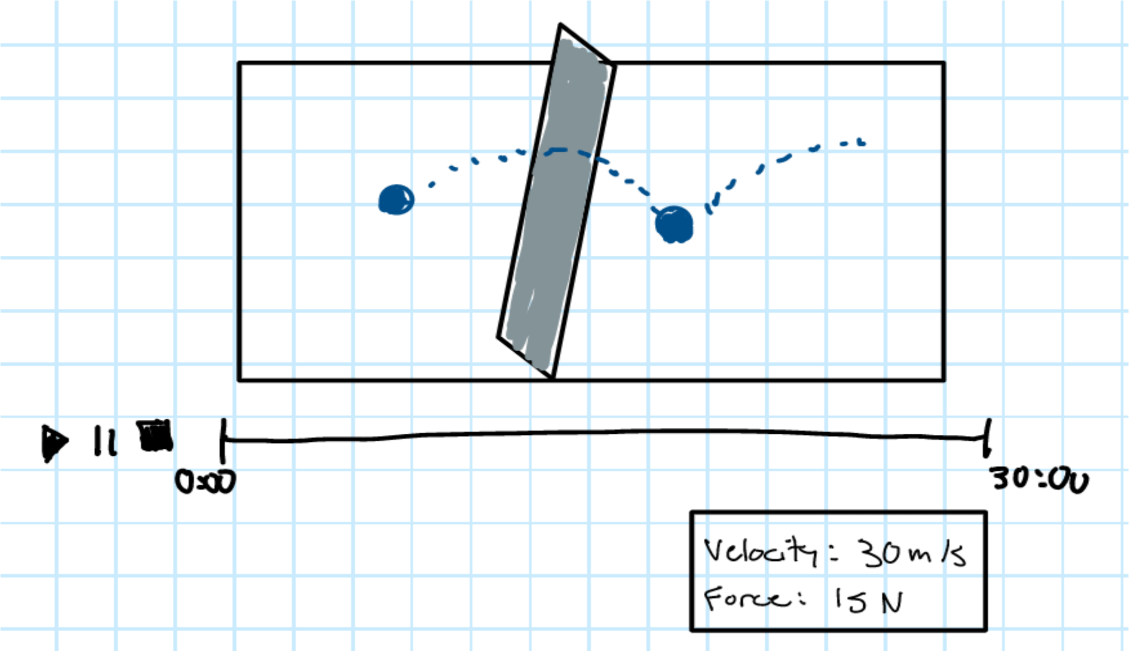
## 4.1 McQueen Zhao



Viewpoint is from the traditional judges viewpoint at high up in the middle of the court

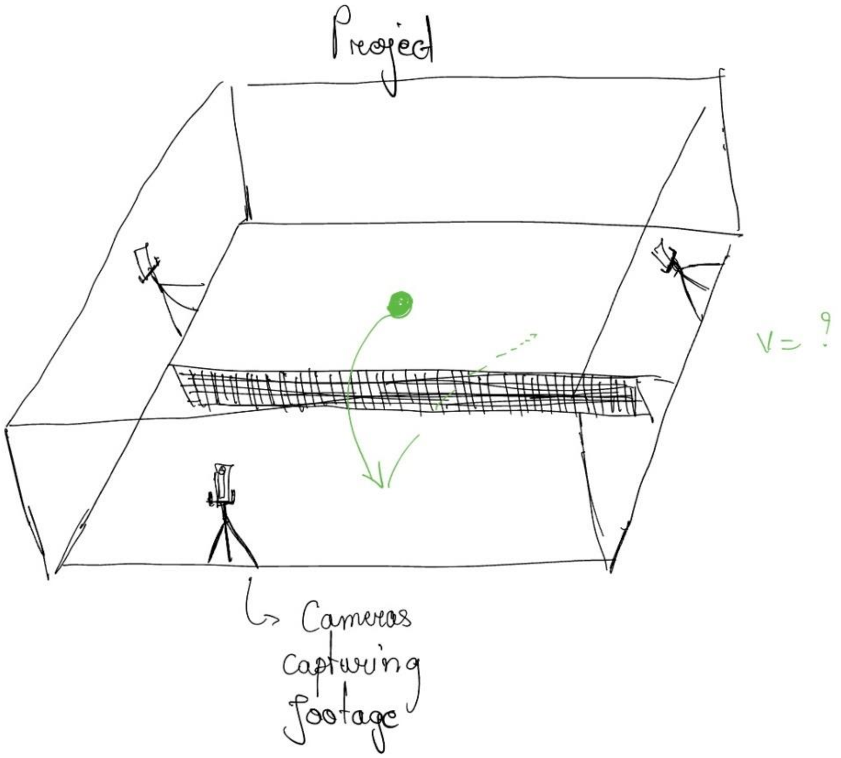
The final render will be from the perspective of a traditional tennis judge. Viewer movement or multiple viewer perspectives may be added if time and budget allow.

## 4.2 Anastasia Kalatcheva

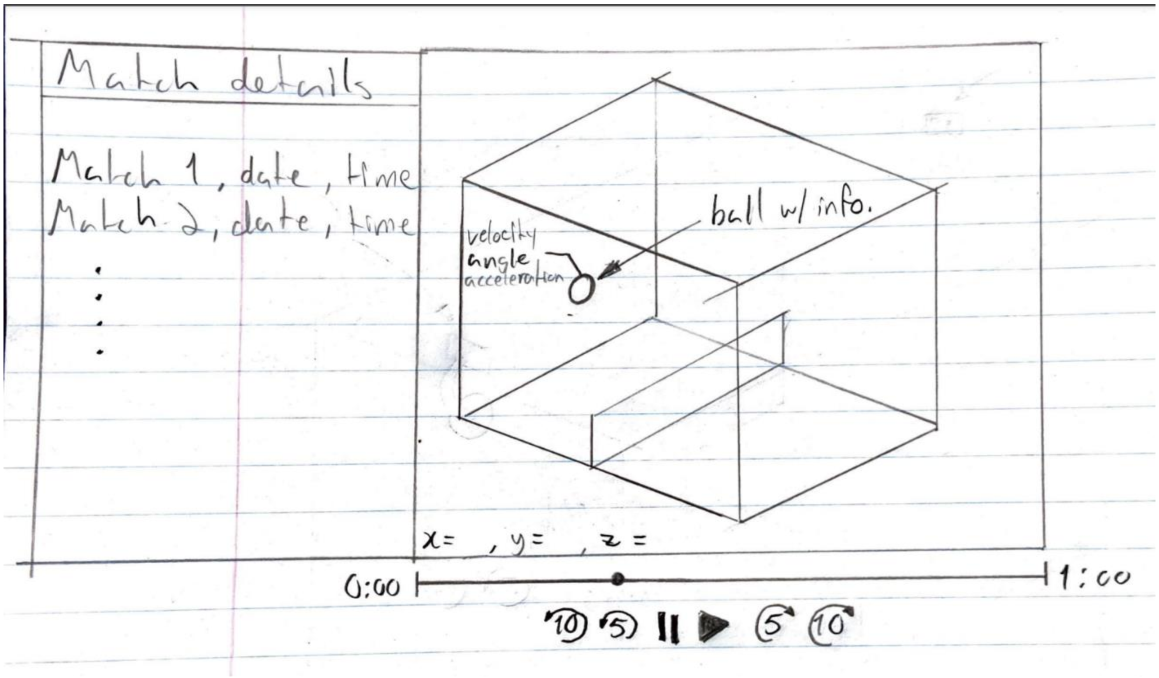


The final rendering of the game will have a middle-elevated view of the court. The game will be able to be paused, sped up, fast forwarded etc. In the bottom corner velocity and other specs about the ball movement will be constantly be shown to reflect the current movement of the ball.

## 4.3 Kenza Tiendrebeogo



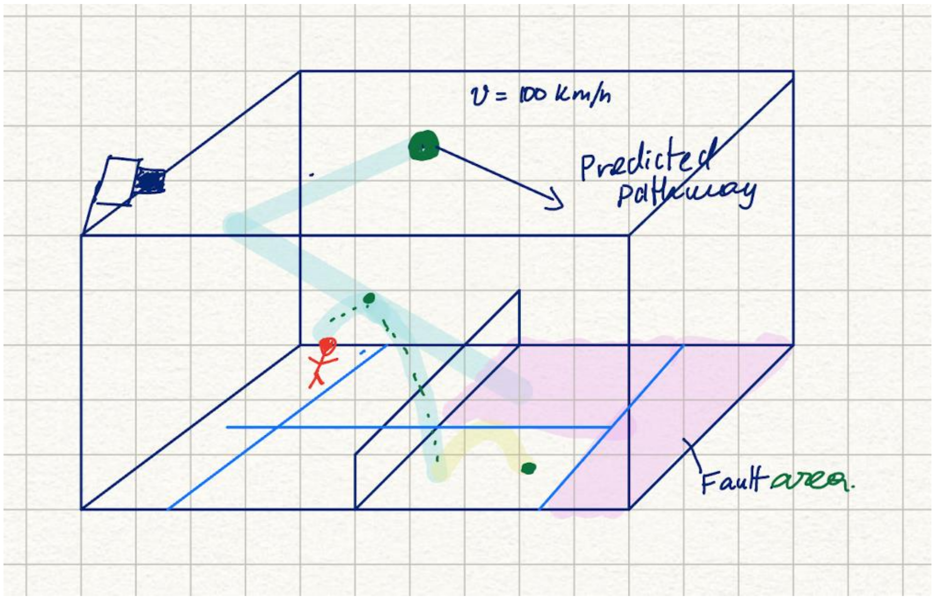
## 4.4 Matthew Waite



The output console will feature a fully manoeuvrable 3D space with useful time options such as an adjustable time bar, rewind and forward 5 or 10 seconds, as well as pause and play. The ball, along with its velocity, angle, and acceleration, will be always visible in the 3D space. X, y, and z coordinates will feature in the bottom left corner of the space. Lastly, a match details section will be included with which the user will be able to select and view matches along with its information.

## 4.5 Anna Kim

The final render will be a 3D plane enclosed in the box that shows object's position where ball's velocity is shown. By using elastic collision formula, the predicted pathway of the ball can be shown on the render as it hits the wall. The render can detect when faults occur during the serve or when the ball hits the ground twice



# 5 3 Functional Solutions

## 5.1 Concept 1

Hardware: Section 2.4

Motion Tracking: Section 3.4

Render: Section 4.1

### 5.1.1 Analysis

Hardware pros: Quick setup, unobstructed view.

Hardware cons: Suction cups can be unreliable at times especially when ball hits the wall. A ladder would also be required for mounting.

Motion Tracking pros: Live render for audience

Motion Tracking cons: No data logging

Render pros: Simple, easy to implement

Render cons: No flexibility in viewpoint or data displayed

## 5.2 Concept 2

Hardware: Section 2.2

Motion Tracking: Section 3.2

Render: Section 4.5

### 5.2.1 Analysis

Hardware pros: Only single camera needed, easy setup

Hardware cons: Less flexibility and accuracy

Motion Tracking pros: Data storage, live rendered viewport

Motion Tracking cons: Hard to implement

Render pros: Displays lots of useful information, projected paths, and fault zones

Render cons: Difficult implementation

## 5.3 Concept 3

Hardware: 2.1

Motion tracking: 3.3

Render: 4.4

### 5.3.1 Analysis

Hardware pros: Cameras are set up outside court and do not have possibility of interfering with the game. Real-time rendering occurs which allows for live game analysis.

Hardware cons: Multiple cameras, Wi-Fi connection is needed which may not always be possible.

Motion tracking pros: Data is stored for possible future use, unity is used to render the 3D space

Motion tracking cons: Might have a maximum of data that is able to be stored

Render pros: Allows for playback of multiple games along with being maneuver the view of the 3D space

Render cons: Maneuverable 3D space will require accurate footage from multiple angles (more than one camera will be needed).

## 6 Decision Matrix

| | **Concepts (combined subsystems)** | **Concept 1**<br>(out of 3 x weighted score) | **Concept 2**<br>(out of 3 x weighted score) | **Concept 3**<br>(out of 3 x weighted score) |
|---|---|---|---|---|
| **Criteria** | Criteria weight | | | |
| **x,y,z coordinates** | 5 | 2 x 5 = 10 | 1 x  = 5 | 3 x 5 = 15 |
| **Mounted outside play area** | 5 | 3 x 5 = 15 | 3 x  = 15 | 3 x 5 = 15 |
| **Functioning Software** | 5 | 2 x 5 = 10 | 2 x  = 10 | 2 x 5 = 10 |
| **1080p** | 4 | 3 x 4 = 12 | 3 x  = 12 | 3 x 4 = 12 |
| **Cost** | 5 | 3 x 5 = 15 | 3 x  = 15 | 3 x 5 = 15 |
| **Data storage** | 5 | 1 x 5 = 5 | 3 x  = 15 | 3 x 5 = 15 |
| **Software compatibility** | 4 | 3 x 4 = 12 | 3 x  = 12 | 3 x 4 = 12 |
| **Simple camera mounts** | 3 | 3 x 3 = 9 | 3 x  = 9 | 3 x 3 = 9 |
| **Angle, velocity, accelaration** | 3 | 1 x 3 = 3 | 3 x  = 9 | 3 x3 = 9 |
| **Ball trajectories** | 3 | 1 x 3 = 3 | 3 x  = 9 | 1 x 3 = 3 |
| **Graph statistics** | 2 | 1 x 2 = 2 | 1 x  = 2 | 1 x 2 = 2 |
| **Aesthetics** | 2 | 2 x 2  = 4 | 2 x  = 4 | 3 x 2 = 6 |
| **Total score** | | 100 | 117 | 123 |

## 7 Final Concept

Upon careful review using the decision matrix we have determined that Concept 3 is the best option thanks to it having the highest total score. The 3 camera system will have coverage over the entire court and will be outside the court as to not interfere with the game. The system uses Wi-Fi which allows for a wireless connection, but some event spaces may prohibit Wi-Fi. We think this is a small downside for the advantage of a wireless system. The motion tracking system will store data for future use and send data to Unity for a live render to use during matches. The data will have to be stored which incurs risk of data loss or corruption. The rendering engine will use Unity to perform a real time or post-game render of the ball. However, a good rendering system will be costly to develop. Overall, we believe this is the best system that fulfills the problem statement.