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GNG2101

Introduction to Product Development and Management for Engineers and Computer Scientist

Course Professor: Dr. Emmanuel Bouendeu

Deliverable C

Conceptual Design and Project Plan

Presented to: Melika Ataebi

Prepared by Group B12

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Introduction

*"Athletes and coaches **playing tennis** are looking for a portable, durable and waterproof product that effectively measures their performance and outputs it via a user-friendly platform that allows constant comparison of statistics amongst themselves and their team."*

The team has generated preliminary conceptual design ideas that answer the interpreted needs of the user based on the problem statement defined above. Based on subsequent analysis and evaluations, the ideas will be combined into one global conceptual design idea that contains three subsystems: the product's ability to detect and collect data during a performance, the product's ability to categorize and analyze the data based on performance and the implementation of a centralized app/website where the user will perceive their stats. This brainstorming process,which bears no judgment, alongside the analysis on which conceptual designs are the most optimal, will be shared with our client during the next meeting. When we share our ideas, we will listen to our client's verbal and non-verbal responses while empathizing with them. We will try to understand what they like and do not like about the design and further iterate our concept development/ideation process.

Functional Decomposition

The functional decomposition of our product enlists the series of tasks the user, as well as the design team, has to complete to satisfy the customer needs outlined in Project Deliverable B. Most importantly, we separated our main function of our product, which is to allow athletes and coaches to measure their athletic performance, into three main subsystems:

1. The product's ability to detect and collect data during a performance
2. The product's ability to categorize and analyze the data based on performance
3. The implementation of a centralized app/website where the user will perceive their stats.

Furthermore, we outlined the tasks to complete each subsystem in a detailed functional decomposition.

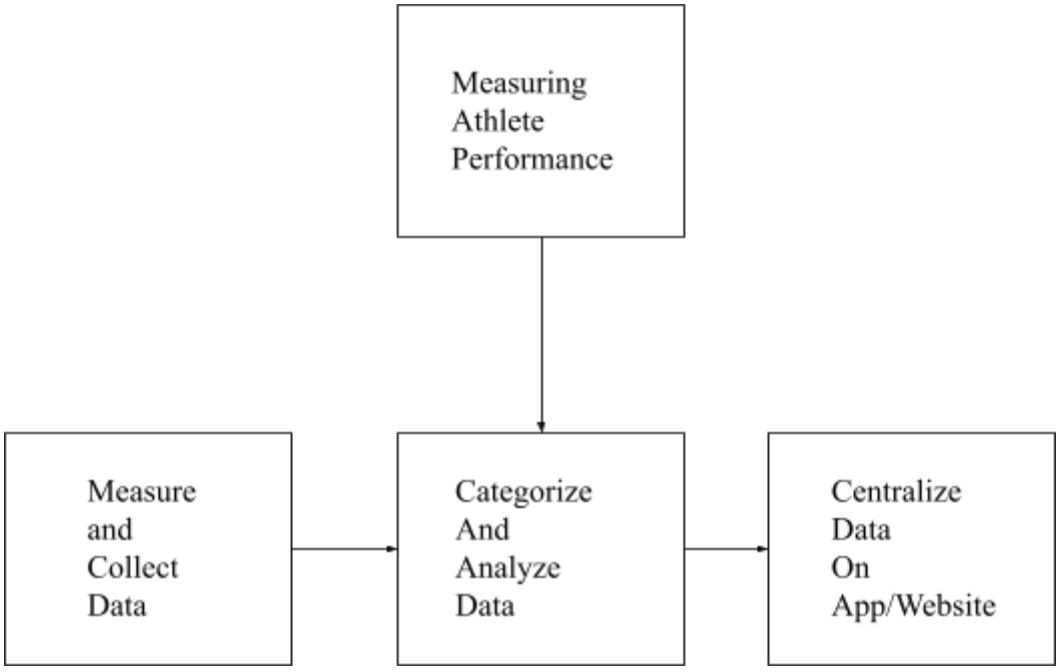


Figure 1. High-level decomposition of athlete statistics measurement product.

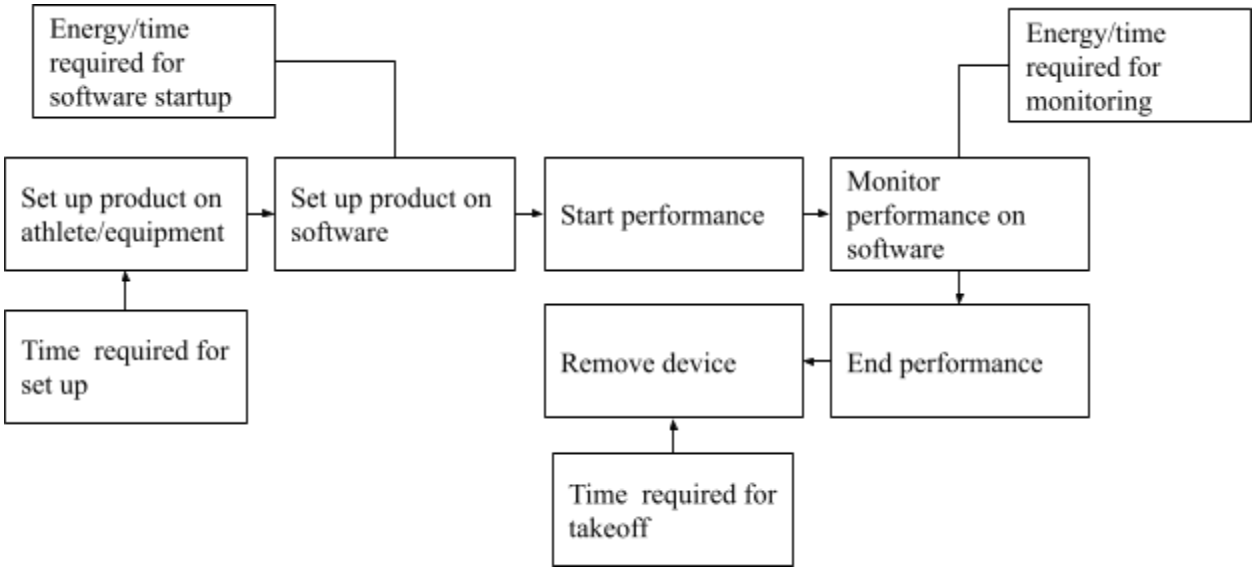


Figure 2. Detailed functional decomposition of first subsystem

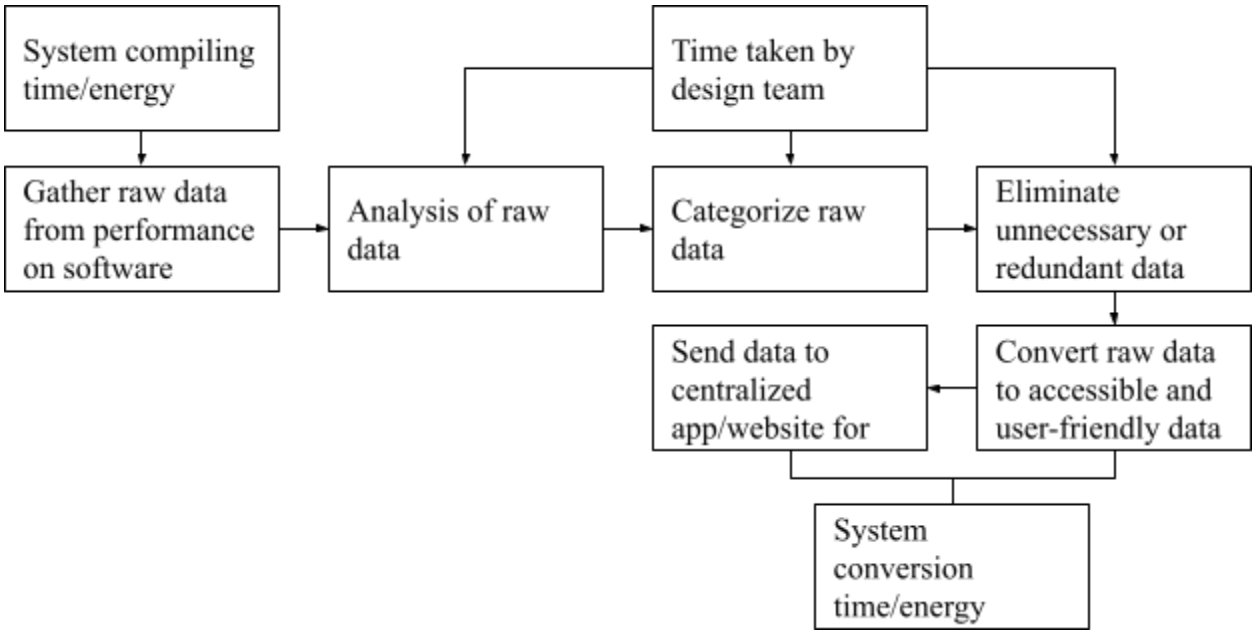
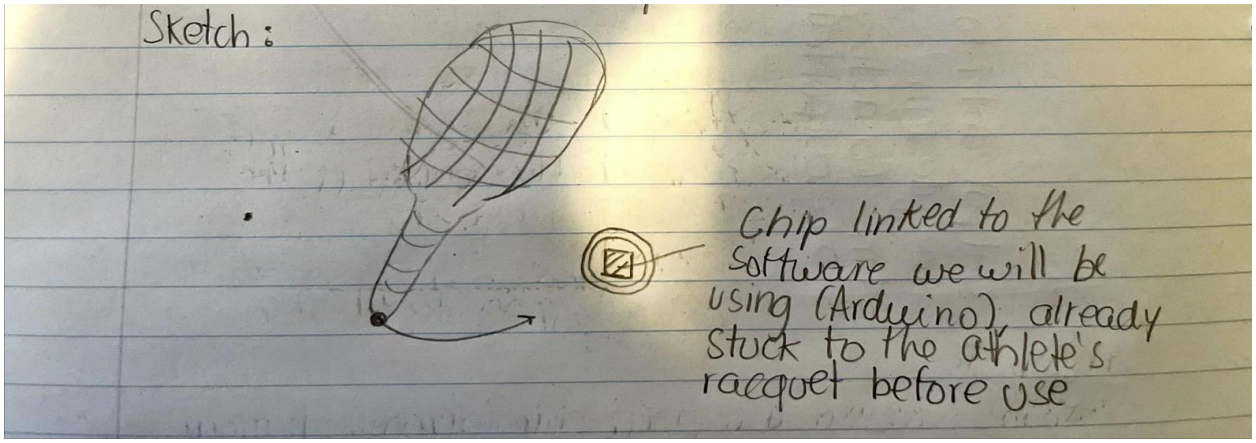


Figure 3. Detailed functional decomposition of second and third subsystems.

Analysis and Evaluation of Design Concepts

Laura's Product Concepts

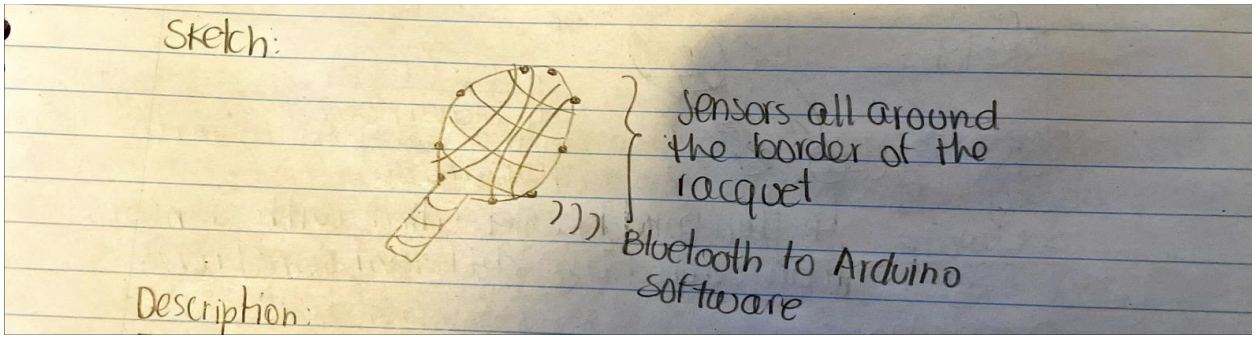
Concept 1: Focuses on Subsystem 1-2



Description: The product consists solely of a chip that will be glued underneath the athlete's racquet. It will be specifically glued to the base of the racquet, where most of the movement occurs and will be placed prior to the athlete's performance. This will reduce and set up time that needs to be done and will not hinder their performance as it is a seamless chip. The chip is connected to the software used by the design team via Bluetooth and acts as a mini computer as it continually collects the data and transfers it to the software in real time.

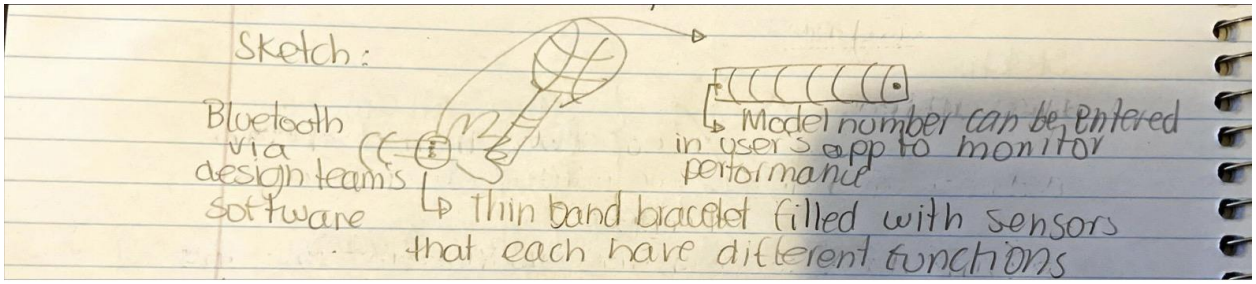
Material: Same material used for a micro bit/Arduino. The chip will be glued with adhesives for laptop manufacture (acrylics, epoxies, etc.) and will be coated with rubber or plastic material to ensure that there is no damage to the chip.
Other uses: It is accessible for other sports as it only includes a chip. The variables that it reads can be tweaked depending on the sport.
Users: Athletes, coaches or anyone looking to improve sport performance, either recreatively or competitively.

Concept 2: Focuses on Subsystem 1-2



Description: Instead of having a singular chip, sensors all around the border of the racquet will allow the design team to receive more data during the athlete's performance. The data can then be averaged to get more accurate values for a singular technique. The sensors are connected to the design's team software via Bluetooth which allows the team to watch the data being stored in real time. The sensors will have to be prepared and attached before the performance as it will take too much time to set up before the practice/game. They will either be stuck the same way as the chip in Concept 1 or will be connected on a singular band which wraps perfectly around the border of the racquet.
Material: The sensor itself will have the same material as the chip in Concept 1 and will also be coated with a thin layer of rubber or plastic to allow for more durability as it is in more contact with the ball during performance.
Other uses: This can be installed for other racquet sports (e.g badminton), but not most sports as it would be too difficult to install for sports that do not have the same physical equipment as racquet sports.
Users: Athletes, coaches or anyone looking to improve sport performance, either recreatively or competitively. More specifically for those playing or interested in racquet sports.

Concept 3: Focuses Subsystem 1-3



Description: Instead of having sensors all around the racquet, a band-sensored bracelet will be provided to each athlete so that they can wear it during their performance. It will be adjustable and breathable to ensure that there is no performance hindrance. The sensors function the same way as in Concept 2, but will have more functions as it is wrapped around the wrist of the player and not just the equipment. These functions include heart beat rate during a specific technique, oxygen levels, etc. The band will also have a unique model number that the user can input in an app/website designed by the team to allow them to see their own data as it is categorized and made easy to navigate through. It can also be shared among other teammates and coaches, making it centralized.

Material: Mesh-like band bracelet, allowing it to be breathable, flexible and light. The sensors, which are seamless through the mesh.

Other uses: It is accessible for other sports; the variables that it reads can be tweaked depending on the sport. More interestingly however, just like a Fitbit or an Apple Watch, it can also be used for everyday life to track activity or performance level.

Users: Athletes, coaches or anyone looking to improve their performance.

Concept Evaluation and Analysis

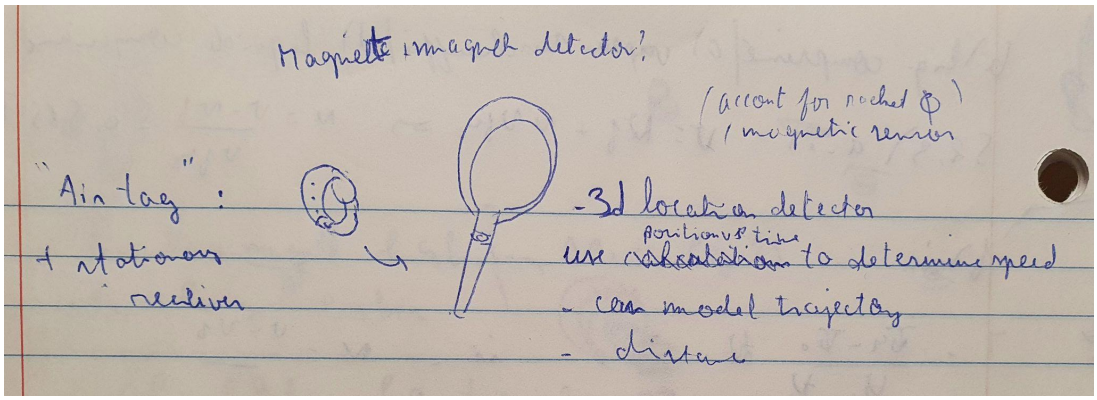
Metric #	Metric	Weight 1/(5-priority+1)	Concept 1 performance	Concept 2 performance	Concept 3 performance
1	Maximum and minimum speed measurable	1	5/5	5/5	4/5
2	Maximum and minimum impact force measurable	1	2/5	5/5	4/5
3	Maximum distance recordable	0.33	1/5	4/5	3/5
4	Record trajectory	0.33	4/5	5/5	3/5
5	Choice of materials	0.25	4/5	3/5	2/5
6	Maximum data storage	0.5	N/A	N/A	N/A
7	Data sorting	0.33	N/A	N/A	N/A
8	Maximum weight	1	5/5	4/5	3/5
9	Maximum size of device	1	5/5	3/5	3/5
10	Set up time	0.5	4/5	1/5	3/5
11	Output data as graphs	0.5	N/A	N/A	N/A
12	Maximum cost	0.5	4/5	1/5	1/5
13	Adaptability to parasports	0.25	5/5	3/5	5/5
14	Minimum life expectancy	1	3/5	2/5	4/5
15	Waterproofness	1	3/5	2/5	4/5
16	Centralization of the data	0.33	N/A	N/A	N/A
Total	**Weighted**		45/5 = 9.0	38/5 = 7.6	39/5 = 7.8

	Average				

Thus, according to the table above, the three concepts have been compared against our design metric criteria outlined in Project Deliverable B and Concept 1 would be the best solution among the three that would best respond to the needs of our client. Most importantly, the chip is within our 50$ budget and is the most feasible idea as we have more knowledge and expertise around that sort of method of measuring athlete performance. It has the shortest set up time which will allow no hindrance in the athlete's routine and its optimal position will allow the accurate and effective measurement of data with the least amount of material. It can also be further developed as we implement some sort of centralized application or website to complement the third subsystem.

Yassine's product concepts:

Concept 1: Subsystem 1



Magnetic localisation: The purpose is to locate the position of the racket using a magnetic piece that would be attached to the racket, and a magnet sensor placed nearby that would capture the fluctuations of the magnetic field over time and from that we can derive position, speed and trajectory in acceptable accuracy. Impact force would be calculated via simplified equations resulting in even less accuracy. Distance would be insignificant since the device needs to be close to the receiver so it will probably only be used for swing training and not in an actual game setting.

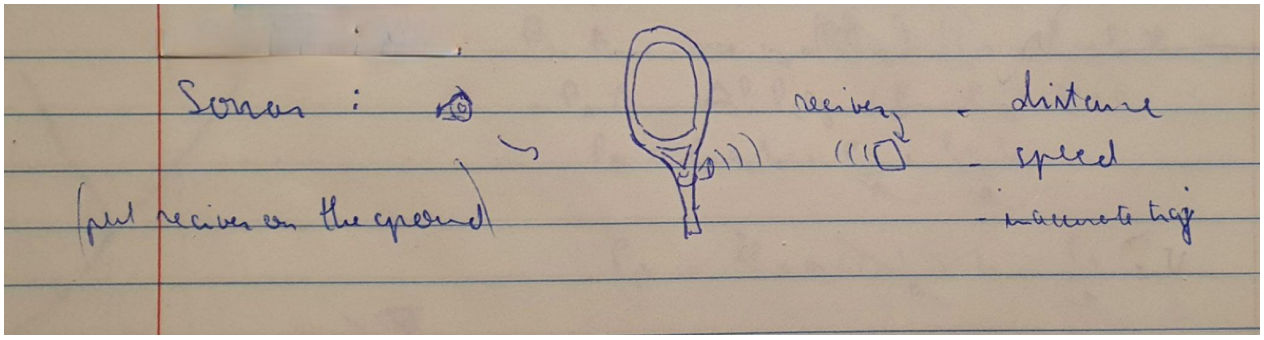
Materials are mainly metals for the sensors, and small amounts of plastic that can be recycled. The size and weight of the device only concerns the part that is attached to the racket (i.e., the magnet) which is way below the target specifications.

The sensors can be set up on any computer using an arduino board for example, and the magnet can be attached rapidly to any type of racket. The sensor set up only needs to be done once for all the tests in a session.

The cost falls below our budget constraints since the few elements composing the device can be found easily on the market at affordable prices.

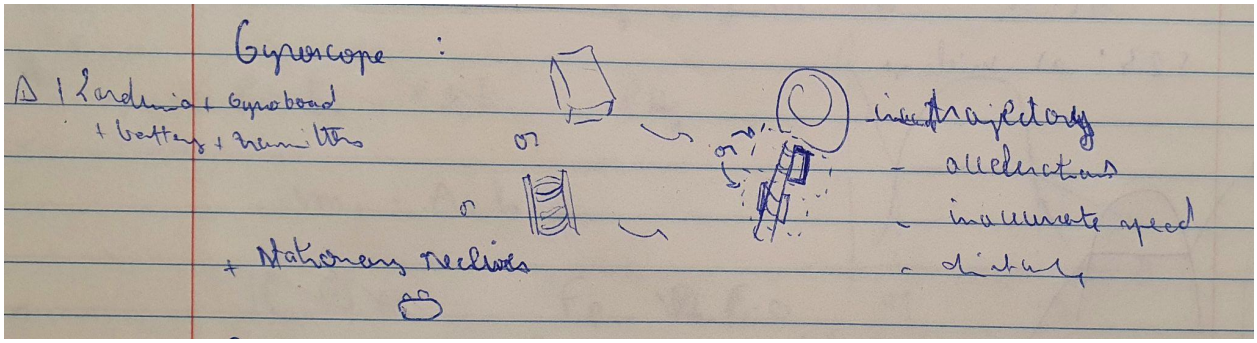
The device is versatile as it can be used on any type of swing motion so implementation in parasports is highly possible.
The sensors operate on low energy and the batteries can be replaced easily.
Water does not affect magnetic waves in a significant way to alter test results. Magnets can be coated to prevent rusting.

Concept 2: Subsystem 1



Sonar: The purpose is to locate the position of the racket using sound waves, a transmitter will be placed near the player, and a receiver will be attached to the racket, this will allow continuous information on the position of the racket with high accuracy. Speed can also be derived with the same accuracy, but the trajectory can be compromised due to the difficulty of 3D localisation using sound waves. Impact force would be an approximation as well, and the distance is not significant for the same reasons as before.
Materials are mainly metals for the sensors, and small amounts of plastic that can be recycled.
The size and weight of the device only concerns the part that is attached to the racket (i.e., the receiver) which is way below the target specifications.
The sensors can be set up on any computer using an arduino board, and the setup only needs to be done once for all the tests in a session. The size and weight of the device should allow the design of a rapid attachment method.
The cost falls within our budget constraints since the few elements composing the device can be found easily on the market at affordable prices and our team members are willing to use some of their own.
The device is versatile as it can be used on any type of swing motion so implementation in parasports is highly possible.
The sensors operate on low energy and the batteries can be replaced easily.
The device will need to be enclosed in a waterproof case.

Concept 3: Subsystem 1 and 2

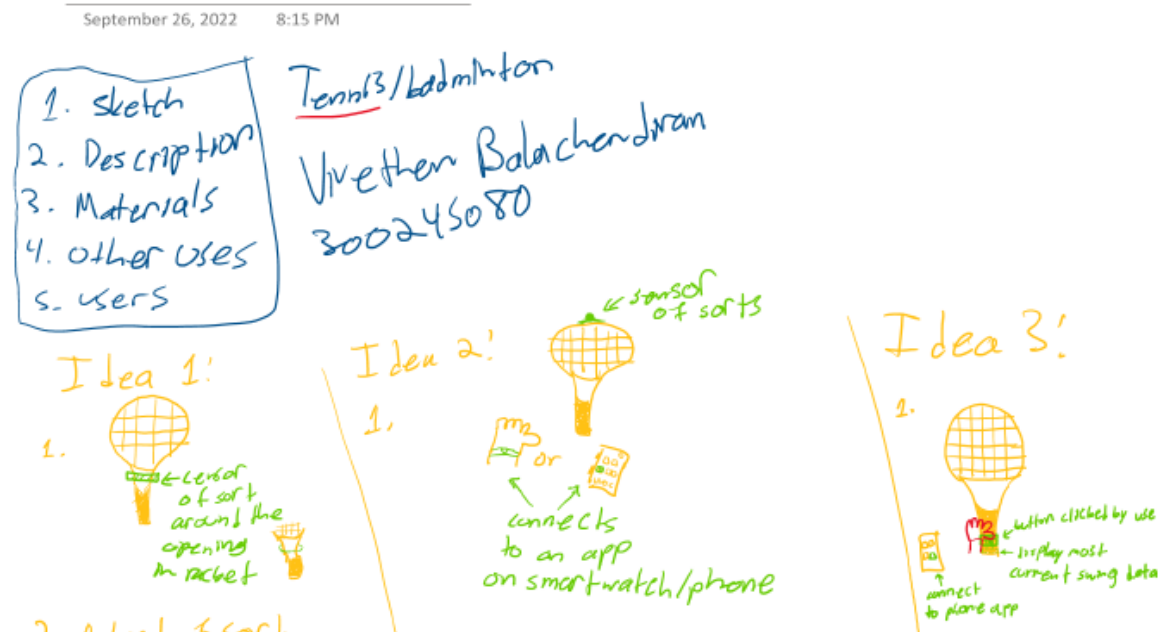


Gyroscope: The purpose is to use the accelerations measured by the gyroscope attached to the racket to determine its 3d trajectory and rotation which will allow precise categorization of data. Recording the initial setting will allow us to calculate the speed and 2D trajectory, although not very accurately. Data will be sent from the gyroscope, linked to an arduino board probably, via bluetooth to the computer so the distance is not significant for the same reasons as before.
Materials are mainly metals for the sensors, and small amounts of plastic that can be recycled.
The size of the device might be a concern because there will be at least two boards plus some wires so the organization will be very important to fit all the components.
Depending on the solution found to attach the device to the racket, the set up time could get bigger because it is more complexe.
The use of several components can increase the price, but all the elements can be either supplied by our team members or found at an affordable price.
The device is versatile as it can be used on any type of swing motion so implementation in parasports is highly possible.
The sensors operate on low energy and the batteries can be replaced easily.
The device will need to be enclosed in a waterproof case.

Metric #	Metric	Priority	Weight 1/(5-priority+1)	Idea 1	Score	Idea 2	Score	Idea 3	Score
1	Maximum and minimum speed measurable	5	1	4/5	0.8	5/5	1	3/5	0.6
2	Maximum and minimum impact force measurable	5	1	3/5	0.6	3/5	0.6	3/5	0.6
3	Maximum distance recordable	3	0.33	1/5	0.066	1/5	0.066	1/5	0.066
4	Record trajectory	3	0.33	4/5	0.264	3/5	0.198	4/5	0.264
5	Choice of materials	2	0.25	4/5	0.2	4/5	0.2	4/5	0.2
6	Maximum data storage	4	0.5	N/A	N/A	N/A	N/A	N/A	N/A
7	Data sorting	3	0.33	N/A	N/A	N/A	N/A	N/A	N/A
8	Maximum weight	5	1	5/5	1	5/5	1	4/5	0.8
9	Maximum size of device	5	1	5/5	1	5/5	1	3/5	0.6
10	Set up time	4	0.5	5/5	0.5	5/5	0.5	4/5	0.4
11	Output data as graphs	4	0.5	N/A	N/A	N/A	N/A	N/A	N/A
12	Maximum cost	4	0.5	5/5	0.5	5/5	0.5	4/5	0.4
13	Adaptability to parasports	2	0.25	5/5	0.25	5/5	0.25	5/5	0.25
14	Minimum life expectancy	5	1	5/5	1	5/5	1	5/5	1
15	Waterproofness	5	1	5/5	1	3/5	0.6	3/5	0.6
16	Centralization of the data	3	0.33	N/A	N/A	N/A	N/A	N/A	N/A
Total					7.18		6.914		5.78

Vivethen's product concepts:

Concept 1-3:



Idea 1:

- A band of sorts that acts as a smartwatch will be used to store and output data. (This band can be attached to the racquet's center, right below the net and above the grip)
- Materials will consist of a rubber-like band for elasticity on the equipment to keep it in place, the technology itself will use software related materials
- Other potential features include those of a normal smartwatch, like a timer/clock
- Used by athletes and anyone wanting to improve in sports

Idea 2:

- A sensor is attached to the top most part of the racquet and sends data via bluetooth to the user's smartphone/smartwatch via an app
- Materials include the sensor and something to attach the sensor to the racquet, we assume the user has a phone/smartwatch to run the app
- May sense other things like the distance the user may be from a ball or any object
- Same people as idea one plus possibly diabled (blind people) who require sensors to prevent bumping into things

Idea 3:

- A button and number display are on the grip part of the racquet, when the user swings they either hold or push the button to activate the measurements, the data is recorded and then outputted immediately on the display while also being forwarded to an app for further analyzing

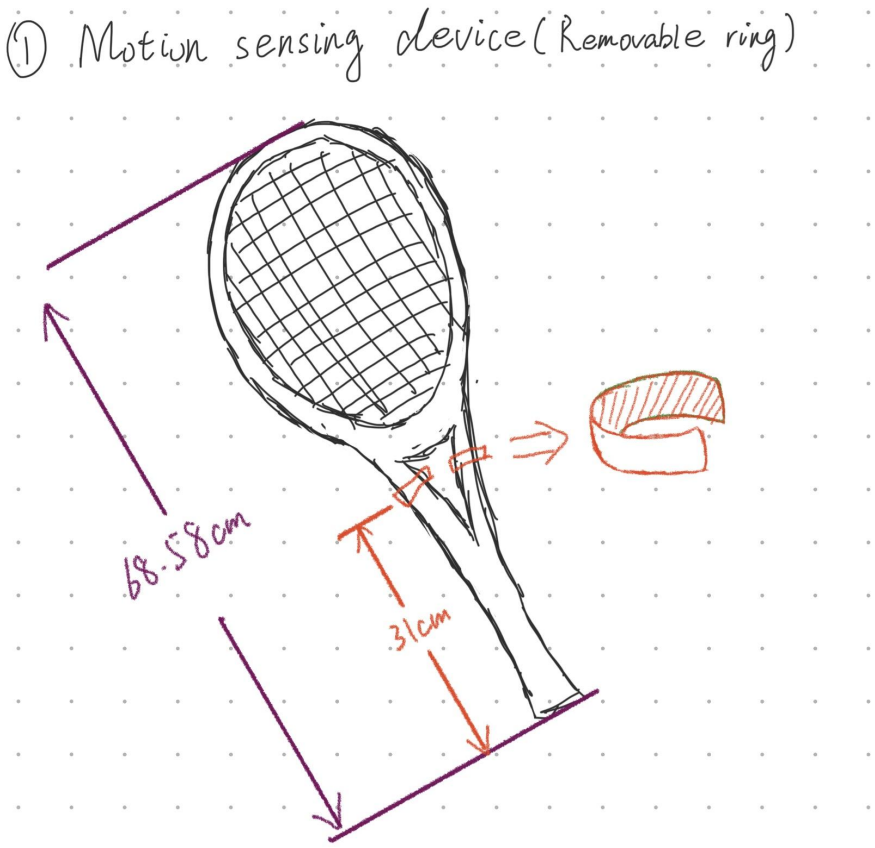
- Small 7 segment display, small easy to activate button, comfy material to prevent interference with the user's swing
- Can also be used as a timer or stopwatch by pressing the button to start/stop it
- Same people as idea one

Metric #	Metric	Weight 1/(5-priority+1)	Product 1 performance	Product 2 performance	Product 3 performance
1	Maximum and minimum speed measurable	1	5/5	5/5	4/5
2	Maximum and minimum impact force measurable	1	2/5	3/5	2/5
3	Maximum distance recordable	0.33	3/5	4/5	3/5
4	Record trajectory	0.33	2/5	2/5	4/5
5	Choice of materials	0.25	2/5	2/5	1/5
6	Maximum data storage	0.5	N/A	N/A	N/A
7	Data sorting	0.33	N/A	N/A	N/A
8	Maximum weight	1	4/5	3/5	2/5
9	Maximum size of device	1	4/5	3/5	4/5
10	Set up time	0.5	4/5	2/5	1/5
11	Output data as graphs	0.5	N/A	N/A	N/A
12	Maximum cost	0.5	1/5	1/5	2/5
13	Adaptability to parasports	0.25	5/5	5/5	5/5
14	Minimum life expectancy	1	2/5	2/5	3/5

15	Waterproofness	1	2/5	1/5	1/5
16	Centralization of the data	0.33	N/A	N/A	N/A
Total	**Average**		36/5 = 7.2	33/5 = 6.6	32/5 = 6.4

Jiayi's product concepts:

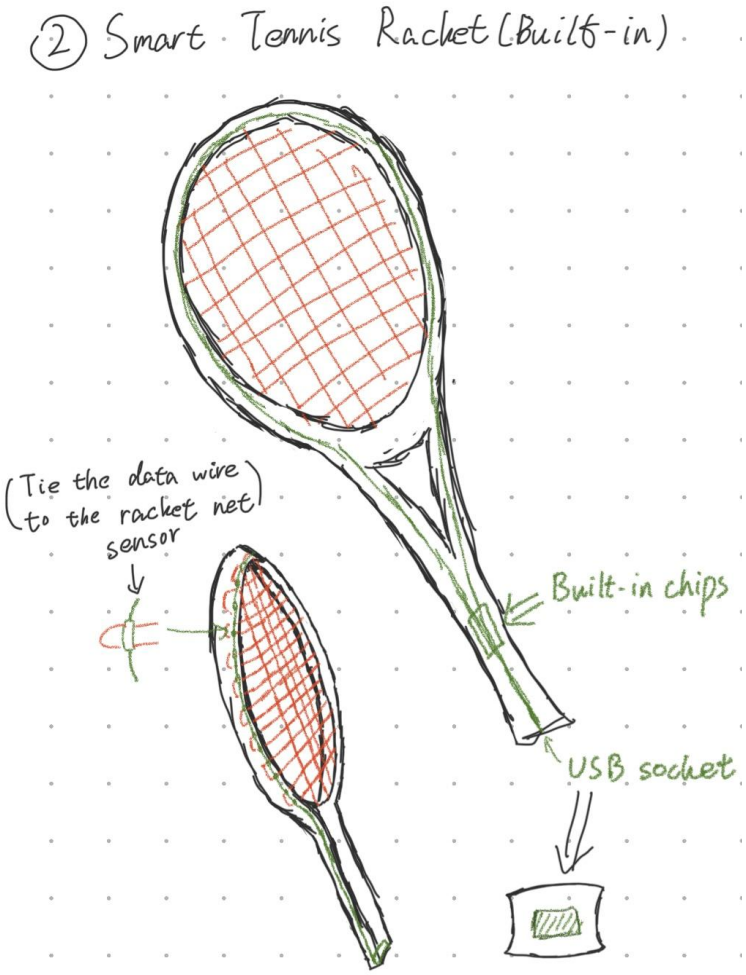
Concept 1:Subsystem 1



Description: This product is designed as a sensing removable ring, which is a pair of rings and will be applied to both sides of the racket shaft. The product is also designed with notches for easy assembly and disassembly. The diameter of the rings should be designed to be placed at the distance of 31 cm from the bottom of the handle; this position is the balance point of the racket, and the rings set at this position can avoid the imbalance of the weight ratio between the net and the handle. As well as the symmetrical design, that is, the installation of two measuring instruments, can avoid uneven masses and the possibility of measuring two parameters at the same time, thus avoiding extreme values of the data. The rings will have a built-in sensor chip and will be connected to the application via Bluetooth for data collection by the test team.
Material: Aluminum or other light alloys; Chip material may be silicon crystal material.

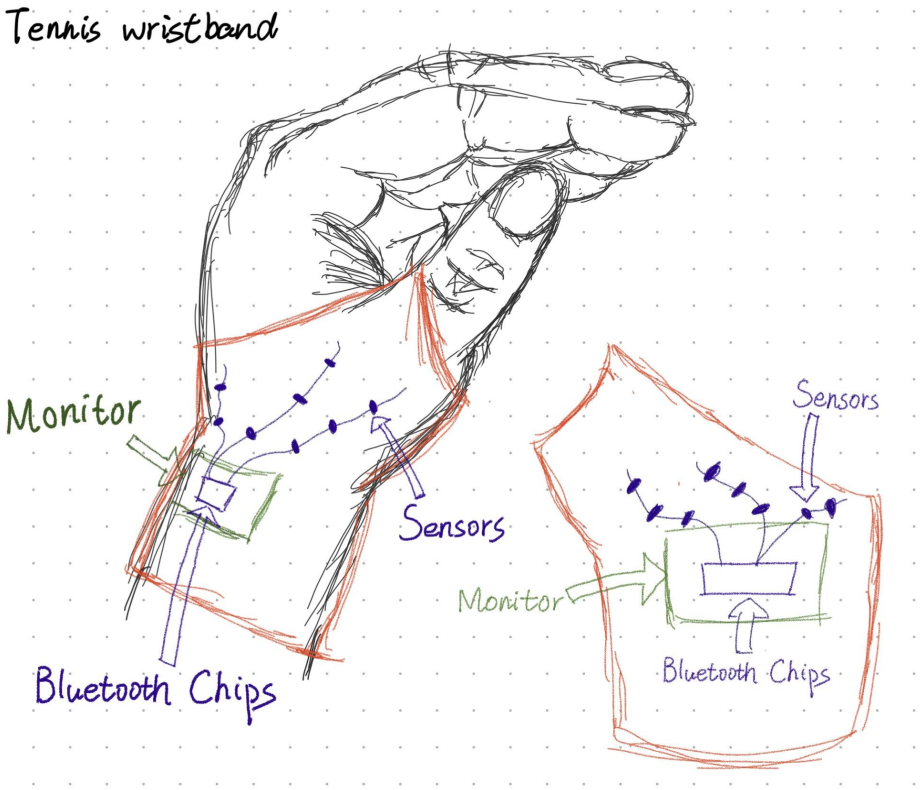
Other uses: Can be used to track daily training.
Users: Athletes, coaches and tennis sport fans.

Concept 2:Subsystem 1-3



Description:This product needs a wired sensor. We can use the sensor to connect the data cable to the net, and collect data about the speed and impact force through the vibration of the net. The product will likely use a built-in design where the cables and sensor are inside the racket. The outputs can be connected to the built-in chip which is in the racket handle, and finally output through the usb socket.
Material: Conductor material: Copper plated. Insulation Materials. chip material. Usb socket material.
Other uses:Can be used to track daily training.
Users:Athletes, coaches and tennis sport fans.

Concept 3:Subsystem 2-3



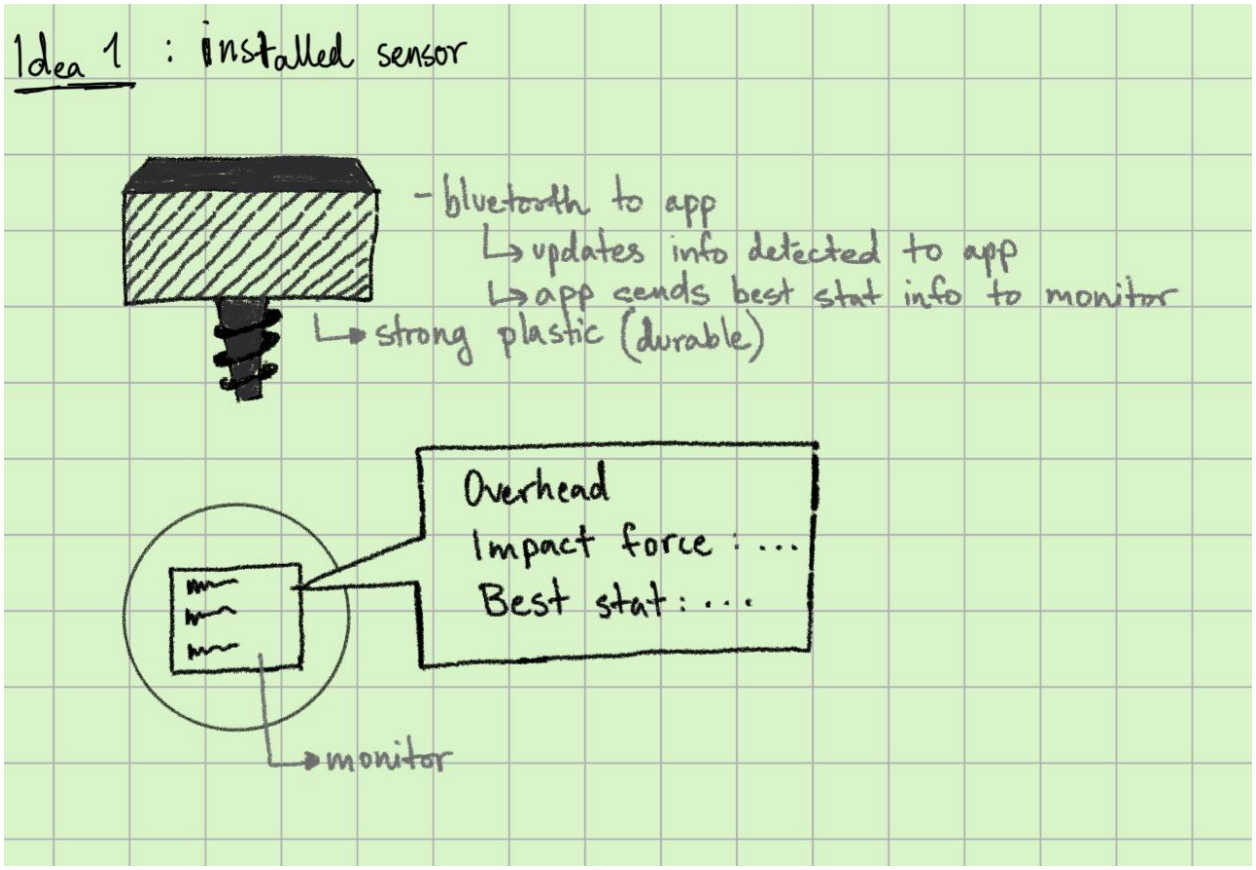
Description:This product consists of wired sensors, a Bluetooth chip and a semi-covered wristband. Meanwhile, this product will be ergonomically designed and committed to provide customers with a comfortable product experience. The product will focus on the two different functions, which are data collection and wrist protection (shock absorption, sweat absorption and anti-slip). This wristband will be designed as an integrated sensor. That is, the sensors will be mounted on the palm of the hand, and the data will be transferred from the palm in contact with the handle to the chip by collecting the vibration frequency, swing angle and other data. The function of this wristband is similar to most sports bracelets, but compared to sports bracelets, it will be more comfortable as well as more functions than bracelets.
Material:Rubber, sensor materials, display materials, chip materials.
Other uses:Protecting the wrist.
Users:Athletes and tennis sport fans.

Concept Evaluation

Metric #	Metric	Weight 1/(5-priority+1)	Concept 1 performance	Concept 2 performance	Concept 3 performance
1	Maximum and minimum speed measurable	1	5/5	5/5	5/5
2	Maximum and minimum impact force measurable	1	3/5	5/5	4/5
3	Maximum distance recordable	0.33	2/5	3/5	1/5
4	Record trajectory	0.33	5/5	5/5	1/5
5	Choice of materials	0.25	3/5	3/5	4/5
6	Maximum data storage	0.5	N/A	N/A	N/A
7	Data sorting	0.33	N/A	N/A	N/A
8	Maximum weight	1	1/5	3/5	5/5
9	Maximum size of device	1	5/5	1/5	4/5
10	Set up time	0.5	4/5	4/5	3/5
11	Output data as graphs	0.5	N/A	N/A	N/A
12	Maximum cost	0.5	3/5	1/5	2/5
13	Adaptability to parasports	0.25	4/5	5/5	4/5
14	Minimum life expectancy	1	3/5	3/5	4/5
15	Waterproofness	1	4/5	3/5	2/5
16	Centralization of the data	0.33	N/A	N/A	N/A
Total	**Weighted Average**		5.712	5.428	5.832

Chelse's product concepts:

Concept 1 (focuses on subsystem 1 and 3):

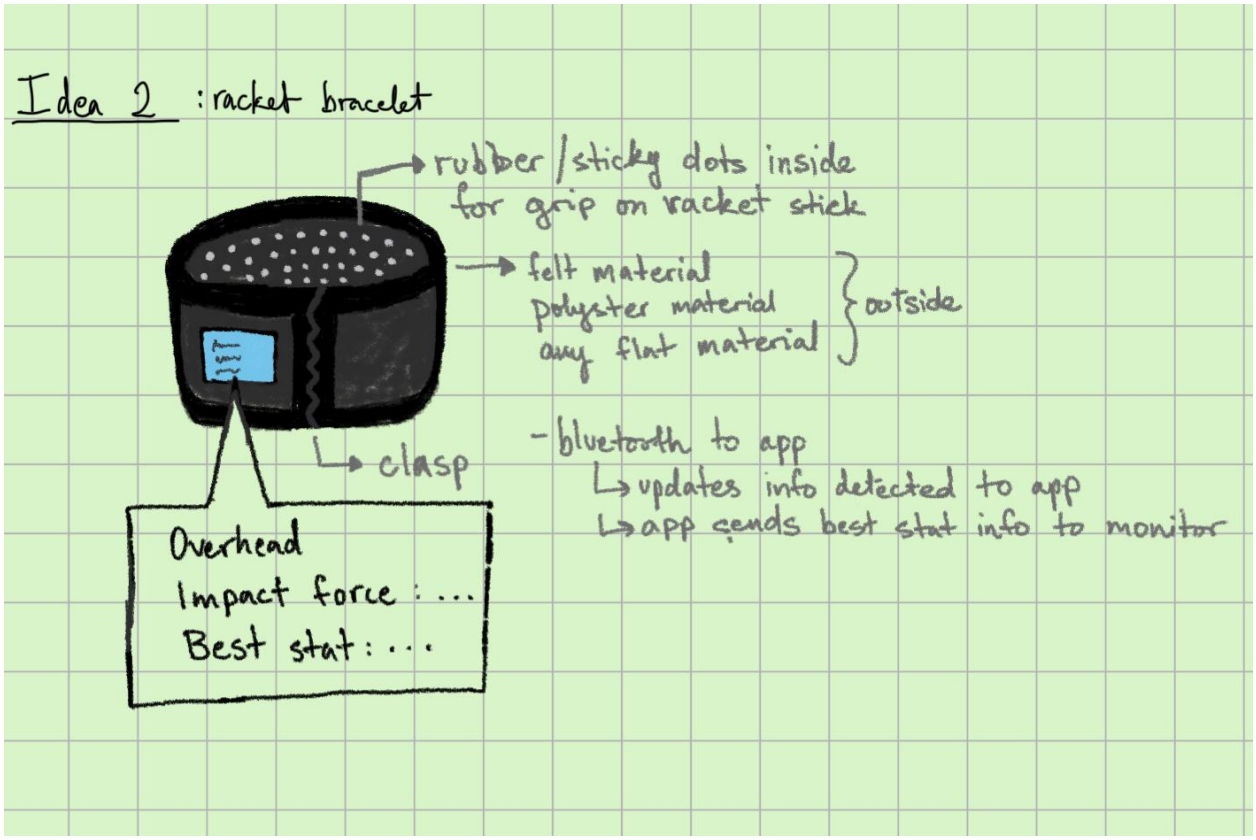


Idea 1:

- An installed sensor to the base of the racket that sense impact force, speed, and all other necessary information
- Material will consist of plastic making it light
- Includes a monitor that shows best stat and current stat in the testing technique
- Is connected to an app via bluetooth and constantly update stats in the app

Metric #	Metric	Priority	Weight 1/(5-priority+1)	Product performance	Score
1	Maximum and minimum speed measurable	5	1	4/5	0.8
2	Maximum and minimum impact force measurable	5	1	4/5	0.8
3	Maximum distance recordable	3	0.33	4/5	0.8
4	Record trajectory	3	0.33	4/5	0.8
5	Choice of materials	2	0.25	5/5	1
6	Maximum data storage	4	0.5	5/5	1
7	Data sorting	3	0.33	5/5	1
8	Maximum weight	5	1	5/5	1
9	Maximum size of device	5	1	5/5	1
10	Set up time	4	0.5	5/5	1
11	Output data as graphs	4	0.5	5/5	1
12	Maximum cost	4	0.5	4/5	0.8
13	Adaptability to parasports	2	0.25	5/5	1
14	Minimum life expectancy	5	1	5/5	1
15	Waterproofness	5	1	5/5	1
16	Centralization of the data	3	0.33	5/5	1
Total					15

Concept 2 (focuses on subsystem 1 and 3):

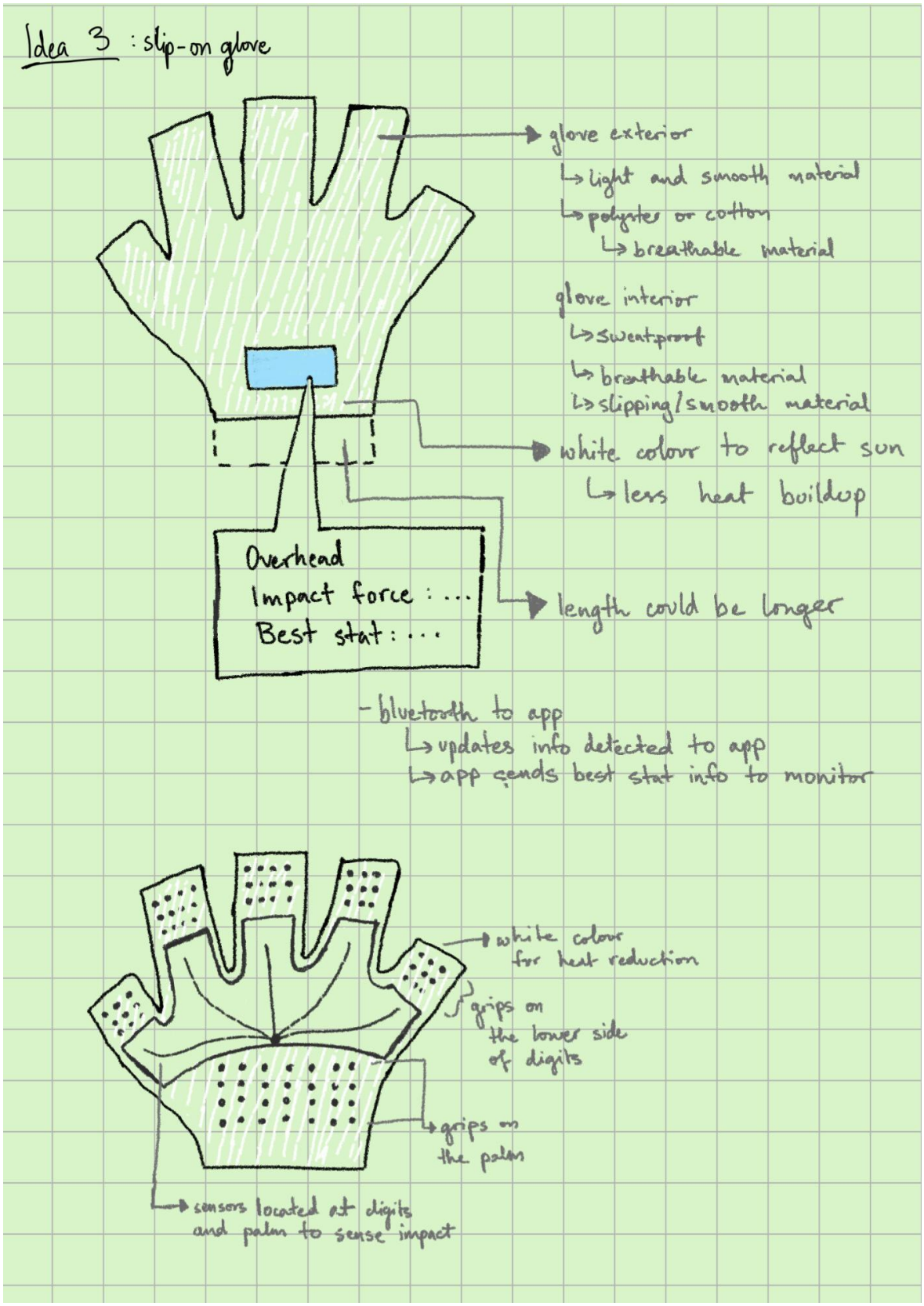


Idea 2:

- A bracelet placed around the racket that sense impact force, speed, and all other necessary information
- Material will consist of lightweight fabric on the outside and rubber dots on the inside for grip
- Includes a monitor that shows best stat and current stat in the testing technique
- Is connected to an app via bluetooth and constantly update stats in the app

Metric #	Metric	Priority	Weight 1/(5-priority+1)	Product performance	Score
1	Maximum and minimum speed measurable	5	1	4/5	0.8
2	Maximum and minimum impact force measurable	5	1	4/5	0.8
3	Maximum distance recordable	3	0.33	4/5	0.8
4	Record trajectory	3	0.33	4/5	0.8
5	Choice of materials	2	0.25	5/5	1
6	Maximum data storage	4	0.5	5/5	1
7	Data sorting	3	0.33	5/5	1
8	Maximum weight	5	1	5/5	1
9	Maximum size of device	5	1	5/5	1
10	Set up time	4	0.5	5/5	1
11	Output data as graphs	4	0.5	5/5	1
12	Maximum cost	4	0.5	4/5	0.8
13	Adaptability to parasports	2	0.25	5/5	1
14	Minimum life expectancy	5	1	5/5	1
15	Waterproofness	5	1	3/5	0.6
16	Centralization of the data	3	0.33	5/5	1
Total					14.4

Concept 3 (focuses on subsystem 1 and 3):


Idea 3 : slip-on glove
glove exterior
↳ light and smooth material
↳ polyster or cotton
↳ breathable material
glove interior
↳ sweatproof
↳ breathable material
↳ slipping/smooth material
white colour to reflect sun
↳ less heat buildup
Overhead
Impact force : ...
Best stat : ...
length could be longer
- bluetooth to app
↳ updates info detected to app
↳ app sends best stat info to monitor
white colour for heat reduction
grips on the lower side of digits
grips on the palm
sensors located at digits and palm to sense impact

Idea 3:

- A slip on glove that is for the player that sense impact force, speed, and all other necessary information
- Material will consist of lightweight fabric on the outside and rubber dots on the inside for grip on to the racket
- Includes a monitor that shows best stat and current stat in the testing technique
- Includes sensors along the bottom of the digits and palm to be able to detect precise information
- Is connected to an app via bluetooth and constantly update stats in the app

Metric #	Metric	Priority	Weight 1/(5-priority+1)	Product performance	Score
1	Maximum and minimum speed measurable	5	1	4/5	0.8
2	Maximum and minimum impact force measurable	5	1	4/5	0.8
3	Maximum distance recordable	3	0.33	4/5	0.8
4	Record trajectory	3	0.33	4/5	0.8
5	Choice of materials	2	0.25	5/5	1
6	Maximum data storage	4	0.5	5/5	1
7	Data sorting	3	0.33	5/5	1
8	Maximum weight	5	1	5/5	1
9	Maximum size of device	5	1	5/5	1
10	Set up time	4	0.5	5/5	1
11	Output data as graphs	4	0.5	5/5	1
12	Maximum cost	4	0.5	4/5	0.8
13	Adaptability to parasports	2	0.25	5/5	1
14	Minimum life expectancy	5	1	5/5	1
15	Waterproofness	5	1	3/5	0.6
16	Centralization of the data	3	0.33	5/5	1
Total					14.4

Group Design Concept

Our final group design concept is a combination of a Bluetooth chip and sensors connected directly to the chip. We decided on this approach because we figured that the Bluetooth chip can only transmit the data that is being sent to it, but cannot actually read or analyze that data. In other words, it is a medium between subsystem 1 and subsystem 2. Subsystem 1 is therefore the sensor that will be reading different categories of the athlete's performance, which is connected directly to the Bluetooth chip, which then transmits to the Arduino software. The Arduino software, alongside the code implemented by the design team, is subsystem 2, as it will analyze and categorize that raw data for the team. Furthermore, we want to implement another output from the Arduino software to a centralized website.

The benefits of this concept is how little to no setup is required as we only need to set up the chip on the racquet (the sensors will already be connected to the chip). Plus, having different components that each do a singular subsystem will allow for better control of our data and its subsequent analysis. However, the drawbacks of this concept is that although we know *what* it should do theoretically, due to the lack of resources, we are not sure *how* we should do it. This will be an area of improvement during the testing and prototyping phase.