ME 476C – Smart Helmet

Preliminary Report

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DISCLAIMER

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1 BACKGROUND

1.1 Introduction

Injuries occur every day and especially when one plays in any physical contact sports, whether that is from hockey to simply as riding a bicycle. Traumatic brain injuries occur when an impact against the head is taken or rapid movements of the head. These brain injuries can have long-term effects on people. A smart helmet will be able to protect the user as they are playing their respective sport by analyzing the environment and make any preparations to ensure the safety of the person. This task will be done by using sensors to see the oncoming impact and have a sensor harden a specific material as the helmet reads the current situation. At the same time, the smart helmet will be able to collect data of the impact and will be able to be accessed to any personnel of the respective sport. As of now, the team will focus on the American sport, football. This will allow the team to focus on one sport and create a system that will be able to withstand constant impacts and be able to monitor players as they play so any staff can determine the player's eligibility. Once testing is completed, the team will be able to create a smart helmet for any sports.

1.2 Project Description

Following is the original project description provided by the sponsor.

> "Falls, accidents are major causes of traumatic brain injury. Traumatic brain injury occurs due to the impact of the head against objects or rapid movement of the head and can have long-term effects on people. While the major task of a helmet is to protect the head against impacts and constrain its motion to prevent very rapid motions, it should also be able to provide data on performance of the helmet as well as health of the person. A smart helmet should first protect the head against impacts/rapid motion to the best possible, and second can monitor and record the acceleration of the head and the impact forces (upon accident or fall) and based on those data make suggestions to the user. It should also optimize the user's performance in terms of speed, safety and other important criteria. You will design a smart helmet with great protection capability against impacts which will be able to recognize the risk of brain injury by monitoring and recording head kinematics as well as optimize the user's performance. Teams may be tasked with a specific sport in mind or make the project applicable to all sports." [1]

1.3 Original System

This project involved the design of a completely new smart helmet system. There was no original system when this project began.

2 REQUIREMENTS

Chapter 2 contains the customer requirements obtained from the client and the engineering requirements that specify the measurable parameters or conditions of the customer needs. Lastly is the house of quality that is based from the customer requirements and engineering requirements.

2.1 Customer Requirements (CRs)

The CRs of the project are listed as follows along with their weights:

-High Protection (5)

High protection is listed as the highest weight because safety is the priority of the client.

-Similar size of helmet (4)

The size of the helmet is a four because the client wants the smart helmet to be similar to those helmets in the current market. No company wants a helmet that is too large and heavy, this does not make sense, so the size of helmet does matter.

-Life Expectancy (4)

The smart helmet should be able to function as a helmet and last as long as a regular helmet.

-More Comfortable (3.5)

The smart helmet needs to be comfortable to the user to ensure the safety of their well-being.

-Transmit Data (4.5)

The client wants the team to be able to collect data of the user and impacts occur during their respective sport.

-Small Sensor (3)

The size of the sensor matters because the sensor must be able to fit within the interior of helmet and still function.

-Strong battery (2)

A battery will ensure the life expectancy of the helmet.

2.2 Engineering Requirements (ERs)

The ERs of the project are based of the CRs in the previous section. The requirements are listed as follows:

-Decrease Impulse

-Maintain Volume

-Increase factor of safety

-Ductility

-Increase power

-Decrease Diameter

-Increase voltage

2.3 House of Quality (HoQ)

The HoQ, which can be seen in Appendix A, aided the team's decision as the coming up with design solutions which can be seen in chapters three and four. The HoQ enabled the team to choose what is the most important part the team should focus on and how to improve the design to create a new design. The requirements are based from the previous two sections of this chapter. These requirements tells how the team will implement a new system into the helmet while remaining to the teams intention of the client.

3 EXISTING DESIGNS

Defining the project is important to understand the goal, and the requirements for the project. The next step after understanding the project is to learn about existing designs. One approach to designing a new, re-engineered system is to learn about the technology that is currently available before coming up with designs. Information on existing products are found from the internet and through engineering literature. This section contains research on existing designs at the system level, functional decomposition, and subsystem level designs. The system level designs are designs relating to the entire project and help with understanding what technology is available that relates to the project. Functional decomposition consists of understanding the necessary inputs and outputs of the system and the various functions of the project. The subsystem level research helps in gaining a better understanding of various applications of the subsystems of the project.

3.1 Design Research

The process for design research consist of research through the internet and gaining information from faculty that has experience in topics related to the project. The internet was able to provide information of the smart helmet technology that is currently available. Effective keywords such as smart, sensing, and football helmet were used in the internet research process to help find technology that closely relates to the project. Faculty with a background related to the project were also pursued for the design research of the project. Dr. Hesam Moghaddam who is also the client of the project shared about brain injury threshold information and the importance of knowing threshold values for the project. Also Dr. Ciocanel shared his understanding of magnetorheological (MR) fluid and its application to the project.

3.2 System Level

An existing system level design is one that accomplishes requirements similar to the smart helmet project. The system level design research in the project helps with understanding products that have similar requirements as the project. Understanding similar systems will be useful for coming up with design ideas for the project. Understanding systems related to the project assures that the design is new, and also helps with coming up with creative ideas by building from existing systems. The faults in system level designs is important to know so this project can improve on those faults and avoid them.

3.2.1 Existing Design #1: Vicis Morphing Helmet with Innovative Padding Design

The Vicis company smart helmet took the approach of creating a new padding design for their smart helmet. Their design includes columns of padding instead of the conventional block shape padding that normal helmets have. The columns allow the helmet to flex more than other helmets and absorb more of the impact than typical helmets. Figure 1 shows the section of the helmet that Vicis implemented their smart design of column shaped padding. This is useful to the project because one requirement of the smart helmet project is to increase the protection and this design satisfies this requirement by doing a simple change to the padding of the helmet.

Figure 1: Vicis Helmet

3.2.2 Existing Design #2: Riddell Sideline Response System and Insite Impact Response System

The Riddell Insite Response system is an impact monitoring system for football helmets that uses sensors that go in the helmet to collect data and report the data to the sideline. This system shown in figure 2 allows the player to be monitored during a game or practice session for serious head injuries that exceed a calculated threshold. This system-level existing design collects data from impacts with sensors and shares that data which is directly related the customer requirement for the smart helmet project of implementing sensors to collect and share data from impacts. This design is helpful for the project because the system can be used to help guide the design of the sensors in the smart helmet and the data collection and sharing system.

Figure 2: Riddell Insite Sensor

3.2.3 Existing Design #3: Xenith helmets

The Xenith helmets include a reengineered padding system that moves with the head instead of with the hit. The padding reduces linear and angular forces which is one of the customer requirements for the smart helmet project. They also changed the adjustment system that is more variable and allows players to get a more custom fit that increases the comfort. The Xenith helmet padding design is shown in figure 3.

Figure 3: Xenith Helmet

3.3 Functional Decomposition

3.3.1 Black Box Model

Black Box model is one of the most important technique for the engineering project. Figure 4 shows the inputs and outputs for the smart helmet project. The inputs are based on three main categories such as energy, material, and signal. However, both inputs and outputs should satisfy the customer needs toward the smart helmet project. This project should accomplish many important functions such as comfort materials, lightweight, safety, and smart technology. The team decided to include the elasticity material in the helmet for the comfort purpose. Figure 4 shows the elasticity material as input and hardened as output in the black box model. Safety is another important function in customer needs. As a result, the team created the kinetic energy as input and injury as output as discussed in Figure 4. Another important function of the customer needs is lightweight. The team is trying to reach the lightest weight as possible in this design. One way of that is to decrease the weight of the helmet by decreasing the elasticity material. Finally, smart technology is one of the customer needs in this project. As discussed in the Figure 4, the team will create a sensor with a smart technology in this project. This customer need will help the team to improve the features of the helmet.

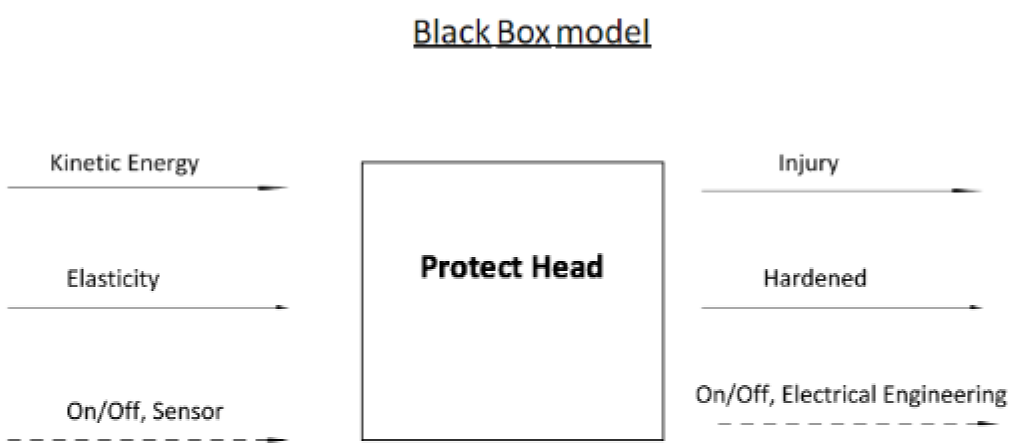

Figure 4: Black Box Model

3.3.2 Functional Model/Work-Process Diagram/Hierarchical Task Analysis

Hypothesized Functional model (HFM) is a very useful technique in this project. The main purpose of the hypothesized functional model is to understand the inputs and outputs of the smart helmet project. It also gives a detailed information about the design project. The HFM is more developed process than the black box model because it breaks the component of the inputs and outputs in detail. Appendix B shows how the components of the customer needs broke down through this project. Appendix B gives the team a brief and detailed ideas about the working process. It helps the team to fully understand how the project works, and what are the main results of this working process. The HFM is a very helpful process for the smart helmet project because it improves the performance of the project. For example, when the team decides to create something, then the team should focus on the results, and the input situation through this design. However, the HFM will help through this situation because it helps the team to know the advantages and disadvantages of the inputs and outputs situation through this project.

3.4 Subsystem Level

After decomposing the project and understanding the inputs and outputs for the system and the various subsystems involved with the project it is important to look at different existing designs that relate to the project. Sensing is a subsystem that is important for the project and was defined in the functional model to be necessary and have a kinetic energy input and a signal output. The next subsystem that is researched is the controllable padding subsystem that relates to the elastic section in the functional model that takes in kinetic energy and a signal and distributes the kinetic energy to the head in a safe way. The last subsystem researched is the data transmission subsystem because from the functional decomposition, the sensor is collecting information and there needs to be a way to transmit the information.

3.4.1 Subsystem #1: Sensing

Sensing is a subsystem defined in the functional decomposition for the smart helmet project that takes kinetic energy input and outputs a signal. To gain a better understanding of this subsystem it is important to investigate existing products that involve this subsystem and see how it is applied. Once knowing how other products apply sensing into their design it will be easier to implement this subsystem into the smart helmet design. Sensing is important to the overall project because it is a requirement from the client to include sensors that can measure linear and angular forces the head can experience in an impact.

3.4.1.1 Existing Design #1: Accelerometers in Phones and Laptops

Phones accelerometers sense acceleration forces and applications use it to determine the devices orientation. Some phones have features of going to sleep when faced down, the accelerometer in the phone is used to sense if the phone is facing down. Laptops also use accelerometers to protect itself, there are accelerometers in laptops that can detect a freefall and stop the hard drive in order to prevent it from becoming damaged during the drop. This relates the sensing subsystem of the smart helmet project because accelerometers like the ones used in phones and laptops can be used for the project to collect the data required by the client. The data that the client wants the project to collect are linear and angular forces and this device does both.

Figure 5: Phone Accelerometer

3.4.1.2 Existing Design #2: Motion Laser Sensor Detectors

Laser sensors are essential in buildings that requires security. Nowadays, most security sensors use the motion laser detector. Figure 6 is an example of the motion laser sensor used in buildings. The team decided to include this type of sensor in the smart helmet project. The main purpose of this sensor is detecting the motion of any movement in a particular range. The motion laser sensor works using programmed codes. One of the most common programming code kit is Arduino and using Arduino, the team will be able to detect any type of motion in the football game. Ultrasonic included in the Arduino is very useful device for detecting the distance of the players. The team will use this device to help the laser performance in the smart helmet project. Safety is one of the most important customer needs in this project. As a result, the team will be able to increase the safety with this specific type of system. The laser sensor will be programmed based on the Ultrasonic device that detect motion. Thus, the motion laser sensor will sense any kind of motion in a specified distance. In addition, the team can use the PIR motion detector which is included in the Arduino kit as well. The purpose of this advance device is to detect any motion for a specified range. This device can be alternative for the Ultrasonic device. The team can use either one of those devices. Moreover, most of the cars use this motion laser sensor that detect any movement. The team can also use this device for the smart helmet project by maximizing and minimizing the ranges of the programmed codes. Overall, a motion detector sensor is a very improved device that can assist the smart helmet project.

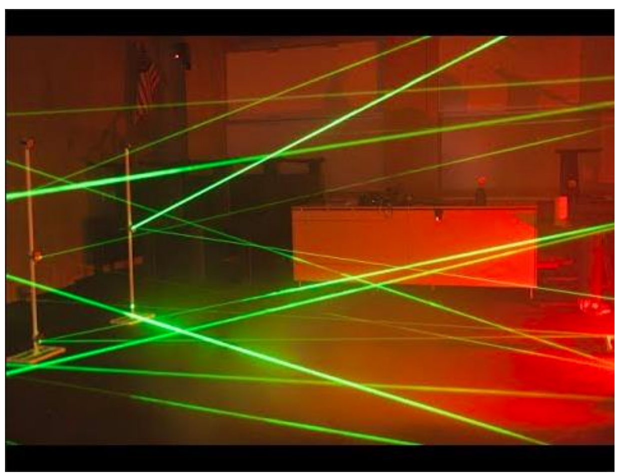

Figure 6: Motion Laser Sensor

3.4.1.3 Existing Design #3: XOnano Smart Foam Sensor

The XOnano smart foam sensor is a sensor imbedded in foam to be used in applications similar to the smart helmet project. The company's initial product was a smart foam football helmet that transmits data in real-time. The smart foam measures the impacts and pressure while not sacrificing the comfortability aspect of the application. This product relates to the project because comfortability and sensing is a customer requirement for the smart helmet project and this design accomplishes both requirements.

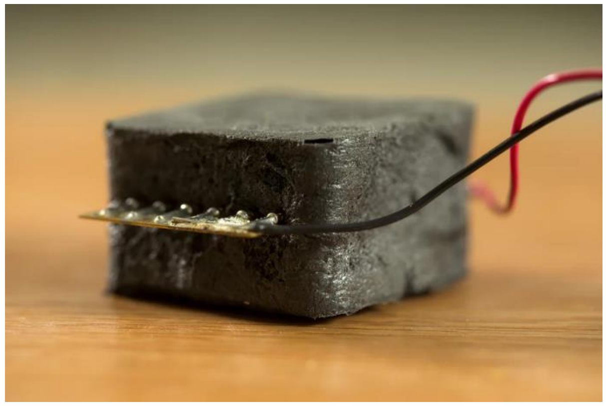

Figure 7: XOnano Foam Sensor

3.4.2 Subsystem #2: *Variable Padding*

The variable padding subsystem is the part of the smart helmet that allows for controllability of the protection in the helmet. An example of padding that allows for variability is ferrofluids that have a stiffness that can change and sometimes be controlled. The controllable padding subsystem satisfies the customer need of implementing a smart and innovative technology into the project while increasing the protection of the product. After analyzing system level designs that collect data from a collision and transmit the data, it is important to keep the project unique by being innovative and this subsystem keeps the project innovative.

3.4.2.1 Existing Design #1: Audi Magnetic Shock Absorber

A shock absorber is used to dampen the forces felt on the car from the uneven ground and Audi was able to implement a controllable fluid called magnetorheological fluid into the system. Figure 8 shows a diagram of the shock absorber and how it implements the MR fluid into the system. This existing design relates to the subsystem of the project for a variable padding because this fluid is used as a variable padding for the shock absorber. A shock absorber is constantly moving up and down while a car is moving, and this relates to the smart helmet project due to football players constantly experiencing impacts to the helmet.

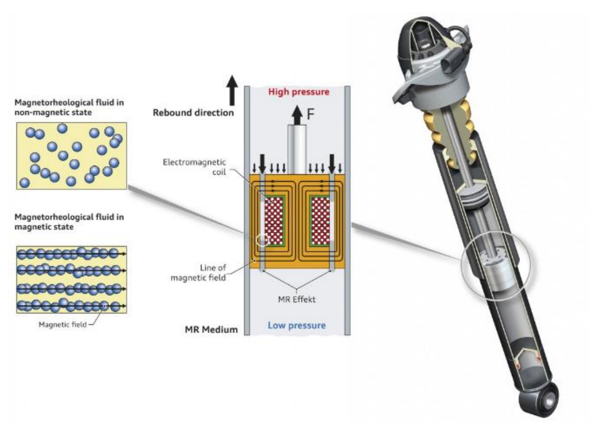

Figure 8: Audi

3.4.2.2 Existing Design #2: Automotive Airbag

Cars are equipped with airbag systems that manipulate the impulse equation by increasing the time an impact occurs so that the forces the driver or passengers experience will be decreased. This system effectively increases the safety in cars and has a similar functional decomposition as the smart helmet project. The airbags inflate rapidly on impact as shown in figure 9, and slowly deflates throughout impact to absorb some of the forces. This relates to the smart helmet project because in both cases there are impacts and a decrease in the forces exerted on the user is required. Airbags could possibly be implemented into the smart helmet project because the system works but needs to be manipulated to work in the application of a smart helmet.

Figure 9: Deployed Airbags

3.4.2.3 Existing Design #3: D30 Armor

D30 is a polymer that provides protection when quick high forces are being applied to it as shown in figure 10 and is soft when there is a force being applied for a long time. This relates to the smart helmet project because it can be used as a padding for the helmet and provides variability compared to conventional foam helmets. This armor is currently used in padding for sports and is effective in protecting players during collisions. The D30 material isn’t controllable but based on the process of making this polymer, the variability can be set based on the needs of the application.

Figure 10: D30 Material Protecting Hand from Hammer

3.4.3 Subsystem #3: Transmit Data

Transmitting data is related to the customer requirement of making the data collected from the sensors available to be analyzed. The functional decomposition of the project also shows that after the sensor collects the data, the next function of the device is to transmit the signal from the sensor to another device that will process the signal. Transmitting information is an important subsystem of the project because the data collected would be useless in the case that it can’t be moved.

3.4.3.1 Existing Design #1: Phone Applications

Most people nowadays have phones on them that have numerous apps that transmits data. For example, there are phone applications that have maps and shows the data relating to the location of the phone. Phones are easily accessible and there are many apps made for them to transmit data. This relates to the subsystem of the smart helmet project of transmitting information because this design is commonly used and is readily available for most people. Figure 11 shows a phone with apps that transmit data.

Figure 11: Phone Applications to Transmit Data

3.4.3.2 Existing Design #2: Car Bluetooth connection with Phones

Bluetooth is used in many applications and are commonly used in newer automobiles allowing the driver to listen to their music and make calls with the car from their phone through a Bluetooth transmission as shown in figure 12. Newer car models also display the information from the phone about what song is playing or who is calling. This relates to the subsystem of the project relating to transmitting the data from the sensor because Bluetooth in cars effectively transmit data from a phone to the car without wires connecting the two which is what is wanted in the smart helmet project. The functional model does not display an input of wires for the transmission which means it is necessary to have a form of wireless transfer of data and Bluetooth does this effectively.

Figure 12: Car Bluetooth Transmission Example

3.4.3.3 Existing Design #3: Live Streaming from Websites

The last existing design for transmitting data is website streaming. There are many websites that transmit data such as Twitch, which streams live video of people playing video games. These websites are effective at allowing people to follow and watch their favorite gamer live. This relates to the project because the data collected from the sensors of the smart helmet could be projected live onto a website where people can stream in and keep updated on the players condition. Figure 13 shows the Twitch streaming website.

Figure 13: Video Game Streaming Website

4 DESIGNS CONSIDERED

After understanding, asking and researching, it was time to work as team to creating the concepts that could help the team to reach the goal. Each member came with two ideas, so the team have ten designs to help to get the job done. All the ideas have put in Pugh Chart that can find in Appendix C. After voting, adding all ideas in Pugh Chart, and discussing relationship between the designs with customer needs, the team have known the successful design that has most positive relationships with the customer needs.

4.1 Design #1: MR Fluid Two

Magnetorheological Fluid two is helmet that comes with sensor contacting with Arduino, and MR fluid which can help to control the viscoelastic. The way that the helmet works is using sensor to know the motion and distance. By defining the distance, Arduino will save data and active MR fluid and viscoelastic to be formed correctly by becoming solid or flexible depending on the collision. MR Fluid two design has two negative relationships with customer needs which are lightweight, and affordable. The reasons why these negative relations exist for this project is MR fluid which is heavy and expensive. The design has three positive relationships which are controllability, safety, data collection. By having MR fluid, the controllability of helmet will be easy by control the viscoelastic after getting the distance between the players, so that will increase the safety of the players from injuries. The design can find in figure 14.

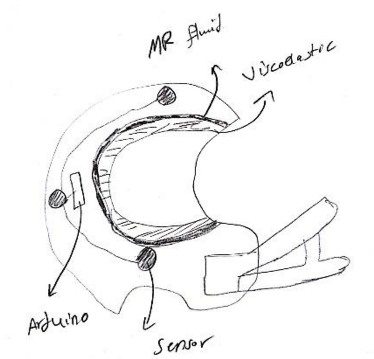

Figure 14: MR Fluid Two Concept

4.2 Design #2: Transferring

Transferring is helmet that comes with sensor, transferring data, and viscoelastic. The work for this helmet is starting with the sensor that contacting with the part of transfer data, so the coach will know players' movement and cases of injury. Also, this helmet comes with viscoelastic that can protect the brain during collision. Transferring helmet has three positive relationships with customer needs. First, this design has lightweight because it is coming without any kind of heavy solid or liquid as MR Fluid two design comes. The cost of the design is not expensive as some of other designs, so that makes the relationship with affordable be positive. Because the transferring helmet does not come with kind of smart ways, the helmet will look better which make the relationship with appearance be positive. In other hand, transferring design has difficulty of controlling the viscoelastic and transferring data which makes negative relationship with controllability. Without having the control of viscoelastic and transferring data in a large percent, the team will not have secure safety, so the team will not hit targets. The design can find in figure 15.

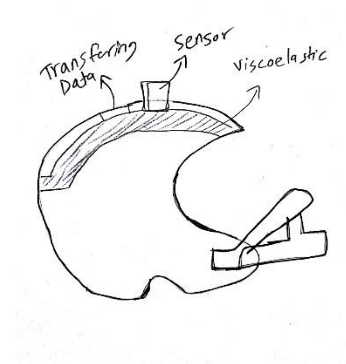

Figure 15: Transferring Design

4.3 Design #3: Airbag

Airbag is the design that has sonar, data collection, and airbag behind section of shell. When the players will start the game, the sonar will feel the body that around each player with determine how strong collision is, so the airbag can dilate correctly depending with collision' cases. The expansion of airbag will be outside of the helmet which reduce the severity of the collision and come back to the helmet normally after protecting the brain. Airbag design has four positive relationships with customer needs. Because it will come with airbag which means it is using gas without having solid or liquid, the helmet is not be heavy. In addition, it is simple design which will help to not pay as other designs, so the relationship with affordable be positive. Airbag is the design that has a large percentage of protection that the team is looking for, the design gets positive rapport with the safety. The design is easy to control and save injury information when it is using the sonar, it ended with positive with controllability as well. However, when the design is protecting the players by using the airbag, the design will not look normally which makes negative relationship with appearance. The Airbag design can find in figure 16.

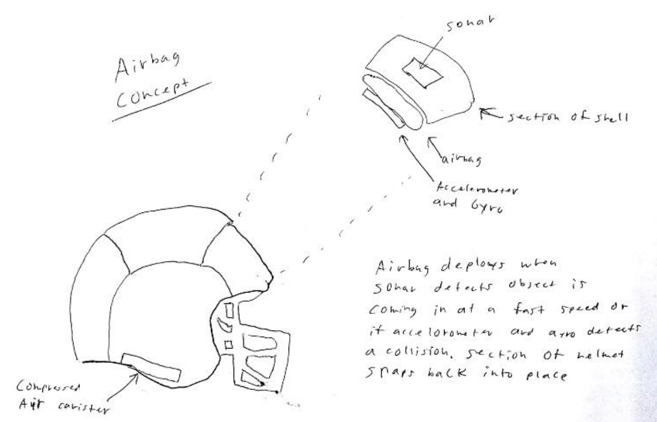

Figure 16: Airbag design

4.4 Design #4: Suba Diving

Instead of creating a helmet with an iron material attached to the football helmet, then the team created a design with a very light weight. The main idea for this design is mixing up the scopa diving's stretched suite with the football helmet. The scuba diving suite is a very starched material because for the movement of the diver in the ocean. Scuba diving suite can also absorb the sweat from the diver's body. As a result, this design is talking about attaching the scuba diving suite to the football's player head. Moreover, scuba diving suite observes the strong movement in the body. Thus, this stretched material can absorbs the strong movement in the player's head. The advantages of the scuba diving helmet are comfortable material, light weight, less expensive, strong movements absorb, and sweats absorb. On the other hand, the disadvantages of this design are skin sensitivity and having an allergic to this specific material. Thus, the scuba diving has three positive relationship with the customer needs which are lightweight, appearance, and safety. The affordable, controllability, sensing are the three-negative relationship with the customer needs. The design can find in figure 17.

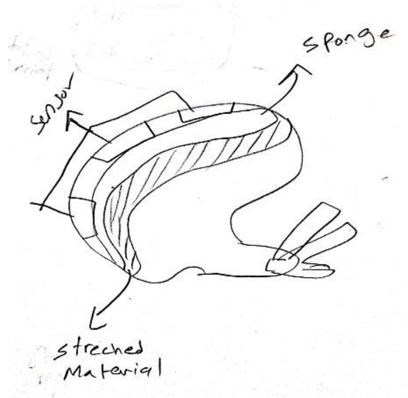

Figure 17: Scuba Diving

4.5 Design #5: Boxing Helmet

The main idea of this design is mixing up the boxing helmet with the football helmet. The shape of boxing helmet is square, and it's attached with a very comfortable material. This comfortable material can absorb the hit from other players. However, the idea of this design is creating a smart helmet for a football player's that has this comfortable material. The football game has a lot of hits and strong movement during the game. As a result, the team decided to create a movement detector that can absorb the motion of the players without any sound. This sensor will absorb the hit before it comes to the smart helmet without knowing the players. The advantages of this design are comfortable material, movement detector, and strong hits absorber. The disadvantages of this design are heavy materials, expensive materials, and long materials that might not be able to fits the helmet. Thus, the boxing helmet has two positive relationship with the customer needs which are safety and appearance. In other hand, the design ends with four negative relationship with the customer needs which are lightweight, controllability, sensing, and data collection. The design can be found in figure 18.

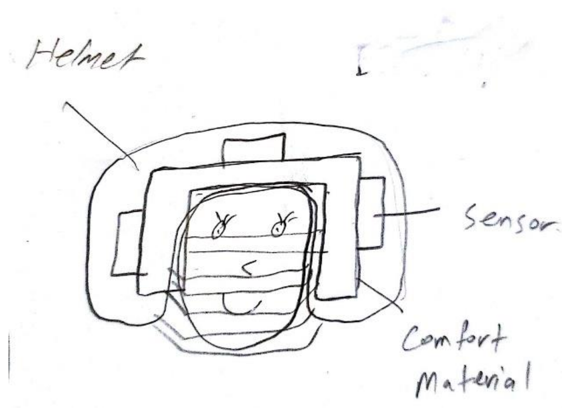

Figure 18: Boxing Design

5 DESIGN SELECTED – First Semester

Chapter 5 contains the rationale for design selection below that will describe the reasons for choosing one of the possible solutions to the project. The rationale for design entails the selection of possible solutions from the generated Pugh Chart and Decision Matrix. Details of the advantages and disadvantages will be given to justify the one possible solution.

5.1 Rationale for Design Selection

The selected design solution will be the utilization of the MR fluid while incorporating the D30 material and laser sensors. The process of choosing the final solution derived from the Pugh Chart, which can be seen in Appendix C, and the design was set as the datum. While the other concepts from Chapter 4 were compared to the MR fluid, the top three designs were then selected and compared in a Decision Matrix as seen in Appendix D. The MR fluid design scored the highest out of all because the design will enable the team to do two main functions. The first main function allows the team to please the client’s needs as their main objective is to have data collection of impact forces of the user. The second function is making the smart helmet “smart” by implementing a system that will enable the helmet to detect oncoming impacts and make any preparations for the impact, i.e., the MR fluid being activated with a magnetic field and allowing the helmet to change the stiffness of the padding.

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7 APPENDICES

7.1 Appendix A: House of Quality

Table A: House of Quality

Project:	**Smart Helmet**
Date:	09/23/2018
	Input areas are in yellow

Legend

- A Vicis
- B Ridell
- C xonano

	Decrease Impulse	Maintain volume	Increase factor of safety	Ductility	Increase power	Decrease diameter
Decrease Impulse						
Maintain volume						
Increase factor of safety						
Ductility		(+)	(++)			
Increase power			(++)			
Decrease diameter		(++)				
Increase voltage			(+)		(++)	

Customer Needs	**Customer Weights**	Decrease Impulse	Maintain volume	Increase factor of safety	Ductility	Increase power	Decrease diameter	Increase voltage	*1 Poor*	*2*	*3 Acceptable*	*4*	*5 Excellent*
		Technical Requirements							**Customer Opinion Survey**				
High protection	5	9	9	9	3	9					C	A	A
Similar size of helmet	4	3	9		3		9					B	AB
Life expectancy	4	9		9		9		3				C	A
More comfortable	3.5	9	3		9		3				A	A	
Transmit data	4.5	9	3			9							
Small sensor	3	9	3				9				BC	A	C
Strong battery	2					9		9			B		A
Technical Requirement Units		N.S	m^3	N/A	N/A	W	m	v					
Technical Requirement Targets		192	114	81	59	140	74	30					
Relative Weight %		27.9	17	12	8.5	20	11	4.4					
Rank order		1	3	4	6	2	5	7					

7.2 Appendix B: Functional Model

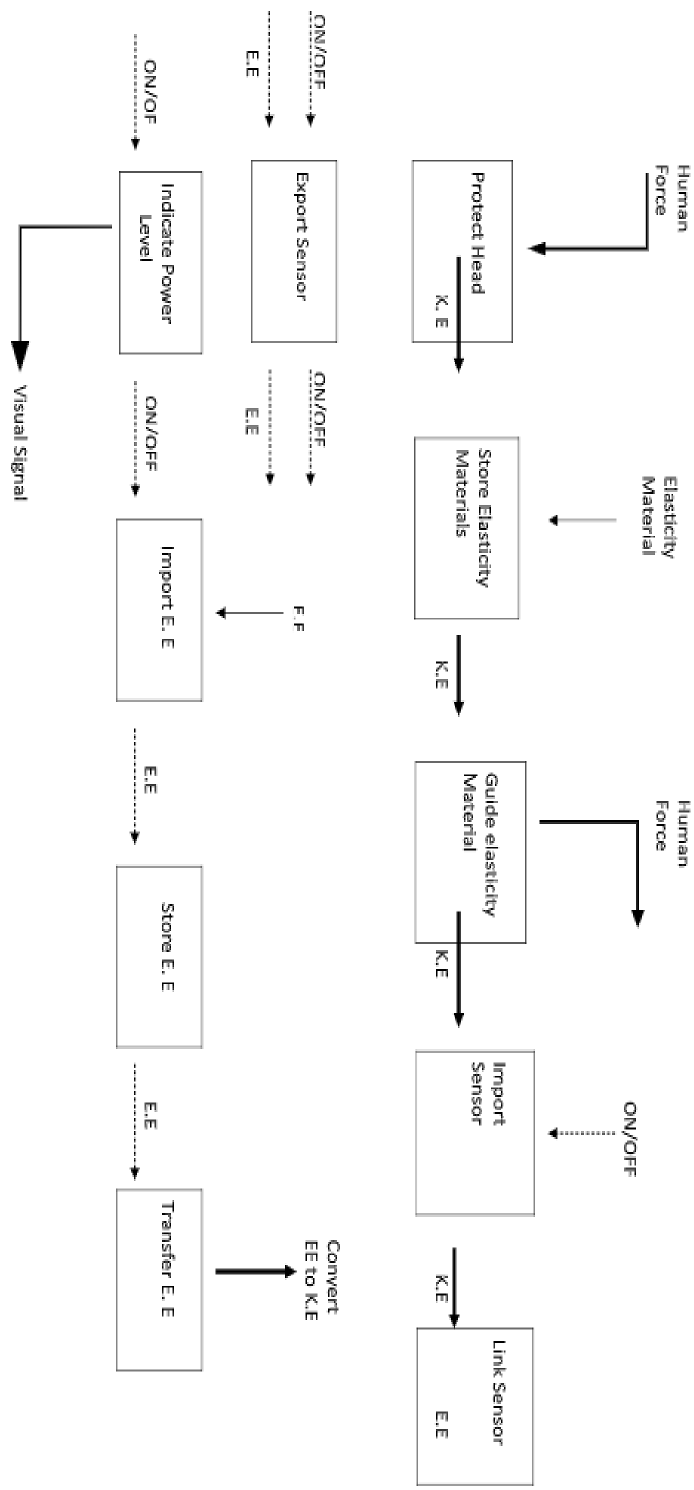
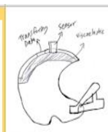
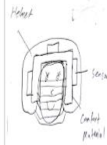
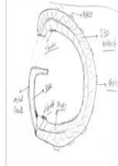
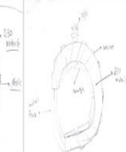


Figure B: Functional Model

7.3 Appendix C: Pugh Chart

Table C: Pugh Chart

Criteria	MR Fluid	Airbag	Transforming	Padding	MR Fluid #2	Transfering	Scupa Diving	Boxing helmet	D3O Helmet	Vibration
										
Light Weight	D	+	+	+	-	+	+	-	-	s
Affordable		+	s	s	-	+	-	s	+	-
Appearance	A	-	+	+	s	+	+	+	+	+
Safety		+	s	+	+	-	+	+	+	+
Controllability	T	+	-	s	+	-	-	-	-	-
Sensing		s	-	-	s	s	-	-	-	-
Data Collection	U	s	-	-	+	s	s	-	s	-
Sum (+)		4	2	3	3	3	3	2	3	2
Sum (-)	M	1	3	2	2	2	3	4	3	4
Sum (s)		2	2	2	3	2	1	1	1	1

Appendix D: Decision Matrix

Table D: Decision Matrix

		Design Options							
		Magnetorheological		Electrorheological		Viscoelastic		Airbag	
Criteria	Weight %	Score (1-100)	Weighted Score	Score (1-100)	Weighted Score	Score (1-100)	Weighted Score	Score (1-100)	Weighted Score
Light Weight	20	20	400	30	600	40	800	50	1000
Affordable	6	40	240	50	300	60	360	50	300
Appearance	5	80	400	80	400	90	450	75	375
Safety	30	90	2700	70	2100	60	1800	60	1800
Controllability	12	90	1080	70	840	10	120	60	720
Sensing	15	80	1200	75	1125	85	1275	80	1200
Data Collection	12	70	840	65	780	80	960	80	960
	100	Total	6860	Total	6145	Total	5765	Total	6355