Individual Analytical Analysis I

Smart Helmet- Type of sensors

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ME 476C- Fall 2018

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The constant development in engineering and material science has resulted in creation of sensors. These sensors are classified in different categories which include; pressure, radar, proximity and laser sensors. The project in question is about selecting the best type of sensors that can be used when developing a smart helmet. All these types of sensors have their own ideal places of application. This paper will discuss in detail all the aforementioned types of sensors and a selection of the ideal type of sensors will be done for the smart helmet after analysis. The following is analysis of these sensors:

Pressure sensors

Pressure sensors are devices that are used to measure the pressure in gases and fluids. The pressure sensor is a device that senses pressure and converts it into an electrical signal depending on the pressure applied. They are designed and manufactured ranging from the sensing element to the packaging for harsh environments. A pressure sensor acts as a transducer. It means that it generates a signal as a function of the pressure imposed [1]. Pressure sensors vary in design, technology, and performance, cost and application suitability. Some pressures are made to measure in a dynamic from very high speed changes in pressure to low changes in pressure [2]. There are various applications that pressure sensors are either used to measure or to control. The ideal places of applications include; the measure water levels, flow in gases and altitudes of places. Certain special pressure sensors are used in areas where they designed to measure cut age pressures ("Development Stages | Pressure Sensors | First Sensor"). It is important to note that these areas may include pressures of gas engines ad combustion engines too. For this project, the best way to calibrate pressure is through impact when players are playing the game. When the impact is made, the sensor should detect the change in pressure at a certain point and send signals to the processor for response and other analysis.

The basic principle for pressure application is defined by the pressure formula which is

$$P = \frac{F}{A}$$

In the above formula;

P is the pressure,

F is the force applied,

A is the area of application of the force

The sensor that is put on the prototype should be so sensitive such that as little as possible pressure causes a signal that triggers a certain reaction. The pressure plates that should be used should also be so thin such that they do not result make the design to be bulky. The best sensors would be so thin in a way that they are non-intrusive. The other variable is that they should be able to measure the magnitude of the force that is applied on the helmet. This can be easily determined by the equation given above and the specific sensor that is chosen.

Radar sensors

These sensors are used to measure the distance between the sensor instrument and the surface of the material being measured. It uses the same technique as the ultrasonic waves. Literally the application of radar is the same way as the sound wave application only that in radar it is the use of electromagnetic waves instead. Thus, it is is an electronic device. For instance, when an individual shout in the direction of a rocky place then they are in a position to hear an echo ("Operating Principle Of Non-Contacting Radar Level Sensors/Gauges (Unguided Wave)"). If they already know the speed of sound in air at that particular places then they can determine the distance in between. It is the same principle as radar sensors only that it is replaced with electromagnetic waves that are created by the sensor. Radar then uses the energy that is reflected from the object and the direction and distance of the object can be determined.

There are ways to use radar sensor. One of example, it is used by motorists to detect detect is their speed is being monitored by the traffic officers or law enforcement using a radar gun [7]. This helps them to reduce the speed before they are caught and penalized for driving at a high speed. It identifies radar devices based on the radio waves it emits. The detector emits scrambled signals which upon reaching the radar the police are unable to detect the speed.

In recent years, some radar detectors have improved technology by using the GPS technology by which they are able to detect the location of the police officers and are able to regulate the speed [6]. They store the locations where the traffic police normally regulate traffic and in future they alarm the motorist when approaching the place.

In the case presented by the helmet, the principle of the radar would work through a refection principle which the basic working mechanism of the radar. The radar sends signals when there is an impact. The signal travels very fast to detect the deformation rate which is a reflection of the magnitude of the impact and then the signal is relayed back. There is a dominant process that needs to be followed every time there are more people that are seen

In the calculation of the signal speed, the formula is

$$R = \frac{c0t}{2}$$

where:
c_0 = speed of light = $3\cdot 10^8\ {}^{m}/_{s}$
t = measured running time [s]
R = slant range antenna - aim [m]

The distances are expressed in kilometers or nautical miles (1 NM = 1.852 km). In the above equation, range can also be defined as the distance that is supposed to be covered by the radar signal in reaching the target site. Conventionally, this distance and velocity is defined as V= s/t. However, there radar speed is defined as a function of the speed of light. The relationship between the range of the radar and the speed of light is given as below

$$c_0 = \frac{2R}{t}$$

It must however be noticed that the radar works in the principle of reflection. As such, the forward and the reverse transverse must be taken into account. The result will be the formula below.

$R = \frac{tc0}{2}$ in meters

It must be noted that to use this sensor, there have to be a surface over which the design can reflect the radar signals. Given that a contact is supposed to be detected, it means that there should be an inner and an outer surface to facilitate the relay and deflection of the signals.

Proximity sensors

Proximity sensors detect the presence of nearby objects without making any physical contact. The object that is being sensed is referred to as proximity sensor's target [8]. Different proximity targets require different proximity sensors. They usually have a long functional life due to the distance between them and their targets and lack of physical contacts. They also lack mechanical parts thus increasing their longevity. Proximity sensors works on the principle of electromagnetic spectrum. This is by sending electromagnetic waves that detect the presence of objects, deformations and disturbances. These waves will work in more or less the same as the lasers do operate. The only difference is that they are defined by rules of electromagnetic radiations and spectrum

In electromagnetic the waves travel is defined by

V = fy

Where V is velocity

F is frequency and

Y is the wavelength of the wave that is sent out.
The most important parameter in the above equation is v which will determine the response time once there is a collision with an object or an individual. The values of frequency and the wavelength are constants that are a function of the electromagnetic wave in question [8]. Frequency does however play a role because it influences the time component of response. This helps to bring out the aspect of the speed. In most of the sensors that relies on these waves, there may be a lag time for the generation of the frequency waves, which may lead to a momenta delay in the delay of the impact information.

Laser sensors

Laser sensors are used where small objects or positions are to be detected. Laser sensors uses laser beam to determine the distance of an object to which the sensor is pointed at [4]. It is made possible and effectual when we measure the time between when the laser is first transmitted towards the target to when its defected back.

Dependent on the sensor the beam can travel anywhere from millimeters to kilometers. This is mainly determined by the type of the sensor. The laser sensors transmit up to 150,000 pulses per second thus allowing precision in reading. Laser systems are divide into four namely: scanners and optics, lasers, photodetector and receiver electronics and navigation systems [3].

The distance covered by the laser beams is determined by the formula, distance equals to speed multiplied by time. This is the common formula that defines speed, distance and time. The formula is as shown below;

$S = D \times T$

Where
S is speed
D is distance
T is Time

When using the time of flight mode method, the distance is divided by two because the method records the time a light pulse travels to a target and back. As an equation, this can be written as;

$$D = \frac{S \times T}{2}$$

The speed component remains constant as the time and the distance components alter. Therefore distance is equal to speed of light multiplied by the time of flight then divide by two as shown in the above equation. The d component is the distance that will be traveled by the laser beam. The distance travelled will be dependent on the impact magnitude, with a large magnitude of impact. With a large impact, the distance traveled will be small due to the deformation and the response that matches the magnitude of the impact will be triggered. The converse also true for small magnitude impacts in terms of the response. Laser sensors offer precision and accuracy when recording distance. When used in a motorcycle helmet it can only provide feedback at a specified angle. The only thing that needs to be done is that the inner lineup of the design should be made to adapt to the laser framework.

Models analysis

Each of the above four models all have a probability of being chosen as the ideal sensor of the smart helmet. An analytical merit analysis would be the best to determine which would be the best sensor to use in the smart helmet. There are several criterions that will be used in the analysis of which would be the best sensor to use in the helmet. Some of the criterions to be used for analysis include; the speed of response of the sensor, the bulkiness of the sensor, the compatibility with helmet, power requirements, durability and the ability to withstand shock. The table below gives a summary of the comparisons made on the four different sensors. For each of the sensors, it was evaluated against each of the criterions and given a relative score as compared to others. The scores were then added to give a total score at the bottom of the analysis table. The sensors were rated on a score of 1 to 10.

Among all the four models that were used, laser is the one travels the fastest with a speed of 186,000 miles per second (Evenson & Peterse, 3). This spend is higher than that of light. The speed of light is at $3 \cdot 10^8$ $^{m}/_{s.}$

Table 1: Summary score for the various designs

Design / Characteristic	Pressure sensors	Laser sensors	Proximity sensors	Radar sensors
speed of response of the sensor	5	9	5	7
shock force	5	8	3	4
durability	7	8	6	4
power requirements	5	7	8	6
the compatibility with helmet	8	9	7	8
the bulkiness of the sensor	7	9	4	4
Total	**37**	**50**	**33**	**34**

From the analysis that was carried out, the laser sensor is the one that scored highest among all the other sensors. The laser sensor is closely followed by the pressure sensor which is then followed by radar sensors. Finally, there are the proximal sensors. Based on the margins above, the laser sensor is far much better sensor than all the others. It will therefore be used for our design of the helmet design.

The team wants to have sensor that tells how the collision strong is before the impact, so the pressure sensors can not be used in making a smart helmet that need to protect player from injuries. Thus, the pressure sensor is slow and the technology used in normally focuses on fluids mostly hence not effective, so it will not be helpful for the project. Rader sensor is available but it is not ideal for a smart helmet because the energy produced by the sensor may not be sufficient to be echoed hence result may not be attained.

Again, proximity sensors are used to determine if an object is close without any contacts. The device itself is in a solid state and it is an electronic device. It is ideal for places that are hazardous in nature. It monitored a device that is set to be monitored so that when it comes close to it then it can be detected. It has an advantage that it has no moving parts at all (Faizan). Only objects that are being monitored when they come close to it is when they can be detected. Objects that are in most cases monitored are the ones which are light in weight, small in size or they can be soft in nature. The fact that they are preferred for small and specific items then it is not ideal for applying its use to creation of the smart helmet. It has no moving parts and hence it cannot be effective in the helmet application.

The price and size of the sensors are closer to each other, but the main point that the team is looking for the speed of the sensor. Therefore, based on the margins above, the laser sensor is far much better sensor than all the others. It will therefore be used for our design of the helmet design. Thus, let remind us what is laser sensor and why it will help the project of the team

The working principle of a laser sensor makes it ideal for the application in creating a smart helmet. It uses a simple technique of triangulation but instead of sound like the radar sensors it uses light. It is quiet during its operation. The triangulation sensor gives the exact distance that is being measured. Even small distances or long distances. Light is emitted from the laser and is directed to the object where the reflected light is focused on the lens. The lens collects the light and is always located close to the emitter itself. Using the linear array camera, the spot created is focused on it (Staff). What the camera accomplishes in this type of thing is to focus it an angle of approximately 45 to 65 to the center. The image that is created from the spot is then analyzed and measured to determine the distance in question. For a smart helmet this technology is ideal and it can help save injuries. It is effective because it is fast and quiet during operation. Its sensitivity is very high and that is why it gives exact results that is needed. This assures the users to be aware of the dangers before they can even happen. Smaller distances are also measured with a high level of accuracy.

Conventionally, laser light travels at a speed of 186,000 miles per second. In a typical helmet, the difference between the inner and the outer layers is about 1.2 inches. The time that the laser will use to travel this distance upon impact is

We convert 1.2 inches to miles

1 inch = 1.57 x 10 ^-5 miles

1.2 inch = 1.884 x 10^-5

T = Dist /Speed

$= \frac{1.884 \text{ x } 10^{\wedge}{-5}}{186{,}000}$

= 1.01 x 10^ -10 Seconds

This is the fastest response time that can be achieved for any device and this makes lasers all the much better based on the aspect of time.

CAD model

The basic laser sensor is made of very few components. This is part of why it is an effective sensor since it is non complex and it would easily fit into a helmet. The major parts of the laser sensor are the laser beam source "red part", the power storage "purple part" and the print board where the components are embedded. The laser produced is projected onto a target. In this case, the target location would be the surface of the helmet, where the laser is to be projected on. The figure below shows all the major parts of the laser sensor

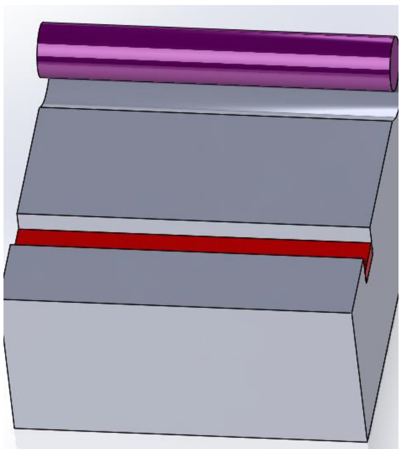

Figure 1; CAD model of the laser scanner

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