ATRANS Final Report

Technological Development of Smart Helmet for Motorcyclist Safety Study

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CHAPTER 1 INTRODUCTION

Road traffic safety is a significant problem in Thailand. According to the National Statistical Office of Thailand, statistic of road traffic accident during 2007 to 2014 reveals that motorcyclist road traffic accident consisting of 25% of all claim accident, which is the highest ranking of traffic accidents classified by type of road user (following by personal car) Furthermore, according to the world's road safety report by WHO as of 2015, death caused by motorcyclist consisting of 23% of all death caused by road traffic, which is the highest ranking following by pedestrian. Regarding to these accidents and death, we can realize how danger of road traffic in Thailand.

In addition, the report of WHO also reveals that wearing of motorcycle helmet can help decreasing the risk of death almost 40% and decreasing the risk of seriously injure about 70% So we believe that if we can find some method or equipment that can force motorcyclist to wear motorcycle helmet, the death of road traffic would be significantly decrease.

Based on these concepts, we decide to invent the intelligent helmet which helps detecting whether motorcyclists are wearing safety helmet or not. If motorcyclist does not wear safety helmet, motorcycle will create alarm to notice motorcyclist to wear helmet before cycling. Besides, this system can store riding record such as speed or location of motorcycle, movement of motorcyclist's head, etc. and those record will be determine whether accident occur or not and then contact to the claim service.

1.1 Objectives

1) Invent the master of helmet that can detect whether it is wearing by motorcyclist or not and could explane the characteristic of head movement of motorcyclist who wearing it.
2) Design analysis system that could evaluate accident situation based on motorcycling characteristic.

1.2 Scope of project

1) Motorcycle helmet modified from the common helmet that cover all area of head of motorcyclist.
2) Modification on motorcycle by add-on external circuit. No modification on driving program in ECU unit.
3) Accident evaluation, based on test data of motorcycling characteristic with suitable protector wearing motorcyclist.

1.3. Methodology

Define scope and specification of system, analysis and design on system, equipment procurement, system development and examination.

1.4. Expected result

1) This project gets attraction from the section that can apply this project in advance development.
2) Increasing of motorcycle helmet wearing rate.
3) Decreasing of death rate in motorcyclist.

CHAPTER 2 Related technologies and knowledge

2.1 Related research and article review

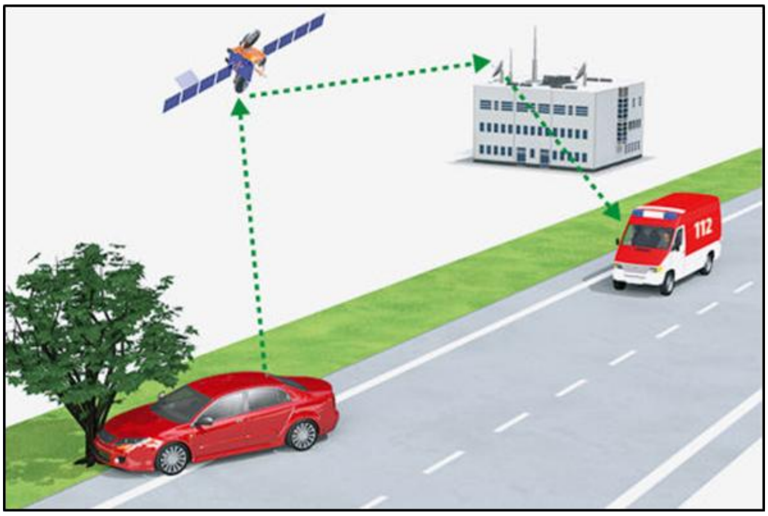
2.1.1 Smart Helmet By International Research Journal Of Engineering And Technology

An objective of this project is to invent circuit that can be applied for Smart Helmet system which can prevent motorcyclist to start engine while not wearing motorcycle helmet. As a basic operation, the Rf Transmitter will be mounted at the helmet, meanwhile, the Rf Receiver will be mounted at the ignition coil of engine. In properly situation, engine cannot be started unless motorcyclist wears helmet, Rf transmitter at the helmet will transmit Rf signal to Rf receiver and enable ignition coil to be able to start engine properly.

Regarding to this concept, we can implement the communication between helmet and ignition coil. However, communication using only Rf standard might be hard to adapt with some specified protocol such as adaption of Rf to be mesh network, which take a lot of effort to modify by ourselves. Therefore, communication under Rf standard between helmet and ignition coil may not satisfy our demand in future.

2.1.2 eCall

eCall is a European claim service assistance for all vehicle in the European Union. There is a case study of eCall that mentioned about accident occurred to some vehicle driver who travel across the state or province and they could not initiate an emergency call by themselves. In this case, the victim must be rescued by other vehicle driver who travels on the same road and see them. Although victims does not get a serious injure, but they might be death if the help had not been available in time. eCall device can senses a severe impact in an accident, it automatically initiates an emergency call to the nearest emergency center and transmits it the exact geographic location of the accident which can reduce gap of rescue time and save many lives that should not have explaneed the death if the help had been available in reasonable time. Presently, eCall system is build-in to the GNSS of vehicle and able to coordinates with GPS and Glonass to find more precise location. Furthermore, European standard is requires all new cars be equipped with eCall technology in near future.



Picture 2.1 Operation diagram of eCall

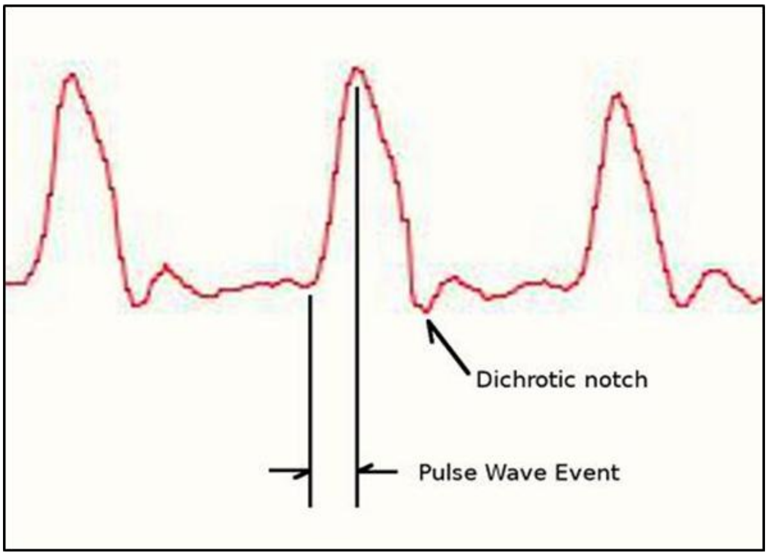
2.2 Algorithm and solutions

2.2.1 Heart rate measuring

In order to detect wearing motorcycle helmet of motorcyclist, we decide to judge by heart rate because only start switch cannot describe that motorcyclist is wearing motorcycle helmet or not. For example, if motorcyclist does not wear motorcycle helmet but press the switch inside of helmet by unknown methods. These methods could not be applied with heart rate due to the fact that there is no heart rate in the object. In this section, we will explane about technologies, theory, principle, and knowledge that required for development of heart rate measuring.

2.2.1.1 Heart rate measuring by Photoplethysmograph

Photoplethysmograph is a measuring instrument that measures the volume of organ by optic. Simple basic of operation is that light emission from source to surface of organ, and then measures the change of light absorption. With this method, when heart pumps blood to any the tissues in hypodermis, light absorption will be changed. An output of Photoplethysmograph is a graph called Photoplethysmogram or PPG



Picture 2.2 PPG graph (Photoplethysmogram)

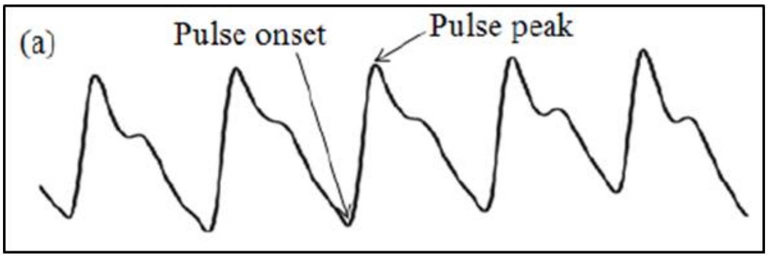
A PPG output from live human is shown in Picture 2.2 which is a wave form with high and low peak and predictable wave form in an infinite loop. With this characteristic, PPG can be applied to measure heart rate, and also be able to detect whether the measuring object of Photoplethysmograph is a live human or not.

However, an output of PPG with high sampling rate usually come out with high noises. These noises can be reducing by a filter called Low-Pass Filter. In this project, we set up the sampling rate at 500 Hz and apply Butterworth Filter as an Algorithm of Low-Pass Filter for noise reduction.

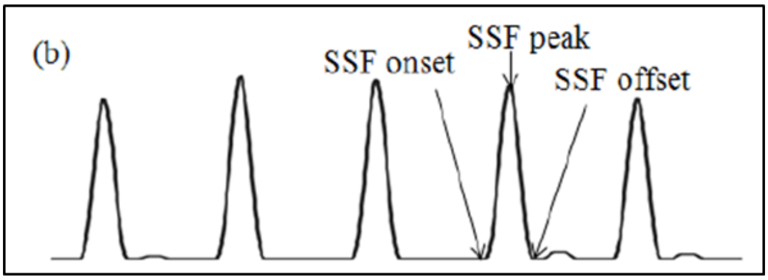
After the noises of PPG were reduced, the next process is to calculate heart rate by simplifying of wave form in order to be easier to detect peaks of wave form. Then the next step is to find the peak of wave form, and finally system will calculate heart rate in Bpm (Beats Per Minute) by using of threshold value.

2.2.1.2 Simplifying wave form to be easier to find peak.

Objective of this process is to simplify output wave form to be able to separate each peak by computer. At first, an output PPG will be input to the Slope-Sum Function or SSF to increase the slope of wave form in rising period which is the positive slope of PPG. And then other period of wave form will be dropped down to vanish from the output graph. An example of output is shown in Picture 2.3 which is the wave form before passing the SSF and Picture 2.4 which is the wave form after passing the SSF.



Picture 2.3 Wave form before passing the Slope-Sum Function



Picture 2.4 Wave form after passed the Slope-Sum Function

Equation of Slope-Sum Function **(**SSF) can be explaneed as following:

$$SSF_i = \sum_{k=i-w}^{i} \Delta x_k \quad \text{where} \quad \Delta x_k = \begin{cases} \Delta s_k & \text{if } \Delta s_k > 0 \\ 0 & \text{if } \Delta s_k \leq 0 \end{cases} \tag{2.1}$$

Which w is the length of Window that store slope of graph and SSF is PPG signal after filtered.

2.2.1.3 Peak detection

By using Hill-Climbing Algorithm, program will detect the PPG signal after SSF passed whether it is the Local Maximum or not. Local Maximum is defined as following:

$$s_i \text{ is local maximum, if } s_{i-1} < s_i \text{ and } s_{i+1} < s_i \tag{2.2}$$

Then system will record that Local Maximum value to compare with the next PPG signal that is another Local Maximum. If the new value is higher or equal to the previous value, or lower but stay in the acceptable range, system will judge the data as a peak. And if program cannot find any peak within 3 minutes, the new Local maximum value will be automatically judged as a new peak.

2.2.1.4 Heart rate calculation in Bpm (Beats Per Minute) by Threshold value

The method is to detect PPG signal after passing the SSF whether its value is higher than the desired value or not. This value is called Threshold value. If input value is higher than threshold value, and when the next PPG signal with value higher than threshold value come again, the heart rate will be calculated by the below equation:

$$bpm = t_{minute} / \Delta t_i \tag{2.3}$$

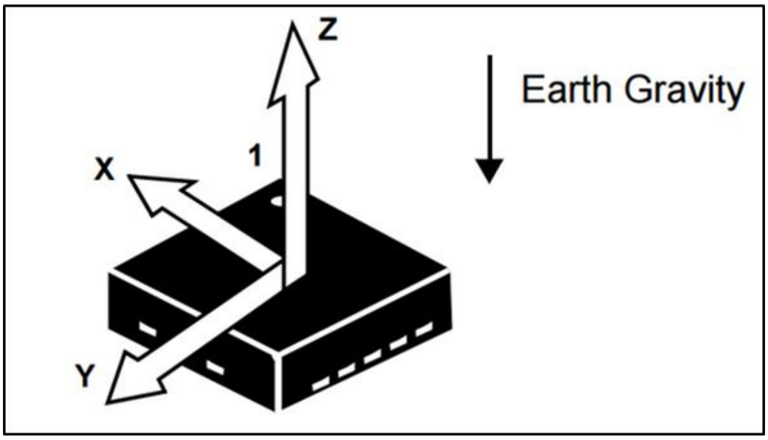
Which t is duration of time after the first PPG signal that exceed the threshold value to the time that the next PPG signal that exceed threshold arrive. t_{minute} is timing in 1 minute which is the same unit as t_i. The threshold value in this project is set to 70% of the average value of the 5 last peaks. After we know the heart rate, it will be evaluated whether it is in the range of normal situation heart rate or not, so that we will know if motorcyclist is wearing helmet or not.

2.2.2 Evaluation of characteristic of head movement.

In order to evaluate the characteristic of head movement, we classify in 3 types of movement which are head turning speed, acceleration of head movement, and angle of head in vertical.

2.2.2.1 Measuring of acceleration of head movement

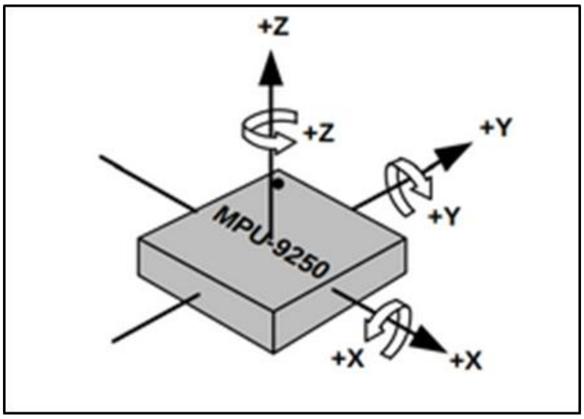
In order to measure acceleration, we can use a device called Accelerometer. This device can measure acceleration in unit of gravitational acceleration or $\boldsymbol{g}$ in 3 axes which are X, Y and Z axis. When placing Accelerometer in the horizontal plane, gravitational acceleration will take action at the Z-axis. So acceleration measured on Z-axis will be approximately $\boldsymbol{1g}$, The three axes compare to the gravitational acceleration are shown in Picture 2.5



Picture 2.5 Axes Accelerometer

2.2.2.2 Measuring of head turning speed

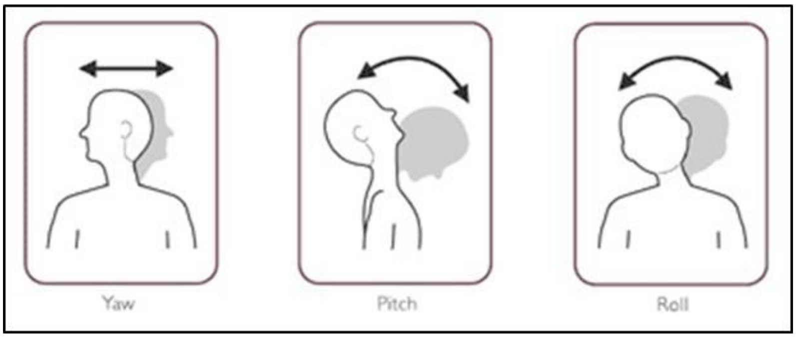
Method of measuring of head movement speed is different from measuring the vehicle speed in straight moving. Most of vehicle speed measurement is a speed in linear motion which is a unit of distance per time. However, head turning speed will be measured as an angular speed in unit of degree per time (Degree/Sec or Rad/Sec) We can measure by using of a device called Gyroscope and classify into 3 axes which are X, Y and Z axis as shown in Picture 2.6



Picture 2.6 An axis of Gyroscope

2.2.2.3 Measuring of head angle in vertical

Measuring of head angle in vertical to evaluate whether motorcyclist is looking up or down by using the differentiation of acceleration on X, Y and Z axis. Due to the facts that the axis that parallel to the gravitational acceleration will has acceleration at least $\boldsymbol{1g}$, therefore, when Accelerometer was rotated, acceleration among the axes will gradually change. Axis of turning can be classified in 3 axes which are Roll, Pitch and Yaw as shown in Picture 2.7



Picture 2.7 An axis of Gyroscope

However, the rotation on Yaw will not effect to the acceleration among X, Y or Z axis, so that Accelerometer cannot measure an angle in this axis. Equations for calculation of angle in Pitch and Roll axis are shown as following:

$$\boldsymbol{Pitch} = \textbf{Arctan}\left(\frac{G_Y}{\sqrt{{G_X}^2+{G_Z}^2}}\right) \tag{2.4}$$

$$\boldsymbol{Roll} = \textbf{Arctan}\left(\frac{-G_X}{G_Z}\right) \tag{2.5}$$

which G is an acceleration on x-axis in multiply unit of g, for example, G_x refer to an acceleration on the X-axis.

2.2.3 Communication between helmet and motorcycle

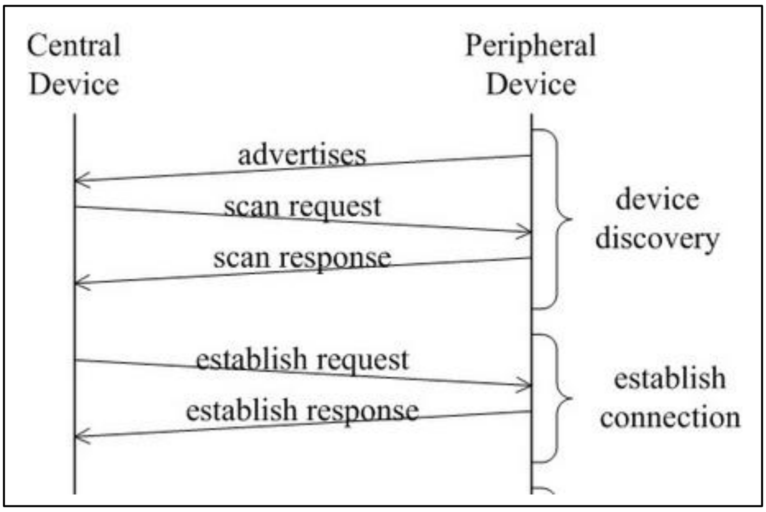
In order to reduce energy consumption and increase the flexibility of devices, we choose the Bluetooth Smart or Bluetooth Low Energy as a technology for communication between helmet and motorcycle. If motorcycle has not been modified to communicate with helmet, users can apply their smart phone in substitute since most people already have smart phone that capable for Bluetooth Smart technology. The performance of Bluetooth Smart we apply in this project are: user identification, data exchange by GATT and operational authentication.

2.2.3.1 User identification

Identification process of Bluetooth Smart is shown as following

1) Motorcycle helmet is a peripheral device that periodically transmits an advertisement signal to recognize the central device about the existence of motorcycle helmet.
2) Motorcycle is a central that scanning for advertisement signal of other peripheral devices.
3) When motorcycle found the advertisement signal, it will evaluate whether it is the advertisement from motorcycle helmet or not. Code inside the advertisement of helmet contains an ID that will activate motorcycle to send request for connection to the helmet.
4) When motorcycle helmet received a connection request, it will evaluate whether it is a request from motorcycle or not. If yes, they will pair together.

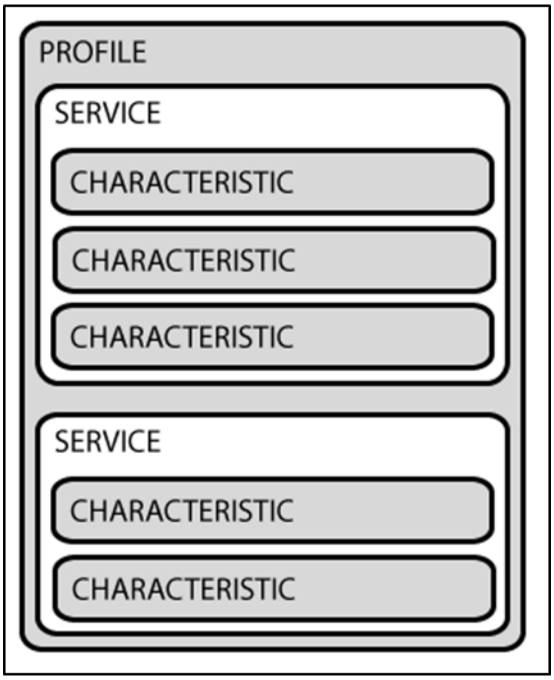
The above processes are shown in Picture 2.8 In addition, scan request and scan response are optional that can be negligible, only necessary in case that the central device require an additional data from the peripheral device before sending the connection request.



Picture 2.8 Data exchange by GATT

GATT of Bluetooth Smart has a method of exchange data as following:

1) Helmet plays role as a GATT Server which store up data structure in Services and Characteristics. Services play role as a data provider meanwhile the detailed data are stored in Characteristics. For example, helmet contain a service called Head Motion Service which is consisting of 3 Characteristics: Acceleration Characteristic, Angular Velocity Characteristic and Head Angle Characteristic
2) Motorcycle plays role as a GATT Client. GATT client will send a data request to GATT Server which is a helmet. GATT Server must specify the required Service and Characteristic.



Picture 2.9 Bluetooth Low Energy Stack

2.2.3.2 Operational authentication

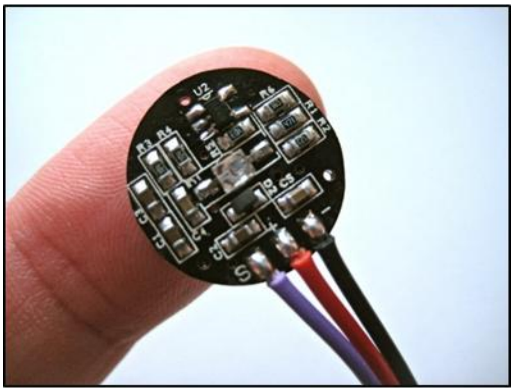
Authentication process will be occurring at GATT Server whenever there is a data read or written request to any characteristic. GATT Server can either accept or reject those requests depend on authority of GATT Client.

2.3 Related technologies

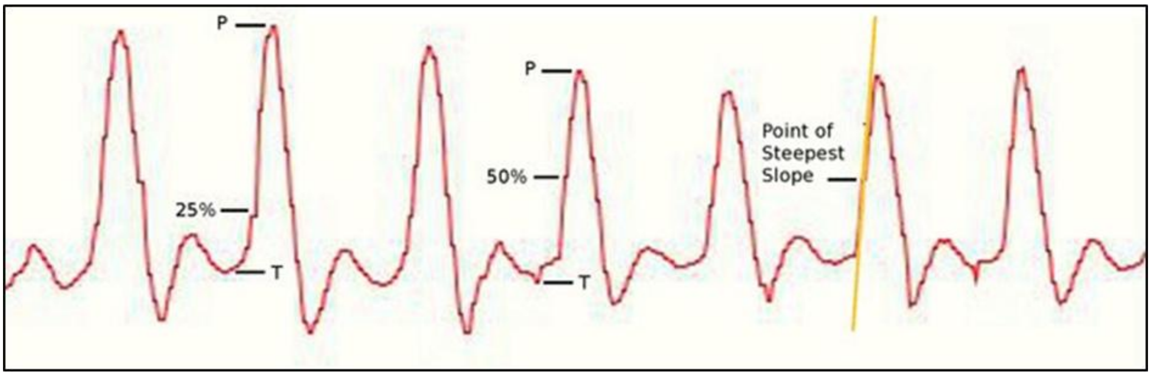
2.3.1 Optical Heart Rate Measurement Sensor

Optical heart rate sensors use a methodology called Photoplethysmography to measure heart rate. PPG is a technical term for shining light into the target organ (finger, earlobe or temples) then measuring the change of light density of reflection. Sensor consists of light emitter and light density receiver for the light reflection. An example of Pulse sensor that we use in this project is shown on Picture 2.10 An Example of Pulse Sensor application is shown in Picture 2.11 An example of output of pulse rate detected by sensor is shown in Picture 2.12

Picture 2.10 Pulse Sensor



Picture 2.11 Example of Pulse Sensor application



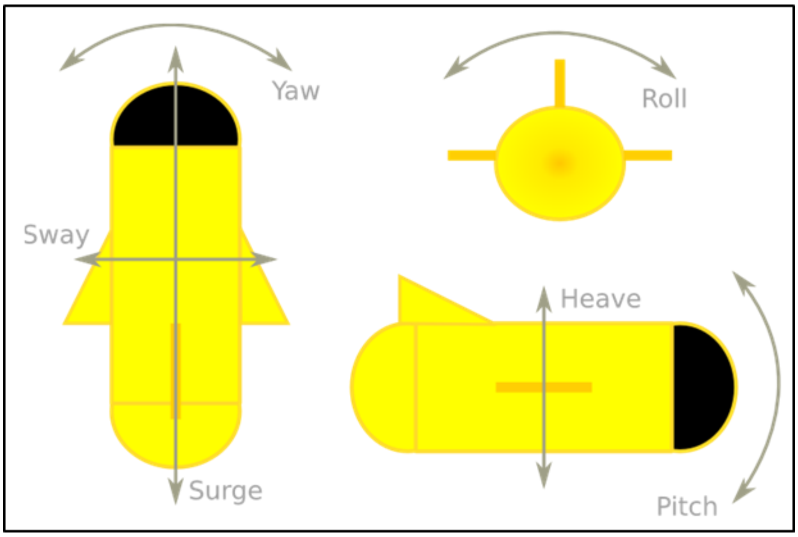
Picture 2.12 Example of pulse rate output detected by sensor

2.3.2 Inertial Measurement Unit: IMU

In order to detect anomaly while motorcycling, we choose a method of determine by the movement of motorcyclist's head. By using head movement monitoring device called IMU (Initial Measurement Unit) In generally, IMU is mounted in an unmanned aerial vehicle for monitoring movement of those aerial vehicle. Inside of IMU consists of at least 2 sensors which are:

1) Accelerometer, use for measuring acceleration on X-Y plane and vertical axis Z by comparison among the acceleration due to gravity of earth at sea level or G, for example, 1g, 2g, 3.5g, 1.02g, etc.
2) Digital Gyroscope, use for measuring angular speed on X-Y plane and vertical axis Z in unit of Degree/Second or Radian/Second

One of anomaly that could be occurring during motorcycling is an abnormal direction of head. In order to calculate the degree of head angle, we apply axes as same as using in general aerial vehicle that are roll pitch and yaw as shown in picture 2.13



Picture 2.13 Axes

Degree of Pitch and Row axes are calculated by using of Accelerometer that be able to measure the acceleration from gravitation among the X, Y and Z axis from the equation 2.4 and 2.5

2.3.3 Bluetooth Smart (Bluetooth Low Energy or Ble or Bluetooth 4.X)

The approach of plug-in energy to motorcycle helmet all the time may not appropriate. Therefore, we choose to reduce energy consumption of helmet as much as possible. As a result, some of calculation will be processed at server and motorcycle that sufficient for energy consumption. So, we have to choose the Wireless Communication Protocol that helps saving the most energy. Regarding to these reason, Bluetooth Smart or Bluetooth Low Energy become our best choice.

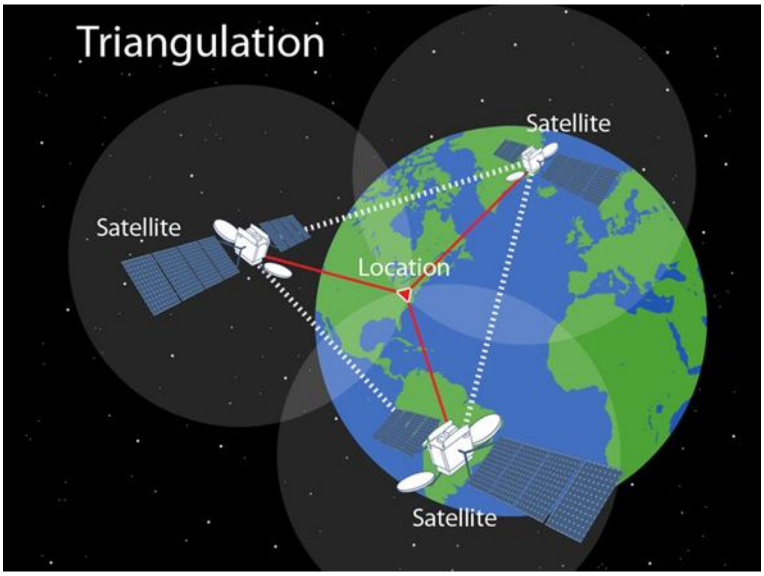
Picture 2.14 Bluetooth Smart or Bluetooth Low Energy (Ble)

2.3.4 Gnss (Global Navigation Satellite System)

Gnss refers to a system to determine location on earth with a constellation of satellites providing signals from space that transmit positioning and timing data. Both Gps and Glonass are examples of Gnss and current system can calculate speed and direction to apply with map application for navigation system. There are 2 type of GNSS:

1) Gps (Global Positioning System) is a global navigation satellite system operated by USA
2) Glonass (Global Navigation Satellite System) is a global navigation satellite system operated by Russia

Although both systems are global application, there are some signal measurement errors in an indoor environment and another seriously trouble is a reflection of tree or building that causes system malfunction.



Picture 2.15 Operation diagram of Gnss

2.3.5 Android Operating System

Android Operating System is a mobile operating system developed by Google based on Linux Kernel. This Os is designed to capable for Touch Screen system, usually be applied on Smart Phone and Tablet. Furthermore, both Smart Phone and Tablet are consisting of many sensors such as Magnetometer, Accelerometer, Gyroscope, Gps, Mobile Communication, Bluetooth and Camera. Since most people have these devices, development under this system is obviously to be more user friendly.

Picture 2.16 Picture of smart phone that use Android operation system.

Chapter 3 System design and analysis

3.1 Overview of working inside the system

Flow of information inside the system is start from the safety helmet, first the driver will equip the safety helmet and cause helmet equip event inside the safety helmet, then the mentioned event will be sent to the motorcycle and make engine start up cycle complete, the driver will able to normally start the engine, at the same time if the helmet put on event is not occurs, the engine start up cycle on the motorcycle will not complete, hence the driver will unable to start the engine. After control panel on the motorcycle received the event from the safety helmet, the motorcycle will send that information to server which will store the information of event from each motorcycle and display them when the user need to see the information.

After the driver able to starts the engine normally, meanwhile the safety helmet will periodically send the read data from sensor on the helmet to the motorcycle to inform head movement status of the driver, other than the information read by the sensor, the safety helmet will calculate abnormal events occurs while driving which those events are:

1) Abnormal turn of head angle from normal angle which occurs while driving the motorcycle. For example: lower the head too much.
2) Acceleration which exceeds specified standard value, which possibly caused by accidents or immediately brake.
3) Angular speed value exceeds specified standard value, which possibly caused by accidents or the driver turn his/her head very fast.
4) The safety helmet unable to detect that the driver is equipping the helmet which this event can be occurred by the diver intentionally remove the helmet or by accident which result in the safety helmet has been separated from the driver's head.

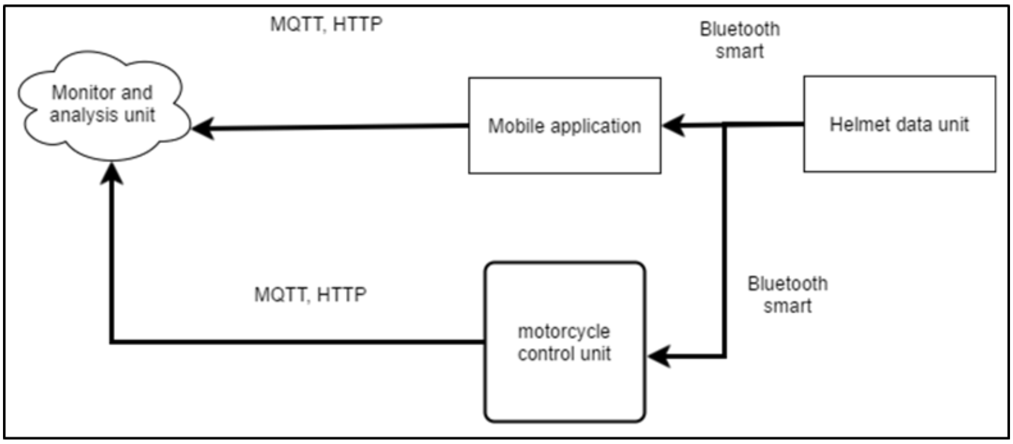
Anyhow the information which acquired by sensor reading or events calculation, all of them will be sent to the motorcycle then forward to the server to store for analysis in the future or to display when needed. Other than the information received from the safety helmet, the motorcycle will also create their own information, which these added information are:

1) Current speed of the motorcycle
2) Current geography location of the motorcycle
3) Geography direction which the motorcycle is heading
4) Present time

These information will be sent to the server by the same reason for information before, by the server side of information will be stored to display on monitor system for user who need to know present status of the driver, for example: currently the driver is driving the motorcycle at which level of speed, or if any abnormal event has occurred to the driver or not. Moreover, the server side is also calculates risk of the road the driver is using, for example: some roads has higher accident statistic than other roads or the driver's self who has driving behavior which tend to cause accident.

3.2 Component inside the system

The system has been separated to main 3 minor systems which are Helmet Data Unit (HDU), Motorcycle Control Unit (MCU), Monitor And Analysis Unit (MAU) and Mobile Application, which these 4 units will contact and send data to each unit as picture 3.1



Picture 3.1 Main component of the system

3.2.1 Helmet Data Unit (HDU)

Collects data from each Sensor on the safety helmet and calculate for abnormal events occurs while driving the motorcycle, after that send these data to Motorcycle Control Unit (MCU) via Bluetooth Smart or Bluetooth Low Energy as Network Protocol and via Mobile Application by using Bluetooth Smart or Bluetooth Low Energy as Network Protocol too.

3.2.2 Motorcycle Control Unit (MCU)

Receive data from HDU and examine if the helmet is equipped or not, if it equipped then off engine startup circuit else keep the circuit on, then create new data Packet by adding:

1) Current speed of the motorcycle
2) Current geography location of the motorcycle
3) Geography direction which the motorcycle is heading
4) Present time

Then send these new data Packet to Monitor And Analysis Unit via MQTT or HTTP as Network Protocol

3.2.3 Monitor And Analysis Unit (MAU)

Receive data from MCU to store and display present driving status of the driver to user, furthermore calculate and analyze received data to find risk of the route which the driver is using.

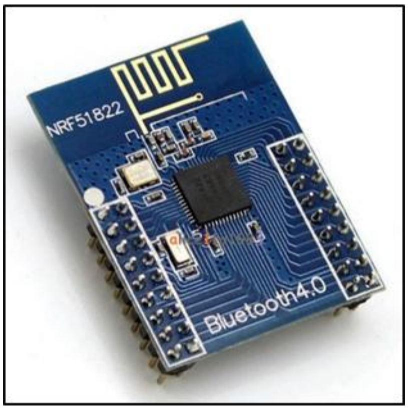
Applied device and technology

3.2.4 Helmet Data Unit (HDU)

Devices which chosen to be using in Helmet Data Unit (HDU) are:

3.2.4.1 Main processor unit NRF51822 Arm Cortex-M0

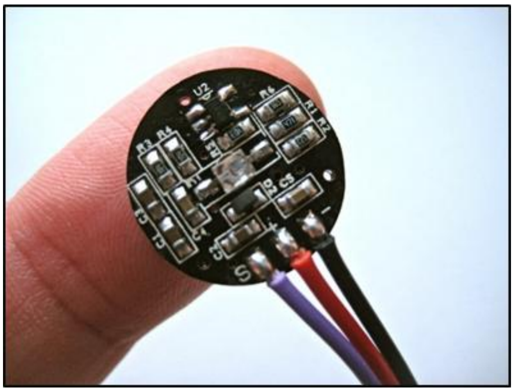
From the energy reason which mentioned in 2.2.1.3 made us to selected architecture of processor unit as Arm Cortex-M0 which is currently the most energy saving architecture of Arm. After searching for this chip model manufacturer, we decided to use NRF51822 which using architecture of the mentioned Arm, and in the chip is also installed Bluetooth Low Energy Module which produced by Nordic Semiconductor company, one of the most famous company in Wireless Communication.



Picture 3.2 Nrf51822 chip Arm Cortex-M0 With Ble Module

3.2.4.2 Optical Heart Rate Measurement

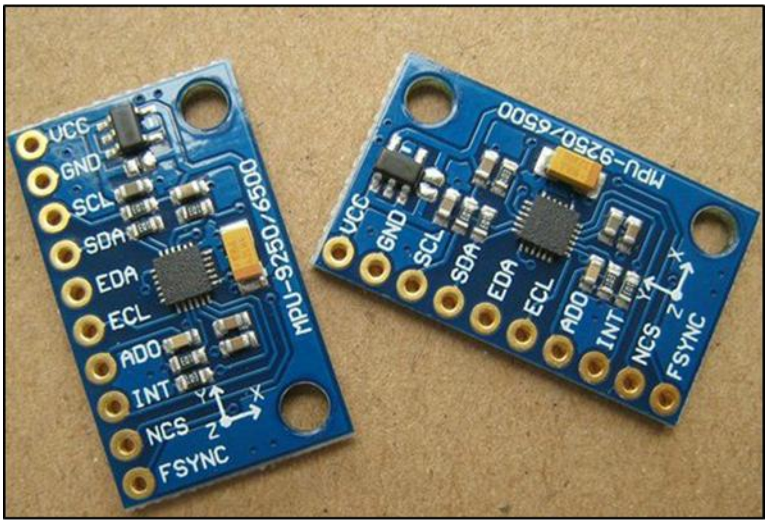
In detection if the helmet is being equipped or not, we using heart rate measurement of object inside of the helmet, with this method we can at least confirm of living thing in the helmet by using Heart Rate Measurement Sensor type Photoplethysmograph that measure from changing density of light reflected from the measured object (in this case are fingers, ear lobule or temporal) as the Sensor has the part that projects light into limb and the part with high density of reflected light. Picture 2.10 shows the sample of Pulse Sensor, the heart rate measurement which developer team is using. Picture 2.11 shows example of using direction of Pulse Sensor. And picture 2.12 shows the sample of heart rate wave read from the Sensor.



Picture 3.3 Example of Pulsesensor usage.

3.2.4.3 Inertial Measurement Unit

At any rate one of abnormality which occurs while driving is abnormal angle turn of head, to find the turning angle of head is using Accelerometer that able to measure acceleration from earth gravity on X, Y and Z axle. In this project the IMU that we selected to use is MPU9250 which is one of famous processing chip in Motion Processing, by Kernel of Android is also support this chip.



Picture 3.4 IMU board which using MPU9250 chip

3.2.4.4 Helmet Data Unit (HDU)
From the need of analyzed system can separates parts on the safety helmet as head movement consideration part, confirmation of the safety helmet is being equipped part and communication between the safety helmet and the motorcycle part.

3.2.5 Motorcycle Control Unit (MCU)
The devices which have been selected to use in Motorcycle Control Unit are:
3.2.5.1 Main processing unit Linkit Smart 7688 DUO
Is a part to brings each status data from the helmet and receives present location value from GNSS then send to the Sever, aside from acting as a communication medium between the safety helmet and the Sever, it is also manage vehicle's engine start up, if the user is not equip the helmet, he/she will unable to starts the engine. This system decided to use Linkit Smart 7688 DUO which is a device with 2 components as follow:

1) MT7688AN Micro Processor has Core as MIPS24KEc which developed by MIPS Technologies and OpenWrt as Operating System to manage each tasks and used in Embedded system such as Routers, Residential Gateways, And Video Game Consoles
2) Atmega32u4 Micro Controller has Core as Atmel AVR which developed by Atmel as a Chipset which being used as many models of Micro Controller

Picture 3.5 Linkit Smart 7688 DUO processing unit

3.2.5.2 Micro Processor to contact HDU NRF51822 chip

We selected to use architecture of processor unit as Arm Cortex-M0 which is an architecture of Arm and the same chip using in Helmet Data Unit.

3.3 Work design and architecture of system

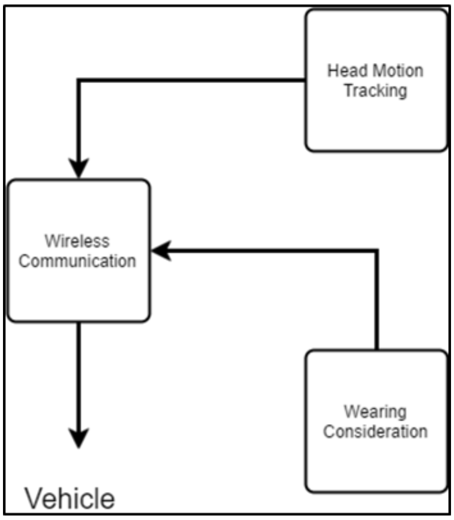
3.3.1 Helmet Data Unit

From the need of analyzed system can separates parts on the safety helmet as head movement consideration part, confirmation of the safety helmet is being equipped part and communication between the safety helmet and the motorcycle part.

3.3.1.1 Placing hardware components in the safety helmet

In each component inside Helmet Data Unit have these following roles:

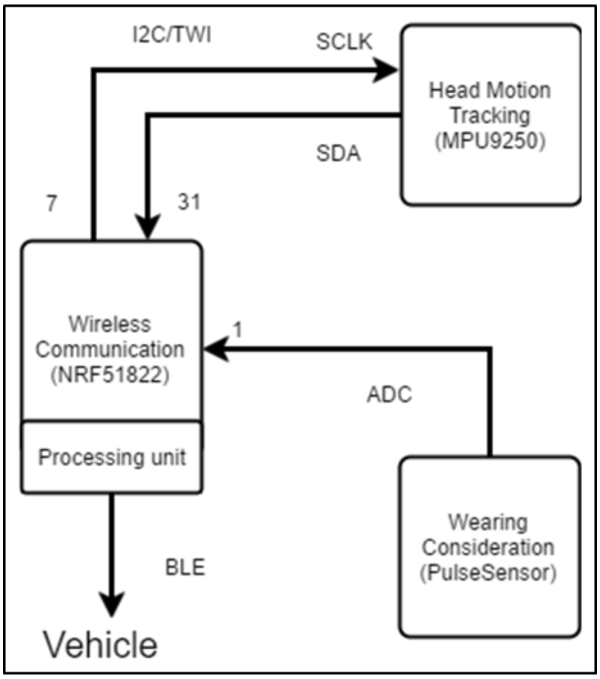
1) Head Motion Tracking: check head movement condition for pulling at the safety helmet, head rotation and size of angle in head look up or look down.
2) Wearing Consideration: check if the helmet is currently proper equip or not.
3) Wireless Communication: take responsibility in communicate between the safety helmet and the motorcycle.



Picture 3.6 Hardware components in the safety helmet

In real development, the developer has placed all hardware and connected them as follow:

1) Head Motion Tracking uses Accelerometer and Gyroscope by using sensor called Inertial Measurement Unit or IMU which IMU is inertia measurement unit. Accelerometer and Gyroscope that IMU using in this project is MPU9250 which including Accelerometer, Gyroscope and Magnetometer inside, the interface using to contact with processing part is I2C (Inter-Integrated Circuit)
2) Wearing Consideration uses Photoplethysmograph or organ capacity measurement by light which Photoplethysmograph will measures heart rate of the driver, the one used in this project is called Pulse Sensor that working with limit switch to increase examination accuracy.
3) Wireless Communication uses NRF51822 which is both Bluetooth Smart module and ARM architecture processing unit under the same IC.

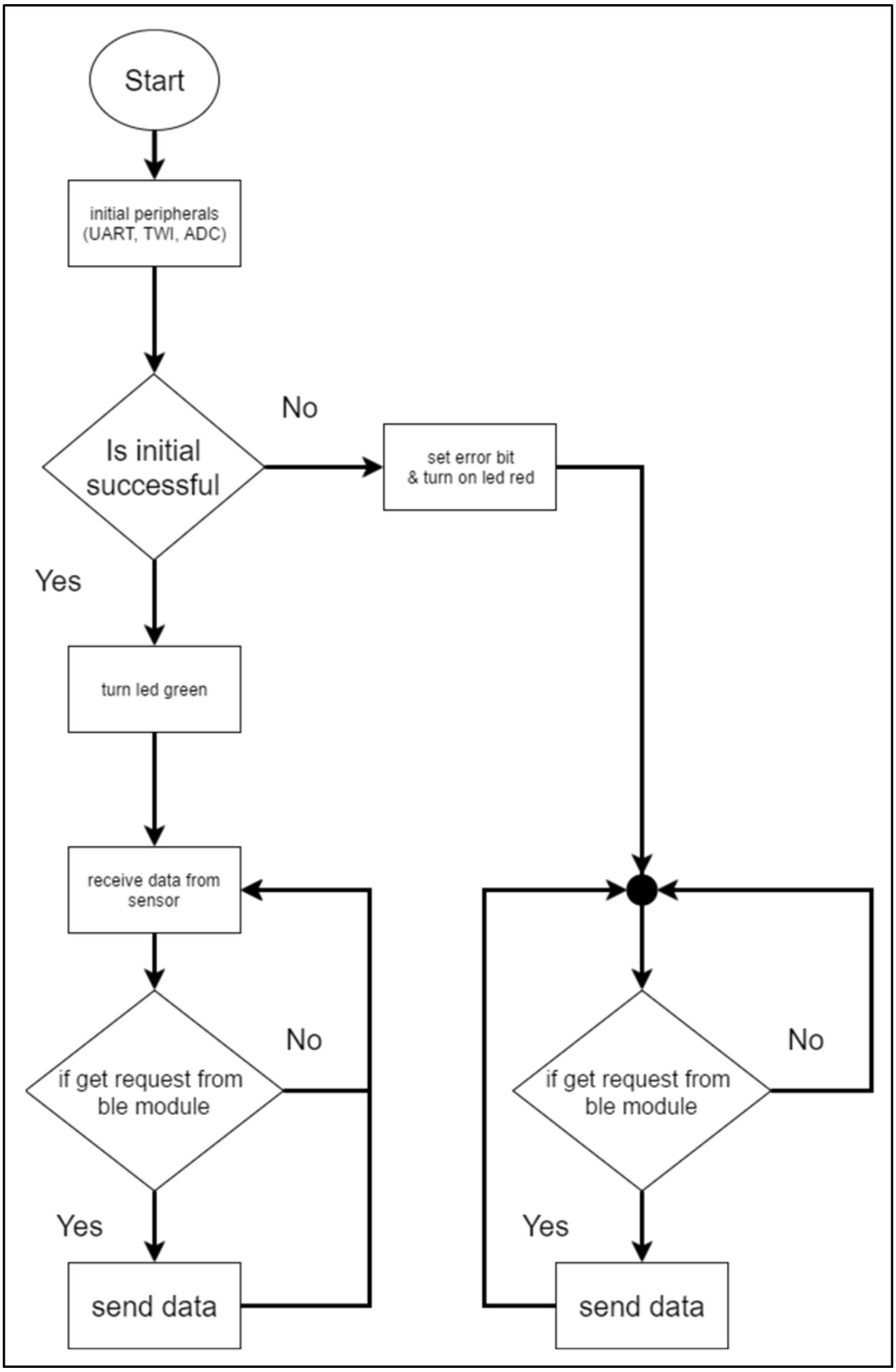


Picture 3.7 Hardware components inside the safety helmet shown connection between each hardware by name and number at edge of the arrows display connecting pin

3.3.1.2 Working procedure design

After activation of hardware inside the safety helmet, inside of the hardware will operate as follow:

1) NRF51822 examines working condition of all hardware inside the safety helmet, if there is any hardware including itself in abnormal status not ready to wok, NRF51822 will display on LED and store detail in specified Characteristic and Service
2) NRF51822 collects head movement status from MPU9250
3) When the user equipped with the helmet, NRF51822 will get that helmet equipment data from Pulse Sensor and limit switch
4) The data in 1 – 3 will be sent to the motorcycle via Bluetooth Smart module by the motorcycle will be a part that request for those data



Picture 3.8 connection of hardware component in the safety helmet

3.3.1.3 Services design and Characteristics inside Bluetooth Smart Profile

Because of there are 3 roles of the safety helmet divided by components which is overall a collection of the driver status then send to the motorcycle that can design Services and Characteristics as follow:

1) Helmet Information Services provides necessary information to the motorcycle which is main Service and only Service in the safety helmet Profile, because there is no other role than bring the data to the motorcycle
2) Error and Event Characteristic collects data which tell the abnormality in status of the safety helmet such as hardware malfunction and inform on occurred event, for example the helmet is being equipped or unusual head movement, by keep the data as shown on picture 3.9

3-bit reserved	2-bit Wearing Status	3-bit Anomaly Type	8 bits Helmet Error

Picture 3.9 Error and Event Characteristic

3) Acceleration Characteristic store raw data of acceleration value occurred on the safety helmet, which maximum value (0x7FFF) is 16G and minimum value (0x8000) is -16G by keep the data as shown on picture 3.10

2-byte Rx	2-byte Ry	2-byte Rz

Picture 3.10 Acceleration Characteristic

4) Angular Velocity Characteristic: keep raw data of angular speed value occurred on the safety helmet which maximum (0x7FFF) is means the angular speed value at 2000 degree/sec and minimum (0x8000) is means the angular value at 2000 degree/sec by store the data as shown on picture 3.11

2-byte Rx	2-byte Ry	2-byte Rz

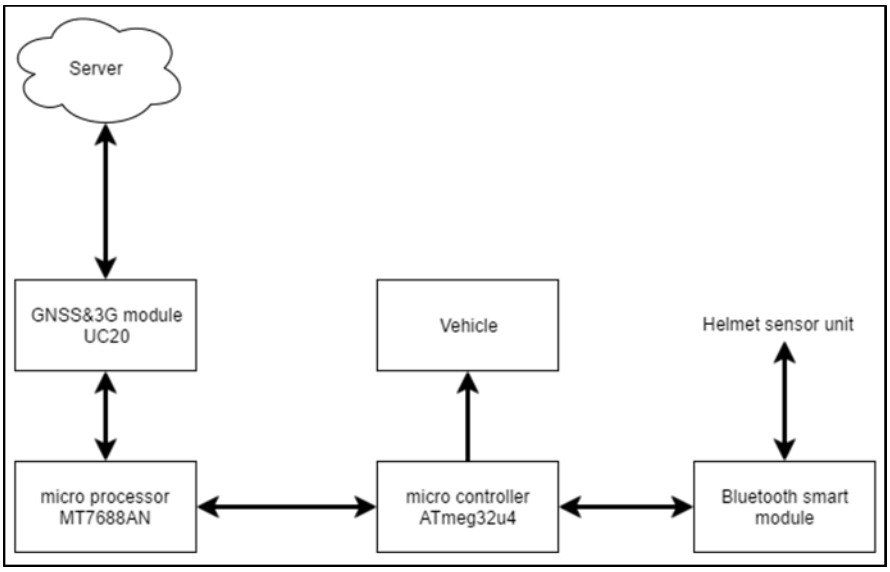
Picture 3.11 Acceleration Characteristic

3.3.2 Motorcycle Control Unit

From the need of analyzed system can divided this unit into 2 parts, motorcycle control part and the safety helmet connection

3.3.2.1 Placing hardware component inside the safety helmet

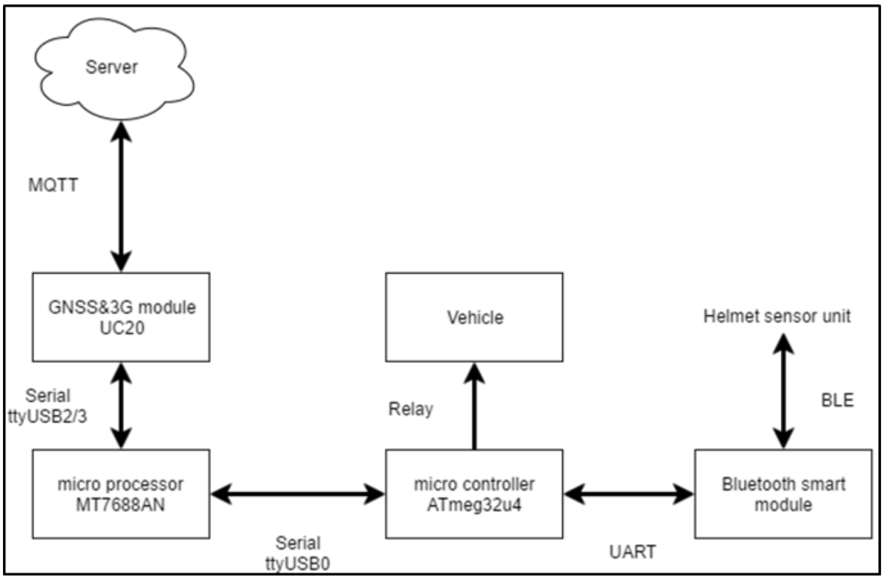
In system operation there are inside communication of Vehicle by communication between Micro Processor and Gnss Module, use Ttyusb2 Micro Processor and 3g Module, use Ttyusb3 which is this Module uses as Default communication route, for connection of Micro Processor and Micro Controller, selected Linkit Smart board use connection route Ttyusb0 as Default, for vehicle control part uses Relay help in controlling. And finally is Bluetooth which using Uart to communicate with Bluetooth Smart Module



Picture 3.12 Hardware components inside the safety helmet

3.3.2.2 Connection between components

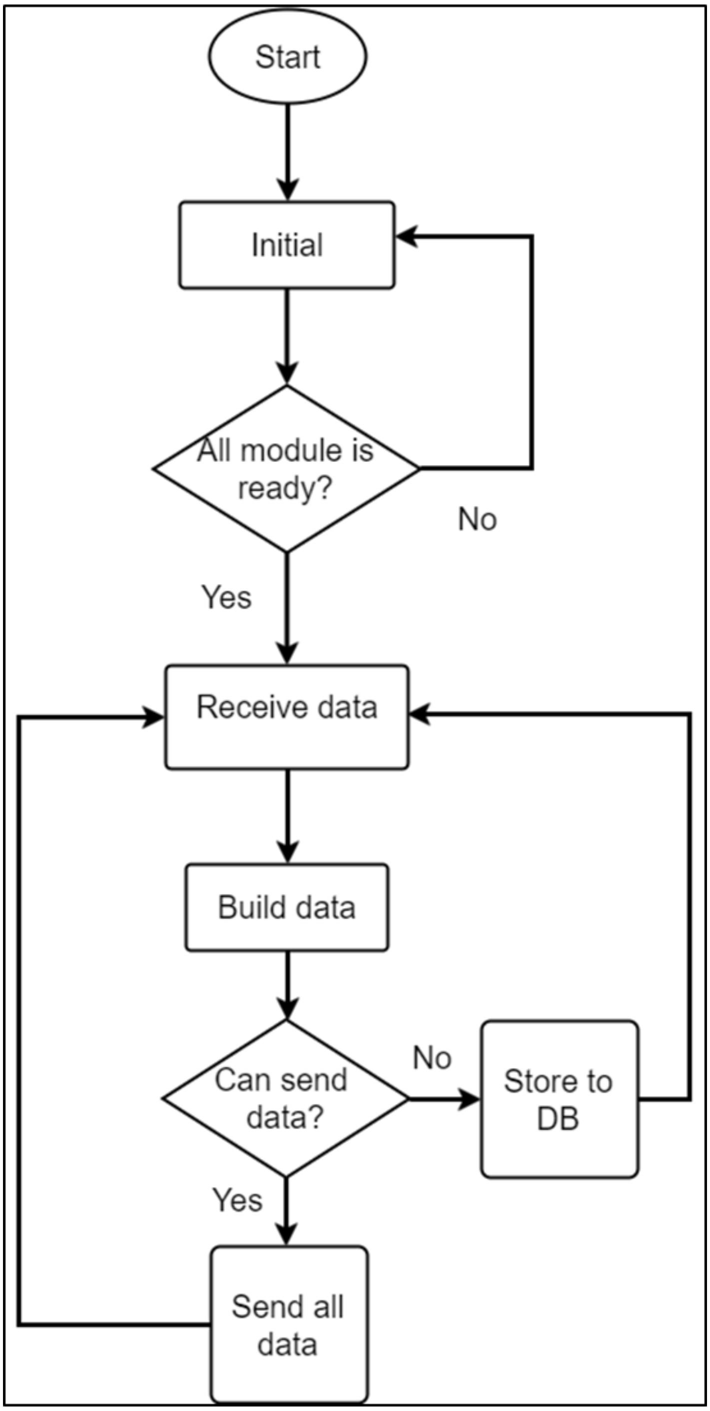
Communication channel inside system in Vehicle part by communicate between Micro Processor and GNSS Module using Ttyusb2, Micro Processor and 3G Module using Ttyusb3 which this communication channel is a cannel that Module use as default communication channel Default between Micro Processor and Micro Controller, Linkit Smart board that selected to use is using communication channel Ttyusb0 as Default, for Vehicle control using Relay to support in control, lastly is Bluetooth will use UART to communicate Bluetooth smart module for communication between the safety helmet and the motorcycle



Picture 3.13 Connection between hardware inside the safety helmet

3.3.2.3 Software operation

For Micro Controller Unit when start operate will connect to Helmet Sensor Unit to check if the safety helmet is being equipped or not, if not it will wait and recheck again, after the helmet equipped it will close the engine start up circuit and let the user to normally start the engine. After that if the helmet is removed while driving, it will not open the circuit but will alert instead. For data request from Helmet Sensor Unit, it will request as Interval every 0.5 second, and continue counting, when meet the specified number (set number is 10) or Alert from abnormal event such as the helmet removal, abnormal head movement or accident occurred, it will send to Micro Processor for next operation.



Picture 3.14 Software operation

3.3.3 Design of Monitor And Analysis Unit: Mau

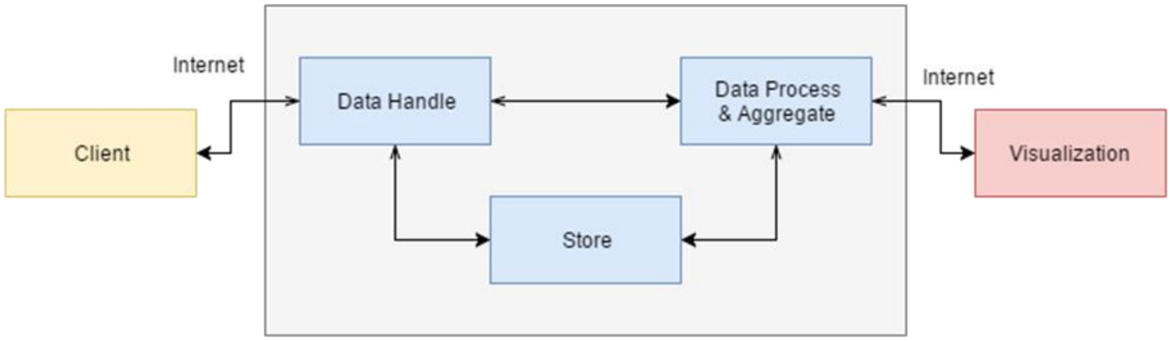
3.3.3.1 Overall of system working procedure

In system operation when the system received data from Client, user side who using the safety helmet will send data via Internet network then access to Server and analyze the data then send to the user. Inside Server system will have 3 main roles of working procedure as follow:

Data Handle is data management by receive the data from Client via Mobile Application on the motorcycle and on Web Application which mainly transfer data with protocol Mqtt and Http, when the safety helmet detected high risk event for accident or when need to send the data, will send the data to Server which have role to receive data.

Data Process And Aggregate is process, analyze and sort the received data in workable format and appropriate to store for example: when received speed data it will analyze if that event use more speed will have high or low risk to occur accident, or analyzed that the driver is driving on high risk to occur accident road, with these

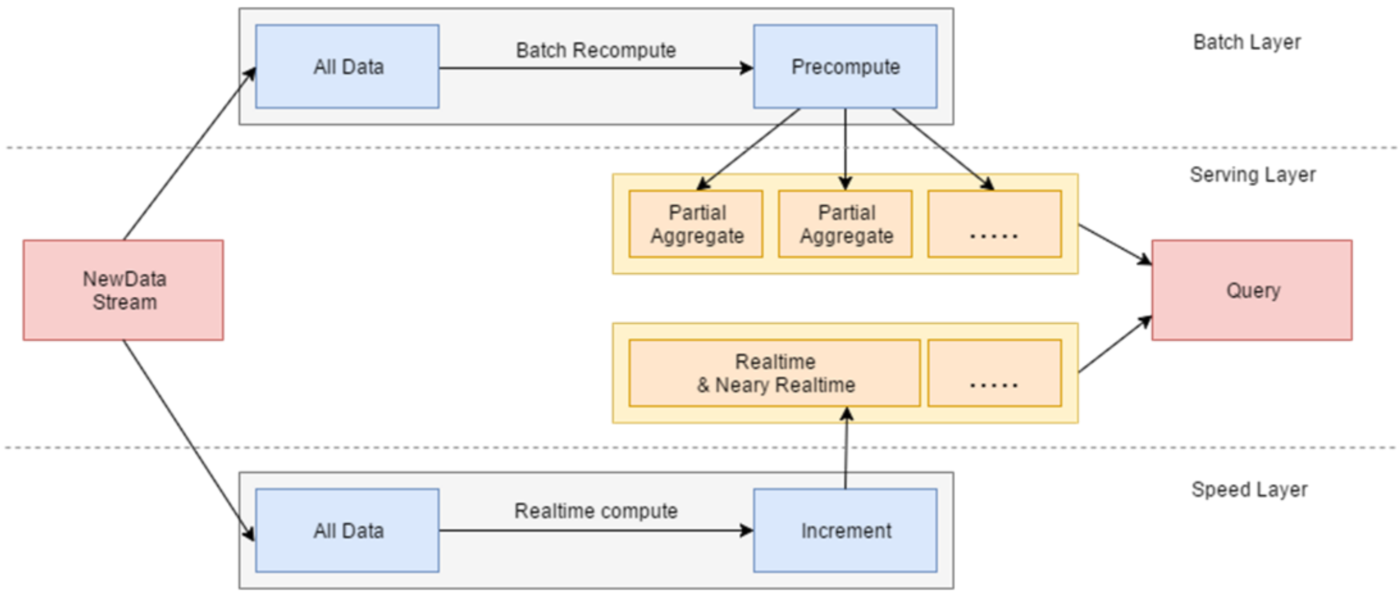
analysis, it needs to get driving data that been stored to analyze too, after the analyzed and sort the data, it will be stored in database and display in Web Application and Mobile Application format.
Store is data storage by its main responsible is to manage data, which data should be kept and how to be kept because some data has frequency to use only one time, it will have different format to store that data.



Picture 3.15 Overall of system operation

3.3.3.2 Architecture of system format

Because of system operation need quick responding, also has chance to receive a lot of data in one period and it need to be ready to trackback the data for analyze driving and safety data which made the developing system need to have main ability to quickly operate, close to real-time in sending data to the user and able to analyze data which stored in database to quickly find relation. To meet those expectation we selected Lambda Architecture which is an architecture using in system that has Real Time processing to be a part of this system, the strong point of this system is stable working, able to support with usage of high amount of data with diversity, including speed in read and write data which have 5 main components as follow:



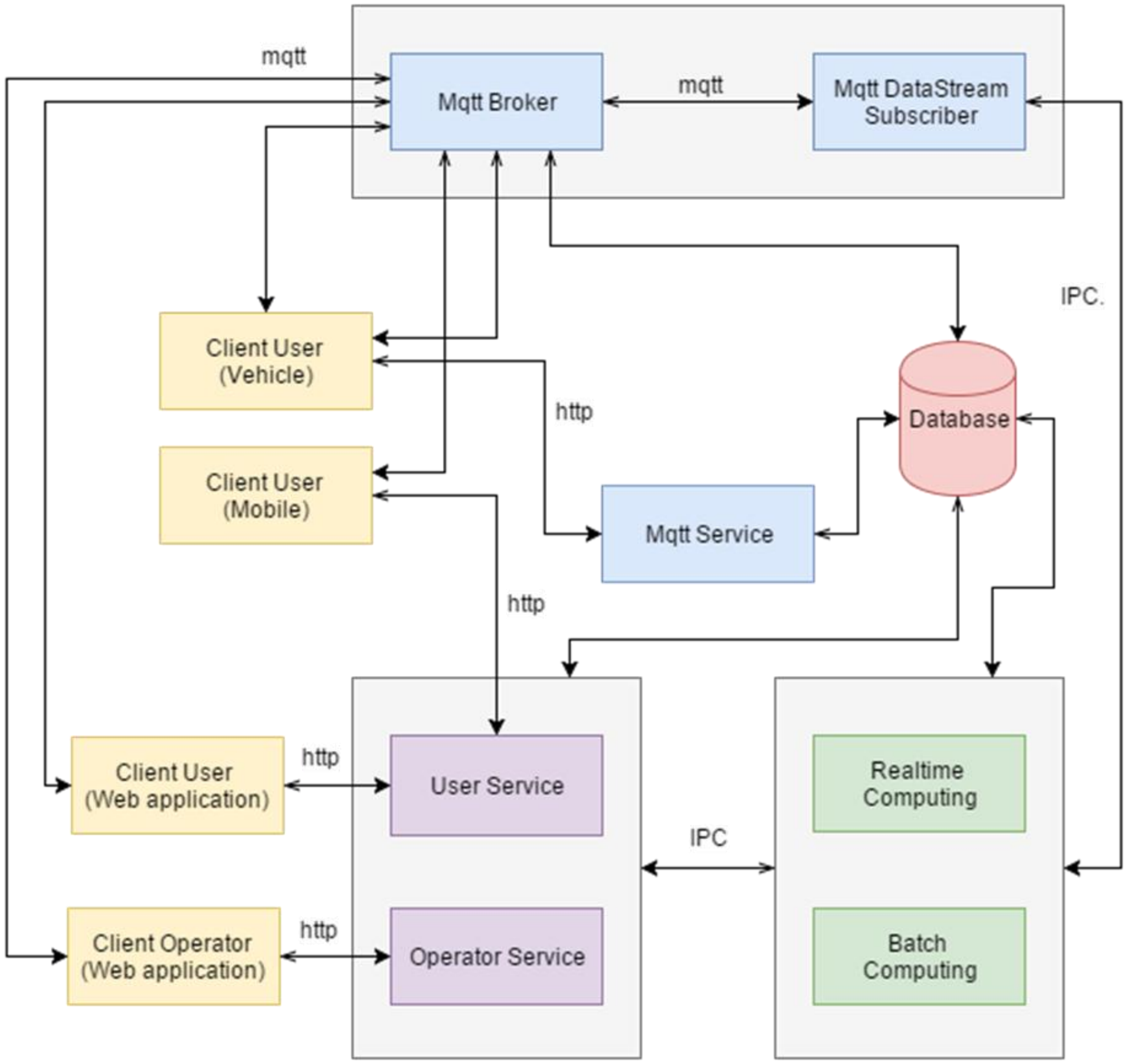
Picture 3.16 Architecture of system

1) New Data Stream is many types of data which come into the system by the received data will distribute to different parts, for example: if the data need to Process with previously stored data, have big size and do not needs speed analysis and response, it will be sent to Batch Layer. For the data that needs less analysis but need quick response, it will be sent to Speed Layer by each part has different strong and weak point.

2) Batch Layer is operation type that not requires quick response and need to Process with other previously stored data which its 2 main function are:
   - Store raw data, no need to process and can only increasing.
   - Process data by report or other format which require calculation by operate as Batch Processing.
3) Serving Layer is a part to collects and sorts data which been processed from Speed Layer and Batch Layer operation for quick access of data.
4) Speed Layer is added part for a system that require high alteration of data and need Real Time data which created to support Serving Layer to operate more freely.
5) Query act to Request data and gather data from Serve Layer and Speed Layer to send the data back to the user as requested.

3.3.3.3. System structure component in detail

Inside of processing system for Server side will separate to 5 main parts by their function and relation as follow:



Picture 3.17 System structure component in detail

1) Data receiving part from Client is a part that receive Client data from Internet which sent via 3g network into Server, this part can compare to Data in Lambda Architecture diagram and connects to 2 main parts in the picture:

- Mqtt Broker is a Processer which functions in receiving data from Client via protocol Mqtt and manage Topic of data received from Client
- Mqtt Data Stream Subscriber is a part perform data receiving from Mqtt Broker to divide Topic of data then send the received data to Batch Layer and Speed Layer.

2) Data analysis and sorting part, this part receives data from Mqtt Datastream Subscriber to analyze data which able to compare with Batch Layer and Speed Layer in Lambda Architecture diagram, there are 2 relate parts as follow:
   - Real Time Computing performs new data sorting or changing which has no relation with previously stored data and require speed in data writing and reading such as speed, status, acceleration, direction or location
   - Batch Computing functions in analyze and find relation of new data and previously stored data such as currently driving road has how much risk to cause accident if compare to present speed or the currently driving road has always cause accident or now and how to do for more safety driving
3) The user data store management part is a part which main operate at Mqtt Service performs in management of Username, Password and also Authorization of Mqtt Broker
4) Client connection part, for this part it will connect and send data to Client for display on Web Application and Mobile Application which can compare with Serving Layer of Lambda Architecture, able to divided into 2 main parts as follow:
   - User Service provides data to Client when requested from Web Application or Mobile Application such as using history, history data.
   - Operator Service provides data to Client when requested from Web Application or Mobile Application such as using history, history data.
5) Data displaying part functions in Visualization data received from Serving Layer and performs data request from Serving Layer by it can be compared with Query in Lambda Architecture which this part will display data for Client to see and Query data to visualize

Chapter 4 Experiment and result

4.1 Experiment of connection between the safety helmet and the motorcycle

Test wireless connection between the safety helmet and the motorcycle by turn on the system on the safety helmet then counting time that the motorcycle create connection to the safety helmet by set the maximum at 20 seconds, if within this 20 seconds the connection between the safety helmet and the motorcycle unable to create will count as the connection failed. The experiment divided to 4 types by distance between the motorcycle and the safety helmet which are distance of the safety helmet is placing on the motorcycle, the distance 3 meters between them, the distance 10 meters between them and the distance 50 meters between them. Each experiment done 20 times, which after the safety helmet is on, the system will immediately receive the connection from the motorcycle

Assumption: If the distance between the safety helmet and the motorcycle is in operation standard distance which Bluetooth Smart standard supports (> 100m) the connection will always be created

Distance of placing the safety helmet on the motorcycle

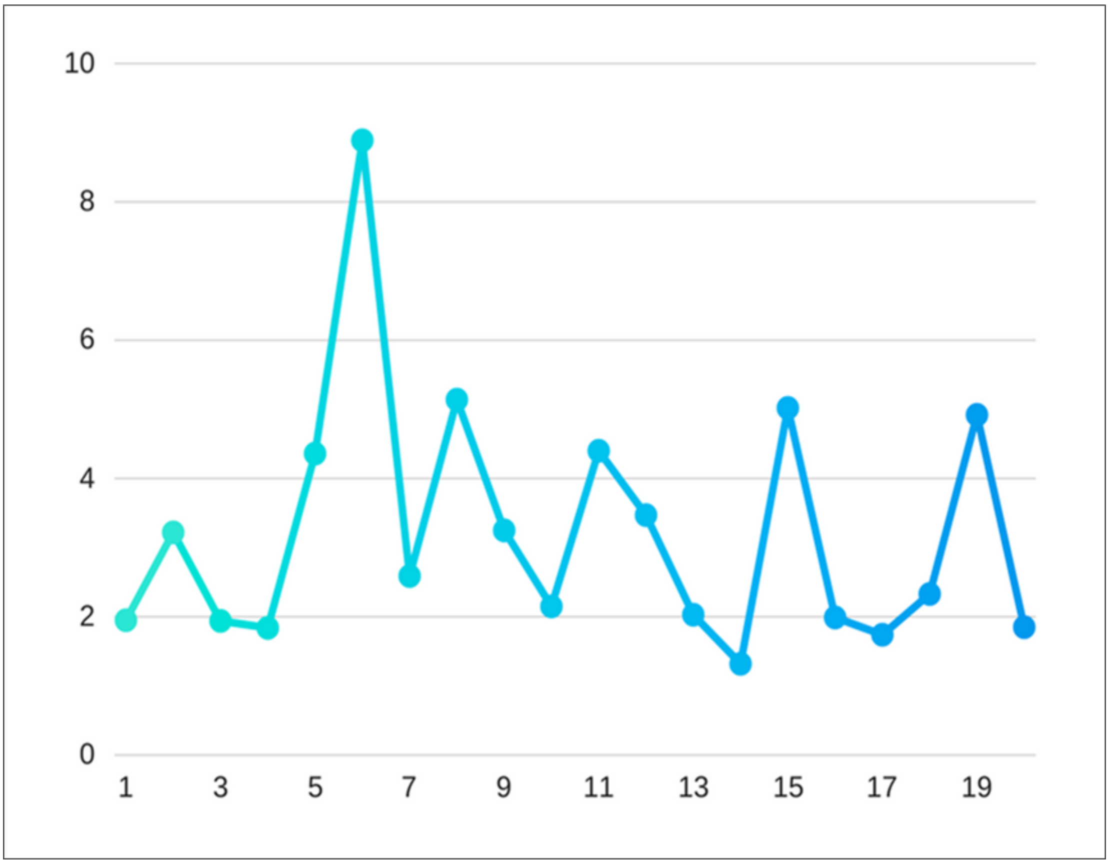
Result

Time	Connected	Not connect	Ratio (%)
20	20	0	100

Data from the experiment

Time	Connecting time (Second)	Connected		Time	Connecting time (Second)	Connected
1	1.94	/		11	4.39	/
2	3.21	/		12	3.46	/
3	1.93	/		13	2.02	/
4	1.83	/		14	1.31	/
5	4.35	/		15	5.01	/
6	8.88	/		16	1.98	/
7	2.58	/		17	1.73	/
8	5.13	/		18	2.32	/
9	3.24	/		19	4.91	/
10	2.14	/		20	1.84	/

The graph below shown relation of all 20 times experiment and time used in each connection



Distance of 3 meters between the safety helmet and the motorcycle

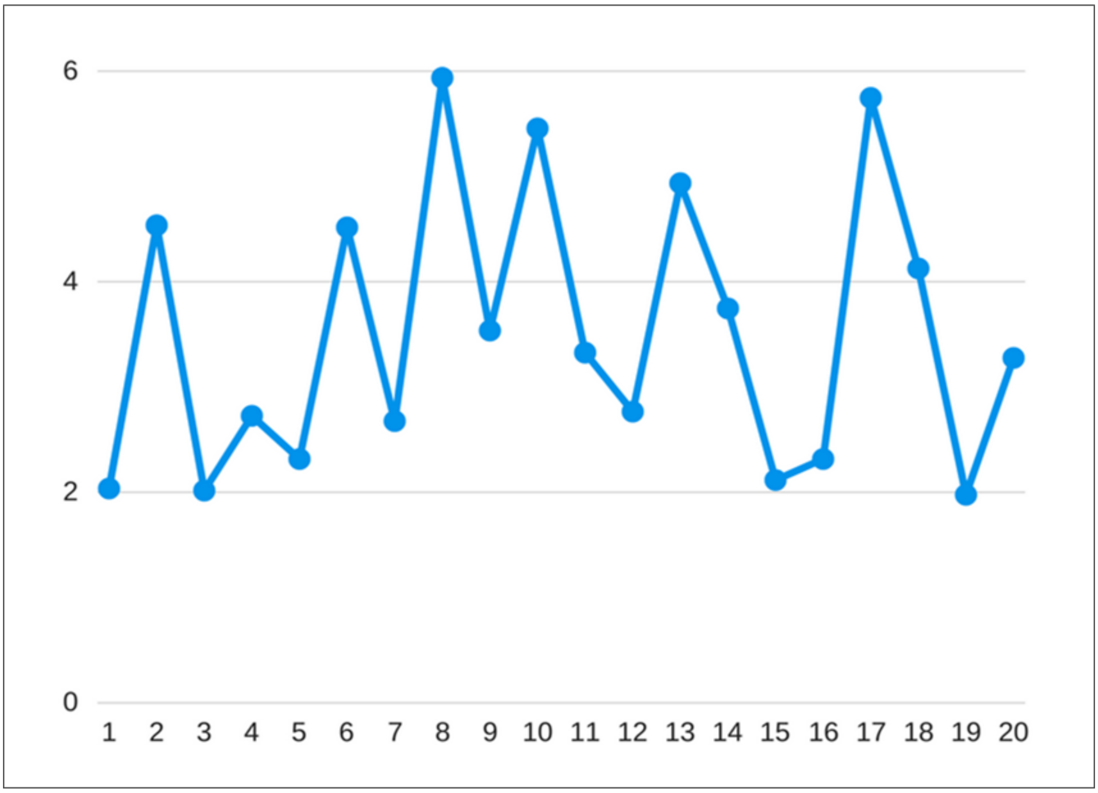
Result

Time	Connected	Not connect	Ratio (%)
20	20	0	100

Data from the experiment

Time	Connecting time (Second)	Connected		Time	Connecting time (Second)	Connected
1	2.03	/		11	3.32	/
2	4.53	/		12	2.76	/
3	2.01	/		13	4.93	/
4	2.72	/		14	3.74	/
5	2.31	/		15	2.11	/
6	4.51	/		16	2.31	/
7	2.67	/		17	5.74	/
8	5.93	/		18	4.12	/
9	3.53	/		19	1.97	/
10	5.45	/		20	3.27	/

The graph below shown relation of all 20 times experiment and time used in each connection



Distance of 10 meters between the safety helmet and the motorcycle

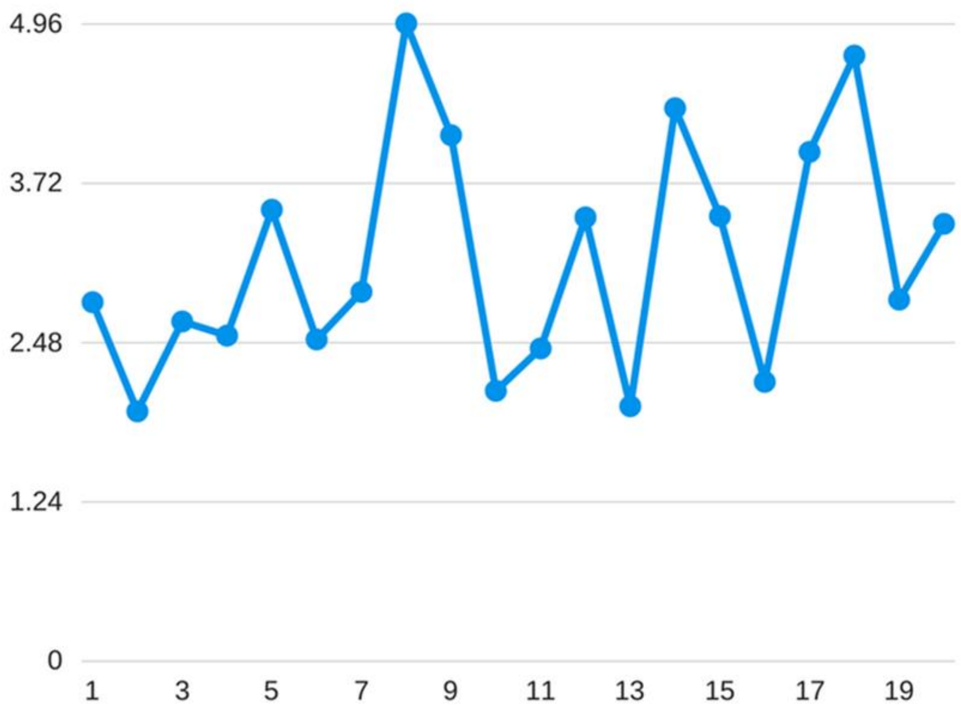
Result

Time	Connected	Not connect	Ratio (%)
20	20	0	100

Data from the experiment

Time	Connecting time (Second)	Connected		Time	Connecting time (Second)	Connected
1	2.79	/		11	2.43	/
2	1.94	/		12	3.45	/
3	2.64	/		13	1.98	/
4	2.53	/		14	4.30	/
5	3.51	/		15	3.46	/
6	2.50	/		16	2.17	/
7	2.87	/		17	3.96	/
8	4.96	/		18	4.71	/
9	4.09	/		19	2.81	/
10	2.10	/		20	3.40	/

The graph below shown relation of all 20 times experiment and time used in each connection



Distance of 50 meters between the safety helmet and the motorcycle

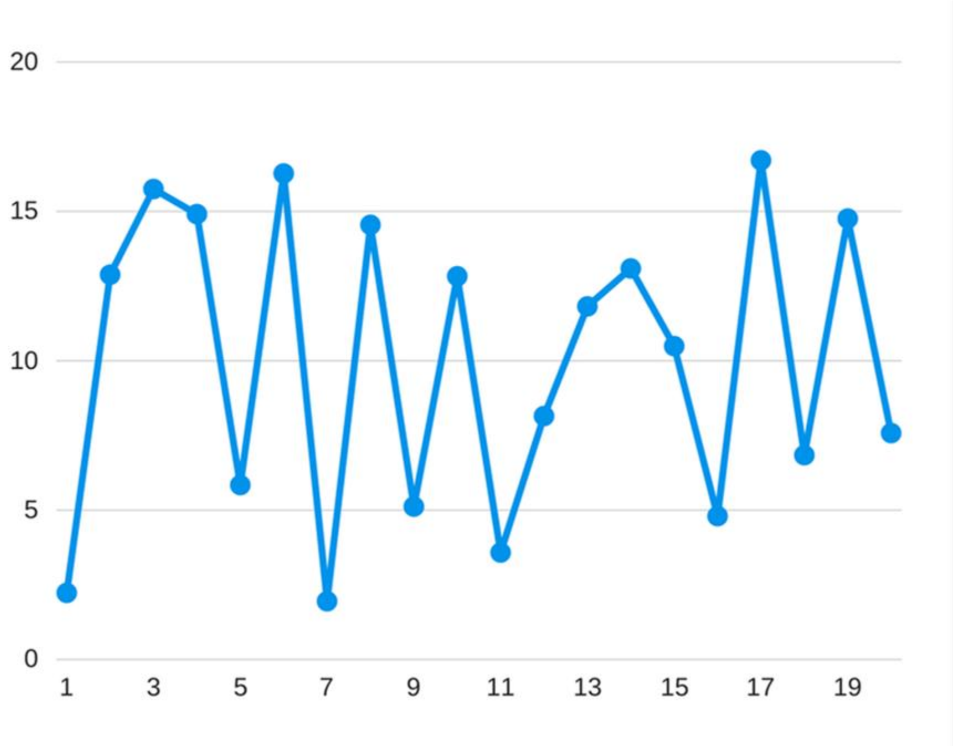
Result

Time	Connected	Not connect	Ratio (%)
20	20	0	100

Data from the experiment

Time	Connecting time (Second)	Connected		Time	Connecting time (Second)	Connected
1	2.21	/		11	3.56	/
2	12.86	/		12	8.13	/
3	15.73	/		13	11.80	/
4	14.89	/		14	13.07	/
5	5.82	/		15	10.47	/
6	16.25	/		16	4.78	/
7	1.93	/		17	16.69	/
8	14.53	/		18	6.82	/
9	5.10	/		19	14.74	/
10	12.81	/		20	7.56	/

The graph below shown relation of all 20 times experiment and time used in each connection



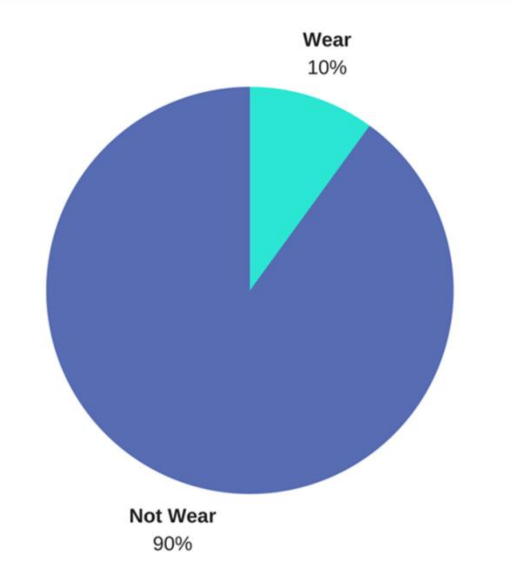
4.2 Experiment on accuracy to check if the safety helmet is being equipped

Test for how accurate and correct of the system to detect if the driver is being equipped with the safety helmet or not, the experiment is done by confirmation on monitor which receive data from the server to see how it response to the safety helmet equipment, if the safety helmet is equipped and monitor show status that the driver is equipped the helmet will count as correct, but if the driver equipped with the helmet while monitor show as not equip will count as incorrect. The experiment divided into 2 types which are equipped the safety helmet and not equipped the safety helmet each done 20 times.

Not equipped the safety helmet

Result

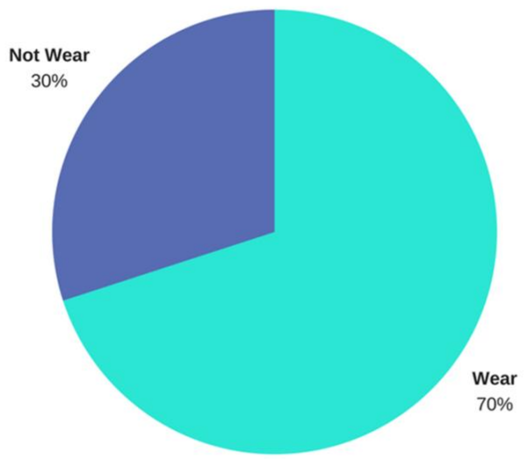
Time	Equipped	Not Equipped	Accuracy (%)
20	2	18	90



Equipped the safety helmet

Result

Time	Equipped	Not Equipped	Accuracy (%)
20	14	6	70



4.3 Experiment of accuracy in detecting abnormality while driving

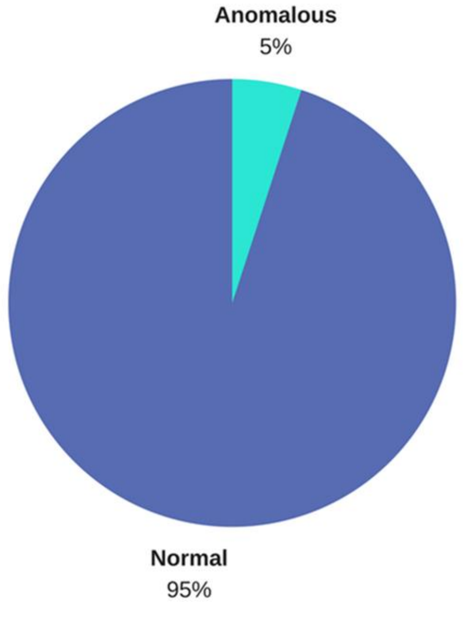
Test to see how accuracy of the system in detecting any abnormality occurs while driving, the experiment is done by confirmation on monitor which received data from the server to see how it response to abnormal head movement. The experiment divided into 3 types of abnormality which are abnormal movement, abnormal incline angle of head and abnormal acceleration each done 20 times.

Abnormal movement experiment

The experiment is done by placed the safety helmet steady on the floor which is a normal movement

Result

Time	Abnormal	Normal	Accuracy (%)
20	1	19	95

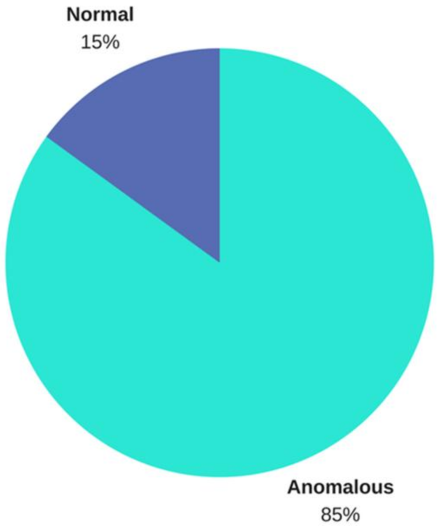


Abnormal incline angle of head experiment

The experiment is done by placed the helmet in angle more than 45 degree in pitch and roll axle which are abnormal angle in driving

Result

Time	Abnormal	Normal	Accuracy (%)
20	17	3	85

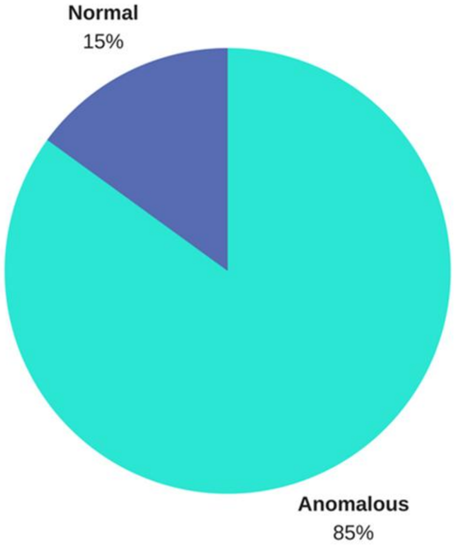


Abnormal acceleration experiment

The experiment is done by pull the safety helmet in high acceleration to created abnormal acceleration to the safety helmet

Result

Time	Abnormal	Normal	Accuracy (%)
20	17	3	85



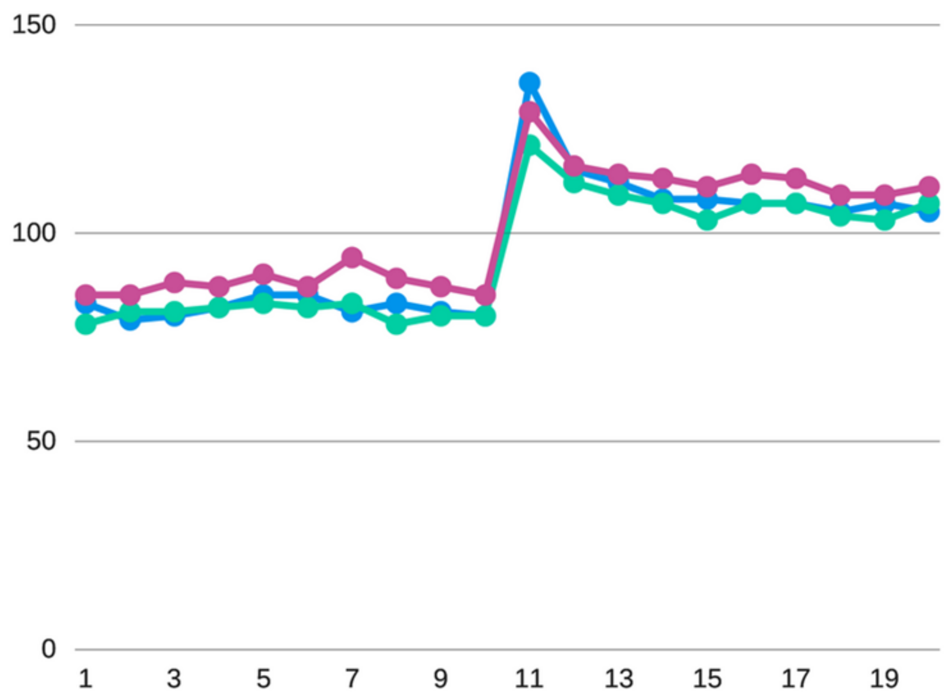
4.4 Experiment of accuracy in heart rate measurement

Test to see how accuracy of the system to measure heart rate of the driver, the experiment is done by equipped Fitbit which is a famous wearable device used to evaluate the exercise such as count the walking steps or measure heart rate to the driver. In this experiment will use only heart rate measurement function of Fitbit which the test has been done 20 times, the first 10 times are heart rate measurement of the driver in normal state (rest) and the last 10 times are heart rate measurement after exercise of the driver, because of the heart rate measured from Fitbit changes very slow, so we compared them like this, first measured heart rate from Fitbit then measured again after 15 seconds to see the maximum and minimum of heart rate from the safety helmet which done 20 times

Result

Time	Fitbit	Minimum	Maximum		Time	Fitbit	Minimum	Maximum
1	83	78	85		11	136	121	129
2	79	81	85		12	115	112	116
3	80	81	88		13	112	109	114
4	82	82	87		14	108	107	113
5	85	83	90		15	108	103	111
6	85	82	87		16	107	107	114
7	81	83	94		17	107	107	113
8	83	78	89		18	105	104	109
9	81	80	87		19	107	103	109
10	80	80	85		20	105	107	111

The graph below shown relation of all experiment 20 times with heart rate measured in each time, the blue, green, red in the graph means heart rate measured from Fitbit, minimum heart rate from the safety helmet and maximum heart rate of the safety helmet accordingly.



Chapter 5 Summary and suggestion

5.1 Summary

After developed and experiment this project we found that the system is working well in detecting if the driver is being equipped with the safety helmet or not, which is enforce the driver to wear the safety helmet every time before start the engine, while abnormality detection in driving is not much accuracy, the system is able to show all status information on monitor which received data from the server.

5.2 Problem, obstacle and solution

1) Emulator in developing mobile application is not supports google map and Bluetooth operation
   Solution
   Need to develop on real device to solve the problems but it also case the development to a bit delay

2) Some library and method has been deprecated or not support on the device use in development
   Solution
   Some library can replace with other method but some are irreplaceable so we have to enforce operation of some method to be able to run but something will not able to display so we need to make sure that when install in newer device it should be operate perfectly

3) In the motorcycle development after installation it consumed much time before able to take the experiment
   Solution
   Experiment on small function with unrelated to overall system, then take overall experiment when ready it will not consume much time in experiment

5.3 Suggestion

1) Able to further develop in case of the safety helmet and the motorcycle distance is more than 50 meters occurred then alert to the user and server
2) Further develop to have one motorcycle able to connect to nearby motorcycle’s system for wider application
3) Develop to be able to alert risk point with voice via safety helmet and also connect to mobile phone to immediately know when there is any call in