**2.2 Subsystem in PCB**

**2.2.1 Power Supply Subsystem**

**Description:**

To enable the PCB and the attached components to work, the power supply subsystem is considered to be consisted of two 5V Batteries as the power supply and a voltage regulator. The voltage regulator will convert input voltage to voltages usable by the corresponding components.

**Requirement:**

The available working time of power supply should exceed the time for a vehicle’s test period on a road, which means we need to check the batteries’ capability. And it could support all the voltage supply requirement of the sensor components. Besides, the power supply subsystem should be fixed well somewhere near PCB to avoid sliding or poor connection when the vehicle is driving.

**2.2.2 Location Tracking Subsystem**

**Description:**

To fetch the location information of the vehicle, our group consider setting a GPS module into the PCB. By using NEO-6M GPS module, we can use the TinyGPS library provided by this module to get varieties of location data we need, such as latitude, longitude and altitude along with time. And we can save these data and upload them into the server by WiFi module for further use.

**Requirement:**

The GPS module should be capable to do location tracking on the vehicle in real time, meanwhile providing location data in enough accuracy to allow us to detect the vehicle’ real-time position on a road.

**2.2.3 Road Anomalies Detection Subsystem**

**Description:**

1. **Accelerometer:**

To measure road quality, the first kind of sensor to be applied is the accelerometer. The sensor can detect real-time acceleration data in 3-D space. What we need is the acceleration in vertical direction or z-axis, and greater vibration amplitude and frequency occurring in such signal denotes worse road condition for vehicles.

According to Newton's second law: A (acceleration) =F (force) /M(mass) . We can obtain the acceleration of a given mass by measuring the force F with piezoresistors. The essence of the acceleration sensor is to cause the deformation of sensitive components inside the sensor through the force, and the corresponding acceleration signal can be obtained by measuring its deformation and converting it into voltage output with the relevant circuit. Our accelerometer will consist of a movable mass, some reed that connect and constrain the mass to balance the force F, and electrodes to convert force to electric signals.

Since the initial state of our accelerometer will still have acceleration of g, we need to exclude this factor with initialization. It can be explained by the formula below.

Gx = (ADCx-offset)/K (unit:m/s^2)

ADCx means sensor output, Gx stands for true acceleration, offset denotes output of sensor when Offset acceleration is 0g, and K is the scale factor.

1. **Gyroscope:**

While the vehicle is static or in a uniform linear motion, the accelerometer itself serves as an ideal inclinometer. In that the vehicle does not always keep its z-axis upright when swerving, however, a gyroscope should used to normalize signals given by accelerometer. The device detects inclining angles of our measuring board in different directions and uses kalman filter algorithm, which would be applied in our filter module [1]. This process is called reorientation.

Without a need for offset, the values of gyroscope can be more easily calculated.

R = ADCrate/K (unit:degree/s)

ADCrate means sensor output, R means angular rate, K stands for scale factor.

1. **Magnetometer**

Magnetometer is an optional sensor that could be applied so as to exclude interference in horizontal directions or x-y plane. It is obvious that gyroscope data variation caused by taking turns will not contribute to our detection for road condition. But if the vehicle wobbles due to potholes on the road surface, the changes of gyroscope then become meaningful. Magnetometer can monitor changes in the horizontal direction based on mistors whose value will change according to its relative direction to geomagnetic field. Since nowadays 6-axes sensor modules that combine two kinds of sensors (accelerometer and gyroscope) are more prevalent and convenient, the application of magnetometer can be tedious and fallible to some extent. Also, GPS system can provide similar information alternatively. Therefore, the magnetometer is optional and not necessary.

**Requirement:**

1. **Interference Immunity**

We consider two types of interferences: environmental and kinematical.

One of the factors that count for the accuracy of accelerometers most is temperature. Capacity accelerometers are more immune to temperature changes, thus becoming a better choice. Meanwhile, the application of gyroscope and filter algorithm lowers the error of vehicle motion as far as possible kinematically.

1. **Low cost**

We consider cost of sensors and further how sensor usage contributes to cost of our whole project.

6-axis sensors in China is relatively cheap. For example, MPU-6050 that contains a 3-axis capacity accelerometer and a 3-axis gyroscope is sold for no more than 100 yuan. More budget though an extra magnetometer requires, it can raise overall accuracy of our detection, thus available to be attached to transportations of lower cost, such as electromobiles and bicycles. Therefore, the cost requirement can be achieved.

1. **Appropriate sensitivity**

High sensitivity does not necessarily mean high accuracy of final results, since it might record too many undesired signals.

The sensitivity of capacity accelerometer lies between piezoelectric accelerometer and servo accelerometer. Due to lower sensitivity, piezoelectric accelerometer can hardly monitor continuous variation of acceleration. Worse still, all three-axis acceleration data were close to 0 g when the vehicle was in temporary freefall while entering or exiting the potholes, but in that case a piezoelectric accelerometer will be out of function [2]. by contrast, the sensitivity of servo accelerometer can be too high to come to an effective result. In conclusion, the capacity accelerometer widely used in mobile phones is also optimal in terms of sensitivity consideration.

1. **Space Limit**

Undoubtedly, the volume of sensors cannot be too large for our vehicle.

We would like to limit the size of 6-axis sensors, so that it occupies less space. MPU-6050, for instance, is a rational option. It has super mini package size, which is 4x4x0.9mm, about the same size of any used chip on the PCB board.

**2.2.4 Control Subsystem**

**Description:**

For better interface with the cloud server, our group consider using a mini controller to communicate with all the sensor subsystem and the WIFI module. We can use a ATmega328 controller to receive the data from the accelerometer and GPS module and

send the data to the backend service using the WiFi module.

**Requirement:**

The control module could capture data from the sensors and check if sensor readings are within certain thresholds. If the data is not in rational range, the connected LED would turn into red to indicate a failed status in receiving data. And the control module should work well with the WIFI module to enable the connection to the cloud server. And another thing worth to be noticed is the control ship mush have enough pins to support all the sensors and module we need.

**2.2.5 WIFI Subsystem**

**Description:**

To enable connect with the cloud server, our group consider using ESP8266 microchip to interface with the control subsystem. This module could transmit the data from the microcontroller to the internet server.

**Requirement:**

The WIFI module could interface with the microcontroller to allow varieties of data to transmit to the server, which means the working frequency of this module should be consistent with the frequency of the Mini controller. Besides, the ESP8266 would be programmed to run a HTTP server, and we can communicate over the cloud server to the backend service by transmitting the data in the required format.

**Reference**

[1] UART GPS NEO-6M User Manualhttps://www.terraelectronica.ru/pdf/show?pdf\_file=%2Fz%2FDatasheet%2FU%2FUART+GPS+NEO-6M+User+Manual.pdf

[2] William Franklin, Kalman Filter Explained Simply. <https://thekalmanfilter.com/kalman-filter-explained-simply/>

[3] Mednis, A.; Strazdins, G.; Zviedris, R. Real Time Pothole Detection using Android Smartphones with Accelerometers Research domain Road infrastructure as blood vessels. In Proceedings of the 2011 International Conference on Distributed Computing in Sensor Systems and Workshops (DCOSS), Barcelona, Spain, 27–29 June 2011.