Individual Analytical Analysis

Smart Helmet- VL53L0X Sensor

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The VL53L0X presents a new experience in Time-of-flight ranging and gesture detection laser sensing by providing a combination of small size, increased accuracy in distance measurement and longer absolute distance (of up to 2m), unparalleled by anything in the market. The high accuracy is attributed to the 940nm advanced VCSEL emitter ranging sensor with the built-in optical cross-talk compensation, which negates the range error and therefore simplifies the selection of a cover glass. The device comes with a wide range of applications in obstacle detection in robotics, 1D gesture recognition and in security through laser assisted autofocus system in cameras. Its application also extends to user detection in personal gadgets such as computers and tablets, and hand detection in the automatic faucets and soap dispensers.

The VL53L0X confers the advantage of offering 2m of absolute range description without depending on target reflectance properties. Its design favors effortless integration, which is attributed to its single power supply, reflowable component and optics. To ensure that seamless efficiency in its use the inter-integrated interface is used for device control and transfer of data with a programmable address. Its application and user control is made simpler through the Xshutdown and Interrupt GPIO functions. The device structural component schematic is composed of an outer VL530X module and an inner VL530X silicon enclosing a detection array SPAD (Single Photon Avalanche Diode), RAM, ROM and Non Volatile Memory compartments, a microcontroller, an advanced ranging core and a VCSEL Driver. The VL53L0X pinout structure is arranged for maximum connection efficiency with twelve pins: five for the ground connection, five for the digital input and output signal connections and two for the supply connection. This is depicted in the diagram below (figure 1).

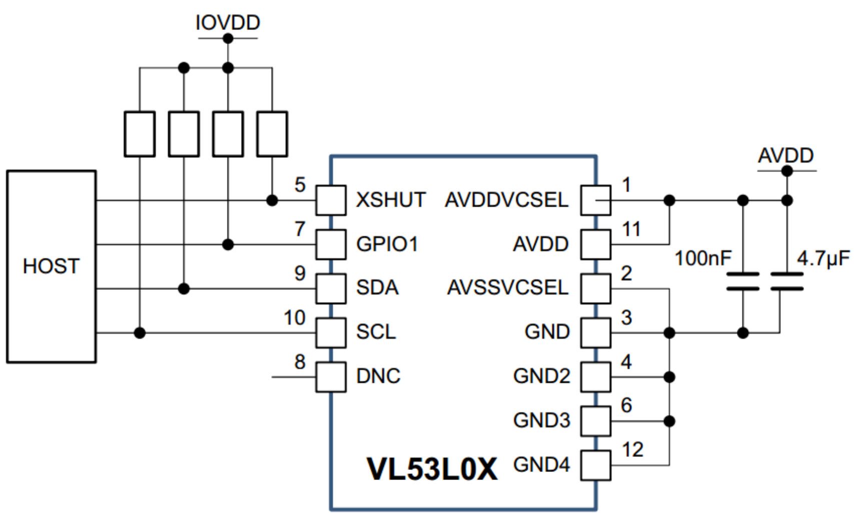

Figure 1. VL53L0X schematic

The product comes in an optical LGA12 package with a 4.4 by 2.4 by 1.0 mm size, which makes it the smallest for easier integration and saves on space. The VL53L0X 940nm VCSEL (Vertical Cavity Surface-Emitting laser) emitter is invisible making it ideal for security and complies to with the latest standard IEC 60825-1:2014 regulation for eye safety. The technical specifications of the product include an operating voltage of 2.6 to 3.5 V and a wide range of operating temperature of -20 to 70°C, which makes it the all-weather choice. The Inter-integrated circuit feature offers up to 400 kHz and a 0x52 programmable address.

An Application Programming Interface (API) enables the host customer application to control the VL53L0X device by the exposure of high-level functions. This gives the user control over the device functions like the ranging and ranging mode, the initiation and calibration and the choice of accuracy. The API makes use of C functions that increase the speed at which end user application are developed, without direct multiple register complication. The API structure enables the easy integration through use of a well-isolated platform for compilation. The firmware event based state machine has the application of AVDD by host as the initial trigger of operational processes. As a result, the device goes to a Hw standby state. The raising of the XSHUT turns the device to the Fw initial boot and then to the Sw standby. When the host initiates the START the device goes into range mode after which depending on the whether it is continuous, continuously timed or single, goes into Range Meas and finally loops back to the Sw standby. The diagram below represents the event based firmware state machine (figure 2).

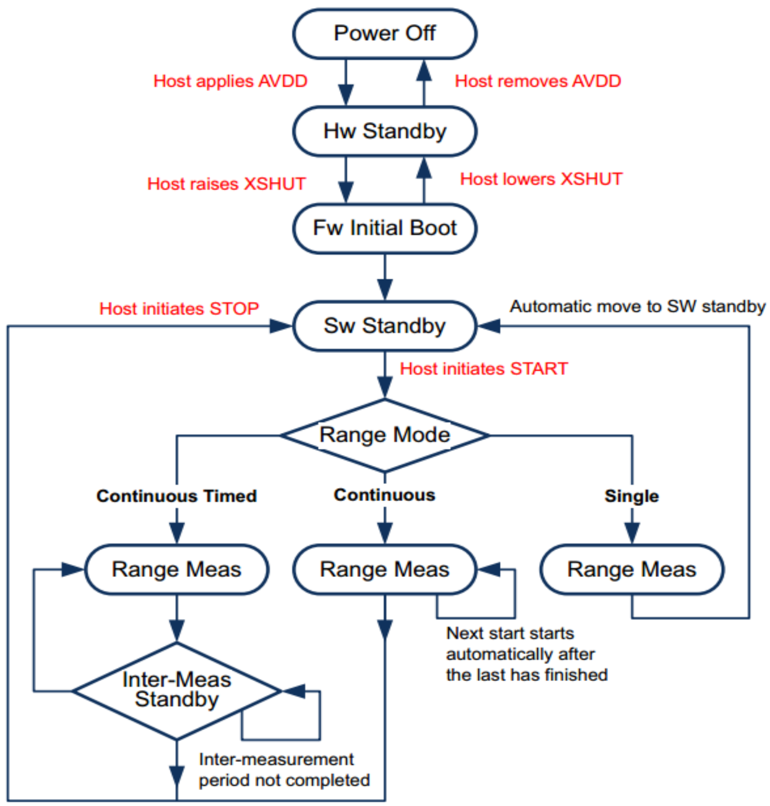

Figure 2. Firmware state machine

The VL53L0X performance gauging for this case is has been done under full field of View (25°), standard reflective targets and default APA control settings. The maximum ranging conditions for the bare module at room temperature and normal voltage for the white target are 120-200cm+ indoors (no infrared) and 60cm -80cm for outdoor overcast. The grey target maximum range targets are 70cm to 80cm for indoors and 40cm to 50cm for outdoors. The ranging accuracy capabilities of the device depend on the set mode with the highest (1.2 m, accuracy less than +/- 3 %) at high accuracy mode intended for precise measurement of distance and the lowest being the high speed mode (1.2m, accuracy +/- 5 %) where time triumphs over accuracy in priority. The ranging offset drifts over changes in distance, the voltage and the temperature with a maximum deviation from normal being less the 3%, +/- 15 mm and +/- 30 mm for the conditions respectively. The typical ranging properties for the default and long range modes are plotted in graphs below figure (3, 4).

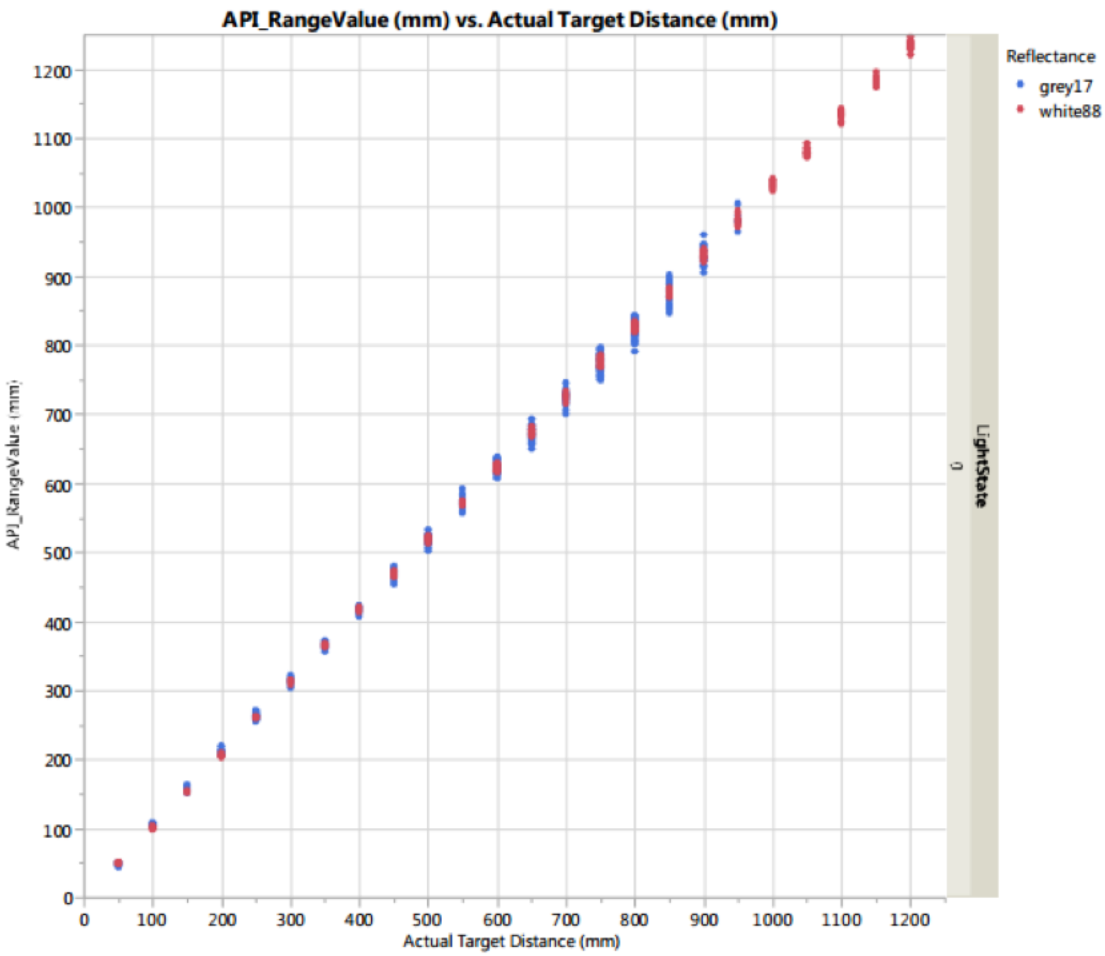

Figure 3. Typical ranging (default mode)

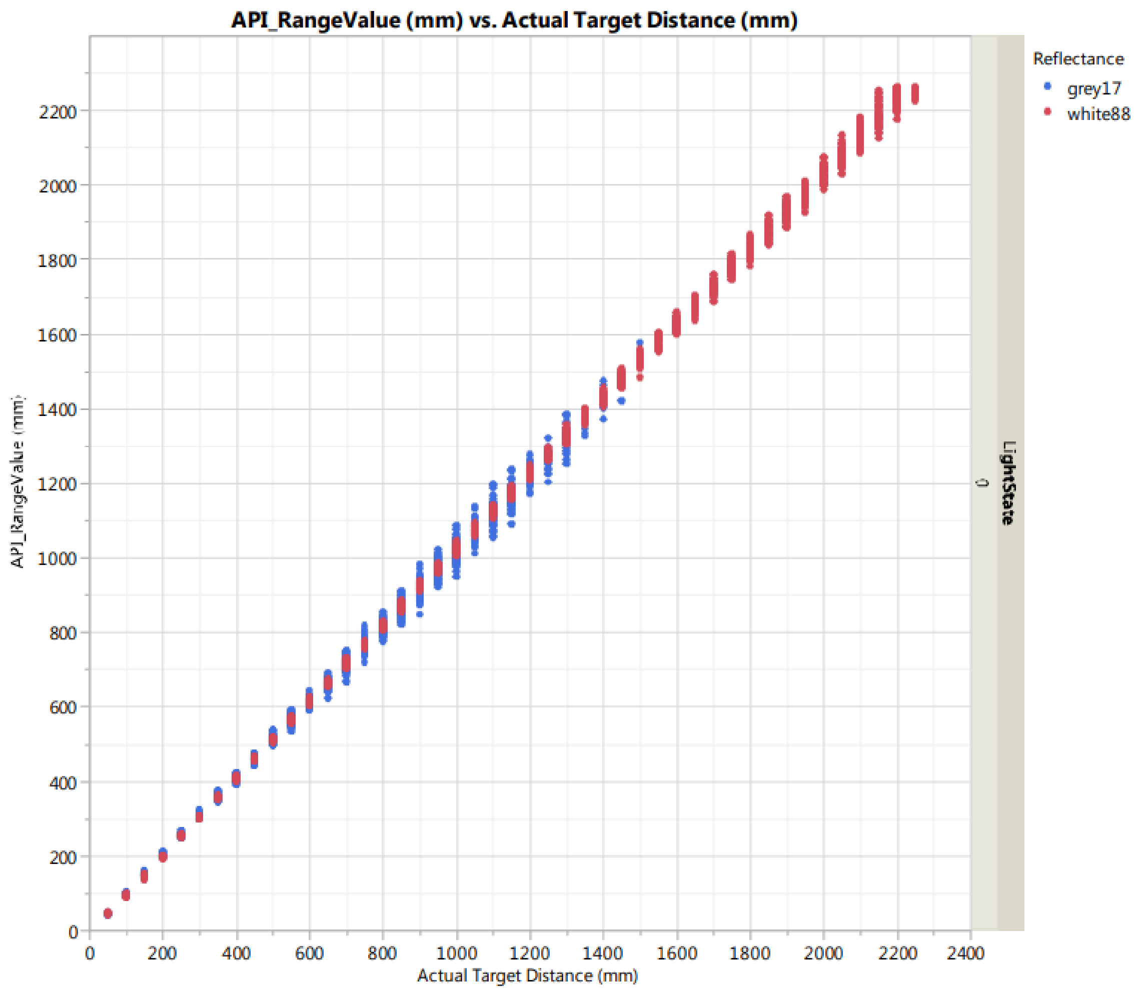

Figure 4. Typical ranging- long range mode

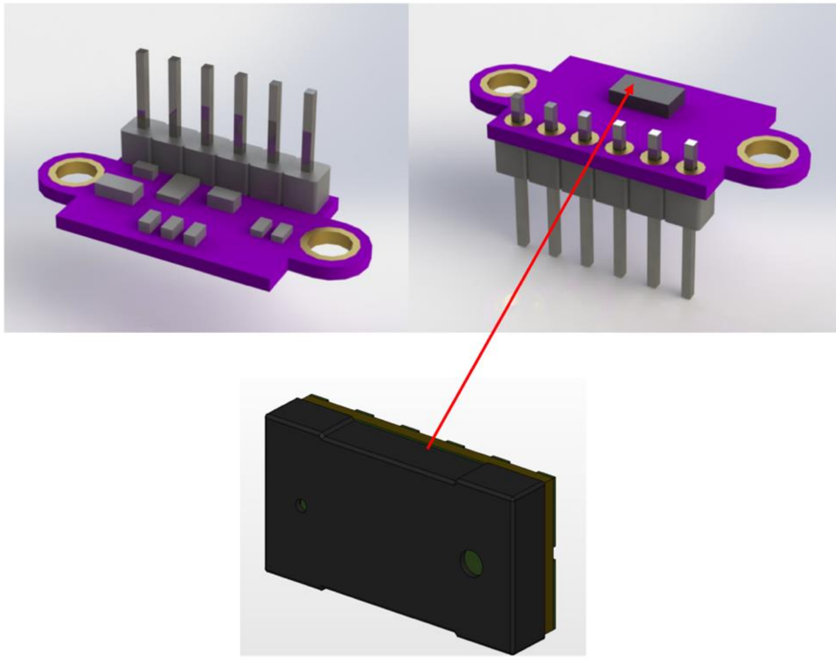

Figure 5. CAD of VL53L0X Sensor

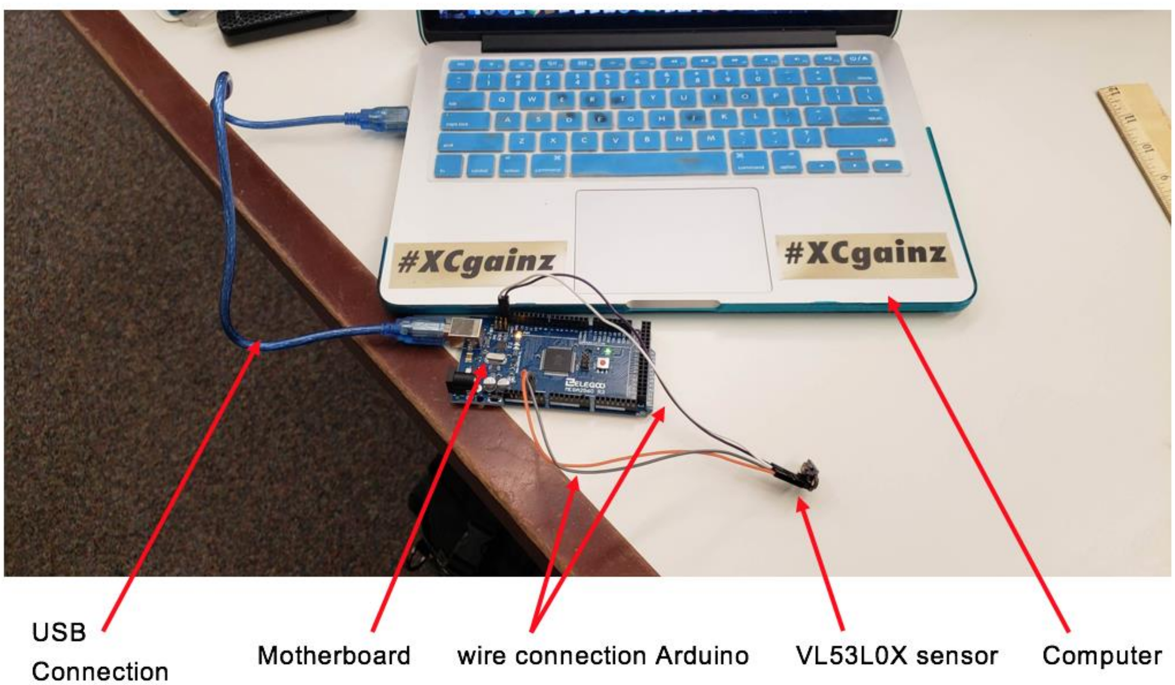

Figure 6. Setup the Arduino

```
#include "Adafruit_VL53L0X.h"

Adafruit_VL53L0X lox = Adafruit_VL53L0X();
double prevPos;
long prevTime, currTime;

void setup() {
  Serial.begin(115200);

  // wait until serial port opens for native USB devices
  while (! Serial) {
    delay(1);
  }

  Serial.println("Adafruit VL53L0X test");
  if (!lox.begin()) {
    Serial.println(F("Failed to boot VL53L0X"));
    while(1);
  }
  // power
  Serial.println(F("VL53L0X API Simple Ranging example\n\n"));
  prevTime = micros();
  prevPos = 0.0;
}


void loop() {
  VL53L0X_RangingMeasurementData_t measure;
  double currPos;
  double velocity;

  currTime = micros();
  //Serial.print("Reading a measurement... ");
  lox.rangingTest(&measure, false); // pass in 'true' to get debug data printout!

  if (measure.RangeStatus != 4) {
    currPos = measure.RangeMilliMeter;

    //Serial.print("Curr pos: ");
    //Serial.print(currPos);
    //Serial.print(", ");
    velocity = (currPos - prevPos)/(double)(currTime - prevTime)*1000000.0;
    Serial.println(velocity);
    prevPos = currPos;
    prevTime = currTime;

  } else {
    Serial.println(" out of range ");
  }
}
```

Figure 7. Code velocity of the sensor

After Setting up the Arduino and using the codes that is shown in figure 7, the sensor was tested by using the hand at different locations and angles. As shown in figure 8, the graph results shows the velocity with the distance that the sensor measured. The positive line of the velocity means the upcoming object, constant line means no change of velocity, and negative line of the velocity means the object that was going way from the sensor.

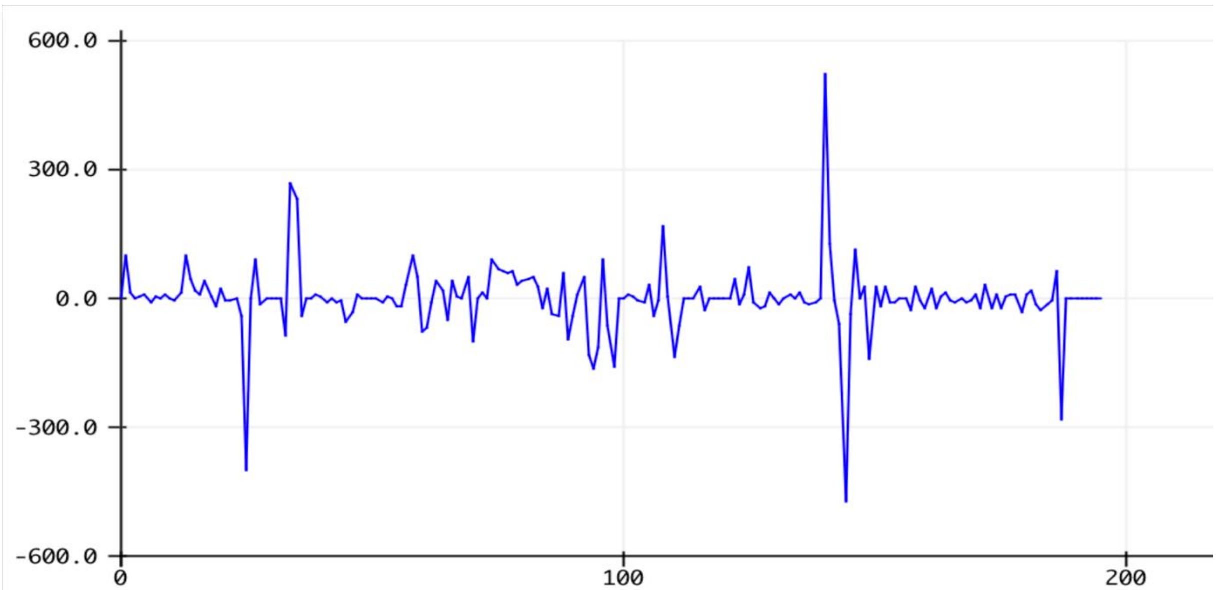

Figure 8. Graph results

After getting the graph results, the data results was taken as is shown in figure 9. As it is said before that the positive and negative numbers are the upcoming and going way velocity of the object. Figure 9 shows some of the measurement that the sensor measured. The highest velocity in the figure was $465.47\frac{\mathrm{m}}{s^2}$. There were some locations that the sensor could not measure the velocity, so it showed "out of range" as the data results figure shows in the next page.

```
-83.18
-7.40
-16.64
186.69
-40.66
-412.28
465.76
-72.08
-55.47
-343.86
 out of range
 out of range
 out of range
 out of range
-49.14
```

Figure 9. Data results

After Setting up the Arduino and having the codes ready, it was time to test the sensor and figure out the highest distance and the angles that the sensor can read. The way that used for testing can find in figure 10 which is about testing sensor with the whiteboard. The sensor was hold into the whiteboard by using the hand with drawing lines as it shows in figure 10.

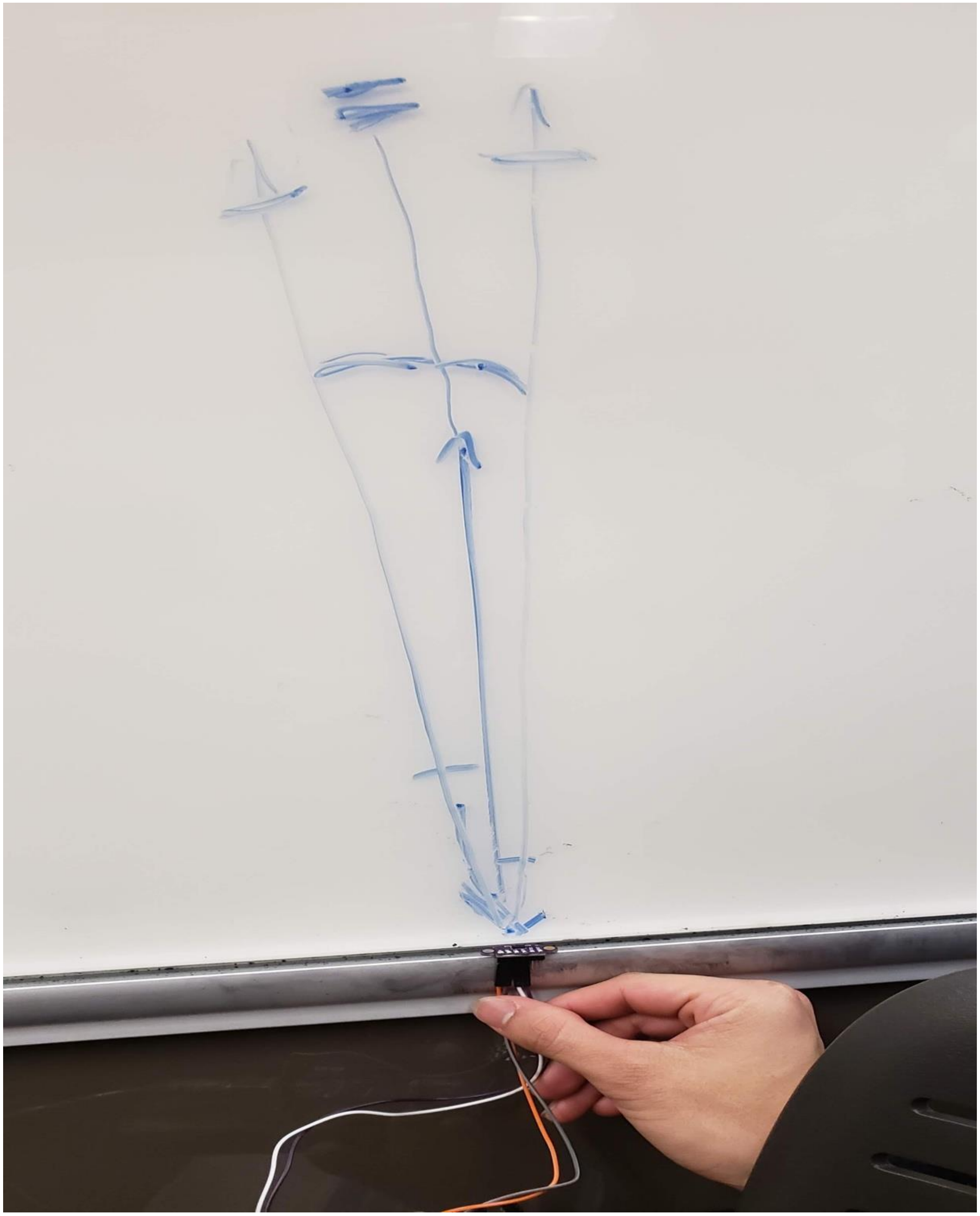

Figure 10. Testing sensor with the whiteboard

After holding the sensor into the whiteboard by using the hand with drawing lines, the highest distance and the angles that the sensor could read were found. Sensor, line and angle rulers were used to draw the figure 11. As figure 11 is shown, there are two pictures which are the results of testing sensor with the whiteboard at 0 degree or 90 degree perpendicular to the sensor.
The data of top picture of figure 11 will be used to end this assignment. The highest distance that the sensor can read is 44.45 cm with 27-30 degree angles around it as the below figure shows.

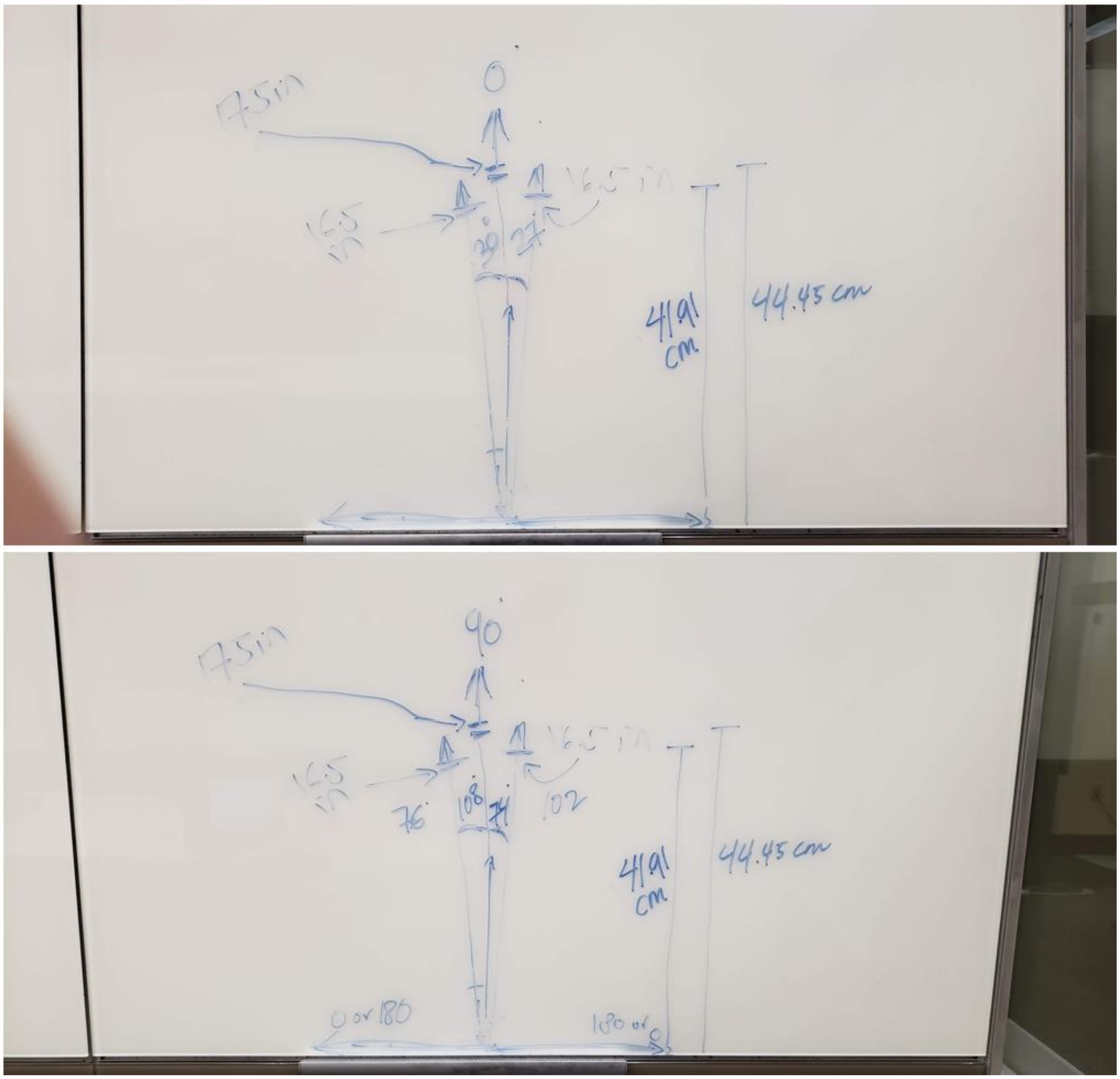

Figure 11. The results of testing sensor with the whiteboard at 0 degree or 90 degree perpendicular to the sensor

After doing the calculations and knowing the highest distance and the angles that the sensor could read, the three sensors are located in the helmet as shown in figure 12. The black, green and red bars are the sensors that will be added to the helmet. Each sensor will read the upcoming object with 27-30 degree around it. The black sensor is located at middle front of the helmet. The green sensor will be located in middle left of the helmet. The last sensor which is in the red color will be added in back right of the helmet to read more angles of upcoming object. The height and width of helmet are shown in figure below which are 43 and 41cm. Thus, the team will not get any problem since the sensor can read till 44.45 cm. The yellow area will not be read by the sensors but since the team will add the gyroscope. All the angles of upcoming will be read and transfer data to the Bluetooth.

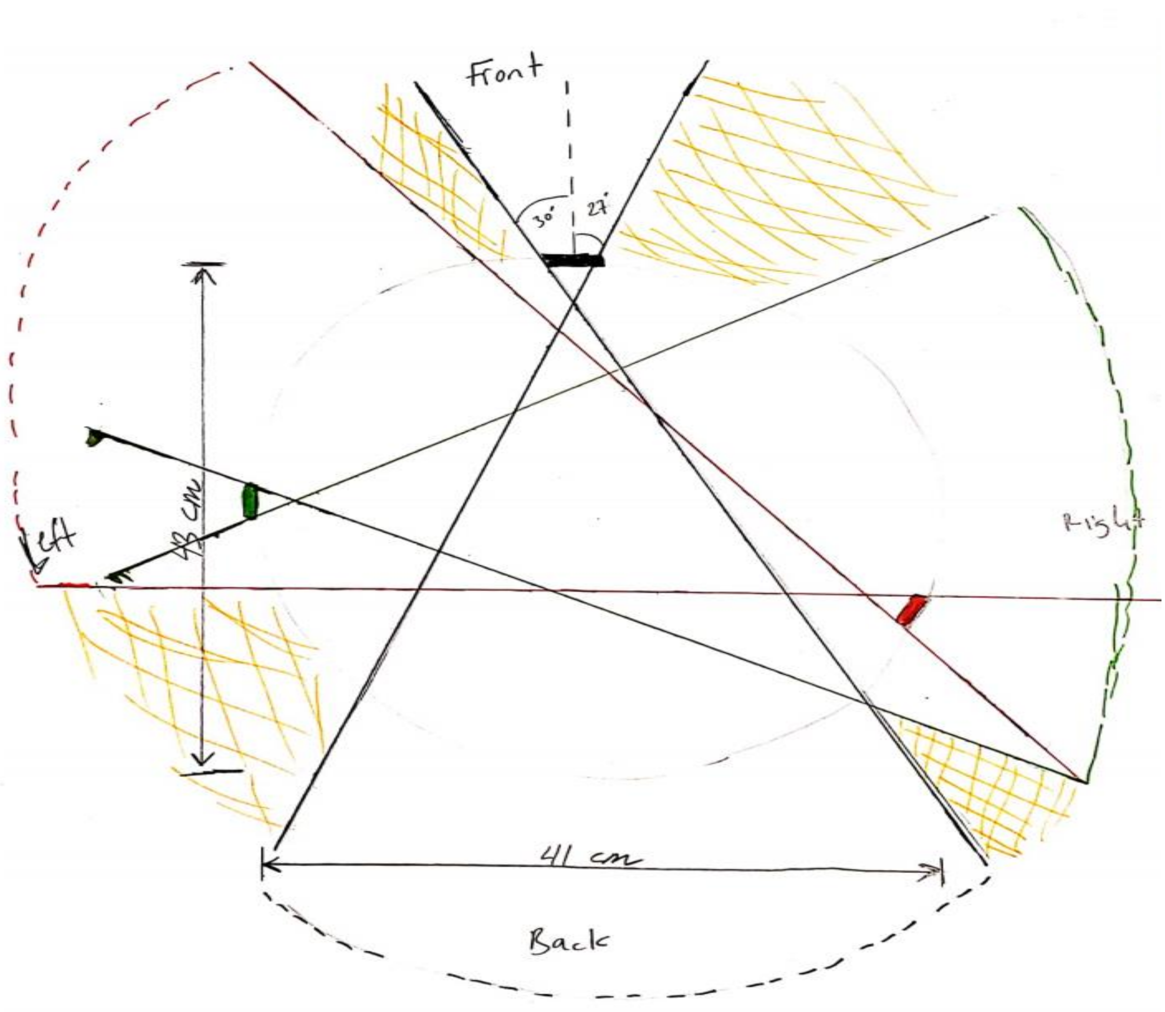

Figure 12. The sensors located in the smart helmet

After testing the sensor and taking the data with comparing to the description of VL53L0X Sensor. There were some human errors such as measuring the distance and the angles by using the hand. However, the data measured was so close to the description which is good enough to decide how many sensors the team need to have in the helmet. The purpose of having the laser sensors in the helmet is trying to know the upcoming players and making sensors work with other parts Bluetooth, gyroscope, DO3 as examples to save the players from injuries.

Work Cited

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