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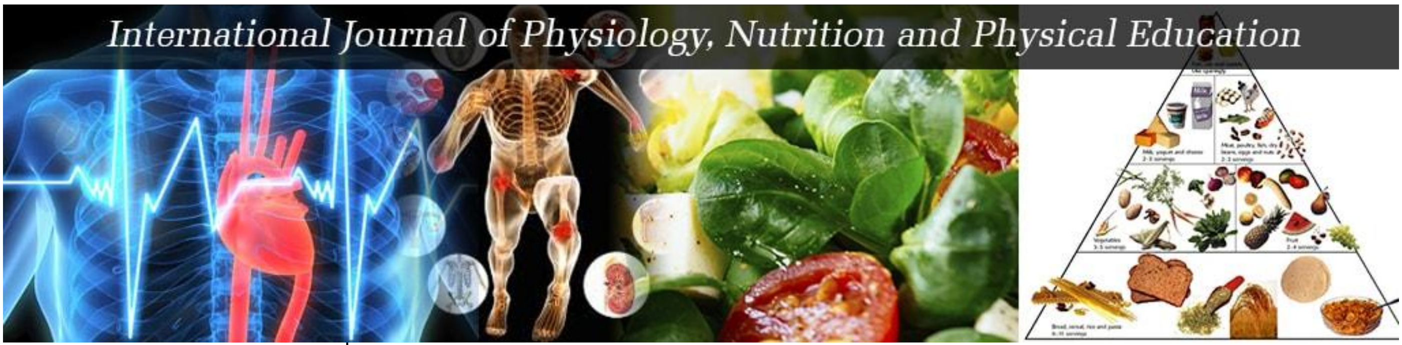

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E-gloves: Wearable assistance in sports training

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Abstract
Sportsmen are trying to improve their game in every way possible, but the equipments and technologies to improve their game are mostly restricted to better their physical attributes and not on their game play. Advanced guidance and equipments are not available for thousands of players in the country. Hence this, paper introduces an electronics glove to assist players in improving their gameplay from anywhere and everywhere. These gloves are pre-calibrated using Inertial Measurement Unit (IMU) for efficient hand movements. Yaw, pitch and roll angles of wrist actions are calculated by gyroscope and accelerometer, present on IMU. A player has to move his/her wrist in a particular way to get the maximum output from a shot. These movements can be compared with the pre-stored values of an expert from the field. This comparison helps the amateur player to understand his/her mistake and rectify it.

Keywords: Electronics glove, IMU, yaw, pitch, roll angle, sports training

Introduction

Sports is played all around the world, in many different forms. Some countries have their own national sports that are played just locally, while there are other sports that are played in nearly every country around the world. According to recent trend, it is becoming a career option to lot of people rather than just a hobby. To achieve success in any filed, it is important that player know all methodologies of the sport as well as practice. There are many electronic gears and equipments to ameliorate ones physical strength but hardly any that work on actual game play. That is why we can see traditional pupil teacher convention followed by many people. The major drawback of this conventional method is that there might be more than 15 students studying under one trainer, which makes it difficult to give individual attention as and when required. Professionalism is an important factor in coaching that contributes to another drawback. A coach with 3 years of experience will show difference in training compared to a coach having 10 years of exposure. In America, surveys are accomplished that showed absence of experience among coaches leading to decrease in participation among students [1].
There are various option by which these drawbacks can be circumvent by numerous ways. We can reproduce real life environment by using technology like Virtual Reality (VR) where a person can get involved into any game virtually. Automated robots are assembled for sports like badminton. Champion robot [2] is machine designed to give ample amount of training to amateurs. Still there are many trainees who depend on human trainers for their practice. The main disadvantage of these machines are time and space for installation. In case of champion robot it needs an intellectual system to be setup in court area and needs continuous image processing of the data.
An Electronics Sports Gloves is introduced in order to help amateurs to attain the required training for different sports. This is a glove based system where players get freedom to practice anyplace anytime and record the results via an app. The working part of the glove is based on

Inertial Measurement Unit (IMU) [3] having widespread of applications like in navigation system, motion sensing, script recognition etc. All these applications use parameters like accelerometer and gyroscope. The IMU used in Electronic sports glove consist of an in-built 3D accelerometer, 3D gyroscope and 3D magnetometer. An accelerometer is an electromechanical device which is used to measure acceleration forces. Static forces like gravitational force and dynamic force like vibrations and movements are analyzed. Acceleration is the rate of change of velocity. A gyroscope is a device used for measuring orientation and angular velocity used to measure magnetism. It measures the direction, strength and change of magnetic field at a particular location.
Movement of hands and wrist actions are essential for many sports. Shots like “cover drive” and “square cut” which are used in cricket needs accurate wrist rotation. If it is practiced wrongly, it may cause wrist twist or torn ligament [4]. Such injuries can evade by having proper knowledge about movements. With the help of IMU rotational parameters such as yolk, pitch, roll can be computed using mathematical equation, which is then displayed in the form of graphs with the help of Arduino. Information obtained from the component can be send to a device near using Bluetooth module or RF module. The player after each shot could understand what his mistake was through the graph, which will be displayed on his phone or laptop and rectify it accordingly, thereby attaining the advantage of practice anytime anywhere without a trainer.

2. Components

An Inertial Measurement Unit (IMU) is a device that measures force, angular rate and magnetic field of a body. It consist of an accelerometer, gyroscope and magnetometer. They work by detecting the changes in pitch, roll and yaw. Here we are using IMU manufactured by Invensense MPU 6050 as it is cheap and accurate.

2.1 MPU 6050 Sensor Module

The MPU 6050 is a Micro Electro Mechanical Systems (MEMS) composed of a three-axis accelerometer and a three-axis gyroscope within it. This enables to assess a system or object's acceleration, speed, orientation, displacement, and many other parameters linked to movement. There is also a Digital Motion Processor (DMP) inside this module, which is strong enough to conduct complicated calculations and thus free up the job for Microcontroller. It has 6 degrees of freedom which provides 6 values as output- 3 from accelerometer and 3 from gyroscope [5]. The IMU sensor has a small size which takes less space on the gloves and makes it light weight. It provides high precision by giving 16 bit digital output.
The communication is based on Inter Integrated Communication (I2C) protocol. It can be easily implemented as it needs only two wires for communication between master and multiple slaves or even multiple master devices. It is capable of accepting input from other sensors like 3-axis magnetometer using an auxiliary I2C bus.
3-axis Accelerometer- It works on the principle of piezoelectric effect. It detects the angle of inclination and its magnitude in x, y and z axes. The axes deflects the movable mass. The 16 bit ADC is used to get digital output.
3-axis Gyroscope- It works on the principle of Coriolis acceleration. When the gyro is rotated about any axes, it causes a vibration which will be detected by MPU 6050. It detects the rotational velocity along x, y and z axes. The resulting signal is amplified, demodulated and filtered to obtain a voltage that is proportional to angular rate.

Digital Motion Processor (DMP): It computes motion processing algorithms. It takes data from accelerometer, gyroscope and from other additional sensor which is connected. It provides data like yaw, pitch, roll angles, portrait sense etc. The resulting data can be read from DMP registers.

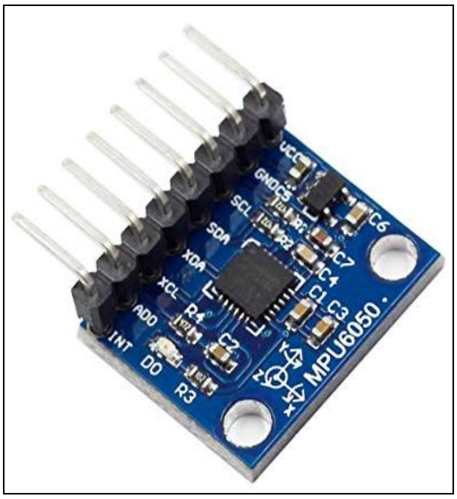

Fig 1: MPU 6050 Breakout Board

2.2 Arduino Nano (ATmega 328)

Arduino Nano is a surface mount breadboard embedded version with integrated USB. It is small and breadboard friendly [6]. It has everything that Diecimila/Duemilanove has (electrically) with more analog input pins and onboard +5V AREF jumper. Physically, it has missing power jack. The Nano automatically sense and switch to the higher potential source of power, there is no need for the power select jumper. Arduino Nano has features comparable to that of Arduino Duemilanove but with a distinct package. The Nano is built in the same way as the Arduino UNO with the ATmega328 microcontroller.
The 32Kb static RAM is sufficient enough to store the values from MPU 6050. It supports I2C communication. It works with a Mini-B USB cable instead of a standard one. It has 6-20V unregulated external power supply or 5V regulated external power supply. Each of 14 digital pins can be used as input or output. The Arduino Nano can be programmed with the Arduino Software. For testing purpose Arduino software is available which gets easy access to all pins and interaction with the microcontroller.

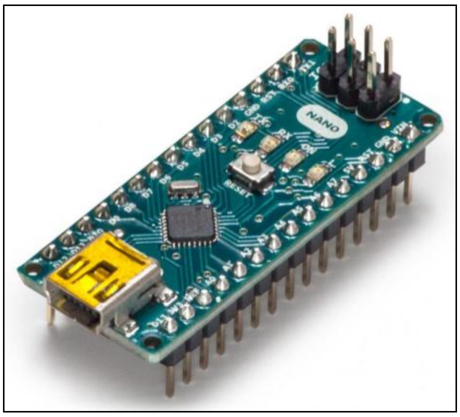

Fig 2: Arduino Nano Board

2.3 HC-05 Bluetooth Module
HC-05 is a Bluetooth module designed for wireless communication [7]. It can be used either in master or in slave configuration. It enables all serial enabled devices to communicate with each other using Bluetooth. It has range up to <100m which depends upon the position of transmitter and receiver, atmospheric conditions and geography.
It has 6 pins and can be used in two modes-

- Data mode- Exchange of data between devices.
- Command mode- It uses AT commands to change settings of HC-05

HC-05 can be easily paired with microcontrollers like Arduino as it uses Serial Port Protocol (SPP). The module is powered with +5V and the Rx pin of module is connected to the Tx pin of MCU and Tx pin of module to Rx pin of MCU. During power up, the key can be grounded to enter into Command mode or by default it will enter in Data mode. The Bluetooth device in named as "HC-05" which will be seen automatically as it is paired with PC. The default password is "1234".

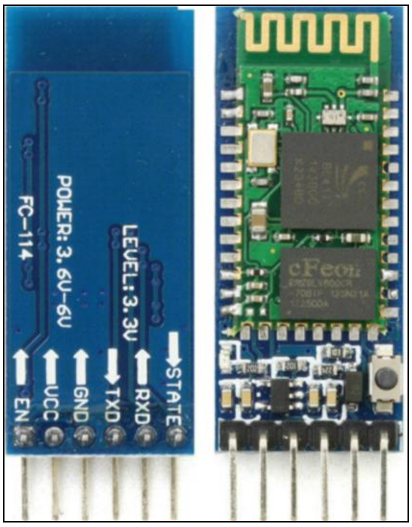

Fig 3: HC-05 Breakout Board

3. Working
The module is designed to sense the wrist movement of the player all the time but the unnecessary movements while he/she is not batting need not be sensed or processed. Fig 4 shows the block diagram of the module. Therefore a mic is installed to trigger the IMU to measure only the necessary movements of the wrist while playing the shot. The whole system is in on state while training so that there need not be any delay while the mic triggers the IMU to start sensing the wrist movements. These movements only need to be measured and compared as the shot is played. The mic gives the signal which helps in realizing when or the point at which the shot was played.

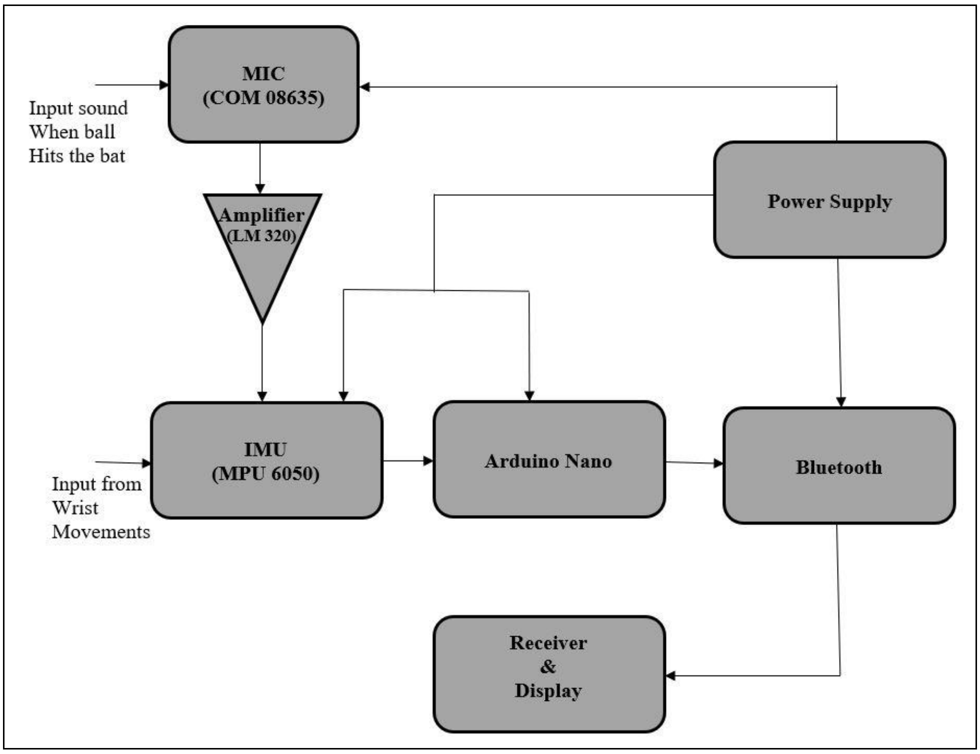

Fig 4: Block diagram of the setup

The process starts when the mic detects the sound from the bat when it hits the ball. This signal triggers the IMU to start sensing. The mic used is COM 08635 which senses the knock when the ball hits the bat. The output from the mic is a feeble electrical signal. Therefore this signal needs to be amplified before giving this as an input to the IMU. A LM380 comparator circuit is used to amplify this audio-electrical signal. The level of amplification can be varied using a potentiometer in the circuit. The resistance can be varied using the potentiometer which varies the output. The potentiometer has to be set such that not only the sound from the impact of the ball hitting the bat is sensed correctly and shouldn't leave it undetected but also no other smaller noises should be detected. Thus this amplified signal is given to the IMU which tells the system that a ball has hit the bat.
The Inertial Measurement Unit (IMU) used is MPU 6050 which has an in-built accelerometer, gyroscope and a magnetometer. All these devices give measurements on all three axis, therefore the whole IMU has nine degrees of freedom. The values from accelerometer and gyroscope can be used to get the Yaw, Pitch and Roll values. These are the rotational movements in all three axis rather than linear. These can be used to track exact movement of the wrist while playing the shot. The Yaw, Pitch and Roll values are calculated using mathematical equations and this process is done in the Arduino. The Arduino is programmed to convert the output from the accelerometer and gyroscope to Yaw, Pitch and Roll values.
The values of the players needs to be compared with that of the expert so the glove is worn by the expert and a particular shot is played. This shot is assumed to be the perfect shot and the wrist movement is sensed and calculated. These values obtained from the expert is taken as the pre-set value which is stored in the program itself. When the player plays the same shot, the values are compared with that of the expert and the deviation from the values of the expert is calculated. This deviation in Yaw, Pitch and Roll values is the actual deviation in the wrist movement of the player in the yaw, pitch and roll directions. The player has to play that particular shot again and again to compare the difference in his shot with the expert. With each shot he/she can get an idea of what his mistake in the movement is and will be able to rectify it and be finally be able to play the perfect shot as the expert.
Shot Integrity is the percentage of closeness of shot of the player with that of the expert. If the shot integrity is 100%, then it means it is a perfect shot. Shot Integrity is calculated by taking the mean of deviation of the yaw, pitch and roll values, after scaling down to 100 and then subtracting this mean from 100%. Therefore better the integrity, better the shot. All these processes are done in Arduino IDE which is used to program the Arduino. The program to measure the expert's value is uploaded into the module and is used to get the preset values. These values are stored in the program. Commands are defined to find the deviation from the expert value. When the player plays the shot, the deviation is calculated in the program itself and the data is send to a nearby device. The player can see the data from a display placed near him to analyze his/her performance. Bluetooth is used as the wireless technology to connect it to the display.
A phone or a laptop can be used to receive the data and display the data on the screen. While training as the shot is played these values need to be sent to a nearby module to display the results so that he/she can analyze the shot and make adjustments in his/her next shot. An app is developed and installed in a mobile and connected by Bluetooth. The data is displayed through this app. The app developed is user friendly and shows the deviation in yaw, pitch and roll values. Shot Integrity is also displayed so that the player gets a better view and will be able to analyze his/her shot.

4. Methodology

The IMU board has got accelerometer, gyroscope and magnetometer with 3-axis which is used to deduce 3 parameters which are yaw, pitch and roll angles. This can be seen in monitoring airplane position. The same method is used there but they use high precision sensors. With the help of these parameters one can accurately monitor the motion of object in space.

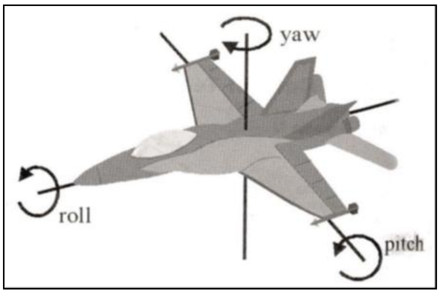

Fig 5: Yaw, pitch and roll axes

The gyroscope gives us information about axis of orientation and the accelerometer gives the information about velocity and acceleration. As mentioned in the specifications of the IMU sensor, it supports I2C communication protocol and it has the capability to give the digital output of 16 bits and hence the quantization error is also kept minimal. The frequency of the operation is kept same so that both the values from gyroscope and accelerometer are available at the same time. The values generated can be modified into a chart or a line graph and can be compared with original values as line graphs are easy to analyze.

5. Mathematical Calculations

The values obtained from IMU are values that are direct and are called raw values. So first they are converted to DPS (Digital Pulse Sampling) by using the inbuilt functions (calcGyro), (calcAccel), (calcMag). Then these values are used with the following equations to obtain angular values YAW, PITCH and ROLL:

$$Pitch\ in\ angle\ in\ radians = \tan^{-1}\left(\frac{Gpz}{Gpy}\right) \quad (1)$$

$$Roll\ in\ angle\ in\ radians = \tan^{-1}\left(-\frac{Gpx}{sqrt\,(Gpy2+Gpz2)}\right) \quad (2)$$

$$Yaw\ in\ angle\ in\ radian: -$$

$$Direction\ (y > 0) = 90 - \left[arcTan\left(\frac{x}{y}\right)\right] * \frac{180}{pi} \quad (3)$$

$$Direction\ (y < 0) = 270 - \left[arcTan\left(\frac{x}{y}\right)\right] * \frac{180}{pi} \quad (4)$$

$$Direction\ (y = 0,\ x > 0) = 0.0 \quad (5)$$

$$Direction\ (y = 0, x < 0) = 180.0 \quad (6)$$

We considered inputs from the accelerometer and gyroscope in the above calculations. Pitch and roll values are calculated using accelerometer values where Gpx, Gpy and Gpz are the acceleration rate changes along x, y and z axes. To calculate yaw values, i.e. angular rotation in x, y, z, gyroscopic values are used. Magnetometer readings can be used to calculate yaw, but gyroscopic values can be used to set more generalized standard deviation values after observing various experimental measurements.

In the program itself, all the calculations are performed. In-built features that use these equations can be found in the library to discover the values of pitch, roll and yaw. These equations can provide positive and negative values that can be used to determine whether clockwise or anti-clockwise movement. All these values are stored and compared to the pitch, roll and yaw values of the players.

6. Algorithm

Initializing the communication channels is taken as the first step. While the ball hits the surface of the bat, parameters from Inertial Measurement Unit are taken and some algorithms are run continuously as this program executes in a recurring loop. Fig. 6 represents flowchart of the used algorithm. The mic triggers to start the entire process, thus the communication channels are initialized. The output values from Inertial Measurement Unit are obtained in radians, and then they are changed to degrees for ease of the user. After conversion, these values are converted into a set of parameters such as yaw, pitch and roll values. Deviation of these values from the mean values (expert value) is calculated by taking simple mathematical difference between the expert values and that of the player. These deviations are displayed on the screen of the mobile used by the player, through an app, via Bluetooth technology. If the deviation values do not vary, then the display will show a message such as “perfect shot” or 100% shot integrity. Players using this value could analyze his/her performance thereby achieving the objective of practice anywhere anytime. These values can be stored for future use. For each sport or for each shot in the same sport only the expert values needs to be changed so s to get the deviation.

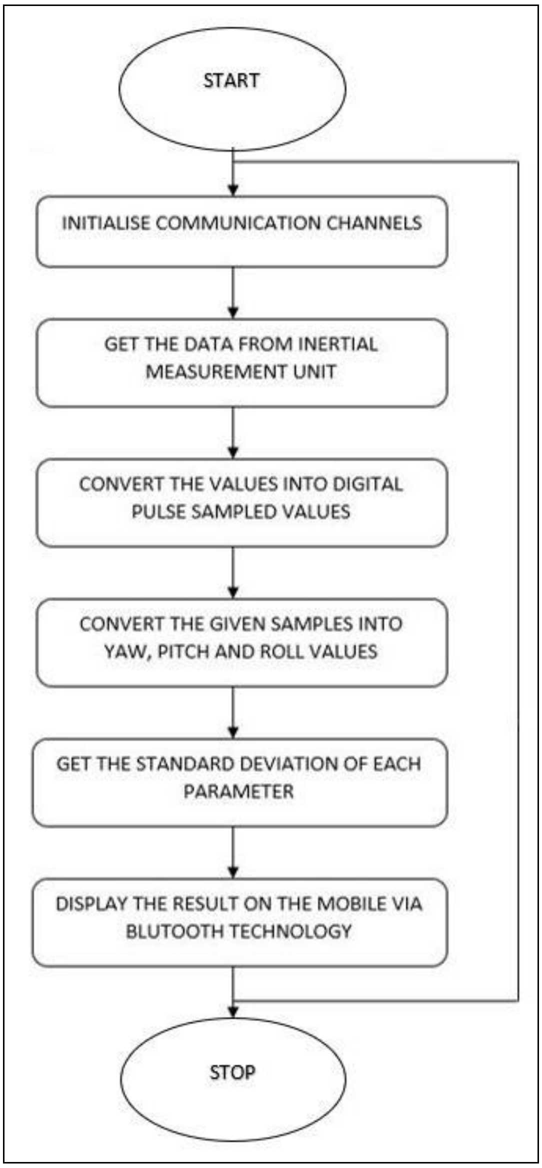

Fig 6: Flowchart of Algorithm

7. Result

We selected “Cricket” for experimentation purpose as it involves considerable hand and wrist movements. The IMU board is placed on top of gloves and its output is obtained after initializing I2C. The result is basically the deviation in Yaw, Pitch and Roll values of the player from that of the expert’s. This deviation is got by simply finding the mathematical difference between the value of the expert and that of the player. Fig 7 shows graphical representation of the deviations.

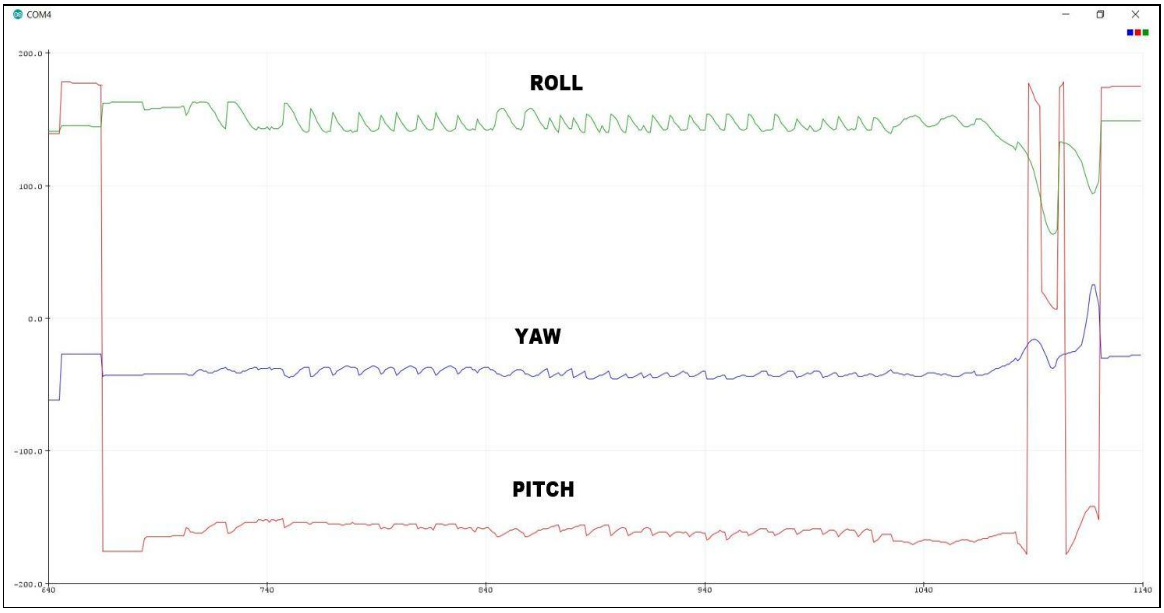

Fig 7: Graphical representation of the deviations

Table 1: Comparison between the reading of expert and player

Wrist Movement	Expert value	Player value	Deviation
Yaw	24	-96	-72
Pitch	294	270	24
Roll	310	22	288

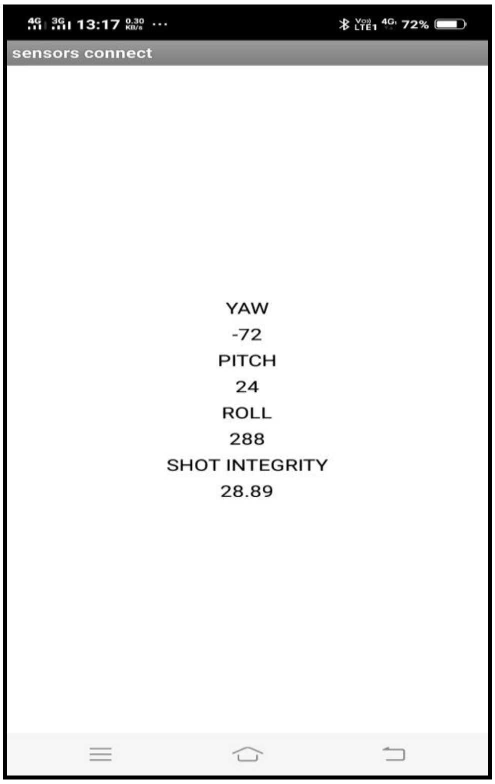

Fig 9: Result displayed in Mobile

The deviations in the player's shot is represented in numbers in the display of the mobile through the app. Shot Integrity is also displayed to make the player aware how good his/her shot was. Real time values for each shot is displayed and this user friendly display makes the player aware of his/her current status and get an idea on where and how he/she has to improve. Fig. 9 shows the display of the app in the mobile.

8. Conclusions

Taking into consideration the number of sportsmen and sportswomen in each sport and their success rates, this new product will aid them to achieve their aspiration. Other than improving basic wrist movements, the product can help produce new and efficient shots, or improve the overall game play. It also helps reduce unwanted injuries which arise as a result of wrong wrist movements and stances. In the coming days, more precise and three dimensional visualizations of various movements can be simulated by putting yaw, pitch, roll, velocity and acceleration parameters in a neural network. Also, all of the instruction statistics could be collected in a cell phone or a computer or it can be uploaded to the cloud so that the gloves user can review his or her improvements or required progress. That information could be represented graphically for ease of use. Also, if a new shot or method turns out useful in a particular sport, then that information could be made accessible via the cloud for other glove users. Also this equipment could be useful in other areas such as music, art etc. In field of art, the grip and hold of the brush or pen and precise arm movements are very important for producing a masterwork. Likewise in devices like guitars and violins, quick and precise wrist motion is necessary for producing particular notes and tunes. The electronic gloves could be calibrated to better draw certain shapes or play particular tones in such cases.

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