A NEW METHOD FOR DETECTING NICK BETWEEN CRICKET BAT AND BALL

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THESIS CERTIFICATE

This is to certify that the thesis titled **A NEW METHOD FOR DETECTING NICK BETWEEN CRICKET BAT AND BALL**, submitted by **Pendem Shravan**, to the Indian Institute of Technology, Madras, for the award of the degree of **Bachelor of Technology**, is a bona fide record of the research work done by him under our supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

KEYWORDS: ACCELEROMETER , CRICKET , NICK DETECTION

This thesis deals with the development of a completely new method to detect the nick between cricket bat and ball. The method involves using an accelerometer and arduino to get the raw acceleration and gyroscopic values. The accelerometer is pinned to the handle of the bat and records the acceleration of it. When there is a sudden impact or nick on the bat there is a large change in the accelerometer values and this change appears as a spike in the graph when plotted in labview.

The hardware in this project consists of an IMU(accelerometer) mpu6050 and an arduino. The accelerometer values are acquired to labview via arduino using a third party software called linx . These values are graphed at real time. Two functions are developed consisting of the accelerometer and gyroscopic values. These functional values are graphed and also stored in an excel sheet with a global time stamp for post analysis.

The prototype system promises good results in detecting the nick, faint edges and straight impacts. The function consisting the acceleration values give a good insight compared to gyroscope values. The labview circuit designed can be easily replicated yet there is scope in improving the accuracy by acquiring samples at higher rate.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS **iii**
ABSTRACT **iv**
LIST OF FIGURES **vi**
ABBREVIATIONS **vii**
1. INTRODUCTION **1**
2. LITERATURE REVIEW **3**
2.1 SNICKMETER…..………………………………….....4
2.2 HOTSPOT……………………………………………………………………………5
2.3 IMU IN SPORTS RESEARCH……………………………………………………...7
3. INTEGRATED ACCELEROMETER BASED APPROACH **9**
3.1 PRINCIPLE OF OPERATION….………...…..…9
3.2 TYPES………………………………………………………………………………10
3.3 SPECIFICATIONS…………………………………………..……………………..10
3.4 OUTPUT……………………………………………..……………………………..11
4. EXPERIMENTAL SETUP AND RESULTS **14**
5. DETAILED RESULTS AND CONCLUSION **20**
5.1 DEAD BAT CONDITION……………………………………...……….………20
5.2 SWINGING BAT CONDITION……………………………………………………...21
5.3 NICK WITH A SWINGING BAT……………………..…………………………….…..22
5.4 CONCLUSION……………………………………………………………….…….26

REFERENCES **27**
CURRICULUM VITE **28**

LIST OF FIGURES

Fig 2.1 Image of a snickometer in use during a cricket match[1]……………………5

Fig 2.2: Use of hotspot technology in cricket. [2]……………………………………6

Fig 3.1: MPU6000 family block diagram ……………………………………...12

Fig 3.2: mpu 6050 accelerometer [5]……………………………………...…. .13

Fig 4.1: Arduino uno connected with a mpu6050 accelerometer[6]…………………14

Fig 4.2: Accelerometer attached to the handle of a bat……………...……………15

Fig 4.3:Block diagram of the data acquisition……………………….……….….16

Fig 4.4 : Labview block diagram of the vi………………………………..…….17

Fig 4.5: Acceleration (x-axis) graph when the bat is gently touched with a ball….…19

Fig 5.1: Graph when the bat is held dead straight……………………………..…..20

Fig 5.2: Individual points on the graph when the bat is held dead straight……..…....21

Fig 5.3: Graph when the bat is swung hard……………………………….……....21

Fig 5.4: Individual points on the graph when the bat is swung hard………..……..22

Fig 5.5: Graph of the nick with a swinging bat …………………………….………..22

Fig 5.6: Individual points on the graph of the nick with a swinging bat…….………23

Fig 5.7: The closer look at the spike…………………………………….…………23

Fig 5.8: Individual points on the graph closer look at the spike……….…………..24

Fig 5.9: Gyroscopic values when nick occurs with the bat…………………………..24

Fig 5.10: Individual points on the gyroscopic graph when there is a nick…………...25

Fig 5.11: A closer look at the spike in gyroscope values……………………………25

Fig 5.12: Individual points on the graph of spike of gyroscopic values……………...26

ABBREVIATIONS

IMU	INERTIAL MEASUREMENT UNIT
BBG	BALL, BAT AND GLOVES
ODI	ONE DAY INTERNATIONAL
LBW	LEG BEFORE WICKET
UDRS	UMPIRE DECISION REVIEW SYSTEM
MEMS	MICRO ELOCTRINIC MANAGEMENT SYSTEMS
IC	INTEGRATED CIRCUIT
ADC	ANALOG TO DIGITAL CONVERTER
I2C	INTER INTEGRATED CIRCUIT
DPS	DEGREES PER SECOND
FIFO	FIRST INPUT FIRST OUTPUT
SDA	SERIAL DATA
SCL	SERIAL CLOCK
IDE	INTEGRATED DEVELOPMENT ENVIRONMENT
I/O	INPUT OUTPUT
API	APPLICATION PROGRAMMING INTERFACE
PWM	POWER WIDTH MODULATION
SPI	SERIAL PERIPHERAL INTERFACE
UART	UNIVERSAL ASYNCHRONUS RECEIVER TRANSMITTER
VI	VIRTUAL INSTRUMENTS

1. INTRODUCTION

Research in sports, exercise and related topics has grown significantly in the past 30 years. To date several research have been conducted in different areas of sports. There is an increasing need for technological development in ball games such as cricket, baseball, soccer etc. These sports involve lot of on field cameras, microphones, infrared and radar sensors. Cricket is one such sport where lot of technology is involved. The game of cricket is defined by a set of international rules. It is a striking sport where the players undertake three activities: bowling, batting and fielding. Bowling in cricket involves a cricket ball of standard dimensions to be bowled to the batsman. Cricket batting is a dynamic interceptive task that involves the batter perceiving the relative motion of the bowled ball and formulating a response for a desired goal.

Inertial sensors are an emerging technology that has been applied in the pursuit of biomechanical assessment of physical activity.In the last 20 years several researchers have conducted experiments using inertial acceleration sensors to understand swing profiles of the bat. This thesis paper involves using a 6-axis accelerometer to detect the impact between a cricket ball and a bat. Accelerometer measures changes in motion in three dimensions and are only in millimetres in size. Inertial acceleration sensors record acceleration values whereas the rate gyroscopes measure the rotation about a single axis and can determine orientation in an angular coordinate system, although they cannot determine angular position. While a single axis accelerometer or a gyroscope can provide useful information in particular circumstances, the use of three axis accelerometer or gyroscope provides higher level of information.

The present technology used to detect the nick between a bat and ball are snickometer and hotspot. A Snickometer, commonly known as Snicko, is used in televising cricket to graphically analyse sound and video, and show whether a fine noise, or snick occurs as ball passess bat. Hotspot is an infrared imaging system used in cricket to determine whether the ball has struck the batsman. Both these technologies enhance the umpire's decision-making accuracy but are costly and not reliable in particular circumstances.

To tackle some of the unpredictable situations where these technologies cannot help much, a new method which is reliable and cost effective is proposed using accelerometer, The inertial acceleration sensor is placed on the top of the handle of the bat. The vibration produced during the nick or impact produces a sharp spike on a smooth acceleration curve of the swing of the bat. This spike appears due to the sudden change in acceleration values during the impact. Two functions comprising the three acceleration values are used to predict the possible impact situations. These functions help in analyzing the nick better.

The accelerometer values that are acquired is assigned to a global time so that they can be cross referenced with the live video and also useful for post analysis. Although the data that we acquire clearly helps in achieving the required task, there is need for achieving high data input to analyse certain situations more precisely. The data that is analyzed consists of different scenarios that can possibly happen, shows more promise in conditions which are difficult to analyze with the existing technology.

2.LITERATURE REVIEW

Cricket batting research, a dynamic interceptive action, requires a strategic plan. During laboratory or simulation-based studies, the analyses can suffer from limited validity, because those studies cannot provide natural performance environment. Most of the available cricket research reported focus on the skill acquisition and sport expertise perspective. The constraints requiring sub-second interceptive action motivated the majority of the works. Fewer published studies have been conducted from a biomechanical perspective. Those biomechanical studies provide the insights into the mechanical differences of the front foot defense and drive in vertical batting shots. Horizontal batting strokes such as the cut, pull and hook are less studied. Most literature is descriptive in nature and addresses the batting sciences with very little use of technology. The research can be divided in several categories: biomechanics and motor control, ecology and assessment, psychology, morphology and physiology, implementation of batting.

Some literature present reviews of batting research while most have documented empirical findings. For a nick detection in cricket many technologies were proposed in the mid 1990s. Two of the most reputed are snickometer and hotspot, which are still in use today. Other technologies like Hawkeye, Ball spin RPM are in use in certain countries to improve the accuracy of the umpire decision review system. However snickometer and hotspot are the only technologies which are used in nick detection in modern cricket.

2.1 SNICKOMETER

Invented in the mid-1990s by English computer scientist Alan Paskett, the Snickometer is used in a slow motion display to determine whether the ball did touch the bat even slightly to determine if it was out.

A snickometer works on a simple principle-filter the ambient noise, and amplify the relevant signal. The ball hitting the bat produces a sound of a particular frequency. The stump mic will pick up the sound of the ball hitting the bat. It first filters this sound which is of a particular frequency from all the ambient noise. This can be achieved with the help of a resonance filter. At the receiver this sound is amplified and plotted to note the variation in the sound. A sharp variation denotes the bat hitting the ball and a flat peak means the bat has hit the pad or part of the body. This plot is viewed along with the replay of the shot to synchronize the movement of the ball and the spike in plot. The main aspect that needs focus is amplification. The sound may be very faint, so faint that it would be very minimal when viewed in the plot, so it needs to be amplified. Before plotting, the signal is filtered to remove the unnecessary background noise.

It only requires a slow motion camera and good microphone which are available in any international cricket match. Thus the cost of the Snickometer is very low making it affordable to any country. Sometimes Snickometer takes a considerable amount of time to give the output. This is due to the synchronization issues of the video and the audio. But with the development of the technology the synchronization will be done automatically and the results will be available as soon as the incident occurs.

Fig 2.1 Image of a snickometer in use during a cricket match[1]

Also the Snickometer only indicates that a contact happened. This contact may be between bat and ball, pad and ball or the bat and pad. It is up to the umpire to take the final decision. Thus this leads to inconclusive replays in some cases. But in Hot Spot it clearly shows the area the contact occurred.

2.2 HOTSPOT

Hot Spot uses technology developed in the military for tank and jet fighter tracking. The technology was founded by French scientist Nicholas Bion, before being worked upon by many companies in Paris and being bought and adopted by the Australian Nine Network. The technology was adapted for television by BBG Sports, the Australian company responsible for the Snickometer, in conjunction with Sky Sports.

Hot Spot is an infra-red imaging system used in to determine whether the ball has struck the batsman, bat or pad. Hot Spot requires two infra-red cameras on opposite sides of the ground above the field of play that are continuously recording an image. Any suspected snick or bat/pad event can be verified by examining the infrared image, which usually shows a bright spot where contact friction from the ball has elevated the local temperature. Where referrals to an off-field third umpire are permitted, the technology is used to enhance the on-field umpire's decision-making accuracy.

Hot Spot has two main advantages over its competing technology, the Snickometer, which is a sound-detection based system. Snickometer often produces inconclusive results indicating contact (potentially any combination of bat, pad and ball) only, whereas the Hot Spot clearly shows exactly what the ball strikes.

Fig 2.2: Use of hotspot technology in cricket. [2]

Precise synchronization of the Snickometer sound with associated pictures takes time, making it currently not suitable for use in the umpire decision review system. Hot Spot technology, even though claimed to be extremely accurate, is not used in many matches.

In the India-England ODI Series in 2011, there were controversial decisions based on the Hot Spot technology going against India's Rahul Dravid on more than one occasion where Hot Spot replays proved inconclusive and yet Dravid was given out. On one occasion, there seemed to be a nick which Hot Spot wasn't able to detect. These incidents threw the role of Hot Spot technology into doubt once again. In the 2013 Ashes, many decisions again cast doubts on Hotspot Technology.

Snickometer is combined with Hot Spot technology to make better judgments about LBW and Catch decisions. Out of the three technologies used in UDRS, Snickometer is the least controversial technology yet it is not even used in UDRS. And the most controversial technology is Hawk Eye which is made mandatory. The Hot Spot technology lies in between and it is made optional in UDRS. Just like humans no technology is hundred percent accurate. So always we have to use the technology wisely and improve the accuracy of decision making process to make the game of cricket more fair to both teams.

2.3 IMU IN SPORTS RESEARCH

The beginning of IMU development was dedicated to the improvement of the technology, especially in sensing, energy consumption, and communication. With time and sensor miniaturization, IMU fused more and more of its sensors, including its triaxial accelerometers, gyroscopes, magnetic field detectors, and pressure temperature sensors. The second major development was the improvement of post-processing. IMUs were mainly used to obtain orientations and translations from its measurements of angular velocity and linear acceleration. Noise and drift of the inertial data were then an important source of measurement errors that had to be corrected.

The present time brings a total democratization and massive use of the IMU in the study of biomechanics, especially sport and clinical biomechanics. Integrated and turnkey systems based on IMU technology are nowadays commercialized. IMU motion capture systems now enable the monitoring of sport activities such as gait, running, biking, and skiing. Every field of research in connection with motion capture and motion analysis are impacted by this substantial development of IMU application. Moreover, new fields of research are opening in pervasive tracking and ecologic motion capture. MoCap (motion capture) in studio in time will be replaced by ecological PeCap (performance capture)[3].

Accelerometers are widely used in development of technology for sports like cricket, hockey, tennis. Research areas cover a wide range of biomechanics, bat swings, impact location and movement. The extensive research in these areas improve the quality of the sport techniques. For example finding the sweet spot in a cricket bat helps to transfer more energy while playing a shot. These sweet spots in the bat are tested by using in accelerometer. Analyzing the sweet spots in a cricket bat helped in better cricketing shots which can be played easily with less effort. These sweet spot detection is used for tennis and badminton racquets too.

3. INTEGRATED ACCELEROMETER BASED APPROACH

One of the most common inertial sensors is the accelerometer, a dynamic sensor capable of a vast range of sensing. Accelerometers are available that can measure acceleration in one, two, or three orthogonal axes. They are typically used in one of three modes:

1.As an inertial measurement of velocity and position

2.As a sensor of inclination, tilt, or orientation in 2 or 3 dimensions, as referenced from the acceleration of gravity (1 g = $9.8 m/s^2$);

3.As a vibration or impact (shock) sensor.

There are considerable advantages to using an analog accelerometer as opposed to an inclinometer such as a liquid tilt sensor-inclinometers tend to output binary information (indicating a state of on or off), thus it is only possible to detect when the tilt has exceeded some thresholding angle.

3.1 PRINCIPLE OF OPERATION

Most accelerometers are Micro-Electro-Mechanical Sensors (MEMS). The basic principle of operation behind the MEMS accelerometer is the displacement of a small proof mass etched into the silicon surface of the integrated circuit and suspended by small beams. Consistent with Newton's second law of motion (F = ma), as an acceleration is applied to the device, a force develops which displaces the mass.

The support beams act as a spring, and the fluid (usually air) trapped inside the IC acts as a damper, resulting in a second order lumped physical system. This is the source of the limited operational bandwidth and non-uniform frequency response of accelerometers.

3.2 TYPES

There are several different principles upon which an analog accelerometer can be built. Two very common types utilize capacitive sensing and the piezoelectric effect to sense the displacement of the proof mass proportional to the applied acceleration. Other types include Hall effect, Heat transfer, Piezoresistive.

3.3 SPECIFICATIONS

A typical accelerometer has the following basic specifications:

1.Analog/digital
2.Number of axes
3.Output range (maximum swing)
4.Sensitivity (voltage output per g)
5.Dynamic range
6.Bandwidth
7.Amplitude stability
8.Mass

Zero g offset (voltage output at 0 g), Noise (sensor minimum resolution), Temperature range, Bias drift with temperature (effect of temperature on voltage output at 0 g), Sensitivity drift with temperature (effect of temperature on voltage output per g), Power consumption are the other specifications of an accelerometer.

3.4 OUTPUT

An accelerometer output value is a scalar corresponding to the magnitude of the acceleration vector. The most common acceleration, and one that we are constantly exposed to, is the acceleration that is a result of the earth's gravitational pull. This is a common reference value from which all other accelerations are measured (known as g, which is ~9.8m/s^2).

Digital output: Accelerometers with PWM output can be used in two different ways. For most accurate results, the PWM signal can be input directly to a microcontroller where the duty cycle is read in firmware and translated into a scaled acceleration value. When a microcontroller with PWM input is not available, or when other means of digitizing the signal are being used, a simple RC reconstruction filter can be used to obtain an analog voltage proportional to the acceleration. At rest (50% duty-cycle) the output voltage will represent no acceleration, higher voltage values (resulting from a higher duty cycle) will represent positive acceleration, and lower values (<50% duty cycle) indicate negative acceleration. These voltages can then be scaled and used as one might the output voltage of an analog output accelerometer. One disadvantage of a digital output is that it takes a little more timing resources of the microcontroller to measure the duty cycle of the PWM signal. Communication protocols could use I2C or SPI.

Analog output: When compared to most other industrial sensors, analog accelerometers require little conditioning and the communication is simple by only using an Analog to Digital Converter (ADC) on the microcontroller. Typically, an accelerometer output signal will need an offset, amplification, and filtration. For analog voltage output accelerometers, the signal can be a positive or negative voltage, depending on the direction of the acceleration. Also, the signal is continuous and proportional to the acceleration force. As with any sensor destined for an analog to digital converter, the value must be scaled and/or amplified to maximally span the range of acquisition. Most analog to digital converters used in musical applications acquire signals in the 0-5 V range.

As a shock detector, an accelerometer is looking for changes in acceleration. This jerk is sensed as an overdamped vibration.

The accelerometer used in this project is MPU6050. The InvenSense MPU-6050 sensor contains a MEMS accelerometer and a MEMS gyro in a single chip. It is very accurate, as it contains 16-bits analog to digital conversion hardware for each channel. Therefore it captures the x, y, and z channel at the same time. The sensor uses the I2C-bus to interface with the Arduino. It contains both an accelerometer and gyro sensor. It is relatively cheap to buy.

Fig 3.1: MPU6000 family block diagram

For precision tracking of both fast and slow motions, the parts feature a user-programmable gyro full-scale range of ±250, ±500, ±1000, and ±2000 °/sec (dps), and a user-programmable accelerometer full-scale range of ±2g, ±4g, ±8g, and ±16g. Additional features include an embedded temperature sensor and an on-chip oscillator with ±1% variation over the operating temperature range[4].

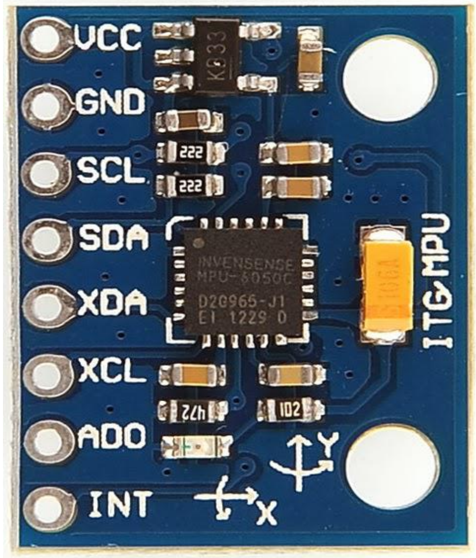


Fig 3.2: MPU 6050 accelerometer [5]

The MPU 6050 sensor is relatively cheap and is available online on any e-selling website. There are a number of breakout boards or sensor boards with the MPU 6050. The price of the MPU 6050 module is Rs.400 on Amazon website as of feb,2017. The maximum price for any breakout board is less than Rs.4000 which is cheaper compared to other accelerometers and gyro sensors.

4. EXPERIMENTAL SETUP AND RESULTS

To get the raw values from the accelerometer, an arduino micro controller is used. Reading the raw values for the accelerometer and gyro is easy. The sleep mode has to be disabled, and then the registers for the accelerometer and gyro can be read. But the sensor also contains a 1024 byte FIFO buffer. The sensor values can be programmed to be placed in the FIFO buffer. And the buffer can be read by the Arduino. A little more complicated is the ability to control a second I2C-device. The MPU-6050 always acts as a slave to the Arduino with the SDA and SCL pins connected to the I2C-bus.

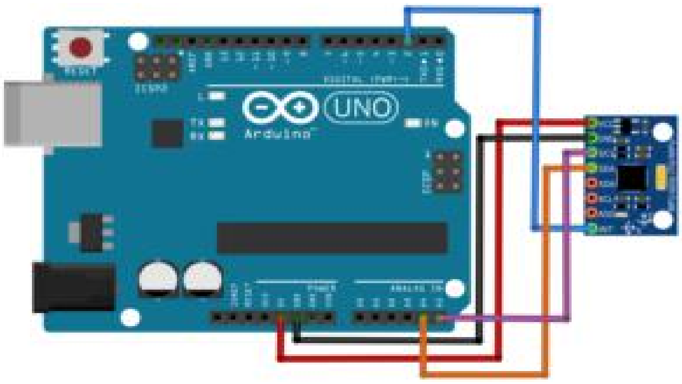


Fig 4.1: Arduino uno connected with a mpu6050 accelerometer[6].

The are many ways to get values from accelerometer through arduino and use them in software for post analysis of the data. There are inbuilt third party libraries for MPU 6050 so that all the 6 values (3 acceleration + 3 gyro) can be acquired with much ease. But these values do not provide any useful information unless properly analyzed. One way that is tried is using Processing IDE.Using processing IDE the values are plotted on a linear scale. But the variation of scale and the data transfer from arduino to processing IDE is much slower. So LabVIEW is used as an alternative to get the information at decent rate from arduino.

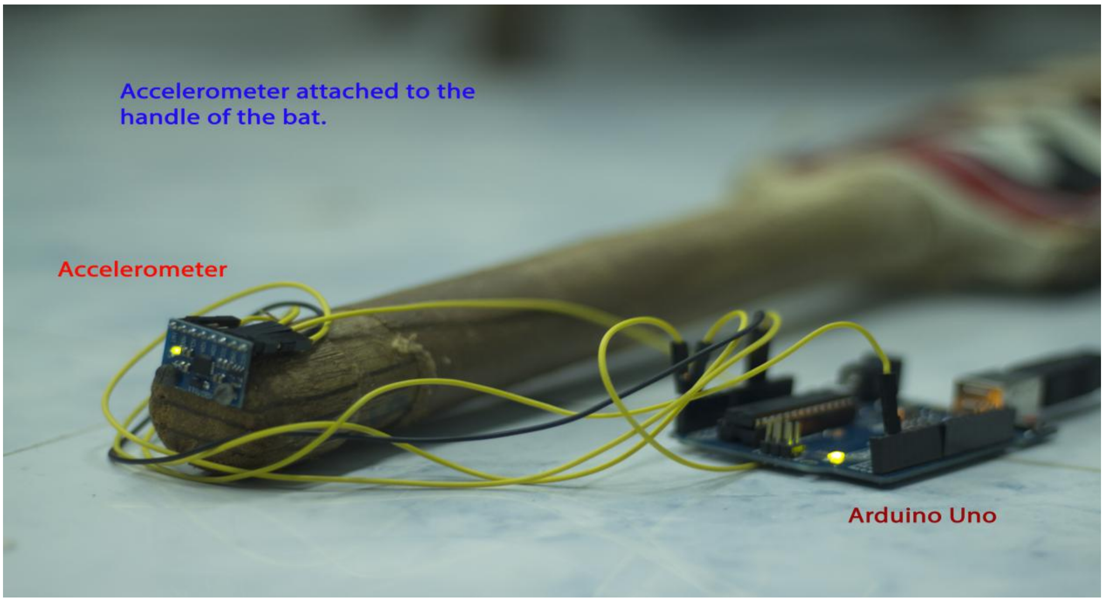


Fig 4.2: Accelerometer attached to the handle of a bat

LabVIEW, short for *Laboratory Virtual Instrument Engineering Workbench*, is a programming environment in which you create programs using a graphical notation (connecting functional nodes via wires through which data flows); in this regard, it differs from traditional programming languages like C, C++, or Java, in which you program with text. However, LabVIEW is much more than a programming language. It is an interactive program development and execution system designed for people, like scientists and engineers, who need to program as part of their jobs.

Programs that take weeks or months to write using conventional programming languages can be completed in hours using LabVIEW because it is specifically designed to take measurements, analyze data, and present results to the user. And because LabVIEW has such a versatile graphical user interface and is so easy to program with, it is also ideal for simulations, presentation of ideas, general programming, or even teaching basic programming concepts. LabVIEW offers more flexibility than standard laboratory instruments because it is software-based. Output appears in any form we want it to be. Charts, graphs, and user-defined graphics comprise just a fraction of available output options.

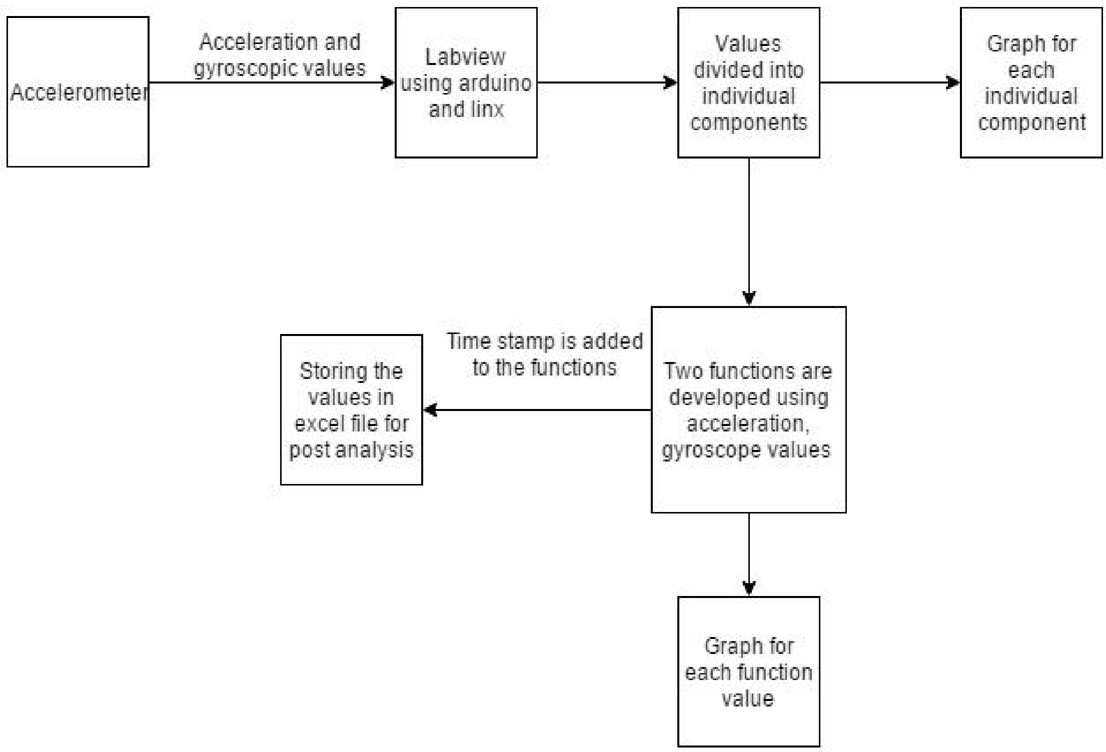


Fig 4.3:Block diagram of the data acquisition

The LabVIEW program development environment is different from standard C or Java development systems in one important respect: While other programming systems use text-based languages to create lines of code, LabVIEW uses a graphical programming language, often called "**G**," to create programs in a pictorial form called a *block diagram*. Graphical programming allows us to concentrate on the flow of data within your application, because its simple syntax doesn't obscure what the program is doing.

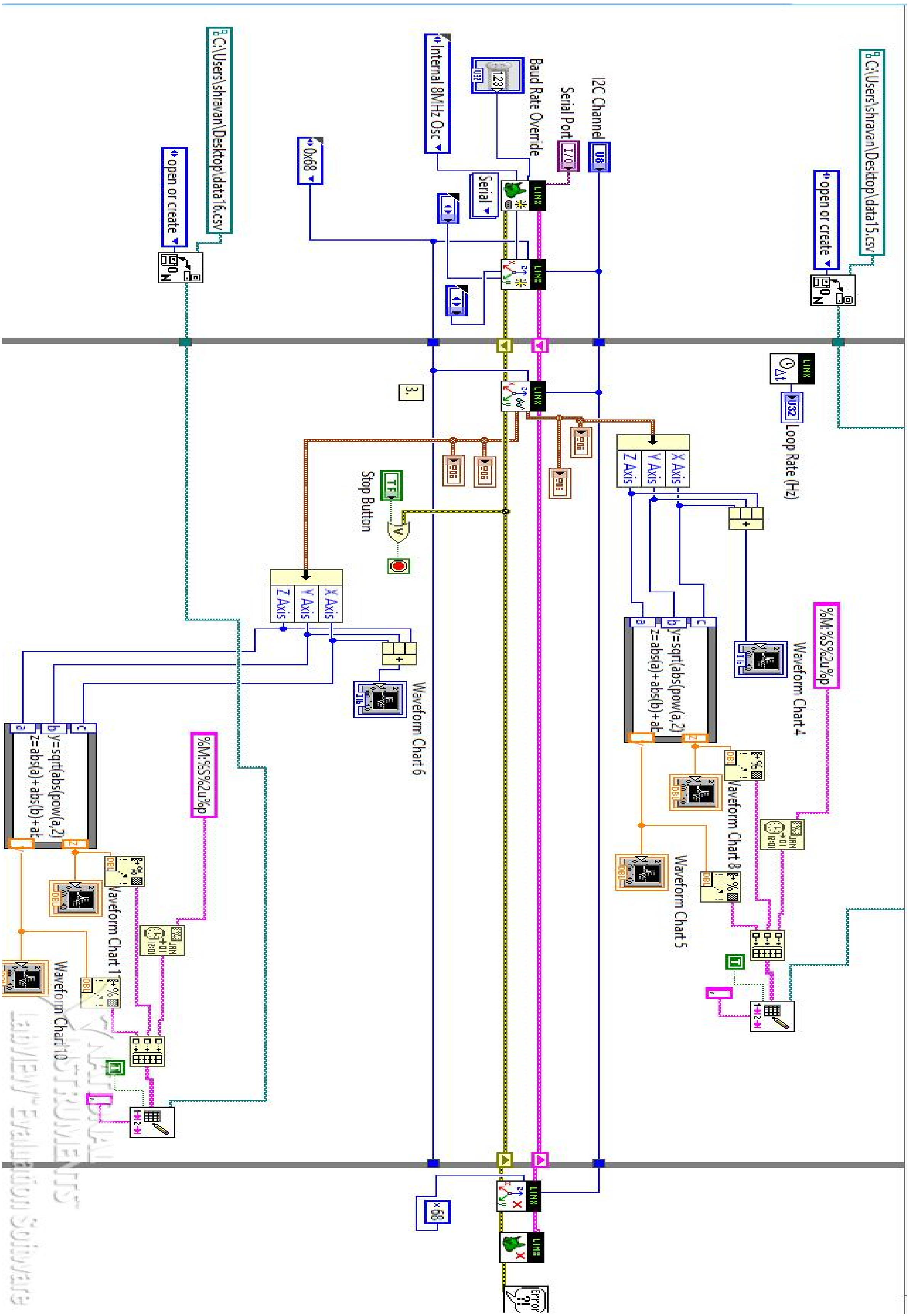


Fig 4.4 : Labview block diagram of the vi.

Although labview is an extremely good tool in analyzing the data, there are no available modules in labview which can receive data using arduino. Developing a module for arduino requires a lot of time. So a third party module linx is used . LINX is an open source project by Digilent and is designed to make it easy to develop embedded applications using LabVIEW. LINX includes VIs for over 30 of the most common embedded sensors as well as hardware agnostic APIs for accessing peripherals like digital I/O, analog I/O, PWM, I2C, SPI, and UART[7]. The linx acquires the data from the arduino through the serial read module. Then these values from the linx are divided into gyro and acceleration values. The acceleration values and the gyro values are further divided into individual axes values and these values are presented in the graphs and charts. Two functions $sqrt(a^2_x+a^2_y+a^2_z)$ and $abs(a_x)+abs(a_y)+abs(a_z)$ are used to demonstrate how the spike appears on a riding curve. The functional values are also graphed. These values are also saved in an excel with a global time stamp so that these data can be post analyzed. The data thus represented is distinguishable when the impact or nick occurs from the other data due to sudden change in acceleration and gyroscopic values.

The frame rate of the camera used in cricket has a high frame rate of 250 frames per second. The data rate acquired from the accelerometer can be as high as thousand samples per second. But the rate is limited by the linx software.The linx software can acquire data at decent rates around 60 samples per sec but cannot acquire data at higher rates. This is because of the interface between arduino and labview. But at the rate what we are acquiring can give us the insight how for faster rates the method is useful in detecting the nick.

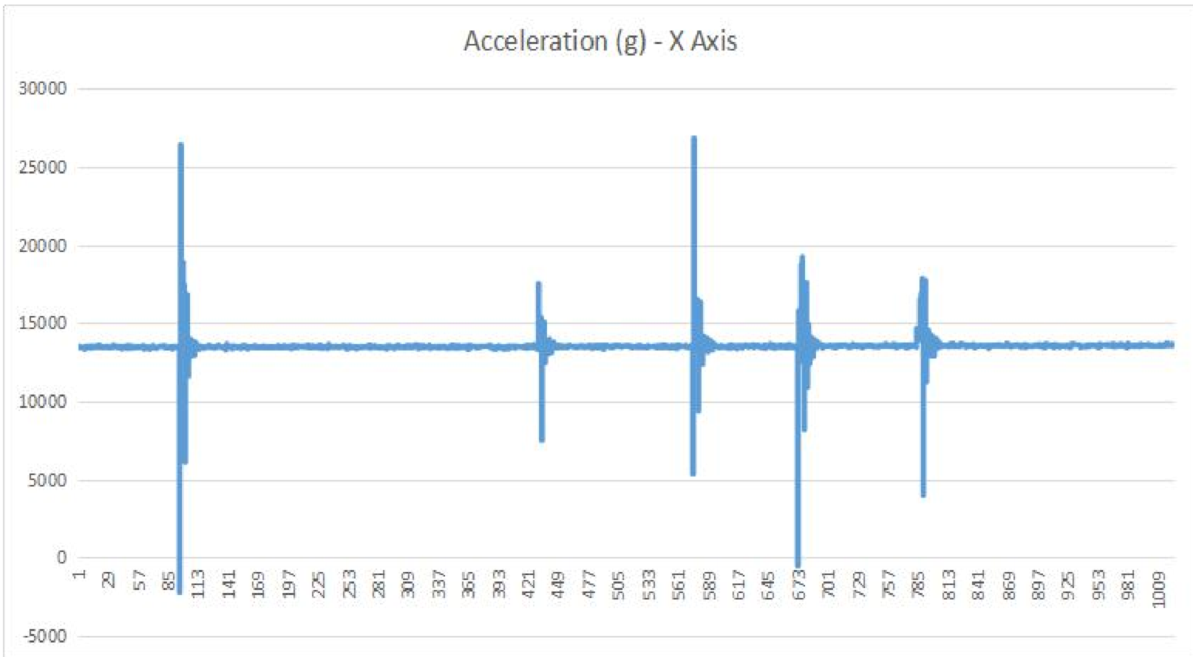


Fig 4.5: Acceleration (x-axis) graph when the bat is gently touched with a ball

The acceleration values for x, y, z axes are independent of each other. Similar to it the gyroscope values of individual axes are not the same. The gyroscope values changes vastly which makes it difficult to analyze the nick. So mainly acceleration values are used for this purpose. The two functions developed are highly effective in detecting the nick even for a small interval of time for which the nick occurs and however small the change in acceleration may be.

5. DETAILED TEST RESULTS AND CONCLUSIONS

The experimental results are analyzed for three different situations namely dead bat condition (where the bat is stationary), swinging bat condition and nick with a swinging bat .

5.1 DEAD BAT CONDITION

Here the bat is held straight without any movement and any swinging of the bat.

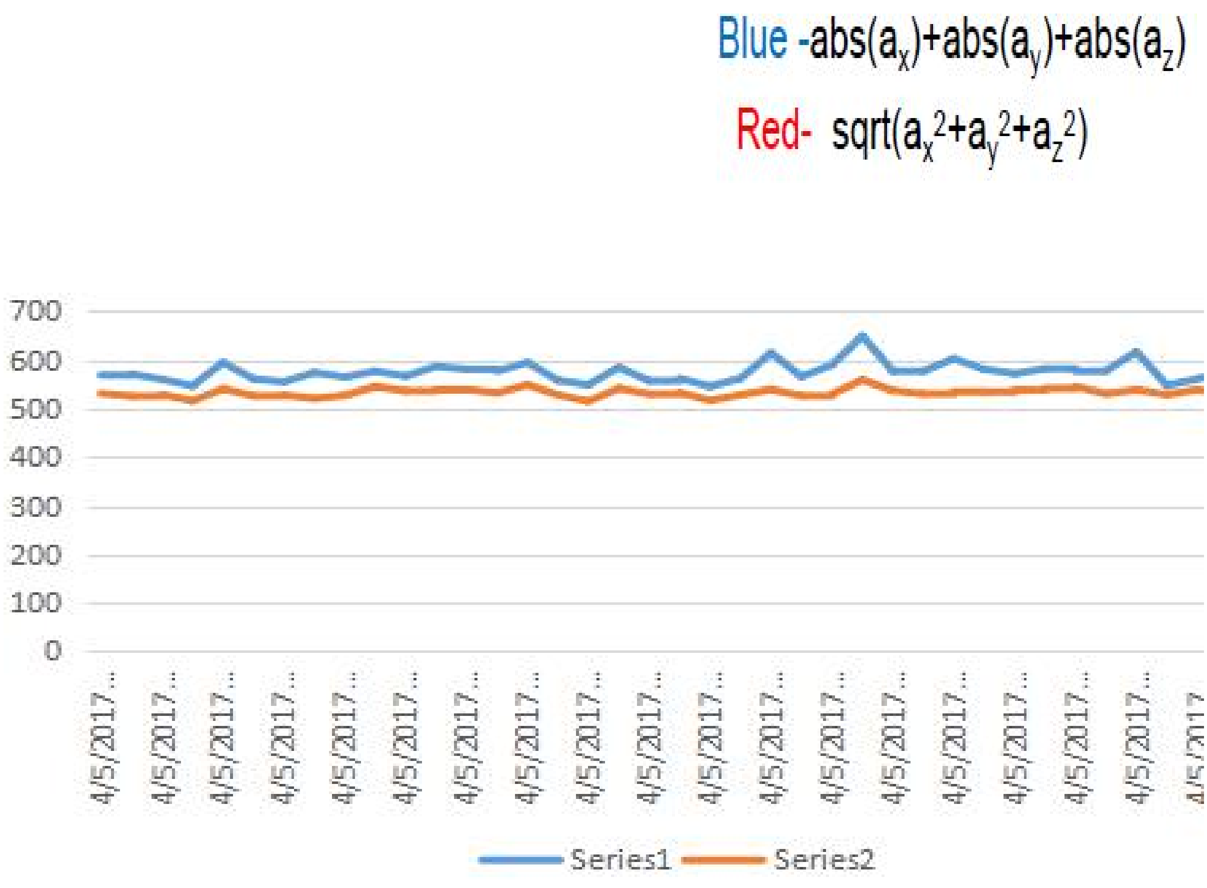


Fig 5.1: Graph when the bat is held dead straight

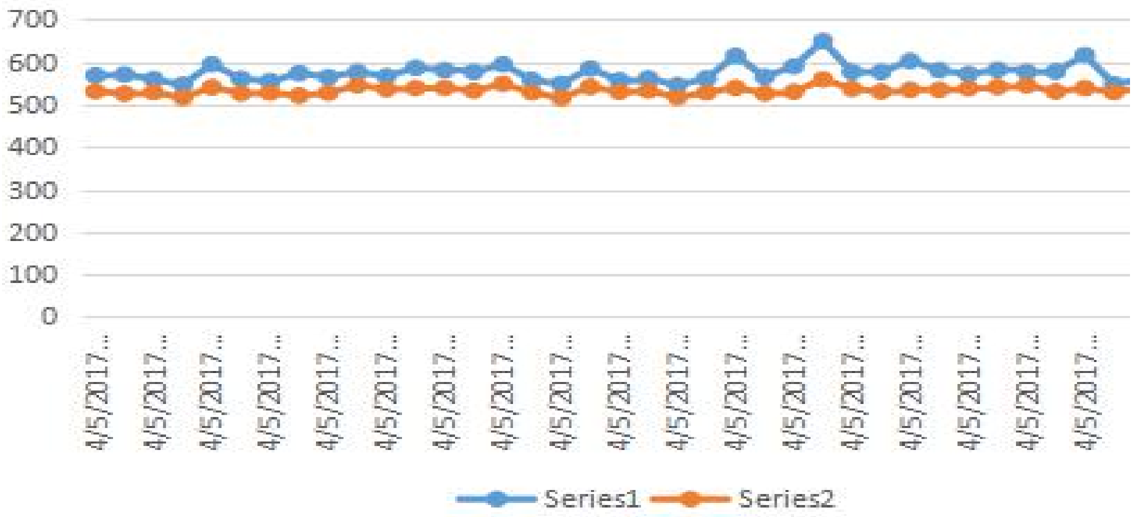


Fig 5.2: Individual points on the graph when the bat is held dead straight

5.2 SWINGING BAT CONDITION

The bat is swung as a normal cricketing shot cover drive and the change in the acceleration values is as follows

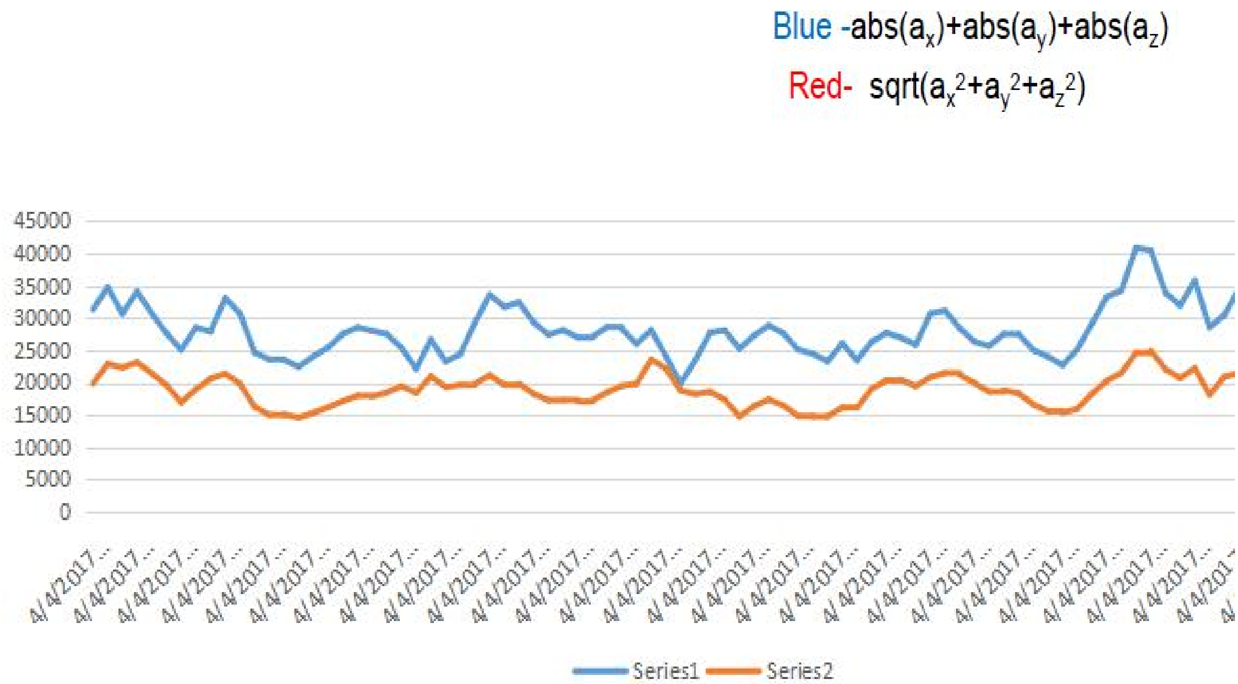


Fig 5.3: Graph when the bat is swung hard

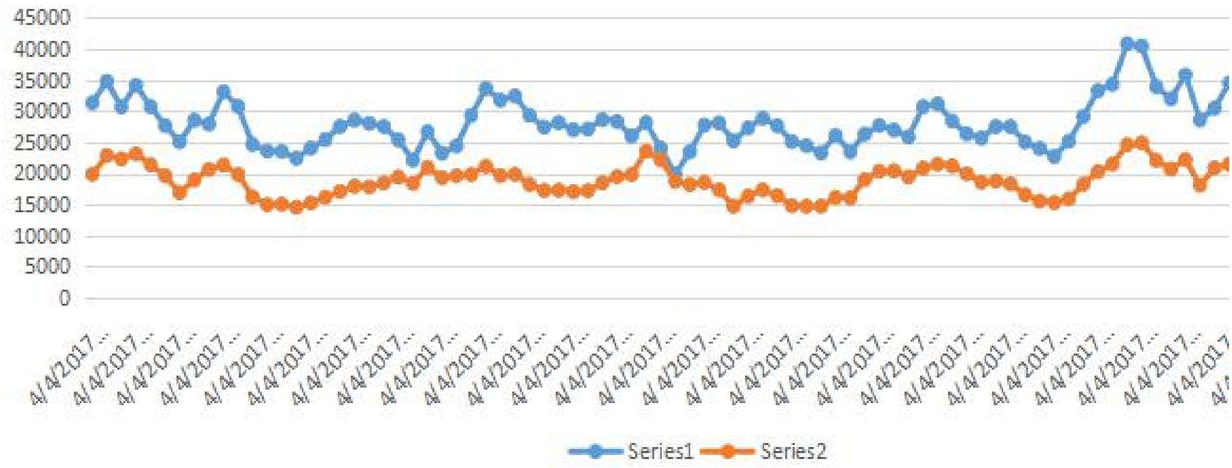


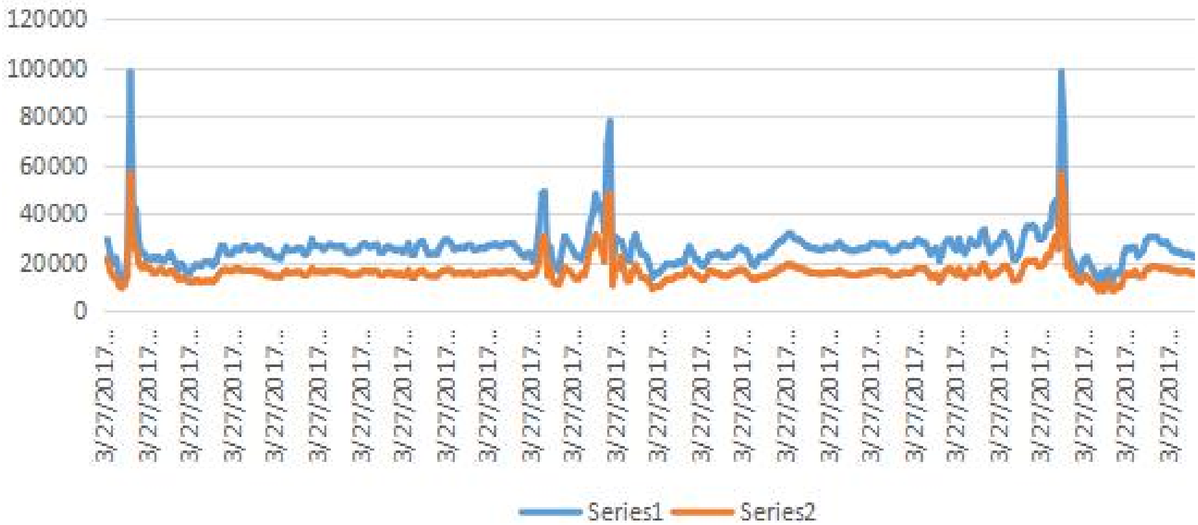
Fig 5.4: Individual points on the graph when the bat is swung hard

5.3 NICK WITH A SWINGING BAT

The bat is swung at a ball thrown producing a nick as the ball passes the bat.

Blue -abs(a_x)+abs(a_y)+abs(a_z)

Red- sqrt($a_x^2+a_y^2+a_z^2$)



.Fig 5.5: Graph of the nick with a swinging bat

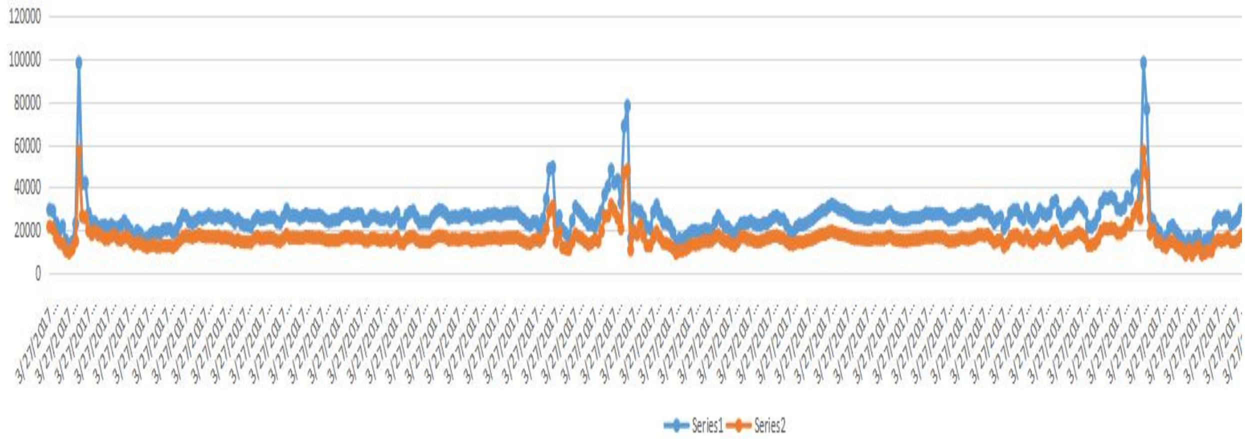


Fig 5.6: Individual points on the graph of the nick with a swinging bat

A closer look at one of the spikes

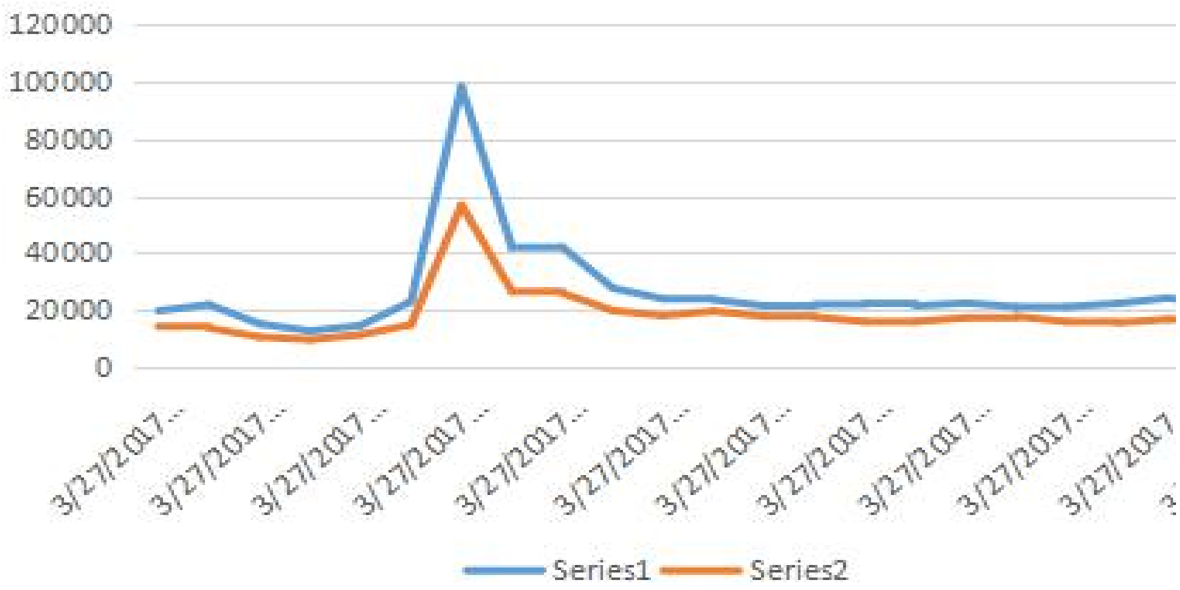


Fig 5.7: The closer look at the spike

As seen in the above a clear spike appears on a smooth riding curve when the ball is nicked by the bat. By acquiring the data at a faster rate it is possible to view the nick as a straight single spike.

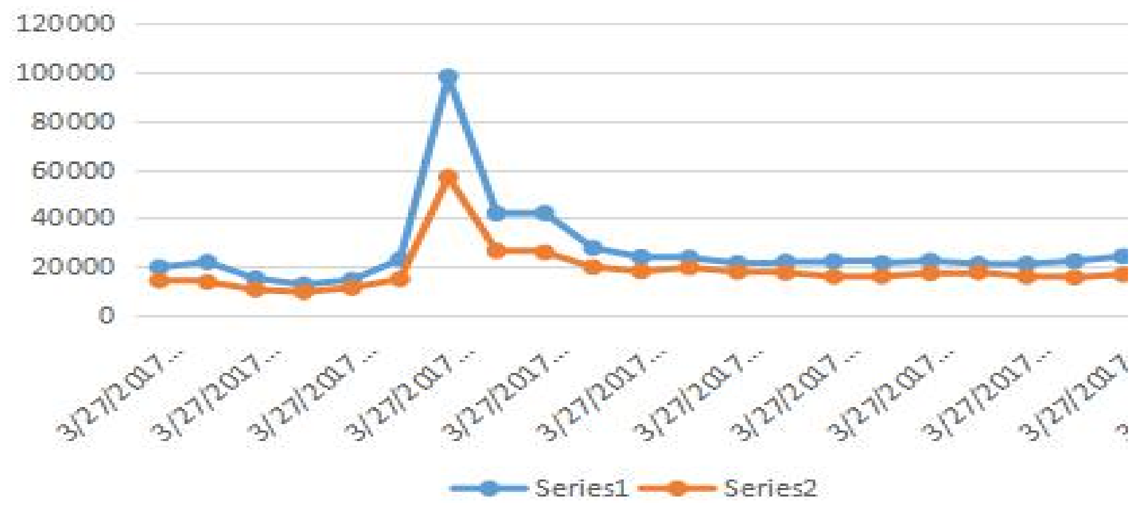


Fig 5.8: Individual points on the graph closer look at the spike

Similar graphs were plotted for the gyroscopic values. The graphs for gyroscopic values are as follows.

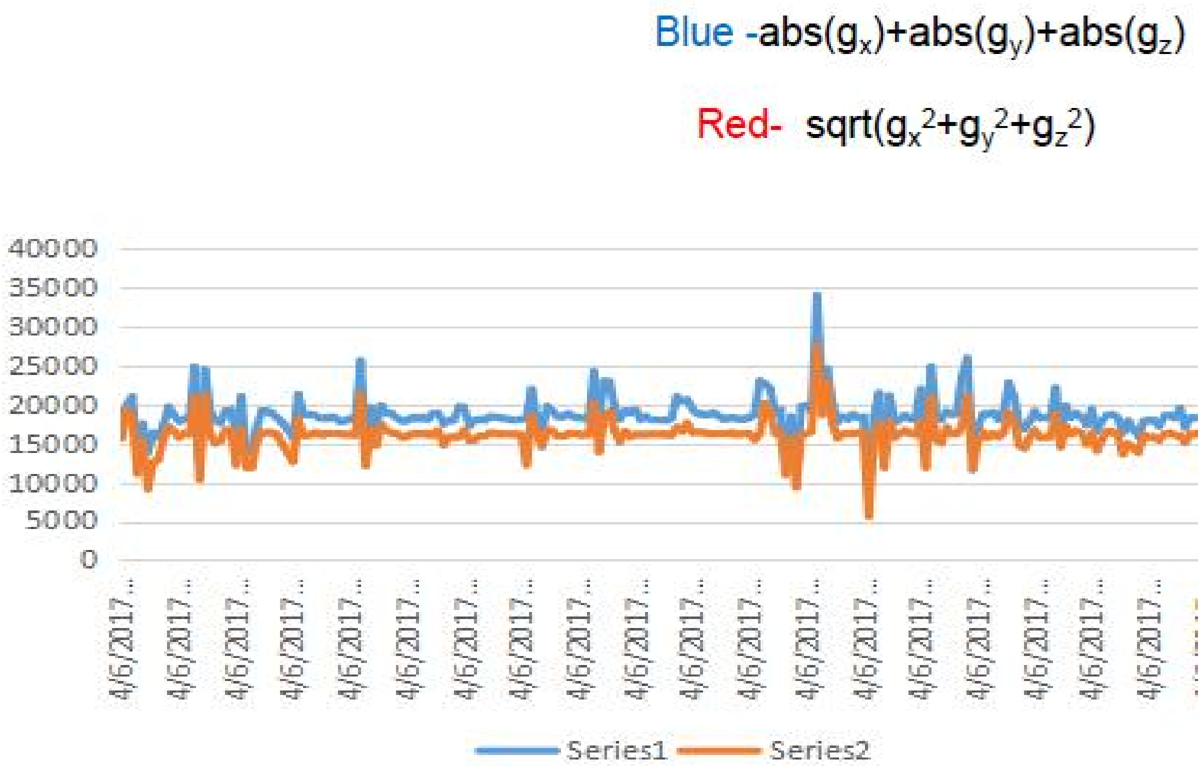


Fig 5.9: Gyroscopic values when nick occurs with the bat

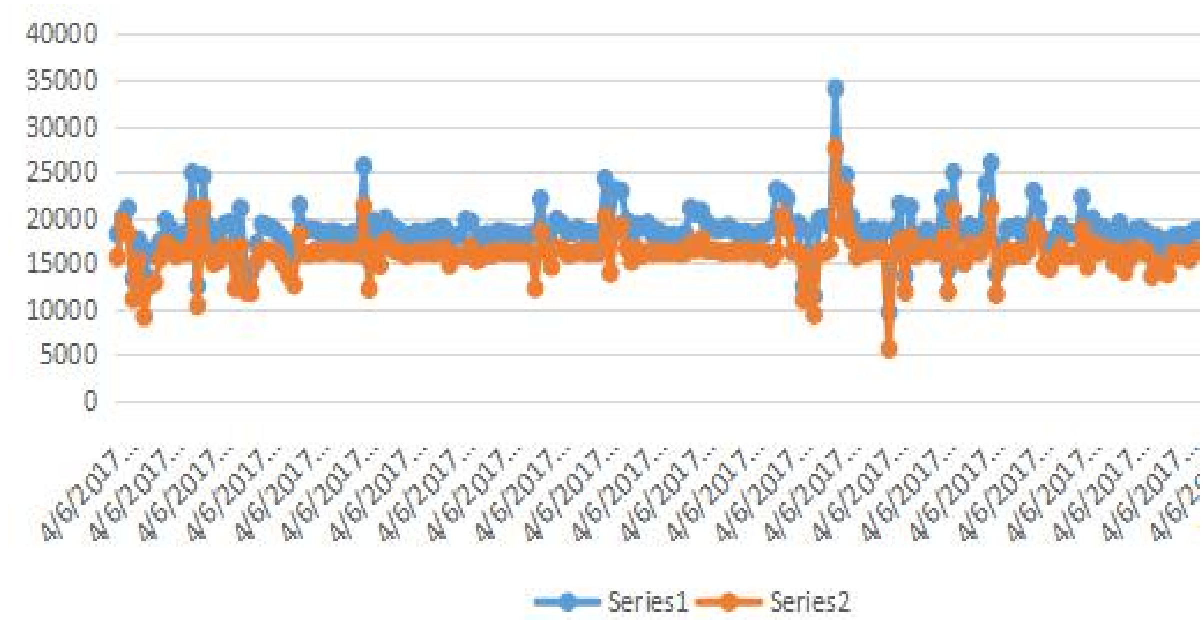


Fig 5.10: Individual points on the gyroscopic graph when there is a nick

A Closer look at one of the spikes

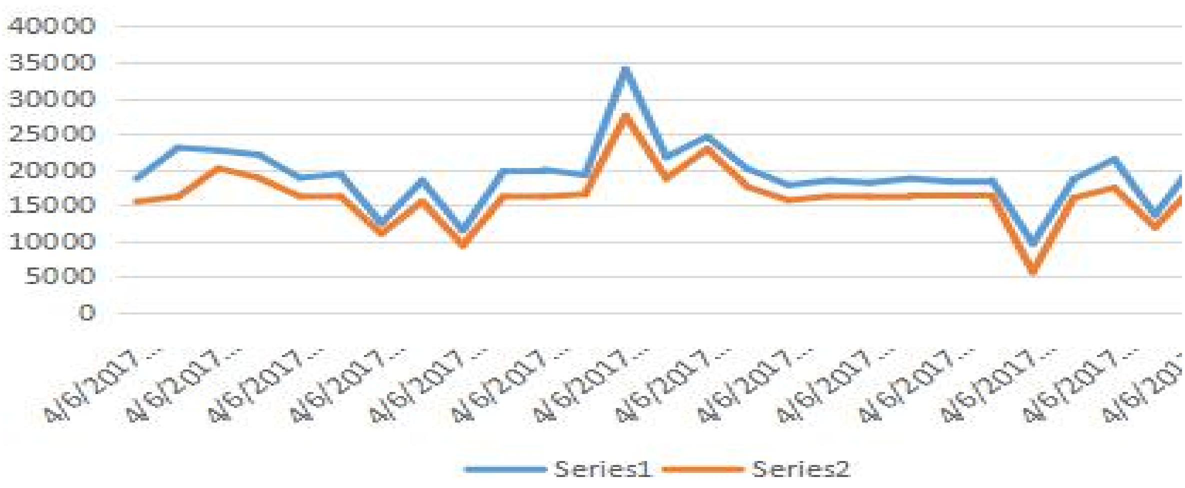


Fig 5.11: A closer look at the spike in gyroscope values

As seen in the graph the change in the gyroscopic values is not uniform when the ball nicks the bat. This may result in false positives. But the change in gyroscopic values can be used in improving the accuracy of the system.

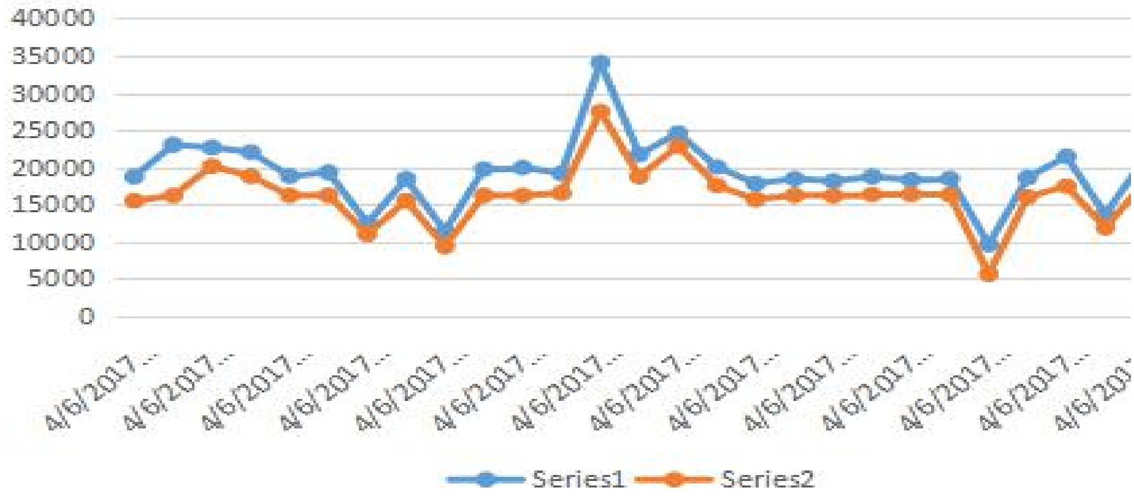


Fig 5.12: Individual points on the graph of spike of gyroscopic values

5.4 CONCLUSION

The main aim of this project is to develop a new method to detect nick between bat and ball using an accelerometer. With the use of arduino and labview we are able to get the raw values of an accelerometer and able to graph the individual axes values both for the acceleration sensor and gyrometer. Two functions are developed to understand and analyze the nick better.

The results obtained from the project has proved that there is a huge scope for IMU’s in sports, especially cricket. The proposed method is cheap , reliable and can be used to analyse and detect the nick properly.

However there are still areas where improvement is needed. The data acquisition rate can be improved to 250 samples per second. A camera input with this system can give a complete system which can replace a snickometer.

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