REAL-TIME HUMAN MOTION CAPTURE USING WEARABLE SENSORS

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Abstract-Real-Time Human Motion Capture using wearable sensors has emerged as a promising technology in various fields, such as sports analysis, rehabilitation, and virtual reality. This work presents a novel approach to capturing human motion in real-time using lightweight and unobtrusive wearable sensors. By employing sensor fusion techniques and advanced algorithms, the system accurately tracks and reconstructs the movements of individuals, providing detailed information about joint angles, velocities, and trajectories. The real-time aspect of the system enables instantaneous feedback, making it ideal for applications requiring immediate analysis or interaction. The proposed method demonstrates high accuracy and reliability, paving the way for widespread adoption of wearable sensor-based motion.

Keywords - Wearable Sensors, Sensor Fusion Techniques, Motion Tracking, Motion Reconstruction, Real-Time sports analysis.

I. INTRODUCTION

Real-time human motion capture using wearable sensors is a innovative technology that enables the accurate and instantaneous tracking of human movement. It has emerged as a promising solution to overcome the limitations of traditional motion capture systems, offering enhanced flexibility, portability, and immediate feedback. This technology finds applications in diverse fields, including entertainment, sports, healthcare, and virtual reality.

Wearable sensors are lightweight devices that can be easily attached to various parts of the body, such as limbs or joints, or integrated into clothing [1]. They capture a wide range of motion data, including joint angles, acceleration, orientation, and velocity. By collecting and processing this data in real- time, the system enables instant analysis, interpretation, and visualization of human motion.

This work explores the current state of real-time human motion capture using wearable sensors, delving into the underlying technologies, challenges, and advancements in the field. It also discusses the diverse applications and potential future developments. Real-time human motion capture using wearable sensors has the power to revolutionize human-computer interaction, elevate physical performance analysis, and reshape industries by providing precise and real-time tracking of human movement [2]

The Fig 1 represents

A: Wearable device is worn on human body segments of interest for motion capture by incorporating tri-axis flow sensors with tri-axis inertial sensors [3]

B. Motion data including three-dimensional motion velocity, motion acceleration, and attitude angles can be measured by our device. The motion velocity and motion acceleration are measured via integral-free approach by using micro flow sensor which avoids accumulative errors

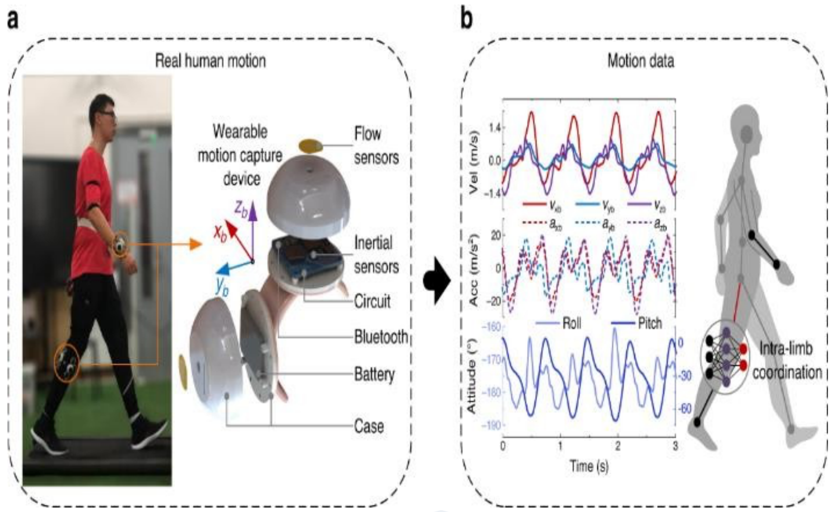

Fig 1 : Process of Real-Time Human Motion Capture

II. LITERATURE SURVEY

After a thorough study on the topic given by renowned authors, we were able to gather ideas for our work. Based on the survey the papers are listed below:

"An Adaptive-Gain Complementary Filter For Real-Time Human Motion Tracking With MARG Sensors In Free Living Environments" by Y Tian, H Wei and J Tan in the year of 2012 [1]..This research paper presents an adaptive- gain complementary filter based on the convergence rate from the Gauss–Newton optimization algorithm (GNA) and the divergence rate from the gyroscope, which is referred as adaptive-gain orientation filter (AGOF).

"Quantified Self And Human Movement : A Review On The Clinical Impact Of Wearable Sensing And Feedback For Gait Analysis And Intervention" by PB Shull and MR Cutkosky in the year of 2014 [2].

III.OBJECTIVES

The Objectives of Real-Time Human Motion Capture Using Wearable Sensor is to implement:

- Accurately capturing the motion of various body parts such as arms, legs, and torso.
- Providing real-time feedback on the motion captured to the user.
- Providing a portable and low-cost alternative to traditional motion capture systems.
- Enabling motion capture in uncontrolled environments such as outdoors or in crowded places.

IV. METHODOLOGY AND IMPLEMENTATION

A. Proposed model

The block diagram of the proposed model is as shown in fig 2.

Sensor Selection: IMU sensors are used as they can measure acceleration, angular velocity and magnetic field of body parts.

Sensor Placement: The placement of the sensors should be such that they can capture the motion of the body parts accurately.

Data Acquisition: The next step is to acquire data from the sensors. The sensors transmit data to a microcontroller, which reads the sensor data and sends it to a computer for further processing

Data Processing: The data is then processed using software developed specifically for the motion capture system. The software typically includes an algorithm to estimate the orientation of the body parts based on the sensor data.

Real-Time Feedback: The results are displayed in real-time on a computer screen. This provides real-time feedback to the user and allows for any necessary adjustments to be made to the system or the motion being captured.

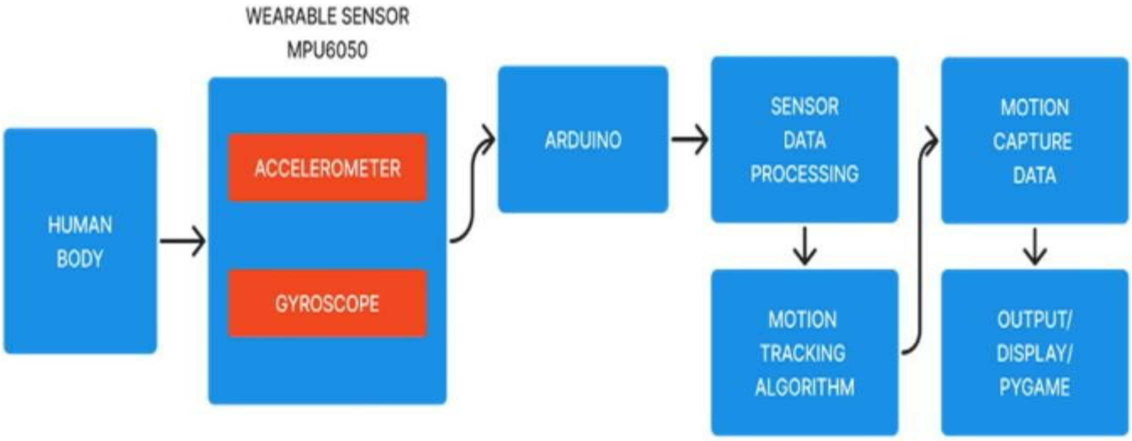

Fig 2: Block Diagram

B. Working Principle

The work of human motion capture analysis using wearable sensors and Arduino involves the integration of computer vision techniques such as py-game with the Arduino microcontroller platform.

- Hardware setup: Connect the MPU6050 sensor to the Arduino board. The MPU6050 is a commonly used accelerometer and gyroscope sensor that can measure linear acceleration and rotational motion. Make sure to follow the wiring instructions and ensure the sensor is securely attached to the subject's body.
- Sensor data acquisition: Use the Arduino board to read the sensor data from the MPU6050. The sensor provides raw data in the form of acceleration and angular velocity values along different axes. The Arduino code can utilize the appropriate libraries or implement algorithms to retrieve this data from the sensor.
- Calibration: Calibrate the sensor to ensure accurate measurements. This involves taking measurements while the subject is in a known, stationary position, and adjusting the sensor's bias or offset values to compensate for any measurement errors.
- Filtering and processing: Apply signal processing techniques to the raw sensor data to remove
- noise and extract relevant motion information. Common techniques include low-pass filtering to smooth the signals, sensor fusion algorithms to combine accelerometer and gyroscope data, and orientation estimation algorithms such as Kalman filtering or sensor fusion algorithms like Mahony or Madgwick filters.
- Motion analysis: Once the sensor data has been processed, you can analyze the motion captured by the

sensors. This can include tasks such as joint angle calculation, gait analysis, gesture recognition, or any other specific motion analysis you require.

- Visualization and interpretation: Visualize the motion capture data to gain insights and interpret the results. You can use libraries like Py-game, as mentioned earlier, to create visual representations of the motion or plot graphs and charts to analyze specific motion parameters.
- Application-specific tasks: Depending on your application, you might integrate the motion capture data with other systems or use it for specific purposes like animation, virtual reality, or physical therapy. This step involves applying the analyzed motion data to achieve the desired outcome.

C . Hardware Implementation

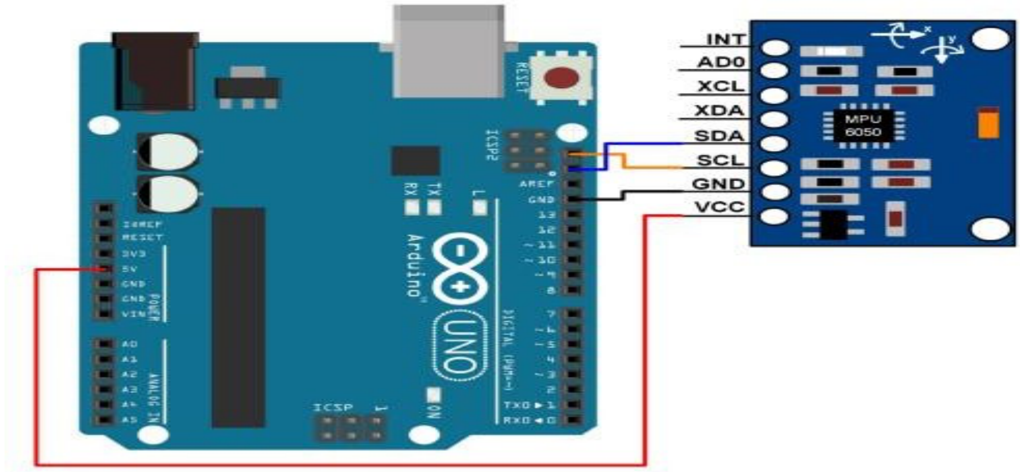

Fig 3: Circuit Diagram

The circuit diagram as shown in fig 3 connects Arduino and MPU6050 sensor. VCC, GND, SDA, and SCL pins establish power, communication, and reference connections. Pull-up resistors stabilize communication. An external power source is optional. USB cable links Arduino to the computer for data transfer. This setup enables motion data reception by Arduino from MPU6050 for processing.

D . Software Implementation

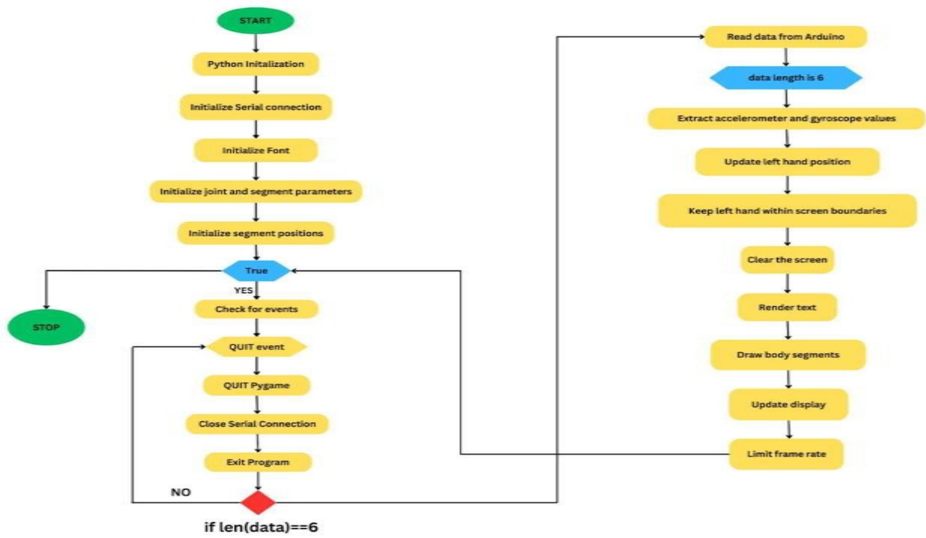

Fig 4: Flowchart

The flowchart in fig 4 demonstrates the real-time motion capturing process using Arduino, MPU6050, and Py- game. It starts by initializing the Arduino and MPU6050, followed by reading motion data from the sensor and transferring it to the computer. Py-game is then initialized to process the motion data and generate visual feedback based on the captured motion. he visual output is displayed on the computer screen, and the process continues in a loop to continuously capture and update the motion data.

III. RESULTS

A. ACCELERATION OF MPU-6050 ALONG CONSTANT DIREECTION

Fig 5: represents the MPU6050 is in a constant position, both, the accelerometer and gyroscope graphs will show flat lines near zero. The accelerometer indicates measurable acceleration on any axis, while the gyroscope suggests no detectable rotational movement. Although there may be slight fluctuations due to sensor noise, the overall pattern signifies a stable and stationary state

Fig 5: Acceleration Of MPU-6050 Along Constant Direction

B. ACCELERATION OF MPU-6050 ALONG POSITIVE X- DIRECTION

Fig 6: represents the MPU6050 is in a constant position, both the accelerometer and gyroscope graphs will show flat lines near zero. The accelerometer indicates number of measurable acceleration on any axis, while the gyroscope suggests no detectable rotational movement. Although there may be slight fluctuations due to sensor noise, the overall pattern signifies a stable and stationary state. This data serves as a reference point for detecting changes in position or motion.

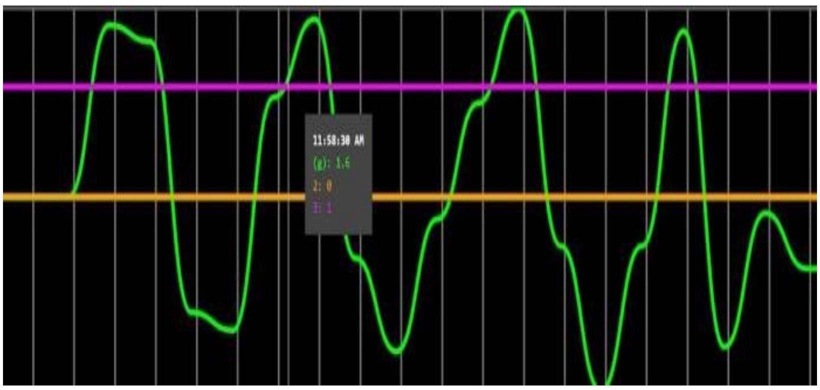

Fig 6: Acceleration Of MPU-6050 Along Positive X-Direction

C. ACCELERATION OF MPU-6050 ALONG NEGATIVE- DIRECTION.

Fig 7: represents that MPU6050 is equipped with a built-in accelerometer that measures linear acceleration. The X-axis represents the horizontal plane, with positive values indicating acceleration to the right and negative values indicating acceleration to the left. The output graph for the X-axis acceleration typically displays time on the horizontal axis and acceleration values on the vertical axis. When the MPU6050 experiences acceleration along the X-axis, the graph will show fluctuating values above or below the zero line, depending on the direction , if the MPU6050 is subjected to a constant rightward acceleration.

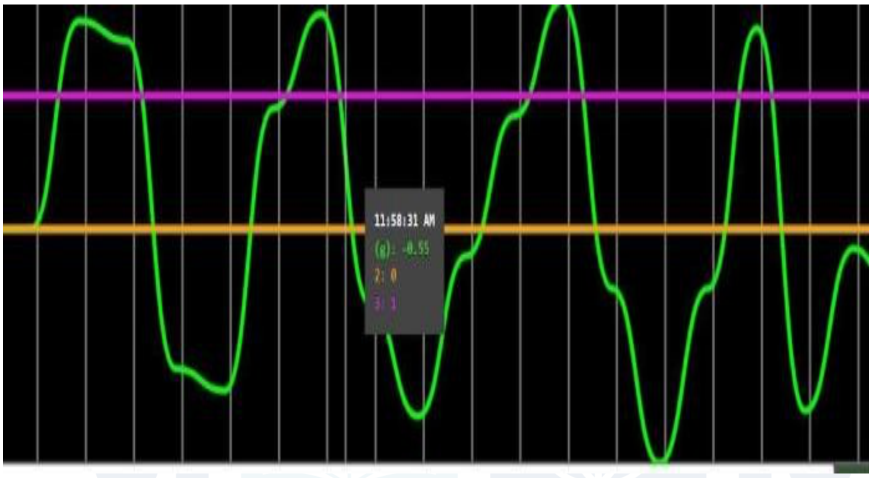

Fig 7: Acceleration Of MPU-6050 Along Negative X-Direction

D. ACCELERATION OF MPU-6050 ALONG Y-DIRECTION

Fig 8: Acceleration Of MPU-6050 Along Y-Direction

Fig 8: represents Y-axis the vertical plane, with positive values indicating upward acceleration and negative values indicating downward acceleration. The output graph for Y-axis acceleration follows a similar format as the X-axis graph, with time on the horizontal axis and acceleration values on the vertical axis. When the MPU6050 experiences acceleration along the Y-axis, the graph will show fluctuations above or below the zero line, depending on the direction. For instance, a consistent upward acceleration will result in a positive value, while a consistent downward acceleration will yield a negative value on the graph.

E. ACCELERATION OF MPU-6050 ALONG Z-DIRECTION

Fig 9: Acceleration Of MPU-6050 Along Z-Direction

Fig 9: represents Z-axis the depth or depth wise acceleration, with positive values indicating acceleration towards the front and negative values indicating acceleration towards the back. The output graph for Z-axis acceleration, again with time on the horizontal axis and acceleration values on the vertical axis, follows a similar pattern as the previous graphs. When the MPU6050 experiences acceleration along the Z-axis, the graph will exhibit fluctuations above or below the zero line, based on the direction. For instance, a consistent forward acceleration will result in a positive value, while a consistent backward acceleration will yield a negative value on the graph.

F. GYROSCOPE OF MPU-6050 ALONG POSITIVE X -DIRECTION

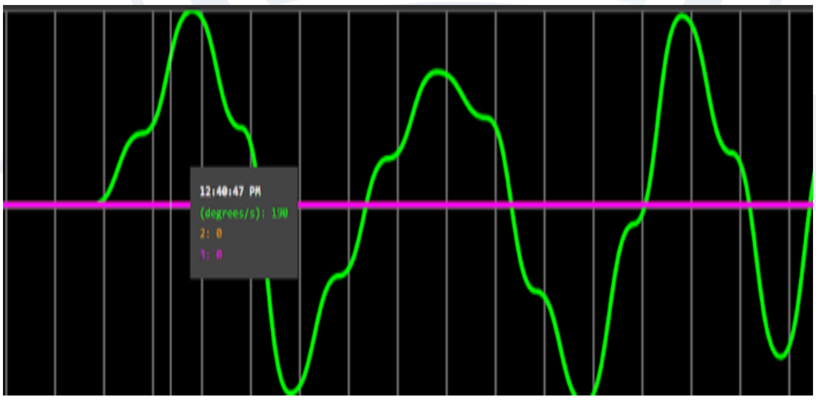

Fig 10: Gyroscope of MPU-6050 Along Positive X-Direction

Fig 10: represents X-axis the horizontal plane, with positive values indicating clockwise rotation and negative values indicating counterclockwise rotation. The output graph for X- axis gyroscope data typically depicts time on the horizontal axis and angular velocity values (in degrees per second or radians per second) on the vertical axis.

G. GYROSCOPE OF MPU-6050 ALONG NEGATIVE X -DIRECTION

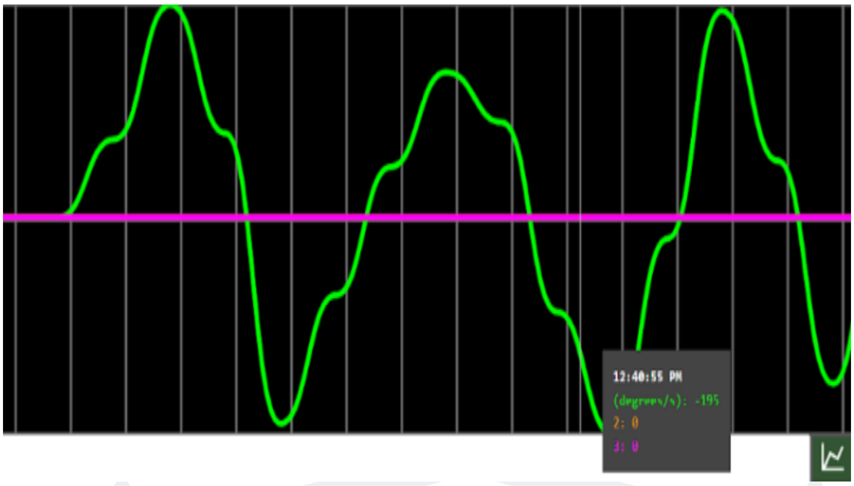

Fig 11 :Gyroscope Of MPU-6050 Along Negative X-Direction

Fig 11: represents X-axis the horizontal plane, with positive values indicating clockwise rotation and negative values indicating counterclockwise rotation. When the MPU6050 experiences rotational movement around the X-axis, the graph will display fluctuations above or below the zero line, depending on the direction and magnitude of rotation

H. GYROSCOPE OF MPU-6050 ALONG Y -DIRECTION

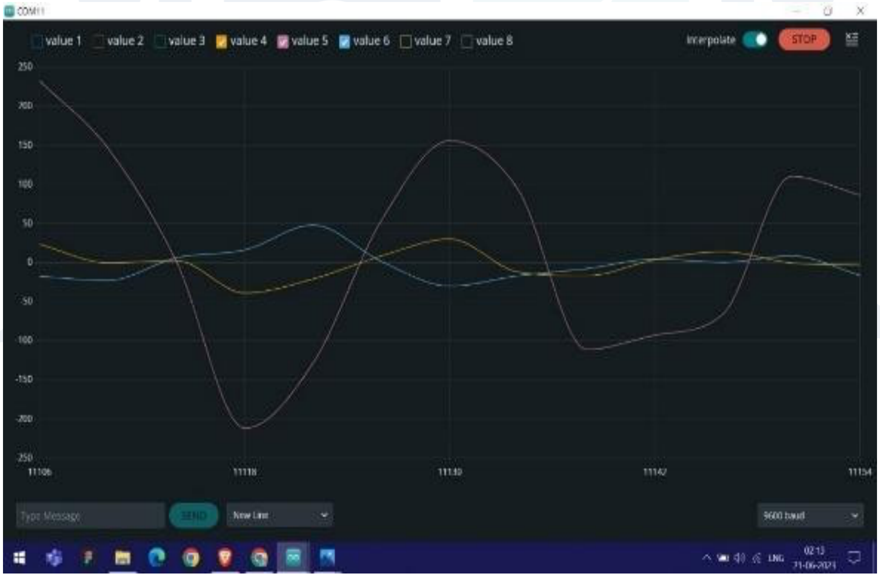

Fig 12: Gyroscope Of MPU-6050 Along Y-Direction

Fig 12: represents the vertical plane, with positive values indicating upward rotation and negative values indicating downward rotation. The output graph for Y-axis gyroscope data follows a similar format as the X-axis graph, with time on the horizontal axis and angular velocity values on the vertical axis. When the MPU6050 experiences rotational movement around the Y-axis, the graph will exhibit fluctuations above or below the zero line.

GYROSCOPE OF MPU-6050 ALONG Z-DIRECTION

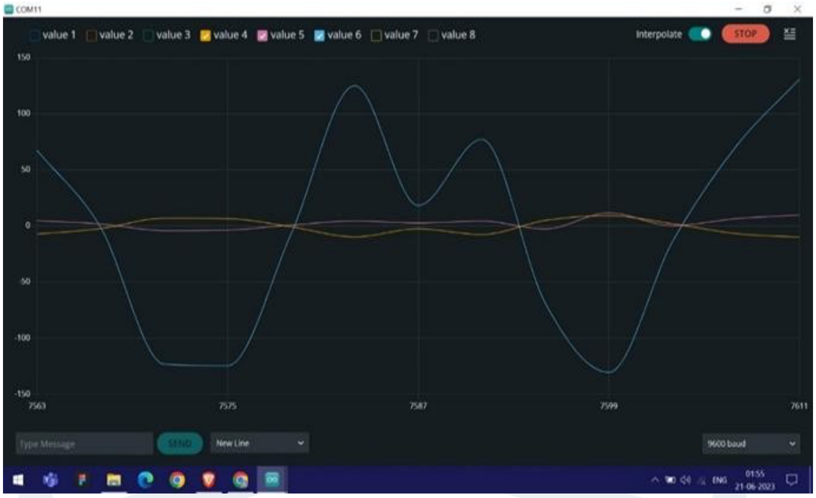

Fig 13: Gyroscope Of MPU-6050 Along Z-Direction

Fig 13: represents the depth or depth-wise z-axis rotation, with positive values indicating clock wise rotation and negative values indicating counterclockwise rotation. The output graph for Z-axis gyroscope data, again with time on the horizontal axis and angular velocity values on the vertical axis,. When the MPU6050 experiences rotational movement around the Z-axis, the graph will display fluctuations above or below the zero line, based on the direction and magnitude of rotation.

I. ROLL, YAW, PITCH REPRESENTATION

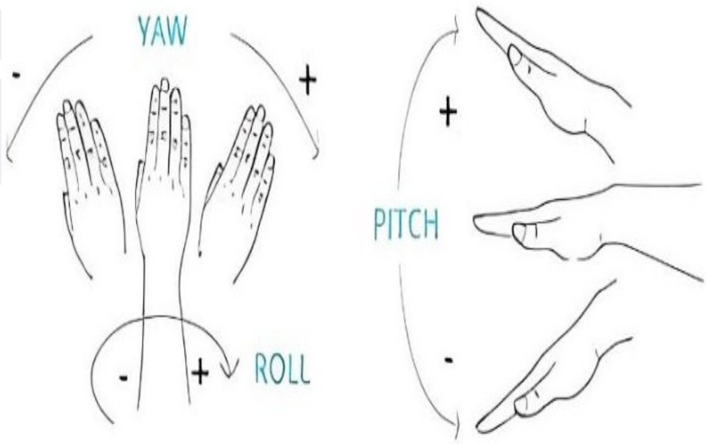

Fig 14: Roll, Yaw, Pitch Representation

J. MOVEMENT OF THE HAND UPWARDS

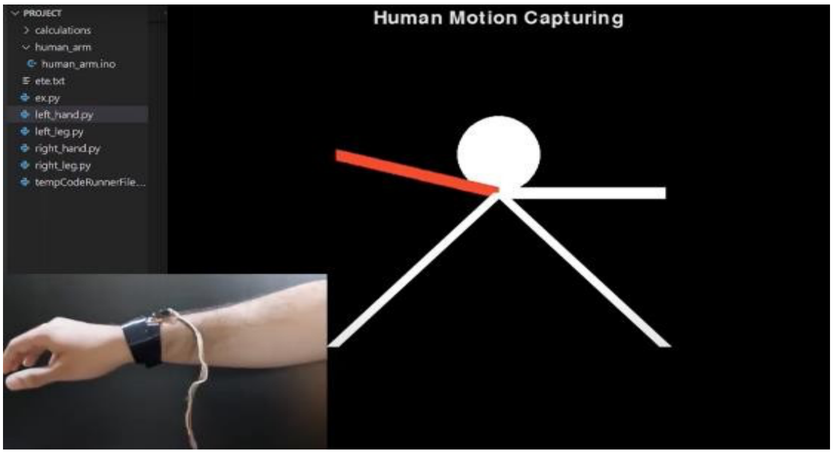

Fig 15: Human Motion Capturing-Hand Upwards

K.MOVEMENT OF THE HAND DOWNWARDS

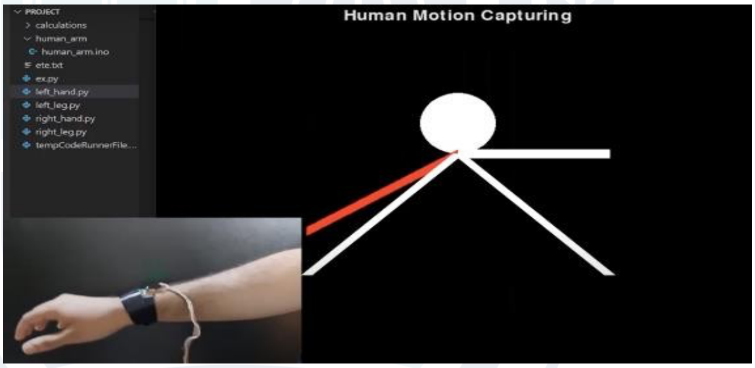

Fig 16: Human Motion Capturing-Hand Downwards

VI . APPLICATIONS

Athletes can wear sensors on their bodies to capture and analyze their movements during training or competitions. The sensors can track parameters such as acceleration, velocity, joint angles, and muscle activity.

By analyzing the data collected from these wearable sensors, coaches and athletes can gain valuable insights into performance metrics and biomechanics [4]. They can identify inefficiencies or flaws in movement patterns, detect potential injury risks, and make data-driven decisions to optimize training regimens.

Furthermore, this technology can be used for real-time feedback, allowing athletes to receive immediate insights on their performance during practice sessions. Coaches can provide corrective instructions based on the data, helping athletes improve their technique and reach their full potential. Overall, wearable sensors for human motion capture analysis offer a powerful tool for enhancing sports performance, reducing the risk of injuries, and optimizing training methods through data-driven analysis and feedback [5].

V. CONCLUSION AND FUTURE WORK

A. CONCLUSION

A portable and low-cost alternative to traditional motion capture systems called real-time human motion sensing using wearable sensors has been successfully implemented. Accurately captured the motion of various body parts by MPU6050 sensor which senses Gyroscope and acceleration parameters along X, Y, Z directions with the help of py-game python library, 2D implementation of real time motion captured is visualized successfully.

The accuracy of the captured data are influenced by sensor placement, calibration, and signal noise. Data processing and interpretation are the advanced algorithms and techniques to extract meaningful information from the raw sensor data. It has offered a non-intrusive and real-time monitoring solution for applications such as sports training, healthcare, entertainment, and robotic. As the technology advances, improving the accuracy and usability of wearable sensors has unlocked their full potential in capturing and analyzing human motion. Used in monitoring patient's movements and tracking progress in healthcare settings [5]

B. FUTURE WORK:

In future some of the modification can make this more useful reliable and give it more applications for real life situations such as,

- 3D implementation of the present model: reconstruction of 3D model which can be achieved through using optimized algorithms which estimates joint angles and other configuration using motion data.
- Usage of GSM networks to transmit data of wearable sensors to main processing unit rather than Arduino serial communication.
- Integration of multiple sensor modalities, such as inertial sensors, electromyography (EMG), and optical sensors, may also be explored to capture a broader range of motion information.

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