Development of Goniometer for Joint Angle Measurement Using Dual MPU6050 and Arduino Uno

Abstract

This project presents the design and implementation of a low-cost, portable goniometer using dual MPU6050 sensors and Arduino Uno boards for measuring relative joint angles. Focusing on the elbow joint, the system computes the angular displacement between two body segments using accelerometer data. One Arduino reads the first sensor and receives angle data from the second Arduino via serial communication. This project is foundational for broader applications in biomechanics, rehabilitation, and wearable motion capture.

1. Introduction

Accurate joint angle measurement is essential in biomechanics, physical therapy, sports science, and rehabilitation engineering. Traditional goniometers are manual and error-prone. This project aims to develop a low-cost, wearable, digital goniometer using two MPU6050 IMU sensors and Arduino Uno boards to measure the relative motion of the elbow joint.

2. Background

IMU sensors

- IMU sensors help determine the 3D position and orientation of an object using angular data. MPU 6050 IMU sensor allows angular orientation estimation using tilt sensing.

MPU-6050 Sensor

- A 6 DOF (Degrees of Freedom) IMU sensor.

Outputs :

  - 3 values from the **Accelerometer** (detects linear acceleration)
  - 3 values from the **Gyroscope** (detects rotational velocity),

- Combines both accelerometer and gyroscope in a single chip.
- Communicates using **I2C protocol**.
- Measures rotational motion in three axes: **Pitch**, **Roll**, and **Yaw**.

Accelerometers

• Measure linear acceleration (rate of change in velocity).

• Provide data on **Pitch** and **Roll** only.

Gyroscopes

• Measure rotational rate/movement.

• Provide full 3-axis rotational data: **Pitch**, **Roll**, and **Yaw**.

Disadvantages of IMUs

It is still not an error-free option for motion sensing needs. Accumulated error, also known as "**drift**," is one of the main disadvantages of IMUs. It is present due to its constant measuring of changes and rounding off its calculated values. When such a process happens for a prolonged period, it can lead to significant errors.

3. Objectives

- To develop a dual-sensor goniometer for elbow joint angle measurement.
- To compute and display the relative angle between two MPU6050 sensors.
- To provide a foundation for full-body joint monitoring.

4. Materials and Methods

4.1 Hardware Used

- Arduino Uno × 2
- MPU6050 Sensor × 2
- Jumper Wires

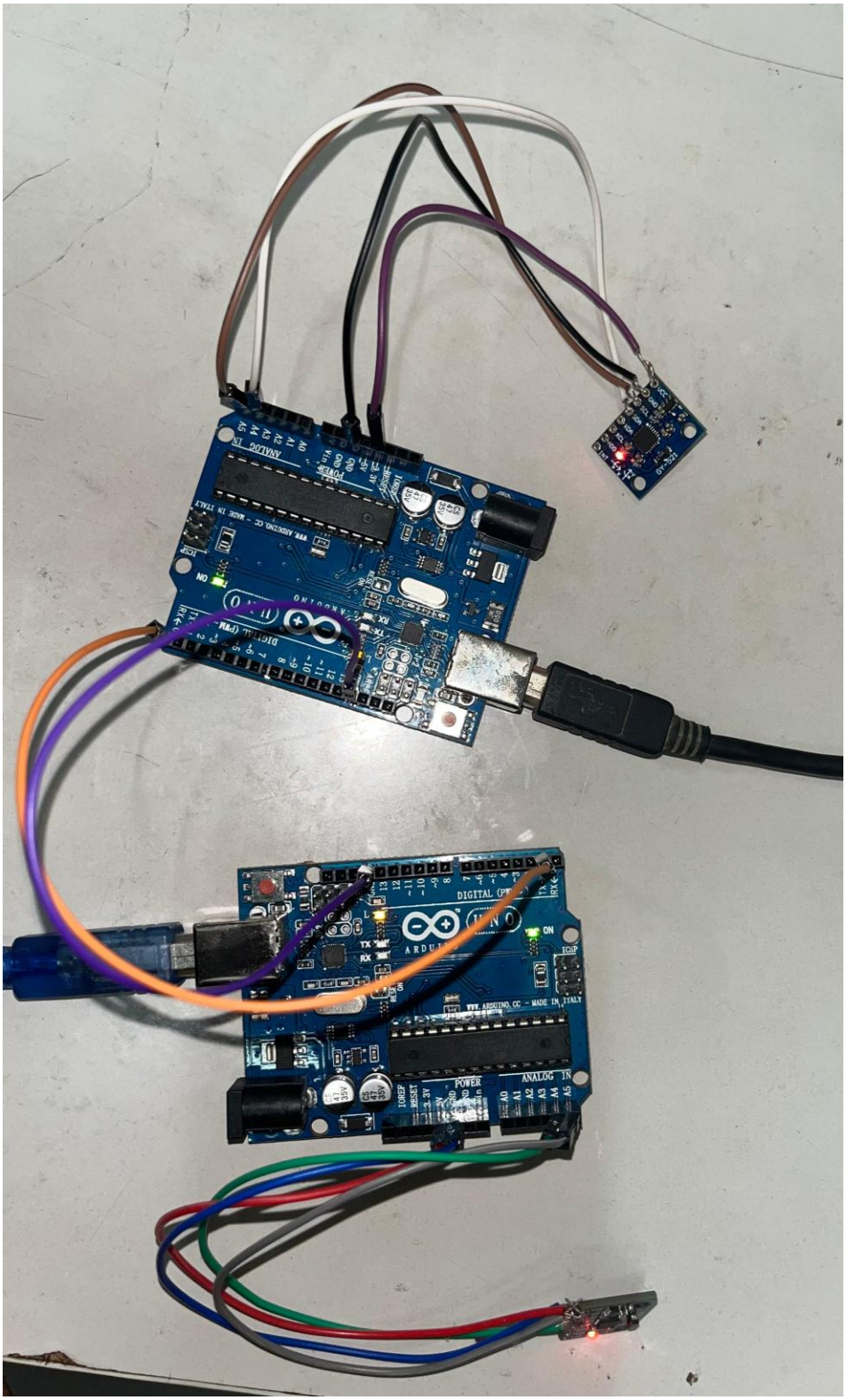
- USB cables × 2

4.2 Circuit Diagram

MPU6050 to Arduino (x2):
MPU6050 VCC → 5V
MPU6050 GND → GND
MPU6050 SDA → A4
MPU6050 SCL → A5

Arduino-to-Arduino Serial (UART):
Arduino 1 RX (Pin 10) ← TX of Arduino 2 (Pin 11)
Common GND

Figure: Block diagram of dual-Arduino MPU6050-based goniometer



4.3 Software and Code Overview

- Code is uploaded separately to each Arduino.
- Arduino 2 (slave)sends angle data via Serial connection.
- Arduino 1(master) reads its sensor and the angle from Arduino 2(slave) to compute relative angle.

4.4 Angle Calculation

Relative Angle = Sensor2 angle – Sensor1 angle

5. Working Principle

When fixed to the upper and lower arm, each MPU6050 gives orientation data. The Arduino calculates tilt angles using. The relative angle between the two sensors represents the joint angle . UART communication allows Arduino 1 to receive angle data from Arduino 2 in real time.

6. Results

Sample Serial Monitor Output:

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====== RELATIVE ELBOW ANGLE SYSTEM ======
Master Angle: 10.43° | Slave Angle: 2.33° | Relative: 8.10°
---- Master Sensor ----
Accel (ax,ay,az): 6084, 4416, 32767
Gyro (gx,gy,gz): 69, -89, -62
---- Slave Sensor ----
Accel (ax,ay,az): 1336, 988, 32767
Gyro (gx,gy,gz): 1276, 1052, 32767
========================================
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Above readings shows the relative angle of elbow flexion/extension ranges.

7. Calibration

Before measuring, the sensors were calibrated while stationary and flat to determine gyro/accel offsets. A simple averaging method was used for calibration.

slave: 1840.00000, -2713.00000, 6364.00000, -24.00000, -16.00000, -64.00000
master : -358.00000, 1653.00000, 7164.00000, 133.00000, -53.00000, -13.00000

8. Applications

- Physiotherapy and rehabilitation (joint monitoring)
- Sports biomechanics
- Human motion capture
- Robotics and exoskeleton control
- Wearable devices

9. Conclusion and Future Work

This project demonstrates a functional, low-cost goniometer for elbow joint angle measurement using two MPU6050 sensors and Arduino Uno boards.

Future work includes:

- Extending to multiple joints (shoulder, knee)
- Adding Metabolic cost

10. References

- Arduino IDE software.
- Chatgpt ,Google
- Libraries - MPU 6050 and I2C dev.