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Motion Sensing Mechanism Using the Lilypad Arduino and IMU Sensors: A Pilot Study

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Abstract

This paper enumerates the mechanism of motion sensing detection using some cool tech—the Arduino LilyPad and the MPU-6050 accelerometer and gyroscope module. Motion sensing is a big deal in making computers more responsive, creating incredible virtual worlds, and crafting wearable gadgets. The MPU-6050 is a star in this—it's small, power-efficient, and crazy accurate, making it a go-to sensor for anything to do with motion. A wearable shirt with a motion sensing sensor with a variation of the real-time processors such as Arduino LilyPad and MPU-6050 was designed and assessed for its motion detection efficacy using inertial measurement sensors such as an accelerometer and gyroscope. The pilot study reveals the importance of selecting processors for wearable electronics system development. The preliminary results were quite promising, and the system needs to be validated with more geriatric groups before commercialization.

Keywords: Motion sensors, Arduino Lilypad, MPU6050.

1 | Introduction

Motion sensing technology is crucial in various domains, revolutionizing human-computer interaction, virtual reality, gaming, and wearable technology. Motion sensing systems enable intuitive control, immersive experience, and novel applications by capturing and interpreting human motion. These systems utilize sensor modules such as accelerometers and gyroscopes to measure and analyze real-time movement. IMU sensors are widely used to measure and assess fall detection, and several attempts have been made in the recent past by using wearables. To monitor the movement of the elderly group, Lin et al. [1] suggested the usage of an IMU sensor in eyeglasses, and the performance of the movement was assessed using five participants by

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considering the various movements, and appropriate labeling was done to understand the different scenarios. The study showed a precision of 95.4%, which shows the method's suitability for geriatric motion detection. Sophini Subramanian et al. [2] have thoroughly reviewed the effect of wearable sensor systems on fall risk assessment. The study revealed the various technologies, strategies adopted, and limitations. A simplified strategy was proposed in [3] to understand and detect the fall very efficiently. The nine-axis IMUs with the machine learning approach showed a potential source for detecting falls. An IoT-driven approach was suggested by Chavan et al. [4] to monitor the fall detection. Saod et al. [5] have shown the potential use of wearable sensors for fall detection. Application of a deep learning-based model was deployed to assess the various nature of falls [6]. Brew et al. [7] have conducted a specific study to evaluate the effectiveness of the smartwatch in detecting falls. A feature selection model was proposed in [8] to assess the effectiveness of the fall detection algorithm.

The selection of a real-time processor plays a vital role in assessing the IMU sensors' efficiency. This paper focuses on motion sensing using the Arduino Lilypad microcontroller and the MPU-6050 accelerometer and gyroscope module. The Arduino Lilypad, specifically designed for wearable applications, provides an accessible and versatile platform for integrating sensors into garments and textiles. The MPU-6050, a compact and high-accuracy sensor module, offers combined accelerometer and gyroscope capabilities in a single package, making it ideal for motion-sensing applications. The importance of motion sensing using Arduino Lilypad and MPU-6050 lies in their potential to enable innovative and practical solutions in various fields [9–13]. Wearable technology, for instance, can benefit from accurate motion sensing for gesture recognition, allowing users to interact with devices through intuitive hand movements. Motion sensing can create immersive gaming experiences by translating real-world actions into in-game controls. Additionally, in healthcare and rehabilitation, motion sensing can aid in monitoring and analyzing human motion, facilitating physical therapy and movement assessment. By leveraging the capabilities of Arduino LilyPad and MPU-6050, this paper aims to contribute to advancing motion sensing technology. The proposed system provides an accessible and cost-effective solution for motion-based applications, fostering creativity and encouraging further exploration in the field. The insights and findings presented in this paper can be a valuable resource for researchers, developers, and enthusiasts interested in motion sensing using Arduino Lilypad and MPU-6050.

2 | Background and Related work

2.1 | Overview of Arduino Lilypad and its Features

The Arduino Lilypad is a microcontroller board designed for wearables and e-textile projects. It is based on the Arduino platform and shares its programming language and development environment. The Lilypad board stands out due to its flexible and compact form, allowing it to be easily integrated into garments and textiles. It offers a range of features, including multiple digital and analog input/output pins, support for various communication protocols, and low power consumption capabilities [11–13]. These features make the Lilypad an ideal choice for motion-sensing applications in wearable devices.

2.1.1 | Introduction to MPU-6050 sensor module and its capabilities

The MPU-6050 is a popular sensor module that combines a three-axis accelerometer and a three-axis gyroscope in a single package. It provides accurate measurement of motion and orientation changes in real time. The accelerometer measures linear acceleration, allowing movement detection in different directions, while the gyroscope measures angular velocity, enabling tracking of rotational motion. The MPU-6050 also includes an embedded temperature sensor and supports I2C communication for easy integration with microcontrollers like the Arduino Lilypad. With its compact size, low power consumption, and high accuracy, the MPU-6050 is widely used in motion sensing applications. Lilypad Arduino is generally used for wearable LED displays, interactive costumes, and health and fitness monitoring applications.

2.1.2 | Review of previous studies and projects related to motion sensing with arduino and MPU–6050

Several studies and projects have explored the capabilities and applications of motion sensing using Arduino and the MPU-6050 module. Research efforts have focused on various areas, including gesture recognition, human motion analysis, interactive gaming, and wearable technology. These studies have proposed different algorithms and techniques for motion data processing, motion tracking, and gesture detection. Some projects have developed motion-based interfaces and interactive systems using Arduino and the MPU-6050. Reviewing these previous works provides valuable insights into the state-of-the-art approaches, challenges, and potential motion sensing applications with the Arduino Lilypad and MPU-6050. By presenting an overview of the Arduino Lilypad and the MPU-6050 module, along with a review of related studies and projects, this paper establishes the foundation for the subsequent sections, enabling a better understanding of the proposed motion sensing system and its significance in the field.

3 | Methodology

3.1 | Lilypad

The Lilypad Arduino is a microcontroller board for wearable technology and e-textile projects. It offers a compact and flexible form factor, making it ideal for integration into garments and textiles. The Lilypad is based on the Arduino platform and inherits its programming language and development environment, allowing for easy and familiar programming. The board features multiple digital and analog input/output pins, which can interface with various sensors, actuators, and components. It also supports different communication protocols, such as I2C and SPI, enabling seamless integration with other devices. The Lilypad Arduino is known for its low power consumption, making it suitable for battery-operated wearable applications. With its unique design and technical capabilities, the Lilypad Arduino empowers designers and developers to create interactive and innovative wearable projects.

3.2 | MPU 6050

This little wonder combines a three-axis accelerometer with a three-axis gyroscope, all wrapped in a neat package. It's like having a motion superhero! People love using this module for motion-related stuff because it's small, doesn't munch up a lot of power, and is super accurate. The MPU-6050 is your go-to for tasks like figuring out gestures, keeping tabs on motion, and getting a feel for how things are tilted or turned. It chats with microcontrollers using the I2C protocol, making it a team player with many different platforms. Oh, and it even comes with its temperature sensor, so it's not just about motion widely used for motion sensing applications due to its

3.3 | Circuit Diagram

The circuit connection for motion sensing using Arduino Lilypad and MPU-6050 involves connecting the necessary pins between the Lilypad and MPU-6050 module [14]. Two jumper wires establish the connection between the SDA (data line) and SCL (clock line) pins of both the Lilypad and MPU-6050. The SDA pin of the MPU-6050 is connected to the SDA pin of the Lilypad, while the SCL pin of the MPU-6050 is connected to the SCL pin of the Lilypad. These connections facilitate communication between the Lilypad and MPU-6050, allowing the Lilypad to receive motion data from the MPU-6050 sensor. (shown in *Fig. 1*) The USB cable is then connected to the Lilypad to power and program the microcontroller. With the circuit connection established, the motion sensing system is ready for further calibration, data acquisition, and real-time motion analysis.

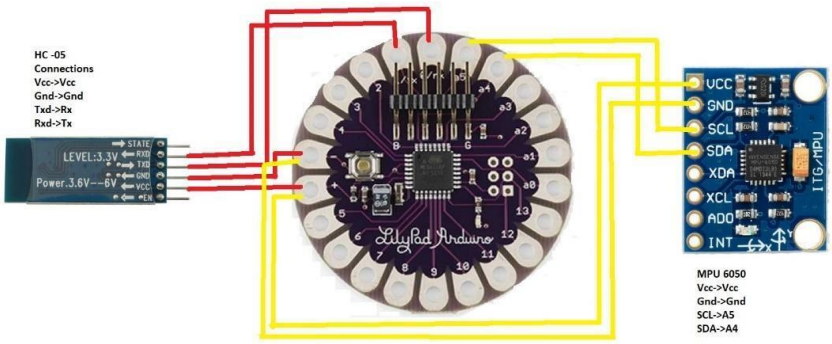


Fig. 1. Lilypad integrated with Bluetooth and MPU 6050.

3.4 | Processsing

The raw accelerometer and gyroscope readings acquired from the MPU-6050 must be processed to extract motion information from sensor data. Processing techniques include data filtering to remove noise and unwanted artifacts, integration of acceleration data to obtain velocity and position, and integration of angular velocity data to derive orientation. Additionally, sensor fusion techniques such as complementary filtering or Kalman filtering can be employed to combine the data from multiple sensors for more accurate motion estimation. (shown in *Fig. 1*)

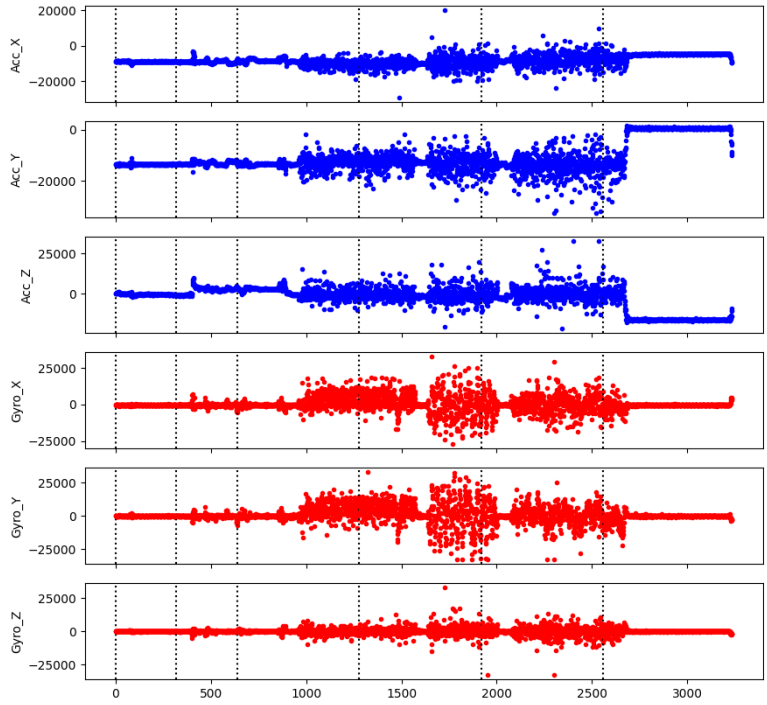


Fig. 2. The plot of accelerometer and gyroscope data obtained using circuit setup.

3.5 | Data Collection Methodology

As the proposed study involves data collection from human participants, all procedures have been followed according to the 1964 Helsinki Declaration. An informed consent form was obtained from all the volunteers who participated in this study. The MS ramaiah medical college and hospital ethical board provided the necessary clearance for the proposed research.

3.5.1 | Data transmission on IDE window

In the context of the motion sensing system using Arduino Lilypad and MPU-6050, the IDE (integrated development environment) window serves as a crucial interface for data transmission. Once the Lilypad processes and analyzes the motion data, it can be transmitted to the IDE window for visualization, logging, or further processing. The IDE window provides a real-time display of the sensor readings, allowing developers to monitor and verify the accuracy of the obtained data. This direct transmission to the IDE window facilitates immediate feedback and debugging during the development process, enabling developers to fine-tune their motion analysis algorithms and validate the system's performance.

Data transmission using Wi-Fi module

We brought in a Wi-Fi module, like the ESP8266 or ESP32, and paired it up with the Lilypad. Now, our Lilypad can connect wirelessly to local networks or the big internet. It allows sending your motion data to far-off devices or cloud services for extra processing or storage. Picture the Wi-Fi module as the friendly bridge connecting our motion-sensing system to the grand network world, ensuring the Lilypad chats effortlessly with other devices or platforms.

3.5.2 | Data transmission using HC-05 bluetooth module

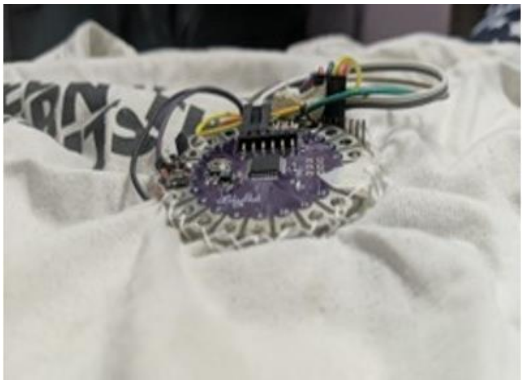
Adding to the cool features, the HC-05 Bluetooth module lets our motion-sensing system share data wirelessly. Our system can connect to Bluetooth-friendly gadgets like smartphones, tablets, or computers by teaming up with the Lilypad. Imagine it — your motion data effortlessly zips over to these devices, giving you real-time visuals or syncing up with your favorite mobile apps. The HC-05 module becomes the trusty sidekick, ensuring smooth and efficient communication with other devices.

3.5.3 | Prototype development

To demonstrate the practical application of the Lilypad Arduino and MPU-6050 sensor, we developed a wearable prototype that integrates these components into a shirt for motion sensing and gesture recognition. The goal was to create a system that could be autonomously powered by a battery, making it genuinely wearable and untethered from external power sources. Materials: To assemble our prototype, we gathered a handful of everyday items: the Lilypad Arduino board, an MPU-6050 sensor module, conductive thread, and a shirt or garment made from e-textile fabric (you know, fabric with conductive goodness). We also brought a LiPo battery and a nifty holder that plays nicely with the Lilypad Arduino. For the hands-on part, we got out our trusty needle and scissors. And if we wanted to jazz things up a bit, we considered adding extra LEDs or actuators for some visual or haptic flair.

I. Sewing Lilypad Arduino onto the Shirt: to ensure seamless integration of the Lilypad Arduino into the shirt, we carefully sewed it onto the fabric using conductive thread. The Lilypad Arduino's small form factor and flat shape make it easy to attach without causing discomfort to the wearer. Care was taken to fasten the board securely to prevent accidental detachment during movement.

II. Connecting the Circuit: using a conductive thread, we connected the various components of the circuit. We attached the MPU-6050 sensor module to the shirt, placing it in an orientation that best captures motion and



gestures when the wearer moves. We then carefully sewed the connections between the Lilypad Arduino and the MPU-6050, ensuring proper communication via the I2C protocol. Additionally, we included optional components, such as LEDs or actuators, to provide visual or haptic feedback to the wearer based on the sensor readings. These components were connected to the Lilypad Arduino using a conductive thread, forming a complete and functional circuit. (shown in *Fig. 3* and *Fig. 4*)

Fig. 3. Lilypad circuit integrated into a wearable shirt.

Fig. 4. Prototype of the wearable shirt.

Battery Integration: We added a nifty LiPo battery to the mix for true independence. We picked a battery that could keep the Lilypad Arduino and the MPU-6050 going for a long time, depending on how it's used. We used a battery holder that fits snugly with the Lilypad Arduino to keep things tidy. After securely placing the battery, we hooked it up to the Lilypad Arduino, ensuring the power supply stayed steady and could handle all the components' needs without a hitch.

Programming: we got into the programming part and worked on the Lilypad Arduino using the Arduino development environment. Our task was to write code that reads data from the MPU-6050 sensor, implements motion sensing, and recognizes gestures. The code also manages connected LEDs or actuators based on the sensor data. We optimized the programming for power efficiency, ensuring we get the most out of the limited battery capacity for more extended usage before needing a recharge.

Testing and Refinement: Once the prototype was fully assembled and programmed, we conducted thorough testing. We evaluated the accuracy of the motion sensing and gesture recognition capabilities and checked the system's response to various movements. Based on the test results, we refined the code and circuit to improve performance and ensure reliable operation. This iterative process helped us achieve a functional and user-friendly wearable prototype. The final result was a shirt with an integrated Lilypad Arduino and MPU-6050 sensor, autonomously powered by a LiPo battery. The prototype demonstrated the potential of wearable technology for motion-based applications, showcasing how such a system could be practically utilized for various interactive and innovative wearable projects.

4 | Discussion

4.1 | Analysis of Obtained Results and System Performance

The results obtained from the motion sensing system using Arduino Lilypad and MPU-6050 provide valuable insights into the system's performance and capabilities. The accuracy and reliability of the motion data extracted from the sensors can be evaluated by comparing the recorded motion with ground truth or reference data. Analysis of the obtained results allows for the assessment of the effectiveness of the system in motion tracking, gesture recognition, or other specific applications. Additionally, performance metrics such as latency,

response time, and power consumption can be measured to gauge the overall efficiency and usability of the system.

4.2 | Limitations and Challenges of the Proposed System

While developing a motion sensing system using Arduino Lilypad and MPU-6050, it's essential to acknowledge potential limitations and challenges. Some of these may involve noise in sensor readings, gradual sensor drift over time, and constraints related to the range and resolution of motion detection. Additionally, the system may be susceptible to external factors such as vibrations or electromagnetic interference, which can impact its overall performance. While working with the Lilypad for our motion sensing system, it's essential to recognize that the Lilypad has some computational limitations. These limitations might affect the motion analysis's complexity and real-time processing capabilities. Dealing with these challenges is critical to enhancing the system's accuracy, resilience, and overall performance.

5 | Conclusion

This paper deeply delved into motion sensing using Arduino Lilypad and MPU-6050. We walked through the hardware setup, explaining how Lilypad and MPU-6050 connect laying the groundwork for crafting a motion sensing system. By tapping into what Arduino Lilypad and MPU-6050 offer, creators and researchers can keep uncovering the possibilities of motion sensing to craft engaging and immersive experiences.

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Author Contribution

The authors equally contributed to the present research at all stages, from the problem formulation to the final findings and solution.

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Conflicts of Interest

The authors have no conflicts of interest to declare relevant to this article's content.

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