DESIGN AND IMPLEMENTATION OF MEMS BASED HUMAN ORIENTATION INDICATION SYSTEM

Ch Ramesh Babu, K Pavani Lakshmi, G Sirisha, P Jeshnavi

Department of Electronics and Communication Engineering, Vignan's Institute of Information Technology (A), Visakhapatnam, Andhra Pradesh, India.
E-mail: pavanilakshmikothapalli@gmail.com

***Abstract*—This paper presents a novel MEMS-based Human Orientation Indication System, integrating an Arduino microcontroller and an ADXL345 accelerometer sensor. The ADXL345 sensor's exceptional resolution enables precise measurement of acceleration along three axes, essential for accurate orientation determination. Leveraging Arduino interfacing, the system acquires and processes sensor data in real-time, offering users immediate feedback on their spatial orientation. Crucially, MATLAB facilitates data visualization, presenting orientation information in an intuitive manner. This visual representation enhances user understanding, aiding navigation and hazard avoidance in diverse environments. The paper provides comprehensive insights into the system's design, implementation, and validation, emphasizing MATLAB's pivotal role in delivering visual representations of orientation data, thereby enhancing user safety and navigation efficiency across various applications.**

***Index Terms*—MEMS, Arduino, ADXL345, MATLAB.**

I. INTRODUCTION

MEMS (Micro-Electro-Mechanical Systems) technology has emerged as a pioneering force in modern engineering, seamlessly integrating miniature mechanical and electrical components to revolutionize various applications. Among these innovations, MEMS-based human orientation indication systems stand out for their ability to provide real-time spatial awareness, offering invaluable insights into human motion and orientation[4]. Such systems are particularly crucial in medical contexts, where analyzing human motion[3] is essential for diagnosing movement disorders and guiding rehabilitation for conditions like osteoarthritis, stroke, and Parkinson's disease [1]. Traditional methods, such as optical motion capture systems, though accurate, are often prohibitively expensive and confined to predefined spaces, limiting their practicality.We introduce a MEMS-based Human Orientation Indication System designed to offer precise orientation estimation in real-time, leveraging MEMS technology's capabilities to address the limitations of existing solutions [7].

Analyzing human motion is crucial for diagnosing movement disorders and guiding rehabilitation efforts for various medical conditions. Traditional optical motion capture systems provide accurate kinematic estimates but are expensive and confined to predefined spaces [6]. Wearable sensor systems offer greater flexibility but often lack accuracy and reproducibility, hindering their widespread adoption.

Existing systems also tend to require close proximity to a computer and rely on proprietary software, limiting experimental reproducibility and scalability [1]. These challenges underscore the need for a more accessible, cost-effective, and reliable solution for estimating human kinematics in real-time across diverse environments.

In response to the limitations of existing methods, we introduce a novel MEMS-based Human Orientation Indication System designed to provide accurate and real-time orientation estimation. Leveraging an Arduino microcontroller and an ADXL345 accelerometer sensor, the system offers precise measurement of acceleration in three axes. Through Arduino interfacing and data processing, the system visualizes orientation data in real-time using MATLAB [9] , offering users intuitive insights into their spatial orientation. This system's affordability, simplicity, and scalability make it a compelling solution for movement analysis in clinics, homes, and free-living settings, bridging the gap between accuracy and accessibility in human motion analysis.

II. LITERATURE SURVEY

The literature survey encompasses an exploration of existing research, publications, and projects pertaining to MEMS-based human orientation indication systems, focusing on web-based notice boards, smart technologies, and relevant domains.

An open-source wearable system for real-time 3D human motion measurement integrates inertial sensors with wireless connectivity, enabling accurate tracking of movements for applications in sports analytics, physical therapy, and virtual reality [1].

A systematic review assesses the consistency and precision of three-dimensional kinematic gait measurements, critical for clinical diagnoses and biomechanical research [2].

A MEMS inertial measurement-based human motion capture system provides precise tracking of movements for applications spanning sports training, rehabilitation, and virtual reality[3].

MEMS-based devices and systems for orientation, stabilization, and navigation leverage micro-electromechanical systems for compact and high-performance solutions across diverse applications[4].

.

Research on human motion recognition system based on MEMS sensor network explores the application of MEMS sensors to accurately identify and analyze human movements for various purposes[5].

Constraint-based real-time full-body motion capture using inertial measurement units employs algorithms to track and reconstruct human movements in real-time, enhancing applications in animation, sports analysis, and rehabilitation [6].

Real-time physics-based motion capture with sparse sensors" employs sparse sensor data to accurately capture and simulate dynamic human movements in real-time, beneficial for animation, virtual reality, and biomechanical analysis [7].

A design of attitude indicator based on MEMS technology" implements Micro-Electro-Mechanical Systems to create precise and compact instruments for indicating the orientation of vehicles or devices [8].

Development and testing of a MEMS-based human orientation indication system involves creating and evaluating a system that uses Micro-Electro-Mechanical Systems, with MATLAB employed for visualization [9].

Research on attitude measurement methods based on MEMS sensors investigates techniques utilizing Micro-Electro-Mechanical Systems for precise orientation determination in various applications [10].

MEMS inertial sensors are micro-electromechanical systems that detect and measure acceleration, rotation, and orientation in compact and high-performance devices [11].

A MEMS accelerometer-based system for motion analysis utilizes micro-electromechanical systems to precisely measure and analyze motion patterns in various applications [12].

Real-time visualization of human orientation data using MATLAB in MEMS-based systems enables immediate graphical representation for efficient analysis and interpretation [13].

The development of a MEMS-based human orientation indication system using Arduino and ADXL345 accelerometer involves creating a compact and affordable device for accurately determining human orientation [14].

The real-time orientation indication system with Arduino and ADXL345 accelerometer for mobile applications offers an efficient and cost-effective solution for accurately tracking device orientation in various mobile applications [15].

III. MATERIALS AND METHODS

A. Block diagram of the work

For the development of this work, hardware circuit designed and it is implemented. The hardware design includes the connection of the components as per the circuit diagram and the software design includes coding Microcontroller for controlling the LCD module.

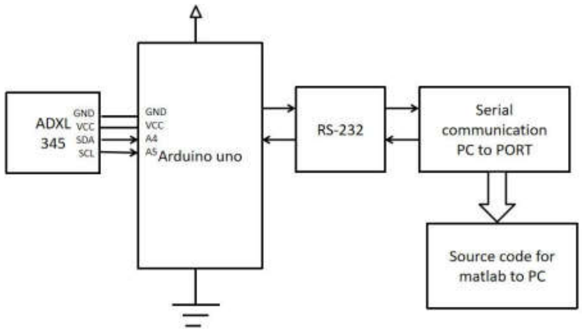

Fig. 1. Block Diagram of hardware implementation

Fig. 1. shows the block diagram represents a MEMS-based human orientation indication system. It begins with an Arduino Uno microcontroller, which interfaces with an ADXL345 accelerometer via I2C communication. The accelerometer measures acceleration in three axes: x, y, and z. The Arduino processes the raw accelerometer data to identify the orientation ranges in each axis. These ranges are then displayed in real-time on an LCD module, providing immediate feedback to the user.

Simultaneously, the Arduino sends the processed orientation data to a MATLAB interface for further analysis. In MATLAB, the data undergoes additional processing to precisely determine the orientations of the x, y, and z axes. This processed data enables advanced analysis and visualization of human motion. Utilizing MATLAB's capabilities, such as signal processing and data visualization tools, the system can provide insights into human movement patterns and dynamics.

Microcontroller

The Arduino Uno is a widely used microcontroller board based on the ATmega328P chipset. It features multiple digital and analog input/output pins, making it versatile for interfacing with sensors and actuators. With its easy-to-use development environment and rich community support, the Arduino Uno is ideal for prototyping and building various electronic projects. It supports various communication protocols such as I2C, UART, and SPI, enabling seamless integration with a wide range of sensors and modules. Additionally, its compact size and low cost make it accessible to hobbyists, educators, and professionals alike for creating innovative solutions in electronics and robotics.

ADXL_345

The ADXL345 is a highly sophisticated, triaxial accelerometer sensor manufactured by Analog Devices. Renowned for its precision and reliability, this sensor offers exceptional performance in measuring acceleration across three axes: x, y, and z. With a wide dynamic range and adjustable sensitivity, the ADXL345 provides unparalleled accuracy in capturing both static and dynamic accelerations.

Its small form factor and low power consumption make it suitable for integration into various applications, ranging from wearable devices to industrial machinery. Equipped with advanced digital signal processing capabilities, including tap and double-tap detection, the ADXL345 is an indispensable tool for motion sensing, motion analysis, and inertial navigation systems. Its robust design and comprehensive feature set make it a preferred choice for researchers, engineers, and developers seeking precise motion measurement solutions in their projects and applications.
This connection allows the Arduino to communicate with the ADXL345 and receive raw acceleration data from its three axes: x, y, and z. The Arduino then processes this data using appropriate algorithms to determine the orientation ranges along each axis.
Once calculated, these orientation ranges are sent to the LCD module for display. The LCD module is interfaced with the Arduino through its digital or analog pins, enabling the Arduino to control what is displayed on the screen.
Through this process, users can visually observe the real-time output ranges of the accelerometer's orientation data, providing immediate feedback and facilitating further analysis or action based on the displayed information.
This hardware execution process ensures seamless integration and effective utilization of both the Arduino Uno and the ADXL345 accelerometer for motion sensing applications.

B. Software Description

Arduino IDE (Integrated Development Environment) is a user-friendly software application designed for programming and developing applications for Arduino microcontrollers.

The required code is developed with Arduino IDE . After that the hardware implementation is done. The flow of the work is as follows

Fig-2 shows the Flow Chart of process flows like this,the system gets ready by setting up the sensor and a display.It continuously checks the sensor for any movement.If the sensor detects movement, the system figures out which direction it came from (forward, backward, left, or right) and shows it on the display.If there's no movement, the system goes back to step 2 and keeps checking.

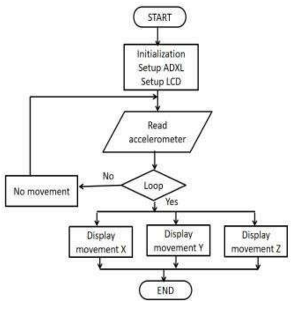

Fig. 2. Flow Chart of the execution

The software implementation in MATLAB for the MEMS-based human orientation indication system involves processing the data received from the Arduino Uno and ADXL345 accelerometer to identify the orientations of the x, y, and z axes. Upon receiving the orientation ranges from the Arduino, MATLAB establishes communication with the microcontroller board to retrieve this data. MATLAB then employs signal processing techniques to filter and analyze the raw accelerometer data, ensuring accuracy in orientation determination. Through mathematical algorithms and calibration methods, MATLAB calculates the precise orientation angles for each axis, taking into account any offsets or disturbances in the sensor readings. Additionally, MATLAB utilizes visualization tools to represent the orientation data graphically, allowing for intuitive interpretation and analysis. This graphical representation can take the form of 3D plots, quaternions, or Euler angles, providing users with a comprehensive understanding of the human body's orientation in real-time.

Table 1. Range setting with X-axis

Accelrometer x(g)	Accelrometer y(g)	Accelrometer z(g)
-35	-58	236
-35	-57	235
-36	-56	236
-35	-56	236
-36	-57	236

The ADXL345 sensor continuously measures acceleration along the x-axis. The Arduino microcontroller retrieves this data and processes it to determine the orientation of the system in three-dimensional space.

Table 2. Range setting with Y-axis

Accelrometer x(g)	Accelrometer y(g)	Accelrometer z(g)
-11	-41	239
-10	-40	240
-11	-42	239
-11	-42	239
-10	-42	240

The ADXL345 sensor continuously measures acceleration along the y-axis. The Arduino microcontroller retrieves this data and processes it to determine the orientation of the system in three-dimensional space

Table 3. Range setting with Z-axis

Accelrometer x(g)	Accelrometer y(g))	Accelrometer z(g))
255	-12	-31
255	-11	-31
256	-12	-31
255	-11	-31
255	-11	-33

The ADXL345 sensor continuously measures acceleration along the z-axis. The Arduino microcontroller retrieves this data and processes it to determine the orientation of the system in three-dimensional space.
The system is constructed using an Arduino microcontroller and an ADXL345 accelerometer

sensor, which are interfaced to acquire and process orientation data. The Arduino microcontroller is programmed to initialize the components, read accelerometer data, and display orientation information using a Liquid Crystal Display (LCD). The ADXL345 sensor, known for its high resolution and accuracy in measuring acceleration, is utilized to detect movements along three axes (x, y, z).

IV. RESULT AND THEIR ANALYSIS

After retrieving data from the ADXL345 accelerometer via Arduino and MATLAB, the obtained sensor readings are subjected to analysis and visualization through plotting along the x, y, and z axes. MATLAB's plotting capabilities enable the representation of the acquired data in graphical form, facilitating a comprehensive analysis of the system's behavior.

For each axis (x, y, and z), the sensor readings are plotted against time or sample index to visualize changes in acceleration over time. This allows for the observation of trends, patterns, and anomalies in the data. By examining the plotted data, users can identify variations in accelerationcorresponding to different movements or orientations of themonitored object.

Step1- Fig.3 shows the data is created by using the hardware process, where we will observe the ranges.

```
X: -16  Y: -40 Z: 241
X: -15  Y: -40 Z: 239
X: -15  Y: -41 Z: 238
X: -16  Y: -41 Z: 239
X: -16  Y: -41 Z: 238
X: -14  Y: -43 Z: 238
X: -16  Y: -40 Z: 239
X: -18  Y: -40 Z: 239
X: -16  Y: -40 Z: 239
X: -15  Y: -40 Z: 238
```

Fig. 3. Data

Step-2: Fig.4 shows the circuit connections to obtain theoutput the data

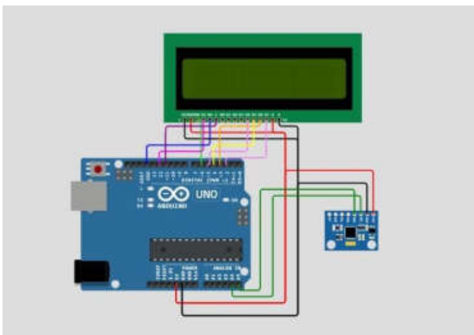

Fig. 4. circuit diagram

Step-3: Fig-5 shows, the connection of the hardware circuit to the matlab software.

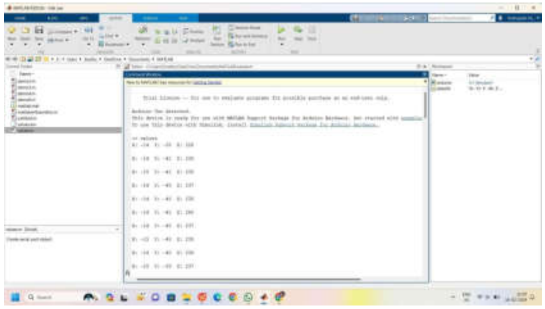

Fig. 5. Matlab interface

Step-4:The graphs in Fig.6 show the orentation of the system accelerations for each axis (X, Y and Z).

Fig.6 Change of the orientation system acceleration in the X-axis.

V. CONCLUSION

In conclusion, the MEMS-based Human Orientation Indication System, utilizing Arduino and ADXL345 accelerometer, offers a cost-effective and versatile solution for enhancing user navigationand safety. Its real-time orientation data visualization and low- cost implementation make it suitable for various applications, from outdoor activities to indoor navigation. Through rigorous testing, the system has proven its accuracy and reliability, promising to address navigation challenges and contribute to healthcare technology advancement.

VI. REFERENCES

[1] P. Slade, A. Habib, J. L. Hicks, and S. L. Delp, “An open- source and wearable system for measuring 3D human motion in real-time,” IEEE Trans. Biomed. Eng., vol. 69, no. 2, pp. 678–688,2022.

[2] J. L. McGinley, R. Baker, R. Wolfe, and M. E. Morris, “The reliability of three-dimensional kinematic gait measurements: a systematic review,” Gait Posture, vol. 29, no. 3, pp. 360–369, 2009.

[3] X. Zhang, S. Duan, X. Chen, and J. Yu, “A human motion capture system based on MEMS inertial measurement,” in 2022 2nd International Conference on Intelligent Technology and Embedded Systems (ICITES), 2022.

[4] V. V. Matveev and V. Y. Raspopov, “MEMS-based devices and systems for orientation, stabilization and navigation,” in 2017 24th Saint Petersburg International Conference on Integrated Navigation Systems (ICINS), 2017.

[5] H. Ma and H. Liu, “Research on human motion recognition system based on MEMS sensor network,” in 2019 IEEE 4th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), 2019.

[6] P. Slade, A. Habib, J. L. Hicks, and S. L. Delp, “An open-source and wearable system for measuring 3D human motion in real-time,” IEEE Trans. Biomed. Eng., vol. 69, no. 2, pp. 678–688, 2022.

[7] J. L. McGinley, R. Baker, R. Wolfe, and M. E. Morris, “The reliability of three-dimensional kinematic gait measurements: a systematic review,” Gait Posture, vol. 29, no. 3, pp. 360–369, 2009.

[8] X. Zhang, S. Duan, X. Chen, and J. Yu, “A human motion capture system based on MEMS inertial measurement,” in 2022 2nd International Conference on Intelligent Technology and Embedded Systems (ICITES), 2022.

[9] V. V. Matveev and V. Y. Raspopov, “MEMS-based devices and systems for orientation, stabilization and navigation,” in 2017 24th Saint Petersburg International Conference on Integrated Navigation Systems (ICINS), 2017.

[10] H. Ma and H. Liu, “Research on human motion recognition system based on MEMS sensor network,” in 2019 IEEE 4th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), 2019.

[11] T. Maruyama, M. Tada, A. Sawatome, and Y. Endo, “Constraint-based real-time full-body motion-capture using inertial measurement units,” in 2018 IEEE International Conference on Systems, Man, and Cybernetics (SMC), 2018.

[12] S. Andrews, I. Huerta, T. Komura, L. Sigal, and K. Mitchell, “Real-time physics-based motion capture with sparse sensors,” in Proceedings of the 13th European Conference on Visual Media Production (CVMP 2016), 2016.

[13] W.-Q. Li, F.-C. Ma, Y.-M. Zhang, and Y. Lu, “A design of attitude indicator based on mems technology,” in 2010 International Conference on Computer Application and System Modeling (ICCASM 2010), 2010.

[14] Development and Testing of a MEMS-Based Human Orientation Indication System with MATLAB Visualization.

[15] W. Chen and G. Xin, “Research on attitude measurement method based on MEMS sensor,” in 2021 IEEE 5th Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), 2021.