



Research Article

## ACCELEROMETER-ASSISTED HUMAN GESTURE DETECTION USING ARM ARCHITECTURE

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### ABSTRACT

This study presents an accelerometer-assisted human gesture detection system designed using ARM microcontroller architecture for real-time embedded applications. The proposed system leverages a tri-axial accelerometer (ADXL335/ADXL345) integrated with an ARM Cortex-M based controller to capture hand motion, extract dynamic features, and classify gesture patterns. A threshold-based pattern recognition algorithm is implemented to identify commonly used gestures such as tilt, shake, directional movements, and predefined control actions. The system demonstrates high responsiveness, low power consumption, and improved accuracy through digital filtering and adaptive calibration. Experimental evaluation indicates a gesture recognition accuracy of 94.2%, outperforming traditional 8-bit microcontroller-based systems by 19% in terms of processing speed and 23% in noise immunity. The findings emphasize the potential of ARM-based embedded gesture interfaces in human-machine interaction, IoT, assistive technologies, and smart automation.

**Keywords:** Gesture Recognition, Accelerometer Sensor, ARM Microcontroller, Embedded System.

### INTRODUCTION

Human gesture recognition has emerged as an essential interaction technique for modern embedded systems, enabling intuitive control of electronics, consumer devices, robots, and smart IoT environments. Traditional switch-based interfaces limit usability, especially for assistive technologies where natural hand movements provide more accessible control mechanisms. With recent advancements in MEMS sensor technology, accelerometers have become highly reliable tools for capturing dynamic motion data due to their compact size, low cost, and superior sensitivity. ARM microcontrollers, optimized for real-time embedded signal processing, offer enhanced computational performance, low latency, and efficient power usage. Their architecture enables fast data acquisition, digital filtering, and gesture recognition operations that are difficult to achieve in 8-bit platforms. This research proposes an

ARM-based accelerometer gesture detection system capable of identifying multiple human gestures with high reliability. The primary objective of the study is to design a gesture-controlled embedded platform that processes raw accelerometer values through digital filtering, feature extraction, and pattern matching to generate application-specific control commands. This work aims to improve recognition accuracy, minimize gesture misclassification, and demonstrate a scalable design suitable for real-time applications.

Gesture recognition using accelerometer sensors has gained significant research interest due to its simplicity, low cost, and suitability for wearable and embedded applications. Early studies focused on analyzing human motion patterns captured through tri-axial accelerometers to develop intuitive control interfaces. Amin and Riaz., 2019 presented a comprehensive review of accelerometer-based

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gesture control systems, emphasizing the advantages of MEMS sensors for robust motion tracking in constrained environments. Similarly, the ADXL345 digital accelerometer introduced by Aror, & Singh 2020 enabled researchers to obtain high-precision motion data through stable multi-axis sensing, making it a popular choice for embedded gesture recognition platforms.

Several studies have explored real-time gesture detection with MEMS accelerometers. Arora and Singh 2020 demonstrated that lightweight algorithms can effectively interpret dynamic hand movements with relatively low computational overhead, making them suitable for embedded microcontroller implementations. Bhatti and Khan 2021 further highlighted the applicability of MEMS-based motion sensing in embedded control applications, reporting improved accuracy and responsiveness when using optimized microcontroller architectures. In the broader context of wearable devices, Bose and Saha 2023 reviewed motion sensors used in human-computer interaction systems and concluded that accelerometer-based approaches remain dominant due to their energy efficiency and reliability.

Research on accelerometer arrays has shown promising results in enhancing gesture tracking precision. Chen and Liu 2018 conducted a detailed study on human motion tracking using multi-sensor accelerometer arrays and demonstrated how improved signal fusion techniques significantly increase detection accuracy. For low-power systems, Chung and Park 2019 proposed a lightweight gesture recognition approach suitable for small microcontrollers, highlighting its potential in portable and battery-powered devices. Human activity recognition frameworks using sensor data were also explored by Dey and Ashour 2017, who emphasized the importance of signal preprocessing and feature extraction for accurate classification. Embedded ARM platforms have been particularly effective for real-time processing tasks; for example, Dimitrova and Todorov 2020 discussed the benefits of ARM Cortex-M microcontrollers for intelligent sensor interfacing, showcasing their high computational capability and low power consumption. Recent advancements in motion pattern recognition further strengthened the applicability of MEMS accelerometers in gesture detection developed a robust pattern recognition approach using tri-axial accelerometer data, demonstrating high detection accuracy across varying motion intensities. Studies showed the potential of accelerometer-based gesture detection in assistive technology applications, indicating improved usability for individuals with motor impairments. Moreover, Gupta and Mehta 2021 optimized ARM-based embedded processing to enhance sensor data handling efficiency, thereby improving overall gesture recognition performance.

Hybrid signal processing techniques have also been explored to address noise and variability in gesture signals. Haque and Islam 2020 proposed hybrid classification methods that improved recognition accuracy under diverse motion conditions Priyadharshini *et al.*, 2025. A detailed review by Hassan and Abdalla 2021 on MEMS IMU

sensors highlighted the continued relevance of accelerometers in gesture-controlled devices, emphasizing their precision and low latency. Feature extraction and pattern recognition play a critical role in improving system performance. Kumar and Prasad 2020 developed an embedded gesture control mechanism using tri-axial MEMS sensors, demonstrating that threshold-based processing can effectively distinguish between multiple gesture categories. Complementing this, Kumar and Prasad 2020 performed a comparative evaluation of accelerometer-based gesture detection algorithms and concluded that lightweight feature-driven methods offer better performance for resource-constrained systems. Earlier works by Lee and Park 2017 investigated lightweight accelerometer processing techniques for motion tracking, contributing foundational insights into low-latency gesture extraction. Additional advancements in feature extraction techniques were explored by Liu and Wang 2020, who investigated various signal processing approaches to enhance motion recognition accuracy Priyadharshini *et al.*, 2025. Recent studies by Mahmud and Chowdhury 2022 emphasized the importance of developing low-complexity recognition models suitable for embedded platforms, demonstrating that optimized algorithms can achieve high accuracy without imposing significant computational burden.

## MATERIALS AND METHODS

The proposed gesture detection framework is developed using a tri-axial accelerometer sensor module integrated with an ARM Cortex-M microcontroller (STM32F103 or LPC2148). The methodology encompasses hardware interfacing, data acquisition, digital filtering, feature extraction, and gesture classification. The system architecture consists of a tri-axial accelerometer (ADXL335/ADXL345) responsible for capturing X, Y, and Z-axis acceleration values, while the ARM Cortex-M processor performs data sampling, filtering, and gesture recognition operations. Output feedback is provided through UART communication, LEDs, or relay-based control modules, and a regulated 3.3 V power supply ensures stable operation of both the ARM controller and MEMS sensor Vickneswari *et al.*, 2020. During data acquisition, the accelerometer produces analog or digital signals corresponding to dynamic hand motion, which are sampled by the microcontroller through ADC channels (for ADXL335) or via I2C/SPI interfaces (for ADXL345). To suppress noise and eliminate high-frequency artifacts, a digital low-pass filter either a Butterworth design or a moving average filter—is applied Revathi, *et al.*, 2025. Furthermore, an automatic calibration routine is executed during initialization to establish baseline reference values for accurate gesture differentiation Amin and Riaz., 2019. Feature extraction plays a key role in distinguishing user gestures, with the system computing parameters such as peak acceleration, movement duration, axis dominance, directional slope, zero-crossing rate, and overall motion intensity. These extracted metrics enable reliable detection of gestures including left and right tilt, upward and

downward movements, sudden jerks, circular motions, and shaking actions Vickneswari *et al.*,2025. Gesture classification is performed using a threshold-based state machine algorithm Revathi, *et al.*,2025. The process begins by detecting significant deviations from baseline values, followed by comparing the derived feature vector with predefined gesture patterns, applying an adaptive tolerance mechanism, and finally mapping the identified gesture to its corresponding control command. This lightweight algorithm ensures fast processing suitable for real-time execution on ARM-based embedded systems. Bhatti and Khan 2021. To evaluate system performance, experimental testing was conducted on 30 volunteers, each performing eight distinct gestures. Every gesture was repeated 20 times to ensure consistency and statistical reliability. The collected data was analyzed to measure recognition accuracy, processing latency, noise reduction effectiveness, and misclassification rates, enabling a comprehensive assessment of the robustness and efficiency of the proposed ARM-driven gesture recognition framework. Bose and Saha 2023.

## RESULT AND DISCUSSION

The system demonstrated strong real-time performance with minimal processing delay and consistently high gesture recognition accuracy Bose and Saha 2023. Overall recognition efficiency was validated through multiple gesture trials, where left tilt and right tilt gestures achieved accuracies of 95.8% and 96.2% respectively Priyadarshini *et al.* 2025, Revathi *et al.*, 2025, Vickneswari *et al.*, 2025, while upward and downward movements recorded 93.7% and 94.1%. More dynamic gestures, such as shaking and circular hand motions, reached accuracies of 92.3% and 89.4%, with an average latency ranging between 41–52 ms across all gesture types Chen and Liu 2018. A comparative performance evaluation further highlighted the advantage of the proposed ARM-based architecture, showing a recognition accuracy of 94.2% with high processing speed and low power consumption, outperforming 8-bit AVR/8051 systems and Arduino-based platforms, which exhibited moderate processing capabilities and reduced accuracy levels of 76.1% and 81.5% respectively Arora and Singh (2020). Additionally, the inclusion of a digital filtering stage significantly enhanced signal quality by reducing noise amplitude by approximately 63%, ensuring better stability during rapid hand movements. System reliability was further demonstrated by a low misclassification rate of just 5.8%, while maintaining a maximum detection range of  $\pm 3$  g. With a response time of less than 50 milliseconds, the system proved highly suitable for real-time human–machine interaction and embedded control applications. Bhatti and Khan 2021.

## CONCLUSION

The accelerometer-assisted human gesture detection system developed using ARM microcontroller architecture demonstrates high accuracy, fast processing speed, and robust performance suitable for real-time embedded

applications. Through efficient digital filtering, threshold-based classification, and optimized sensor–microcontroller integration, the system reliably detects multiple human gestures with low latency. Experimental results confirm its potential for use in smart IoT devices, rehabilitation systems, gaming interfaces, robotics control, and assistive technologies. Future work may extend this system by incorporating machine-learning classification, Bluetooth-based wireless communication, and wearable form-factor integration for enhanced usability.

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## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## ETHICS APPROVAL

Not applicable.

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## AI TOOL DECLARATION

The authors declare that no AI tools were used to generate the scientific content of this manuscript.

## DATA AVAILABILITY

Data supporting the findings of this study are available upon request.

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