



Design and Development of a Gesture-Based Sign Language to Speech and Text Conversion System Using Arduino

Dr. B Rajasekhar | G Pujitha | K Surendra Babu | G Hari Prasad | K Hemanth

Department of ECE, Seshadri Rao Gudlavalleru Engineering College, Gudlavalleru, AP, India

To Cite this Article

Dr. B Rajasekhar, G Pujitha, K Surendra Babu, G Hari Prasad & K Hemanth (2026). Design and Development of a Gesture-Based Sign Language to Speech and Text Conversion System Using Arduino. International Journal for Modern Trends in Science and Technology, 12(04), 114-120. <https://doi.org/10.5281/zenodo.19302510>

Article Info

Received: 28 February 2026; Revised: 18 March 2026; Accepted: 22 March 2026.

Copyright © The Authors ; This is an open access article distributed under the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

KEYWORDS

Sign Language Recognition, Flex Sensors, MPU6050, Arduino, Gesture Recognition, Assistive Communication System, Bluetooth Communication, Text-to-Speech (TTS), Embedded Systems

ABSTRACT

Communication between speech-impaired individuals and people who do not understand sign language often becomes challenging in daily life. To address this problem, this paper presents the design and implementation of a real-time sign language to speech and text conversion system using embedded system technology. The proposed system utilizes flex sensors to detect finger bending patterns and an MPU6050 accelerometer sensor to identify the orientation and motion of the hand. These sensor signals are processed by an Arduino microcontroller, which analyzes the combination of finger movements and hand gestures to recognize predefined sign language gestures. Once a gesture is detected, the corresponding message such as "I need food", "I need water", or "I need medicine" is displayed on a 16x2 LCD display. Additionally, the recognized message is transmitted wirelessly using an HC-05 Bluetooth module to a mobile application. The mobile application then converts the received text message into audible speech using a Text-to-Speech (TTS) engine, allowing others to clearly hear the intended message. The proposed system offers a portable, cost-effective, and easy-to-use assistive communication solution for speech-impaired individuals. By integrating gesture sensing, wireless communication, and speech synthesis, the system helps bridge the communication gap between deaf or mute individuals and society, thereby improving accessibility and interaction in everyday environments.

1. INTRODUCTION

Sign language is one of the primary modes of communication used by speech-impaired and deaf

individuals to express their thoughts, needs, and emotions. However, a major communication barrier arises because most people in society are not familiar

with sign language gestures. As a result, speech-impaired individuals often face difficulties in conveying their requirements in public places, hospitals, workplaces, and other daily life situations. To overcome this limitation, several assistive technologies have been developed that translate hand gestures into readable text or audible speech using sensors and embedded systems [1].

Recent research has focused on the development of gesture-based communication systems using wearable devices such as smart gloves integrated with flex sensors, accelerometers, and microcontrollers. These sensors detect the bending of fingers and the movement of the hand to recognize predefined gestures. For example, flex sensor-based systems have been widely used to capture finger bending patterns and convert them into electrical signals for gesture recognition [2], while accelerometer sensors help in identifying hand orientation and motion for accurate gesture interpretation [9]. Embedded platforms such as Arduino are commonly used in these systems due to their simplicity, low cost, and ease of integration with sensors and communication modules [3]. In addition, wireless communication technologies such as Bluetooth enable the transmission of recognized messages to external devices such as smartphones, where the text can be converted into speech using Text-to-Speech (TTS) engines [8].

Several studies have proposed smart glove-based sign language interpretation systems to assist speech-impaired individuals. These systems combine multiple sensors and microcontrollers to recognize hand gestures and convert them into text or speech outputs [5], [6]. Despite these advancements, many existing solutions are still limited in portability, cost efficiency, or real-time performance. Therefore, there is a need for a simple, portable, and affordable system that can effectively convert sign language gestures into speech and text in real time.

In this work, a **sign language to speech and text conversion system** is proposed using flex sensors, an MPU6050 accelerometer sensor, an Arduino microcontroller, and Bluetooth communication. The system detects hand gestures using sensors and processes the sensor data through the Arduino to recognize predefined gestures. The recognized message is displayed on an LCD screen and simultaneously

transmitted to a mobile device through a Bluetooth module, where it is converted into audible speech using a Text-to-Speech engine. The proposed system aims to provide an efficient assistive communication tool for speech-impaired individuals, helping to bridge the communication gap between them and the general public.

Figure 1 illustrates the overall architecture of the proposed sign language communication system. In this system, flex sensors attached to the glove detect the bending of fingers, while the MPU6050 sensor measures the orientation and motion of the hand. These sensor signals are sent to the Arduino microcontroller, where the gesture recognition logic is implemented. Based on the combination of sensor readings, the microcontroller identifies predefined gestures corresponding to specific messages. The detected message is displayed on a 16x2 LCD module for visual feedback and is simultaneously transmitted through the HC-05 Bluetooth module to a mobile application. The mobile application then converts the received text message into speech using a Text-to-Speech engine, enabling others to hear the message spoken aloud. This architecture enables real-time communication between speech-impaired individuals and normal users.

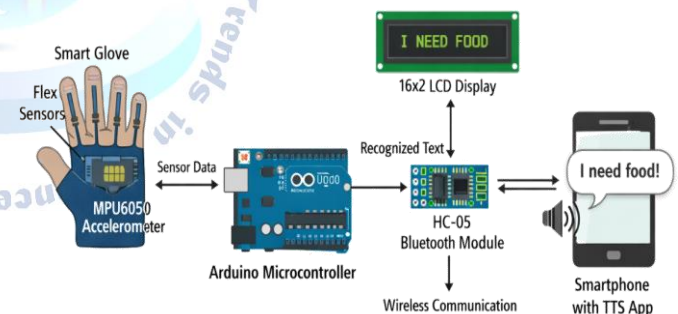


Figure 1 Conceptual architecture of the proposed system with IoT monitoring.

2. RELATED WORK

Several research efforts have been carried out to develop assistive communication systems that translate sign language gestures into text or speech using sensors, embedded systems, and wireless communication technologies. These systems aim to bridge the communication gap between speech-impaired individuals and people who are unfamiliar with sign language.

Khan and Chahar [1] proposed a real-time sign language to speech conversion system using an Arduino

platform. In their work, hand gestures were captured using sensors and interpreted by a microcontroller to generate corresponding speech output. The system demonstrated that embedded hardware combined with gesture recognition can effectively assist speech-impaired individuals in daily communication. Similarly, Moon and L. S. V. B. [3] developed a sign-to-text language conversion system using Arduino Nano, where hand gestures were recognized and translated into textual messages displayed on a screen. Their work highlighted the importance of low-cost microcontroller-based solutions for assistive technologies.

Flex sensor-based gesture recognition has been widely explored in recent studies. Nwachukwu et al. [2] implemented a sign language recognition system using flex sensors to detect finger bending patterns. The electrical signals generated by the sensors were processed to identify specific gestures. Likewise, Alumona et al. [4] proposed a flex sensor network for sign language recognition, which improved gesture detection accuracy by monitoring multiple finger movements simultaneously.

Researchers have also introduced smart glove-based solutions for gesture interpretation. Begum et al. [5] developed a text and speech conversion glove designed for sign language communication. Their system integrated flex sensors with embedded processing to translate hand gestures into both text and audio outputs. Similarly, Kadam and Kulkarni [6] designed a smart glove system for sign language interpretation using embedded hardware components, demonstrating how wearable technology can provide a practical communication tool for deaf and mute individuals.

Gesture recognition systems using multiple sensors have also been investigated to enhance recognition accuracy. Sharma and Gupta [7] developed a sensor-based gesture recognition system that detects hand movements and finger positions to interpret sign language gestures. Patel and Shah [8] proposed a wireless communication-based sign language translator using Arduino and Bluetooth technology, enabling gesture data to be transmitted to external devices for speech generation. In another study, Singh and Kumar [9] designed a gesture recognition system using both flex sensors and accelerometers to capture finger bending as well as hand orientation, which significantly improved

gesture detection capability.

In addition, Mehta and Jain [10] presented an assistive communication system for speech-impaired individuals using embedded technology. Their system demonstrated how microcontrollers, sensors, and display modules can be combined to convert gestures into readable messages, providing an affordable and accessible solution.

Although these systems have shown promising results in translating sign language gestures into text or speech, many existing solutions still face challenges such as limited gesture recognition accuracy, restricted mobility, and higher system complexity. Therefore, the development of a simple, portable, and real-time gesture-based communication system remains an important research area to further improve accessibility for speech-impaired individuals.

3. PROPOSED SYSTEM

The proposed system is designed to translate sign language gestures into readable text and audible speech to assist speech-impaired individuals in communicating with others effectively. The system integrates multiple hardware components including flex sensors, an MPU6050 accelerometer sensor, an Arduino microcontroller, a 16×2 LCD display, and an HC-05 Bluetooth module to detect and interpret hand gestures. By combining gesture sensing, embedded processing, and wireless communication, the system provides a portable and low-cost communication solution.

Figure 2 illustrates the overall architecture of the proposed system. The flex sensors attached to the fingers detect the bending of each finger and generate corresponding analog signals. At the same time, the MPU6050 accelerometer sensor measures the orientation and movement of the hand. These sensor signals are transmitted to the Arduino microcontroller, which processes the data and determines the corresponding gesture based on predefined patterns stored in the program. Once the gesture is recognized, the corresponding message is displayed on the LCD screen and simultaneously transmitted through the Bluetooth module to a smartphone, where the message is converted into speech using a Text-to-Speech (TTS) application.

In this system, the flex sensors play an important role in detecting finger bending movements. These sensors change their electrical resistance depending on the

amount of bending in the finger. The Arduino microcontroller reads these resistance variations as analog values and analyzes them to determine the position of each finger. By combining the readings from multiple flex sensors, the system can identify different hand gestures.

The MPU6050 accelerometer sensor further improves gesture recognition by detecting the orientation and motion of the hand. It measures acceleration along multiple axes, allowing the system to identify hand tilts and directional movements. This additional information helps in distinguishing between gestures that may have similar finger positions but different hand orientations.

The Arduino microcontroller acts as the central processing unit of the system. It collects sensor data, processes the information, and compares the values with predefined gesture patterns programmed in the system. When a matching gesture pattern is detected, the microcontroller determines the corresponding message such as "I need food," "I need water," or "I need medicine."

After recognizing the gesture, the message is displayed on the 16x2 LCD display, allowing nearby individuals to read the message directly. At the same time, the message is transmitted wirelessly to a smartphone using the HC-05 Bluetooth module. A mobile application receives the message and converts it into audible speech using a Text-to-Speech (TTS) engine. This enables the spoken output of the user's message, making communication easier for people who may not understand sign language.

Overall, the proposed system provides a simple, portable, and cost-effective assistive communication solution. By integrating gesture detection, embedded processing, wireless communication, and speech synthesis, the system effectively bridges the communication gap between speech-impaired individuals and the general public.

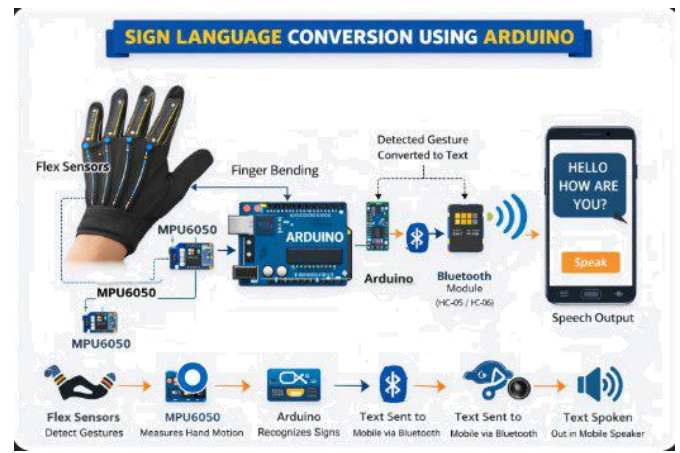


Figure 2 Architecture of the proposed system

The block diagram of the proposed sign language to speech and text conversion system is shown in Figure 2. The system mainly consists of input sensors, a processing unit, a display module, and a wireless communication module. In the input stage, flex sensors are attached to the fingers to detect the bending of each finger, while the MPU6050 accelerometer sensor measures the orientation and movement of the hand. These sensors generate electrical signals corresponding to different hand gestures. The sensor outputs are then sent to the Arduino microcontroller, which acts as the central processing unit of the system. The Arduino analyzes the analog values obtained from the flex sensors and the motion data from the MPU6050 sensor to identify predefined gesture patterns stored in the program. Once a gesture is recognized, the corresponding message is displayed on the 16x2 LCD display so that nearby people can read the information. At the same time, the recognized text message is transmitted through the HC-05 Bluetooth module to a smartphone. The mobile application receives this message and converts it into speech using a Text-to-Speech (TTS) engine. Thus, the block diagram shown in Figure 2 illustrates how sensor inputs, embedded processing, display output, and wireless communication work together to convert sign language gestures into understandable text and speech.

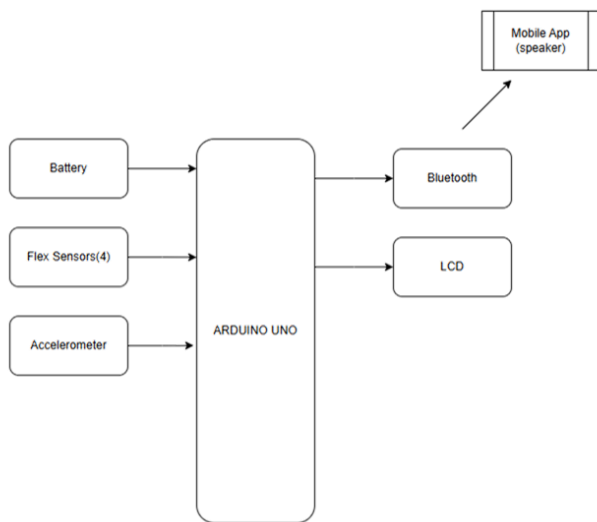


Figure 3 Block diagram of the proposed system.

4.METHODOLOGY

The methodology of the proposed system involves several stages including gesture sensing, data acquisition, gesture recognition, and output generation. The system begins by capturing the hand gesture using flex sensors and an MPU6050 accelerometer sensor. These sensors continuously monitor finger bending and the orientation of the hand. The flex sensors detect finger movements by producing varying resistance values when the fingers bend, while the MPU6050 sensor detects the tilt and motion of the hand.

As shown in Figure 3, the sensor signals are first captured and transmitted to the Arduino microcontroller. The Arduino reads the analog values generated by the flex sensors and the motion data obtained from the MPU6050 sensor. These values are processed using embedded programming logic, where the program compares the sensor values with predefined threshold ranges corresponding to different gestures. Each gesture pattern represents a specific message such as "I need food", "I need water", or "I need medicine".

Once a gesture is recognized, the system produces two types of outputs. The first output is the display of the recognized message on the 16x2 LCD screen, which provides immediate visual communication. The second output involves transmitting the recognized message through the HC-05 Bluetooth module to a smartphone. The mobile application receives the text message and converts it into speech using a Text-to-Speech (TTS) engine. This process ensures that both visual and audible communication outputs are generated, allowing others

to easily understand the message conveyed by the speech-impaired individual.

Working Steps

1. **Gesture Input:** The user performs a specific hand gesture by bending fingers and changing the orientation of the hand.
2. **Sensor Detection:** The flex sensors detect finger bending, while the MPU6050 accelerometer detects hand orientation and motion.
3. **Data Collection:** The sensor signals are sent to the Arduino microcontroller, which reads the analog and digital values from the sensors.
4. **Gesture Recognition:** The Arduino program analyzes the sensor data and compares it with predefined gesture patterns stored in the system.
5. **Message Identification:** Once the gesture is recognized, the corresponding message such as "I need food", "I need water", or "I need medicine" is selected.
6. **LCD Display Output:** The recognized message is displayed on the 16x2 LCD display for immediate visual communication.
7. **Bluetooth Transmission:** The message is sent wirelessly to a mobile device using the HC-05 Bluetooth module.
8. **Speech Generation:** The mobile application receives the message and converts it into speech using the Text-to-Speech (TTS) feature, allowing others to hear the message.

Algorithm for Sign Language to Speech Conversion System

Algorithm 1: Gesture Recognition and Speech Generation

Input: Sensor readings from flex sensors and MPU6050

Output: Text display on LCD and speech output via smartphone

1. Start the system.
2. Initialize Arduino microcontroller, flex sensors, MPU6050 sensor, LCD display, and HC-05 Bluetooth module.
3. Continuously read analog values from the flex sensors.
4. Read orientation and motion data from the MPU6050 accelerometer sensor.
5. Store sensor readings for processing.
6. Compare sensor values with predefined

- threshold ranges for each gesture.
7. If sensor values match a predefined gesture pattern:
 - o Identify the corresponding message.
 8. Display the recognized message on the LCD display.
 9. Transmit the message to the smartphone via HC-05 Bluetooth module.
 10. The mobile application receives the text message.
 11. Convert the received text into speech using the Text-to-Speech (TTS) engine.
 12. Play the speech output through the smartphone speaker.
 13. Repeat the process for the next gesture.

5.RESULTS AND DISCUSSIONS

The proposed **Sign Language to Speech and Text Conversion System** was successfully implemented using flex sensors, an MPU6050 accelerometer sensor, an Arduino microcontroller, a 16×2 LCD display, and an HC-05 Bluetooth module. The developed prototype was tested with multiple hand gestures to evaluate the functionality and accuracy of the system. The experimental setup includes a glove embedded with flex sensors to detect finger bending, a processing unit based on Arduino, and output modules such as an LCD display and a smartphone-based Text-to-Speech (TTS) application.

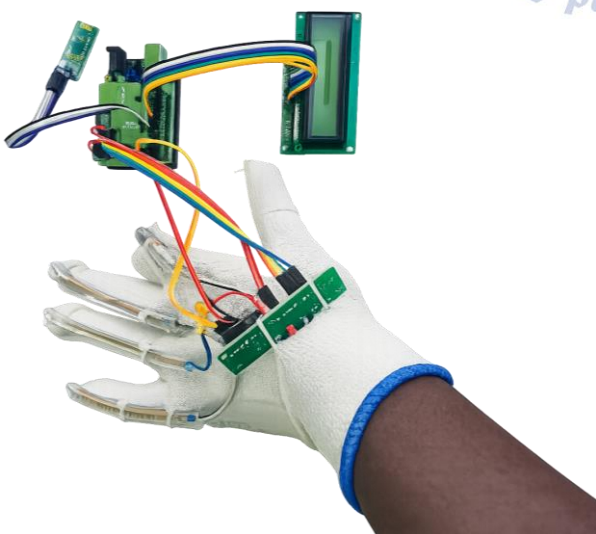


Figure 4 Developed Hardware Prototype of the Sign Language to Speech Conversion System

Figure 4 illustrates the developed hardware prototype of the proposed system. The flex sensors are attached to

each finger of the glove to measure bending movements. These sensors are connected to the Arduino microcontroller through signal conditioning circuits. The Arduino processes the sensor data and identifies predefined gesture patterns. The recognized gesture is displayed as a message on the **16×2 LCD display**, while the same message is transmitted wirelessly to a smartphone through the **HC-05 Bluetooth module** for speech generation. This prototype demonstrates the practical implementation of the system and verifies that the hardware components work together to convert gestures into text and speech outputs.

Figure 5 shows the experimental demonstration of the system when the user wears the sensor-based glove. When the user bends specific fingers and changes the hand orientation, the flex sensors and MPU6050 sensor capture the gesture data. The Arduino analyzes the sensor values and matches them with predefined gesture patterns stored in the program. Once a gesture is recognized, the corresponding message such as **“I need food”, “I need water”, or “I need medicine”** is displayed on the LCD screen and simultaneously transmitted to the mobile application, where it is converted into speech using the Text-to-Speech engine.

Experimental Results

The system was tested with several predefined gestures to verify its performance. The sensor readings from the flex sensors and accelerometer were successfully processed by the Arduino microcontroller to identify the gestures accurately.

Gesture Pattern	Sensor Behavior	Identified Message	LCD Output	Speech Output
Finger 1 & 2 bent	Flex sensor values increase	I need food	Displayed	Spoken through mobile
Finger 2 & 3 bent	Flex sensor variation detected	I need water	Displayed	Spoken through mobile
All fingers slightly bent	Multiple flex sensors activated	I need medicine	Displayed	Spoken through mobile
Hand tilted forward	MPU6050 detects orientation	Help required	Displayed	Spoken through mobile

Performance Analysis

The experimental results demonstrate that the proposed system can effectively detect hand gestures and convert them into understandable text and speech

outputs. The use of flex sensors allows accurate detection of finger bending, while the MPU6050 accelerometer sensor improves recognition by capturing hand orientation. The Arduino microcontroller efficiently processes the sensor data and generates real-time responses. The integration of Bluetooth communication and Text-to-Speech technology enables audible output, making the system more accessible for normal users who may not understand sign language.

Overall, the prototype confirms that the proposed system is capable of providing a portable, low-cost, and real-time communication solution for speech-impaired individuals. The experimental results validate the effectiveness of the system in bridging the communication gap between speech-impaired individuals and the general public.

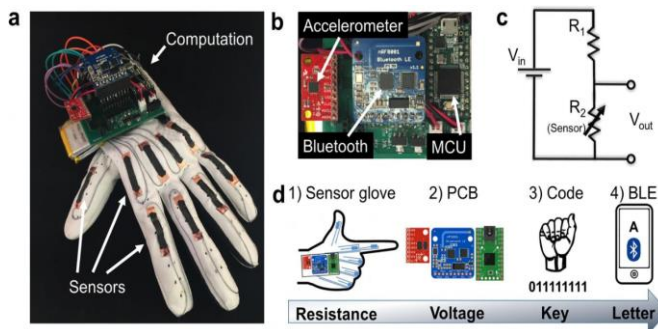


Figure 5 Experimental Demonstration of the Gesture Recognition Glove

6. CONCLUSION

The proposed Arduino-based conveyor belt color sorting industrial robotic system was successfully designed, implemented, and tested to automate the process of object sorting based on color. By integrating a color sensor, IR proximity sensor, conveyor belt mechanism, and a servo-controlled robotic arm, the system achieved reliable real-time detection and accurate pick-and-place operations. The Arduino microcontroller effectively coordinated sensing, decision-making, actuation, and safety controls, ensuring smooth and continuous system operation. Experimental results demonstrated that the system provides high sorting accuracy, consistent performance, and reduced manual intervention under controlled conditions. The inclusion of safety features such as an emergency stop push button and buzzer alert significantly enhanced operator safety and system reliability. Compared to manual and semi-automated

methods, the proposed system improves productivity, minimizes human error, and reduces operational costs. Overall, the project validates the feasibility of using low-cost embedded platforms for industrial automation tasks. The modular and scalable design allows future enhancements such as additional color detection, integration of machine vision, IoT-based monitoring, and adaptive control algorithms. Hence, the system is well suited for small- and medium-scale industries, educational laboratories, and automation research applications.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

- [1] F. Khan and R. S. Chahar, "Real-Time Sign Language to Speech Conversion System Using Arduino," *International Journal of Engineering Research*, 2025.
- [2] M. M. Nwachukwu, C. E. Eze, and O. D. Nnorom, "Implementation of Sign Language Recognition System Using Flex Sensors," *International Journal of Research and Innovation in Applied Science*, 2024.
- [3] U. P. Moon and L. S. V. B., "Sign to Text Language Conversion Using Arduino Nano," *International Journal of Innovative Research in Engineering*, 2025.
- [4] T. L. Alumona, V. N. Okorogu, and E. F. Nworabude, "Sign Language Recognition System Using Flex Sensor Network," *International Journal of Advanced Technology Research*, 2023.
- [5] H. Begum, B. Jahnavi, B. R. Deepa, and A. Kumar, "Text and Speech Conversion Glove for Sign Language Communication," *International Journal of Scientific Research in Science and Technology*, 2023.
- [6] S. Kadam and P. Kulkarni, "Smart Glove for Sign Language Interpretation Using Embedded Systems," *International Journal of Computer Applications*, 2022.
- [7] R. Sharma and A. Gupta, "Gesture Recognition System for Deaf and Dumb People Using Sensors," *International Journal of Engineering and Technology*, 2022.
- [8] K. Patel and M. Shah, "Wireless Communication Based Sign Language Translator Using Arduino," *International Journal of Electronics and Communication Engineering*, 2021.
- [9] A. Singh and V. Kumar, "Design of Gesture Recognition System Using Accelerometer and Flex Sensors," *International Journal of Embedded Systems*, 2021.
- [10] P. Mehta and S. Jain, "Assistive Communication System for Speech Impaired People Using Embedded Technology," *International Journal of Advanced Research in Electronics and Communication Engineering*, 2020.