Chapter 21
Fusion Model-Based Robotic Arm Using Laboratory Virtual Instrument Engineering Workbench

D. Monisha and R. Vanithamani

1 Introduction

A robot is commonly used in vital applications and to assist humans in difficult tasks and high-risk areas [1]. Several factors are facilitating the fusion of the physical, digital, and biological worlds as a result of industrial revolution 4.0, including an increased interaction between humans and machines [2]. These robots can be programmed for a variety of tasks, for example, speech recognition, gesture control, and peripheral device control [3]. Roboarms include a manipulator that mimics the functioning of the human arm and is usually programmable. As a general rule, the manipulator is connected to the computer and moves by linear or rotational displacement [4]. Material handling, welding, part assembly, painting, spraying, and medical operations using robotic arms are some uses of robotic arms [1].

During the past two decades, remote laboratories have become more popular among engineers. Practicing in a safe environment enables us to practice using real, physical components before using them. Additionally, it provides a virtual interface to a real-life, physical laboratory. The environments in laboratories and industries that use or manufacture hazardous materials make it difficult for people to work safely. Similarly, hospitals also perform the sensitive task of human waste removal by uneducated people without the proper knowledge and guidance. Many doctors find it difficult to treat patients with communicable diseases, which spread when infected secretions like nasal secretions come into contact with surfaces in the environment [5].

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Following the introduction, Sect. 2 covers the related work regarding the applications and systems. Section 3 discusses the hardware and software utilized in this work, and the Sect. 4 reports on the results of the proposed work. Finally, Sect. 5 concludes the work and discusses the potential future scope of this work.

2 Literature Review

Robotic arms are designed similarly to human arms. Linkages connect the robotic arm to the stepper motor, which controls its movement. There are a number of articles here that deal with robotic arm design and implementation. The table below outlines the device designed and the input signal or control used.

Sahoo et al. (2019) designed a robotic arm with a stepper motor that could operate in different angles. The robot was programmed in LabView environment and operated in three degrees of freedom. The motor driver distributed current equally among the three stepper motors and three stepper motors were used [1]. Hidalgo et al. (2005) employed fuzzy controllers for the movement of wrist and elbow. Surface EMG electrodes were used to acquire the EMG signal, which was then used to measure the motor potential. An additional electrode was used to serve as a reference electrode for the acquisition using a two-electrode system. The signals were measured from three muscles: flexor carpi radialis, flexor radial artery, and biceps brachii. Because of the strain of the electrode placement or muscle on the arm, there were several oscillations in the stable part [5].

In 2016, J. J. A. Mendes Junior et al. presented a band with a signal conditioning circuit consisting of acquisition, filtering, and isolation. In this study, two algorithms were used to control the robot's actuation based on the surface EMG of the biceps brachii [6]. The robotic arm designed by Pol et al. (2016) has four degrees of freedom, including a base, shoulder, elbow, and wrist. To estimate the position accurately, the inverse kinematics method was applied. For evaluating the inverse kinematics, the cosine law was used as an analytical tool. There were three control modes implemented in the designed robot: Standalone control mode, Semi-autonomous control mode, and Autonomous control mode [7]. As shown in Angal et al. (2016), my RIO was used to pick up objects from the floor. An RFID reader, an IR sensor, a motor driving circuit, and a gripper were employed in this project. For obstacle detection, an IR sensor was used, which had a maximum range of 80 cm [3]. Gautam et al. (2017) discussed different ways to review the development of industrial robots. Observations revealed that the accelerometer-based robotic arm offered precise and accurate movements, was user-friendly, and was easy to use. Robotic arms were developed for welding, painting, picking up objects, and for medical purposes. Manpower requirements for hazardous tasks could be reduced because of robotic arms.

Using SimMechanics, Kumar et al. (2017) developed a prosthetic arm and simulated its torque, power, and cost. Using the ANFIS machine learning algorithms, the robotic arm was controlled and decided what to do. With six degrees of freedom, the microcontroller on the PIC provided supervisory control. As a result, this work had high flexibility, simple structure, and low energy consumption. The sensory feedback system, which resembled the human arm, was also advantageous [8]. EEG signals were used by Sunny et al. 2015, to develop a robotic arm. An electric field acquired by the 10–20 electrode system was used to control the Brain–Computer Interface-based robotic arm. A translational algorithm was used to generate the device command for the system. Emokey software was used to implement the algorithm. In this paper, the aim was to develop a limb amputee with characteristics similar to a biological limb [9].

In the method, the Electric wheelchair (EWC) wheel rotation is controlled by a PID controller. In this study, the cost-effectiveness of the system and the improvement of performance were the main topics. Users of EWC were able to see the display system from their sitting position. A PID controller controls the DC motor, controlling the direction of movement of the EWC based on the eye pupil position. Based on derivative (D) control, the proposed system responded quite quickly, and it significantly reduced the delay time between the user and the system. Comparing the results of a canny edge detector to other edge detection approaches, this approach provided good results. The proposed system had the additional benefit of detecting objects in front of the EWC [10]. A voice interface was developed to ask experts questions. In addition, a robotic interface was developed to converse automatically with clients. This was done under the supervision of the experts in order to respond. Due to the application of an embedded platform designed for the edge computing, the proposed system would be able to run in any room. By submitting it to the audio file form and validating it based on the recognition scores and the estimation accuracy percent, the advantage of the system can be understood [11]. The developed robotic arm was fully functional and responded to the movements of the user as expected. An accelerometer was attached to the arm of the human user. In addition to position information, the accelerometers transmit speed data as well. In addition to the glove, which controls the claw's flex sensor, the user wears a headset with a screen for taking measurements. A robotic arm moved from one location in any given room to another on a mobile base [12].

It is proposed to implement a Web-based control system using the MQTT (Message Queuing Telemetry Transport) communication protocol and the ESP8266 (a network data transmission module). With these technologies, an accurate and real-time robotic manipulator can be controlled remotely from a platform independent web application [13]. The robot arm is equipped with five servomotors that allow it to move in four axes. Material was picked up by the holder, which mixes it with the material it receives, as well as moving it from one place to another. The android application was controlled by the Arduino Nano microcontroller by using a Bluetooth module connected to the Arduino Nano [14]. Implementing a multisensory system within a model-based environment while considering constraints was described in the authors' paper. A CAD model database was used to determine geometric features and constraints using an environment model. In order to predict sensor responses to certain features and interpret raw sensor data, sensor models were used. Constrained MMS estimates were used to recursively predict, match, and update feature locations.

Table 1 Summary of literature review

S. no	Author and year	Device	Input	Programming tool
1	Tauheed Khan Mohd et al. (2017)	Gesture band—Myo band	EMG and speech signal	C, C++
2	A. K. Sahoo et al. (2019)	Medical robots	3 degrees of freedom	LabVIEW
3	J. J. A. Mendes Junior et al. (2016)	Band	Surface EMG	LabVIEW
4	Yogesh Angal et al. (2016)	RIO robot	IR sensor	LabVIEW
5	M. Hidalgo et al. (2005)	Robotic arm	EMG signal	LabVIEW
6	Rahul S. Pol et al. (2016)	Robotic arm	4 degrees of freedom	LabVIEW
7	Vudattu Sachin Kumar et al. (2017)	Prosthetic arm	6 degrees of freedom	SimMechanics
8	Sunny T. D. et al. (2015)	Robotic arm	EEG	EMOKEY

By using a robot arm–mounted simulation system for localization of known objects features, the effects of applying different constraints to estimation were demonstrated [15]. In the paper, a 4 degree of freedom robotic arm was designed and manufactured. After designing the robotic arm using Fusion 360, the components were printed using 3D printers. In order to create 3D models, ideaMaker printer software was used. Testing for functionality was done by actuating stepper motors attached to the robot arm after the robotic arm has been assembled [16].

All the approaches that were discussed here were focused on,

- Efficient design
- Low cost
- User-friendly and ease of operation
- Advanced sensing and control options
- High-performance actuators
- Low-cost construction and energy consumption.

The proposed work is developed with all the abovementioned features. The methods and the components used in this work are discussed in the next section (Table 1).

3 Methodology

This section explains about the methodology used. Figure 1 shows the block diagram of the proposed work. The components involved are discussed in detail.

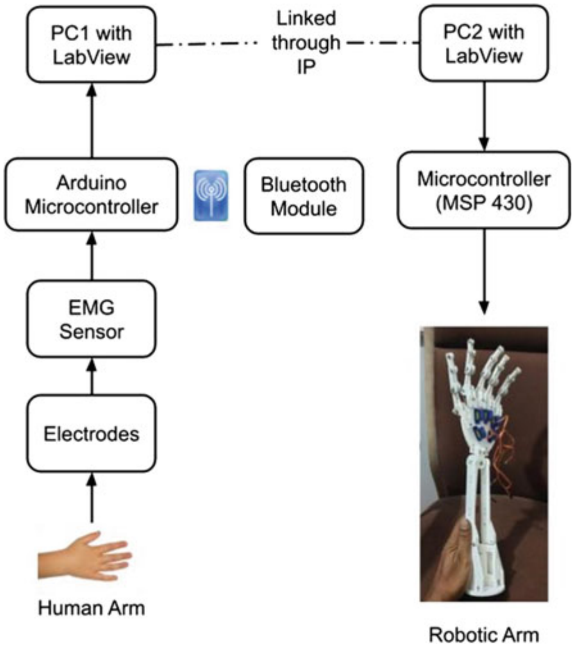


Fig. 1 Block diagram of the proposed system

EMG Surface Electrodes

The input to the system is acquired through EMG surface electrodes, which are placed in the human arm. It is placed in the biceps as shown in Fig. 2.

A differential amplifier is implemented in this project utilizing bipolar electrodes and a reference electrode. An Arduino UNO board receives an input EMG signal from a three-lead differential muscle sensor module, amplify, filter, rectify, smooth

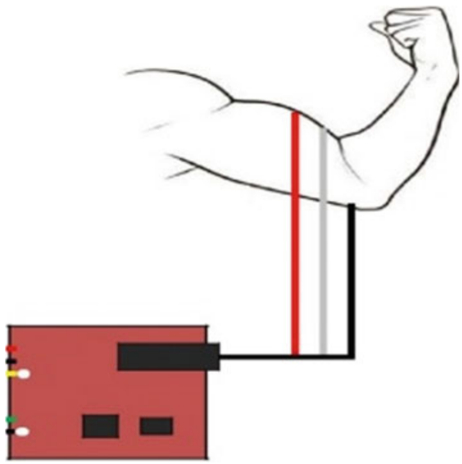


Fig. 2 Electrode placement and EMG sensor module

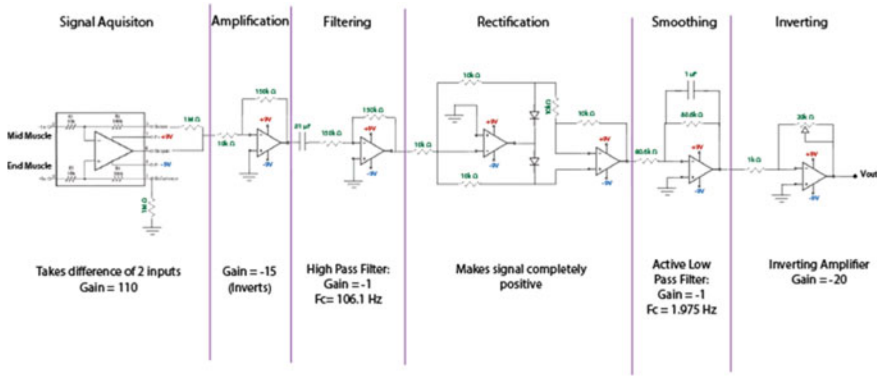


Fig. 3 Circuit diagram of signal conditioning circuit

and invert the signal, and give the output to a three-lead differential muscle sensor module. Figure 3 shows the circuit diagram of signal conditioning circuit.

The bipolar electrodes maximize the probability of reading the same signal when the electrode is placed in the optimal position which is parallel to the muscle fibers [7].

Microcontroller

ATMEGA 328

A typical Arduino board has 14 digital pins and 6 analog pins. The total number of GPIO pins on the board is 20, which should be sufficient for many beginner and intermediate level projects. There are also Rx and Tx pins on the board that can be used to connect Serial Communication Devices. In addition, the header file SoftwareSerial can be included to define an additional pair of Rx and Tx pins. A computer using Arduino is capable of detecting various environmental data using sensors and controlling lights, motors, etc., based on those readings. ATmega328 microcontroller is used for the analysis of signal, speech processing, and thresholding. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It can be powered by connecting it through USB or AC-to-DC adapter or battery to get started.

MSP430

The MSP430 is a mixed-signal microcontroller which is built around a 16-bit CPU. The MSP430 is designed for low cost and, specifically, low power consumption embedded applications. This microcontroller is used along with LabVIEW to control the robotic arm. It is an ultra-low power measuring and controlling instrument, and therefore, the power consumption can be reduced.

HC05 Bluetooth Module

The secondary input is given through human speech recognition. In case of failure of surface electrodes, the arm can be controlled through voice. It is enabled through Bluetooth module HC05. HC05 is an UART serial converter module, which is used to transfer data through wireless communication. This work uses master–slave configuration.

Programming Tool

A key feature of LabVIEW for Remote applications is through the support of Web-enabled remote panel control. With this feature, it is possible to create a user interface for controlling the robotic arm and also for viewing and interacting with the front panel from another LabVIEW environment or from a web browser through IP address. LabVIEW comes with a web server that automatically deploys the application, and in the client side, the user will be able to see the user interface. Remote clients see live front panel updates without any programming. Multiple clients can view the same panel simultaneously, but only one client can control the front panel at a time. The flowchart for LabVIEW analysis is shown in Fig. 4. The advantage of LabVIEW remote front panel is that it can easily integrate with all the LabVIEW tools already available for accessing, measuring, and interacting with hardware. In a few seconds or minutes, we can publish anything you do in LabVIEW on the Web. ECG monitoring can be carried out by a physician or nurse from anywhere in the world. Having access to remote monitoring extends to nurse call stations, giving nurses the opportunity to work remotely. The front panel for remote operation from a client side is developed using LabVIEW 2013 to implement the remote monitoring concept. An authentication mechanism is employed to allow access to the resources.

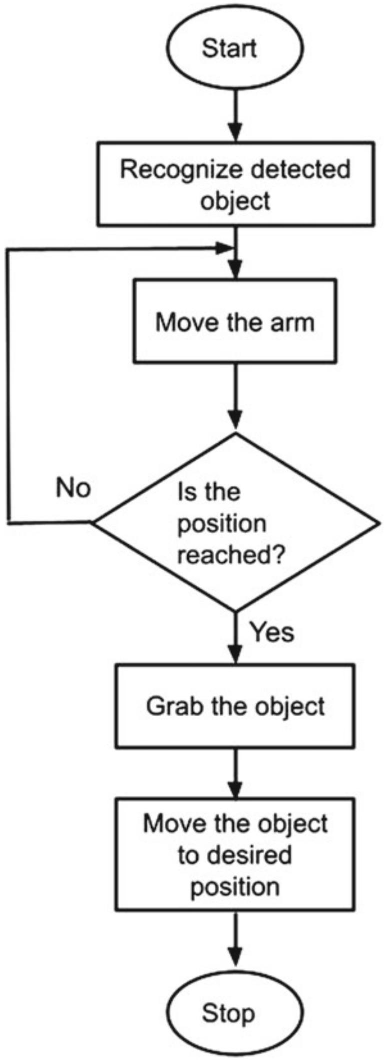
Experimental Setup

A master–client paradigm is used for the experimental setup. An EMG sensor detects movement in the muscles, and voice commands control the arm through voice command. Gestures include movement in the right and left direction, picking up and dropping objects. By using the IP address of the Arduino microcontroller, the master programming technique is controlled. MSP430 microcontroller is used to send instructions to the robot arm from the client PC. In the event that a hand movement or a gesture is not detected, voice commands are employed to compensate. Sensor signals from the EMG electrodes are given priority. There has been a significant increase in the accuracy of the system in the medical domain [2].

4 Results and Discussions

Figures 5 and 6 show the master and the client remote panel in LabVIEW environment. The connection between them is done using the IP address, by this interference of other signals can be avoided. The advantage of this work is its fusion model, using

Fig. 4 Flowchart of LabVIEW programming



the input from both sensor and voice recognition. The remote panel in LabVIEW enables the arm to be controlled from remote places. The speech signal is an easier way to give input to the robotic arm than the EMG signal.

The final prototype of the proposed work, the transmitter, and the receiver section are shown in Fig. 7. The developed model is shown in Fig. 8.

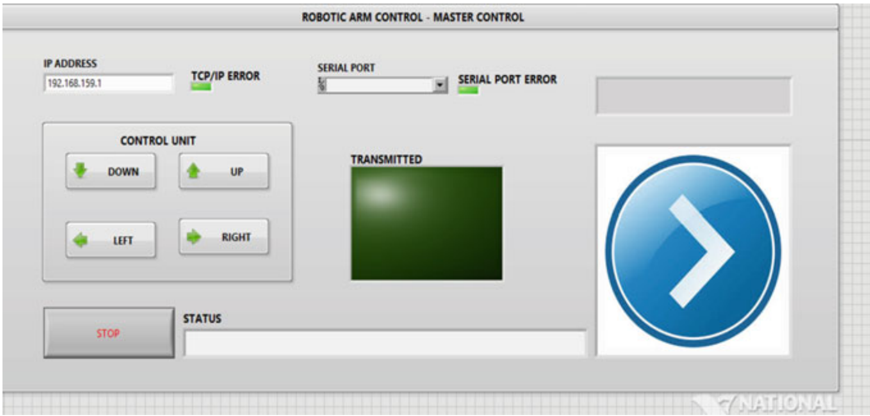


Fig. 5 Master control remote panel

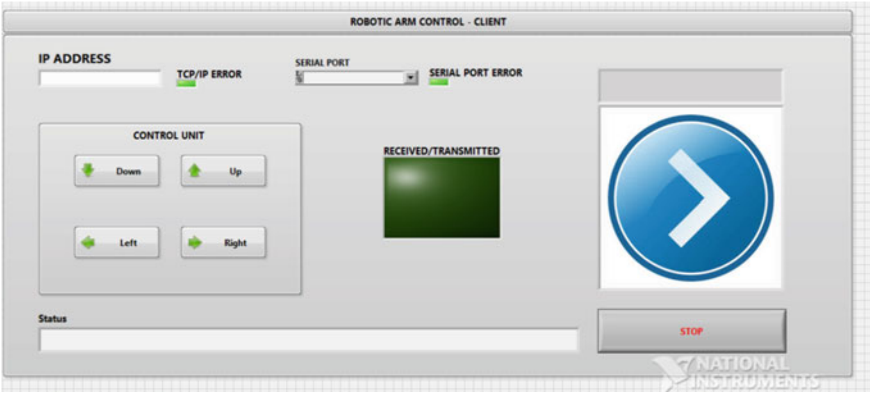
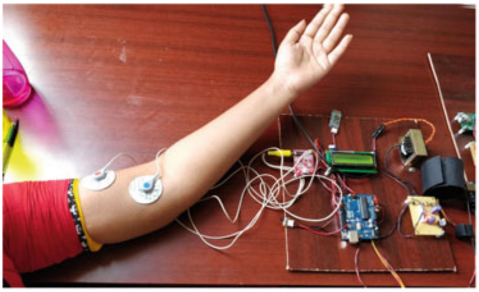


Fig. 6 Client control remote panel

5 Conclusion

In the experimental setup, fusion of myoelectric signals and speech signals increased the accuracy of the model. They can also be used in industries and laboratories to collect hazardous waste in factories and labs. Hospitals can use them to remove biomedical waste and biological waste after surgery. Future works include the development of a wireless system for controlling robotic arms. For the development of the robotic arm, EEG signals can also be utilized in addition to EMG signals.



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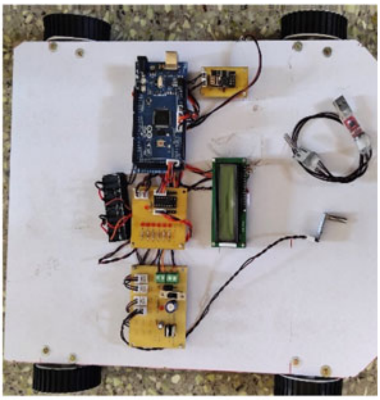
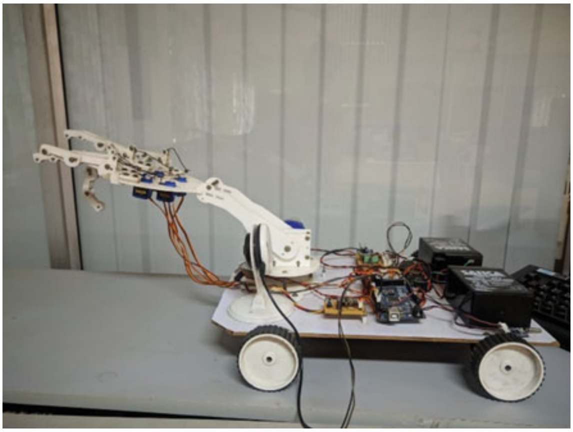


b

Fig. 7 Experimental model of the proposed work: **a** Transmitter section. **b** Receiver section

Fig. 8 Prototype of the proposed robotic arm



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