Human Gesture Recognition for Real-Time Control of Humanoid Robot

Aswath S, Chinmaya Krishna Tilak, Amal Suresh, and Ganesha Udupa

***Abstract*—**There are technologies to control a humanoid robot in many ways. But the use of Electromyogram (EMG) electrodes has its own importance in setting up the control system. The EMG based control system helps to control robotic devices with more fidelity and precision. In this paper, development of an electromyogram based interface for human gesture recognition for the control of a humanoid robot is presented. To recognize control signs in the gestures, a single channel EMG sensor is positioned on the muscles of the human body. Instead of using a remote control unit, the humanoid robot is controlled by various gestures performed by the human. The EMG electrodes attached to the muscles generates an analog signal due to the effect of nerve impulses generated on moving muscles of the human being. The analog signals taken up from the muscles are supplied to a differential muscle sensor that processes the given signal to generate a signal suitable for the microcontroller to get the control over a humanoid robot. The signal from the differential muscle sensor is converted to a digital form using the ADC of the microcontroller and outputs its decision to the CM-530 humanoid robot controller through a Zigbee wireless interface. The output decision of the CM-530 processor is sent to a motor driver in order to control the servo motors in required direction for human like actions. This method for gaining control of a humanoid robot could be used for performing actions with more accuracy and ease. In addition, a study has been conducted to investigate the controllability and ease of use of the interface and the employed gestures.

***Keywords*—**Electromyogram, Gesture, Humanoid Robot, Microcontroller, Muscle sensor.

I. Introduction

THIS paper suggests a control of a humanoid robot using gestures produced by a human body. Instead of using a remote control unit or mobile phone [1], the humanoid robot is controlled by various gestures performed by the human body. These gestures are understood by the microcontroller using the EMG electrodes attached to the human body. When a person performs some kind of gestures, the corresponding muscles that produce the gestures generate action potentials at the nerve end on the muscles, which are analogous in nature. Action potentials are short-lasting electric membrane potential generated by special types of voltage-gated ion channels embedded in a biological cell. These action potentials produced are recorded using EMG electrodes. Electromyography is an experimental technique used to evaluate and record the electrical activity produced by the skeletal muscle. EMG based muscle sensors are used to amplify the action potentials that are produced at the nerve end and are sent to the microcontroller for the further control of the humanoid robot. Fig.1 shows the humanoid robot used in this paper.

Fig.1 Humanoid Robot

EMG measures electrical currents that are generated in a muscle during its contraction and represent neuromuscular activities. EMG signals can be used for a variety of applications including clinical applications, human- computer interaction and interactive computer gaming [2]. Nowadays many different types of bio-signals, such as skin conductance or electrocardiogram, can be measured with many differing procedures. Depending on the respective signal, these bio-signals are utilized in industrial applications, such as medicine or entertainment [3]. Some bio-signals have also been shown to be suited for the creation of a new communication interface between humans and computers. In this area the use of bio-signals offers brand new possibilities when compared to the conventional, mostly audio-visually based human-computer interfaces. Thus, with the help of bio-signals, it is today possible to detect emotions [4], make music [5] or develop smart clothes [6]. The famous polygraph is also based on bio-signals.

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Many bio-signal based interfaces are used for controlling and communication. For disabled people especially, they offer the possibility of making their lives easier. There have been some promising attempts for the development of a new generation of bio-signal controlled prostheses [7], which are much more user-friendly and more easily accepted than customary prostheses. Even people with severe disabilities and whose normal communication channels do not work anymore may receive help by the creation of a new communication interface based on bio-signals. This is one major aim of brain computer interface (BCI) research, where communication can take place simply by measuring thoughts. Besides BCIs, which mainly use electroencephalographic signal (EEG) [8], the most important bio-signal for controlling interfaces has become the signals received from the EMG. This is due in great part to the fact that most bioelectric signals, such as the EMG or EEG, can be recorded in a comparatively simple and inexpensive manner. As it is usually possible to receive the bioelectric signals free of pain by placing the electrodes on the surface of the skin, user acceptance compared to other bio-signal measurement methods is also proportionally high. The EMG signal represents the natural electrical activity of the human body, which is used to control the skeletal muscles. Nowadays it is possible to control, in addition to the aforementioned prostheses, robotic arm [9], mobile phones [10] and MP3 players [11] with the help of EMG signals. These systems are usually based on the performance of several gestures which are recognized through their EMG signals taken from one set of muscle fibers rather than taking two sets of signals at a time. The type of gesture depends on the number and the positioning of the measuring sensors and varies from nearly motionless arm gestures[12], to hand gestures [11, 13] and movements of single fingers, for example for virtual typing [14]. In 1999, NASA also successfully developed an EMG based controlling interface: It simulates the landing of an aircraft which is solely controlled by gestures resulting from the navigation of a virtual joystick [15]. An EMG based real-time controlling interface was developed to navigate an RC car with the help of four different hand gestures [16]. This paper extends the idea of the technology to control a more powerful device like humanoid robots to perform human like actions with high accuracy by considering two or more sets of muscle fibers at a time for gesture recognition. This increases the ability in recognizing the gesture. This model can be a very significant device in the areas where direct interference of human being is quite impossible; hence it would be a very useful topic to do further research on it. Humanoid robots are being developed to perform human tasks like personal assistance, where they should be able to assist the sick and elderly. In essence, since they can use tools and operate equipment and vehicles designed for the human form, humanoids could theoretically perform any task a human being can, as long as they have the proper software. However, the complexity of doing so is deceptively great.

II. ELECTROMYOGRAPHY (EMG)

Measuring muscle activity by detecting its electric potential is referred to as electromyography. EMG has traditionally been used for medical research. However, with the advent of ever shrinking yet more powerful microcontrollers and integrated circuits, EMG circuits and sensors have found their way into all kinds of control systems. Electromyography is the study of muscle function by measuring the electrical signal associated with the muscle contraction. This muscle contraction could be either voluntary or involuntary in nature and is measured in motor units. This muscle fiber contracts when the action potentials (impulse) of the motor nerve which supplies it, reaches a depolarization threshold. The depolarization generates an electromagnetic field and the corresponding potential is measured as a voltage. The depolarization, which spreads along the membrane of the muscle, is a muscle action potential. These action potentials are recorded using the EMG electrodes and are converted, rectified and smoothed For best results, the EMG electrodes are to be placed at points on the muscles, which on contraction produce more voltage due to motor nerves. Also measures have to be taken for reducing the noise in the signal as much as possible. Even cleaning off the dead cells on the skin reduces the noise by reducing the resistance by 200%. This information from the muscle sensor is fed to the Arduino microcontroller for taking over the control of the humanoid robot. A Fig.2 showing the retrieval of EMG signals is shown below.

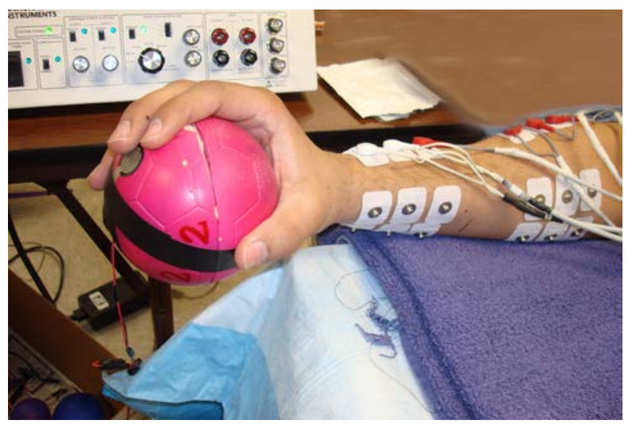


Fig. 2 Retrieval of Muscle Signals using EMG

III. CIRCUIT DESIGN

The main components of this prototype are Arduino Microcontroller, EMG electrode, Differential Muscle Sensor, Zigbee module and CM-530 controller. EMG electrode is used in measuring muscle activation via electric potential as a byproduct of muscle contraction. An EMG is the summation of action potentials from the muscle fibers under the electrodes placed on the skin. The more muscles that fire, the greater the amount of action potentials recorded and the greater the EMG reading. First the muscle group (e.g. bicep, forearm, calf) for gesture recognition are determined and electrodes are placed. Then the other end of the three EMG electrodes should be connected to the 3.5mm cable port of the differential muscle sensor. The differential muscle sensor is a device which converts the raw EMG signal to an amplified, rectified and smoothed EMG signal, which works well with the analog to digital converter (ADC) of the microcontroller. The Fig.3 shows the pin mapping of the muscle sensor.

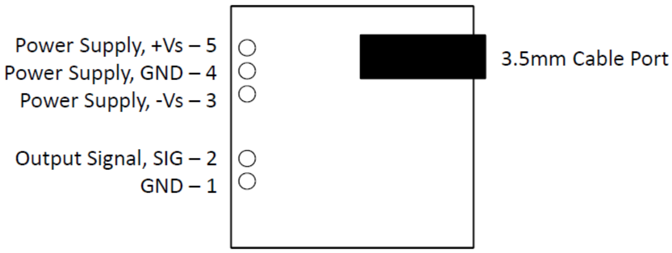


Fig. 3 Pin mapping of muscle sensor.

Power supply of 18 volt is given across +Vs (Pin (5)) and –Vs (Pin (3)), then the GND pin (4) and pin (1) is grounded. The output signal from the SIG (pin (2)) of the muscle sensor is fed to the Analog input 1 (pin (24)) of the Arduino microcontroller. Figure 4 shows the Arduino pin mapping. Arduino is programmed to convert the amplified EMG analog signal to a particular digital from by using the ADC feature of the Arduino microcontroller. The output of the ADC is fed to the Arduino Zigbee shield transmitter. The Arduino board is interfaced with the humanoid robot CM-530 controller via Zigbee wireless interface. Another Zigbee which is acting as the receiver is attached with the Humanoid controller. Every binary information sent from the Arduino is received at the humanoid controller through the Zigbee wireless interface. The humanoid robot is made-up of high torque (15 kgcm) 18 dynamixal servo motors, which are interconnected. The servo motors are arranged in such a pattern to resemble human like moves. These servos are controlled by the CM-530 controller. Based on the particular pattern of binary values received at the CM-530 controller the movements of servos is programmed in the required way for human like moves with the help of programming software Roboplus.[1] The RoboPlus software has two components RoboPlus task and RoboPlus motion. The RoboPlus motion is GUI supported, which is used to create and modify robot's motion data. The motion data is used in RoboPlus task to write the required program for the Humanoid Robot.

IV. Implementation Of Control System

The EMG signals required for the human gesture recognition for real-time simulation of humanoid robots are taken from the muscles using EMG electrodes and are fed to the muscle sensor for the amplification and smoothening of the signal, which is further fed to the Arduino microcontroller as shown in the Fig. 5 to take over the control of the humanoid robot.

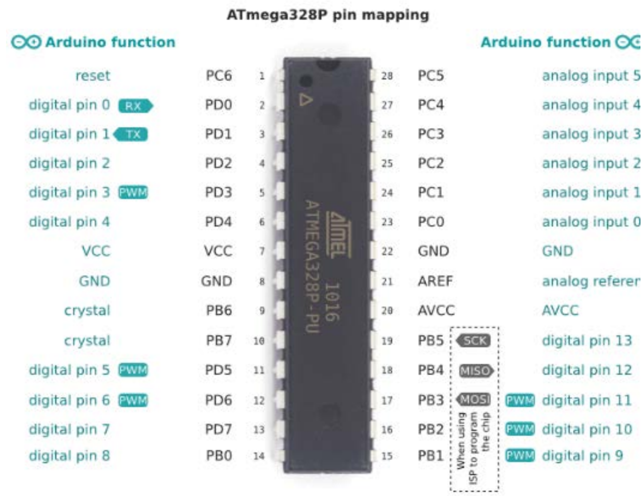


Fig. 4 Arduino Atmega328P pin mapping

The amplified output from the muscle sensors are sent to the ADC channel in the Arduino microcontroller. This digital signal is easily decoded and respective output commands are programmed into the microcontroller for the humanoid actions to take place.

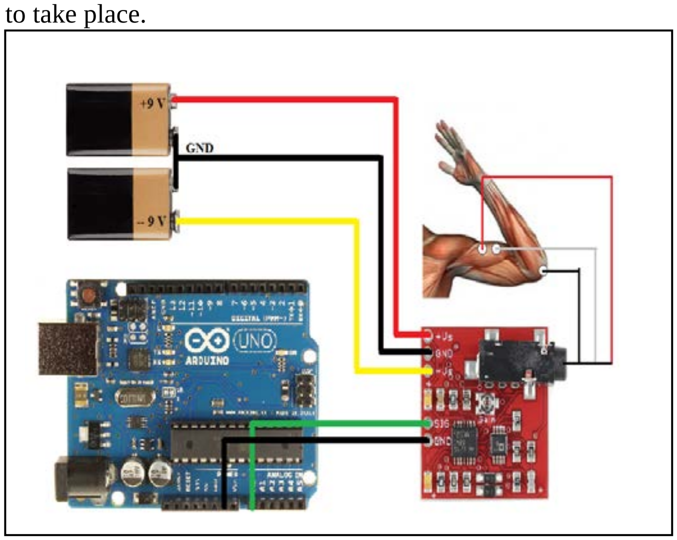


Fig. 5 Circuit diagram of retrieving EMG signal

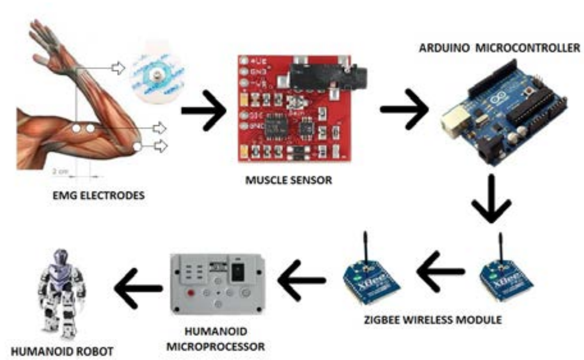


Fig. 6 Block diagram representing the concept

The above Fig. 6 delineates the complete schematic block diagram of Electromyography concept for real-time human gesture based control of humanoid robot. In order to activate the humanoid robot for specific task, we have to move certain muscle group with EMG attached (e.g. bicep, forearm) to incorporate such moves. When the muscle group is moved, the attached EMG collects the muscle activation via electric potential as a byproduct of muscle contraction. The output of the EMG electrode is send to the differential muscle sensor, where the raw EMG signal is amplified, rectified and smoothed. The output from the muscle sensor is then fed to the ADC of the Arduino microcontroller, where the analog EMG signal is converted to a particular digital form. The outputs of the ADC are fed to the Arduino Zigbee shield transmitter. The Arduino output goes to RXD pin-6 on Zigbee (TXD). Zigbee transmitter sends the Arduino output to the Zigbee receiver connected to the CM-530.The Zigbee (receiver) sends the received output to CM-530 through TXD pin2. The program installed on the CM-530 processor is executed and the humanoid robot performs the required action. Fig.7 shows the experimental setup of the EMG based control system for the humanoid robot.

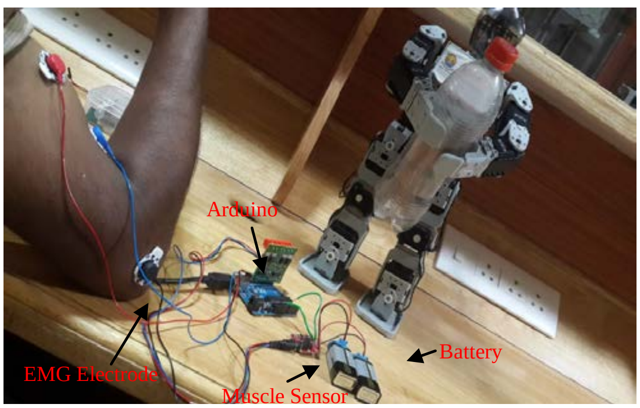


Fig. 7 Experimental Setup

V. Results And Discussion

The process was implemented by recording a set of EMG signals from the muscle fibers using an EMG electrode. The corresponding communication signal from the EMG electrodes are amplified, filtered and smoothed using the muscle sensor. The different waveforms generated from the set of muscle fibers are shown in the figure 8, 9, 10 and 11. The signals are recognized using muscle sensor and are sent to Arduino microcontroller for interfacing the humanoid robot with the human gestures.

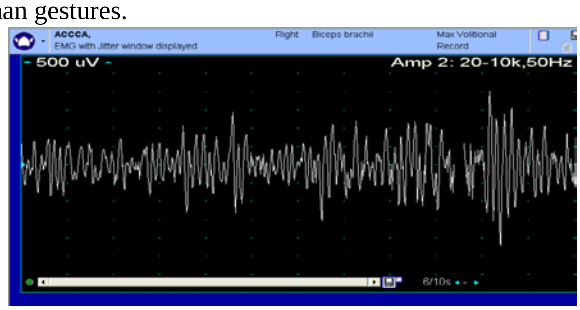


Fig. 8 EMG signal at the Biceps Muscle

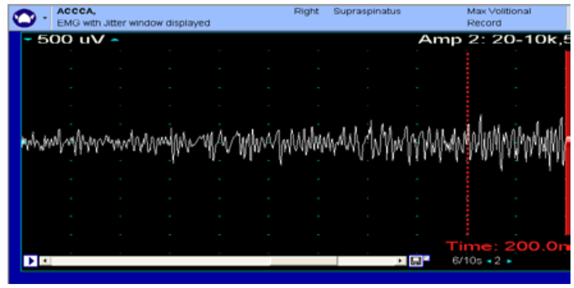


Fig. 9 EMG signal at the Supraspinatus Muscle

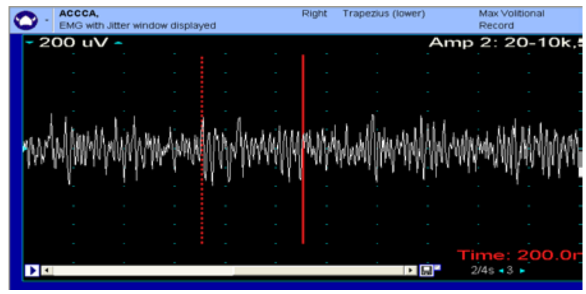


Fig. 10 EMG signal at the Trapezius Muscle

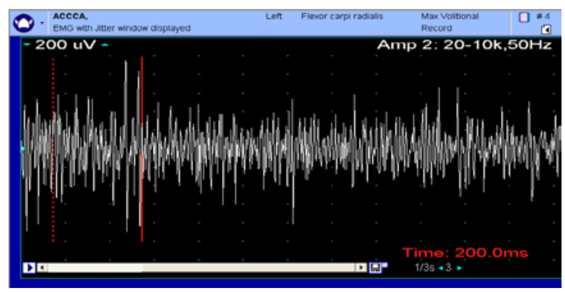
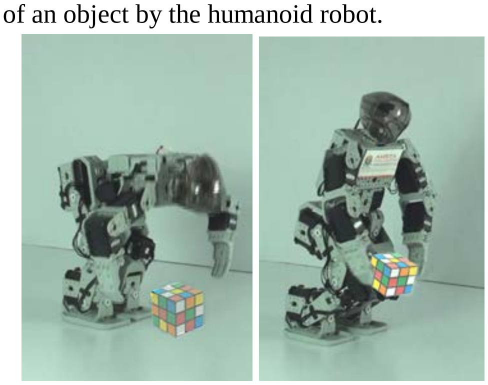


Fig. 11 EMG signal at the flexor carpi radialis Muscle

For example, the two signals form biceps and flexor carpi radialis muscles are taken for recording the action of closing and opening the fist. The actions performed on producing these gestures are shown. Fig 12(a) shows the bending of the humanoid robot for picking an object and Fig.12 (b) shows the picking of an object by the humanoid robot.



(a) (b) .

Fig. 12 Humanoid robot actions. (a) Bending for picking the object. (b) Picking and moving back to initial position.

A collection of such waveform commands are taken and are sent to the arduino microcontroller. The microcontroller is programmed to send instructions to the humanoid robot to perform a specific job like picking objects. When we curl the fist or open the fist, it commands the humanoid to bend and pick an object. It is observed that the humanoid robot is capable of doing the pick and place and movement actions without much delay and the performance is satisfactory.

VI. Application

Electromyography signals are used in many biomedical applications. Its use with the humanoid robot can bring up many applications that include first-responder purpose for the army, i.e., during any terrorist attack, this humanoid robot with a camera could be sent for more precise and accurate movements at the instant for providing first-response. Such EMG controlled humanoid robots could also be used for diffusing bombs.

An interface device based on EMG could be used for controlling various devices with gestures recognized by observing the EMG activity of the associated muscles. Use of EMG can make it possible to program certain commands to the humanoid robot which can be triggered by the air gestures and a series of actions can make it perform tasks with much more fidelity. This method could hence be used by persons with spine injury to perform tasks for their self needs which help them stay self-relying up to an extent.

VII. Conclusion

The gesture controlled humanoid robot is programmed to ease the works of the human beings and get things done without much strain. Only small gestures are defined for conveniently performing bigger tasks.

The robot performs pick and place task and the performance results are found to be satisfactory. The Humanoid Robot is controlled by the technology of recording and decoding the gestures performed by using a muscle sensor and amplifying it and further control of the humanoid robot is taken over by the arduino microcontroller through a zigbee wireless interface.

Humanoid Robot can replicate the complete action similar to humans by incorporating EMG electrodes at main muscle group of the human body. This model can be a very significant device in the areas where direct interference of human being is quite impossible; hence it would be a very useful topic to do further research on it.

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