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MEMS Accelerometer based control of Prosthetic Hand

Deepika Princess D., Priya R. and Mohan Jagannath
Department of Biomedical Engineering, SMK Fomra Institute of Technology, Chennai, Tamil Nadu, INDIA

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Abstract

The main objective of prosthetic is to replace, as close as possible, the functional capacity formerly held by limb deficient person. The art of life is to show your hand. Various designs are available based on mechanical, electrical and myoelectric. In all such existing designs remain the drawbacks, such as complex mechanical setup, sensitive sensor and non-recognition of objects. Another factor that includes with it is cost. In this paper, we design a prosthetic hand with two fingers, thumb and index fingers, which do the basic operation such as grasping and holding operation. These operations are identified by the identifiers that recognize the finger motion based on surface MEMS accelerometer. This will reduce the cost and complexity of the design. This can be improved further for more operations. This hand can further be implemented as robotic hand in the medical, for Tele-surgery.

Keyword: Prosthetic hand, MEMS based identifier, MEMS accelerometer, adaptive sensor.

Introduction

The hand is where the mind meets the world. It's a part of way of expression. People who suffer from this amputation feel the pain of lost. The loss of limb has great impression on the person's social status as well as the psychological pressure. The cost is one of the factor, that gives how well limbs perform and how cosmetically appealing, other factors includes the skills that technicians have to make the limbs, and the materials for fabrication. These give the properly fit limb which shows the result of a close working relationship between the prosthetist and the patient. Ultimately, the design and fit of the socket is what determines the patient's acceptance, comfort, suspension, and energy expenditure. There are technologies to replace the loss of hand, but all these holds difficulties and drawbacks.

Myoelectric Arm: Prosthetic hands are available in various designs. One of the existing systems is the myoelectric arms[1]. It uses EMG signal for its stimulation from the stump of the amputee. Those myoelectric signals are pulled out from the surface of the muscles using electrodes. The movement of the hands is controlled by the motor which is driven by the pulses generated by using the microcontroller. This system uses EMG in electrical control system and linear approach in mechanical system. When definite muscle group gets contracted it provides grasping functionality. Like this for each activity some corresponding functions should be stimulated.

This system provides a light weight and compact myoelectric arm in which the myoelectric signals are read by the myo electrodes. These myoelectric signals are amplified and processed to measure the muscles electricity. Using suitable sensors these EMG signals[2] can be acquired. The processed signals are designed to control the degree of freedom in prosthetic limb. EMG signals are usually of low amplitude (10Hz-500Hz) which contains user intention information. For different motions of user, multiple EMG channels are used to acquire each data using corresponding electrodes.

Here disc electrodes (Ag/AgCl) are used. It should be placed on the surface of the forearms by using a conductive paste. When there is a change in the forearm muscles there evokes an action potential due to the large fibers in the forearms. The EMG signal is allowed for amplification, filtering and rectification. The final processed signal is given to microcontroller and using ADC, the analog signal is converted to digital one. The output from the microcontroller is used to drive the servo motor for intended functions. The motors are controlled by the external driver circuits.

The output of the motor makes the prosthesis to rotate with corresponding functions. The drawbacks of this existing system are as follows. The EMG sensor is unreliable due to the artifacts, wire breakage can occur. There is an inconvenience in doffing and donning of electrodes and the maintenance of skin should be difficult. Due to these drawbacks this system is not so popularized in the market.

Biomimetic Design: Prosthetic hand based on Biomimetic design[3] is another existing system which uses prototype 1.0. In this system the prosthetic hand mimic the natural hand. This prosthetic hand is designed by comparing it with the functions and properties of the natural hand. This system is also based on the EMG signal for its function. It has 15 degrees of freedom. It is designed to give six grasping functionalities of hand such as to give power to hold an object, Palm-up, to act as hook, Oblique, Precision and to pinch.

This Biomimetic approach is used to overcome the poor functionality and low controllability of the previous systems. Based on this approach an upper limb prosthesis controlled by EMG signal is designed. Prototype 1.0 is developed by carefully analyzing the biomechanics of human hand (structure, operation, functionality and control mechanism) and its properties. Then selection of Materials is analyzed. After analyzing the requirements the expected properties are developed using the prototype 1.0. This is called Biomimetic approach.

The prosthesis based on this approach consists of five fingers which are designed to do the six functionalities. A DC gear motor is embedded in the palm which forms the grasp modes by its inward and outward movement. The material used for the fabrication of skeletal structure is Nylon. When compared with Teflon, Steel and Aluminum nylon is the best suitable and cost effective than all materials.

Finally all the requirements are assembled in one unit. This prototype is compared with the human building block where all the properties are more similar to each other. The designed prototype weighs about 520g. The whole system is actuated by extracting EMG signals from the subject. Finally this prosthesis exhibits all geometrical functions of the hand.

This system has a very complicated design. It takes long time to mimic the natural hand. It is unable to implement the abduction and adduction functions. The mechanical set up is difficult to understand. It provides less comfort to the patients.

Bebionic and Ilimb Hands: The hand named iLimb[4] is the commonly available prosthetic hand released by Touch Bionics. It is designed based on the individual fingers known as digits. The motors and the gear box are implemented for each finger. A person missing partial fingers can also use this design. In this set up it has a spring linkage which prevents the damage of the hand from hitting in to a hard object. It has totally 5 degrees of freedom and 14 grip patterns. It included open and closure of the hand using EMG signal from the muscle of the remaining amputee. The BeBionic[4] hand is very similar to the iLimb design which is developed by RSL Steeper. It is designed in such a way to reduce the cost of the previously established model. But both models have the same functional drawbacks. However it has many drawbacks such as it doesn't provide force feedback to the user. So the precision task is difficult to perform. Because of the difficulty in precision it doesn't provide grip to hold the object. So the object will be dropped easily.

The above stated designs hold drawbacks which is still a hazard to the patients, in the mean of amputation. To relieve them, we propose this design of prosthetic hand.

Methodology

The main problems for prosthetic limb in most of the countries are lack of skilled persons to update, no proper construction for fitting, and aligning, and for wearing it up and removing without hurting needs more training. Though there are more demand for this, there is a very few training mobilized. Studies by the World Health Organization (WHO) indicate that while the current supply of technicians falls short by approximately 40,000, it will take about 50 years to train just 18,000 more skilled professionals[5]. The other factors to be kept in mind are the cost factor, this is important to be analyzed for the society. And for individual satisfaction, cosmetic issue will also lay its hand. To overcome all the difficulties in the existing method, in this paper we have implemented a new design of prosthetic hand with two fingers, thumb and index finger which implements fundamental motions, such as grasping and holding, required in daily life.

In order to control each finger of the developed Prosthetic finger independently, an identifier which recognizes the finger motions based on the surface MEMS accelerometer, and recognition rate of the finger motions was examined. And an adaptive sensor is used to recognize the object.

An accelerometer is a device that measures the vibration or acceleration of motion of a structure that measures the changes in speed of anything that is mounted on it. It is an electromechanical device that measures acceleration forces which may be static like the constant force of gravity pulling at our feet, or they be dynamic could be caused by moving or vibrating the accelerometer. The MEMS sensor used in this is accelerometer whose axis is used for doing the fundamental action. The Accelerometers are available in one, two or three axes. Here we are using with two axes. When the axis is X then it does the action of grasping and if the axis is Y then it does the action of holding. To identify the object, that is, to recognize the object we implement an adaptive sensor for the identification operation. The microcontroller used here is PIC, which has the inbuilt analog to digital converter and helps for the UART interface.

This proposed method can be further improved for many more operations. This method is an advanced vision of the existing systems that has a drawback in sensitive sensors such as myoelectric sensor and complex training procedures with non-recognition problems. The person with both hand amputations can use this low cost device for their fundamental operation, Grasping and Holding. This will replace their natural hand loss. Thus it will be the best design of the prosthetic so far implemented.

Mems accelerometer: Most accelerometers are Micro Electro Mechanical Sensors (MEMS). The basic principle of operation behind the MEMS accelerometer is the displacement of a small proof mass etched into the silicon surface of the integrated circuit and suspended by small beams. Consistent with Newton's second law of motion (F = ma), as an acceleration is applied to the device, a force develops which displaces the mass. The support beams act as a spring, and the fluid (usually

air) trapped inside the IC acts as a damper. Under the influence of external accelerations the proof mass deflects from its neutral position. This deflection is measured in an analog or digital manner. Most commonly, the capacitance between a set of fixed beams and a set of beams attached to the proof mass is measured.

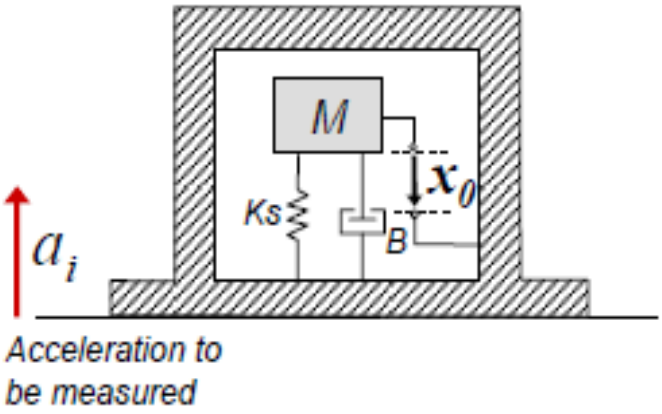

Figure-1
Accelerometer working operation

The 3 axis accelerometer is based on the principle of capacitive sensing. The figure-1[6] shows basic principle of accelerometer sensor. The sensor is made of spring loaded, micro machined structure, mounted on silicon base. Force on the structure changes the position of seismic mass attached on the spring. This deflection is measured using fixed plate capacitor sensors. The change in acceleration unbalances capacitor plate distance, observed by modulation/demodulation circuits and thus, resulted in output proportional to acceleration. The sensing can be static (gravity) or dynamic (forced acceleration). The MEMS accelerometer which is used in this is ADXL330 which are low cost, low power, complete 2axis accelerometers with a measurement range of either ±2 g/±10 g. The ADXL330 can measure both dynamic acceleration (e.g., vibration) and static acceleration (e.g., gravity). The outputs are digital signals whose duty cycles (ratio of pulse width to period) are proportional to the acceleration in each of the 2 sensitive axes.

Working Process: The objective of our work is to design a prosthetic hand that has two fingers which can do two fundamental motions, such as grasping and holding operation. To accomplish our objective, we have designed using the MEMS accelerometer that acts as the identifier of the fundamental motions such as grasping and holding. Figure 2 depicts the block diagram of the design. Here we are using two axes fashion, if the axis is X, then it does the grasping operation and if the axis is Y, then it does the holding operation. The MEMS surface sensor identifies the angle and gives as an analog signal, which is converted into digital signals and given to the microcontroller.

The Microcontroller used is PIC16F877A, initially we were using basic 8051, which lacked inbuilt A/D conversion, and for the analog to digital conversion and for UART operation, PIC microcontroller is used. This was tested with the UART, MAX232 to find how reliable the motors are. And the input from the MEMS sensor can also be checked with the UART. The Motors used in this is stepper motor, we are using seven motors for the correct flexibility of holding operation. Three motors are placed along the index finger and two motors in thumb finger and other one between the two fingers. Since stepper motor has a advantage of operation of step moment. This will be used for the exact holding posture of the object. For the fabrication, we are using Surface Mount (SMT) technology. This will give good cosmetic appearances.

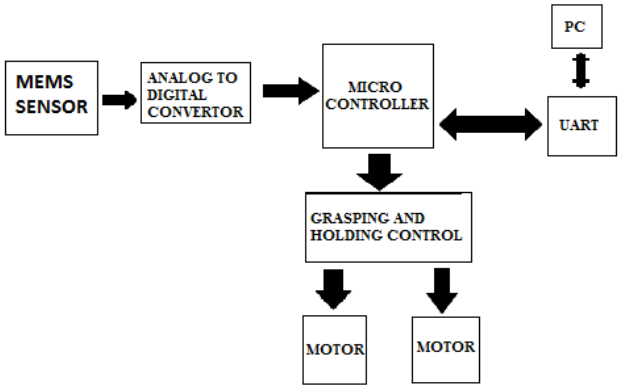

Figure-2
Block diagram of the design

Results and Discussion

With the implementation of MEMS Accelerometer, adaptive sensor and seven motor systems will provide a best operation of the fundamental motion of hand - grasping and holding. The flow of process is shown in the figure 3, which will give a clean view of the signal process.

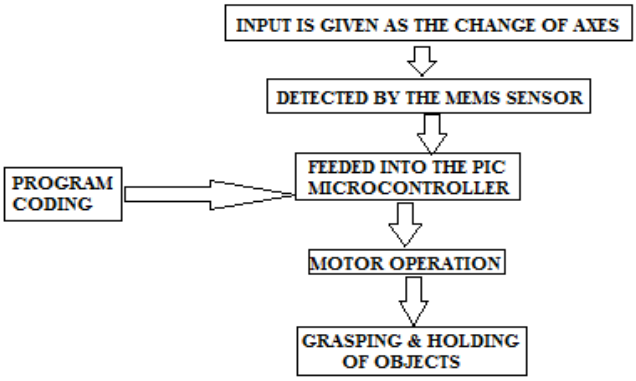

Figure-3
Flow of operation of signal

The Result may be similar to the natural hand operations. Further this technique can be implemented to all the five fingers with various operations. Thus this method not only will relieve the person from the loss of hand, it will also reduce the cost and training period. And this can also be implemented in the field of surgery as robotic hand.

Conclusion

The design of prosthetic hand using EMG signal to control has been historically unreliable of the surface EMG sensor because of artifacts, wire breakage, inconvenience of doffing and donning electrode, maintenance of the skin condition, and repeatability of electrode placing. And yet other designs have pros and cons. Our design of prosthetic hand will be able to make a wide difference among the society. This not only can be used for the prosthetic replacement, it can also be used as robotic hand in surgeries too. It can also incorporate many further operations. Thus it is the apt design of prosthesis.

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