Prosthetic Upper Limb

Introduction

Many people lose their hands and/or legs as a result of accidents or due to complications arising out of diseases or post-operation infections. Amputation of a person's body part influences the life of affected psychologically as well as physically. Every year 1,250 new hand amputations are registered in the United States of America. Although statistics are not available for Pakistan, institutions like the Armed Forces Institute of Rehabilitation Medicine (AFIRM) Rawalpindi reveal that the numbers of hand amputation cases in Pakistan are on the increase. Currently, rehabilitation of such people is mostly done with the help of dummy limbs made of wood, plastic and/or other light materials.

The project of developing an upper prosthetic limb is a joint venture between Armed Forces Institute of Rehabilitation Medicine (AFIRM) and NUST, College of Electrical and Mechanical Engineering. The basis of this venture is to facilitate military personnel who have lost arm(s) in combat or any other mishap. We aim to provide a locally manufactured, functionally optimized and economically affordable solution to upper limb amputees in Pakistan. At Department of Mechatronics Engineering, we are currently targeting both above elbow and below elbow amputees by developing appropriate prosthesis which includes automated hand grips and elbow joints.

Uniqueness of the project:

Upper limb prosthesis is still a completely un-explored field in South Asia since no product has yet been developed. Currently, there is no institute in Pakistan which is fabricating functional prosthetic upper limbs which was one of the main reasons of for starting the project. The few rehabilitation institutes which are providing prosthetic upper limbs acquire them from international companies on demand from the patients. But this is a rare case, as the cost of such limbs is extremely great and so the majority of amputees either prefer no prosthesis or the cosmetic prosthesis which is a static attachment with the appearance of a hand.

Prosthetic Upper limbs available all around the world can be characterized into two main categories namely the body powered and the externally powered prosthetic upper limbs. The body powered limbs usually require the amputee to wear a harness around the shoulders which provides a physical connection between the artificial hand and the amputee's shoulder through a string. As the amputee pushes his/her shoulder forward, which requires considerable force, the grip of the prosthetic hand opens and vice versa. Externally powered limbs, however, are brain controlled but very costly. In the course of the project, we have developed four different prototype limbs which are briefly described below:

a. Myo Electric Prosthetic Upper Limb

Initially a Myo Prosthetic Upper Limb was designed and manufactured which was regarded as one of the top rated undergraduate projects of the University. This

below elbow prosthetic limb used brain signals from motor points as input to control the actuation of the hand grip and wrist rotation. This limb was tested on a patient and allowed him to voluntarily control the motion of the prosthetic hand for doing complex tasks like picking and releasing objects.

Figure 1. On the left: Testing the Prototype on the Patient. On the right: The fabricated robotic hand

b. Inertial Sensor based Prosthetic Upper Limb

To develop a more reduced cost solution, another approach which used accelerometer sensor was implemented. This technique required the patient to use head movement for the opening and closing of the grip. The results of this project were also very encouraging according to the feedback from the amputee. This limb had lesser electronic circuitry and low cost making it compact as well as affordable.

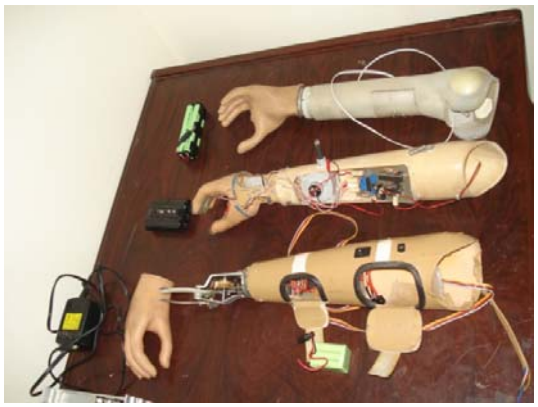

Figure 2. The different developed Upper limb prototypes

c. Automation of Conventional Prosthetic Upper Limb

Another idea for giving below elbow prosthetic limb a product oriented shape was to automate the conventional body powered limb. The goal of attempting his strategy was to maximize easy and comfortable actuation of the grip by the amputee. The fabricated limb allowed the patient to activate grip by extending the

opposite shoulder forwards which was sensed by the transducer and used as an input by the embedded circuit. An array of feedback sensors on the finger tips allowed the prosthetic hand to automatically detect if an object was held with sufficient strength to be picked.

d. Above elbow Prosthetic Upper limb

Along with the below elbow prosthetic limbs described above, we are also developing robotic arms for above elbow amputees. This requires addition of an automated elbow joint along with its actuation sensors and electronic circuits. The developed limb required the patient to press soft switches placed in the armpits for controlling both the elbow joint and the grip.

Figure 3. Testing the above elbow limb prototype on an amputee

The final Product form and its advantages:

With our research and experience, we have finally been able to develop a fully functional below elbow prosthetic limb which is a hybrid between body powered and externally powered prosthetic upper limbs. Details of the developed product follow:

Figure 4. The finalized prototype of below elbow prosthetic hand

a. Technical Advantages

Our prototype uses the physical design of conventional body powered limb, with a motorized gripper and a small electronic circuit, to provide the patient an easy to use and cheap upper prosthesis solution. We have not only mitigated the force required to actuate the limb but our prototype also allows the user to pick objects with voluntarily controlled gripping force just like the brain controlled limb. During the project, we have been in continual contact with doctors at Armed Forces Institute of Rehabilitation Medicine (AFIRM) and have their positive feedback about our work. The doctors believe that our prosthetic upper limb provides all the requisite functionality and is ready for production. Apart from certain electronic components, most of the project items can be acquired from the local market. This is one of the major factors which can help ease the process of bringing this project as a product in the market. We have tested our prototype on patients from AFIRM and have found very good response.

b. Economic Advantages

The overall estimated cost of our prototype is Rs. 47000 which when compared to any externally powered prosthetic upper limb manufactured by different companies around the world is smaller manifold. The actual cost of a myo–electric arm from Otto Bock, an international company, is around USD 80, 000 or PKRs 4,800,000. Yet they have a definite impact upon the lives of the disabled people. We believe that our product will find customers in local as well as international market.

c. Design Advantages

Around the world, the two major concepts seen in the making of prosthetic limbs is that either they are myo-electric (brain controlled) or body powered. However, we have used a novel concept in our design which has made it easier to reduce cost as well as make the training of the amputee easier. Our prototype requires the patient to use his healthy shoulder for actuation of the gripper, just like the body powered limb, but with enormously reduced actuation force. This helps us bypass the complex and costly interface of the embedded electronic system with the brain and give the patient a comfortable source for actuation. On the other end, the embedded electronic system appropriately drives the motor enabling the gripper to open or close with enough gripping force to hold various commonly used items such as a glass owater. The patient can grip objects of various sizes and also control the magnitude of gripping force through his shoulder movement.

Competitors around the world:

The companies around the world which deal in upper limb prosthesis are:

a) Otto Bock (Germany)
b) Motion Control Inc. (USA)
c) Touch Bionics (Scotland)