Chapter two
Literature review

2.1 Introduction:

In the domain of handicapped people, the amputees are one of the most important groups in the world. The aim of developing prostheses is mainly to improve their conditions of life and to help them recover independence and dignity [1]. Replacing an amputated limb is a complex problem, as it is necessary to replace the osseous structure, to collocate a locomotive system and to give to the prosthesis a command system. The real challenge for the engineering is to make the system occupy the same space that the arm occupied originally, to make it weight less than it weighted before, to make it produce a similar force to that produced by a sound am and in addition to control the whole system by a simplified control scheme[1].

A prosthetic limb is an artificial device that replaces a missing body part. A limb may be amputated or missing because of a blood vessel disorder (such as atherosclerosis or damage due to diabetes), cancer, an injury (as in a motor vehicle accident or during combat), or a birth defect. In the United States, slightly less than 0.5% of people have an amputation. However, the percentage is likely to increase in the coming years because atherosclerosis and diabetes have become so widespread, as has obesity. Obesity increases the risk of atherosclerosis and diabetes and thus may contribute to an increase in amputations [1].

2.2 History of prosthetics:

The evolution of prosthetics is a long and storied history, from its primitive beginnings to its sophisticated present, to the exciting visions of the future. The long and winding road to the computerized leg began about 1500 B.C. and has been evolving ever since. There have been many refinements to the first peg legs and hand hooks that have led to the highly individualized fitting and casting of today's devices. But to appreciate how far the prosthetics field has come, we must first look to the ancient Egyptians [2].

Prosthetic care goes back to the fifth Egyptian Dynasty (2750-2625 B.C.); archaeologists have unearthed the oldest known splint from that period. The earliest known written reference to an artificial limb was made around 500 B.C., Herodotus wrote of a prisoner who escaped from his chains by cutting off his foot, which he later replaced with a wooden substitute. An artificial limb dating from 300 B.C. was a copper and wood leg unearthed at Capri, Italy in 1858 is shown in figure 2.1. In 1529, French surgeon, Ambroise Pare (1510-1590) introduced amputation as a lifesaving measure in medicine. Soon after, Pare started developing prosthetic limbs in a scientific manner. In 1898, Dr. Vanghetti invented an artificial limb that could move with through muscle contraction. In 1946, a major advancement was made in the attachment of lower limbs. A suction sock for the above-knee prosthesis was created at University of California (UC) at Berkeley [2].

Figure 2.1: Copper and wood leg

2.3 Modern Prosthetics:

How do modern prosthetic limbs compare to those of historical times? One major difference is the presence of newer materials, such as advanced plastics and carbon-fiber composites. These materials can make a prosthetic limb lighter, stronger and more realistic. Electronic technologies make today's advanced prosthetics more controllable, even capable of automatically adapting their function during certain tasks, such as gripping or walking. Additional materials have allowed artificial limbs to look much more realistic, which is important to Trans-radial and Trans-humeral amputees because they are more likely to have the artificial limb exposed [3].

In addition to new materials, the use of electronics has become very common in artificial limbs. Myoelectric limbs, which control the limbs by converting muscle movements to electrical signals, have become much more common than cable operated limbs. Myoelectric limbs allow the amputees to more directly control the artificial limb. Computers are also used extensively in the manufacturing of limbs [3].

Advancements in the processors used in myoelectric arms has allowed for artificial limbs to make gains in fine-tuned control of the prosthetic. The Boston Digital Arm is a recent artificial limb that has taken advantage of these more advanced processors. The arm allows movement in five axes and allows the arm to be programmed for a more customized feel. Raymond Edwards, Limbless Association Acting CEO, was the first amputee to be fitted with the I-LIMB by the National Health Service in the UK [3].

2.4 previous works:

Daniel Graupe et. al., employs parallel filtering to discriminate between the various limb functions of interest to achieve fast discrimination and control as required for practical applications, since this allows the identification itself to be performed off line. Intel 8080 microprocessors at double precision (incorporating hardware multipliers), have yielded an 85 percent success rate in discrimination between four to five limb functions using a single electrode [4].

H.T. Law et. al., an electrically driven locking mechanism has been built, which is controlled by the electromyogram (EMG) of the surviving, muscles in the upper arm. Hybrid technology is suited for the construction of the associated electronic circuitry. Many similar applications are now being considered in attempts to improve the performance of upper-limb prostheses [5].

HaeOck Lee et. al., discussed externally powered upper extremity prosthesis as a system. The necessary components to design a better prosthetic arm are divided into four subsystems: input, effecter, feedback. Current research is reviewed in terms of these subsystems. Each subsystem performs its own task, but they are related to each other and together they function to make up a prosthetic upper extremity, which provides the movement to the amputee [6].

Shuxiao Wang et. al., presents a robotic arm for stroke patents. Two SEMG (Surface Electromyography) signals collected from bicipital muscle and triceps muscle of arm, which are used to control robotic arm. When patients want to flexile arm, the SEMG signal of bicipital muscle is larger than that of triceps muscle. On the other hand, when patient want to extend arm, the SEMG signal of triceps muscle is larger than that of bicipital muscle. The robotic arm's rotation direction is decided by the difference of two SEMG signals. The torque and speed of the robotic arm are controlled by the amplitudes of SEMG signals. The system is based DSP (Digital Signal Processor). H-bridge is used to drive DC motor [7].

Hiroyuki Takeda et. al., developed a novel prosthetic arm with a five-fingered prosthetic hand using our original pneumatic actuators and a slender tendon-driven wrist using a wire drive and two small motors. Because the prosthetic hand's driving source is comprised of small pneumatic actuators, the prosthetic hand is safe when it makes contact with people; it can also operate flexibly. In addition, the arm has a tendon-driven wrist to expand its motion space and to perform many operations [8].

Deepak Joshi et. al., discussed the trends undergoing in all the various steps involved in EMG (Electromyogram) based prosthetic hand development. In order to overcome some limitations of current prosthetic hands mainly related to the proper functionality and controllability, the prosthetic hand has been designed following a biomechatronic approach based on biologically inspired design solutions. The majority of electrically powered prosthetic hands are based on a simple design that limits motion to one degree of freedom. Designs of multi-articulated prosthetic hands have had limited success due to their complexity and number of mechanical components. Classical EMG (myoelectric) controllers have failed in the past, since they were based on only determining existence or non-existence of an EMG signal. Recent work has approached this multifunctional control problem using a large number of electrodes, though still considering only a limited part of the EMG spectrum [9].

Tanmay Pal et. al., on-line characterization system has been developed for DC motors. These sensitive applications require high precision and high speed of response. The system has been programmed on ARM microcontroller, it actuates DC motor and automatically collects data while it is being accelerated and attains a steady speed ; the embedded routines process it instantly and returns the current values of inertia, friction coefficient, back-emf constant and torque constant. A prototype system for DC motor control has been developed in laboratory, it has been characterized and control experiments have been performed [10].

Hardeep S. Ryait et. al., SEMG signals can be detected by sensors placed over the skin surface onto the muscle tissue. Here single electrode is used with SEMG signal as actuator. Muscle activities from a single location (over group of muscles near triceps brachii) on arm during gripping and elbow movement were carried out. The electrode was placed on the upper arm, one hand width under the armpit. Movements were analyzed by deriving RMS values from the acquired SEMG. The microprocessor controlled prosthetic arm is designed to perform the operation of gripping [11].

2.5 Prosthetic Arm:

A prosthetic limb is an artificial device or a replacement of missing body part. A prosthetic arm is a fake arm for those who amputated their arm. Earlier Armorers used prostheses mainly in battle to hold sword and shield. The Alt-Rupp in hand was a typical hand that used springs and push button to hold and release fingers. Modern prosthetic principles evolved after Second World War. In 1949 first myoelectric switch was developed. Earlier body powered prosthesis components have not much changed because most of the research has focused on externally powered prosthesis and high cost of manufacturing investment [12].

The number of the handicapped has been increasing due to many reasons like traffic accidents, accidents in workshops and diseases. Hand parts are very important parts and have complicated functions. Loss of these parts makes humans anxious and causes many functional troubles. The prostheses with the same performances as natural upper extremity shall make the physical handicapped have the same daily life as they had one before they lost their extremities. Thus it is hoped to make the prostheses serving for their lost one. Recent advancements in technology of mechatronics have helped us develop the mechanism of the externally powered upper extremity prostheses close to that of natural extremity. At present, the prostheses with multi degree-of-freedom and multi-function have been studied. There are many actuators which are electric-motor, gas pressure cylinder, hydraulic cylinder, and so on [13].

In the United States 41,000 persons are registered who had hand amputation or a complete arm. There would be 1,000,000 such persons worldwide with the same frequency of occurrence [3]. Main factors for a loss of an upper extremity are accidents followed by general diseases and injuries from war. The loss of an upper limb results in a drastic restriction of function for an individual. Therefore, in the last 3 decades an increasing number of handicapped persons have been provided with prosthetic hands that have the shape of a human hand. However, surveys on using such artificial hands revealed that 30 to 50% of the handicapped persons do not use their prosthetic hand regularly. The main factors for the rejection of conventional prosthetic hands were:

- Heavy weight: although commercial prosthetic hands have about the same mass as human hands they appear to be unpleasantly heavy because the mass is transmitted by a lever arm to the short stump of the amputated arm.

- Low functionality: The gripping abilities are restricted with the conventional prosthetic hand as it can only perform a single pincer-like grip movement. The fingers have only one degree of freedom and cannot adapt to the shape of an object. The consequence is an increased force that is necessary to hold an object stable.

- Robot-like movement: Movement appears unnatural because of limited DOF

To overcome these disadvantages a lot of efforts have been done worldwide [14].

2.6 Prosthesis in the World:

The different prostheses developed by the main prosthetic societies: UTAH, OTTA BOCK and PROTEOR concentrate 90% of the market. These are classified in three categories namely; aesthetics prostheses, mechanical prostheses and myoelectric prostheses [15].

2.6.1 Aesthetics Prostheses:

This type of prosthesis is generally used by patients and their aim is only aesthetics. The prosthetic part is created from a standard mould and resemblance to the healthy member. This kind of prosthesis does not carry out any movement. It only serves to restore the patient body appearance. This kind of prosthesis is for instance manufactured by the OTTO BOCK society.

2.6.2 Mechanical Prostheses:

Currently three kinds of mechanical elbow products are offered to the patients. This kind of prostheses tries to approach the functionality of the lost member. It can be manual (use with the assistance of the healthy member) or with cable [15]. The first kind is the elbow with toothed rack. The pushbuttons are actuated by the valid hand or by a cable. Many drawbacks are attached to this mechanical elbow such as noise of the toothed rack, the limited number of positions of the front arm and the bad aesthetic of the pushbutton.

The second kind of elbow is the elbow with friction. This moves on the friction of a spiral spring on the axis of the elbow. A cable ordered by the other shoulder actuates blocking: one traction locks it, another unbolts it. It maintains the position less firmly but more functional than the previous. In addition, it needs a double order from the amputee, which is not always easy to carry out.

The third kind is an automatic elbow from OTTO BOCK. The front part is manufactured out of plastic and is not very solid. Its distal part (near to the wrist) is cylindrical and is simply cut to the length of the healthy member.

2.6.3 Myoelectric Prostheses:

Myoelectric signals (Electromyogram or EMG) are electrical signals that are registered from the muscles activities. A great number of applications are possible with these signals. The functional motor activities can be measured by placing the surface electrodes directly on the skin. The EMG signals are complex with noise and they are easily influenced by many factors. Then, from the interpretation to the use, the EMG needs several specific treatments. The consequences of the Viet Nam war were at the origin of the development of the UTAH products. This society was the first to propose the EMG technology to control the prosthesis. The OTTO BOCK society also proposes prosthesis of hand coupled with a myoelectric elbow. Unfortunately, the whole system proposed by this society is too expensive for patient. The hand is a tree legs grip with an aesthetic glove [15].

2.7 Types of Prosthetic Arms:

Prosthetic arms may be categorized as:

- Mechanical Arm.
- Electrical Arm.
- Hybrid Arm.
- Myoelectric Arm.

2.7.1 Mechanical Arm:

Mechanical prostheses are functional prostheses that use some motion of the body to exert the force required to control the prosthetic component. Bowden cable is used in the prosthetics field. It consists of an inner core cable that is free to move within a sleeve cable which is fixed in place at either end. These devices require a harness, to be worn about the shoulders, to which one or more Bowden cables are attached. These prostheses are also lightweight, durable and of relatively low cost. However, body-powered prostheses have a number of shortcomings. The major issues are the uncomfortable harness mechanism, the somewhat ungainly control motions, particularly in the case of above-elbow prostheses, restricted range of motion and limited load-lifting capacity [16].

2.7.2 Electrical Arm:

These are externally powered devices. They receive their power from an external electric source to the body. These are relatively new (last 15 to 20 years) addition to the armamentarium of prosthetic devices.

(a) ***Touch Switches:*** A pair of touch switches remains in contact with antagonistic wrist muscles flexors and extensors. The wrist flexors activate the 'CLOSE' switch while extensors operate the 'OPEN' touch switch.

(b) ***Control Circuit:*** Each micro switch is connected to a Flip-flop which is configured to operate in set-reset mode. It is 'SET' by the micro switch and 'RESET' by the limit switches provided at the extremities of hand positions

(c) ***Control Relay:*** A relay working at 6V or 9V operates the motor. When the flip-flop has one polarity, DC voltage is applied by the relay to the motor and the motor rotates in one direction. When flip-flop output changes its polarity due to operation of second touch switch, the relay also changes the polarity of DC voltage being applied to the motor.

Consequently, motor rotates in opposite direction. In this way, the hand closes and opens.

2.7.3 Hybrid Arm:

When body-powered and externally powered systems are linked together they are called hybrid systems. Hybrid systems are used most frequently with persons who have amputations above the elbow or who have bilateral arm amputations. Such systems can provide the user with high gripping and/or high lifting capacities of powered systems and fine control of body power. Providing the amputee with a body-powered limb on one side and an electric-powered limb on the other side, they enable the wearer to use the limb that is most appropriate for a specific task. This method also enables the limbs to be operated independently of each other i.e. the body motions required to operate the body-powered side do not influence the state of the powered side of limb and vice versa, as they are decoupled [16].

2.7.4 Myoelectric Arm:

The electrically powered prosthesis under the control of myoelectric signals from residual muscles did not become commercially available until late 1960s and did not gain widespread clinical acceptance until the early 1980s. Myoelectrically controlled upper limb prosthesis offers the highest level of rehabilitation available today. Myoelectric signals are produced by a muscle when it contracts.

- Three surface electrodes are generally used in this type of arm, one acting as reference electrode, another as active electrode and the third as ground electrode. The difference signal between reference and active electrode is processed to reduce noise in the system.
- The frequency range of EMG signal which shows change with opening and closing of hand is 10 to 500 Hz and is dominant in the 50 to 150 Hz range.
- A normally innervated muscle shows no electrical activity at rest. These signals provide important information on the physiological status of the skeletal muscle and its nerve supply. The intensity of EMG signal increases as the muscle tension increases.
- There are two sets of muscles in forearm which get activated whenever an object is grasped or left by our fingers. These muscle groups are called flexors and extensors. In myoelectric prosthesis, it is achieved by making the use of these two muscles to open or close the terminal device. The electrodes accommodated in the prosthetic socket pick up the signals from these muscles which after conditioning are used to control the prosthesis [16].

Prosthetic arm is one of the main requirements for those persons who have lost their arm due to some mishap. The main requirement of prosthetic arm is to provide the functionality of the natural hand.