Chapter 1
Neuroprosthetics:
Introduction

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ABSTRACT

Neuroprostheses use electric stimuli to stimulate neural structures, muscles, or receptors in order to support, augment, or partly restore the respective disordered or lost function. The objective is to help the patient to participate in everyday life. The use of a neural prosthesis can improve the quality of life of the person concerned. The future of neuroprosthetics is challenging as well as interesting as it deals with several latest technological advancements that connect both biology and technology together. This chapter briefly explains the current advancements and future challenges related to Neuroprosthetics research.

INTRODUCTION

Neuroprosthetics is a fast-growing area that brings together Biomedical Engineering and Neuroscience and seeks to interface the neural systems directly to prostheses. The main objective is to restore motor, sensory, and cognitive functions. Neuroprosthetics are electrical stimulation technologies that replace or assist malfunctioned neuromuscular system and attempt to restore the normal body functions. These devices are either implanted or worn (like wrist band or head band) on the body. Some of the examples include intramuscular stimulation systems or implanted neuromuscular control systems (Finn & LoPresti, 2003; Hoffmann & Micera, 2011).

Neural prostheses are applied with the aim of compensating an existing motor or sensory neural dysfunction. They electrically stimulate neural information in the peripheral, spinal and central nervous system of human body to restore or replace neurological task. In this scenario, two information transfers can be distinguished. They are:

- **Inward Information Transfer:** This procedure involves activating any of the intact senses by proper stimuli or by direct electrical stimulation.

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- **Outward Information Transfer:** This method includes stimulation after recording biological information of certain muscle of neural activation (Hoffmann & Micera, 2011; Lee, Min, Jeong, Kim, & Kim, 2011; Mahmoudi, Pohlmeyer, Prins, Geng, & Sanchez, 2013).

Neural prostheses use Electroencephalography (EEG), Electromyography (EMG) interfaces to bypass dysfunctional pathways in the nervous system, by applying electronics to replace lost function. For example, cochlear implants use electronics to detect and encode sound and then stimulate the auditory nerve to allow deaf individuals to hear. It has several applications. Some of the major ones include the following:

- Brain machine interface for motor control.
- Brain activity monitoring for epilepsy prediction.
- Proprioceptive feedback for upper-limb prosthetics.

Neuroprosthetics design includes five main principles, which include:

- In human body, motor neuron information are presented in distributed manner;
- Multiple neuronal information can be extracted in real time;
- Neuroprosthetics design takes the advantage of plasticity of human body;
- Various neuronal information pattern encode the same movement; and
- Hence, recording few neuronal information is sufficient to extract the relevant neural information (Carmena, 2013; Ganguly, Dimitrov, Wallis, & Carmena, 2011; Kramme, Hoffmann, & Pozos, 2011).

APPLICATION OF NEUROPROSTHETICS

Neuroprosthetics has several applications. Some of the most frequently used neuroprosthetics applications are described below in brief:

Cochlear Implant

Cochlear implant is one of the widely used methods to restore hearing in young and old. This method enables the restoration of auditory imitations and speech commands. Using this method, deaf children are often be benefitted with hearing and speaking. The auditory nerve system has to be healthy and intact in order to use the cochlear implant system in human. Cochlear implant compensates for the lost function in the inner ear. In general approach, it is placed in the cranial bone behind the ear. A stimulating electrode is placed inside the cochlea. The number of channels and the cochlear implant electrodes determine the allowable bandwidth of speech signal. In order to achieve better quality, cochlear implant of each individual need to be optimised for audio/speech requirements. Cochlear implant is not practicable for individuals whose both auditory nerves are damaged (King, Nahm, Liberatos, Shi, & Kim, 2014; Kwon, Perry, Wilhelm, & Healy, 2012; Nittrouer, Caldwell-Tarr, & Lowenstein, 2013).

Cardiac Pacemaker

In recent years, Cardiac Pacemaker is regarded as one of the most frequently used neuroprosthetics device. It is mainly used for heart stimulation to compensate for any pathological changes such as cardiac arrhythmia. The effect of cardiac arrhythmia can be positively influenced by proper stimulation. For many years, cardiac pacemakers