Nerve and machine interface
The coupling of electrical devices to the human nervous system has long been the realm of science fiction.

However, technological advancements of the past several decades have now made this phenomenon a reality.
Nero-prosthetics

- CNS target
- PNS target
- Invasive
- Non-invasive
CNS-based interface

- **Nerve-Brain interface**
- CNS-based approaches attempt to restore motor function by directly deriving commands from the patient’s motor cortex.
Nerve-Brain interface

- EEG Signals
- Brain Activities
- Brain Computer Interface
- Control Signal

Examples of control signals include
- Keyboard
- Wheelchair
- Mouse

Control of brain activities through brain-computer interface.
Three necessary components

- Electrode: An interface with the nervous system must be developed
- Signal decoding
- External Devices
- Computer, the person’s own muscles, robotic arms, or even semiautonomous robots
Electrode

- Interface with central nerve system and record EEG signals.
The success of any BMI system depends on a significant degree on the choice of BMI decoders that extract motor parameters from the sample of neuronal electrical activity recorded in real time.
External devices
Invasive nerve interface

- **Implant in grey matter**

Advantages & Disadvantages:
- Measures neuronal activities **more effective**
- Might leave behind **irreversible lesions in the cerebrum**
Non-invasive technique

- Obtains a movement intent via surface (scalp) electrodes over the motor cortex.
- Using this approach, which avoids the risks associated with surgery.
- Relatively weak signals.
Non-invasive technique
History

- Research on BCIs (brain computer interface) began in the 1970s.

- Following years of animal experimentation, the first neuroprosthetic devices implanted in humans appeared in the mid-1990s.
Clinical applications

- Restoring damaged hearing, sight and movement

- EG:
  1. amyotrophic lateral sclerosis (ALS)
  2. CNS damage including spinal cord injuries
  3. stroke resulting in substantial deficits in communication and motor function.
Clinical application

- The most widely used neuroprosthetic device is the cochlear implant which, as of 2010, had been implanted in approximately 219,000 people worldwide.

- There are also several neuroprosthetic devices that aim to restore vision, including retinal implants.
Hearing implants make it possible for people with profound hearing loss to process sound and learn speech.

A device known as a cochlear implant has a portion positioned behind a person's ear,

1. Microphone
2. Speech processor
3. Transmitter receiver that converts sound to electric impulses

while another part is surgically placed under the skin. Electrode array
Retinal implants

- **Epiretinal Implants** (on the retina)
- **Subretinal Implants** (behind the retina).
- Retinal implants provide subject with low resolution images by electrically stimulating retinal cells. Such images may be sufficient for restoring specific visual abilities, such as light perception and object recognition.
Communication with locked-in syndrome

- LIS is defined as complete paralysis with one or a few voluntary functions left (usually small eye movements).
- TLIS consists of complete cessation of volitional control of all voluntary somatic–motor functions.
- Intact auditory and tactile perception and intact cognitive functions.
Communication with locked-in syndrome

- In a thorough review of the literature it was proposed that BCIs using P300 ERPs, SCPs, and SMR control could provide slow but effective *verbal communication* in all stages of ALS.
Movement restoration in stroke and spinal cord injury

- Hochberg et al. implanted a 96-microelectrode array into the hand region of the motor cortex of a tetraplegic patient.
- The patient learned to open and close a prosthetic hand distant from his own hand with intention-driven neuronal ensemble activity.
Movement restoration in stroke and spinal cord injury

- In 2003, Pfurtscheller et al. reported a tetraplegic patient who, after extensive training to increase and decrease central mu-rhythms was able to control an electrostimulation device (FES) applied to hand muscles.

- The patient was able to grasp a glass and bring it to his mouth after he had learned with feedback and reward over a period of 4 months to regulate his mu-rhythm.
Toward a whole-body neuroprosthetic

- Not only can BMI control motor functions by neuronal ensemble activity recorded with chronic implants.
- Recently they have demonstrated for the first time brain–machine–brain interfaces (BMBIs) that incorporate somatosensory feedback loops that transmit information from the actuator to the brain.

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Toward a whole-body neuroprosthetic

- Brain signals are processed by a powerful computer cluster and converted into commands that drive a life-like avatar
- brain-controlled whole-body navigation system will be eventually translated into a mind-operated whole-body exoskeleton.

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whole-body exoskeleton
Interface approaches for PNS

- Alternatively, outside the CNS
- typically take one of two forms:
  1. electrodes that are implanted in or around the damaged peripheral nerve
  2. electrodes that are implanted within, or on the surface of skeletal muscle
Interface approaches for PNS

- electrodes that are implanted in or around the damaged peripheral nerve
Interface approaches for PNS

- Earlier proposals for measuring peripheral nerve activity were based on
  1. the use of sieve electrodes
  2. needle point holder-shaped electrodes
  3. cuff electrodes
- unable to meet the requirement for low invasive and distinguish the activity of individual nerve fibers.
Interface approaches for PNS

- Kaneko, (AIST and Toyohashi University of Technology in Japan)
- selective Vapor-Liquid-Solid (VLS) growth technique
- electrode development using Nanotechnology widely accepted
Development

- Improved prosthetic devices
- Tackling some of mankind’s disorders
  - Deafness
  - Blindness
  - Paralysis
  - Epilepsy
  - Parkinson’s disease
The ideal neuroprosthesis

- should be a functional facsimile of the amputated limb
- facilitate continuous bidirectional communication between the CNS and the external environment.
- focus on the re-establishment of motor control, relying on visual feedback
The oldest known prosthetic devices, such as those found on Egyptian mummies in 710 BC, were made of papier-mâché and wood.

Today, different types of prosthetics are made with life-like precision and ultra-modern materials.
Cosmetic Prosthetics

- Reasons to choose cosmetic prosthetics
  1. Can use his remaining limb for all of his functional needs
  2. Unable or unwilling to undertake the training needed
  3. Much lighter for older or weaker patients
Cosmetic Prosthetics

- Restores only a limited portion of the functional aspects
- It can be designed to passively grip or hold light objects.
- First choice to replace a lost finger or partial hand
Body-powered Prosthetics

- A cable-activated prosthesis uses cables attached to a harness that secures the prosthesis to the patient.
- It depends on the motion of the residual limb to control and power the functions of the prosthesis.
- The amputation level will determine the complexity of the prosthesis.
Body-powered Prosthetics

- For higher level amputations, double- or triple-cabled harnesses may be required.
- In the triple-cable system, the prosthetic terminal device, used to replace some functions of the hand, utilizes one of the cables.
- The other two cables are used to restore elbow flexion and elbow locking to the above-elbow prosthesis.
Myoelectric Externally Powered Prosthesis

- During the last decade, myoelectric prosthesis have been used with greater success in upper-limb fittings.
- It can be prescribed for a child as young as two years old.
- Geriatric patient will not be a candidate because it is much heavier than a cosmetic.
How Myoelectric Prostheses Work

- The remaining muscles are naturally activated when the patient attempts to move his “phantom hand.”
- It is these control signals, in turn, control the actions of the myoelectrical prosthesis.
The Otto Bock System Electric Hand is the most commonly used electric hand in North America. It is available in three adult sizes, determined by the circumference at the knuckles.
Targeted Muscle Reinnervation (TMR)

- The TMR process begins with a surgical intervention to redirect arm nerves.
- During the healing process after surgery, the arm nerves grow and create a new connection with the surgically segmented pectoral muscle.
Targeted Muscle Reinnervation (TMR)

- A surgical technique that transfers residual arm nerves to alternative muscle sites.
- After reinnervation, these target muscles produce electromyogram (EMG) signals on the surface of the skin that can be measured and used to control prosthetic arms.
Doctors and lab personnel attach sensors to tiny ink dots on Kitt's residual arm in order to measure how her muscles respond to her attempts to control them. Unlike the simpler task of fitting the prosthesis, which has only a handful of sensors, this setup can take hours.
Next, the Dynamic Arm-TMR prosthesis is fitted
Highly sensitive electrodes integrated into the prosthetic socket
A complex electronic analysis process converts the signals and identifies the desired movement.
This enables the user, to control the movements of the prosthesis.
Bilateral upper extremity prosthesis
Brain-machine interactive control (BMIC) of prosthetic limbs

the direct neural control of prosthetic limbs is a far more nascent field
In 1999, a seminal study described the control of a robotic arm using signals directly derived from the rat motor cortex.

Since then, there have been a number of exciting advances reported in the literature, in both central nervous system (CNS)- and peripheral nervous system (PNS)-based approaches.
to achieve basic movement control of robot arms using signals extracted from motor cortex has now been amply demonstrated. However, the controlled movements are in general slow. In the future, move as quickly as natural limbs through three dimensions in natural environments.
High speed and natural movements is a major challenge
Robotics and Bionics

- Prosthetics has a burgeoning area of study that uses implanted and computer-monitored biosensors similar to those used in robotics.
- These sensors detect brain, nerves and muscular signals to control artificial limbs.
- Computer-controlled body suits, attached to surgically implanted sensors, can help those with spinal cord injuries walk.
BCI in Consumer Electronics

New Brain-Wave Toy Lets You Do 'Jedi Mind Trick'

UNCLE MILTON'S 'STAR WARS'-THEMED FORCE TRAINER, WHICH LETS YOU LEVITATE A BALL USING BRAIN WAVES.
BCI & The Military

- Exoskeleton advance human-robotic augmentation
- The Berkeley suit has been tested on four paraplegic users. They were each able to walk within 2 hours of training.
BCI Latest Developments

- Hybrid assistant limb

a Japanese-developed robot suit. The suit is designed to help restore mobility to the elderly and handicapped, as well as to give military personnel superhuman strength. Jan 2012
The **XWave iPhone accessory** is another recent BCI product release.

This headset plugs directly into compliant iPhones and reads brainwaves.
Look forward

- fully-implantable BMI could restore limb mobility in paralyzed subjects or amputees.
- The details of this system have to be worked out through future research
- Clinical applications should be encased in the patient’s body as much as possible.
Making the prosthetic feel like the subject’s own limb using microstimulation of cortical sensory areas.
Look forward

- Wireless telemetry offers a viable solution for this purpose.
- The prosthesis should not only have the function of the human arm in terms of power and accuracy of the actuators
- but also equip with the sensors of touch and position signals can be transmitted back to the subject’s brain.