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**SCHOOL OF BIO AND CHEMICAL ENGINEERING**

**DEPARTMENT OF BIOMEDICAL ENGINEERING**

# UNIT – I –REHABILITATION ENGINEERING– SBM1307

## UNIT-1
## INTRODUCTION OF REHABILITATION

## 1. Introduction

- Rehabilitation is the (re)integration of an individual with a disability into society.
- This can be done either by enhancing existing capabilities or by providing alternative means to perform various functions or to substitute for specific sensations.
- Rehabilitation engineering is the “Application of science and technology to ameliorate the handicaps of individuals with disabilities”
- *Rehabilitation technology* (or *assistive technology*) narrowly defined is the selection, design, or manufacture of augmentative or assistive devices that are appropriate for the individual with a disability. Such devices are selected based on the specific disability, the function to be augmented or restored, the user’s wishes, the clinician’s preferences, cost, and the environment in which the device will be used.

## 2. PRINCIPLES OF REHABILITATION ENGINEERING

- Knowledge and techniques from different disciplines must be utilized to design technological solutions that can alleviate problems caused by various disabling conditions. Rehabilitation engineering is intrinsically multidisciplinary. For example, principles from the fields of electronic and communication engineering are paramount when designing an environmental control system that is to be integrated with the user’s battery-powered wheelchair.
- When the goal is to develop an implanted functional electrical stimulation orthosis for an upper limb impaired by spinal cord injury, principles from neuromuscular physiology, biomechanics, biomaterials, and control systems would be the most applicable.
- Rehabilitation engineering design is the creative process of identifying needs and then devising an assistive device to fill those needs.

Key elements of the design process involve the following sequential steps:

- Analysis
- Synthesis
- Evaluation
- Decision
- Implementation

**Analysis**

- They overlook the important first step of doing a careful analysis of the problem or need.
- Rehabilitation engineers first must ascertain where, when, and how often the problem arises.

- What is the environment or the task situation? How have others performed the task? What are the environmental constraints (size, speed, weight, location, physical interface, etc.)?
- What are the psychosocial constraints (user preferences, support of others, gadget tolerance, cognitive abilities, and limitations)?
- What are the financial considerations (purchase price, rental fees, trial periods, and maintenance and repair arrangements)?
- Answers to these questions will require diligent investigation and quantitative data such as the weight and size to be lifted, the shape and texture of the object to be manipulated, and the operational features of the desired device.
- An excellent endpoint of problem analysis would be a list of operational features or performance specifications that the ‘‘ideal’’ solution should possess.

**Synthesis**

- A rehabilitation engineer who is able to describe in writing the nature of the problem is likely to have some ideas for solving the problem. The synthesis of possible solutions usually follows the analysis of the problem.
- The synthesis of possible solutions is a creative activity that is guided by previously learned engineering principles and supported by handbooks, design magazines, product catalogs, and consultation with other professionals.
- While making and evaluating the list of possible solutions, a deeper understanding of the problem is reached
- A recommended endpoint for the synthesis phase of the design process includes sketches and technical descriptions of each trial solution.

**Evaluation**

- Depending on the complexity of the problem and other constraints such as time and money, the two or three most promising solutions should undergo further evaluation, possibly via field trials with mock-ups, computer simulations, and/or detailed mechanical drawings.
- Throughout the evaluation process, the end user and other stakeholders in the problem and solution should be consulted.
- Experimental results from field trials should be carefully recorded, possibly on videotape, for later review.
- One useful method for evaluating promising solutions is to use a quantitative comparison chart to rate how well each solution meets or exceeds the performance specifications and operational characteristics based on the analysis of the problem.

**Decision**

- After comparing the various promising solutions, more than one may appear equally satisfactory. At this point, the final decision may be made based on the preference of the user. Sometimes choosing the final solution may involve consulting with someone else who may have encountered a similar problem.

**Implementation**

- To fabricate, fit, and install the final (or best) solution requires additional project planning that, depending on the size of the project, may range from a simple list of tasks to a complex set of scheduled activities involving many people with different skills.

## 2.1 Key Engineering Principles

Each discipline and sub discipline that contributes to rehabilitation engineering has its own set of key principles that should be considered when a design project is begun. For example, a logic family must be selected and a decision whether to use synchronous or asynchronous sequential circuits must be made at the outset in digital design.

- A few general hardware issues are applicable to a wide variety of design tasks, including
    - worst-case design
    - computer simulation
    - temperature effects
    - reliability
    - Product safety.
- In worst-case design, the electronic or mechanical system must continue to operate adequately even when variations in component values degrade performance.
- Computer simulation and computer-aided design (CAD) software often can be used to predict how well an overall electronic system will perform under different combinations of component values or sizes.
- The design also should take into account the effects of temperature and environmental conditions on performance and reliability. For example, temperature extremes can reduce a battery's capacity. Temperature also may affect reliability, so proper venting and use of heat sinks should be employed to prevent excessive temperature increases.
- For reliability and durability, proper strain relief of wires and connectors should be used in the final design.
- Product safety is another very important design principle, especially for rehabilitative or assistive technology.
- An electromechanical system should always incorporate a panic switch that will quickly halt a device's operation if an emergency arises. Fuses and heavy-duty gauge wiring should be employed throughout for extra margins of safety.
- Mechanical stops and interlocks should be incorporated to ensure proper interconnections and to prevent dangerous or inappropriate movement.
- When the required assistive device must lift or support some part of the body, an analysis of the static and dynamic forces (biomechanics) that are involved should be performed.

- The simplest analysis is to determine the static forces needed to hold the object or body part in a steady and stable manner.
- The basic engineering principles needed for static and dynamic analysis usually involve the following steps:
    - Determine the force vectors acting on the object or body part, determine the moment arms, and ascertain the centers of gravity for various components and body segments.
- Under static conditions, all the forces and moment vectors sum to zero.
- For dynamic conditions, the governing equation is Newton's second law of motion in which the vector sum of the forces equals mass times an acceleration vector (F ¼ ma).

## 3. Rehabilitation Concepts

- Effective rehabilitation engineers must be well versed in all of the areas described above since they generally work in a team setting, in collaboration with physical and occupational therapists, orthopaedic surgeons, physical medicine specialists and/or neurologists.
- Some rehabilitation engineers are interested in certain activities that we do in the course of a normal day that could be summarized as *activities of daily living* (ADL). These include eating, toileting, combing hair, brushing teeth, reading, etc.
- Other engineers focus on *mobility* and the limitations to mobility.
- Mobility can be personal (e.g., within a home or office) or public (automobile, public transportation, accessibility questions in buildings).
- Mobility also includes the ability to move functionally through the environment.
- For instance, an ill-fitted wheelchair cushion or support system will most assuredly limit mobility by reducing the time that an individual can spend in a wheelchair before he or she must vacate it to avoid serious and difficult-to-heal pressure sores.
- Other groups of rehabilitation engineers deal with *sensory disabilities* , such as sight or hearing, or with *Communications disorders* , both in the production side (e.g., the non-vocal) or in the comprehension side.
- For any given client, a rehabilitation engineer might have all of these concerns to consider (i.e., ADLs, mobility, sensory and communication dysfunctions).
- A key concept in physical or sensory rehabilitation is that of *residual function or residual capacity*. Such a concept implies that the function or sense can be quantified, that the performance range of that function or sense is known in a non-impaired population, and that the use of residual capacity by a disabled individual should be encouraged.
- These measures of human performance can be made subjectively by clinicians or objectively by some rather clever computerized test devices.
- A rehabilitation engineer asks three key questions:

    Can a diminished function or sense be successfully augmented?

    Is there a substitute way to return the function or to restore a sense?

And is the solution appropriate and cost-effective?

- These questions give rise to two important rehabilitation concepts: **orthotics and prosthetics**.
- An *orthosis* is an appliance that aids an existing function.
- Prosthesis provides a substitute.
- An artificial limb is prosthesis, as is a wheelchair.
- An ankle brace is an *orthosis*. So are eyeglasses.

## 3.1Engineering Concepts in Sensory Rehabilitation

- Of the five traditional senses, vision and hearing most define the interactions that permit us to be human.
- These two senses are the main input channel through which data with high information content can flow.
- Rehabilitation engineers attempt to restore the functions of these senses either through augmentation or via sensory substitution systems.
- Eyeglasses and hearing aids are examples of augmentative devices that can be used if some residual capacity remains.
- A major area of rehabilitation engineering research deals with *sensory substitution systems*
- If sight is lost, how can it be replaced? A simple pair of eyeglasses will not work, since either the sensor (the retina), the communication channel (the optic nerve and all of its relays to the brain), or one or more essential central processors (the occipital part of the cerebral cortex for initial processing; the parietal and other cortical areas for information extraction) has been damaged.
- For replacement within the system, one must determine where the visual system has failed and whether a stage of the system can be artificially bypassed.
- If one uses another sensory modality (e.g., touch or hearing) as an alternate input channel, we normally read printed text with our eyes. We recognize words from their (visual) letter combinations.
- The development of Braille condenses all text characters to a raised matrix of 2 by 3 dots (26 combinations), with certain combinations reserved as indicators for the next character (such as a number indicator) or for special contractions.
- Trained readers of Braille can read over 250 words per minute of grade 2 Braille (as fast as most sighted readers can read printed text!). Thus, the Braille code is in essence a rehabilitation engineering concept where an alternate sensory channel is used as a substitute and where a recoding scheme has been employed.
- Rehabilitation engineers have designed other ways to read text. To replace the retina as a sensor element, a modern high resolution, high sensitivity, fast imaging sensor (CCD, etc.) is employed to capture a visual image of the text.
- One method, used by various page scanning devices, converts the scanned image to text by using optical character recognition schemes, and then outputs the text as

speech via text-to-speech algorithms. This machine essentially recites the text, much as an sighted helper might do when reading aloud to the blind individual. The user of the device is thus freed of the absolute need for a helper. Such *independence* is often the goal of rehabilitation.

- Perhaps the most interesting method presents an image of the scanned data directly to the visual cortex or retina via an array of implantable electrodes that are used to electrically activate nearby cortical or retinal structures.
- Deafness is another manifestation of a loss of a communication channel, this time for the sense of hearing.
- Totally deaf individuals use vision as a substitute input channel when communicating via sign language (also a substitute code), and can sign at information rates that match or exceed that of verbal communication.
- Hearing aids are now commercially available that can adaptively filter out background noise (a predictable signal) while amplifying speech (unpredictable) using autoregressive, moving average (ARMA) signal processing.
- With the recent advent of powerful digital signal processing chips, true digital hearing aids are now available

## 3.2 Engineering Concepts in Motor Rehabilitation

- Limitations in mobility can severely restrict the quality of life of an individual so affected.
- A wheelchair is a prime example of a prosthesis that can restore personal mobility to those who cannot walk.
- Given the proper environment (fairly level floors, roads, etc.), modern wheelchairs can be highly efficient.
- Wheelchair user could certainly go down a set of steps (not recommended), climbing steps in a normal manual or electric wheelchair is a virtual impossibility. Ramps or lifts are engineered to provide accessibility in these cases, or special climbing wheelchairs can be purchased.
- Wheelchairs also do not work well on surfaces with high rolling resistance or viscous coefficients (e.g., mud, rough terrain, etc.),
- Loss of a limb can greatly impair functional activity. The engineering aspects of artificial limb design increase in complexity as the amount of residual limb decreases, especially if one or more joints are lost.
- Dynamically lockable knee joints were designed for artificial limbs for above-knee amputees.
- Artificial hands, wrists and elbows were designed for upper limb amputees.
- Careful design of the actuating cable system also provided for a sense of hand grip forces, so that the user had some feedback and did not need to rely on vision alone for guidance.

- Perhaps the most transparent (to the user) artificial arms are the ones that use electrical activity generated by the muscles remaining in the stump to control the actions of the elbow, wrist and hand
- This electrical activity is known as myoelectricity, and is produced as the muscle contraction spreads through the muscle.
- Thus, a high level of modality-specificity is maintained since the functional element is substituted only at the last stage. All of the batteries, sensor electrodes, amplifiers, motor actuators and controllers (generally analog) reside entirely within these myoelectric arms.
- An individual trained in the use of a myoelectric arm can perform some impressive tasks with this arm.
- Current engineering research efforts involve the control of simultaneous multi-joint movements (rather than the single joint movement now available) and the provision for sensory feedback from the end effector of the artificial arm to the skin of the stump via electrical means.

**3.3 Engineering Concepts in Communications Disorders**

- Speech is a uniquely human means of interpersonal communication.
- Problems that affect speech can occur at the initial transducer (the larynx) or at other areas of the vocal tract.
- They can be of neurological (due to cortical, brainstem or peripheral nerve damage), structural, and/or cognitive origin.
- A person might only be able to make a halting attempt at talking, or might not have sufficient control of other motor skills to type or write.
- If only the larynx is involved, an externally applied artificial larynx can be used to generate a resonant column of air that can be modulated by other elements in the vocal tract.
- If other motor skills are intact, typing can be used to generate text, which in turn can be spoken via text-to-speech devices described above.
- The rehabilitation engineer often becomes involved in the design or specification of *augmentative communication aids* for individuals who do not have good muscle control, either for speech or for limb movement.
- A whole industry has developed around the design of symbol or letter boards, where the user
- can point out (often painstakingly) letters, words or concepts. Some of these boards now have speech output.
- Linguistics and information theory have been combined in the invention of acceleration techniques intended to speed up the communication process.
- These include alternative language representation systems based on semantic (iconic), alphanumeric, or other codes; and prediction systems, which provide choices based on previously selected letters or words.

## 4. Key Ergonomic Principles

- Ergonomics or a human factor is another indispensable part of rehabilitation engineering and assistive technology design.
- Applying information about human behaviour, abilities, limitations, and other characteristics to the design of tools, adaptations, electronic devices, tasks, and interfaces is especially important when designing assistive technology.
- Several ergonomic principles that are especially germane to rehabilitation engineering are discussed in the following sections.

### 4.1 Principle of Proper Positioning

- Without proper positioning or support, an individual who has lost the ability to maintain a stable posture against gravity may appear to have greater deformities and functional limitations than truly exist.
- During all phases of the design process, the rehabilitation engineer must ensure that whatever adaptation or assistive technology is being planned, the person's trunk, lower back, legs, and arms will have the necessary stability and support at all times.
- Consultation with a physical therapist or occupational therapist familiar with the focus individual during the initial design phases should be considered if postural support appears to be a concern.

### 4.2 Principle of the Anatomical Control Site

- Since assistive devices receive command signals from the users, users must be able to reliably indicate their intent by using clear and proper actions.
- Given the variety of switches and sensors that are available, any part of the body over which the user has reliable control in terms of speed and dependability can serve as the anatomical control site.
- Once the best site has been chosen, an appropriate interface for that site can be designed by using various transducers, switches, joysticks, and keyboards.
- In addition to the obvious control sites such as the finger, elbow, shoulder, and knee, subtle movements such as raising an eyebrow or tensing a particular muscle can also be employed as the control signal for an assistive device.
- Often, the potential control sites can and should be analyzed and quantitatively compared for their relative speed, reliability, distinctiveness, and repeatability of control actions.
- Field trials using mock-ups, stopwatches, measuring tapes, and a video camera can be very helpful for collecting such performance data.

### 4.3 Principle of Simplicity and Intuitive Operation

- The universal goal of equipment design is to achieve intuitively simple operation, and this is especially true for electronic and computer-based assistive devices.
- The key to intuitively simple operation lies in the proper choice of compatible and optimal controls and displays.

- Compatibility refers to the degree to which relationships between the control actions and indicator movements are consistent, respectively, with expectations of the equipment's response and behavior.
- When compatibility relationships are incorporated into an assistive device, learning is faster, reaction time is shorter, fewer errors occur, and the user's satisfaction is higher.
- The rehabilitation engineer needs to be aware of and follow some common compatibility relationships and basic ergonomic guidelines, such as:
    - The display and corresponding control should bear a physical resemblance to each other.
    - The display and corresponding control should have similar physical arrangements and/or be aided by guides or markers.
    - The display and corresponding control should move in the same direction and within the same spatial plane (e.g., rotary dials matched with rotary displays, linear vertical sliders matched with vertical displays).
    - The relative movement between a switch or dial should be mindful of population stereotypic expectations (e.g., an upward activation to turn something on, a clockwise rotation to increase something, and scale numbers that increase from left to right).

**4.4 Principle of Display Suitability**

- In selecting or designing displays for transmission of information, the selection of the sensory modality is sometimes a conclusion, such as when designing a warning signal for a visually impaired person.
- The rehabilitation engineer must take advantage of the intrinsic advantages of one sensory modality over another for the type of message or information to be conveyed.

**4.5 Principle of Allowance for Recovery from Errors**

- Both rehabilitation engineering and human factors or ergonomics seek to design assistive technology that will expand an individual's capabilities while minimizing errors.
- However, human error is unavoidable no matter how well something is designed. Hence, the assistive device must provide some sort of allowance for errors without seriously compromising system performance or safety.
- Errors can be classified as errors of omission, errors of commission, sequencing errors, and timing errors.
- A well-designed computer-based electronic assistive device will incorporate one or more of the following attributes:
    - The design makes it inherently impossible to commit the error (e.g., using jacks and plugs that can fit together only one way or the device automatically rejects inappropriate responses while giving a warning).
    - The design makes it less likely, but not impossible to commit the error (e.g., using color-coded wires accompanied by easily understood wiring diagrams).

- The design reduces the damaging consequences of errors without necessarily reducing the likelihood of errors (e.g., using fuses and mechanical stops that limit excessive electrical current, mechanical movement, or speed).

**4.6 Principle of Adaptability and Flexibility**

- One fundamental assumption in ergonomics is that devices should be designed to accommodate the user and not vice versa.
- As circumstances change and/or as the user gains greater skill and facility in the operation of an assistive device, its operational characteristics must adapt accordingly.
- In the case of an augmentative electronic communication device, its vocabulary set should be changed easily as the user's needs, skills, or communication environment change.
- The method of selection and feedback also should be flexible, perhaps offering direct selection of the vocabulary choices in one situation while reverting to a simpler row-column scanning in another setting.
- The user should also be given the choice of having auditory, visual, or a combination of both as feedback indicators.

**4.7 Principle of Mental and Chronological Age Appropriateness**

- When working with someone who has had lifelong and significant disabilities, the rehabilitation engineer cannot presume that the mental and behavioral age of the individual with disabilities will correspond closely with that person's chronological age.
- In general, people with congenital disabilities tend to have more limited variety, diversity, and quantity of life experiences.
- Consequently, their reactions and behavioural tendencies often mimic those of someone much younger. Thus, during assessment and problem definition, the rehabilitation engineer should ascertain the functional age of the individual to be helped.
- Behavioral and biographical information can be gathered by direct observation and by interviewing family members, teachers, and social workers.
- Special human factor considerations also need to be employed when designing assistive technology for very young children and elderly individuals.
- When designing adaptations for such individuals, the rehabilitation engineer must consider that they may have a reduced ability to process and retain information.
- For example, generally more time is required for very young children and older people to retrieve information from long-term memory, to choose among response alternatives, and to execute correct responses.
- Studies have shown that elderly persons are much slower in searching for material in long-term memory, in shifting attention from one task to another, and in coping with conceptual, spatial, and movement incongruities.

The preceding findings suggest that the following design guidelines be incorporated into any assistive device intended for an elderly person:

- Strengthen the displayed signals by making them louder, brighter, larger, etc.
- Simplify the controls and displays to reduce irrelevant details that could act as sources of confusion.
- Maintain a high level of conceptual, spatial, and movement congruity, i.e., compatibility between the controls, display, and device's response.
- Reduce the requirements for monitoring and responding to multiple tasks.
- Provide more time between the execution of a response and the need for the next response. Where possible, let the user set the pace of the task.
- Allow more time and practice for learning the material or task to be performed.

## 5. Knowledge of disability act 1995

The government of India has put in place an Act for the disabled to make sure the disabled also form an important part of nation building. The Persons with Disabilities (Equal Opportunities, Protection of Rights and Full Participation) Act, 1995 came into force on February 7, 1996. It is a significant step which ensures equal opportunities for the people with disabilities. The Act provides for both the preventive and promotional aspects of rehabilitation like education, employment and vocational training, reservation, research and manpower development, creation of barrier- free environment, rehabilitation of persons with disability, unemployment allowance for the disabled, special insurance scheme for the disabled employees and establishment of homes for persons with severe disability etc.

**The main provisions of the Act are:**

**Prevention and early detection of disabilities**

- Surveys, investigations and research shall be conducted to ascertain the cause of occurrence of disabilities
- Various measures shall be taken to prevent disabilities. Staff at the Primary Health Centre shall be trained to assist in this work
- All the Children shall be screened once in a year for identifying 'at-risk' cases
- Awareness campaigns shall be launched and sponsored to disseminate information
- Measures shall be taken for pre-natal, peri natal, and post-natal care of the mother and child

**Education**

- Every child with disability shall have the rights to free education till the age of 18 years in integrated schools or special schools
- Appropriate transportation, removal of architectural barriers and restructuring of modifications in the examination system shall be ensured for the benefit of children with disabilities
- Children with disabilities shall have the right to free books, scholarships, uniform and other learning material

- Special Schools for children with disabilities shall be equipped with vocational training facilities Non-formal education shall be promoted for children with disabilities
- Teachers' Training Institutions shall be established to develop requisite manpower
- Parents may move to an appropriate forum for the redressal of grievances regarding the placement of their children with disabilities

**Employment**

3% of vacancies in government employment shall be reserved for people with disabilities, 1% each for the persons suffering from:

- Blindness or Low Vision
- Hearing Impairment
- Locomotor Disabilities & Cerebral Palsy
- Suitable Scheme shall be formulated for
- The training and welfare of persons with disabilities
- The relaxation of upper age limit
- Regulating the employment
- Health and Safety measures and creation of a non- handicapping, environment in places where persons with disabilities are employed
- Government Educational Institutes and other Educational Institutes receiving grant from Government shall reserve at least 3% seats for people with disabilities.
- No employee can be sacked or demoted if they become disabled during service, although they can be moved to another post with the same pay and condition.
- No promotion can be denied because of impairment.

**Affirmative Action**

Aids and Appliances shall be made available to the people with disabilities. Allotment of land shall be made at concessional rates to the people with disabilities for:

- House
- Business
- Special Recreational Centres
- Special Schools
- Research Schools
- Factories by Entrepreneurs with Disability

**Non-Discrimination**

- Public building, rail compartments, buses, ships and air-crafts will be designed to give easy access to the disabled people
- In all public places and in waiting rooms, the toilets shall be wheel chair accessible. Braille and sound symbols are also to be provided in all elevators (lifts)
- All the places of public utility shall be made barrier- free by providing the ramps

**Research and Manpower Development**

- Research in the following areas shall be sponsored and promoted
- Prevention of Disability
- Rehabilitation including community based rehabilitation
- Development of Assistive Devices
- Job Identification
- On site Modifications of Offices and Factories
- Financial assistance shall be made available to the universities, other institutions of higher learning, professional bodies and non-government research- units or institutions, for undertaking research for special education, rehabilitation and manpower development

**Social Security**

- Financial assistance to non-government organizations for the rehabilitation of persons with disabilities
- Insurance coverage for the benefit of the government employees with disabilities.
- Unemployment allowance to the people with disabilities who are registered with the special employment exchange for more than a year and could not find any gainful occupation

## 6. Rehabilitation Team

1. Rehabilitation is a continuous process where a team of doctors, nurses, therapists and various other medical professionals is formed to help the patient recover from his present state of illness to a normal state of health.
2. The rehabilitation team is formed based on the illness of the patient.
3. For example the doctors, nurses and therapists in a drug rehabilitation team will be different from those in an accident rehabilitation team. Each member of the team with his/her individual expertise has a different approach in healing the patient.
4. Various needs of the client decide which therapist will be a part of the rehabilitation team. Some of these needs are the client's illness, duration of illness, severity of the same, financial capability of the client and his insurance coverage.

**Usually a rehabilitation team comprises of the following members:**

5. **Physiatrist:** The Physiatrist is the leader of the rehabilitation team. He assesses the patient carefully and monitors the patient's progress. He decides what all medical services the patient needs and then designs the program as per the patient's need. He will design a patient oriented treatment program based on which the other members of the team will be decided. His specialization is physical medicine and rehabilitation.
6. **Neuropsychologist:** Often after a serious illness or brain damage, a patient may not able to behave or think as he use to before the accident. Severe brain damage may be

the cause for this. So a Neuropsychologist monitors these changes and then designs such programs that will help the patient recover quickly. A Neuropsychologist will also educate the family members of the patient to accept this change in the patient and ways to deal with it.

7. **Physical therapist:** After a traumatic brain injury a person may suffer from musculoskeletal or neuromuscular issues. This injury affects his daily activities. The work of a physical rehabilitation therapist is to work on improving this problem of the patient. He will focus on the development of posture, strength, physical independence, quality movement, balance coordination and other sensory motor activities.
8. **Nurses:** who deal with rehabilitation patients are trained to take care of the everyday need of the patients. Often after severe brain or physical injury a person may find it difficult to take care of oneself, so these nurses are trained to take care of patients.
9. **Speech/language Pathologist:** A person suffering from any sort of brain injury may face difficulty in talking clearly. Therefore, it becomes difficult for the family members to understand what the patient is trying to say. Sometimes, the patient may also feel frustrated when he is not able to communicate properly. In such cases, a speech therapist helps the patient by checking his condition and then designing a specific program of exercises and therapies that would help him communicate with the society.
10. **Occupational therapist:** The work of an occupational therapist is to make a patient learn advanced independence skills that will help him in various ways in his personal life. The patient will be taught cooking, laundering, shopping and banking by an occupational therapist.
11. **Recreational therapist:** the job of a recreational therapist is to make a patient indulge in all those activities that the patient enjoys. He brings a positive attitude in a patient by making the latter realize that life can be fun and enjoyable.
12. **Rehab counsellor:** After any kind of a traumatic incident, be it accident or illness a patient goes through depression and other negative feelings. It is very important that a rehab counsellor counsels the patient and adds positive attitude in him. This is important as healthy mind will lead to a faster healing.
13. These medical experts form a rehabilitation team and help the patient in various ways to get back to a normal life.

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**Unit-1**
**2marks**

1. State the principle of proper positioning.
2. Give few design guidelines to be incorporated into any assistive device intended for an elderly person.
3. List the various concepts of rehabilitation engineering.
4. Differentiate adaptability and flexibility of prosthesis.
5. What are the desirable factors needed to design a prosthetic device?
6. Give the relationship between age appropriateness and anatomical site.
7. Define the terms with respect to rehabilitation engineering a) Prosthetics b) Orthotics
8. What are the key elements in a design process?
9. Is age a significant factor in rehabilitation engineering, Justify.
10. What is rehabilitation engineering?
11. State the legal considerations related to rehabilitation.
12. Define ADL.

**10marks**

1. As a rehabilitation engineer, what would be the major activities to overcome day to day needs of disabled people?
2. What is the essential role played by rehabilitation and assistive technologists in rehabilitation process? Explain with principles and examples.
3. List the key engineering and ergonomic principles in the rehabilitation field. Discuss about the principle of anatomical control site.
4. Describe the Ergonomic aspects present in controlling devices in a working environment.
5. Explain how the sensory and motor concepts are used in rehabilitation engineering.
6. Discuss about the PWD act for persons with disabilities.
7. Outline the concepts and principles of rehabilitation engineering.
8. If a person with a lost limb approaches you for rehabilitation, how will you apply the principles of rehabilitation to the need and design a rehabilitative device.

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# UNIT – II –REHABILITATION ENGINEERING– SBM1307

# Unit-2
# Orthopedic Prosthetics and Orthotics in Rehabilitation

- An *orthopedic prosthesis* is an internal or external device that *replaces* lost parts or functions of the neuroskeletomotor system.
- In contrast, a *orthopedic orthosis* is a device that *augments* a function of the skeletomotor system by controlling motion or altering the shape of body tissue.
- For example, an artificial leg or hand is prosthesis, whereas a calliper (or brace) is an orthosis.
- When a human limb is lost through disease or trauma, the integrity of the body is compromised in so many ways that an engineer may well feel impressed by the design requirements for a prosthetic replacement.
- Orthotic devices are classified by acronyms that describe the joint which they cross.
- AFO is an ankle-foot orthosis, a CO is a cervical orthosis (neck brace or collar)
- TLSO is a thoraco lumbo sacral orthosis (spinal brace or jacket).
- The main categories are braces for the cervix (neck), upper limb, trunk, lower limb, and foot.
- Orthosis are generally simpler devices than prostheses, but because orthosis are constrained by the existing body shape and function, they can present an equally demanding design challenge.
- External orthotics are often classified as structural or functional,
- Structural- implying a static nature to hold an unstable joint and the latter
- Functional- a flexible or articulated system to promote the correct alignment of the joints during dynamic functioning.
- An alternative orthotic approach utilizes functional electrical stimulation (FES) of the patient’s own muscles to generate appropriate forces for joint motion

**2.1 Designers of orthotic and prosthetic devices are aware of the three cardinal considerations—function, structure, and cosmesis.**

- For requirements of **Function**,
    1) Objectives of treatment should be clear,
    2) understand the clinical condition.
    3) Functional prescription is a preferred route for the medical practitioner to specify the requirements, leaving the implementation of this instruction to the prosthetist, orthotist, or rehabilitation technologist.
    4) Knowledge of the biomechanics that underlies both the dysfunction in the patient and the function of proposed device to be coupled to the patient.
    5) Kinematics, dynamics, energy considerations, and control all enter into this understanding of function.
- **Structure** is the means of carrying the function, and finally both need to be embodied into a design that is cosmetically acceptable.

Some of the fundamental issues in these concepts are

- To function well, the device needs an effective coupling to the human body.
- The Shapes are also evolved to achieve appropriate load distribution for stability of coupling between prosthetic socket and limb
- In orthotic design, a system of usually three forces that generates a moment to stabilize a collapsing joint (Fig. 140.1).

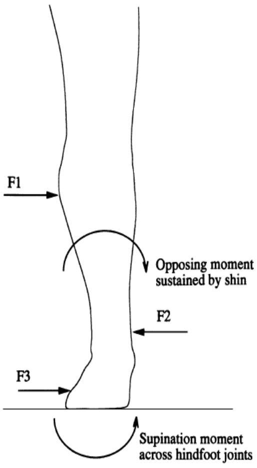


FIGURE 140.1 Three-force system required in an orthosis to control a valgus hindfoot due to weakness in the hindfoot supinators.

- Alignment is a second factor influencing the interface loading. For lower limb orthosis, the net action of the ground reaction forces and consequent moments around the natural joints are highly dependent on the alignment taken up by the combination of orthosis and shoe.
- Adjustability may be important, particularly for children or progressive medical conditions.
- In orthosis small angular motions are needed, these may be provided by material flexibility rather than mechanisms.
- The structural requirements should be incorporated into an ISO standard (ISO 13404,5; ISO 10328).
- Not only are the load level and life critical, but so is the mode of failure. Sudden failure of an ankle bolt resulting in disengagement of an artificial foot is not only potentially life-threatening to an elderly amputee who falls and breaks a hip but also can be quite traumatic to unsuspecting witnesses of the apparent event of auto amputation.
- Design and choice of materials should ensure a controlled slow yielding, not brittle fracture.
- A further consideration is the ability of the complete structure to absorb shock loading, either the repeated small shocks of walking at the heel strike or rather more major shocks during sports activities or falls. This minimizes the shock transmitted through the skin to the skeleton, known to cause both skin lesions and joint degeneration.

- Finally, the consideration of hygiene must not be overlooked; the user must be able to clean the orthosis or prosthesis adequately without compromising its structure or function.

The third element of *cosmesis* completes the trilogy.

- Appearance is a major factor and its has a great psychological importance to the user.
- As examples, to provide realistic cosmetic covers for hand or foot prostheses.
- Advanced manufacturing technology,

    Optical shape scanning linked to three-dimensional (3D)
    Computer-aided design
    CNC machining can give customized shapes

- In providing cosmesis, the views of the user must remain paramount. The wearer will often choose an attractive functional design in preference to a life
- Upper limb prostheses are a more interesting engineering challenge than lower limb,
- An artificial arm comprise a socket with a terminal device offering a pincer grip (hand or hook) that can be operated through a Bowden cable by shrugging the shoulders.
- Another, method is to take a muscle and tether its tendon through an artificially fashioned loop of skin: the cable can then be hooked through the loop
- Power can be Pneumatic power in the form of a gas cylinder which is cheap and light
- Gas-powered grip on a hand can be a good solution
- Input control to these powered devices can be from surface electromyography or by mechanical movement
- The physical design in prosthetic and orthotic devices has changed substantially over the past decade.
- The sockets of artificial limbs have always been fashioned to suit the individual patient, historically by carving wood, shaping leather, or beating sheet metal. Following the introduction of thermosetting fiber-reinforced plastics hand-shaped over a plaster cast of the limb residuum, substitution of thermoforming plastics that could be automatically vacuum-formed made a leap forward to give light, rapidly made, and cosmetically improved solutions.
- Polypropylene is the favored material in this application.
- Carbon fiber composites substituted for metal have certainly improved the performance of structural components such as limb shanks.

## 2.2 Computer-Aided Engineering in Customized Component Design

- Computer-aided engineering has found a fertile ground for exploitation in the process of design of customized components to match to body shape.
- Example: sockets for artificial limbs - produce a well-fitting socket during the course of a single patient consultation.

**Traditional methods**

- Casting the residual limb in plaster of paris
- Pouring a positive mold

- Manual rectification and then socket fabrication over cast long process.

**Advanced technology**

- Residual limb shapes can be captured in a computer,
- Rectified by computer algorithms, and
- CNC machined to produce the rectified cast in an hour
- Vacuum-formed machinery to pull a socket rapidly over the cast
- The socket can be ready for trial fitting in one session.

**Advantages**

- The shape is stored in digital form in the computer and can be reproduced or adjusted whenever and wherever desired.

**Development Stages**

1) **Hardware –**
    a. Difficult considering low budget
    b. Requirement are considerably different from those of standard ones
    c. Dimensions in millimetres, not microns
    d. To measure limb or trunk parts that are encumbered by the attached body, which may resist being orientated conveniently in a machine and which will certainly distort with the lightest pressure
    e. Need to reproduce fairly bulky items with strength to be used as a sacrificial mold
2) **Instrumentation**
    - For body shape scanning has been developed
    - Using methods of silhouettes, Moiré fringes, contact probes measuring contours of plaster casts, and light triangulation.
    - Lots of developments in rapid prototyping
3) **Graphics and Algorithms**
    a. Need to achieve rectification
    b. Extent to which the computer acts as a tool for the prosthetist to exercise his or her traditional skills using 3D modeling and on-screen sculpting as a direct replacement for manual rectification
    c. The computer system should take over the bulk of the process by an expert systems approach.
    d. Series of rectification maps can be held as templates, each storing the appropriate relief to be applied over a particular anatomic area of the limb.

**Finite-element analysis**

a. Employed to model the soft tissue distortion occurring during limb loading
b. To look at the influence of severity of rectification in resultant distribution of interface stress
c. modelling is unusual and nonlinear
d. Tissues are highly deformable but incompressible
e. In reality, compression is there under localized external pressure due to loss of blood and fluids
f. Difficult to define boundaries of the limb segment at the proximal end, still attached to the body, where soft tissues can easily bulge up and out. This makes experimental determination of the stress-strain curves difficult.
g. A nonlinear model with interface elements to be considered, since the frictional conditions at the interface determines the balance between shear and direct stress

## 2.3 Computer-aided design (CAD) techniques in the design of bespoke orthopedic footwear

- Generation of a customized mold, or shoe last, for each foot and design of patterns for the shoe uppers.
- The philosophy of design of shoe lasts is quite different from that of sockets, because last shapes have considerable and fundamental differences from foot shapes.
- In this instance, a library of reference last shapes is held, and a suitable one is selected both to match the client's foot shape and to fulfill the shoemaking needs for the particular style and type of shoe.

**Ampfit system**

- The schematic of the process followed in development of the Shoemaster system is shown in Fig. 140.7.
- Design of shoe inserts is, with systems to capture, manipulate, and reproduce underfoot contours now in commercial use.
- An example is the Ampfit system, the foot is placed on a platform to which preshaped arch supports attached.
- A matrix of round-ended cylinders is then forced up by gas pressure through both platform and supports, supporting the foot with an even load distribution.
- The shape is captured from the cylinder locations and fed into a computer, where rectification is done.
- A CNC machine then routs the shoe inserts

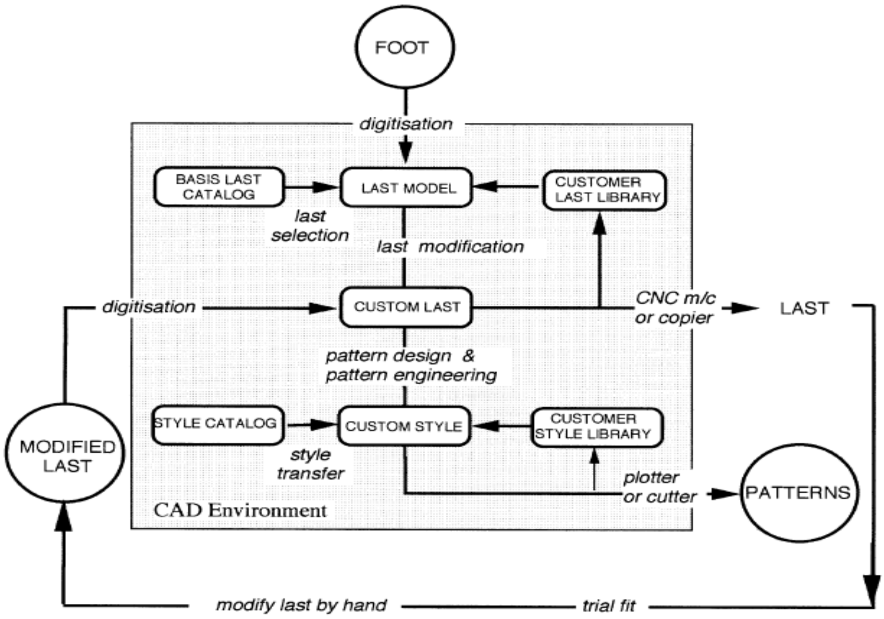


FIGURE 140.7 Schematic of operation of the Shoemaster shoe design system based on selection of a basis last from a database of model lasts. A database of styles is also employed to generate the upper patterns.

## 2.3 PROSTHETIC DEVICES

### 2.3.1 Intelligent Prosthetic Knee

- The control of an artificial lower limb is problematic during the swing phase, during which the foot is lifted off the ground to be guided into contact ahead of the walker.
- A prosthetic lower limb needs to be significantly lighter than its normal one as the muscles do not control them.
- Two technological advances have helped.
  - First, carbon fiber construction has reduced the mass of the lower limb
  - Second, pneumatic or hydraulically controlled damping mechanisms for the knee joint have enabled adjustment of the swing phase to suit an individual's pattern of walking.
- Swing-phase control of the knee should operate in three areas:
  - Resistance to flexion at late stance during toe-off controls any tendency to excessive heel rise at early swing.
  - Assistance to extension after midswing ensures that the limb is fully extended and ready for heel strike.
  - Resistance before a terminal impact at the end of the extension swing dampens out the inertial forces to allow a smooth transition from flexed to extended knee position.
- In an normal artificial limbs, parameters of these controls are determined by fixed components (springs, bleed valves)
- If the users subsequently walk more slowly, the limb will tend to lead,

- While if the amputee walks more quickly, the limb will tend to fall behind or lag
- In an intelligent system, a 4-bit microprocessor is used to adjust a needle valve, via a linear stepper motor, according to duration of the preceding swing phase.
- The unit is programmed by the prosthetist to provide optimal damping for the particular amputee's swing phase at slow, normal, and fast walking paces.

### 2.3.2 A Hierarchically Controlled Prosthetic Hand

- Control of the intact hand is hierarchical. It starts with the owner's intention, and an action plan is formulated based on knowledge of the environment and the object to be manipulated.
- For gross movements, it relies on "pre-programmed" coordination from the central nervous system.
- Fine control leans heavily on local feedback from force and position sensors in the joints and tactile information at the skin.
- In contrast, conventional prostheses depend on the conscious command of all levels of control and so can be slow and tiring to use.
- Current technology is able to provide both the computing power and transducers required to recreate some of a normal hand's control.

FIGURE 140.10 The Southampton hand prosthesis with four degrees of freedom in a power grip. An optical/acoustic sensor is mounted on the thumb.

- A suitable mechanical configuration is shown in Fig. 140.10.
- Four 12-V dc electric motors with gearboxes control, respectively, thumb adduction, thumb flexion, forefinger flexion, and flexion of digits 3,4, and 5. Digits 3, 4, and 5 are linked together by a double-swingletree mechanism that allows all three to be driven together.
- When one digit touches an object the other two can continue to close until they also touch or reach their limit of travel.

The movement of the digits allows one of several basic postures:

- **Three-*point chuck:*** Precision grip with digits 1, 2, and 3 (thumb set to oppose the midline between digits 2 and 3); digits 4 and 5 give additional support.
- **Two-*point grip:*** Precision grip with digits 1 and 2 (thumb set to oppose forefinger); digits 3, 4, and 5 fully flexed and not used or fully extended.

• **Fist*:*** As two-point grip but with thumb fully extended to allow large objects to be grasped.
• ***Small Fist:*** As fist but with thumb flexed and abducted to oppose side of digit 2.
• ***Side, or key:*** Digits 2 to 5 half fully flexed with thumb opposing side of second digit.
• ***Flat hand:*** Digits 2 to 5 fully extended with thumb abducted and flexed, parked beside digit 2.

- The controller coordinates the transition between these positions.
- Potentiometers detect the angles of flexion of the digits; touch sensors detect pressure on the palmer surfaces of the digits
- The whole hand may be operated by electromyography signals from two antagonistic muscles in the supporting forearm stump, picked up at the skin surface.

### 2.3.3 A Self-Aligning Orthotic Knee Joint

- Knee orthosis are often supplied to resist knee flexion during standing and gait at an otherwise collapsing joint.
- The rigid locking mechanisms on these devices are manually released to allow knee flexion during sitting.
- Fitting is complicated by the difficulty of attaching the orthosis with its joint accurately aligned to that of the knee.
- The simple diagram in Fig. 140.11 shows how misplacement of a simple hinged orthosis with a notional fixed knee axis would cause the cuffs on the thigh and calf to press into the soft tissues of the limb (known as *pistoning*).

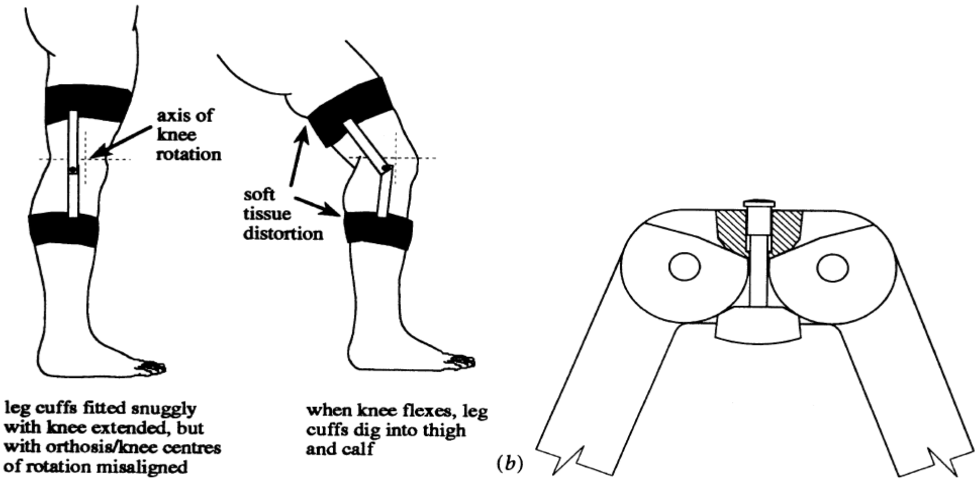


FIGURE 140.11 The problem caused by misplacement of a single-axis orthotic joint (*a*) is overcome by an orthosis (*b*) with a self-aligning axis. (The Laser system, courtesy of Hugh Steeper, Ltd., U.K.)

- The human knee does not have a fixed axis, though, but is better represented as a polycentric joint.
- The problem of alignment still remains, to overcome this specific problem, the knee mechanism has been designed with not one but two axes (Fig. 140.11).

- The center of rotation is then free to self-align. This complexity of the joint while still maintaining the ability to fixate the knee and meeting low weight requirements is only achieved by meticulous design in composite materials.

## 2.4 FES Systems

- Functional Electrical Stimulation (FES) help in regaining functional movements in numerous paralyzed humans
- FES activates innervated but paralyzed muscles, by using an electronic stimulator to deliver trains of pulses to neuromuscular structures.
- The basic phenomenon of the stimulation is a contraction of muscle due to the controlled delivery of electric charge to neuromuscular structures.
- FES systems can restore
  - goal-oriented (hand and arm) movements
  - cyclic (walking and standing) movements

### 2.4.1 Restoration of Hand Functions

- The objective of an upper extremity assistive system is directed toward establishing independence to the user.
- Efforts in developing upper extremity FES systems were targeted toward individuals with diminished, but preserved, shoulder and elbow functions, with lack of wrist control and grasping ability.
- The FES systems can be divided among the source of control signals to trigger or regulate the stimulation pattern: shoulder control, voice control, respiratory control, joystick control, and position transducers or trigger.
- The division can be made based upon the method to which patterned electrical stimulation is delivered: one to three channel surface electrode systems, multichannel surface stimulation system, multichannel percutaneous systems with intramuscular electrodes, and fully implanted systems with epimysial electrodes.

There have been several designs of FES systems.

1) FES grasping systems used to provide prehension and release used a splint with a spring for closure and electrical stimulation of the thumb extensor for release.
2) The use of a simple two-channel stimulation system and a position transducer (sliding potentiometer). The shift of the potentiometer forward from its neutral position causes opening by stimulating the dorsal side of the forearm; a shift backward causes closing of the hand by stimulating the volar side of the forearm.
3) The follow-up of initial FES system in Japan, where many subjects are implanted with up to 30 percutaneous intramuscular electrodes that are used for therapy, but not to assist grasping. The approach in functional grasping relates to subjects lacking not

only hand functions but also the elbow control and the system uses either a voice or suck/puff control and pre-programmed EMG-based stimulation patterns.

4) The approach taken at Ben Gurion University, Israel used a voice controlled multichannel surface electrode system. 12 bipolar stimulation channels and a splint are used to control elbow, wrist, and hand functions. The system was tuned for the needs of every single user.
5) The work of Nathan resulted with a commercial device called Handmaster. This device is approved as a therapeutic device claiming that it is improving grasping functionality in humans after stroke.
6) The group at the Institute for Biokibernetik, Karlsruhe, Germany suggested the use of EMG recordings from the muscle, which is stimulated. The aim of this device is to enhance the grasping by using weak muscles. In this case, it is essential to eliminate the stimulation artifact
7) The Case Western Reserve University (CWRU) fully implantable system has a switch to turn the system on and off and select the grasp and a joystick to proportionally control aperture of the hand for palmar and lateral grasp
8) The Bionic Glove - A sensor is used to detect wrist movement, and trigger opening and closing of the hand. A microcomputer is built into the battery operated stimulation unit, which detects movements and controls three channels to stimulate thumb extension and flexion, and finger flexors. Clinical evaluation of the Bionic Glove showed that the stimulation is beneficial for persons with tetraplegia both therapeutically and as an orthosis.
9) Rehabilitation Institute in Belgrade with the so-called Belgrade grasping/reaching system showed that most persons with tetraplegia responding to stimulation of the biceps and triceps brachii muscles improve their function within six weeks to the stage at which they become reluctant to use FES assistance for manipulation

**FIGURE 142.1** Bionic glove for restoration of grasping in persons with tetraplegia used for multicentre trials [7,22]. The upper panel shows electrodes, stimulator, and the glove, while the bottom panel shows the glove mounted and ready for use.

### 2.4.2 Restoration of Standing and Walking

- The application of FES to restoration of gait analysis.
- Currently, FES for gait rehabilitation is used in a clinical setting in several rehabilitation centers and there is a growing trend for the design of devices for home use.

**Single-channel stimulation system**

- Current surface FES systems use various numbers of stimulation channels.
- This system is only suitable for stroke patients and a limited group of incomplete spinal cord injury patients.
- These individuals can perform limited ambulation with assistance of the upper extremities without an FES system
- The FES in these humans is used to activate a single muscle group.

**Multichannel system**

- A multichannel system with a minimum of four channels of FES is required for ambulation of a patient with a complete motor lesion of lower extremities and preserved balance and upper body motor control.
- Bilateral stimulation of the quadriceps muscles locks the knees during standing.
- Multichannel percutaneous systems for gait restoration - to activate many different muscle groups. A preprogrammed stimulation pattern is delivered to ankle, knee, and hip joints, as well as to paraspinal muscles.
- A surface electrode is used as a common anode. Interleaved pulses are delivered with a multichannel, battery-operated, portable stimulator. The hand controller allows the selection of gait activity. These systems were limited to the clinical environment. The application was investigated in complete spinal cord lesions and in stroke patients.
- A multichannel totally implanted FES system uses a 16-channel implantable stimulator attached to the epineurium electrodes. Femoral and gluteal nerves were stimulated for hip and knee extension

## 2.5 Hybrid Assistive Systems (HAS)

- Integration of two assistive systems (FES and an external mechanical orthosis)
- These systems are called hybrid assistive systems (HAS) or hybrid orthotic systems (HOS)
- HAS design - combines relatively simple rigid mechanical structures for passive stabilization of lower limbs during stance phase and FES systems.
- These systems combine the use of a gait orthosis with multichannel stimulation
- On the basis of accumulated experience, the following features can serve as criteria for a closer description of various HAS designs:
  - Partial mechanical support,
  - Parallel operation of the biological and mechanical system, and

- Sequential operation of the biological and the mechanical system.

The partial mechanical support refers to the use of braces to assist FES only at specific events within a walking cycle.

FIGURE 142.2 An incomplete tetraplegic subject walking with a hybrid assistive system. The particular system incorporates a six-channel surface stimulation system and a powered self-fitting modular orthosis [88].

## 2.6 Active Prostheses

The role of active prosthesis is to extend the function provided by a “non-externally” powered and controlled artificial organ; hence, to improve the overall performance of motor function, ultimately providing a better quality of life.

### 2.6.1 Active Above-Knee Prostheses

- Artificial legs of different kinds have been in use for a long time
- But in many cases they are inadequate for the needs of amputees, specifically for high above-knee amputations (e.g., hip disarticulation), bilateral amputees, and patients who have demanding biomechanical requirements (e.g., subjects involved in sports)
- Modern technology has led to improved designs of below-knee prostheses (BKP)

**Below-knee amputees (BKP)**

- perform many normal locomotor activities and participate in many sports requiring running, jumping, and other jerky movements
- The y are made using readily available and easy-to-work-with plastic and graphite alloys for building the artificial skeletal portion of the shank and foot
- BKP are light, easy to assemble, and reliable
- They provide good support and excellent energy absorption, which prevents impact, jerks, and allows the push-off phase in the gait cycle
- Without ankle joints, duplicate the behavior of the normal foot–ankle complex during swing and stance phases of the step cycle

**Above-knee prostheses (AKP)**

Commercially available AKPs suffer from several drawbacks.

The requirements for an AKP were

- The prosthesis must support the body weight of the amputee like the normal limb during the stance phase of level walking, on slopes and on soft or rough terrain.
- The prosthesis should provide "stability" during weight bearing activity, i.e., it prevents sudden or uncontrolled flexion of the knee.
- The second requirement is that the body is supported such that undesirable socket/stump interface pressures and gait abnormalities due to painful socket/stump contact are prevented.
- The third requirement, the prosthesis should duplicate as nearly as possible the kinematics and dynamics of normal gait.
- "self-contained" active AKPs are being incorporated into modern rehabilitation.
- The self-contained principle implies that the artificial leg contains the energy source, actuator, controller, and sensors (Fig. 142.3).

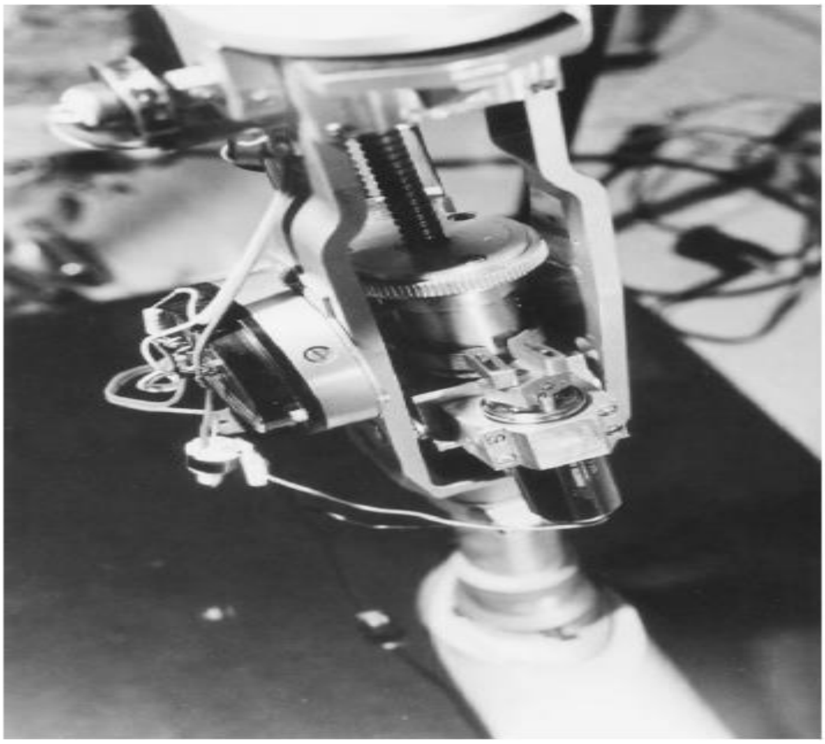

FIGURE 142.3 A self-contained, battery powered, microcomputer controlled above-knee prosthesis using artificial reflex control [104].

- Devices such as the polycentric knee mechanism with a hydraulic valve, or the AKP with friction type brake satisfy some of the above performance requirements.
- The final prototype version of an active self-contained AKP allow controlled flexion and extension throughout the gait cycle

- Product of Otto Bock Company, Germany - leg uses an efficient knee controller with a custom built hydraulic valve and a single chip microcontroller with a rule-based control scheme
- Advantages of the externally powered and controlled leg
  - An increased speed of locomotion
  - Better gait symmetry
  - lower energy cost and rate
- They leg allows controlled knee bounce after heel contact, limited push-off at the end of the stance phase, and effective flexion and controlled knee extension during the swing phase of gait.
- The knee joint of a standard endoskeletal prosthesis is fitted with an actuator having two independent braking units and the extension-flexion driver with a ball-screw mechanism. The rechargeable battery power supply is designed for up to three hours of continuous level walking.
- The Motorola 68HC11-based microcontroller has been fitted into the interior of the prosthesis fulfilling self-containing principles.
- A hierarchical controller allows for intention recognition (volitional actions of the subject), adaptation to environmental changes.

### 2.6.2 Myoelectric Hand and Arm Prostheses

- The control signals going to the prosthesis come from the myoelectric activity of the muscle which controls the lost limb.
- In some sense, the brain's own signals are used to control the motion of the prosthesis.
- Two systems based on myoelectric control are used with success (Fig. 142.4).

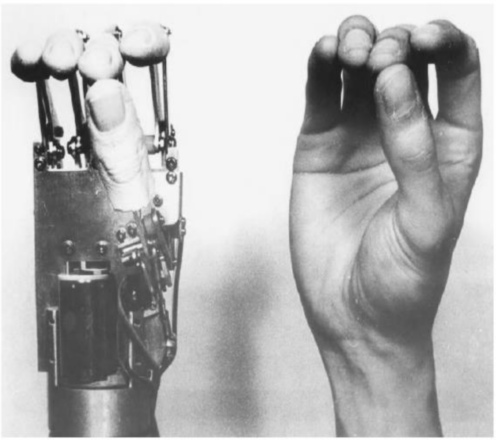

FIGURE 142.4 The Waseda University prototype of a myoelectric artificial hand.

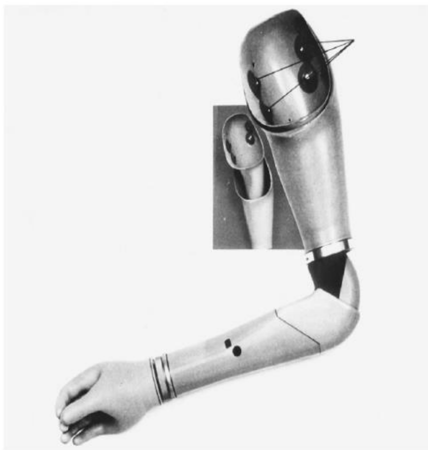

FIGURE 142.5 The Utah arm [107].

- The Otto Bock myoelectric hand uses the technique of detection of the fixed threshold of the integrated rectified surface electromyography. Extension/flexion of the targeted muscle group serves as the on/off control, which causes opening and closing of the hand, respectively. Two sets of electrodes are used to detect this differential signal.

- The Utah arm utilizes the myoelectric signal which controls the elbow (Fig. 142.5).
- The signals are full wave rectified and differentiated to give the command signal.
- The Utah arm has a wrist rotator and it can be combined with different grasping systems. Most of the artificial hands used in everyday activities do not include the five finger dexterity, except in the devices that are mechanically pre-programmed.
- An externally controlled elbow–wrist–hand prosthesis was evaluated. The shoulder joint position is measured with a potentiometer, mounted between the upper arm and trunk.
- An important feature of the system is that disabled humans can learn how to control the system within minutes using trial-and-error procedure.

## 2.7 Orthotics

### 2.7.1 Foot orthosis (FO)

Foot orthoses (commonly called "orthotics") are devices inserted into shoes to provide support for the foot by redistributing ground reaction forces acting on the foot joints while standing, walking or running. They may be either pre-moulded (also called pre-fabricated) or custom made according to a cast or impression of the foot. A great body of information exists within the orthotic literature describing their medical use for people with foot problems as well as the impact "orthotics" can have on foot, knee, hip, and spine deformities. They are used by everyone from athletes to the elderly to accommodate biomechanical deformities and a variety of soft tissue conditions. Custom-made foot orthosis are effective at reducing pain for people with painful high-arched feet, and may be effective for people with rheumatoid arthritis, plantar fasciitis or hallux valgus ("bunions"). For children with juvenile idiopathic arthritis (JIA) custom-made and pre-fabricated foot orthosis may also reduce foot pain.[12] Foot orthosis may also be used in conjunction with properly fitted orthopaedic footwear in the prevention of foot ulcers in the at-risk diabetic foot.

### 2.7.2 Ankle–foot orthosis (AFO)

An AFO with ankle hinge worn on the left foot

An ankle–foot orthosis (AFO) is an orthosis or brace that encumbers the ankle and foot. AFOs are externally applied and intended to control position and motion of the ankle, compensate for weakness, or correct deformities. AFOs can be used to support weak limbs, or to position a limb with contracted muscles into a more normal position. They are also used to immobilize the ankle and lower leg in the presence of arthritis or fracture, and to correct foot drop; an AFO is also known as a foot-drop brace. An AFO is generally constructed of lightweight polypropylene-based plastic in the shape of an "L", with the upright portion behind the calf and the lower portion running under the foot. They are attached to the calf with a strap, and are made to fit inside accommodative shoes. The unbroken "L" shape of some designs provides rigidity, while other designs (with a jointed ankle) provide different types of control. Focusing on children with cerebral palsy (CP), there are a wide variety of ankle foot orthoses used in clinical practice which are characterised by their design, the material used and the stiffness of that material. Changing any of these three components will alter the effect of the ankle foot orthosis on gait. While, there are a wide variety of AFOs used in clinical practice, which are characterised by their design, the material used and the stiffness of that material, there are calls for standardisation of the terminology

Obtaining a good fit with an AFO involves one of two approaches:

1. Provision of an off-the-shelf or prefabricated AFO matched in size to the end user
2. Custom manufacture of an individualized AFO from a positive model, obtained from a negative cast or the use of computer-aided imaging, design, and milling. The plastic used to create a durable AFO must be heated to 400 °F (200 °C), making direct molding of the material on the end user impossible.

The International Red Cross recognizes four major types of AFOs:

| **Flexible AFOs** | **Anti-Talus AFOs** | **Rigid AFOs** | **Tamarack Flexure Joint** |
|---|---|---|---|
| May provide dorsiflexion assistance, but give poor stabilization of the subtalar joint. | Block ankle motion, especially dorsiflexion; do not provide good stabilization for the subtalar joint. | Block ankle movements and stabilize the subtalar joint; may also help control adduction and abduction of the forefoot. | Provide subtalar stabilization while allowing free ankle dorsiflexion and free or restricted plantar flexion. Depending upon the design; may provide dorsiflexion assistance to correct foot drop. |

The International Committee of the Red Cross published its manufacturing guidelines for ankle–foot orthosis in 2006. Its intent is to provide standardized procedures for the manufacture of high-quality modern, durable and economical devices to people with disabilities throughout the world.

**Brace** is a rigid and semi-rigid device which is used for the purpose of supporting a weak or deformed body member or restricting or eliminating motion in a diseased or injured part of the body. Elastic devices, stockings, garter belts and other similar devices are not within the scope of a brace. An orthosis can be classified as either prefabricated (off-the-shelf or custom fitted) or custom-fabricated.

**Lumbar Sacral Orthosis (LSO)**: Designed to control gross movement of the trunk and motion of the vertebrae in one or more planes of motion, lateral/flexion, anterior flexion/posterior flexion, or axial rotation.

**Thoracic Lumbar Sacral Orthosis (TLSO)**: The posterior portion of the brace extends from the sacrococcygeal junction to just inferior to the scapular spine. The anterior portion of the orthosis at a minimum extends from the symphysis pubis to the xiphoid. These devices do not include elastic or equal shoulder straps or other strapping methods.

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**Unit-2**

**2 Marks**

1. Differentiate a prosthesis and orthosis.
2. What is the purpose of a HAS?
3. What are the three cardinal considerations to be followed while designing a prosthesis?
4. Define Maps and templates in CAD designing of a prosthetic limb.
5. Is there a need of CAD/CAM in rehabilitation? Justify.
6. Name few orthotic devices and their uses.
7. List few applications of LSO.
8. State the disadvantages of designing an artificial limb conventionally.
9. What is a Milwaukee brace?
10. Identify the different finger movements when designing a artificial hand.

**10 Marks**

1. How will you be able to design limb prosthesis? Explain the use of finite element analysis in modeling soft tissue distortion.
2. Elaborate on the role of computer aided engineering in developing customized component design.
3. Design an intelligent prosthetic knee and hierarchically controlled hand with necessary explanation.

4. If a person suffers from severe back pain and curved spine, what type of orthotic device will you design for him? Discuss about the same
5. Discuss about the various types of orthotic devices available for the lower limb.
6. Plan a technique to restore hand and leg functions using Functional Electrical Stimulation (FES).
7. Summarize on the construction and working of a myoelectric arm and hand.
8. Explain the working mechanism of a active above knee prosthesis.

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**SCHOOL OF BIO AND CHEMICAL ENGINEERING**

**DEPARTMENT OF BIOMEDICAL ENGINEERING**

# UNIT – III –REHABILITATION ENGINEERING– SBM1307

# UNIT-3
# WHEELED MOBILITY

## 3.1 Introduction and History of Wheel Chair

- Centuries ago, people with disabilities who survived for an extended period of time were transported on **hammocks slung** between poles which were carried by others.
- The **wheelbarrow** was developed and soon became a common mode of transportation for people with disabilities. Because wheelbarrows were used to transport materials, during this period in history, people with disabilities were looked upon as outcasts from society.
- The **renaissance**, the French court popularized the first wheelchairs. Wheelchairs were overstuffed arm chairs with wheels placed upon them. This enabled movement, with assistance, indoors.
- The **wooden wheelchair** with wicker matting was developed. This type of chair remained the standard until the 1930s.
- **Franklin D. Roosevelt was not satisfied with the wooden wheelchair and had many common metal kitchen** chairs modified with wheels.
- In the 1930s, Everest experienced an accident that left him mobility impaired. He worked with a fellow engineer Jennings to develop steel wheelchairs.
- **Everest & Jennings** to manufacture wheelchairs. Following World War II, medical advances saved the lives of many veterans with spinal cord injuries or lower limb amputations, who would have otherwise died. Veterans medical centers issued these veterans steel framed wheelchairs with 18 inch seat widths.
- These wheelchairs were designed to provide the veteran some mobility within the hospital and home, and not to optimize ergonomic variables. Just as among the ambulatory population, mobility among people with disabilities varies.
- Mobility is more of a functional limitation than a disability related condition.

**Powered mobility**

- It has tremendous positive psycho-social effects on an individual.
- Power wheelchairs provide greater independence to thousands of people with severe mobility impairments
- Power wheelchairs began in the 1940's as standard cross-brace folding manual wheelchairs adapted with automobile starter motors and an automobile battery. The cross-braced wheelchair remained the standard for a number of years.
- When the rigid power wheelchair frame was developed, space became available under the seat for electronic controls, respirators, communication systems, and reclining devices.
- By the mid-1970s, wheelchairs had evolved to the point where people had acquired a significant level of mobility.

- A **personal automobile** has a profound effect on persons' mobility and ability to participate in society.
- A wheelchair is suitable for short distances and for many situations where an unimpaired person would walk.
- Modifications to vehicles may be as simple as a lever attached to the brake and accelerator pedals, a complete joystick controlled fly-by-wire system.
- Modifications to other components of the vehicle may be required to provide wheelchair access.
- **Micro-cars**, enlarged wheelchairs which travel at bicycle speeds, are convenient for many people who wish only to travel to the local grocery store or post office.
- **Micro-cars** are also useful for people who like to travel along bicycle paths or drive short distances off-road.

### 3.2 Categories of Wheelchairs

There are two basic classes of wheelchairs:

Manually powered

Externally powered

#### 3.2.1 Externally powered wheelchairs

- Electrically powered wheelchairs. There are approximately 200,000 wheelchairs sold annually within the US of which about 20,000 are powered wheelchairs.
- Most wheelchairs are purchased by third-party-payers (e.g., insurance companies, government agencies).
- This requires the market to be responsive to wheelchairs user's needs, prescriber expertise and experience, third-party-payer purchase criteria, and competition from other manufacturers.

#### 3.2.2 Depot wheelchairs

- Intended for institutional use where several people may use the same wheelchair.
- They are inappropriate for active people who use wheelchairs for personal mobility.
- Designed to be inexpensive, accommodate large variations in body size, to be low maintenance, and often to be attendant propelled.
- They are heavy and their performance is limited.
- A typical depot wheelchair will have swing away footrests, removable armrests, a single cross-brace frame and solid tires.

#### 3.2.3 One arm wheel Chair

- People who have impairment of an arm and one or both lower extremities may benefit from a one arm drive wheelchair that uses a linkage connecting the rear wheels.

- This allows the user to push upon the pushrim of one wheel and to propel both wheels.
- To effectively turn the wheelchair, the user must have the ability to disengage the drive mechanism.
- Some people have weakness of the upper and lower extremities and can gain maximal benefit from wheelchair propulsion by combining the use of their arms and legs or by using only their legs.

**3.2.4 Foot-drive wheelchair**

- Greatly depends upon how the user can take greatest advantage of their motor abilities.
- Indoor spaces are more limited and one is often required to get close to furnishings and fixtures to use them properly.

**3.2.5 Indoor wheelchairs** often use rear castors

- Rear castor designs make the wheelchair less stable in lateral directions.
- Have short wheelbases.
- All wheelchairs are not propelled by the person sitting in the wheelchair.
- In many hospitals and longterm care facilities, wheelchairs are propelled by attendants. Attendant propelled wheelchair designs must consider the rider and the attendant as users. The rider must be transported safely and comfortably.
- The attendant must be able to operate and easily, safely and with minimum physical strain.
- Active users often prefer highly responsive wheelchairs which fit their physical and psychosocial character.

**3.2.6 Ultralight wheelchair**

- The ultra light wheelchair evolved from the desire of wheelchair users to develop functional ergonomic designs for wheelchairs.
- Ultralight wheelchairs are made of such materials as aluminum, alloy steel, titanium, or composites.
- The design of ultra light wheelchairs allows a number of features to be customized by the user or be specified for manufacture.
- The most common features of all are the light weight, the high quality of materials used in their construction, and their functional design.
- Many people can benefit from ultralight wheelchair designs.

- The desire to achieve better performance has led wheelchair users, inventors, and manufacturers to constantly develop specialized wheelchairs for sports. There is no real typical sports wheelchair as the design depends heavily on the sport.
- Basketball and tennis wheelchairs are often thought to typify sports wheelchair design. However, racing, field events or shooting wheelchairs have little in common with the former.
- Some wheelchairs are made to change configuration from reclining to sitting, and from sitting to standing.
- Most stand-up wheelchairs cannot be driven in the stand-up setting in order to insure safe and stable operation.
- Standing gives the user the ability to reach cabinet and counter spaces otherwise inaccessible. Standing has the additional advantage of providing therapeutic benefits, i.e., hemodynamic improvements, and amelioration of osteoporosis.
- Stairs and other obstacles persist despite the progress made in universal design. Stair-climbing wheelchairs are electrically powered wheelchairs designed to ascend and descend stairs safely under the occupant's control.
- **Stair-climbing wheelchairs** are quite complicated, and often reconfigure themselves while climbing stairs. The additional power required to climb stairs often reduces the range of the wheelchair when compared to standard power wheelchairs.

### 3.3 Wheelchair Structure and Component Design

- Several factors must be considered when designing a wheelchair frame:
- what are the intended uses
- what are the abilities of the user
- what are the resources available
- What are the existing products available

- These factors determine if and how the frame will be designed and built.
- Successful designs of wheelchairs can only be accomplished with continuous input from and interaction with wheelchair users.
- The durability, aesthetics, function, ride comfort, and cost of the frame are dependent on the materials for construction, the frame geometry, and fabrication methods.
- One of the issues that make wheelchair design more complicated is the fact that many users are dependent upon wheeled mobility every day, nearly all day.

#### 3.3.1 Materials

- Most wheelchairs are made of either aluminum or steel. Some chairs are made of titanium or advanced composite materials, primarily carbon fiber.

- All of these materials have their strengths and weaknesses.

- **Aluminum wheelchairs**

- Tungsten Inert Gas (TIG) welded (i.e., electrically welded together in a cloud of inert gas). They are bolted together using lugs.
- Wheelchair frames are constructed of round drawn 6061 aluminum tubing. This is one of the least expensive and most versatile of the heat treatable aluminum alloys.
- It has good mechanical properties and high corrosion resistance. It can be fabricated using most standard techniques.

- **Steel wheelchairs**

- Mild steel (1040 or 1060) or chromium-molybdenum alloy (4130 or 4140) seamless tubing commonly called chro-moly.
- Mild steel is very inexpensive and easy to work with.
- It has a low strength to weight ratio compared to other materials.
- Chro-moly is widely used because of its weldability, ease of fabrication, mild hardenability, and high fatigueability.
- Made of tubing 0.028-0.035 inches in wall thickness but diameters vary depending on the expected loads from between 0.25 to 1.25 in.
- More and more of the high-end wheelchairs are made of titanium.

- **Titanium wheelchair**

- Titanium is a lightweight, strong, nonferrous metal.
- Titanium wheelchair frames are TIG welded.
- Titanium is the most exotic of the metals used in production wheelchairs and the most expensive.
- Titanium requires special tooling and skill to be machined and welded.
- It has very good mechanical properties and high corrosion resistance.
- It is resilient to wear and abrasion.
- Titanium is used because of its availability, appearance, corrosion resistance, very good strength and light weight.
- A drawback of titanium, besides cost, is that titanium once worn or if flawed may break rapidly (i.e., it has a tendency towards brittle fractures).

- **Advanced composites**

- used in aerospace and industrial applications
- The materials include Kevlar, carbon fiber, and polyester limestone composite.
- Kevlar is an organic fiber which is yellow in color and soft to the touch. It is extremely strong and tough. It is one of the lightest structural fabrics on today’s market.
- Kevlar is highly resistant to impact, but its compression strength is poor.

- **Carbon fibers**

- Made by changing the molecular structure of Rayon fibers by extreme stretching and heating.

- Carbon fiber is very stiff (high modulus of elasticity), very strong (high tensile strength) and has very low density (weight for a given volume).

- **Composites**

- Come as cloth or yarn. It is woven into bidirectional or unidirectional cloth. Unidirectional weaves can add strength along a particular direction.
- Composites must be bound together by resin or epoxy.
- Generally, polyester resins or various specialty epoxies (e.g., Safe-T-Poxy) are used.
- To achieve greatest strength a minimum amount of epoxy must be used while wetting all of the fibers. This is often achieved through a process called bagging.
- To increase the strength and stiffness of structural components a foam (e.g., styrofoam, urethane or PVC) core is used.
- The strengthening occurs because of the separation of the cloth layers (it now becomes more like a tube than a flat sheet).

- **Polyesther limestone composites**

- Used widely in industrial high voltage electrical component enclosures.
- A blend of polyester and limestone are used to form a mixture which can be molded under pressure and heated to form a stiff and durable finished product.
- It has high impact strength, and holds tolerances well, but have substantially lower strength to weight ratios than other composites.
- Their primary advantage is cost, very inexpensive and readily available. Composites can be molded into elaborate shapes which opens a multitude of possibilities for wheelchair design.

### 3.3.2 Frame Design

- Presently all common wheelchair frames center around tubular construction. The tubing can either be welded together or bolted together using lugs.

There are two basic common frame styles:

1. **Box frame**
    - The box frame is named such because of its rectangular shape, and that tubes outline the edges of the “box”. It is very strong and very durable.
    - The box frame provides great strength and rigidity. If designed and constructed properly the frame only deflects minimally during normal loading
    - Most of the suspension is provided by the seat cushion, the wheels and the wheel mounting hardware.
2. **Cantilever frame**
    - **A cantilever frame** is named so because the front and rear wheels, when viewing the chair from the side, appear to be connected by only one tube; this is similar to having the front wheels attached to a cantilever beam fixed at the rear wheels.
    - Both frame types require cross bracing providing adequate strength and stiffness.

The cantilever frame is based upon a few basic principles:

- The frame can act as a suspension,
- There are fewer tubes and they are closer to the body which may make the chair less conspicuous
- There are fewer parts and fewer welds which makes the frame easier to construct.

### 3.3.3 Wheels and Casters

**Fig 3.1 Caster**

- Casters can be as small as 2 in. in diameter or as large as 12 in. in diameter for wheelchairs designed for daily use.
- Casters are pneumatic, semi-pneumatic, or solid (polyurethane).
- Pneumatic casters offer a smoother ride at the cost of increased maintenance, whereas polyurethane casters are very durable.
- Semi-pneumatic tires offer a compromise. Most active users prefer 5 in.
- Polyurethane casters or 8 inch pneumatic casters for daily use.
- An 8-in. caster offers a better ride comfort at the expense of foot clearance.
- Caster foot clearance is maximized with a 2-in. “Roller Blade” caster often used for court sports (e.g., basketball, tennis, and racquetball).

**3.3.4 Rear wheels** come in three common sizes 22, 24, and 26 in.

**Fig 3.2 Rear wheel**

They come in two styles:

Spoked and MAG

- **MAG wheels** are typically made of plastic and are die cast. MAG wheels require minimal maintenance, and wear well.
- **Spoked wheels** are substantially lighter, more responsive, and are generally preferred by active manual wheelchair users.

**Rear tires can be two types: pneumatic or puncture proof.**

- **Pneumatic ti**res can either use a separate tube and tire or a combined tube or tire (sew-up). Commonly, a belted rubber tire with a Butyl tube (65 psi) is used. However, those desiring higher performance prefer sew-up tires or Kevlar belted tires with high pressure tubes (180 psi).
- **Puncture proo**f tires are heavier, provide less suspension, and are less lively than pneumatic tires.

**The chair must be designed to optimize the interaction of the wheels with the ground. Four critical performance factors need to be considered:**

- Castor Flutter, (2) Castor Float,
- Tracking, and (4) Alignment.

- **Castor flutter** is the shimmy (rapid vibration of the front wheels) that may occur on some surfaces above certain speeds.
- **Castor float:** When one of the castors does not touch the floor when on level ground, the wheelchair has castor float. Castor float decreases the stability and performance of the wheelchair. A manual wheelchair uses rear wheel steering via differential propulsion torque.
- **Tracking** is the tendency of the wheelchair/rider to maintain its course once control has been relinquished.
- Tracking is important, as the rider propels the hand rims periodically (about every second) and if the chair does not track well it will drift from its course between pushes and force the rider to correct heading. This will waste valuable energy and reduce control over the chair.
- **Alignment** generally refers to the orientation of the rear wheels with respect to one another.
- It is desirable to have the rear wheels parallel to one another without any difference between the distances across the two rear wheels at the front and back.
- Misalignment on the order of 1/8 inch can cause a noticeable increase in the effort required to propel the wheelchair.

## 3.4 Ergonomics of Wheelchair Propulsion

- The most important area of wheelchair design and prescription is determining the proper interaction between the wheelchair and the user.
- This can lead to reducing the risk of developing repetitive strain injury while maximizing mobility.
- Cardiovascular fitness can be improved through exercise which requires a properly fitted wheelchair.

**Kinematics**

- Kinematic data by itself does not provide sufficient information for the clinician to implement appropriate rehabilitation intervention strategies or for the engineer to incorporate this information into wheelchair design changes.
- Kinematic data are commonly collected at 60 Hz, which is the maximum frequency of many videotape-based systems.
- Kinematic data analysis shows that experienced wheelchair users contact the pushrim and push to nearly 90° in front. This is significantly longer than non-wheelchair users.
- Lengthening the stroke permits lowering the propulsion moment and may place less stress on the users' joints.
- Evaluation and possible retraining of wheelchair users is to determine the optimal stroke kinetics and kinematics.
- Wheelchair propulsion kinematic data are typically cyclic (i.e., a person repeats or nearly repeats his/her arm motions over several strokes).
- Each marker of the kinematic model (e.g., shoulder, elbow, wrist,) of each subject generates an x and y set of data which is periodic.
- The frequencies of the x and y data are dependent upon the anthropometry of the individual, the construction of the wheelchair, and the speed of propulsion.
- Characteristic stroke from a set of kinematic data including several strokes can be developed.

**Kinetics**

- The SMART wheel was developed to measure the pushrim forces required for evaluating net joint forces and moments to allow the clinician and researcher to study the level of stress experienced by the joint structures during wheelchair propulsion.
- The SMART wheel uses a standard wheelchair wheel fitted with three beams 120° apart and each has two full strain gage bridges.
- The strain gage bridges are each interfaced through an instrumentation amplifier to a micro-controller which transmits the data through a mercury slip-ring to the serial port of a computer.
- Kinetics of wheelchair propulsion is affected by speed of propulsion, injury level, user experience, and wheelchair type and fit.

**Van Der Woude et al.** have reported on an ergometer which detected torque by way of a force transducer located in the wheel center and attached to what is referred to as the "wheel/hand rim construction".
The ergometer was adjusted for each subject's anthropometric measurements.

**Brauer and Hertig** measured the static torque produced on push-rims which were rigidly restrained by springs and mounted independent of the tires and rims of the wheelchair. The spring system was adjustable for the subject's strength. The wheels were locked in a fixed position. Torque was measured using slide-wire resistors coupled to the differential movements between the push-rim and wheels and recorded using a strip chart recorder.

**Brubaker, Ross, and McLaurin** examined the effect of horizontal and vertical seat position (relative to the wheel position) on the generation of static push-rim force. Force was measured using a test platform with a movable seat and strain gauged beams to which the push-rims were mounted. Pushing and pulling forces were recorded using a strip chart recorder.

### 3.4.1 Net Joint Forces and Moments

- Net joint forces and moments acting at the wrist, elbow and shoulder during wheelchair propulsion provide scientists and clinicians with information related to the level of stress borne by the joint structure.
- Joint moments and forces are calculated using limb segment and joint models, anthropometric data, kinetic data, and kinematic data.
- Joint moment's data shows that forces at each joint vary among subjects in terms of peak forces, where they occur during the propulsion phase, and how quickly they develop.
- Peak net joint moments occur at different joint angles for different subjects, and conditions (e.g., speed, resistance).
- Convention for joint angles is that 180 degrees at the elbow represents full extension; while at the wrist, this is the hand in the neutral position (flexion less than 180 degrees and extension greater than 180 degrees).
- Joint angles at the shoulder are determined between the arm and the trunk, with zero measured at the point where the trunk and arm are aligned.
- Wheelchair users show maximum net shoulder moment between 20° and 40° of extension.
- Some wheelchair users also show a rapid rise in the elbow extensor moment at the beginning of the stroke with the elbow at about 120°. This moment value begins to decrease between 150°and 170°. At the wrist, the peak moments occur between 190° and 220°.
- Net joint moments and force models need to account for hand center of pressure, inaccuracies in anthropometric data, and joint models related to clinical variables.

**3.5 Power Wheelchair Electrical Systems**

- Some people are impaired to an extent that they would have no mobility without a power wheelchair
- Some people may have limited upper body mobility and may have the ability to propel a manual wheelchair for short distances
- A power wheelchair may provide greater mobility. It is best to suggest a power wheelchair for longer excursions, and a manual wheelchair for in home and recreational use

**User Interface**

- Power wheelchairs are often used in conjunction with a number of other adaptive devices.
- For people with severe mobility impairments, Power wheelchairs is used with
    - communication devices
    - computer access devices
    - respirators
    - Reclining seating systems

**Joystick:**

- The joystick is the most common control interface between the user and the wheelchair.
- Joysticks produce voltage signals proportional to displacement, force, or switch closures.
- **Displacement joysticks** may use either potentiometers, variable inductors (coils) or optical sensors to convert displacement to voltage.
- **Inductive joysticks** are most common as they wear well and they can be made quite sensitive. Joysticks can be modified to be used for chin, foot, elbow, tongue or shoulder control.
- **Force sensing joysticks use three basic transducers:**
    - simple springs and dampeners on a displacement joystick
    - cantilever beams with strain gages
    - fluid with pressure sensors.

  Force sensing joysticks which rely on passive dampeners or fluid pressure generally require the user to have a range of motion within normal values for displacement joysticks users.
- **Beam-based force sensing joysticks** require negligible motion, and hence may be used for people with limited motion abilities.
- People who exhibit intention or spastic tremor or with multiple sclerosis may require special control considerations.
- Signal processing techniques are often required to grant the user greater control over the wheelchair. The signal processing is typically incorporated into the controller.

Some people lack the fine motor control to effectively use a joystick. An alternative for these people is to use a switch control or a head position control.

- **A switch control** simply uses either a set of switches or a single switch and a coded input, i.e., Morse code or some other simple switch code.
- The input of the user is latched by the controller and the wheelchair performs the task commanded by the user.
- The user may latch the chair to repeatedly perform a task a specified number of times, e.g., continue straight until commanded to do otherwise.
- Switch control is quite functional, but it is generally slower than joystick control. Switch inputs can be generated in many ways
- The input can come from a sip-and-puff mechanism which works off of a pressure transducer.
- Switches may be mounted on the armrests or a lap tray for hand or arm activation, on the footrest(s) for foot activation, or on a head rest for head activation.
- The motion of the head can also be used for proportional control by using ultrasonic sensors.
- Ultrasonic sensors can be mounted in an array about the headrest.
- The signal produced by the ultrasonic sensors is related to the position of the head. Hence, motion of the head can be used to create a proportional control signal.
- Ultrasonic head control and switch control can be combined to give some users greater mastery over their power wheelchair.
- Switches can be used to select the controller mode, whereas the ultrasonic sensors give a proportional input signal.
- A critical consideration when selecting or designing a user interface is that the ability of the user to accurately control the interface is heavily dependent upon the stability of the user within the wheelchair.
- Often custom seating and postural support systems are required for a user interface to be truly effective.

**Integrated Controls**

- People with severe physical impairments may only be able to effectively manipulate a single input device.
- Integrated controls are used to facilitate using a single input device (e.g., joystick, head switches, voice recognition system) to control multiple actuators (e.g., power wheelchair, environmental control unit, manipulator). This provides the user with greater control over the environment.
- The M3S-Multiple Master Multiple Slave bus is designed to provide simple, reliable access to a variety of assistive devices.
- Assistive devices include input devices, actuators, and end-effectors. M3S is based on the Computer Area Network (CAN) standard.

- Clinicians and users often desire to combine products from various sources to achieve maximal independence. The result is to have several devices with their own input devices and overlapping functions.
- Integrated controls provide access to various end-effectors with a single input device. The M3S provides an electronic communication protocol so that the system operates properly.
- M3S is an interface specification with basic hardware architecture, a bus communication protocol, and a configuration method.
- An M3S system consists of a microcontroller in each device and a control and configuration module (CCM).
- The CCM insures proper signal processing, system configuration, and safety monitoring.
- The CCM is linked to a display (e.g., visual, auditory, tactile) which allows the user to select and operate each end-effector.

**Power System**

- To implement a motor controller, a servo-amplifier is required to convert signal level power (volts at milliamps) to motor power (volts at amps).
- Typically, a design requirement for series, shunt, and brushless motor drives is to control torque and speed, and hence, power.
- Voltage control can often be used to control speed for both shunt and series motors. Series motors require feedback to achieve accurate control.
- Linear servo amplifiers are not generally used with power wheelchairs primarily because of their lower efficiency than chopper circuits.
- A motor can be thought of as a filter to a chopper circuit, in this case, the switching unit can be used as part of a speed and current control loop.
- Benefits of increased efficiency are increased brush life, gear life, and lower probability of field permanent magnet demagnetization.
- Switching or chopper drives are classified as either unidirectional or bi-directional.
- They are further divided by whether they use dynamic braking. Typically, power wheelchairs use bi-directional drives without dynamic braking.
- The average voltage delivered to the motor from a switching drive is controlled by varying the duty cycle of the input waveform.
- There are two common methods of achieving this goal: (1) fixed pulse width, variable repetition rate, and (2) pulse-width modulation (PWM).
- Power wheelchair servo-amplifiers typically employ PWM.
- Pulse width modulation at a fixed frequency has no minimum on-time restriction.
- For analysis, a d.c. motor can be modeled as a RL circuit, resistor and inductor, or in series with a voltage source.

## 3.6 Personal Transportation

- Adaptive equipment requirements increase with the degree of impairment and desired degree of independence in areas such as personal care, mobility, leisure, personal transportation, and employment.
- People are concerned that they receive the proper equipment for them to safely operate their vehicle.
- Access and egress equipment have the greatest maintenance requirements.
- Other devices such as hand controls, steering equipment, securement mechanisms, and interior controls require less maintenance.
- Physical functional abilities such as range of motion, manual muscle strength, sensation, grip strength, pinch strength, fine motor dexterity, and hand-eye coordination all may be related to driving potential.
- Driving characteristics must also be evaluated when determining an individual's potential to safely operate a motor vehicle.

Factors influencing driving potential

-Throttle force

-Brake force

-Steering force

-Brake reaction time

-Steering reaction time

**3.6.1 Vehicle Selection**

- Automobile for wheelchair users is not an ideal one.
- Automotive consumers with disabilities are also concerned about
    - Ease of entry
    - Stowage space for the wheelchair
    - Seat positioning
    - Reduced size
    - Increasingly sloping windshields
    - Lower roofs
- The ability to load the wheelchair into a vehicle is essential.
- Some individuals with sufficient strength and a suitable vehicle are able to stow their wheelchairs inside the vehicle without the use of assistive devices.
- Many people must rely on an external loading device.
- The selection of the appropriate vehicle should be based upon the client's physical abilities and social needs.
- An approach to overcome the problems associated with a smaller car is to use a car-top wheelchair carrying device. These devices lift the wheelchair to the top of the car, fold, and stow it.

**3.6.2 Lift Mechanisms**

- **Wheelchair lifts**: wheelchair for transferring into a passenger vehicle seat
- **Platform lifts** may use a lifting track, a parallelogram lifting linkage, or a rotary lift.
- Lift devices are either electromechanically or electro hydraulically powered.

- The platform often folds into the side doorway of the van.
- **Crane lifts**, also called swing-out lifts, have a platform which elevates and folds or rotate into the van.
- Lifts may either be semi-automatic or automatic.
- **Semi-automatic lifts** require the user to initiate various stages (e.g., unlocking door, door opening, and lowering lift) of the lifting process.
- **Automatic lifts** are designed to perform all lift functions. They usually have an outside key operated control box, or an interior radio controlled control box.
- Some lifts use electrohydraulic actuators to lift and fold, with valves and gravity used to lower the lift.
- **Crane lifts** may swing out from a post at the front or rear of the side door.
- Interlocking mechanisms are available with some lifts to prevent the lift from being operated while the door is closed.
- The Society of Automotive Engineers (SAE) has developed guidelines for the testing of wheelchair lift devices for entry and exit from a personal vehicle.

### 3.6.3 Wheelchair Restraint Mechanisms

- Securement systems are used to temporarily attach wheelchairs to vehicles during transport. Many wheelchair users can operate a motor vehicle from their wheelchair, but are unable to transfer into a vehicle seat.
- Wheelchairs are flexible, higher than a standard automobile seat, and not fixed to the vehicle. The passenger is restrained using a harness of at least one belt to provide pelvic restraint and two shoulder or torso belts that restrain both shoulders.
- A head support may also be used to prevent rearward motion of the head during impact or rebound.
- A three point restraint is the combination of a lap belt and a shoulder belt (e.g., pelvic torso restraint, lap-sash restraint, lap-shoulder restraint).
- The relationship between injury criteria and the mechanics of restraint systems are important to insure the safety of wheelchair users in motor vehicles.
- Hip and head deflections are often used criteria for determining potential injury.

### 3.6.4 Hand Controls

- Hand-controls are available for automatic and manual transmission vehicles.
    - Portable hand-controls
    - Long-term hand controls
- Portable hand-controls are designed to easily attach to most common automobiles with a minimal number of tools.
- Hand-controls are
    - Available for either left or right hand control. Many hand controls are
    - Attached to the steering column.
    - Either clamp to the steering column or are attached to a bracket which is bolted to the steering column or dash

    - Installation of the hand-controls should not interfere with driver safety features (e.g., air bags, collapsible steering columns).
    - The push rods of the hand-control either clamp directly to the pedals or the levers connected to them.
- Most systems activate the brakes by having the driver push forward on a lever with a hand grip.
- The throttle, or gas pedal, is operated in a number of ways. Some systems use a twist knob or motorcycle type throttle.
- Another method is to rotate the throttle-brake lever downwards
- It is common to have the same vehicle driven by multiple people which may require the vehicle to be safely operated with hand-controls, and the OEM foot controls.
- Care must be taken to insure that the lever and brackets of the hand-controls do not restrict the driving motions of foot control drivers.
    - Many people have the motor control necessary to operate a motor vehicle, but they do not have the strength required to operate manual hand-controls.
    - Automatic or Fly-By-Wire hand-controls use external actuators (e.g., air motors, servo mechanisms, hydraulic motors) to reduce the force required to operate various vehicle primary controls.
    - Power steering, power brakes, six-way power seats, and power adjustable steering columns can be purchased as factory options on many vehicles.
    - Six-way power seats are used to provide greater postural support and positioning than standard automotive seats.
    - They can be controlled by a few switches to move fore-aft, incline-recline, and superior inferior. This allows the user to position the seat for easy entry and exit, and for optimal driving comfort.
    - Power adjustable steering columns also make vehicles more accessible. By using a few buttons, the steering column can be tilted upwards or downwards allowing positioning for entry/exist into the vehicle, and for optimal driving control.

## 3.7 Tricycle

### Introduction

Worldwide, 100-130 million people need wheelchairs, but less 10% either own or have means of obtaining one because of these people live in developing countries where are not available. Design and functionality as a whole has been improved over the past several decades, but there is a need for new technology and innovative designs. The assistive device users are over age 65, with expected as the baby boomers age and the life expectancy increases.

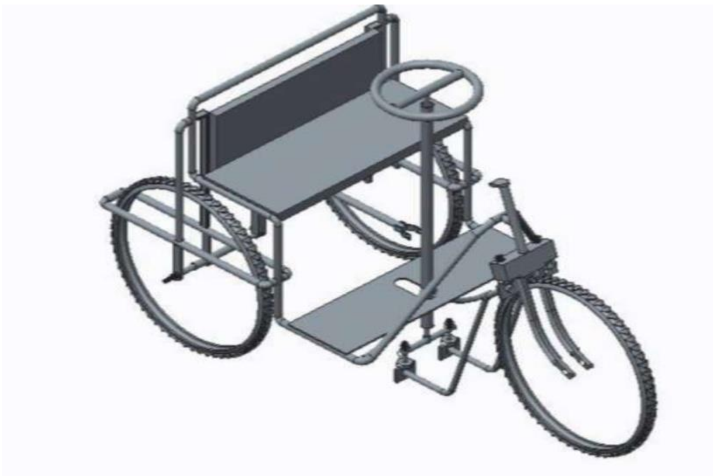

**Fig: 3.3 Tricycle**

**Working Principals**

1. When we apply the force on steering in forward and backward direction liver and crank provide the motion to wheel chair by converting the sliding motion into rotary motion.
2. The motion of direction of wheelchair is controlled by steering.
3. The device is operated by to and from motion of steering which help to rotate the wheel, the turning action takes place by tilting the steering forward and backward direction.

**Objective**

- It is a homemade 3-wheel handicapped cycle.
- It is simple and light weight
- Disc brakes wheelchair and hand cycle hybrid that a self-propulsion mechanism that converts push pull motion to forward movement, such as
    - 8 speed hub gear
    - Bicycle style steering
    - Foot stirrup
    - Gearing for hills
    - Anti rollback mechanism
    - 16" front and 20" rear wheels
    - Internal hub gear
    - Integrated driveshaft.etc.

**Scope & Function Scope**

1. It is used for very large amount of Japan.
2. If need to be handicapped human.
3. Then it was need of in market used for handicapped human.

**Function:** 1. More powerful up to hand are move on. 2. Manuel control. 3. The motion of direction of wheelchair is controlled by steering. 4. Pressure can be adjust, etc

**Hardware & Resource Hardware:**

1. Welding Machine. 2. Screw Driver. 3. Drill Machine. 4. Lathe Machine etc.

**Resources:** We use the some material such as:-

1. Still alloys commonly used for wheelchairs are mild steel, alloy steel, and chromium-nickel molybdenum alloy steel.
2. Due to cost and availability restrictions, the team will likely a combination of aluminum and steel to construct the assesory.


**Fig.2 Steering Fig.1 Bearing Fig.3 Break pad Fig.4 Internal hub gear**


**Fig.5 Cable yoke Fig.6 Wheel Fig.7 Break Lever**

**Vehicle Mechanics**

In order to optimize performance and endurance, the vehicle losses must be minimized and the hand cycle well. Rolling resistance issues that play in hand rim are equally relevant in hand cycles. Rolling must be minimized through lightweight design and material, wheel alignment and maintenance.

**Breaking & Propulsion**

1. The propulsion system must move the wheelchair and be in both the forward and reverse directions.
2. Brakes must be able to slow the wheelchair in addition to it to a complete stop.

3. The basic function of brakes is to slow or stop a moving (i.e. wheels) to prevent loss of control of the object.
4. The brake lever cannot require more than 35 pounds of grip force to actuate.

**Details Dimensions (Cm)**

1. Distance between center of two rear wheels 72 cm
2. Between center of front and rear wheel 128 cm
3. Length of connecting rod 50 cm
4. Radius of pedal 8 cm
5. Length of rear axle 35 cm
6. Heat of seat from center of rear exal 37 cm
7. Height of steering from footpad 67 cm
8. Length of steering rod 55 cm
9. Length of outer rod 47.5 cm
10. Diameter of steering wheel 32 cm
11. Length of direction rod 67 cm
12. Distance between center of front and steering rod (at center position) 67 cm
13. Height of seat from footpad 37 cm and Height of footpad from ground 33 cm

**Steering Systems**

1. The user must be able to steer the chair at all times, unless an attendant is pushing the Chair. Maintaining control of the direction of the chair at all times is essential not only for user safety, but also to maximize the independence of the individual. When there is not an attendant pushing the chair, the user must have full control to be able to safely manoeuvre it.
2. The modification accessory cannot interfere with an attendant's ability to push/control the chair. This will be accomplished by providing a means of disengaging the

**Conclusion**

The hand cycle has evolved into a contemporary assistive for sports, leisure and daily use, as well as for training, . Even in rehabilitation, hand cycling is being as a good training alternative in early rehabilitation also frail individuals. It is expected that the current booming development of crank propelled tricycles in the industrialized countries serve not only the young and active wheelchair user, but also the less well-trained individual or those with more extensive limitations.

**References**


- Bronzino, Joseph D. The Biomedical Engineering Handbook, Second Edition, Two Volume, 2000, CRC Press LLC.
- Robinson C. J, Rehabilitation Engineering, CRC Press. 1995.
- Ballabio E. et al, Rehabilitation Technology, IOS Press. 1993.

**Unit-3**

**2 Marks**

1. Mention the advantages and disadvantages of manual wheelchairs.
2. What is the role of hand controls in a wheelchair.
3. State the advantages of automated over manual wheelchair.
4. Draw and highlight the major parts of a powered wheel chair.
5. List the different steps involved in fabrication of a wheelchair.
6. Point out the various components of a wheelchair.
7. What are the different categories of wheel chairs?
8. State the need for power wheel chair electrical system.
9. How will you select the type of vehicle for personal transportation in wheel chairs?
10. List out the requirements of a wheelchair.
11. How does a tricycle help in rehabilitation?
12. What is wheeled mobility?

**10 Marks**

1. Elaborate on the types of wheelchair designs quoting their variations in structural and functional aspects and control systems.
2. Discuss about the fundamental of a manual wheel chair's propulsion stating the biomechanics involved behind its operation.
3. Design a powered wheel chair system and discuss about the components used.
4. Summarize on the wheel chair history, its category and design.
5. Describe the design process of a wheelchair. Compare between a manual and a powered wheelchair.
6. Explain in detail the design and types of tricycles.
7. Write about the following factors involved in personal transportation using a wheelchair a) vehicle selection b) lift mechanism c) wheel chair restraint mechanism d) hand controls.

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**SCHOOL OF BIO AND CHEMICAL ENGINEERING**

**DEPARTMENT OF BIOMEDICAL ENGINEERING**

# UNIT – IV –REHABILITATION ENGINEERING– SBM1307

# UNIT-4
# 4. SENSORY AUGMENTATION AND SUBSTITUTION

- ***Sensory augmentation systems*** such as eyeglasses and hearing aids enhance the existing capabilities of a functional human sensory system.
- ***Sensory substitution*** is the use of one human sense to receive information normally received by another sense.
- Braille and speech synthesizers are examples of systems that substitute touch and hearing, respectively, for information that is normally visual (printed or displayed text).

Human Sensory Systems

| Visual | Auditory | Tactual |
|---|---|---|
| Visual augmentation | Auditory augmentation | Tactual augmentation |
| Tactual vision substitution | Visual auditory substitution | Tactual substitution |
| Auditory vision substitution | Tactual auditory substitution | |

## 4.1 Visual System

- The human visual system processes information in a parallel fashion.
- A single glimpse acquires a wealth of information; the field of view for two eyes is 180 degrees horizontally and 120 degrees vertically.
- The spatial resolution in the central (foveal) part of the visual field is approximately 0.5 to 1.0 minute of arc although Vernier acuity, the specialized task of detecting a misalignment of two lines placed end to end, is much finer, approximately 2 seconds of arc.
- Low-contrast presentations substantially reduce visual acuity.
- ***Severe visual impairment*** is defined to be 20/70 vision in the better eye with best refractive correction.
- ***Legal blindness*** means that the best corrected vision is 20/200 or that the field of view is very narrow (<20 degrees).

### 4.1.1Visual Augmentation

- People with certain eye disorders see better with higher- or lower-than-normal light levels; an illuminance from 100 to 4000 lux may promote comfortable reading.
- Ideal illumination is diffuse and directed from the side at a 45-degree angle to prevent glare. The surrounding room is preferably 20% to 50% darker than the object of interest.
- Refractive errors cause difficulties in focusing on an object at a given distance from the eye
- The most common vision defects are
    - **Myopia (near-sightedness)**

    - **hyperopia (far-sightedness)**
    - **astigmatism (focus depth that varies with radial orientation)**
    - **presbyopia (loss of ability to adjust focus, manifested as far-sightedness)**
- These normally can be corrected with appropriate eyeglasses or contact lenses and are rarely the cause of a disability.
- **Magnification** is the most useful form of image processing for vision defects that do not respond to refractive correction. The simplest form of image magnification is getting closer; halving the distance to an object doubles its size.
- Magnifications up to 20 times are possible with minimal loss of field of view. At very close range, eyeglasses or a loupe may be required to maintain focus.
- Hand or stand magnifiers held 18 to 40 cm (not critical) from the eye create a virtual image that increases rapidly in size as the object-to-lens distance approaches the focal length of the lens.
- **Lenses are rated in diopters**

  $$\mathbf{D = 1/}f$$

  where $f$ is the focal length of the lens in centimeters. The useful range is approximately 4 to 20 D;
- For distance viewing, magnification of 2 to 10 times can be achieved with hand-held telescopes at the expense of a reduced field of view.
- **Closed-circuit television (CCTV) systems** magnify print and small objects up to 60 times, with higher effective magnifications possible by close viewing.
- Users with vision as poor as 1/400 (20/8000) may be able to read ordinary print with CCTV.
- Some recent units are portable and contain black/white image reversal and contrast enhancement features.
- Electrical stimulation of the visual cortex produces perceived spots of light called ***phosphenes*.** Some attempts, summarized have been made to map these sensations and display identifiable patterns, but the phosphenes often do not correspond spatially with the specific location on the visual cortex.

### 4.1.2 Tactual Vision Substitution

- With sufficient training, people without useful vision can acquire sufficient information via the tactile sense for many activities of daily living, such as walking independently and reading.
- For example, long cane allows navigation by transmitting surface profile, roughness, and elasticity to the hand.
- These features are *perceived* to originate at the tip of the cane, not the hand where they are transduced.
- Electronic aids such as the hand-held Mowat sonar sensor provide a tactile indication of range to the nearest object.
- Braille reading material substitutes raised-dot patterns on 2.3-mm centers for visual letters, enabling reading rates up to 30 to 40 words per minute (wpm).
- Contracted Braille uses symbols for common words and affixes, enabling reading at up to 200 wpm.
- The Optacon (*op*tical-to *ta*ctile *con*verter) converts the outline of printed letters recorded by a small, hand-held camera to enlarged vibrotactile letter outlines on the user's fingerpad.

- The camera's field of view is divided into 100 or 144 pixels, and the reflected light intensity at each pixel determines whether a corresponding vibrating pin on the fingertip is active or not.
- Ordinary printed text can be read at 28 (typical) or 90 (exceptional) wpm.
- Spatial orientation and recognition of objects beyond the reach of a hand or long cane are the objective of experimental systems that convert an image from a television-type camera to a matrix of electrotactile or vibrotactile stimulators on the abdomen, forehead, or fingertip.
- With training, the user can interpret the patterns of tingling or buzzing pints to identify simple, high-contrast objects in front of the camera, as well as experience visual phenomena such as looming, perspective, parallax, and distal attribution.

### 4.1.3 Auditory Vision Substitution

- **Electronic speech synthesizers** allow access to electronic forms of text storage and manipulation.
- A number of products appeared that converted the screen information to speech at rates of up to 500 wpm, thereby giving blind computer users rapid access to the information revolution.
- **Automated optical character recognition (OCR**) combined with speech synthesis grants access to the most common printed materials (letters, office memorandums, bills), which are seldom available in Braille or narrated-tape format.
- A few devices have appeared that convert the output of sonar-like ultrasonic ranging sensors to discriminable audio displays.
- For example, the **Sonic guide** uses interaural intensity differences to indicate the azimuth of an object and frequency to indicate distance, subtle information such as texture can sometimes also be discriminated.

## 4.2 Auditory System

- The human auditory system processes information primarily serially using two receptive channels.
- Human hearing is sensitive to sound frequencies from approximately 16 to 20,000 Hz and is most sensitive at 1000 Hz.
- At this frequency, a threshold root-mean-square pressure of 20 Pa (200μbar) can be perceived by normally hearing Sound pressure level (SPL) is measured in decibels relative to this threshold.
- Sounds increasing from 100 to 140 dB become uncomfortable and painful
- Short exposures to a 160-dB level can cause permanent hearing impairment
- Continuous exposures to sound levels over 90 dB can cause slow, cumulative damage.
- Hearing sensitivity falls off drastically at lower frequencies
- Hearing loss is then specified in decibels relative to the reference threshold

### 4.2.1 Auditory Augmentation

- For Loss of speech comprehension people seek medical attention for hearing impairment.
- Functional impairment begins with 21- to 35-dB loss in average sensitivity, causing difficulty in understanding faint speech
- Losses of 36 to 50 dB and 51 to 70 dB cause problems with normal and loud speech.

- Losses greater than 90 dB are termed *profound* or *extreme* and cannot be remedied with any kind of hearing aid; these individuals require auditory substitution rather than augmentation.
- Hearing loss is caused by conduction defects in the middle ear (tympanic membrane and ossicles) or by sensorineural defects in the inner ear (cochlear transduction mechanisms and auditory nerve).
- Conduction problems often can be corrected medically or surgically.
- If not, hearing aids are often of benefit because the hearing threshold is elevated uniformly over all frequencies, causing little distortion of the signal.
- Sensorineural impairments differentially affect different frequencies and also cause other forms of distortion that cannot be helped by amplification or filtering.

Most hearing aids perform three basic functions.

1. **Amplification** compensates for the reduced sensitivity of the damaged ear.
2. **Frequency-domain filtering** compensates for hearing loss that is not spectrally uniform.
   For example, most sensorineural loss disproportionately affects frequencies over 1 kHz or so, so high-frequency pre emphasis may be indicated.
3. **Automatic gain control (ACG)** compresses the amplitude range of desired sounds to the dynamic range of the damaged ear.

- Typical AGC systems respond to loud transients in 2 to 5 ms (attack time) and reduce their effect in 100 to 300 ms (recovery time).
- Sophisticated multiband AGC systems have attempted to normalize the ear’s amplitude/frequency response, with the goal of preserving intact the usual intensity relationships among speech elements.
- The fundamental frequency the first formants is due to vocal cord vibration and second formants is due to the spectral peaks of speech that characterize different vowels and place of articulation are crucial to speech recognition.

- The primary design goal for hearing aids should be to preserve and make audible the individual spectral components of speech.
- The cochlear implant is termed as auditory augmentation device because it utilizes the higher neural centers used for audition.
- The implant replaces the function of the (damaged) inner ear by electrically stimulating the auditory nerve in response to sound collected by an external microphone.
- Though the auditory percepts produced are extremely distorted and noise like due to the inadequate coding strategy, many users gain sufficient information to improve their lipreading and speech-production skills.

### 4.2.2 Visual Auditory Substitution

- **Lipreading** is the most natural form of auditory substitution, requiring no instrumentation and no training on the part of the speaker.
- The result is that 30% to 50% of the words used in conversational English look just like, or very similar to, other words (homophenes). Therefore, word pairs such as buried/married must be discriminated by grammar, syntax, and context.
- **Lipreading** does not provide information on voice fundamental frequency or formants. With an appropriate hearing aid, it can supply some of this missing information, improving lipreading accuracy.

- For the profoundly deaf, technological devices are available to supply some or all of the information.
- **Fingerspelling**, a transliteration of English alphabet into hand symbols, can convey everyday words at
  up to 2 syllables per second.
- **American Sign Language** uses a variety of upper body movements to convey words and concepts rather than just individual letters, at the same effective rate as ordinary speech, 4 to 5 syllables per second.
- **Automatic speech-recognition** technology may soon be capable of translating ordinary spoken discourse accurately into visually displayed text, at least in quiet environments; this may eventually be a major boon for the profoundly hearing impaired.

### 4.2.3 Tactual Auditory Substitution

- Tadoma is a method of communication used by a few people in the deaf-blind community and is of theoretical importance for the development of tactual auditory substitution devices.
- Sign language requires training by both sender and receiver, in Tadoma, the sender speaks normally.
- The trained receiver places his or her hands on the face and neck of the sender to monitor lip and jaw movements, airflow at the lips, and vibration of the neck.
- Experienced users achieve 80% keyword recognition of everyday speech at a rate of 3 syllables per second.
- **Tactile vocoders** perform a frequency analysis of incoming sounds, similarly to the ear's cochlea and adjust the stimulation intensity of typically 8 to 32 tactile stimulators to present a linear spectral display to the user's abdominal or forehead skin.

## 4.3 Tactual System

- Humans receive and combine two types of perceptual information when touching and manipulating objects.
- ***Kinaesthetic*** information describes the relative positions and movements of body parts as well as muscular effort.
- **Muscle and skin receptors** are primarily responsible for kinesthesis
- **Joint receptors** serve primarily as protective limit switches.
- ***Tactile*** **information** describes spatial pressure patterns on the skin given a fixed body position. Everyday touch perception combines tactile and kinaesthetic information; this combination is called ***tactual or haptic perception.***
- The tactile sense is often considered inferior to sight and hearing. However, the tactile system possess some of the same spatial and temporal attributes as both of the "primary" senses
- With over 10,000 parallel channels (receptors) the tactile system is capable of processing a great deal of information if it is properly presented.
- Surgically repaired fingers may not have tactile sensation for a long period or at all, depending on the severity of nerve injuries; it is known that insensate digits are rarely used by patients

- Insensate fingers and toes (due to advanced Hansen's disease or diabetes) are often injured inadvertently, sometimes requiring amputation. Anyone who has had a finger numbed by cold realizes that it can be next to useless, even if the range of motion is normal.
- The normal sensitivity to touch varies markedly over the body surface.
- The threshold forces in dynes for men (women) are lips, 9 (5); fingertips, 62 (25); belly 62 (7); and sole of foot, 343 (79)
- The fingertip threshold corresponds to 10-m indentation. Sensitivity to vibration is much higher and is frequency-and area-dependent.
- A 5-cm 2 patch of skin on the palm vibrating at 250 Hz can be felt at 0.16-m amplitude; smaller areas and lower frequencies require more displacement.
- The minimal separation for two non vibrating points to be distinguished is 2 to 3 mm on the fingertips, 17 mm on the forehead, and 30 to 50 mm on many other locations. However, size and localization judgments are considerably better than these standard figures might suggest.

### 4.3.1 Tactual Augmentation

- Example, an automobile with power steering
- Remote-control robots (telerobots) used underwater or in chemical- or radiation-contaminated environments

**Tactile display of spatial patterns on the skin uses three main types of transducers**

- ***Static tactile*** displays use solenoids, shape-memory alloy actuators, and scanned air or water jets to indent the skin.
- ***Vibrotactile*** displays encode stimulation intensity as the amplitude of a vibrating skin displacement (10 to 500 Hz); both solenoids and piezoelectric transducers have been used.
- ***Electrotactile*** stimulation uses 1- to 100-mm2-area surface electrodes and careful waveform control to electrically stimulate the afferent nerves responsible for touch, producing a vibrating or tingling sensation.
- Tactile rehabilitation has received minimal attention in the literature or medical community. One research device sensed pressure information normally received by the fingertips and displayed it on the forehead using electrotactile stimulation , Subjects were able to estimate surface roughness and hardness and detect edges and corners with only one sensor per fingertip.
- Phillips prototype tactile feedback systems that use the intact tactile sense to convey hand and foot pressure and elbow angle to users of powered prosthetic limbs, often with the result of more precise control of these devices.
- Slightly more attention has been given to tactile augmentation in special environments.
- Astronauts, for example, wear pressurized gloves that greatly diminish tactile sensation, complicating extravehicular repair and maintenance tasks. Efforts to improve the situation range from mobile tactile pins in the fingertips to electrotactile stimulation on the abdomen of the information gathered from fingertip sensors

### 4.3.2 Tactual Substitution

- Because of a paucity of adequate tactual display technology, spatial pressure information from a robot or remote manipulator is usually displayed to the operator visually.

**Disadvantages**:

(1) The visual channel is required to process more information (it is often already heavily burdened), and

(2) Reaction time is lengthened, because the normal human tactual reflex systems are inhibited.

**Advantage** of visual display is that accurate measurements of force and pressure may be displayed numerically or graphically.

- Auditory display of tactual information is largely limited to warning systems, such as excessive force on a machine.
- The engine of a bulldozer will audibly slow down when a heavy load is lifted; by the auditory and vibratory feedback, the operator can literally "feel" the strain.
- The user normally controls the environment by hand, head, and body movements; these are sensed by the system, which correspondingly adjusts the information presented on a wide-angle visual display and sometimes also on a spatially localized sound display. The user often describes the experience as "being there," a phenomenon known as ***Telepresence.***
- One can only imagine how much the experience could be enhanced by adding kinesthetic and tactile feedback, quite literally putting the user in touch with the virtual world.

### 4.4 Augmentative and Alternative Communication

- The inability to express oneself through either speech or writing is the most limiting of physical disabilities.
- Meaningful participation in life requires the communication of basic information, desires, needs, feelings, and aspirations.
- The lack of full interpersonal communication substantially reduces an individual's potential for education, employment, and independence.
- Through multidisciplinary contributions, individuals who cannot speak or write effectively have access to a wide variety of techniques, therapies and systems designed to ameliorate challenges to verbal communication.

The field of augmentative and alternative communication (AAC) consists of many different professions,

- speech-language pathology
- regular and special education
- occupational and physical therapy
- engineering, linguistics, technology, and others
- Experienced professionals now can become certified as Assistive Technology practitioners and/or suppliers
- Engineering plays a significant role in the development of the field of AAC and related assistive technology.
- Engineering contributions range from relatively independent work on product definition and design to the collaborative development and evaluation of tools to support the contributions of other professions, such as classical and computational linguistics and speech-language pathology.
- Augmentative communication can be classified in a variety of ways ranging from unaided communication techniques, such as gestures, signs, and eye pointing, to highly sophisticate electronic devices employing the latest technology.

**Technology-based AAC systems have taken two forms:**

- hardware designed specifically for this application
- Software that runs on mass market computer hardware

**Three basic components comprise AAC systems**

- language representation method (including acceleration techniques),
- the user interface
- the outputs

### 4.4.1 Language Representation Methods and Acceleration Techniques

The ultimate goal of AAC intervention is functional, interactive communication.
The four purposes that communication fulfills are

(1) Communication of needs/wants
(2) Information transfer
(3) Social closeness
(4) Social etiquette

- To achieve communication competence, the person using an AAC system must have access to language representation methods capable of handling the various vocabulary and message construction demands of the environment.
- Professionals rely on the theoretical models of language development and linguistics to evaluate the effectiveness of an AAC language representation method.
- **Language** is defined as an abstract system with rules governing the sequencing of basic units (sounds, morphemes, words, and sentences), and rules governing meaning and use
- An individual knows a language when he or she understands and follows its basic units and rules.
- Knowledge of language requires both linguistic competence (understanding the rules), and linguistic performance (using these rules).
- In addition to the language representation method, the acceleration technique(s) available in an AAC system contribute(s) to communication competence.

***Alphabet-based language representation methods*** involve the use of traditional orthography and acceleration techniques that require spelling and reading skills.

- AAC systems using orthography require the user to spell each word using a standard keyboard or alphabet overlay on a static or dynamic display.
- A standard or customized alphabet overlay provides use for all the rules and elements of a natural language; however, spelling letter-by-letter is a slow and inefficient
- **Abbreviation systems** represent language elements using a number of keystrokes typically smaller than that required by spelling.
- For example, words or sentences are abbreviated using principled approaches based on vowel elimination or the first letters of salient words.
- Abbreviation systems can be fast, but require not only spelling and reading skills, but memory of abbreviation codes.

**Word prediction** is another acceleration technique available from many sources. Based on previously selected letters and words, the system presents the user with best guess choices for completing the spelling of a word.

- The user then chooses one of the predictions or continues spelling, resulting in yet another set of predictions.

- Prediction systems have demonstrated a reduction in the number of keystrokes, but recent research reports that the actual communication rate does not represent a statistical improvement over spelling.
- The reason for word predication's failure to improve rate is that increased time is needed to read and select the word table choices.

***Picture Symbol-based language representation methods*** involve the use of graphic or line drawn symbols to represent single word vocabulary or messages (phrases, sentences, and paragraphs).

- A variety of AAC symbol sets are available on devices or software depicts the linguistics elements available through the system.
- Picture Communication Symbols (PCS), DynaSyms, and Blissymbols are popular symbol sets used in either dedicated or computer-aided systems.
- Understanding symbol characteristics is necessary to make clinical decisions about vocabulary organization and system selection.
- The choice of picture communication language representation methods is facilitated when teams use a goal-driven graphic symbol selection process.
- Vocabulary size and representation of linguistic rules (grammar) are concerns for users relying on graphic symbol sets.
- Users of static display systems have a limited number of symbols available on any one overlay; however, they have ready access to that vocabulary.
- Dynamic display users have an almost unlimited number of symbols available as vocabulary for message generation; however, they must navigate through pages or displays to locate a word.

***Semantic Compaction or Minspeak*** is perhaps the most commonly used AAC language representation method with this method, language is represented by a relatively small set of multi meaning icons.

- The specific meaning of each icon is a function of the context in which it is used.
- Semantic compaction makes use of a meaningful relationship between the icon and the information it represents; it does not require spelling and reading skills, and yet is powerful even for people with these skills.
- The performance of Minspeak stems from its ability to handle both vocabulary and linguistic structures as found in the Minspeak Application Programs (MAPS) of Words Strategy and Unity.
- Both MAPS support the concept of a core and fringe vocabulary. They provide the architecture for handling rules of grammar and morphology. The number of required keystrokes is reduced relative to spelling.
- Predictive selection is an acceleration technique used with Minspeak. When this feature is enabled, only those choices that complete a meaningful sequence can be selected.

### 4.5 User Interface

- Most AAC systems employ a user interface based on the selection of items that will produce the desired output .
- Items being selected may be individual letters, as used in spelling, or whole words or phrases expressing thoughts, or symbols that represent vocabulary.
- The numerous techniques for making selections are based on either direct selection or scanning.

**Direct selection** refers to techniques by which a single action from a set of choices indicates the desired item. A common example of this method is the use of a computer keyboard. Each key is directly selected by finger.

- Expanded keyboards accommodate more gross motor actions, such as using the fist or foot.
- Sticks are held in the mouth or attached to the head using a headband or helmet. Light pointers are used to direct a light beam at a target.
- Indirect pointing systems might include the common computer mouse, trackball, or joystick.
- Alternatives to these for people with disabilities are based on the movement of the head or other body part.
- Figure 144.1 depicts direct selection in that the desired location is pointed to directly.

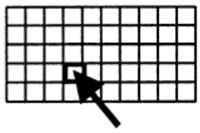

FIGURE 144.1 Direct selection.

**Scanning** refers to techniques in which the individual is presented with a time sequence of choices and indicates when the desired choice appears.

- A simple linear scanning system might be a clock face type display with a rotating pointer to indicate a letter, word, or picture.
- Additional dimensions of scanning can be added to reduce the selection time when the number of possible choices is larger.
- A common technique involves the arrangement of choices in a matrix of rows and columns.
- The selection process has two steps. First, rows are scanned to select the row containing the desired element. The selected row is then scanned to select the desired element. This method is called **row-column scanning**. See Fig. 144.2.

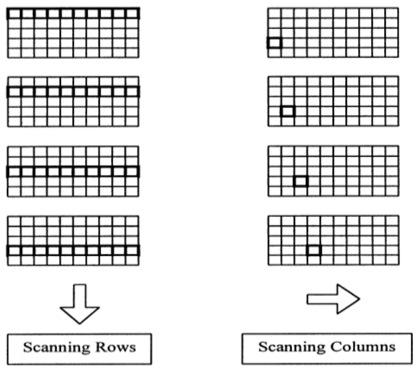


FIGURE 144.2 Row-column scanning.

- Both direct selection and scanning are used to select elements that might not of themselves define an output.
- In these cases the output may be defined by a code of selected elements.
- A common example is Morse code by which dots and dashes are directly selected but must be combined to define letters and numbers.
- Another example, more common to AAC, has an output defined by a sequence of two or more pictures or icons. Scanning, and to some degree direct selection, can be faster when the choices are arranged such that those most frequently used are easiest to access.

- For example, in a row-column scanning spelling system that scans top to bottom and left to right, the most frequently used letters are usually grouped toward the upper left corner.
- Consideration of factors such as cognitive load, environmental changes, fatigue, aesthetics, and stability of physical skill often influence the choice of the best selection technique.

**4.6 Outputs**

- AAC system outputs in common use are speech, displays, printers, beeps, data, infrared, and other control
- formats.
- Outputs are used to facilitate the interactive nature of "real time" communication. Users may rely on auditory and visual feedback to enhance vocabulary selection and the construction of messages.
- The speech and display outputs may be directed toward the communication partner to support the exchange of information.
- AAC speech output normally consists of two types: synthetic and digitized.
- **Synthetic speech** usually is generated from text input following a set of rules. It is associated with AAC systems that are able to generate text. These systems have unlimited vocabulary and are capable of speaking any word or expression that can be spelled.
- Commonly used synthetic speech systems like DECtalk™ offer a variety of male, female, and child voices.
- Most synthetic speech systems are limited to a single language, although bilingual systems are available.
- Further limitations relate to the expression of accent and emotion. Research and development in artificial speech technology is attacking these limitations.
- **Digitized speech** is essentially speech that has been recorded into digital memory. Relatively simple AAC systems typically use digitized speech.
- The vocabulary is entered by speaking into the system through a microphone.
- People who use these systems can say only what someone else said in programming them.
- They are independent of language and can replicate the song, accent, and emotion of the original speaker.
- RS-232c serial data output is used to achieve a variety of functional outcomes.
- Serial output permits the AAC system to replace the keyboard and mouse for computer access, a procedure known as **emulation.**
- The advantage of emulation is that the language representation method and physical access method used
- for speaking is used for writing and other computer tasks
- **Serial output** is environmental control. Users are able to operate electrical and electronic items in their daily-living surroundings.
- Particular sequences of characters, symbols or icons are used to represent commands such as answering the telephone, turning off the stereo, and even setting a thermostat.

- In addition, the serial output also may be used to monitor the language activity for purposes of clinical intervention, progress reporting, and research.
- **Infrared communication** now is available in many AAC devices. **Infrared output** supports the same functions as the RS-232c serial data output, but without requiring direct wiring or linking between operating devices.
- Infrared interfaces providing computer access improve the independence of AAC users because no physical connection needs to be manipulated to activate the system.
- Infrared interfaces can perform as environmental control units by learning the codes of entertainment and other electronic systems.

**References**


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- Robinson C. J, Rehabilitation Engineering, CRC Press. 1995.
- Ballabio E. et al, Rehabilitation Technology, IOS Press. 1993.


**Unit-4**

**2 Marks**

1 Write the need for sensory augmentation.
2 Expand and define AAC.
3 What is augmentive and alternative communication?
4 How many types of outputs does a AAC speech output normally consists of?
5 Give the various augmentation and substitution devices available in RE.
6 Differentiate auditory substitution and auditory augmentation with examples.
7 Brief on tactile perception.
8 What is Tadoma?
9 Analyze the types of information received by humans when touching and manipulating objects.
10 List few visual auditory substitution methods.
11 Categorize AAC speech outputs.

**10 Marks**

1. Describe in detail about visual augmentation and substitution.
2. Discuss the different types of language representation methods and acceleration techniques as part of the augmentative communication system.
3. What are the four purposes that are fulfilled by communication? Explain the methods to accelerate communication.
4. Discuss about the outputs, outcomes interventions and techniques with respect with AAC.
5. Describe tactual augmentation and substitution.
6. Highlight the role of outputs and training in alternative communications.
7. Elaborate on the loss of hearing and point out the ways to augment and substitute the same.
8. Give the classification of visual impairment and explain devices for visual augmentation.

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**SCHOOL OF BIO AND CHEMICAL ENGINEERING**

**DEPARTMENT OF BIOMEDICAL ENGINEERING**

# UNIT – V –REHABILITATION ENGINEERING– SBM1307

# UNIT-5

## ADVANCED APPLICATIONS IN REHABILITATION ENGINEERING

### 5.1 Computer Assisted Lip reading

As the hearing impaired learn the lip reading using a computer-assisted lip-reading system, they can freely learn lip reading without the constraints of time, place or situation. Within the communication process of human beings, the speaker's facial expression and lip-shape movement contains extremely rich language information.

Lip reading is used to understand or interpret speech without hearing it, a technique especially mastered by people with hearing difficulties. The ability to lip read enables a person with a hearing impairment to communicate with others and to engage in social activities, which otherwise would be difficult. Lip reading is a technique of understanding speech by visually interpreting the movements of the lips, face and tongue when normal sound is not available.

The speaker to make movements of the lips, teeth and tongue which are often visible in face-to-face communication. Information from the lips and face supports aural comprehension. The extent to which people make use of seen speech actions varies with the visibility of the speech action and the knowledge and skill of the perceiver.

2 main things in lip reading:

**PHONEME**

Any of the perceptually distinct units of sound in a specified language that distinguish one word from another, for example *p*, *b*, *d*, and *t* in the English words *pad*, *pat*, *bad*, and *bat*.

**VISEME**

A viseme is a generic facial image that can be used to describe a particular sound.

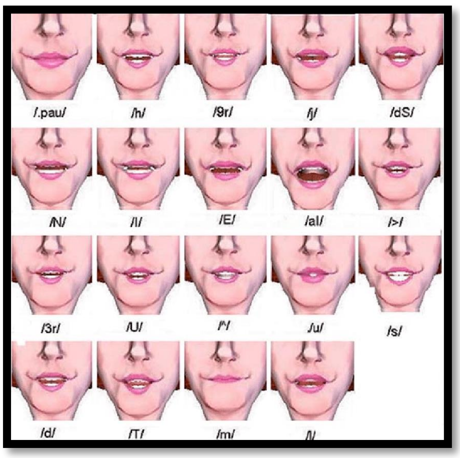


FIG 1: Viseme

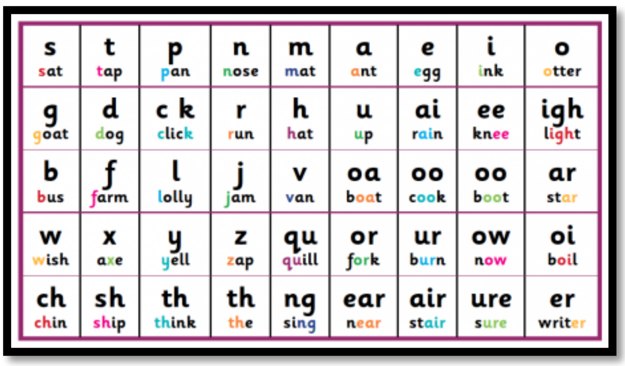



FIG 2: Phoneme

One of the oldest methods is language laboratory training by using tape recorded drills and practice exercises to supplement face to face language instruction. In this method, leaners have the advantage of training relatively independently at their own pace and convenience.

The computerized speech reading system simulates face to face intervention. This consist of 8 training lessons, each focusing on a particular viseme that is practiced by a modified discourse tracking method using viseme specific texts. These skills evaluated separately by means of tracking rate, receiver strategy and inferred error type.

It is possible for a computer assisted instructional system to provide the learner with interactive feedback, making the experience more like face-to-face instruction by a teacher than it would be in a traditional, non-reactive language laboratory. The computer allows the instructor to record the details of learner performance and to analyze these data for the quantitative evaluation of learning. Most of the instructors were highly educated professionals who lived and worked in a major urban community.

The aim of the training was to enhance lip reading skills in order to complement auditory speech reception.

Computer assisted lip reading becomes difficult when:

- Acoustic signal is degraded
- Background noise interferes with auditory speech reception
- Rate of speech is rapid
- Language is complex
- Topic of conversation is unfamiliar

Lip reading has3 Targeted component skills:

- Visual speech perception
- Use of linguistic redundancy
- Use of feedback between message sender and receiver

Computer assisted lip reading consisted of 8 lessons which provides concentrated practice with consonants visemes. Lessons concentrating on vowel viseme were not developed because auditory perception of vowels is much better than auditory perception of consonants and also because the classification of vowel visemes is even more controversial. Two other lessons were developed which is equivalent for pre and post training comparisons or for general practice by learner who has completed the training lessons.

This face-to-face computer assisted lip reading has 4 components:

- Review of previously taught lessons.
- Training in recognition of a new viseme.

- Practice identifying new and old visemes in segments of discourse.
- Recapitulation

Throughout these lessons, the learner views a monitor that shows either a computer-generated screen or a video taped recording of the teacher. The computer-generated screens consist of printed instructions or a display of feedback presented in work sheet. For the videotaped, a color head, head and shoulders frontal view is professionally recorded.

The practice texts are recorded both in paragraph and phrase format. The practice section of the lesson is introduced by playing the paragraph first at slow speaking rate then at a fast-speaking rate. This affects reading comprehension rate and individual differences in reading comprehension abilities have shown to be highly corelated with the listening comprehension abilities. All the topics are considered to be challenging but familiar to the learner.

Natural communication has two major functions:

- Transactional function – expression of the content
- Interactional function – expression of personal attitudes

**PROCEDURE**

The computer assisted lip reading procedure regulates the role of the sender, completely eliminates the interactional function of communication and focuses on the role of the receiver in accordance with the goals of the training.

The computer-controlled computer assisted lip reading differs from face-to-face procedure in 3 major ways:

- Sender decisions about message transmission and feedback is predetermined in the training algorithm and are perfectly replicable.
- The receiver has more choices, including the option to move to any phrase at any time and to return later to complete a phrase.
- Response is typed and is displayed for the duration of the lesson on a worksheet on the computer screen.

**FIG 3: Videotaped recording of the teacher**

**Transmission decisions**

The sender is recorded on the computer-controlled video tapped. The sender preselects based on 3 parameters:

- Speaking rate
- Phrase length
- Modality of presentation

*Rate and length of transmission:*

The paragraph and phrase readings of the text will be recorded at 2 speaking rates, representing slow normal speech (74 words per minute) and fast normal speech (129 words per minute). Phrase length will be determined prior to videotaping and each phrase will be recorded separately. Phrase length averages 2.7 words, with the maximum of 6 words, which is well within memory capacity.

*Modality of transmission:*

The modality of the transmission is both the audio and visual signal. This includes enabling either visual only or a combined audio-visual presentation.

**Feedback decisions**

In the face-to-face procedure, feedback is provided which include labelling the error or the word level spelling match of the response. Word position is ignored if the word level spelling match is unsuccessful.

**Receiver strategies**

In a face-to-faceprocedure, the receiver executes 2 main types of action:

- Elicit a feedback – guessing the answer
- Elicit a retransmission – by a response such as "what?"

Depending on the response, the message is retransmitted to the sender.

In videotaping procedure, the receiver has a choice of 3 types of actions:

- Elicit feedback by typing a guess.
- Replay the videotape.
- Move to another phrase with the option to return later.

**Outcome measures:**

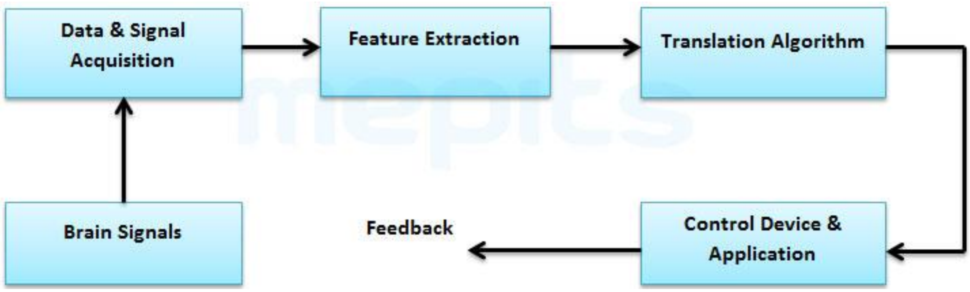
The only outcome measure usually reported for the face-to-face procedure is the rate in words per minute, where the total includes transmission response, and the correction time.

### 5.2 Brain Computer Interface

BCI is a method by which the brain signals are used to control an external device. In simple terms, this technology acts as an interfacing platform between the brain and a device. BCI is popularly known by the names **Brain Machine Interface** (BMI), **Synthetic Telepathy Interface** (SMI), **Direct Neural Interface** (DNI), or by **Mind-Machine Interface** (MMI).

**BCI System**

A BCI system consists of three components: Signal or Data Acquisition, Signal Processing (Feature Extraction, Feature Translation), and Output Device. These components are controlled by a protocol which defines the timing for operation, signal processing details, nature of device commands and the performance.




*Signal Acquisition*

Signal acquisition in a BCI helps in the measurement of brain signals using a sensor modality. The sensor is basically a device implanted in the brain usually multi-electrode arrays that records the signals directly related to the movement. The signals can be amplified to levels suitable for electronic processing. Also, they can be subjected to filtering to remove electrical noise or other undesirable signals. After amplification and filtering process, the signals can be digitized and transmitted to a computer.

*Feature Extraction*

Feature extraction in Brain Computer Interface (BCI) is the process of analyzing the digital signals to distinguish signal characteristics and represent them in a compact form suitable for translation into output commands. These features been extracted should have good correlations with the users intent.

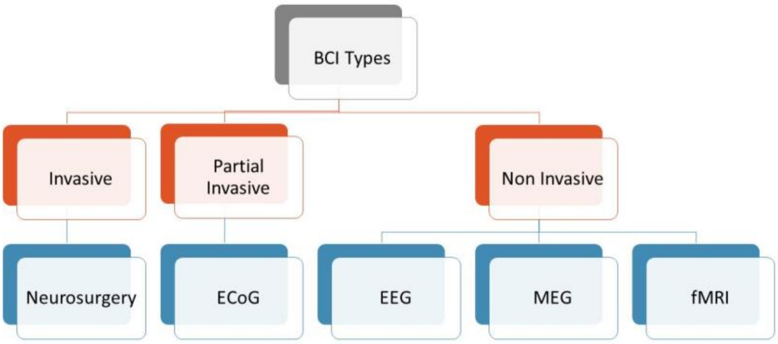
*Feature Translation*

Resulting signal features are passed to the feature translation algorithm, which converts the features into the commands for the output device (i.e., commands that accomplish the users need).

*Output Device*

The commands from the feature translation algorithm operate the external device of the Brain Computer Interface (BCI), providing functions such as cursor control, letter selection, robotic arm operation etc. The device operation then provides feedback to the user finally, thus completing the closed loop of Brain Computer Interface(BCI).

TYPES OF BCI :




**Invasive BCIs -** generally use electrodes (sensors) that are implanted directly into the grey matter of the brain during neurosurgery. Since they lie in the grey matter of the brain, invasive BCI produce the highest quality signals. But, the main disadvantage is that they are prone to scar tissue build-up, causing the signal to become weaker, as the body reacts to a foreign object (electrodes) in the brain.

**Partially Invasive BCI** - This BCI use electrodes that are mainly implanted in the skull and exterior to the brain. Better resolution, good frequency range and high quality signals are some of its advantages. Here ECoG measures the electrical activity of the brain taken from beneath the skull. The partially invasive BCI electrodes are embedded in a thin plastic pad that is placed above the cortex, beneath the dura mater (thick membrane that surrounds the brain and spinal cord).

**Non-invasive BCI** - has minimum signal clarity but it is considered to be the safest. This type of BCI has been found to be successful in giving a patient the ability to move muscle implants. In the non-invasive technique, medical scanning devices or sensors are mounted on caps or headbands and they help to read the brain signals. Less signal clarity in non-invasive BCIs is because; the electrodes cannot be placed directly on the desired part of the brain.

**EEG Based Non-Invasive BCI:** EEG generally provides the recording through the electrodes placed on the scalp with a conductive gel or paste. Number of electrodes used by the current EEG BCI is within a range of few to 100 electrodes. Since electrode gel can dry out and also the setting up procedure has to be repeated before each session of BCI use, EEG-based BCI are not convenient. As a possible solution, dry electrode arrays can be used. To get better recordings, scientists place the electrodes accurately by following the International 10-20 System.

**MEG and fMRI Non-Invasive BCI-** Today, MEG and fMRI are being used as brain signal recording techniques for non-invasive BCI widely. fMRI usually measures small changes in the blood oxygenation level dependent signals associated with the brains cortical activation. Controlling robot arms and playing Pong in real time are some recent fMRI BCI experiments. MEG detects magnetic fields within the brain.

**Applications**

- **Neural Impulse Actuator:** This brain BCI mouse is marketed as a playing game product which allows controlling games with thoughts.

- Bionic Eye**:** It is an artificial retina. The bionic eye is developed by Second Sight Medical Products.

- **Deep Brain Stimulator:** Product from Medtronic used to treat Epilepsy, Depression, Dystonia etc.

- **Robotic Foot:** Manufactured by Osscur is helpful for the disabled people.

- Pill Cam**:** A capsule with a camera which is swallowable. This product is good for endoscopy. Given Imaging is the manufacturer of it.

- **Artificial Arm:** Developed by DEKA and Development Corporation, is good for paralyzed patients.

- **Powered Exoskeleton**: It is a robotic exoskeleton, which helps old people for walking and lifting objects.

- **Wireless BCI Systems:** It consist of clip-on electrode holders for dry MEMS, a DAQ unit and wireless transmission circuitry. These systems are really good as a Brain Computer Interface (BCI).

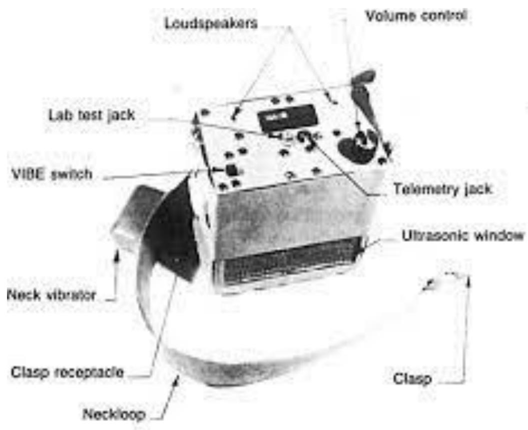
- **Mind Reader Google Glass:** Combining **Google Glass** with BCI headsets.

**Advantages and Disadvantages**

Some of the good advantages of BCI are direct communication between brain and devices, better living for paralyzed people etc. While the disadvantages of BCI are; ill effects in the brain due to viral attacks, requiring excessive training for proper usage, high cost, slow speed, lack of better sensor modality, invasive BCIs are risky since it requires neurosurgery etc.

## ELECTRONIC TRAVEL APPLICATION

### 5.3 Path Sounder




*ON-OFF switch and charging jack are on bottom—not visible in photo.*

### E Model Path sounder

- It is a small battery-operated sonar device designed as a secondary ETA—intended to complement but not replace the long cane. Chest mounted, it warns the user of objects within the field of view above and below the waist, just outside shoulder width, and in the direct travel path.
- The Path sounder emits bursts of ultrasonic waves into space at the rate of 15 pulses per second. The sonic cone has a maximum diameter of approximately 20-24 in. (50-61 cm) at a distance of 6 ft (182 cm) from the traveller’s chest.
- The E Model Path sounder has two output signals — vibratory (tactile) and auditory.
- To indicate obstacles in the travel path on the far range (3 to 6 feet), the device buzzes (auditory mode) or provides chest vibrations (tactual mode). To indicate obstacles in the path at the near range (0 to 3 feet), the Path sounder beeps (auditory mode) or provides neck vibrations (tactual mode). For example, an overhanging sign would be detected at 6 feet and the device would buzz. As the person came within 3 feet of the obstacle the buzz would automatically change to a beep. The maximum area of coverage for the chest-mounted device is slightly below the waist to above the head and just outside the shoulder width.
- Echoes from objects further out than 6 ft (182 cm) are excluded from Mobility Devices by timing circuits. In accordance with the "go-no-go" concept, no special electronic attention is paid to the size of an object. Echoes from objects of varying sizes are reduced to a uniform level by a circuit limiter. Vibratory signals indicate the presence of objects in the same two zones: when an object is detected in the outer protection zone, the entire unit vibrates rapidly on the chest ( "chest vibes " ), and when the object being approached appears in the inner protection zone, the chest vibes stop and a neck strap transducer vibrates against the back of the neck ("neck vibes ").

- The vibratory system was incorporated not only to serve hearing disabled blind persons, but also to replace an auditory signal in a noisy location where masking of sounds might take place, and as an inconspicuous private signal.
- The ultrasonic waves that detect objects are emitted through the screened ultrasonic "window" in the front of the Path sounder0 and would be blocked if covered by clothing. The unit does not usually hang vertically on a person's body but tilts upward, so tilt allowance is incorporated in the design. An arrow on the left side of the device indicates the direction of maximum sensitivity for a person of normal build and posture, and should point horizontally ahead. The device may be returned to the manufacturer for adjustment to accommodate individual postural differences. The Path sounder also has a simple ranging capability called "ramp," that produces a buzz when an object approaches or is approached, at first faint, then growing louder and still louder. When operating in a noisy environment, this feature should be set at full volume. The external rubber sonar horns which transmitted the ultrasonic pulses and received the echoes from objects on the II Model Path sounder were considered cosmetically unsightly by some users. The E Path sounders have rubber horns, too, but they are now inside the unit. The cosmetic improvement makes the unit less sensitive to close objects such as clothing and other poor reflectors.

**THE SE PATH SOUNDER**

- The SE Model operates in the same way as a useful device to assist blind persons confined to wheelchairs as an E Path sounder but consists of two units, a headset and a control box connected by two cables .The headset assembly is worn just above the ears, and the control unit may be held in a pouch or affixed to a wheelchair . By putting the transducers in the headset (transmitter in the right and receiver in the left), the scan and search patterns are easily performed by head motion in a natural manner. The two output modes in the SE Pathsounder are the auditory signals emitting from miniature loudspeakers inside the headpieces and a vibrator located in the control unit. Path sounders have an internal nickel-cadmium battery that operates for from 2 to 5 hr, depending upon usage .
- The E and SE Path sounders battery chargers have battery status capability that automatically adjusts charge time to battery needs.

**Limitations**

The present Path sounders are not waterproof, and if exposed to heavy rain they will not function . The aid can be restored to normal operation by being allowed to dry out for a day. There are no particular problems associated with hot weather use, but the battery loses strength rapidly at very low temperatures.

### 5.4 Laser Cane

The C-5 Laser (Light by Stimulated Emission of Radiation) Cane was invented by J. Malvarn Benjamin of Bionic Instruments, Inc., and works on the principle of infrared light. The C·5 Laser Cane is an adapted long cane and is used in the same manner. "The cane was designed to enhance the environmental probing ability of the long cane, to reduce tension while travelling, enabling the user to make more graceful progress.

The C-5 Laser Cane emits pulses of infrared signal which, if reflected from an object in front of it, are detected by a photodiode placed behind a receiving lens. The angle made by the diffuse reflected ray passing through the receiving lens is an indication of the distance to the object detected . This principle of optical triangulation was chosen in preference to an ultrasonic approach because of its simplicity and small beam width.

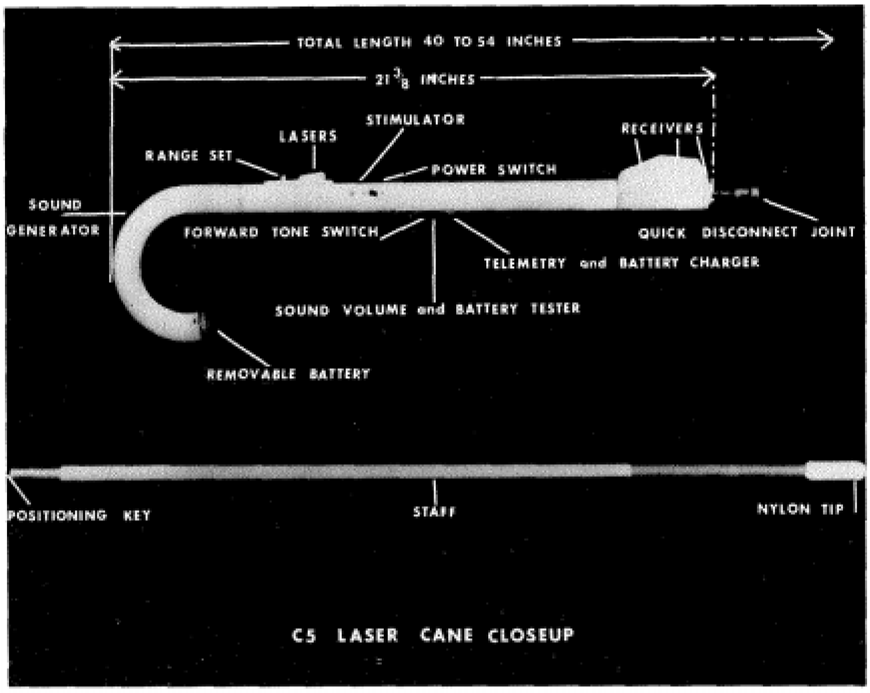


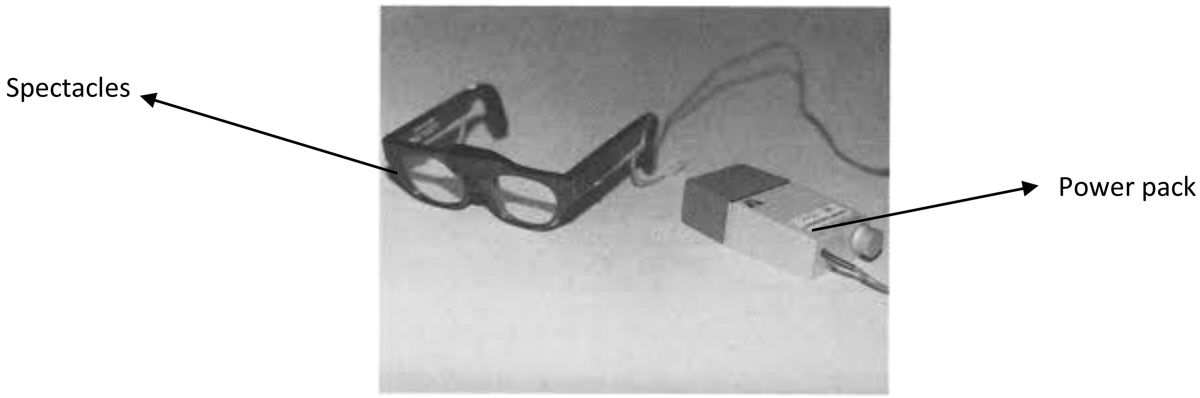

FIGURE 3.—C-5 Laser Cane.

The electronic components are mounted near the top of the cane with auditory and vibratory modes providing information from three beams. The up channel detects objects at head level, the forward channel functions at waist level (adjustable range 5 or 12 feet), and the down channel operates at ground level, three feet in front of the cane tip. High (2600 Hz.), middle (1600 Hz.), and low (200 Hz.) sounding tones are emitted from the respective channels when an object is in range and interrupts the «pencil-thin" beams transmitted from the cane. The forward channel is the only channel with a tactual display (a tiny pin vibrates against the index finger when placed on the side of the cane).

The Laser Cane weighs approximately 16ounces. It has a rechargeable battery, charging unit, and telemetry unit which is used to monitor the cane’s signals

5.5. **The Sonic Guide**

The Binaural Sensory Aid (later known as the Sonic guide) was developed in 1966 by Leslie Kay at the University of Canterbury, Christchurch, New Zealand. This device, like the Path sounder uses sonar waves which are transmitted and received, and then translated into auditory signals. The electronics are mounted in spectacle with an accompanying power pack. The Sonic guide differs from the Path sounder in that it can be used both as an obstacle detector and environmental sensor.




The Sonic guide signals enable the user to

(a) Estimate distance from objects by relating it to the pitch (pitch gets lower as the user approaches an object),

(b) Determine the direction/location of objects by amplitude differences (an object on the user's right side produces a louder sound in the right ear)

(c) Identify object surfaces through tonal characteristics (a round metal pole will reflect echoes that have pure tone quality).

The maximum range of the Sonic guide is 15 to 20 feet ahead with horizontal and vertical beam widths of 60 degrees. Scanning movements of the head (vertically and horizontally) enable the user to receive a great deal of environmental information because of the very wide, cone-like beam. Tiny ear tubes are attached to the bottom of the eyeglass frame to allow the user to hear the ultrasonic signal. The Sonic guide is equipped with a battery charger and rechargeable batteries. There is also a monitor unit available for training purposes.

Historically, the use of the sonic guide (as with the other devices) has been limited to adult blind travellers, often only cane users. In the late 1970s, a growing interest in the use of the Sonic guide as a tool for expanding contact with the external world for infants and toddlers widened. In its original form, the sonic guide was not satisfactory for use with very young children because its physical structure was unsuitable and its range was too long for practical use with infants.

Two devices, the Infant Sonic guide and the Canterbury Children's Aid were developed to make the ETA accessible to the young blind population.

5.6 **Nottingham Obstacle Detector**

The Nottingham Obstacle Detector is a hand-held ultrasonic mobility aid for use by visually handicapped people. It provides the user with information about the distance of objects up to a distance of approximately eight feet ahead. The aid is intended to supplement environmental information provided by the blind person's primary aid.

The development of the Nottingham Obstacle Detector emerged from a detailed study of the Ultra Sonic Aid .

The "ideal" specifications for the NOD, drawn up by Armstrong in 1973, were that it should

(1) Have a finite range of 7.5 feet (2.3 meters),

(2) Have a beam width of 2.6 feet (0.79 meters) at a range of 6 feet (1.8 meters) corresponding to an open doorway at 6 feet,

(3) Have six discrete range zones, the presence of an obstacle in a zone activating the appropriate one of six outputs,

(4) Include an inhibit switch so that in the presence of more than one obstacle, only one output-that corresponding to the nearest obstacle would be activated,

(5) Be totally silent in the absence of an obstacle in the beam, and

(6) Respond only to the presence of an object and not give textural information.

To produce a working realization of these specifications, a number of major design decisions had to be taken, such as the method of information-gathering, the method of achieving a narrow beam, and the method of display generation.

The final version of the aid, the NOD, transmits pulses of high-frequency sound (ultra-sonics) ahead of the user so that any object which falls within the beam reflects some of this sound back to the receiver of the device. The distance, or range, of the obstacle is determined by the length of time an individual sound pulse takes to travel from the NOD to the target and back again. The simple display has eight possible outputs; to each is assigned one of the notes of the major musical scale (with the lowest note representing the nearest distance zone). This makes the relationship between distance and output as meaningful as possible.

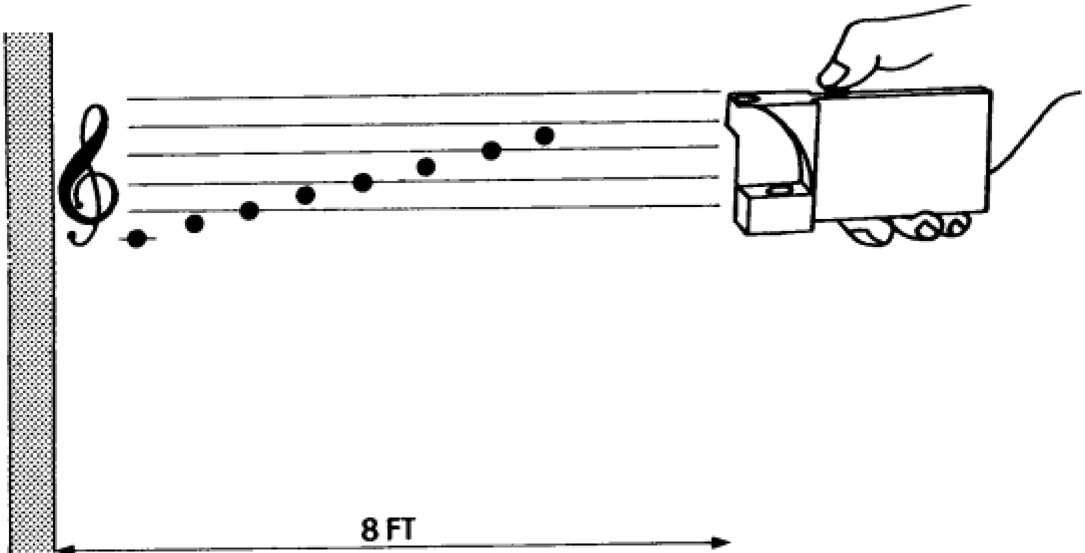



Figure 1. Range is coded by means of the Major musical scale.

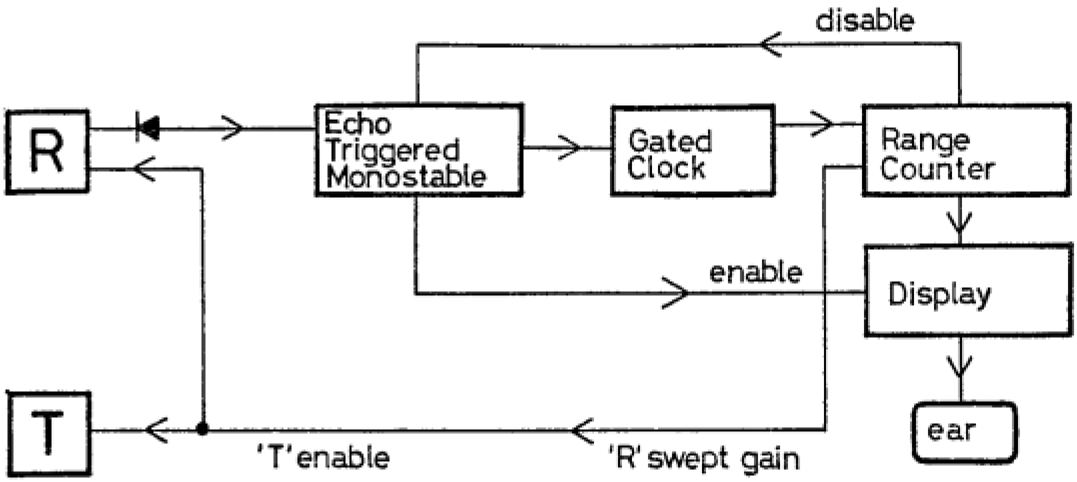



Figure 2. The functioning elements within the Nottingham Obstacle Detector.

The device is shown in block diagram form in Figure 2.

A gated clock is used to increment a decade divider, the range counter, at intervals of approximately 1.5 ms. On count zero, the transmitter is enabled and a short pulse of ultra-sonic energy is released. During counts "1" to "8," the receiver is enabled. Any above-threshold echo received during this period will fire the echo triggered mono-stable, which performs two functions: (1) it stops the gated clock, thus preventing the range counter from being incremented, and (2) it enables the auditory display. The particular display frequency is one of eight obtained by dividing down from a master oscillator using a quotient that depends on the information stored in the range counter. After the period of the display (determined by the monostable), the count continues through to "9" and after a short pause returns to "O" to begin a new cycle. The NOD uses CMOS integrated circuits, which results in a very low power consumption. It includes a rechargeable battery, and it is recommended that users plug the charger into the aid for an overnight charge once every two weeks. To simplify intermittent use, the aid incorporates an internal loudspeaker the action of which is overridden if use with an ear piece is preferred.

### 5.7 **Sonic Torch**

The Kay Sonic Torch was the first widely used modern ETA, developed in 1959 (K a y , 1964). Its designer - Dr. Leslie Kay is one of the most recognizable names in assistive technology. The Sonic Torch was a flashlightlike device that utilized a narrow-beam ultrasonic sensor and a mono earphone output. The torch transmitted a wide-bandwidth ultrasonic signal (40-80 kHz) four times per second, which was multiplied by the received reflected signal, creating a complex sound in the auditory range (approximately 400-8000 Hz). The resulting signal was quite rich in information. The loudness and pitch corresponded to the distance (louder lower sounds meant a nearby obstacle, high pitched quieter sounds more distant reflections). The timbre of the sounds corresponded to how well the target surface reflected the sonar, allowing an experienced user to distinguish between different surfaces, e.g. a sidewalk and grass. The Kay Sonic Torch had many later versions - it was made attachable to a traditional long cane and greatly decreased in size, and its most current version is known as the BAT K-Sonar Cane.

### 5.8 Electro Cortical Visual Prosthetics

- The electrical stimulation of the visual cortices has the potential to restore vision to blind individuals.
- The principle of electrical stimulation in the brain is that the electrodes produce an effect on the tissue at short time scales (from millisecond to minutes) during stimulation, depending on the electrical parameters.
- The studies reporting implantation of a visual cortical prosthesis either with surface or intra cortical electrodes allow us to define several important points which need further investigations.
- A large part of the the visual field map of central vision on the cortex lies in the calcarine sulcus.
- In addition to the difficulty of the surgical intervention to implant the prosthesis, the type of electrodes is essential. It seems very unlikely that a rigid electrodes array will be implanted in this sulcus given the difficulty of access.
- However, flexible electrodes array would be a potential solution and particularly useful in order to induce phosphenes in foveal vision. Some prototypes have been already developed for intra cortical electrodes and surface electrodes.
- Cortical arrays of electrodes fabricated on smooth, flexible and ultra-thin materials like parylene provide better coverage of the target area by conforming completely to the shape of the cortex. The same advances can also improve penetrating electrodes. By significantly diminishing their diameter and fabricating them on a soft, thin

substrate, those implants promise to cause minimal damage during implantation, and no chronic damage, since the mismatch between a rigid material and soft neural tissue is mitigated due to the soft nature of the implant.

- Nevertheless, the implantation in the calcarine sulcus could lead to other technological problems including wireless transmission of information and long-term stability of the prosthesis.
- **High-number of electrodes for restoring a useful vision** in order to restore a useful vision, it will be likely necessary to induce hundreds of phosphenes to achieve basic tasks of everyday life as psychophysics of prosthetic vision seems to indicate.
- Intra cortical electrodes would allow increasing the spatial resolution in semi-peripheral vision due to their low size and the minimal inter space electrodes of 500 µm to obtain distinct phosphenes. This technology would allow reaching a number of electrodes high enough for acuity-mediated tasks like reading, navigation or objecting and facing recognition. In addition, the amount of current needed to induce the phosphenes will be reduced by the use of intra cortical electrodes array while having a good mapping of the rest of the visual field with surface electrodes.
- **Waveform uniformity** It seems difficult to conclude on the most adequate parameters of stimulation for the evocation of phosphenes in the visual field of the patients: parameters are variable or incomplete between the various studies with surface or intra cortical electrodes. More particularly, the shape of the electrical wave is squared or symmetrical in the majority of the studies.
- Squared waveforms are a common shape for electrical brain stimulation. But thresholds are similar for cells and axons with the rectangular cathode stimulation.
- **Variability in frequency and duration of the pulses** We can also observe a strong variability in the duration of the pulse. This lack of selectivity of the stimulation and the lack of clear data makes difficult the interpretation of the results concerning the optimal electrical parameters for evoked visual responses. The frequency and duration of the pulses can clearly be a criterion to stay in a safe stimulation domain while maximizing the perceptual effect for long term use.
- **Shape of electrodes:** The shape of the electrode has two major influences. Firstly, the shapes have an impact on the electrode performance and on energy consumption, which can be an important criterion for long term implant and neural stimulation efficiency required for clinical efficacy.
- In second, the shape of the electrode has a direct influence on the electrical properties of the stimulation.
- **Chronic Stimulation** The early studies report the implantation of cortical neuro prosthesis complications is headaches and would be due to an activation of the meningeal fibers.
- It is difficult to conclude on the parameters of safe chronic stimulation. Indeed, in addition to not having a clear view on the parameters of electrical stimulation applied in the early studies, no implantation of a fully working neuro prosthesis has been achieved, allowing the induction of hundred of phosphenes via the simultaneous activation of a large number of stimulation electrodes.
- **Long-term stability of the implant:** The stability of the prosthesis for years is a challenge. Intracortical microelectrodes are highly invasive. By penetrating the cortex, tissue responses like glial encapsulation, neuro inflammatory responses or neuronal

cell loss can prevent their long-term stability and efficiency. Surface/subdural electrodes are now known to have more reliable long-term stability.

- **Biocompatibility and electrode materials:** The biocompatibility of the materials used for the implantable part is essential for long-term implantation. In this case, the biocompatibility of a material is assessed by its ability not to induce toxicity, and to produce a minimal inflammatory reaction of the tissues for the long term use. Mostly, the materials for implantable electrodes manufacturing are silicone and platinum. During the last decade, the development of new materials for electrodes such as the PEDOT:PSS (mixtures of poly (3, 4-ethylenedioxythiophene) and polystyrenesulfonate) has demonstrated progress in terms of biocompatibility.
- **Conversion of the visual scene into patterns of spatio-temporal stimulation:** The conversion of a visual scene into patterns of spatio-temporal stimulation involves two steps: the optimization of visual information and the transformation of this optimized visual information into patterns of electrical stimulations.
- **Micro-coils** Another strategy outside the traditional electrode-based cortical visual prosthetics is the use of magnetic stimulation by means of micro-coils. They are small implantable inductors that magnetically activate neurons. The brain stimulation of cortical pyramidal neurons in vitro has been reported as reliable and could be confined to spatially narrow regions ($<60\ \mu$m).

### 5.9 Ultrasonic Travel Aid for Visually Impaired:

- In 2010, the World Health Organization estimates that there were about 285 million people in the world with disabling eyesight loss (246 millions are visually impaired (VI) and 39 millions are totally blind).

- Portability, simplicity, reduced dimensions and cost are among the major pros of the ultrasonic travel aid system, which can detect and localize (angular position and distance from the user) obstacles eventually present in the volume in front of the person and on the ground in front of them.

- The first and older device used by VI subjects is a very well known (passive) device: the cane (commonly known as the white cane). The cane is light, portable and cheap and these characteristics certainly have contributed to its success and its dissemination. The most relevant drawback of this device is definitely the inspection range which is limited to a restricted part of the ground (< 1 m) in front of the user's feet; the cane cannot provide information regarding obstacles which are not located on the ground and in the area explored by the cane tip.

- Since early eighties, active devices for obstacle detection have been proposed. Such system are commonly known as Electronic Travel Aids (ETAs) and have been mainly based on use of laser and ultrasonic (US) transducers. Few of them can also be found on the market [2-4]; in the majority of the cases they detect the presence of an obstacle, but they need to be driven by the user and cannot localise the position of the obstacle.

- The aim of the ultrasonic travel aid is to present a multi-sensing, obstacle detection system composed by four ultrasonic sensors; it presents the characteristics to be: portable, standalone, multi-sensing sensors. the proposed system can continuously explore the volume in front of the VI user and provide an aural feedback if one or more obstacles are found; this feature allows the VI subject to anticipate the presence of the obstacles in the explored volume.

- **Materials and Methods:** The control of the device is based on the use of a microcontroller (PIC 18F877A) which is used to process input signals from the sensors, to control the temperature an relative humidity conditions and to provide the output information to the user by visual and audio feedbacks . Four ultrasonic sensors realize the volume scanning and, eventually, detect the presence of a possible obstacle; their output signals are used by the microcontroller as inputs.

- The four ultrasonic sensors used are based on a single piezo crystal (XL-MaxSonar-EZ MB 1320) working at 42 kHz; the crystal is firstly excited in order to emit a short wave pack and then it is used as a receiver to collect eventual echoes caused by reflections from objects eventually present in the explored cone (field of measurement: 3 cm to 3 m). Two sensor are used to explore the left and right area, while one sensor is used to explore the central area (sensor B) and one sensor is used to explore the ground in front of the subject (sensor F).

- The system is aimed to explore the volume in front of the user. The main advantage respect to the state of the art for ultrasonic system for obstacle detection is the possibility to not only measure the distance from the obstacle, but to be also able to localize the position of the obstacle (left, center up, center down, right).

- A specific functionality has also been implemented for the exploration of the obstacle at the ground level: the sensor is able to explore the ground surface at about 2 m sending an alert signal to the subject if a ground obstacle (such as a step or a hole) is detected in the area in front of the user feet. Specific attention has also been put on the portability of the device and on the eventual stigma effect on the VI user. For this reason, the system has been designed in order to be light and easily placed on the belt buckle, living the subjects hands free. Portability is also ensured by the reduced dimensions and the battery supply; while basic system-to-user communication protocol reduce to the minimum the training time.

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**Unit-5**

**2 Marks**

1. State the role of BCI in rehabilitation.
2. Compare the advantages and disadvantages of electro cortical prosthesis.
3. Differentiate a laser cane and a polarized ultrasonic travel aid
4. Identify the need of a light probe for visually impaired people.
5. What is the use of ultrasound waves in a sonic cane?
6. Examine the factors requires to improve orientation and mobility of disabled people
7. List the components of a Nottingham obstacle sensor.
8. Define ETA.
9. Sketch the design of a path sounder
10. Which group of people considers lip reading as an augmentation?

**10 Marks**

1. Discuss about computer assisted lip reading.
2. Propose a design for any two electronic travel applications for blind.
3. List some specific impairments and related technologies used for rehabilitation.
4. Explain about the interfaces in compensation for visual perception.
5. How does brain computer interface help to rehabilitate a disabled person. Justify
6. Enumerate the future developments in rehabilitation engineering.
7. Elaborate on the working of LASER cane and give its advantages over standard cane.