Assistive Robotics and Electronics in Rehabilitation Medicine

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Robots

ASSISTIVE TECHNOLOGY

- Any item, piece of equipment or product system whether acquired commercially off the shelf, modified, or customized that is used to increase or improve functional capabilities of individuals with disabilities.

ASSISTIVE TECHNOLOGY

- Improve the independence and quality of life of persons with disabilities
- Growing importance for the rehabilitation professional to be aware of available systems and ongoing research efforts
- Rapid advances occurring

Legislation

- Individuals with Disabilities Education Act (IDEA)
  - Assistive technology (AT) must be provided by the school district at no cost to the family.
  - Assistive technology must be determined on a case by case basis; if needed to ensure access to free and appropriate public education, AT is required.
  - If the individualized education plan team determines that AT is needed for home use to ensure free and appropriate public education, it must be provided.
  - The student's individualized education plan must reflect the nature of the AT and the amount of supportive AT services required.

Legislation

- American with Disabilities Act (ADA) and the Reauthorization of the Rehabilitation Act
  - Mandates that AT devices and services are considered and provided as a means to acquire vocational training and to enter into and maintain employment.

Legislation

- International Classification of Impairments, Disabilities, and Handicaps (*ICIDH*) -1980
- International Classification of Functioning, Disability and Health (*ICF*) –Present Day
  - moves away from a 'consequence of disease' classification to a more positive 'components of health' classification.

International Classification of Functioning, Disability and Health (ICF)

- *Body functions* are the physiologic functions of body systems (including psychologic functions).
- *Body structures* are anatomic parts of the body such as organs, limbs, and their components.
- *Impairments* are problems in body function or structure, such as a significant deviation or loss.
- *Activity* is the execution of a task or action by an individual.
- *Participation* is involvement in a life situation.
- *Activity limitations* are difficulties an individual may have in executing activities.
- *Participation restrictions* are problems an individual may experience in involvement in life situations.
- *Environmental factors* make up the physical, social, and attitudinal environments in which people live and conduct their lives.

Communication Disorders

- Vocal communication allows humans to interact, form relationships and direct the events of their lives.

Communication AT

- Low-cost microprocessors capable of storing digitized speech.
- These low-tech, digital voice output devices work like a tape recorder, allowing recording and storing of simple phrases into memory within the device.

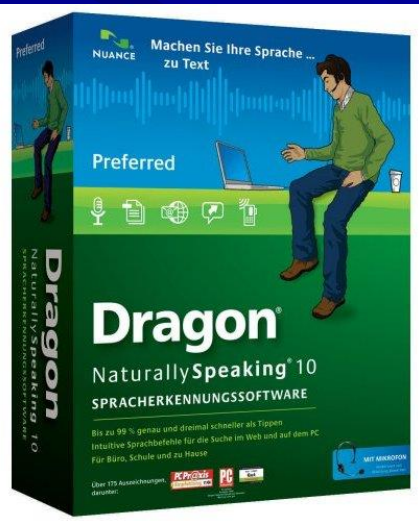
- When users want to speak, they simply press a button and the device speaks the prerecorded message

Communication AT

- Synthesized speech – *Pathfinder, Dynamyte, and LightWriter*
  - Uses rules of phonics and pronunciation to translate alphanumeric text into spoken output through speech synthesizer hardware
  - These devices speak words and phrases that have been typed and/or previously stored.
  - Allow users to speak on any topic and use any words they wish.
  - These systems can encode several thousand words, phrases, and sentences

Communication AT

- Co:Writer
  - predicts the word or phrase an individual is trying to spell as they begin to type a word
- Voice Recognition
  - software can be useful for persons that are unable to develop writing skills



AT for Vision Impairments

- Screen magnification software
  - Zoomtext
- Optical character recognition
  - convert print into digital form, where it can then be listened to by way of the computer's speech synthesizer

ASSISTIVE TECHNOLOGY FOR MOBILITY IMPAIRMENTS

- AT devices have been developed to provide access to computers to individuals with upper body mobility impairment.

AT for Mobility Impairments

- Expanded keyboards
- Smaller keyboards (e.g. the Tash Mini Keyboard) designed for persons with limited range of motion and endurance
- Voice recognition (VR) is a mass market technology that has become essential for computer access for many persons with motor impairment - Dragon
- Devices that rely on an onscreen keyboard that is visible on the computer monitor, such as the Head Mouse and Tracker 2000
  - The user wears a head-mounted signaling device or a reflective dot on the forehead to select keys on the onscreen keyboard, choose commands from pull-down menus, or direct mouse movement

Electronic Aids to Daily Living

- Control:
  - audiovisual equipment (e.g. television, video players and recorders, cable, digital satellite systems, stereo),
  - communication equipment (e.g. telephone, intercom, and call bells),
  - doors, electric beds, security equipment, lights, and appliances (e.g. fan).
- Controlled directly (by pressing a button with a finger or pointer, or by voice command) or indirectly (by scanning and switch activation).

Physically Assistive Robots (PAR)

- Provide mechanical assistance to persons with disabilities

PAR

- IBOT wheelchair from Independence Technology
  - computerized wheelchair which can raise the user up to eye level by balancing on two of its four drive wheels or climb stairs by rotating one set of drive wheels over the other set
- TopChair uses rubber caterpillar tracks to climb stairs

Assistive Robotics

- “Smart” wheelchairs and walkers frequently utilize combinations of sonographic, radiofrequency and laser guidance to detect their environment
  - PAM-AID walker80, by Guido Inc. and the MARC smart walker

Figure 1.
Front view of Guido robotic walker.

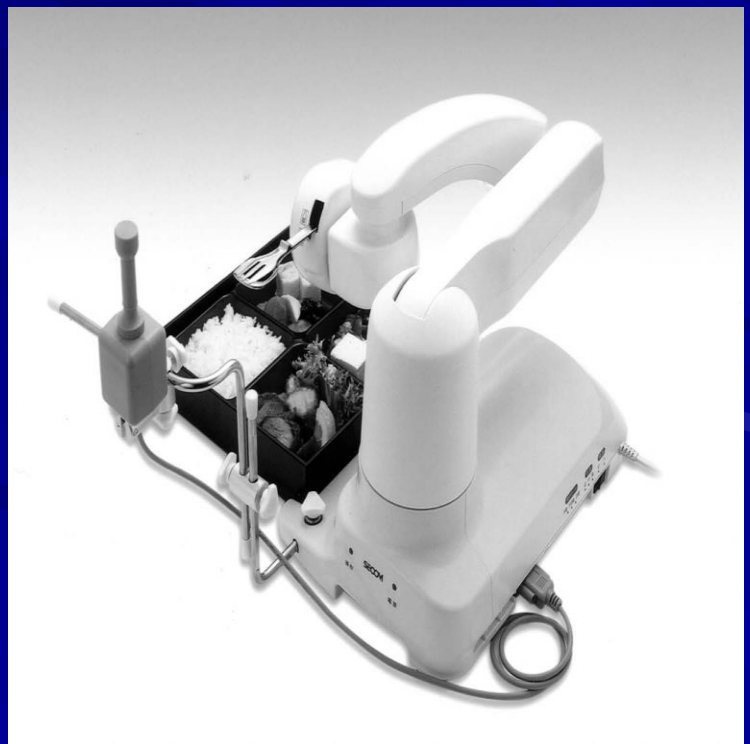
ADL Devices

- Most commonly investigated robots in recent literature is the Assistive Robot Manipulator (ARM), also known as Manus, produced by Exact Dynamics
  - mounted to side of a power wheelchair for general manipulation
  - for persons with neurologic injuries preventing upper extremity function, such as high tetraplegia
  - have incorporated cameras into their system and developed computer vision algorithms for retrieving items
  - washing face & hands, brushing teeth, combing hair, shaving, or applying make-up), lying in bed (bringing objects near), in a wheelchair (eating, drinking, bringing objects near), and in the kitchen (opening cupboard doors, moving utensils

ARM

Feeding Devices

- Mealtime Partner, SECOM MySpoon
  - allow self-feeding in persons who are otherwise dependent in this activity of daily living



Occupational Devices

- Earliest examples of an assistive robotic system in the literature is the Desktop Vocational Robotic Assistant (DeVAR) created at Stanford University
  - DeVAR allowed people with high spinal cord injuries to function more independently in a workplace setting
  - small robotic arm mounted on an overhead track system above a desk and was controlled using discrete word voice commands to engage the robot to perform tasks

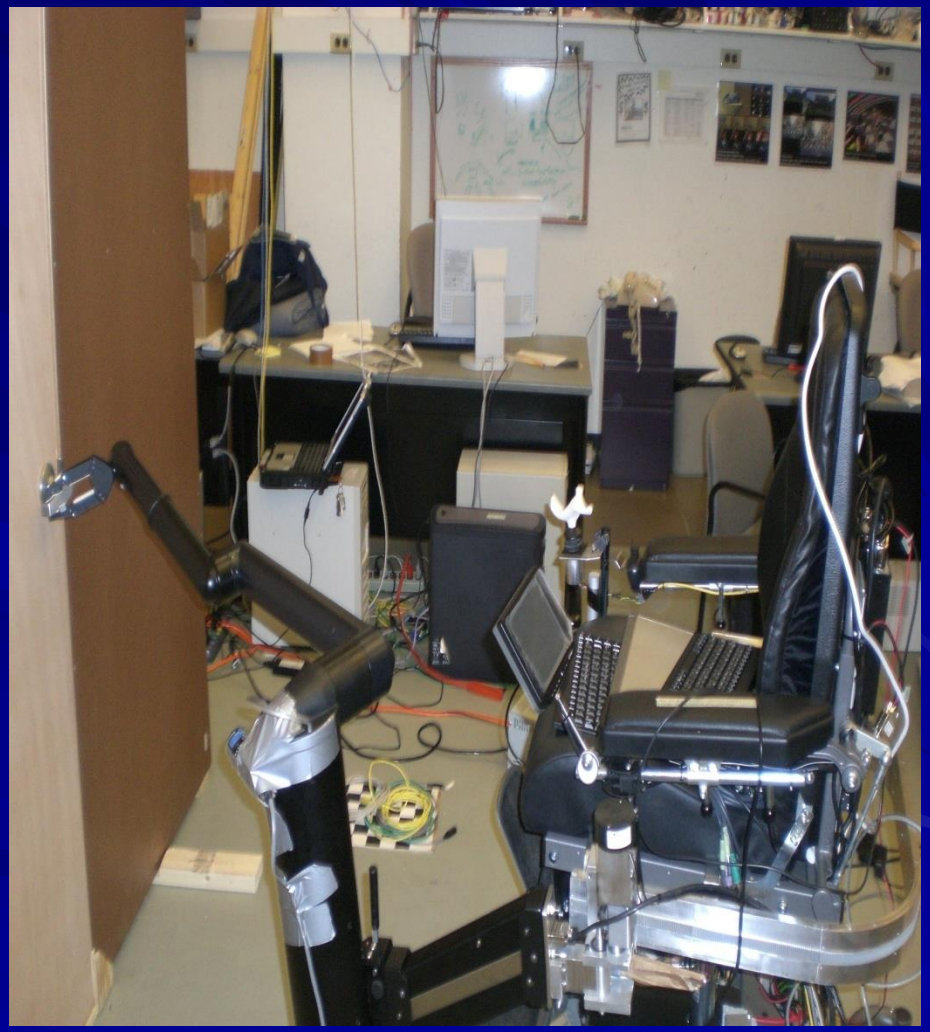
KARES

- Consists of a robot manipulator arm attached to the side of a power wheelchair and server control system accepts inputs from the user and sensors
- Autonomous control of the robot using visual sensing controls, specifically for use during feeding
- Several user interfaces have been demonstrated including an eye mouse, an EMG interface, a head interface, and a shoulder interface

Personal Mobility and Manipulation Appliance (PerMMA)

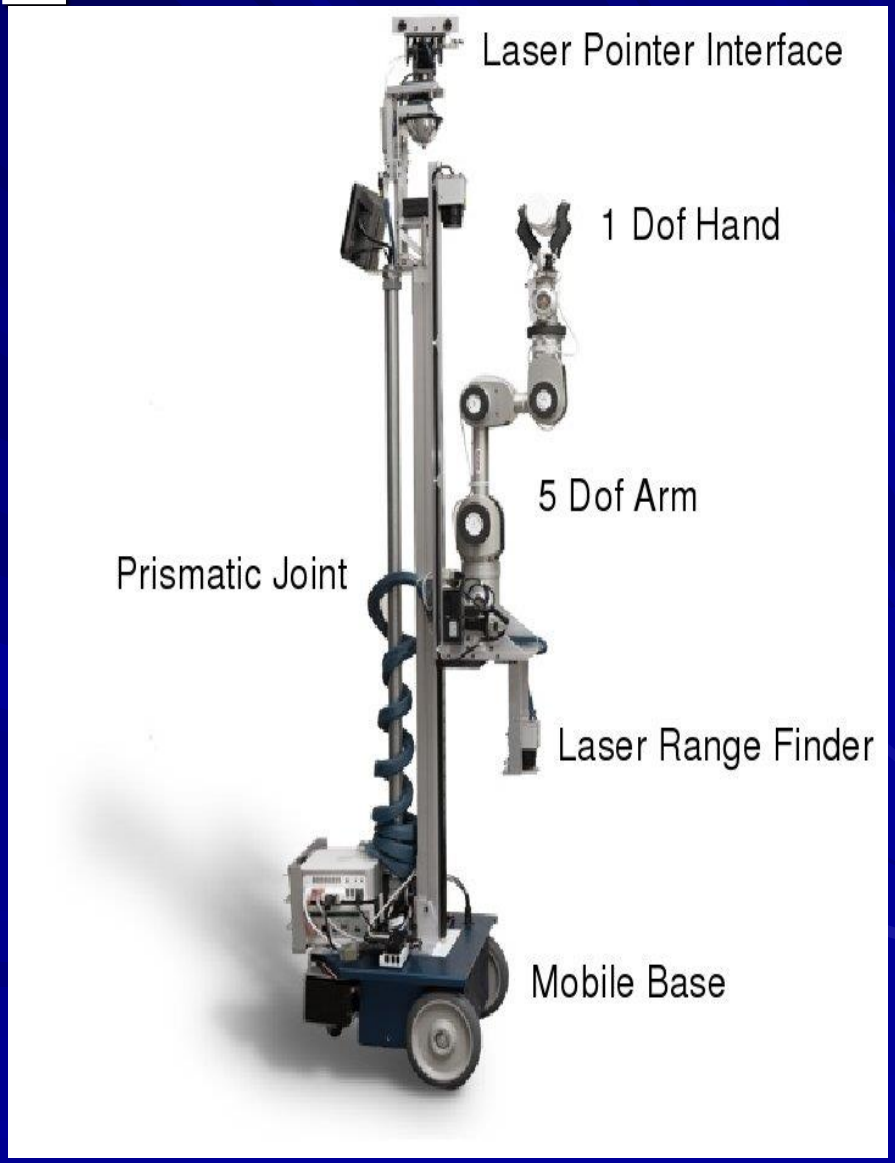
PerMMA

- bi-manual manipulation assistance, as well as coordinated mobility
- two ARMs mounted on a custom track attached to a power wheelchair with a custom, flexible input controller
- accomplishing complex tasks, such as door opening and microwaving a meal, using combinations of these modes



EI-E

- Designed to fetch items in the home environment for people with disabilities
  - mobile robotic base with a manipulator arm mounted on a vertical track
  - user indicates the object they would like to fetch using a laser pointer and a combination of camera and laser range finder sensors help the robot identify, navigate to, grasp, and return the object to the user



Home Exploring Robotic Butler

HERB

- Entails a robotic manipulator mounted on top of a Segway base that will perform complex task around the home using environmental information from cameras that serve as inputs to advance path planning algorithms
- Early work has focused on manipulating kitchen items, such as loading a dishwasher and retrieving specific items from a cluttered cabinet

CERO an office robot

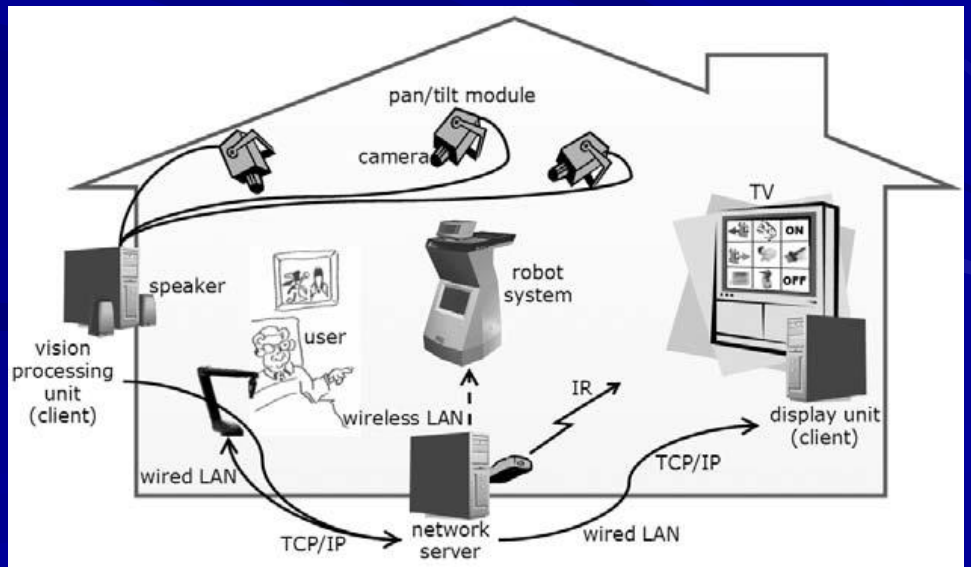
- Service robots are designed for fetch and carry tasks

Assistive Robotics

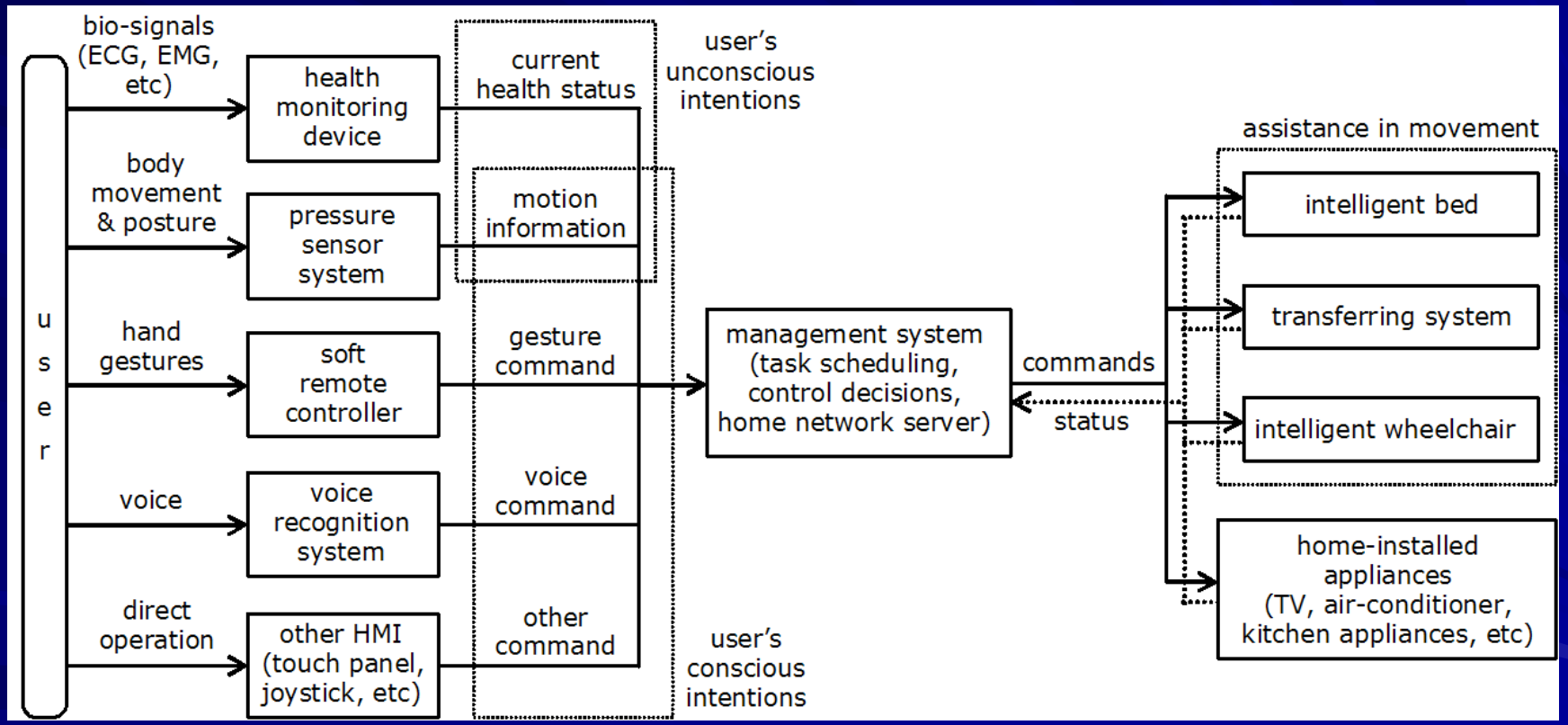
- Computer vision and proximity based exteroceptors allow robots to avoid and work around obstacles in their environment as well as to identify objects to interact with
  - PR-2 by Willow Garage
    - Visual systems can allow mobile robots to negotiate and examine their environment, which is important for sophisticated mobile robots designed for home applications

Smart Homes

- Smart houses can be seen as a compilation of many different assistive technology systems. The Intelligent Sweet Home (ISH) project combines a smart wheelchair, smart bed, and a transfer robot



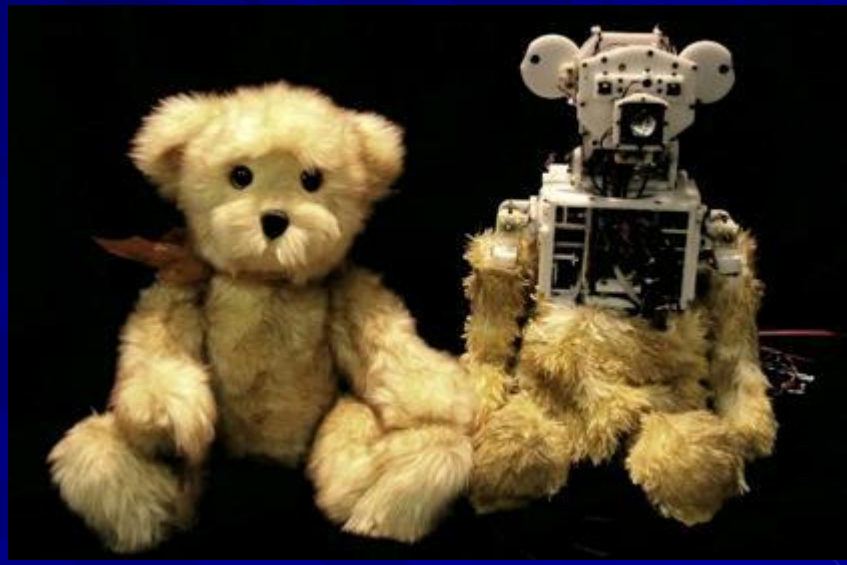
Smart Homes


bio-signals (ECG, EMG, etc)
health monitoring device
current health status
user's unconscious intentions
body movement & posture
pressure sensor system
motion information
hand gestures
soft remote controller
gesture command
voice
voice recognition system
voice command
direct operation
other HMI (touch panel, joystick, etc)
other command
user's conscious intentions
user
management system (task scheduling, control decisions, home network server)
commands
status
assistance in movement
intelligent bed
transferring system
intelligent wheelchair
home-installed appliances (TV, air-conditioner, kitchen appliances, etc)

Socially Assistive Robotics (SAR)

- Robotic devices:
  - create close and effective interaction with a human user for the purpose of giving assistance and achieving measurable progress in convalescence, rehabilitation, and learning

SAR



- Non-contact human-robot interaction
- Ability to adapt its personality based on the personality of the subject and their performance on the exercises. The robot could become more nurturing or challenging based on the introverted or extroverted nature of the subject

SAR: PARO

- Being used to provide personalized cognitive assistance, motivation, and companionship to people

User Interfaces and Control Systems

- 40% of wheelchair users find steering nearly impossible with conventional power wheelchair interfaces
- Wheelchairs/Assistive robots' ease of use depends upon a workable user interface
- Importance of the practitioner in recommending the proper device for the individual, given the physical capabilities of the person with disability

Control Systems

- Physical control mechanisms such as joysticks are among the simplest user interfaces

- Chin and head-based controls as well as shoulder and scapular based systems

Control Systems

- Gesture-based human robot interface
  - Robots use computer vision to interpret gestures by the user
- Voice recognition technology has developed considerably in recent years and has often been used for robotic wheelchairs (e.g., NavChair, SENARIO, TetraNauta

Control Systems

- More exotic input methods that have been implemented include tracking the user's eye movement through electroculargram (e.g., Wheelesely71 , SIAMO)

Control Systems

- Brain-computer interface (BCI) provides a communication channel between a user's brain and the outside world
  - relies upon the motor activity of a user to deliver commands to a robot
  - capable of bypassing the motor step and directly communicating with the user's nervous system interpretation of brain signals

YouTube - BrainGate lets your brain control the computer.flv

Sensory and Feedback Systems in Robotic Assistive Devices

- Humans rely on sensory feedback to perform many important functions including gathering information about their surroundings, motor skill learning, and movement control
- Sensors and feedback controls allow an assistive robot (AR) to gather sensory input about its internal state and that of external elements including the user and objects in the environment

Sensory and Feedback Systems

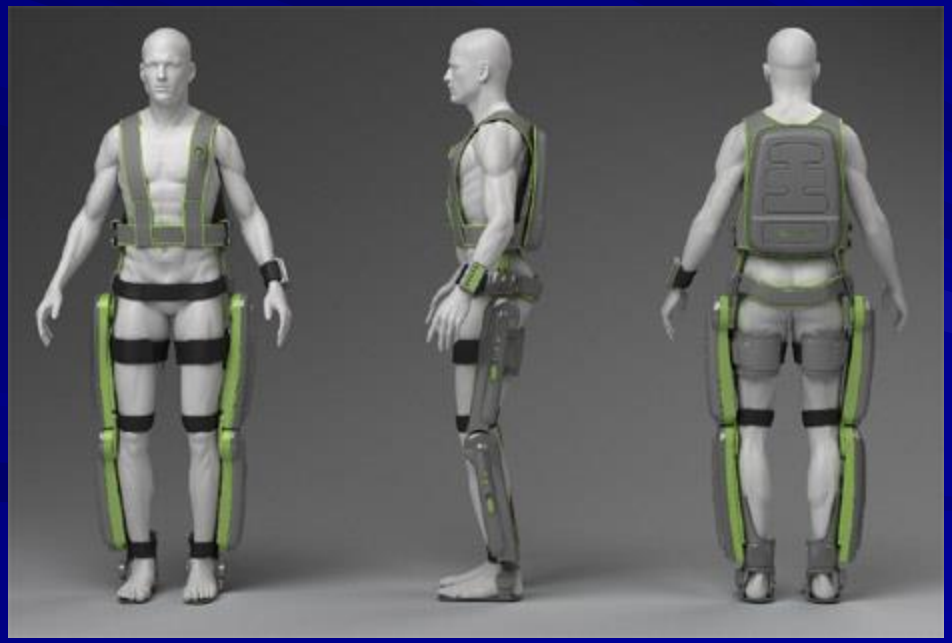
- Proprioceptive systems allow a robot to sense itself
  - exteroceptive systems can be either force/tactile based such as pressure and vibration sensors
- Microprocessor controlled knees use strain gauges to sense forces and alter resistance to motion in joints at appropriate points in the gait cycle
  - Otto Bock c-leg™102 and the Ossur Rheo Knee

Robotic Knees

- Improved accelerometers and gyrometers are utilized in a new generation robotic prostheses capable of using actuators to move target joints.
- Power Knee™

ReWalk

- Gyrometers for sensory feedback and control to allow upright bipedal ambulation in persons with paraplegia



Hybrid Assistive Limb: HAL

Super Soldiers

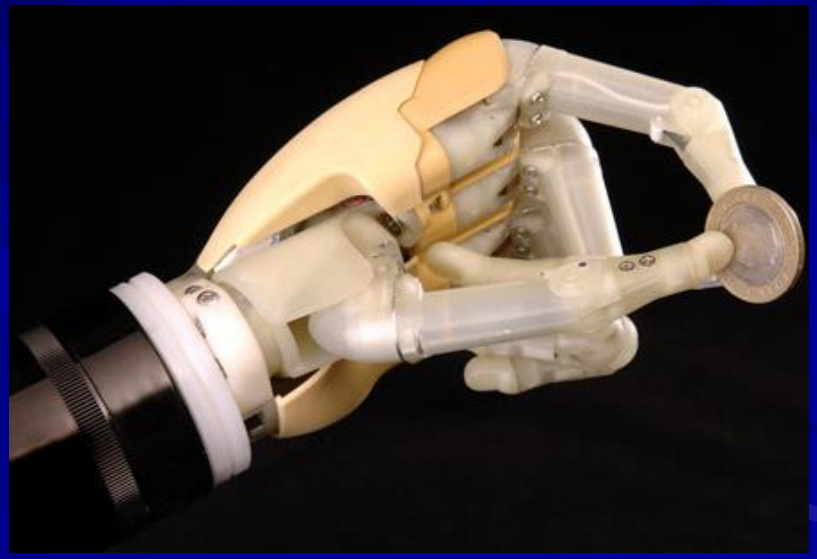
Sensory and Feedback Hands

- In addition to receiving information, robotic devices are capable of returning sensory feedback to the user
  - Electrical and vibratory feedback to the user has been well investigated in myoelectric hands
  - Pressure based feedback in the form of cuffs around the limb of the user to indicate amount of grasp force has been investigated

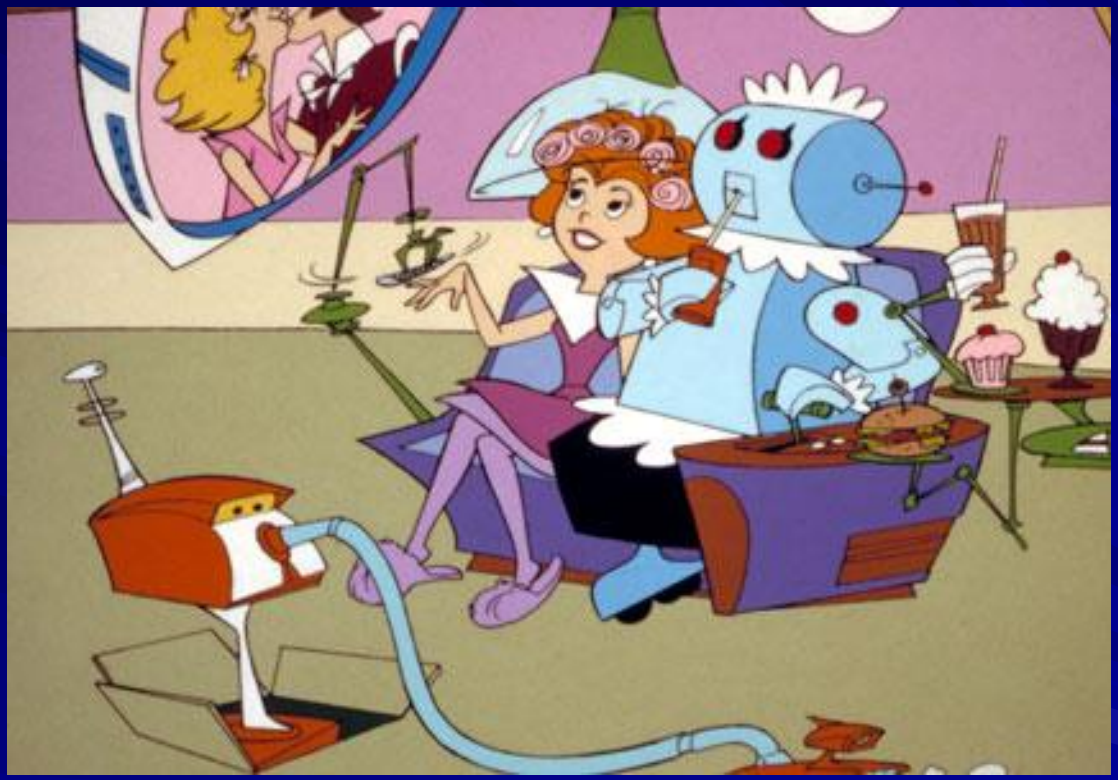
SensorHand

- Pressure sensing and corresponding alteration of force applied by the robot is utilized in robotic hand prostheses to prevent slippage without applying so much force as to crush the object

Robotic Limbs



Ideal Home



Questions?

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