ROBOT-ASSISTED REHABILITATION (II)

LOWER-LIMB REHABILITATION

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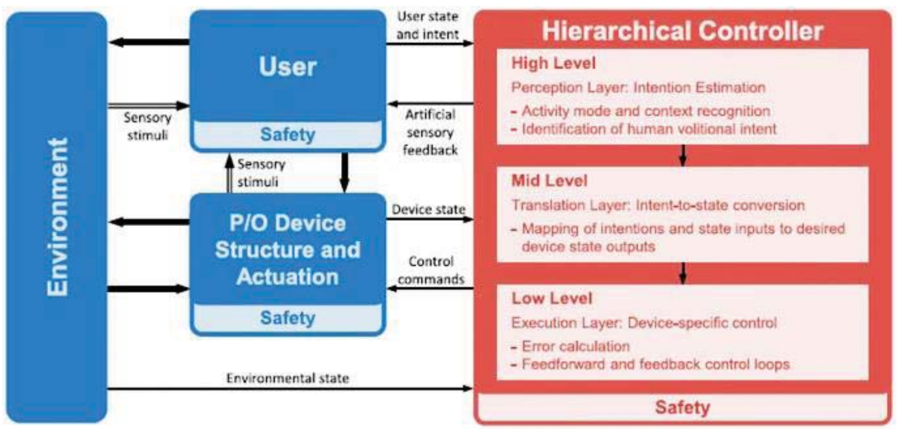
Robot-Assisted Rehabilitation: State of Art

- Relieve the drawbacks of the traditional rehabilitation interventions
  - lack of repeatability
  - short training sessions
  - assessment only based on observation
- Aims
  - safely facilitate the restoration of abilities by providing a task-oriented and repetitive training and monitoring the patient progresses

Types of Therapeutic Movement

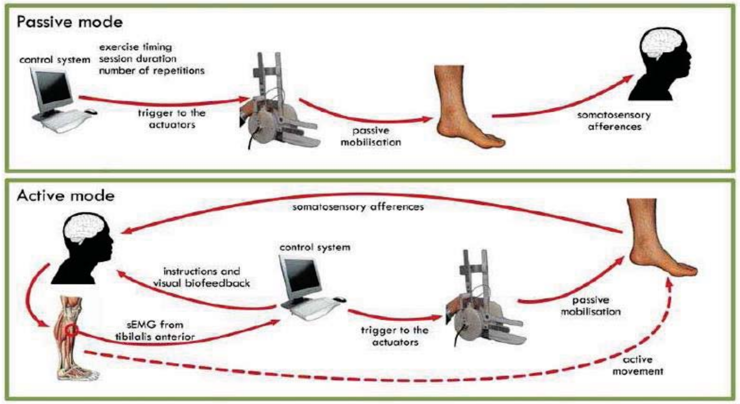
- Passive movement
  - outside force is completely responsible for the movement
- Active assisted movement
  - patient provides some effort, but also receives some assist from an outside force
- Active movement
  - patient provides the entire effort. No outside help is provided.
- Anti-gravity movement
  - motion that causes a body part to provide effort to move against the force of gravity
- Gravity reduced movement
  - motion is supported in some way and motion occurs perpendicular to the direction of gravitational force, sliding along the supporting surface

Generalized Control Framework for Lower Limbs



Robot-Assisted Training Modes

- According to patient's different recovery stages



Foot Plates Based End-Effector Devices

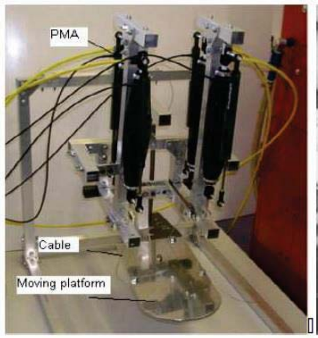
- Feet will positioned on the foot plates, which controlled by programmable systems to stimulate different phases of gait


Gait Trainer GTI

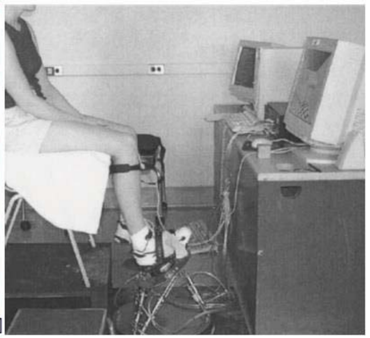

Haptic Walker

Platform Based End-Effector Devices

- Enable the patient to be stationary, just with lower limb fixed on the platform

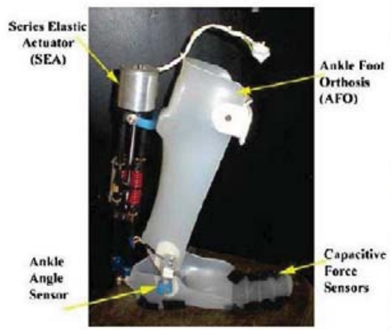


4-axis redundant parallel robot


Rutgers Ankle

Leg Orthoses and Exoskeletons

- Provide walk power assistance



AAFO


KAFO

Symbiotic Interaction

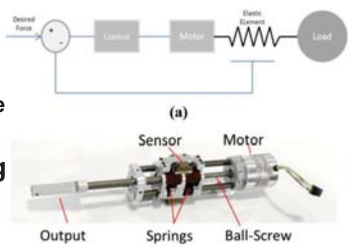
- Automate the assist-as needed physical rehabilitation paradigm
  - allow minimization of robot guidance and at the same time continuously challenge the subject
- Patient-cooperative device
- Interfaces with brain and muscle that allow for detailed assessment and monitoring of mechanical and neuromotor deficits
- Adaptability and learning approaches to balance safety with a more versatile function to handle multiple situations

Bioinspired Actuation

- Conventional actuator technologies
  - electric actuator
    - ➢ easily controllable and power efficient
    - ➢ require for most gait-related application gear reduction to achieve the desired torque
  - hydraulic and pneumatic actuator
    - ➢ include variable volume pressure chambers to convert a pressurized liquid or gas in a mechanical torque to create motion
    - ➢ silent, precise, smooth, and impervious to dusty and wet environment
    - ➢ support high specific power and force
    - ➢ enable backdrivability and twice lightweight than electric actuator
  - Electric actuators are 92% more power efficient

Bioinspired Actuation

- Compliant actuator
  - including elastic (or compliant) structures in the electromechanical actuators widely adopted with the introduction of Series Elastic Actuators
    - ➢ exhibit low impedance, low friction, and acceptable dynamic range
  - Major benefit of is that it allows implementing a torque control loop through a position control
  - Results also in a better resistance to impact, which can, in turn, benefit comfort and safety



(a)

(b)

Bioinspired Actuation

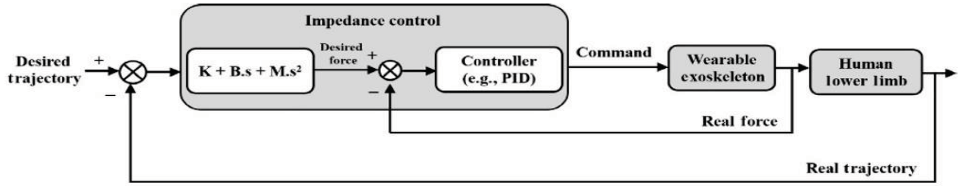
- Lightweight, low power controllable actuators
  - behave like human muscles
  - include timed application of springlike behavior with quasi-passive mechanism at joints
  - adaptively change the demand of muscle forces and joint moments during walking

Bioinspired Control

- Biomechanical principles
  - reduction in net muscle moments about the joint for user's adaptation to robotic assistance
  - biological leg stiffness is modulated in order to achieve a combined linear stiffness, with a reduction in energy consumption

Bioinspired Control

- Admittance and impedance controllers
  - establish a dynamic relationship between an output force and an input trajectory, using dynamic properties, such as stiffness, damping, and inertia
  - mechanical admittance may be considered as a dynamic extension of compliance since it determines the output trajectory (angular position) from a mechanical interaction by monitoring the force (mechanical torque)



Bioinspired Control

- Setting references for robotic control
  - reference kinematic patterns could be shaped for individual subjects and range of desired gait speeds in training, based on normative gait databases
  - simplify the process of personalization of speed-dependent reference trajectories, it has been proposed to apply regression-based models for reconstructing body-height and speed-dependent angular trajectories

Bioinspired Control

- Neuromusculoskeletal (NMS) modelling for feedback and control
  - ability of measuring muscle forces and joint variables is needed to quantify and predict joint function
  - EMG to translate the measured individual's neuromuscular patterns into muscle and joint force estimates via EMG-driven musculoskeletal modeling
    - ➢ subject-specific musculoskeletal model continuously estimates the state and forces of the muscles

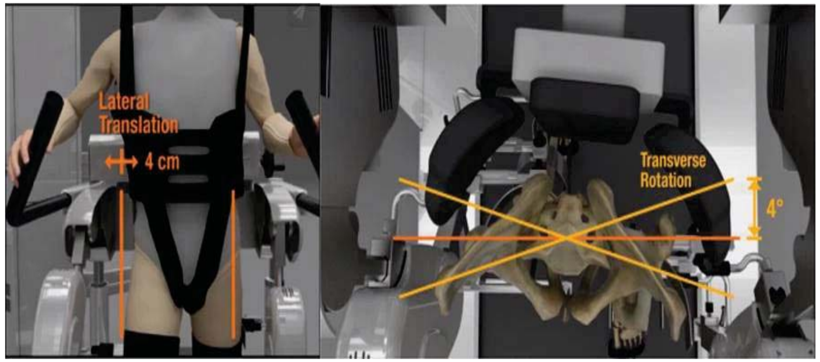
Treadmill-based Exoskeleton

- **Usually consists of a body weight support system while walking on a treadmill frame**

Lokomat

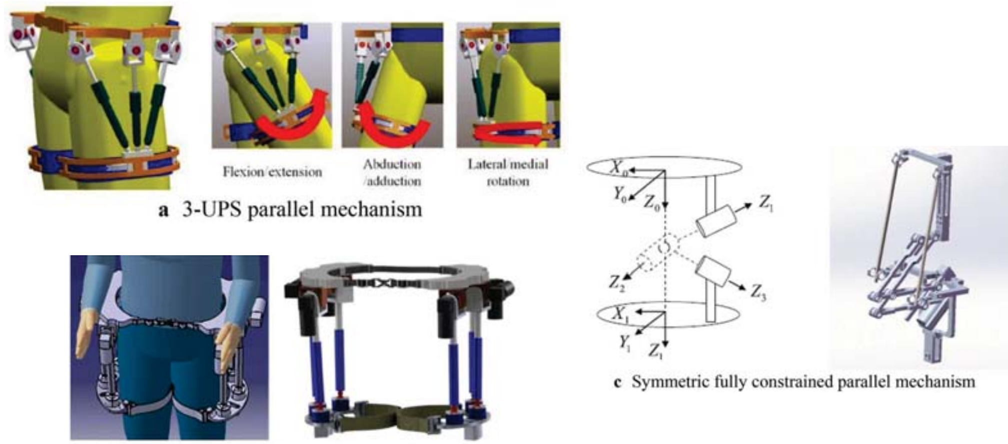
LOPES

Optional FreeD Module



Overground Lower limb Rehabilitation Exoskeletons

Design Mechanism of Hip Joint

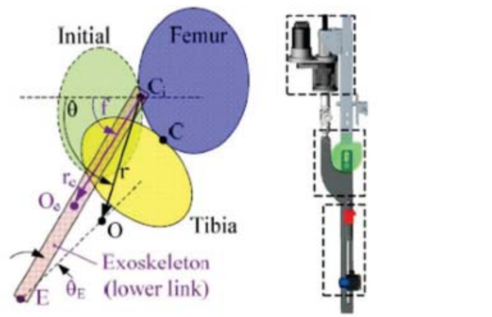


a 3-UPS parallel mechanism

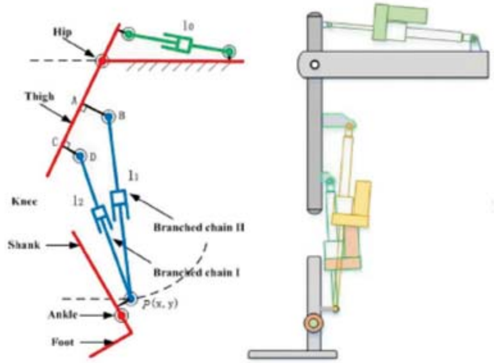
b Metamorphic parallel mechanism

c Symmetric fully constrained parallel mechanism

Design Mechanism of Knee Joint



a Adaptive knee to eliminate the negative effects



b Serial-parallel hybrid mechanism

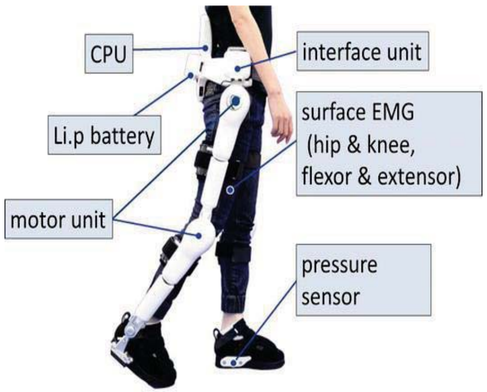
ReWalk

- Powered exoskeleton that allows thoracic motor complete individuals with SCI to walk independently
- Electrically actuated

(ReWalk Robotics, Inc., Marlborough, MA, USA)

HAL

- Detects the bioelectric signals generated by patient's muscle activities and/or the floor reaction force signals caused by patient's intended weight shift
- Electrically actuated



(Hybrid, Assistive Limb, Cyberdyne Inc., Japan)

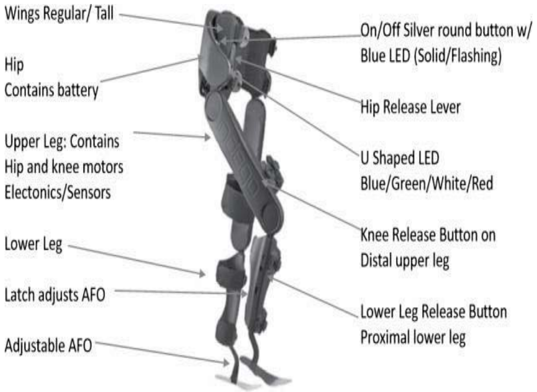
Ekso

- Provides functional rehabilitation in the form of over-ground weight bearing stepping
- Electrically actuated

(Ekso Bionics, Richmond, CA, USA)

Indego

- On-board microprocessors receive signals from integrated sensors that provide feedback on the user's posture and tilt
- Electrically actuated



(Parker Hannifin Corp., Cleveland, OH,USA)

HANK

- Work in both assist-as-needed mode and predefined movement
- Electrically actuated

(GOGOA, Urretxu, Spain))