Stroke Rehabilitation
Novel Technologies and therapy

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Quiz (10 point)

• (4 pt) What is the limitation of “assist-as-needed” protocol?

• (6 pt) List 3 methods for detecting the motion intent in robot-assisted stroke rehabilitation
Overview

• Upper limb exoskeleton
  • Rehabilitation using video game and virtual reality

• Lower limb exoskeleton
  • Controller design for various assistive strategies
Upper Limb Stroke Rehabilitation: Gaming and Virtual Reality
Intensive therapy can recover a significant amount of lost motor control.

Video games encourage patients to practice more at home:
- Provide a motivating context
- Provide performance feedback
Cognitive, visual and motor losses after stroke

- Memory and speech
- Unilateral neglect
- Paralysis and weakness
How to recover the lost function?

- Overcoming learned non-use
- Learning to use existing redundant neural pathways
- Developing new neural pathways through brain plasticity
Traditional stroke therapy

- Perform repeated motions under therapist supervision
  - Non-purposeful exercises
  - Purposeful exercises

- Practice at home
  - Prescribed by therapist
  - Only 31% patients actually do it
Commercial games and consoles
Commercial games and consoles
Commercial games and consoles
Limitation of commercial games
Desired properties in stroke rehabilitation games

Important human factors for stroke rehab games
  - Identification of the target audience, visibility and feedback

Meaningful play and challenges

Game design criteria

Games that adapt to a patient’s level of recovery
Considerations in rehab game design

- Social context
  - Multi-player games provide additional motivations
  - Competitive / collaborative games

- Type of motion required
  - Single or multi-joint motions

- Cognitive challenges
Games for example

- Motor, visual and cognitive challenges
Learned Lessons in previous user studies

How to make games playable for a broad range of stroke patients?
  • Assume no use of hands
  • Simple games should support multiple methods of user input
  • Calibrate to the patient’s motion range
  • Direct and natural mappings are necessary
Learned Lessons in previous user studies

• How to ensure that games are valuable from a therapeutic perspective?
  • Ensure that users’ motions cover their full range
  • Detect compensatory motion
  • Allow coordinated motions
  • Let therapists determine difficulty
Learned Lessons in previous user studies

• How to make games fun and challenging?
  • Audio and visuals are important
  • Automatic difficulty adjustments provide adequate challenge
  • Non-Player Characters (NPCs) and Storylines are intriguing
Kinect-based applications for stroke rehab
Limitations of Kinect-based Stroke Rehab

- Reasonable accuracy, but only for gross motions
- Unable to accurately assess internal joint rotations of shoulder
- Cannot capture rehab goals that include fine motor skills
- Not suitable for severely disabled patients
Lower Limb Exoskeletons
Controller Design and Assistive Strategies
Lower Limb Wearable Robots

- Multi-joint VS single-joint devices
- Waling assistance VS rehabilitation
• Devices for hip, knee and ankle
  • Fundamentally different joint functions
  • Assistive strategies unique to single-joint device
  • Muscle stiffness, proportional myoelectrical control
Multi-joint Exoskeletons
Assistive Strategies for Multi-joint Devices

• Sensitivity amplification
• Predefined gait trajectory control
• Model-based control
• Predefined action based on gait pattern
• Adaptive oscillators-based controllers
• Hybrid assistive strategy
Gait Cycle

A. Heel strike (initial contact)
B. Loading response (foot flat)
C. Midstance
D. Terminal stance (heel off)
E. Preswing (toe off)
F. Initial & Mid-swing
G. Terminal swing

Stance Phase (60%) - Push Off - Swing Phase (40%)

- Double support (10%)
- Single support (40%)
- Double support (10%)
- Single support (40%)
Sensitivity amplification controller

- Control based on Inverse dynamic model
  - Inverse dynamic models for different gait phase
  - How to detect gait phase?
Sensitivity amplification controller
Sensitivity amplification controller

- Power augmentation
  - Positive feedback loop

- Limitations
  - Instability due to amplifying disturbance
  - Need accurate model
Predefined gait trajectory control

- Desired gait trajectory
  - Pre-recorded from a healthy person
  - Extrapolate from a gait analysis data

- To improve usability and flexibility
  - Trajectory parametrization
Model-based control

- Desired robotic action based on human-exoskeleton model
  - Gravity compensation, ZMP, ...
Adaptive oscillators-based control

- Adaptive frequency oscillator
- Extended to wearable robotics
  - Periodic locomotion-related signals features
- Limited application on LL exo
Case Study: An Assistive Control Approach for a Lower-Limb Exoskeleton

• Assist walking without governing the spatiotemporal nature of the footpath

• Enable patients to select step length and time

• Maintain the ZMP within their own support polygons
Controller design

- Gravity compensation
- Feedforward movement assistance during swing
- Knee joint stability reinforcement during stance
Cooperative Control using FES

- Adaptive stimulation profile generator
- Muscle dynamics
- Predefined joint angle trajectory
- PD controller
- Joint dynamics

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\[ \tau_{exo} \]

\[ \tau_m \]
Cooperative Control using FES

1. right leg swing (right quads controlled)
   left leg stance (left hams controlled)

2. double-support (no FES)

3. left leg swing (left quads controlled)
   right leg stance (right hams controlled)

Step completed

Initiate step

Step completed
Generating Exoskeleton Gait Trajectory using Alternate Motor Inputs
Reference


