Movement Therapy Robots

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Portions of this material provided by
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U.S. Demographics of Potential Therapy Robot Users

- **Stroke:**
  - 800,000 cases per year (incidence)
  - 6.5M people in the US have had a stroke (by 2050, cost projected to be $2.2 Trillion)

- **Cerebral palsy:**
  - 300,000 - 500,000 prevalence
  - 8,000 incidence

- **Orthopedic interventions:**
  - Post knee & hip replacement exercise
  - Ankle surgery
  - Trauma
Stroke Rehabilitation Strategies

- Important variables in optimal rehabilitation
  - Quantity
  - Duration
  - Intensity/repetition
  - Task-specific

- Robotic control strategies
  - Assisting movement
  - Challenging movement
  - Simulating normal tasks
  - Non-contact coaching


Research Phases in Robot-Assisted Stroke Therapy

1. Replicating the therapist
2. Augmenting the therapist
3. Designing the super-therapist
4. Enabling the inner therapist

H.F. Machiel Van der Loos (UCB)
Phase 1: Replicating the therapist
MIME: Mirror-Image Movement Enabler (PA VA/Stanford)
Robotic system assisting upper limb neuro-rehabilitation

Facilitates paretic elbow and shoulder movement

Four modes of exercise:
- Passive
- Active-Assisted
- Active-Resisted
- Bimanual


Statistically significant improvement in Fugl-Meyer and clinical strength scales after 4-week regimen of daily 1-hour sessions.


ARM Guide (Rehab Institute of Chicago)

Linear slide with motor
6-dof force sensing

Phase 2: Augmenting the therapist
Driver’s SEAT (PA VA/Stanford)

An upper limb one-degree-of-freedom robotic therapy device that incorporates a modified PC-based driving simulator.

GENTLE/s (EU project)

Phase 3: Designing the super-therapist
Adding, then Removing Force-Field

A 315° trajectory from one stroke subject. (a) unperturbed baseline, (b) late machine learning, (c) early training, (d) late training, (e) aftereffects, (f) early washout, and (g) late washout. Desired trajectories are bold dotted lines, average trajectories are bold solid lines, individual trajectories are thin lines, and shaded areas indicate running 95% confidence intervals of ensemble.

‘Paris’ VR System (Rehab Institute of Chicago)

Goal: Better transfer to Activities of Daily Living

- 5-axis WAM manipulator
- Full-arm movement
- Projection of objects through glass
- Virtual object manipulation

http://www.smpp.northwestern.edu/robotLab/
Phase 4: Enabling the inner therapist
Using affect to change robot behavior


Lower-Extremity Rehabilitation Robots
PAM + ARTHUR walking aid

- Treadmill-based
- Pelvis assist (PAM) + walking assist (ARTHUR)
- PAM: linear actuators to support pelvis
- Linear actuators on rail to provide foot motion assist

http://www.eng.uci.edu/~dreinken/Biolab/biolab.htm
Lokomat Treadmill Walker

- Each side = 2 dof
- Linear actuators
- Supported treadmill walking
- Patients with stroke, iSCI

http://www.research-projects.unizh.ch/med/unit43000/area198/p1237.htm
UBC-CARIS Lab Balance Training


A case study: Compensation for cerebellar injury

Allison Okamura (Stanford, JHU), in collaboration with: Amy Bastian (JHU and KKI), David Grow (NMT), and Nasir Bhanpuri (JHU)
Motion Incoordination: Cerebellar Ataxia

Control

Cerebellar
Bias
Variability
Measurement system

KINARM exoskeleton robot
control perturbations

model
If a patient has **hypermetria**, use the robot to **decrease** their inertia.

If a patient has **hypometria**, use the robot to **increase** their inertia.
What does this mean?

We find patient specific biases in dynamics representation.

We can replicate by creating a mismatch in control dynamics (inertia) and using simulation.

We can partially correct by altering patient limb inertia with a robot.

This does not correct trial-to-trial variability.
What about planar reaching?

null field  compensation (helping)  null field  compensation (worsening)  null field

Figure 48: Cerebellar subject makes targeted reaching movements to four targets. The task is divided into five blocks: the first, third, and fifth blocks are null blocks where the robot is passive. During the second block, the robot applies a change in dynamics predicted to help. During the fourth block, the opposite change in dynamics is made, which we expect to hinder performance. Hand paths and errors are color coded by direction.
Isometric Training for Stroke Rehabilitation

- Rehabilitation robots enable
  - repetitive, controlled training
  - performance quantification
- Isometric training
  - requires minimal ability
  - involves simpler and cheaper devices

we are just getting started...

Michele Rotella, Margaret Koehler, Ilana Nisky, and Amy Bastian
Isometric Training for Stroke Rehabilitation

What type of isometric control strategy is best for learning (visuomotor rotation perturbation)?

**Movement control**

**Isometric control of position**
Isometric Training for Stroke Rehabilitation

What type of isometric control strategy is best for learning (visuomotor rotation perturbation)?

**Movement control**

**Isometric control of velocity**
User guidance with wearable haptics
In an ideal world, medical robotics includes:

• Quantitative descriptions of patient state
• Use of models to plan intervention
• Design of devices, systems, and processes to connect information to action (= robotics)
• Incorporating human input in a natural way
• Goal: improve health and quality of life

But these are only the technical challenges...