Rehabilitation (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.
Split Steering Wheel


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


Predicting and Correcting Ataxia Using a Model of Cerebellar Function and an Exoskeleton Robot

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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 (Healthy)  Cerebellar
Exoskeleton robot
Single-jointed reaching: Arm flexion
control perturbations

model
Internal model inertia bias determined by the computational model is highly correlated with dysmetria.
Results of robot intervention

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

If a patient has **hypometria**, use the robot to **increase** their inertia

Individuals  Group

![Graph showing results of robot intervention before and after intervention for individuals and group.](image)
We find patient-specific biases in dynamics representation.

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

We can partially correct dysmetria by altering patient limb inertia with a robot. This does not correct trial-to-trial variability.
User guidance with wearable haptics
Key features of robot-assisted interventions

• Quantitative descriptions of patient state
• Use of models to plan intervention
• Design of devices, control, and processes to connect information to action (= robotics)
• Incorporate human input in a natural way

Ultimate goal: Improve health and quality of life