Affordable Therapy and Service Robots for Health and Function Monitoring

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1. Patents filed on Rehab CARES robot system
2. Equity in a spin-off company of UPENN called Recupero Robotics, LLC.
UPENN LOVE
Rehabilitation Robotics Lab

• The lab consists of an interdisciplinary team working in the fields of robotics, rehabilitation, and neuroscience.

• Our mission is to translate research findings into the development of affordable, assistive and therapeutic robots that can provide effective neurorehabilitation both nationally, and around the world.

Core Research Areas

- Affordable robots for Global Health
- Mobile Therapeutic Assistance
- Neuro-rehabilitation
Lab Team (Past and Present)
Learning Objectives

• Background
• Technology-assisted rehabilitation
• Case for Therapy and Service Robots in Community
• Integrated Systems Health Management? How work?
Motivation

• Communicable and Non-communicable diseases.
  • NCDs were 68% of all deaths globally in 2012.
  • It is estimated to increase to 73% by 2020.
  • Cardiovascular diseases account for about 30% of NCD deaths (~17.7 million)
  • Stroke account for about 11.9% of NCDs deaths.
  • Survival often means living with disability or decreased function

• Ageing Populations
  • Populations are aging → 20-30% over 65 age by 2030;
  • Age is a leading risk factors for many diseases.
Disability and Age: USA

Ref: 2016 Disability Statistics
by Lewis Kraus, MPH, MCP at the Center on Disability at the Public Health Institute
ICF: Common Areas of Function/Impairment

- **Cognition** – understanding & communicating
- **Mobility** – moving & getting around
- **Self-care** – hygiene, dressing, eating & staying alone
- **Getting along** – interacting with other people
  - Interpersonal Interactions
- **Life activities** – domestic responsibilities, leisure, work & school
  - Domestic Life
  - Major Life Areas
- **Participation or Community, Social and Civic Life** – joining in community activities

![Prevalence Rates: Age 65 to 74 years (%)](chart.png)
Technology Can Bridge This Gap
Therapy and Service Robots
Observing Human-Human

Therapy Session
Capturing Roles and Cues

- Multimedia Video Analysis Software: MVTA
- 8 Videos Coded independently by 2 therapists
Modelling Intent

Ideally the robot should take on three roles as demonstrator, observer and helper and co-act with the patient. The helper role is often seen in hands-on effector THERAPY ROBOTS (e.g., ADLER, Theradrive). Demonstrator and Observer Roles are often found in ASSISTIVE ROBOTS or SERVICE ROBOTS (e.g., Nao). Fluid transitioning from contact to non-contact with a patient is not often done due to huge safety concerns about soft and hard impacts.
Therapy Robots

- Originally developed to treat neurological disorders such as stroke and cerebral palsy.
  - Function to automate and deliver autonomous or semi-autonomous therapy for arm (or leg or joint)
  - Function to assess level of disability and impairment remaining in a limb arm (or leg)
  - Outcome >>> reducing motor impairment, increasing function and driving brain re-organization
- Currently being developed to treat a variety of diseases and disorders, e.g., Multiple Sclerosis
- Typically function in clinics or supervised settings
Haptic TheraDrive

• Single Degree of Freedom Robot

• Assessment Metrics:
  • Root Mean Square Error (Accuracy)

• Gaming

Assistive Robots = Service Robots in Rehabilitation/Medical Settings

- Replace other functions or activities or things (e.g. surveillance robots)
- Replace a loss limb (e.g., prosthetics)
- Replace the function of a paralyzed limb and do tasks instead of the limb (e.g., wheelchair robot)
Demonstrator/Observer roles >>

Baxter: Elder Exercise

• Collaboration with Dr. Kuchenbecker and Dr. N Watts
• Elder Exercise Care

Demonstrator role >>
Flo: Mobile Therapist

- Combination of two off the shelf robots (Nao and VGo)
- Designed to provide remote and in-person “hands off” therapy
Therapy and Service
Robots for Elders in the Community
Living Independently for Elders – A Mercy LIFE Center

- Community-based setting
- All-inclusive care
  - Clinical care
  - Rehabilitation care
  - Doctors, Nurses, Therapists, Caregivers
- Elders > 65 age
- Elders have various levels of function
- Medicare/Medicaid
- 80% African American
- 75% Female
- GOAL >> MAINTAIN ELDERS INDEPENDENCE

- NSF Partnerships for Innovation: Building Innovation Capacity program (Grant #1430216; IIP-1430216).
- Rehab Robotics Lab, MOD Lab (Dr. Yim, PI), Penn Nursing (Dr. Cacchione), Savioke, Inc. (Dr. Lau)
Activity and Participation >> Independence

• Activity is a execution of a task or activity by the elder
• Participation is involvement in a life situation
• Impairment >> Activity Limitation >> Participation Restrictions
• Participation promotes inclusion in life activities in the context of the persons community
• External factors such as social roles, social environment, political environment, physical environment, psychological environment may lead to activity limitations and participation restrictions and therefore independence reduction.

Ref: PM&R Secrets 2nd Edition and ICF ref
Can we develop an affordable social robot that can support elders at the LIFE center?

- $20,000,
- Mobile,
- Manipulates

What tasks should it do?
Elder Care: Low-Cost Assistive Mobile Robot
System Description: Savioke Hardware

Specifications:
- 177mm touchscreen monitor, storage bin
- Navigation: Lidar and sonar sensors
- Speakers added for enhancing interaction
- Camera for recording the interaction
Mobile only Deployments*

Autonomous Hydration reminder and Water delivery

Walking encouragement

System Description: Mod Lab’s Manipulator

\[ l_1 = 20 \text{cm}, \quad l_2 = 80 \text{cm} \]
Reaching Objects/Corn Toss Games
Therapy and Service Robots as Integrated System Health Managers
Integrated Systems Health Management

- Fault detection (detecting that something is wrong)
- Fault isolation (determining the location of the fault)
- Fault Diagnostics (isolation & identification)
- Fault identification (determining what is wrong; that is, determining the fault mode)
- Fault prognostics (determining when a failure will occur based conditionally on anticipated future actions)
Scenario 1: Fully Autonomous Robot

Patient Unable to do task/ Expresses doubt; Physical/Verbal Cue

Robot Demonstrator
Patient Observer

Demo Completed;

Robot Helper
Patient Performer with Assistance

Patient Error; Physical Cue

Robot Observer
Patient Performer

Patient

Autonomous Robot Guidelines

- Assist the elder with tasks
- Monitor the elder actions
- Provide either physical or verbal feedback based on user performance
  - Physical assistance if provided should be safe
- Able to modify level of robot involvement required for task
- Able to track individual elders and group of elders
- Able to communicate with elder - preference
- Able to switch out of HELPER to either OBSERVER OR DEMONSTRATOR modes
- Monitor the elder health over time
- Alert clinicians, medical doctors and caregivers to decline
- Suggest actions/tasks to elder increase activity and social engagement
Fault detection (detecting that something is wrong)

• Monitor unusual function in key domains
  • Heart rate – Pulse Oximeters
  • Pain levels – Visual Analog Scales
  • Exertion levels – Borg Scales
  • Emotional levels – Face expression and Galvanic Skin Function
  • Gait – stride length
  • Location – GPS
  • Social activity – calls, visits, level of contact with others
  • Communication – responsiveness
  • Brain activity - EEG
  • Range of Motion – joint sensors, 3D motion capture
  • Body kinematics - 3D motion capture
  • Muscle kinetics - EMG
  • etc

• What are the threats to independent function in key domains: Cognition, mobility, hearing, vision etc.?
Fault Diagnostics (isolation & identification)

• Fault isolation (determining the location of the fault)
  • Gather periodic clinical/therapy data from records
  • Gather data on adverse events – e.g., falls, hospitalization, ER visits
  • Gather robot-interaction data
  • Measure current function in the key domains including medical to learn unusual changes
  • Isolate areas impacted

• Fault identification (determining what is wrong)
  • Compare current function to past functional levels
  • Isolate anomaly
Fault Prognostics (determining when a failure will occur based conditionally on anticipated future actions)

• Define elder typical actions over time
• Define elder frequency of adverse events – e.g., falls, hospitalization, ER visits
• Increase robot interaction/actions to probe for possible deviations
• Define group actions over time
Possible Barriers to Acceptance of Scenario 1

• Robot replaces human contact and may seem impersonal
  • Human does motivation and psychological aspect of therapy
• Robot interaction with human must be VERY safe
• Robot will not be as good as therapist
• Robot may not be versatile to monitor more than one human >>>
  alone or in groups
• Robot may not be able to easily obey privacy and security rules
• Requires human to wear sensors
Questions

• What are best strategies for overcoming barriers and creating an ACCEPTABLE Therapy/Service Robots that can do IHSM?
• How do we overcome barriers of low number of data?
• How do we juggle the need to track the individual AND the group?
• How can the Therapy/Service Robots that can do IHSM do SHARED management?
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QUESTIONS?