Robotic Cane
as an Ambient Super-Limb
for Assistive Elderly Motion Transition

Song Chaoyang
Department of Mechanical and Energy Engineering
Southern University of Science and Technology
songcy@sustech.edu.cn
A Social Challenge for Everyone, Especially the Elderly

“Challenge to balance or strength > Ability to stay upright”

1 in 4 older adults reported a fall.

Even though falls are common, most adults who fall don’t tell their doctor.

More than 27,000 older adults died as a result of falls—that’s 74 older adults every day.

Among older Americans falls are the #1 cause of:
• Death from injury
• Injuries

1/5 falls causes a serious injury
• a broken bone or head injury.

Fear of falling
• seriously affect an aging adult’s quality of life
• keep a person from being active and thriving.

Source: USA CDC

The big shift
Old-age dependency, population aged 65 and over per 100 people aged 25–64

- Japan
- Germany
- Rich world
- United States
- China
- Developing world

Source: UN Population Division

Old-age dependency indicates the ratio between the number of persons aged 65 and over (age when they are generally economically inactive) and the number of persons aged between 15 and 64. The value is expressed per 100 persons of working age (15-64)
Falls Happen During Motion Transition

Sit-to-Stand is among the high-risk levels of motion states

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Motion State</th>
<th>Where aids are needed</th>
<th>Where aids are needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>In-seat Motion</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Low</td>
<td>Sitting State</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>High</td>
<td>Sit-to-Stand Motion</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Low</td>
<td>Standing State</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>High</td>
<td>Walking Motion</td>
<td>High</td>
<td>Low</td>
</tr>
</tbody>
</table>

• Health-based risks
  • This includes things like balance problems, weakness, chronic illnesses, vision problems, and medication side-effects. They are specific to an individual person.

• Environmental risks
  • These are things like home hazards (e.g. loose throw rugs), outside hazards (e.g. icy sidewalks), or risky footwear (e.g. high heels). This category can also include improper use of a walker, cane, or other assistive device.

• Triggers
  • These are the sudden or occasional events that cause a challenge to balance or strength. They can be things like a strong dog pulling on a leash, or even health-related events like a moment of low blood sugar (hypoglycemia) in a person with diabetes.

Leslie Kernisan, MD MPH
Assistive Tools for Sit-to-Stand

For motion transition from Sitting on Chair, Bed & Toilet to Walking

Medline Bed Assist bar
Medline Toilet Safety Rails
Able Life Universal Stand Assist
Carex Upeasy Seat Assist Plus

Can we Design Intelligence for Geriatric Assistive Device?

Or how can we better assist the brain and muscle of the elderly during sit-to-stand?

### Table 1. Comparison of Assistive Devices

<table>
<thead>
<tr>
<th>Assistive device</th>
<th>Pros</th>
<th>Cons</th>
<th>Examples of conditions indicated for use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canes</td>
<td>Improves balance; adjustable</td>
<td>Should not be used for weight bearing; umbrella handle may cause carpal tunnel syndrome</td>
<td>Mild ataxia (sensory, vestibular, or visual); mild arthritis</td>
</tr>
<tr>
<td>Offset cane</td>
<td>Appropriate for intermittent weight bearing; shotgun handle puts less pressure on palm</td>
<td>Commonly used incorrectly (backward)</td>
<td>Moderate arthritis</td>
</tr>
<tr>
<td>Quadripod (four-legged)</td>
<td>Increased base of support; can bear larger amount of weight; stands freely on its own</td>
<td>Slightly heavier than straight cane; awkward to use correctly with all four points on ground simultaneously</td>
<td>Hemiparesis</td>
</tr>
<tr>
<td>Crutches</td>
<td>Able to completely redistribute weight off of lower extremities; permits 80 to 100 percent weight-bearing support; inexpensive</td>
<td>Difficult to learn to use; requires substantial energy expenditure and strength; risk of nerve or artery compression, unable to use hands</td>
<td>Lower extremity fracture</td>
</tr>
<tr>
<td>Forearm (Lofstrand)</td>
<td>Frees hands without having to drop crutch; less cumbersome to use, particularly on stairs</td>
<td>Permits only occasional weight bearing</td>
<td>Paraparesis</td>
</tr>
<tr>
<td>Platform crutches</td>
<td>Forearm is used to bear weight rather than hand</td>
<td>Difficult to learn to use</td>
<td>Rheumatoid arthritis</td>
</tr>
<tr>
<td>Walkers</td>
<td>Most stable walker; folds easily</td>
<td>Needs to be lifted up with each step; slower, less natural gait</td>
<td>Severe myopathy; severe neuropathy; cerebellar ataxia</td>
</tr>
<tr>
<td>Front-wheeled (two-wheeled) walker</td>
<td>Maintains normal gait pattern; does not need to be lifted up with each step</td>
<td>Large turning arc; less stable than standard walker</td>
<td>Severe myopathy; severe neuropathy; paraparesis; parkinsonism</td>
</tr>
<tr>
<td>Four-wheeled walker (rollator)</td>
<td>Easy to propel; highly maneuverable, with small turning arc; typically has seat and basket</td>
<td>Not for weight bearing; less stable than front-wheeled walker; does not fold easily</td>
<td>Moderate arthritis; claudication; lung disease; congestive heart failure</td>
</tr>
</tbody>
</table>

---

**Geriatric Assistive Device Selection**

- Does the patient need one or both upper extremities for weight bearing or balance?
  - One
    - What frequency of weight bearing is needed?
      - Standard cane
      - Offset cane
      - Quadripod cane
      - Four-wheeled walker (rollator)
      - Front-wheeled walker or forearm crutches
      - Front-wheeled or standard walker
      - Both

---

*Use with caution: this type of walker is appropriate if balance or cognitive impairment is mild and the patient could benefit from having a seat.*

---

**SRL as a potential solution?**

Towards an Ambient Super-Limb For Elderly Care

Design Concept of A Robotic Cane System

- Pneumatic linear actuation
- Inflatable vest for human-machine interface
- Privacy-safe recognition & prediction

Depth Camera
Inflatable Vest
Toilet
Bed
Chair

Pneumatic-Driven Robotic Cane

AncoraSIR.com
Robotic Cane Design

Biomechanical modeling with a linearly actuated cane
Gradually Reduced Peak Force Exerted by Human Leg

Reduced Ground Reaction Force with a Robotic Cane

- Assistive Sit-to-Stand can be much more complicated than the current design
- Current progress establishes the first steps towards an autonomous assistive device

Source: ACC New Zealand
Inflatable Vest

An inflatable swimming suit sewed inside a jacket with cane hooks under the arms

- Design issues with active assistance for the elderly as a wearable device
- Yet to be solved with a better design
Experiment Setup

Depth sensing for ambient motion recognition and intention detection

- Robotic Cane
- Soft Wearable
- Stair Embedded with Force Plates
- Depth Camera
- Marker Point
- Table for Evaluation

AncoraSIR.com
Depth Sensing for Ambient Intelligence

Towards an environment that satisfies our needs mostly without our having to think about it

- Ambient control of assistive robot for the elderly requires rich motion data
  - *Consumer-grade depth sensing vs. Industrial-grade motion capture*
- Future research on ambient control of super-limb robots for the elderly?
SRL Design for the Elderly

Case with the Cane

Body Function

Cognitive and physical needs increase

Design complexity increases

Level 1: Sensing

Level 2: Level 1 + Actuation

Level 3: Level 2 + System Design

Well Performed

Under Performed

AncoraSIR.com
Super-limb for the Elderly?

On-going research on robotic cane as a super-limb for elderly assistance

- Is direct-drive a suitable actuation for elderly lower-limb assistance?
- Can we design a super-limb that is smaller, lighter, quieter, and cheaper?
- How to emulate the human assistance for super-limb of elderly sit-to-stand?
- Should we focus on the robot or the system for the elderly?

Towards an ambient design of super-limb for elderly assistance
Research · Innovation · Entrepreneurship

Southern University of Science and Technology (SUSTech) is a research-oriented public university founded in Shenzhen, China’s innovation center.
Bionic Design & Learning Lab

Song Chaoyang
songcy@sustech.edu.cn

Assistant Professor with Department of Mechanical & Energy Engineering
Adjunct Assistant Professor with Department of Computer Science and Engineering

Bionic Design & Learning Lab

Lobster-inspired Design Inspiration
Rigid-Soft Interaction with Natural Joint of Resolute

Robot Learning

DeepClaw Robot Learning System
Mobile & Reproducible Robot System for Learning and Benchmarking

ME336 Collaborative Robot Learning
23/02/2023

Robot Learning

Bionic Education

AncoraSIR.com

11/8/2019
Bionic Design & Learning Lab | Song Chaoyang | songcy@sustech.edu.cn

21
Welcome to stay for SUSTech Night 8:20PM tonight here

Thank you ~

Song Chaoyang
Department of Mechanical and Energy Engineering
Southern University of Science and Technology
songcy@sustech.edu.cn

Dr. Wan Fang
Prof. Fu Chenglong
Prof. Harry Asada
Prof. Wang Zheng

Wu Xia
Liu Ziqi
Chen Mingdong
Liu Haiyuan

Funding Support by:
• SUSTech-MIT Joint Center for Mechanical Engineering Education and Research,
• National Students' Innovation and Entrepreneurship Training Program (201914325006)