2019 IROS Workshop on Supernumerary Robotic Limbs

November 4, 2019, The Venetian Macau Resort Hotel, Macau, China

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

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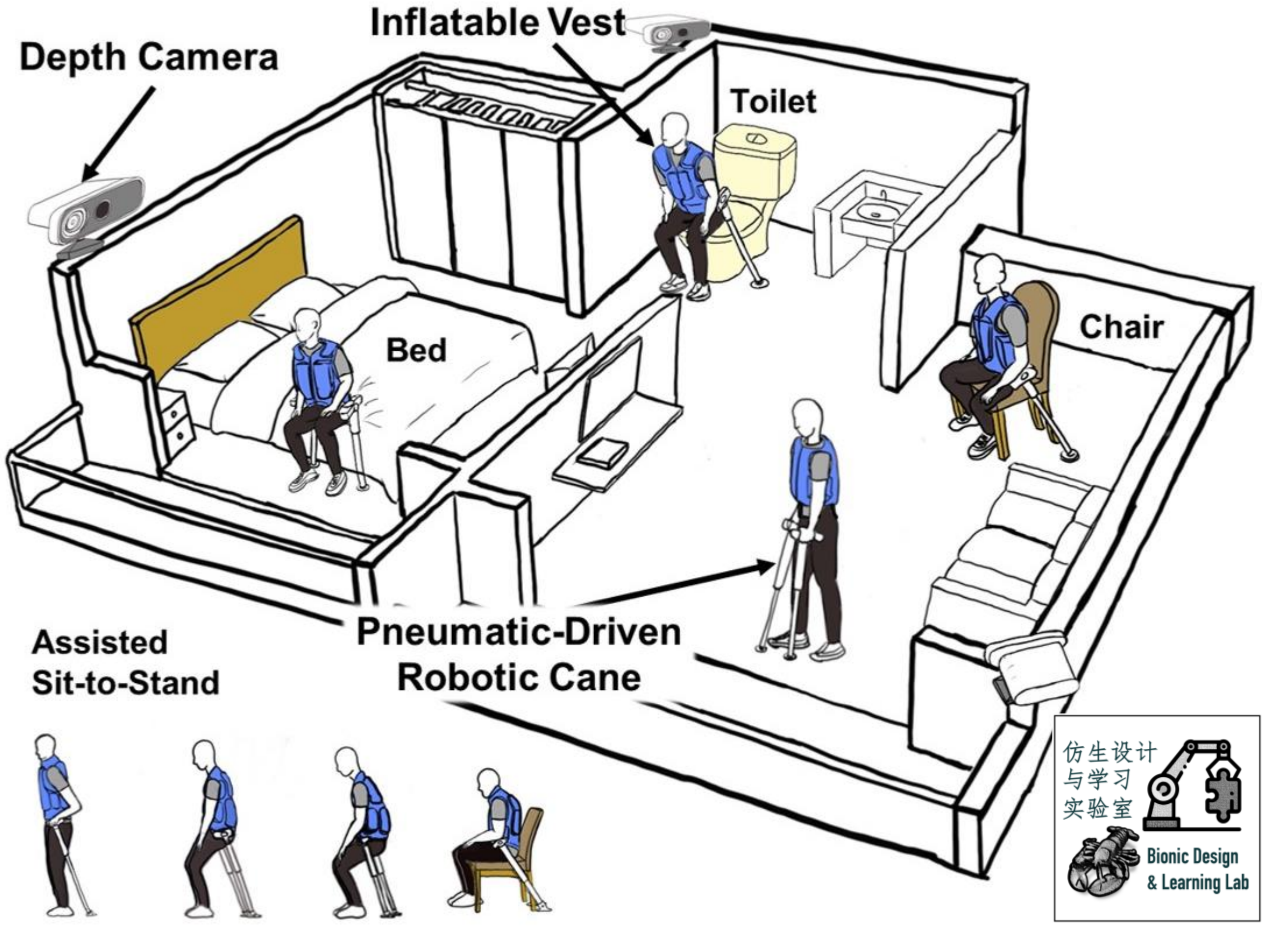
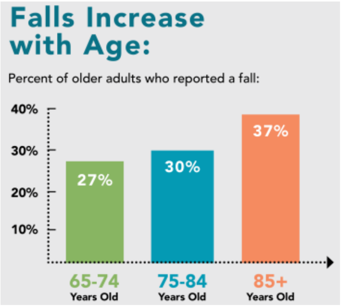


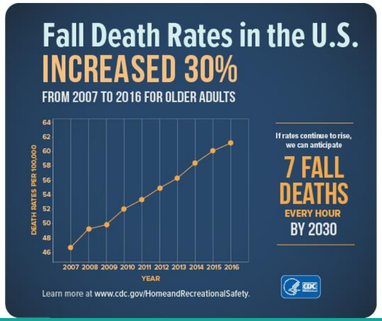

Boston Dynamics

A Social Challenge for Everyone, Especially the Elderly

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

Source: USA CDC



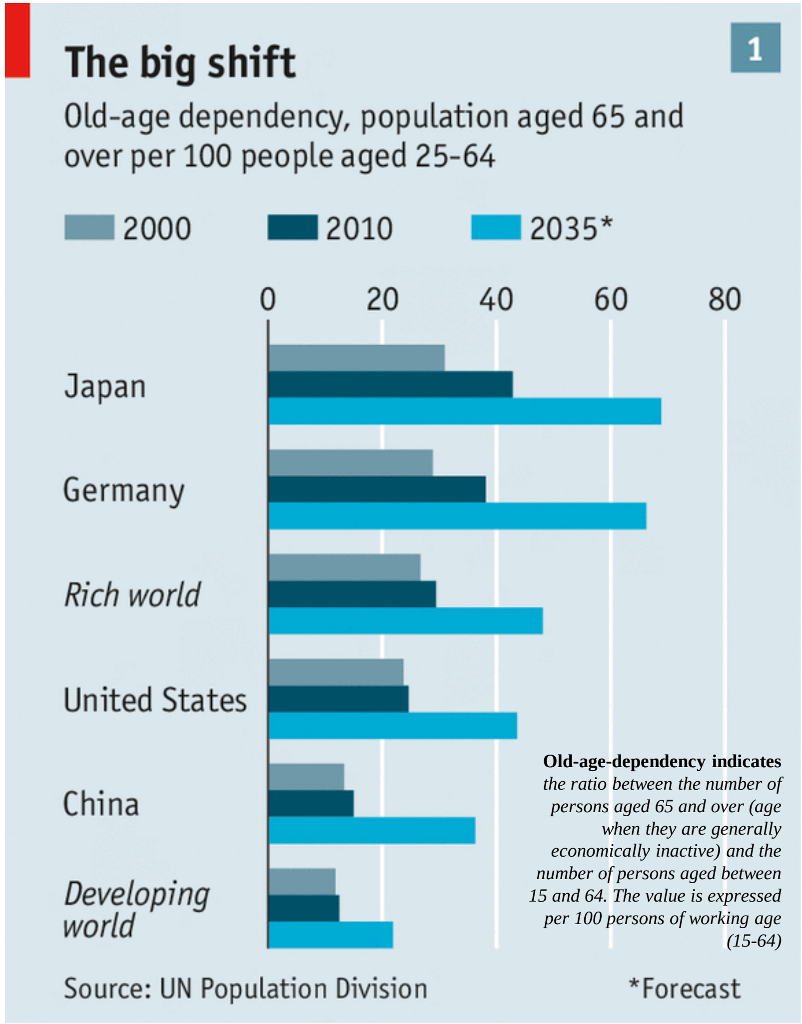


1/5 falls causes a serious injury

- a broken bone or head injury.

Fear of falling

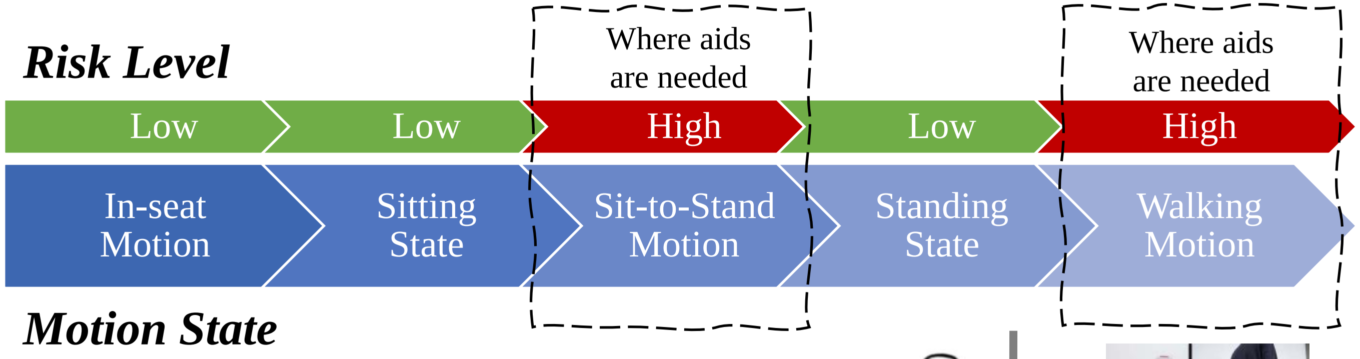
- seriously affect an aging adult’s quality of life
- keep a person from being active and thriving.

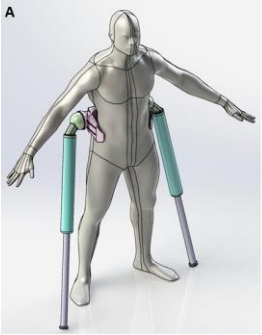


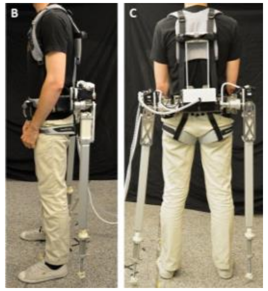
Old-age-dependency indicates *the ratio between the number of persons aged 65 and over (age when they are generally economically inactive) and the number of persons aged between 15 and 64. The value is expressed per 100 persons of working age (15-64)*

Falls Happen During Motion Transition

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







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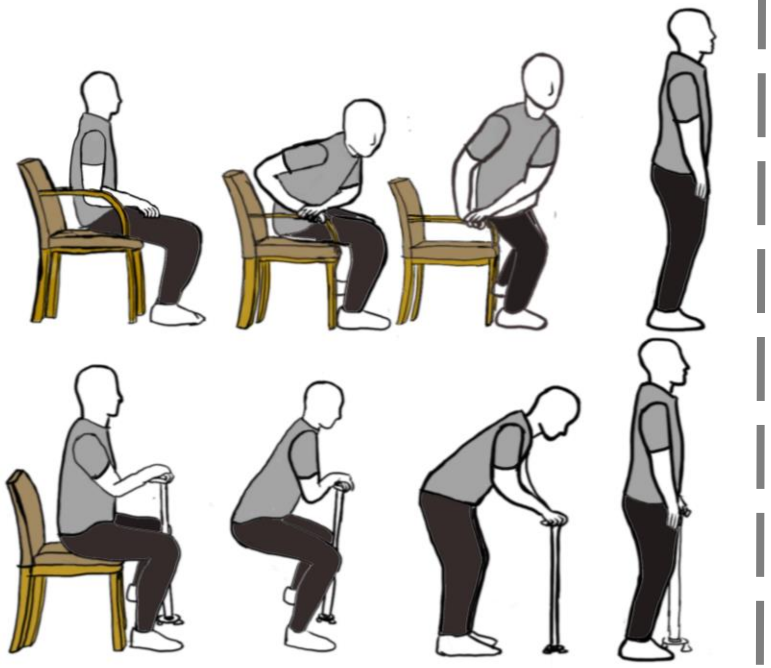

- **Health-based risks**
  - This includes things like balance problems, weakness, chronic illnesses, vision problems, and medication side-effects. They are specific to an individual person.
- **Environmental risks**
  - These are things like home hazards (e.g. loose throw rugs), outside hazards (e.g. 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

Bradley, Sara M., and Cameron R. Hernandez. "Geriatric assistive devices." American family physician 84.4 (2011).

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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?

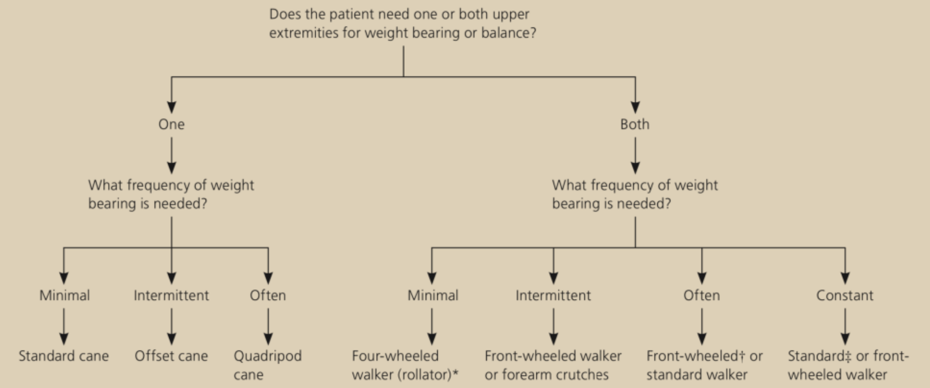
Or how can we better assist the brain and muscle of the elderly during sit-to-stand?

Bradley, Sara M., and Cameron R. Hernandez. "Geriatric assistive devices." American family physician 84.4 (2011).

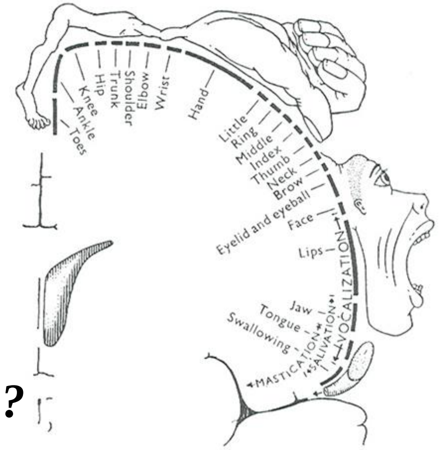
Table 1. Comparison of Assistive Devices

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

Geriatric Assistive Device Selection



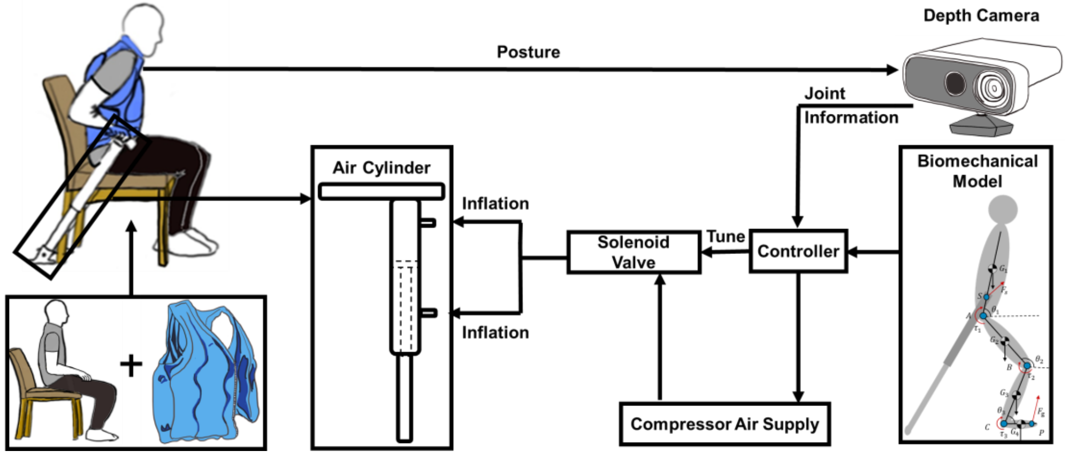
*—Use with caution; this type of walker is appropriate if balance or cognitive impairment is mild and the patient could benefit from having a seat.
†—If the patient requires weight-bearing assistance, but not constantly, a front-wheeled walker may suffice.
‡—If the patient requires weight bearing all of the time, a standard walker may be preferred because it is more stable.

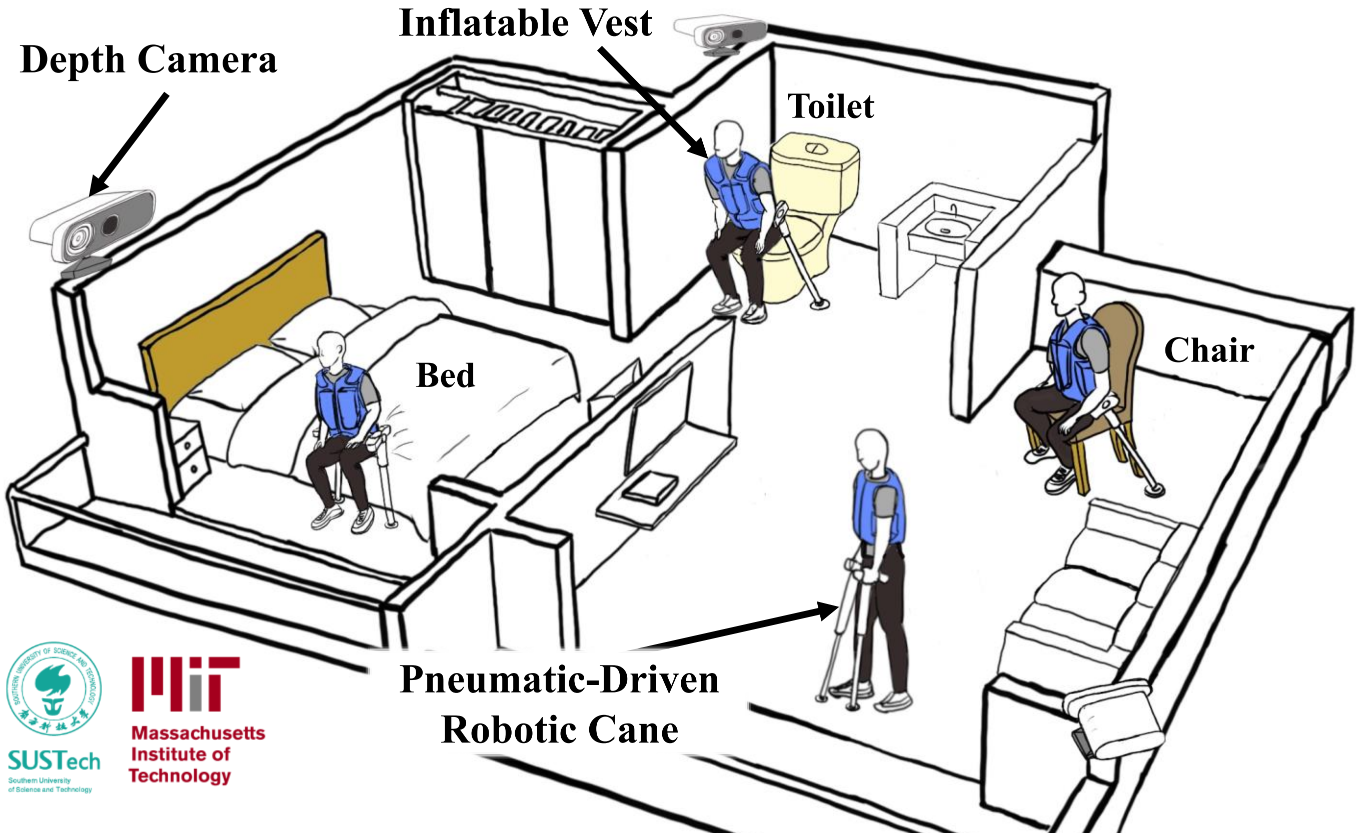


SRL as a potential solution?

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

RoboSoft 20'
to-be-submitted

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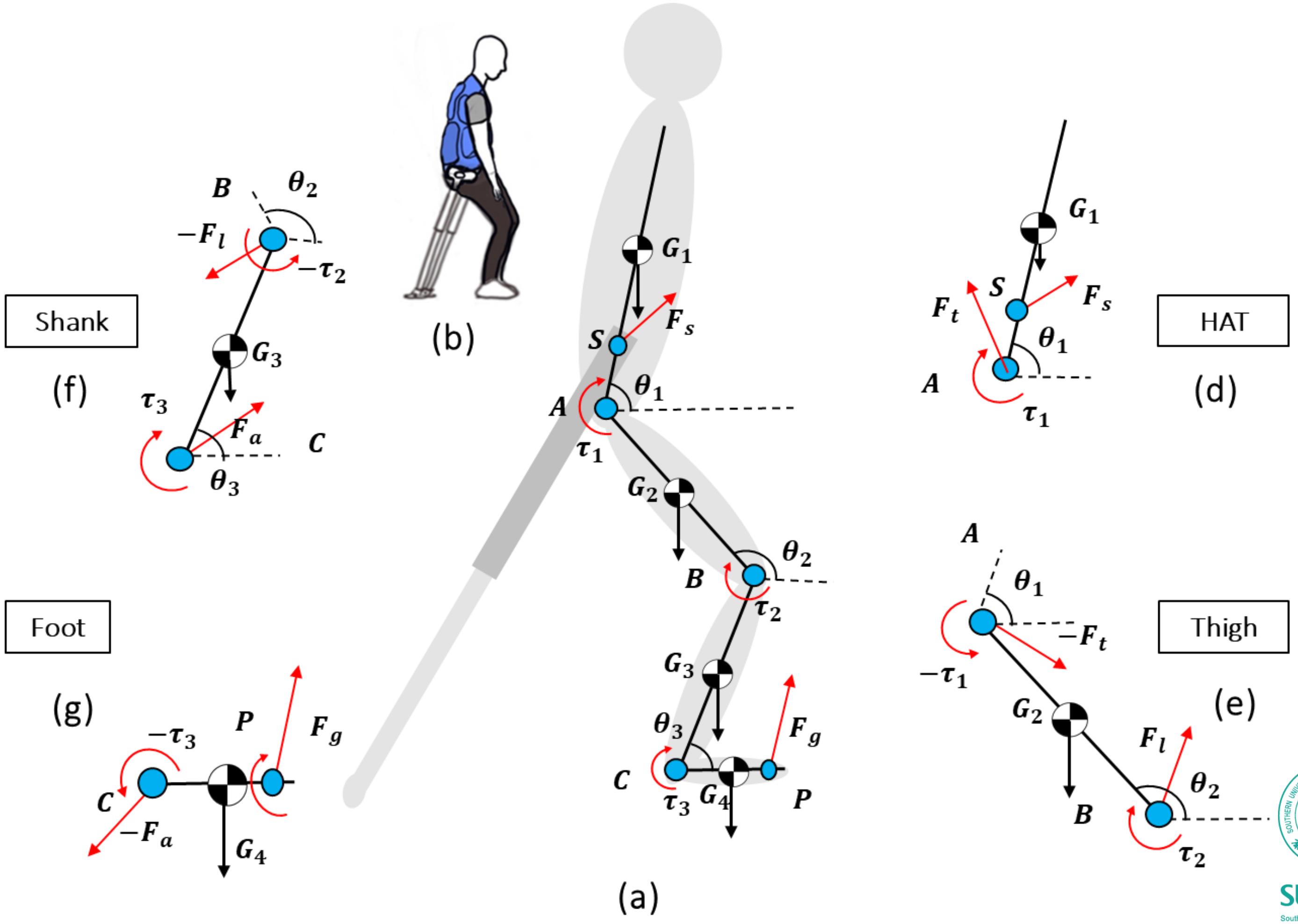
Robotic Cane Design

Biomechanical modeling with a linearly actuated cane



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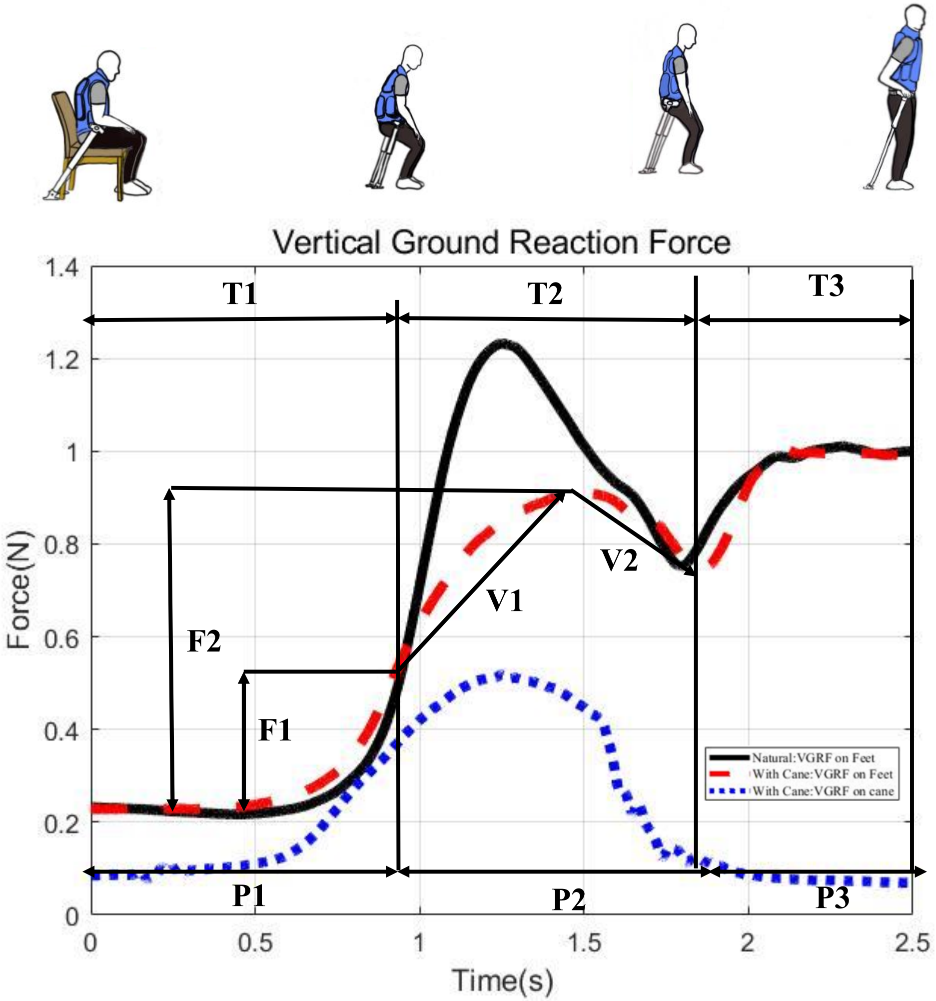
Gradually Reduced Peak Force Exerted by Human Leg

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

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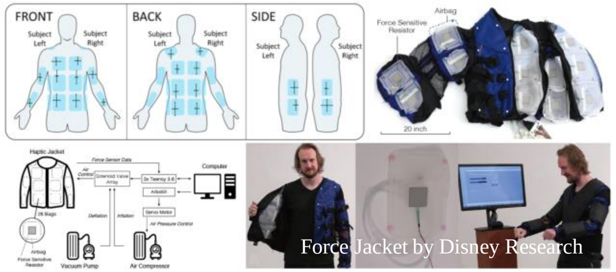
Inflatable Vest

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

Before & After Inflation

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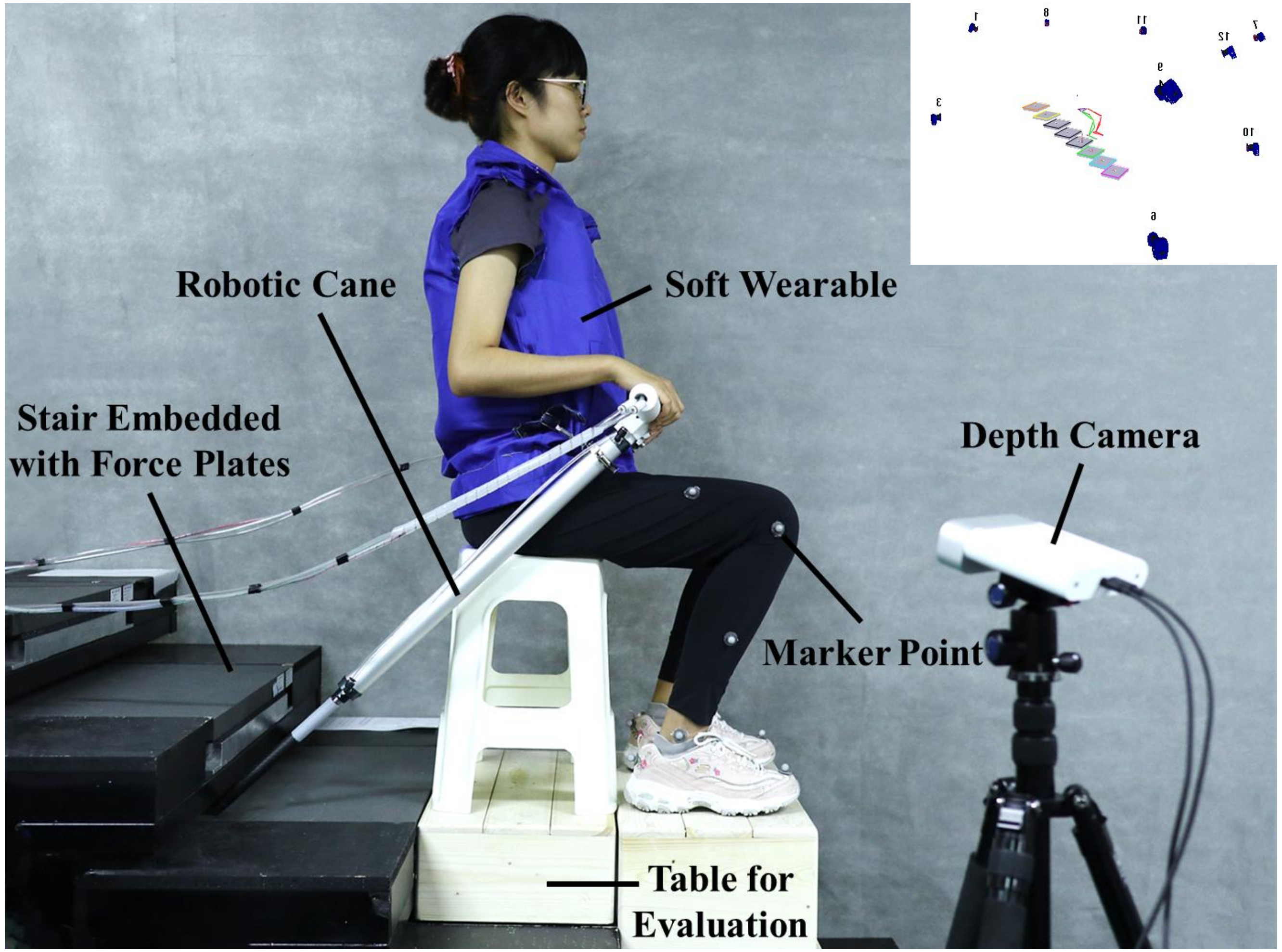
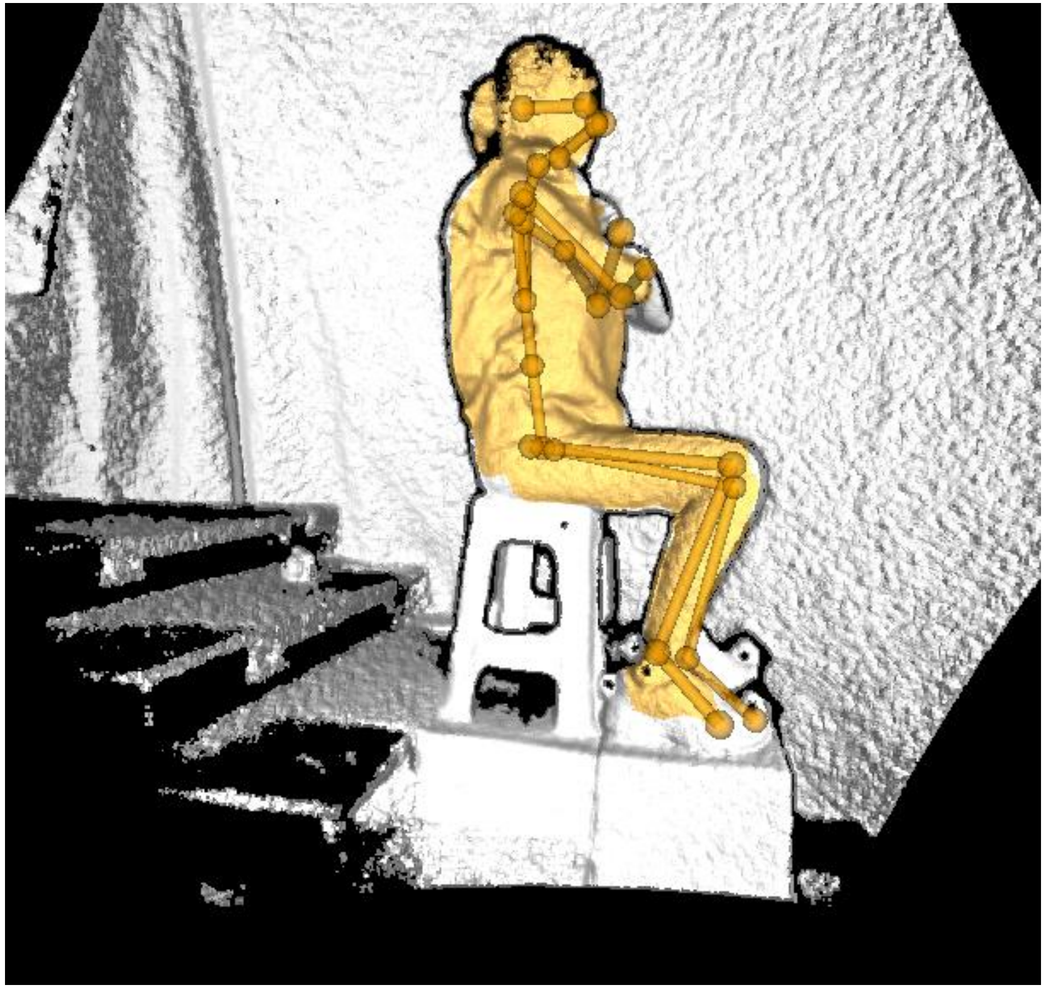
Experiment Setup

Depth sensing for ambient motion recognition and intention detection





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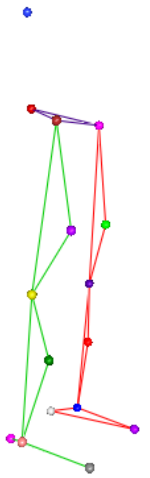
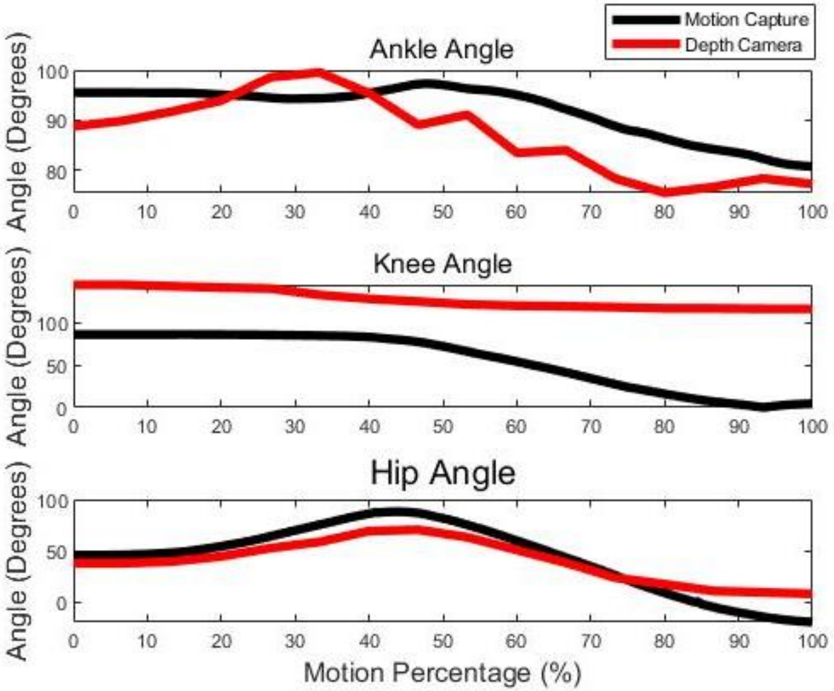
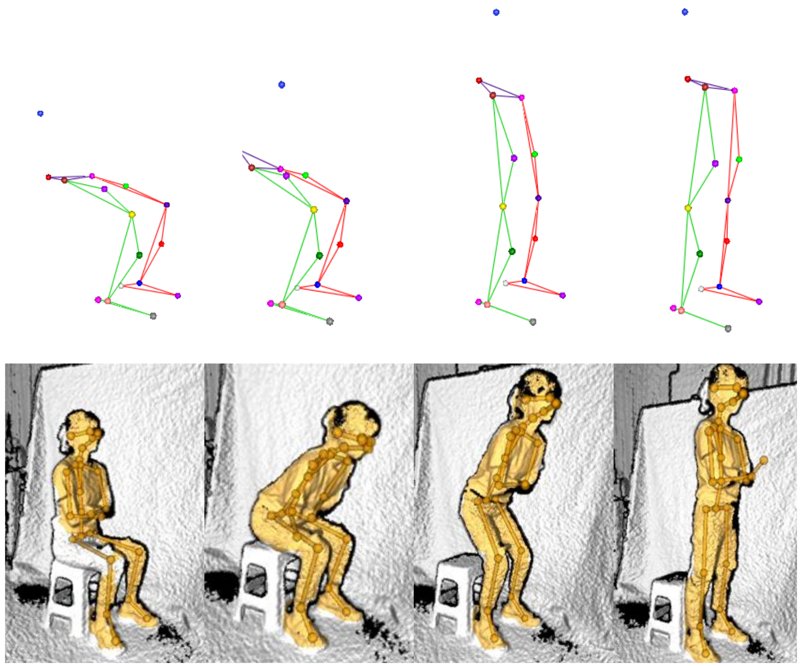
Depth Sensing for Ambient Intelligence

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?







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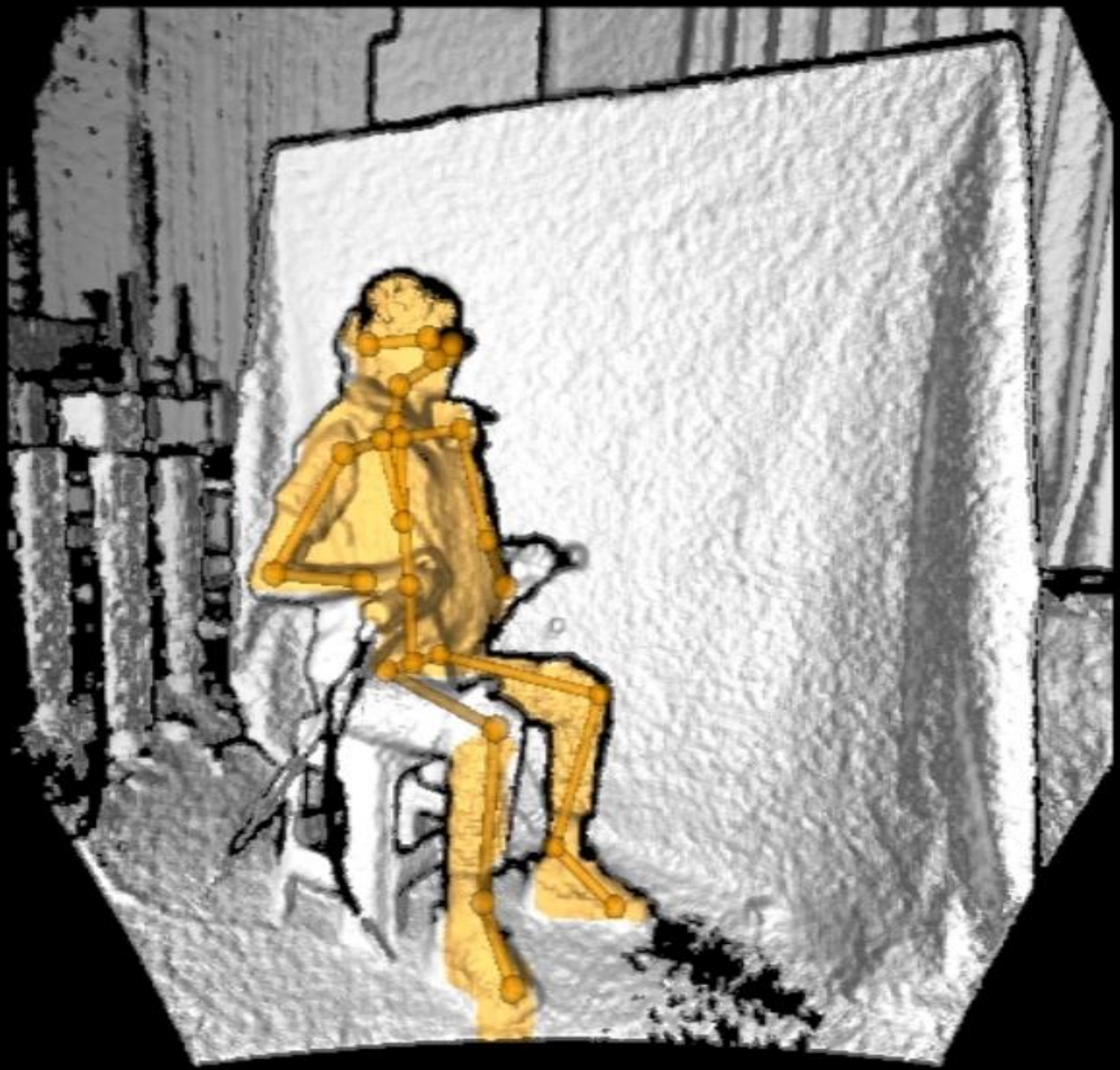


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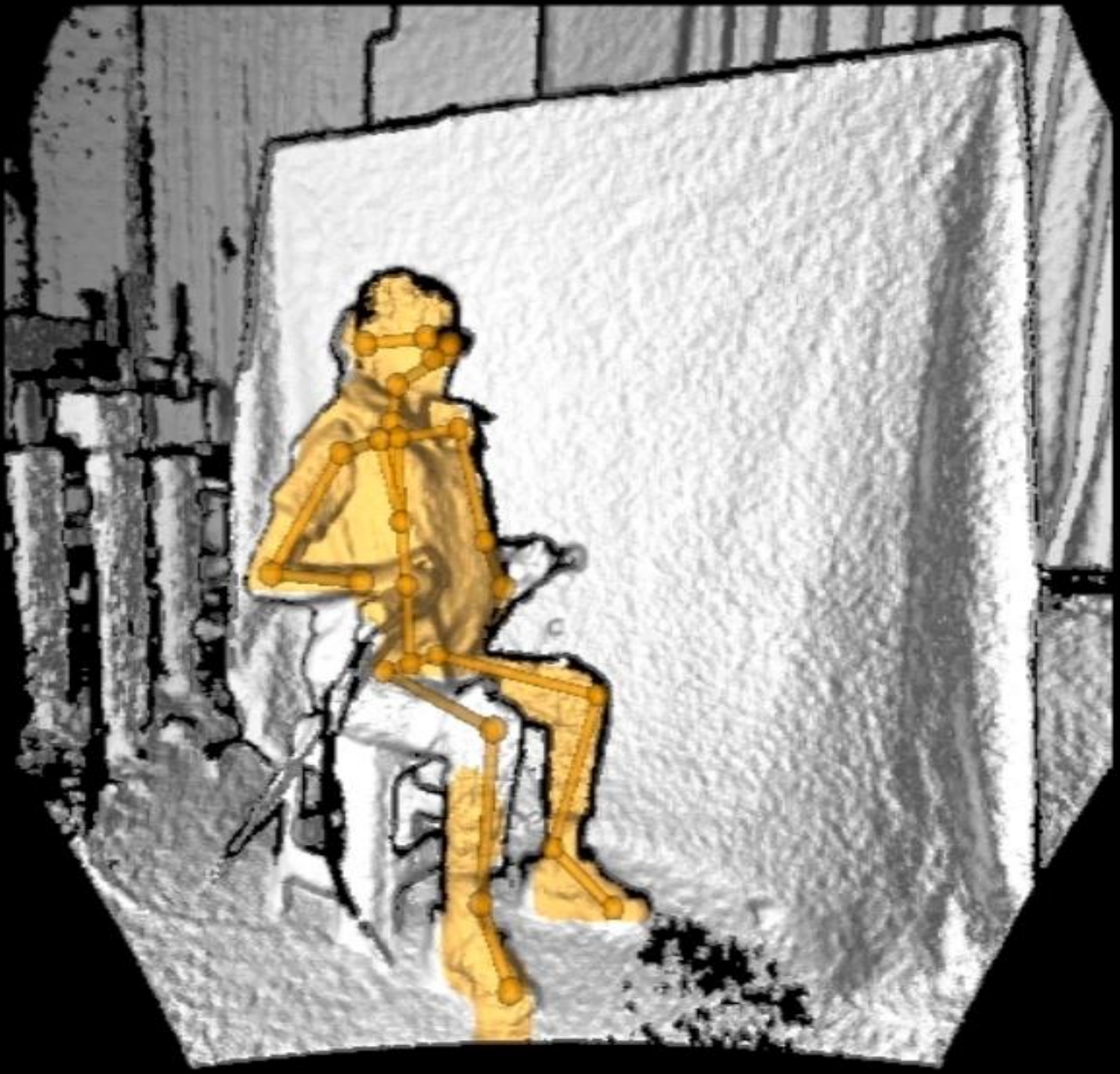


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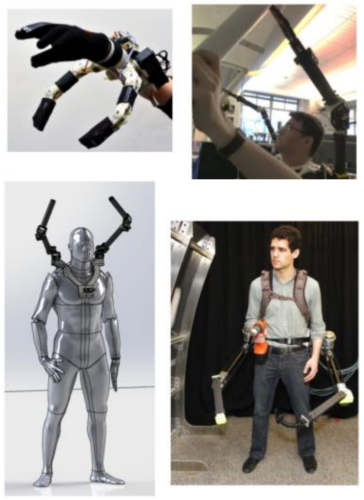
SRL Design for the Elderly

Case with the Cane



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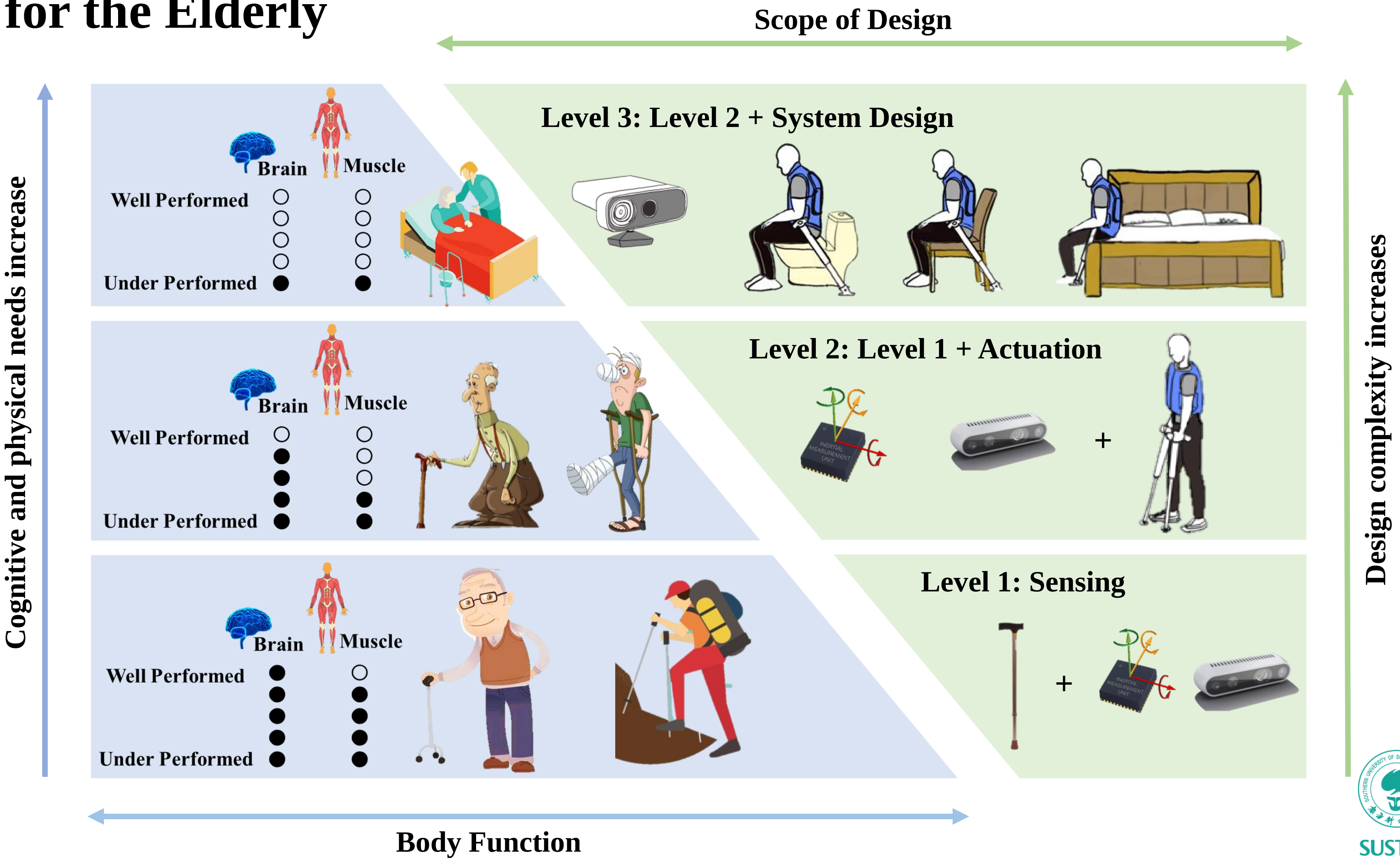

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Super-limb for the Elderly?

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

- Is direct-drive a suitable actuation for elderly lower-limb assistance?
- Ca qu ca
- 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

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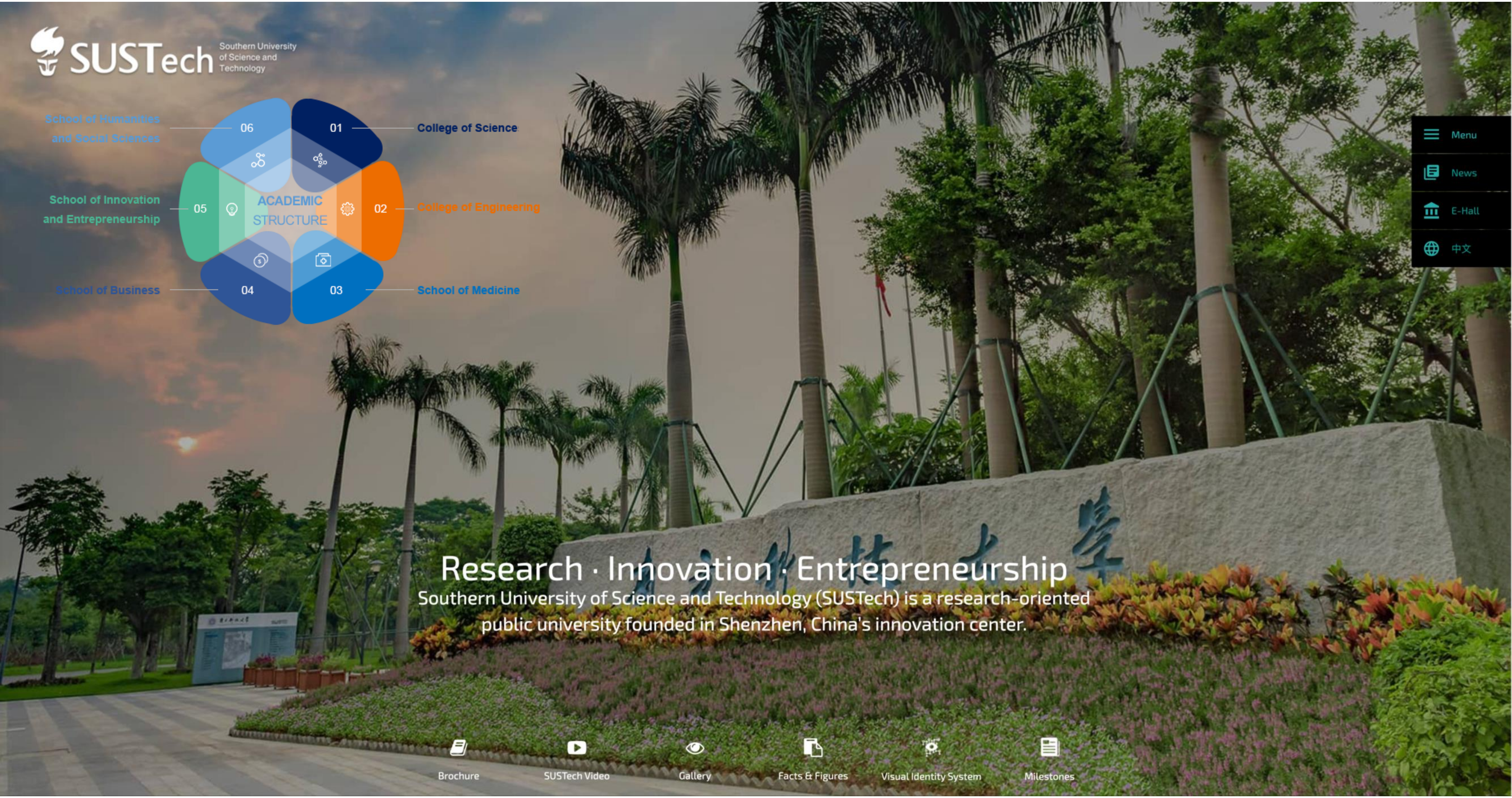

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ZHENG WANG

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Professor
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SHUAI GUO

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HONGQIANG WANG

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WENDE KE

Teaching Associate Professor
Research Areas: robot control, Multi-robot cooperation

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Robotic Manipulation, Autonomous Intelligent Systems, Control and Learning

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Legged Robot, Robot Dynamics, Robot Force & Torque Control

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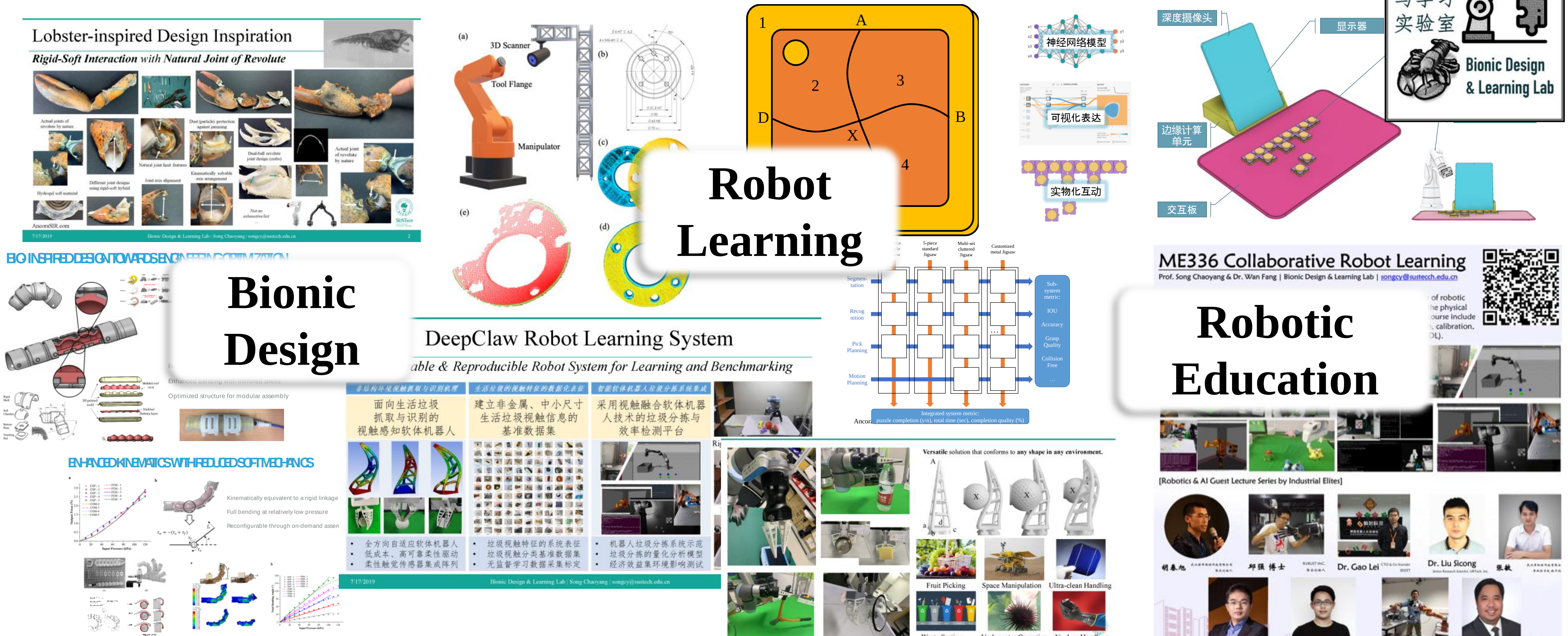
Bionic Design & Learning Lab



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南方科技大学 机器人研究院 SIR Bionic Design & Learning Lab

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Prof. Wang Zheng

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

Thank you ~

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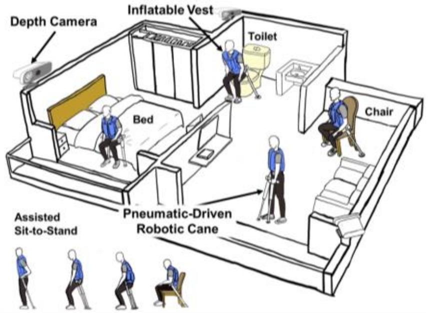

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