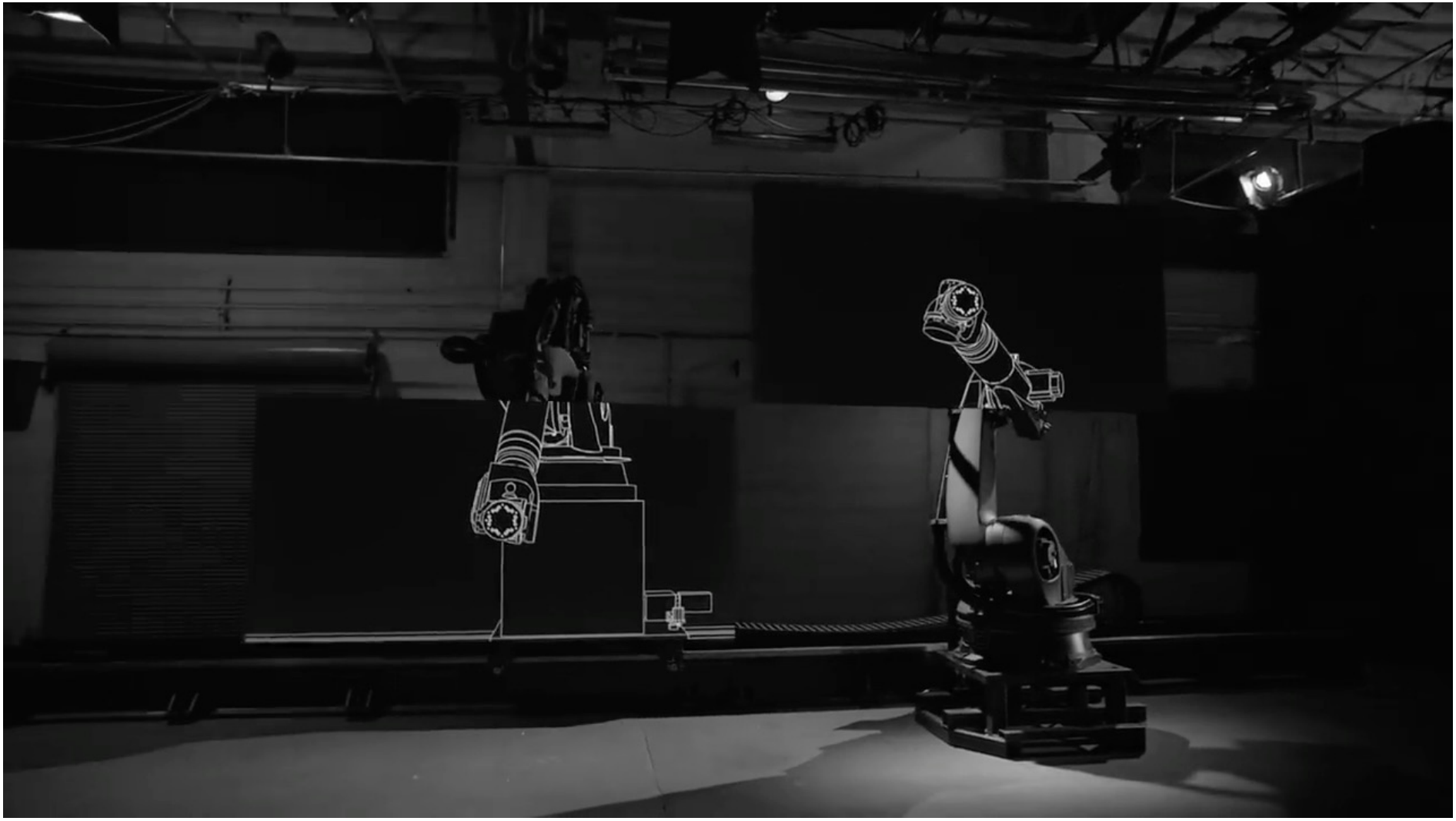
Week 03 | Lecture 04
Robots & AI for Social Good

Wan Fang
Southern University of Science and Technology

Robot of the Day



Box by BotnDolley: https://www.youtube.com/watch?v=lX6JcybgDFo

Robots & AI for Social Good

- AI4SG = AI × SDGs
- Robots4SG Exemplified
  - TeachBot for Industry, Innovation and Infrastructure?
  - Fighting Pandemic for Good Health and Well-being?
  - SuperCane for Good Health and Well-being?
  - DeepClaw for Quality Education?
  - Wasteless for Responsible Consupmtion and Production?
  - SOPHIE for Life Below Water?
- Design Science

AI for Social Good

The challenges facing our world today have grown in *complexity* and increasingly require *large, coordinated efforts*: between countries; and across a broad spectrum of governmental and non-governmental organisations (NGOs) and the communities they serve.

Guidelines for AI4SG collaborations

G1	Expectations of what is possible with AI need to be well-grounded.
G2	There is value in simple solutions.
G3	Applications of AI need to be inclusive and accessible, and reviewed at every stage for ethics and human rights compliance.
G4	Goals and use cases should be clear and well-defined.
G5	Deep, long-term partnerships are required to solve large problems successfully.
G6	Planning needs to align incentives, and factor in the limitations of both communities.
G7	Establishing and maintaining trust is key to overcoming organisational barriers.
G8	Options for reducing the development cost of AI solutions should be explored.
G9	Improving data readiness is key.
G10	Data must be processed securely, with utmost respect for human rights and privacy.

nature communications
10.1038/s41467-020-15871-z

AI4SG = AI × SDGs

nature machine intelligence

AI4SG is formally defined as the design, development and deployment of AI systems in ways that help to

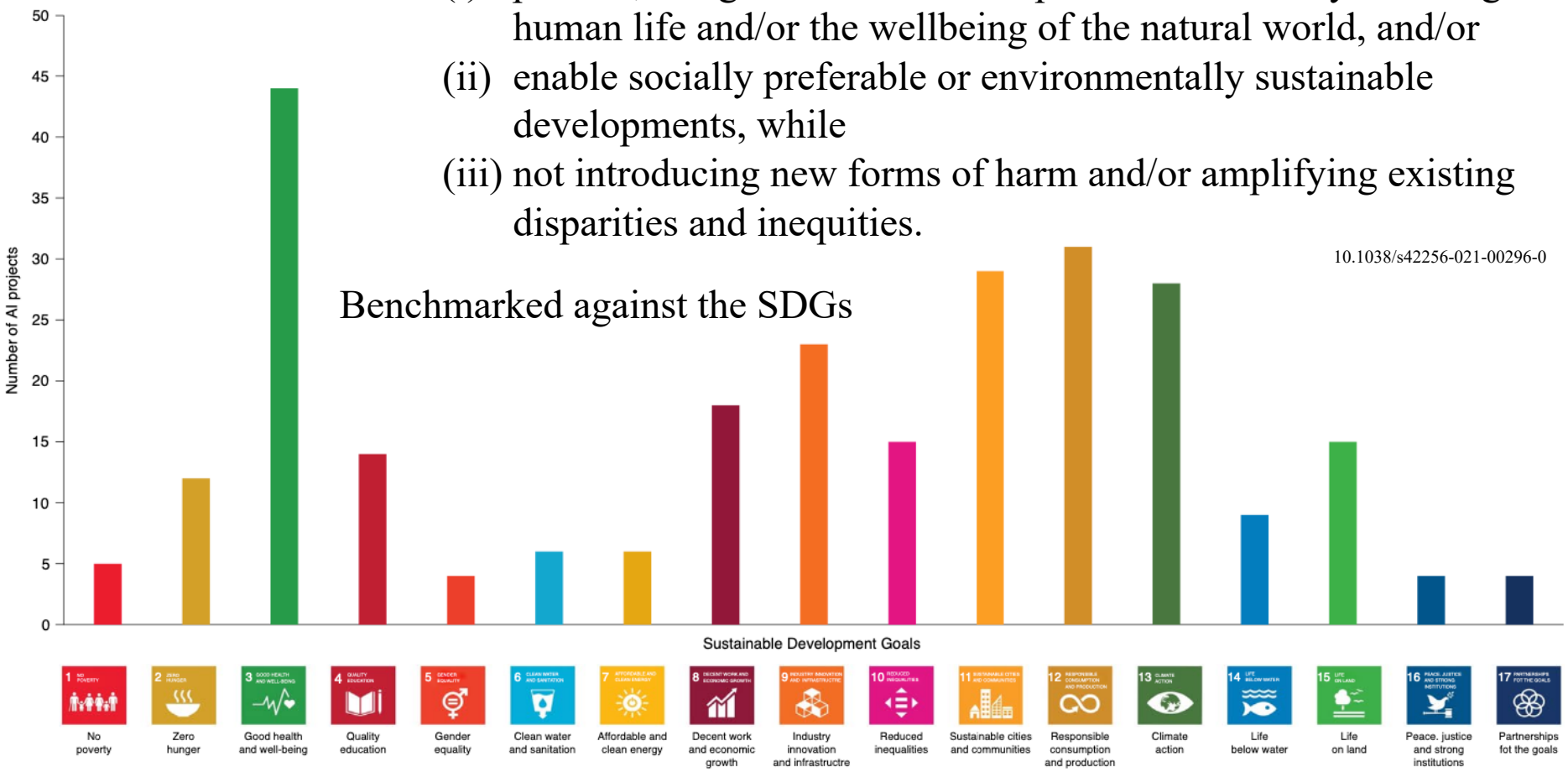
(i) prevent, mitigate and/or resolve problems adversely affecting human life and/or the wellbeing of the natural world, and/or

(ii) enable socially preferable or environmentally sustainable developments, while

(iii) not introducing new forms of harm and/or amplifying existing disparities and inequities.

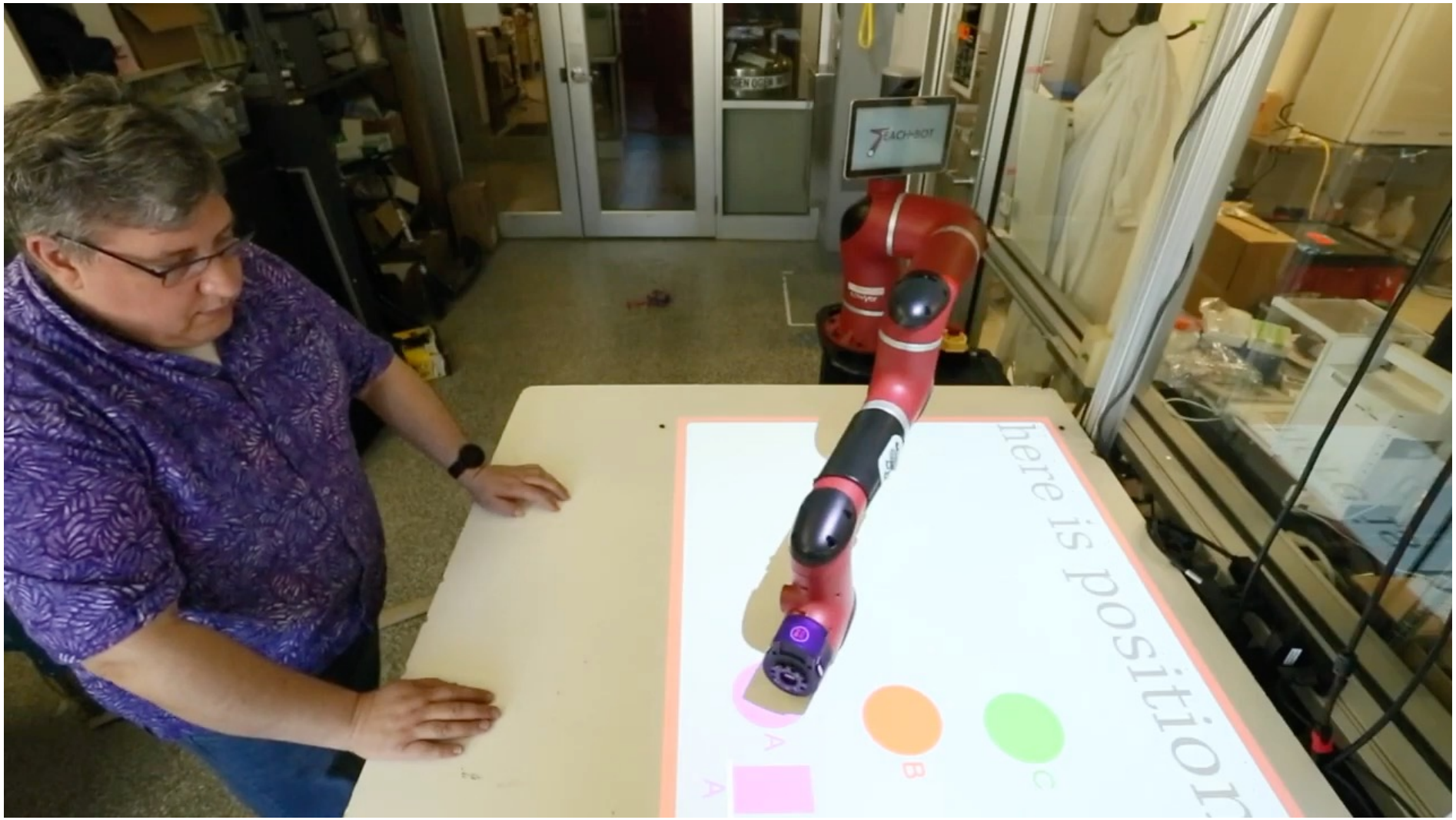
10.1038/s42256-021-00296-0

Benchmarked against the SDGs



9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

TeachBot

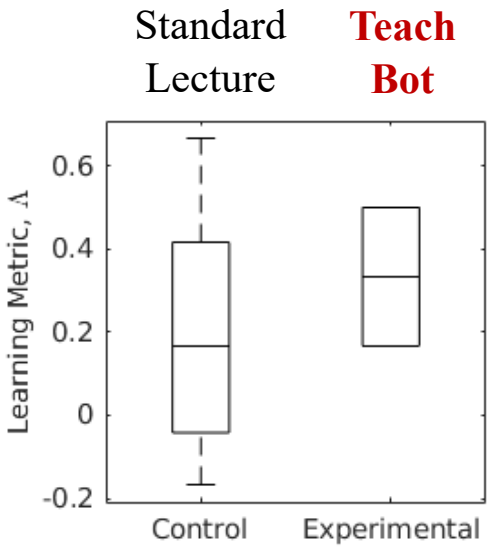


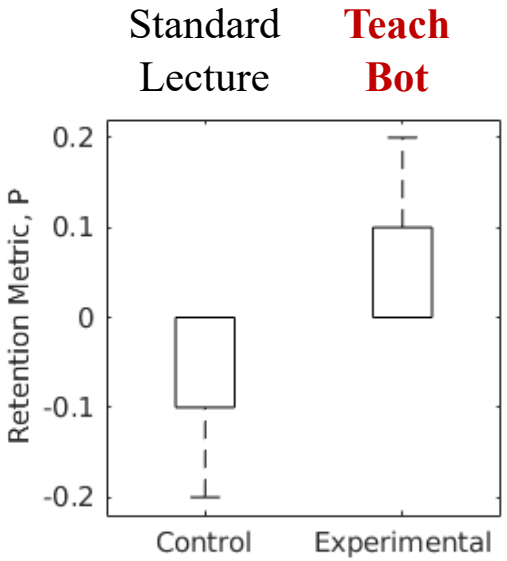
Experimental Results

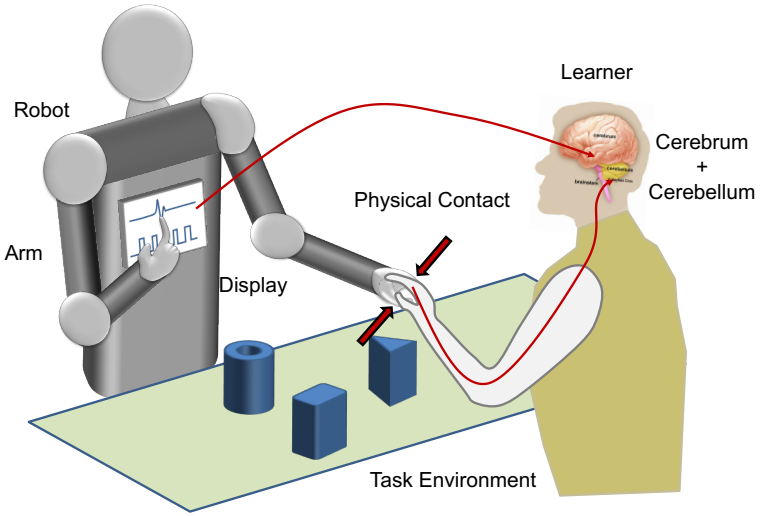
- A learner can improve learning effectiveness, when a high-level perception through eyes and a low-level stimulus through hand motion take place at the same time.

D. Satterthwait, "Why are 'hands-on' science activities so effective for student learning?", Teaching Science, Volume 56, Number 2, June 2010

  - The TeachBot group outperformed the regular lecture group on both metrics



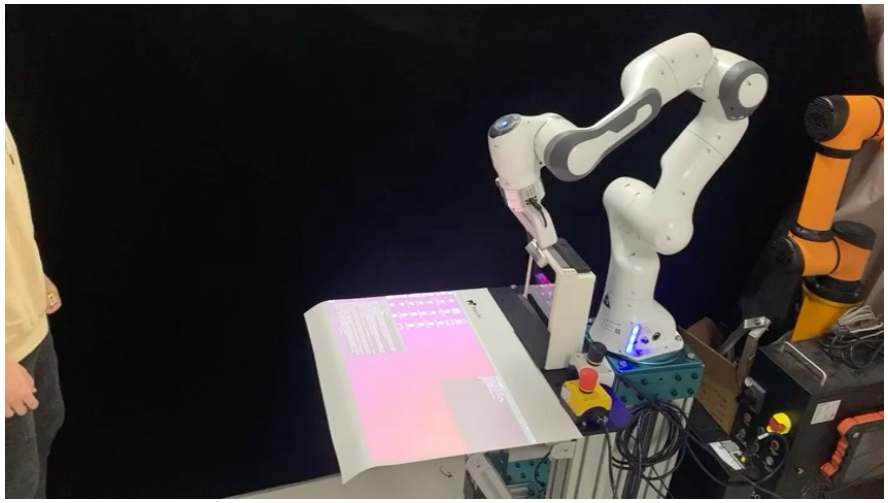


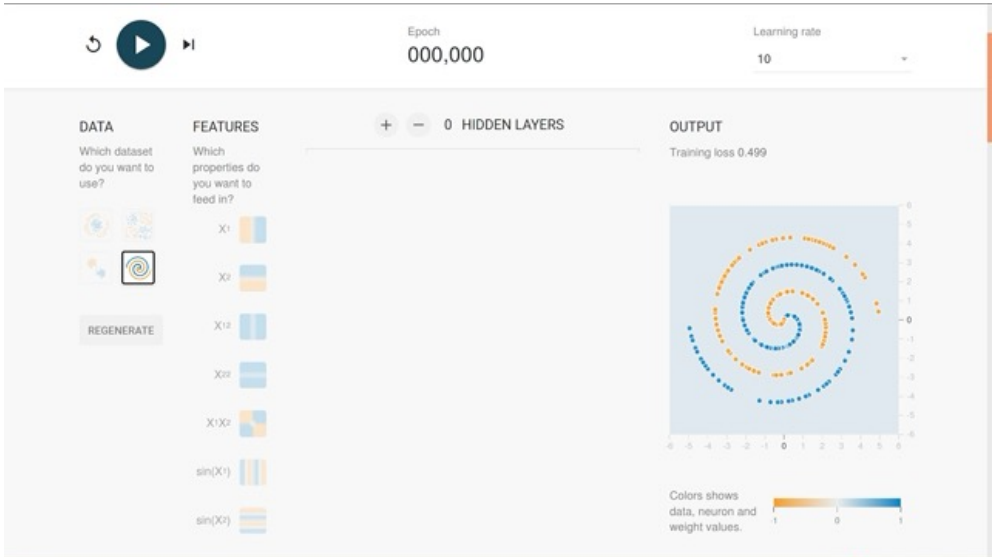


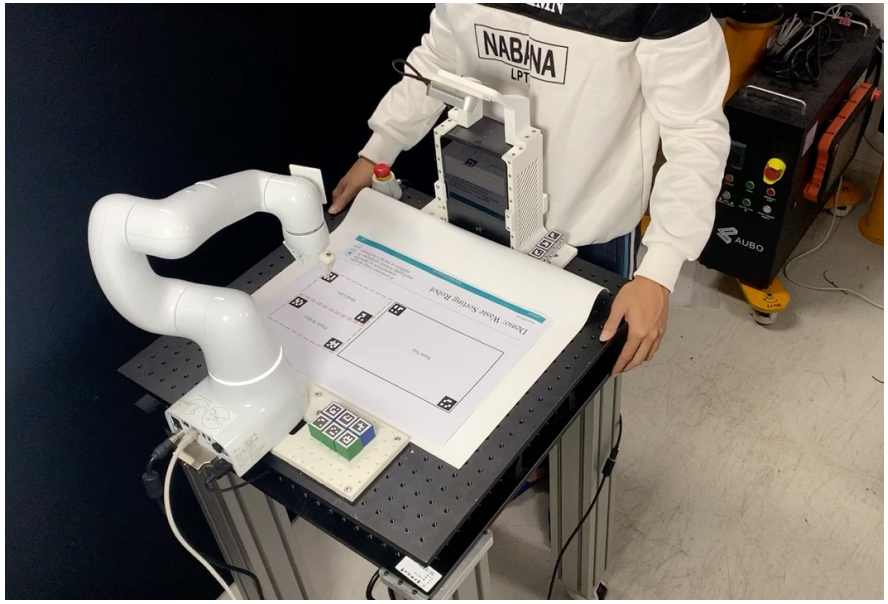
Asked the same questions a week later; How much did they memorize?

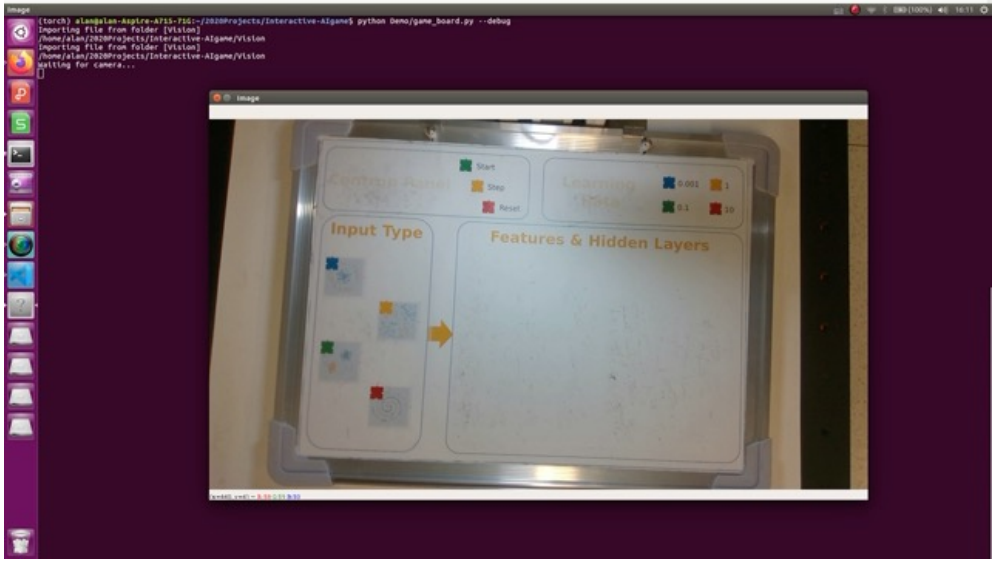
4 QUALITY EDUCATION

DeepClaw

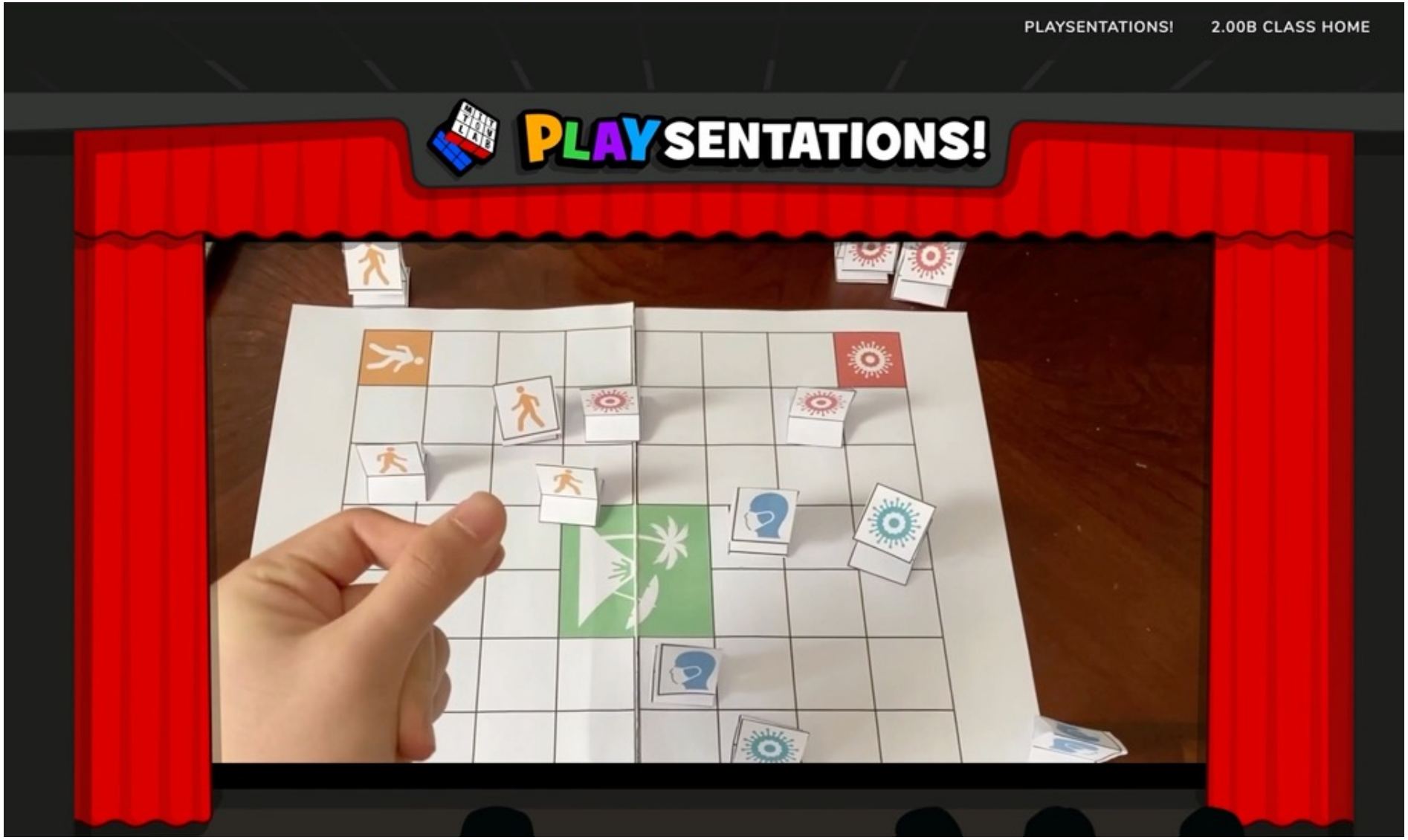








Fighting Pandemic

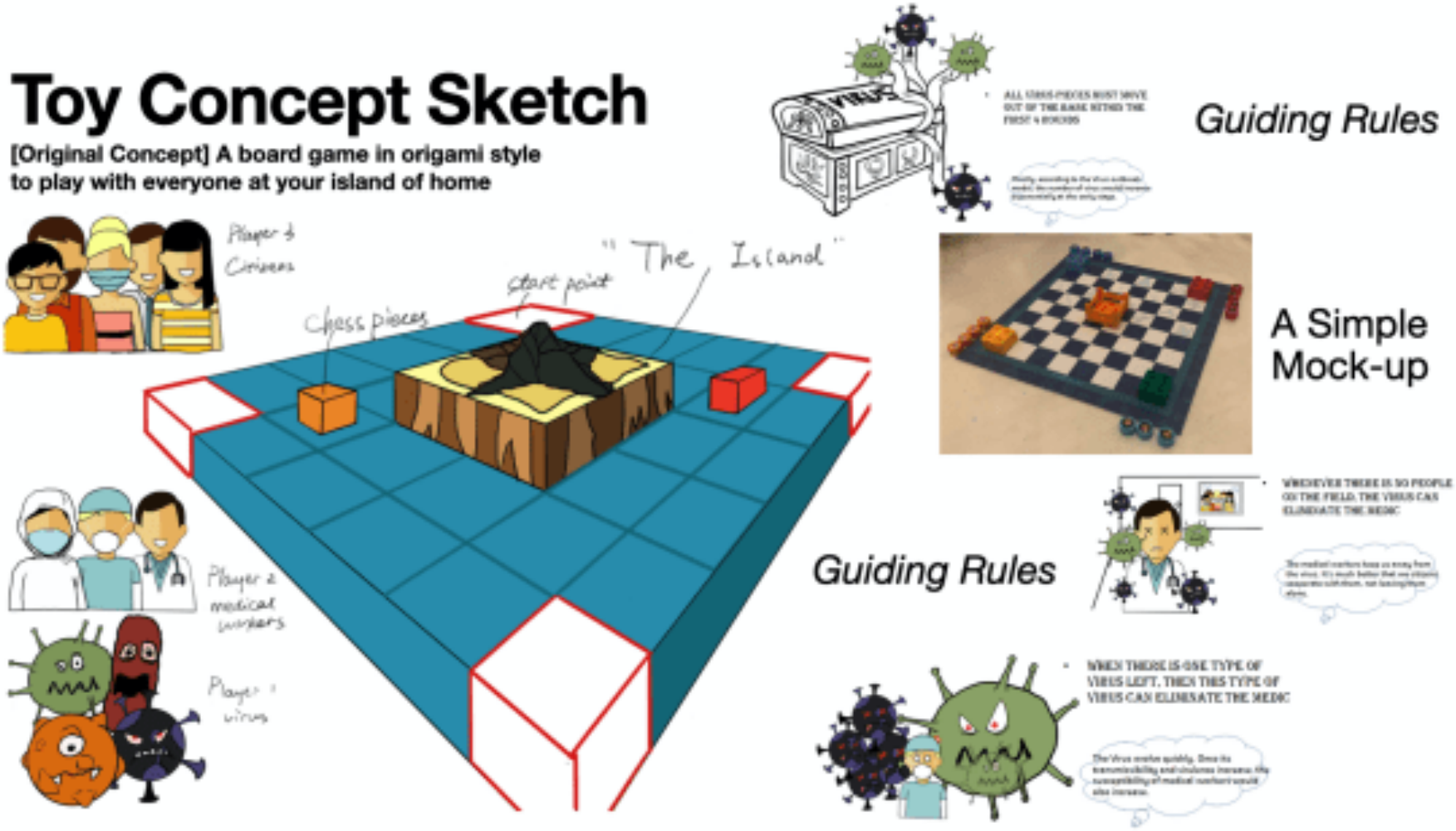


Fighting Pandemic

Can we design a toy game that generates strategies during a pandemic?

When the Scientists talk about models ... let's try some games

Fighting Pandemic

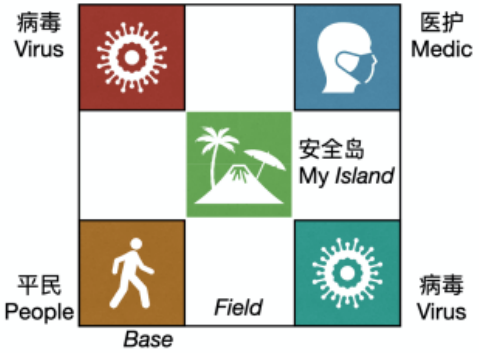


Fighting Pandemic

游戏准备、规则介绍、玩后交流

Print => Cut => Fold => Play => Share

- Lots of Virus
- Closer to the People
- May also harm the Medic
- Team Health vs Team Disease



游戏准备、规则介绍、玩后交流

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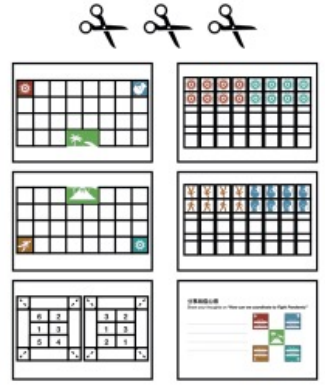

游戏准备、**规则介绍**、玩后交流

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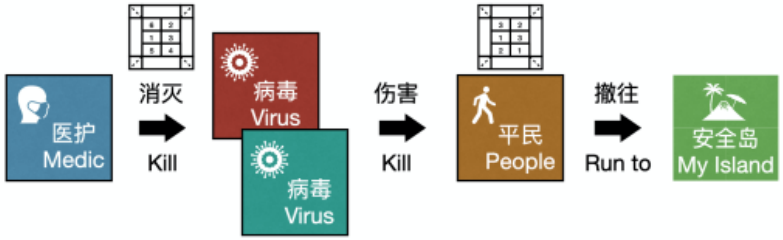
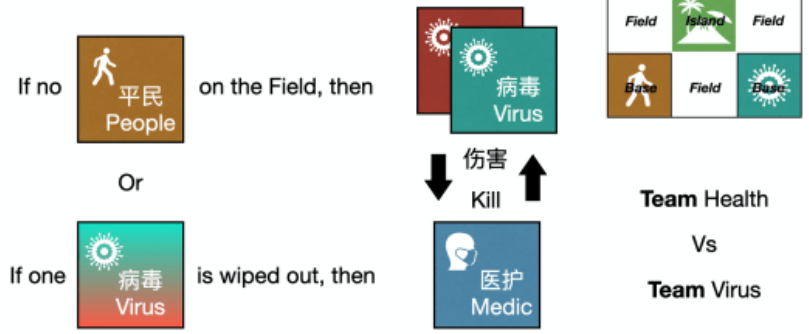


1. People moves 1st using a dice of 3, then Virus/Medic move using a dice of 6
2. Only People can run to the Island
3. Cannot step on the same grid twice in a move

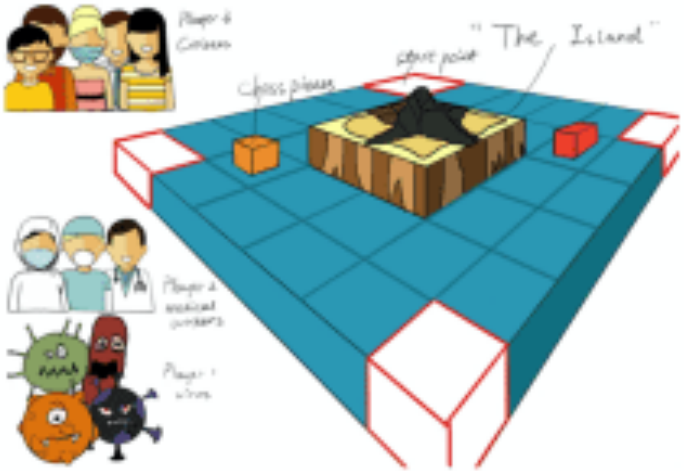
游戏准备、**规则介绍**、玩后交流

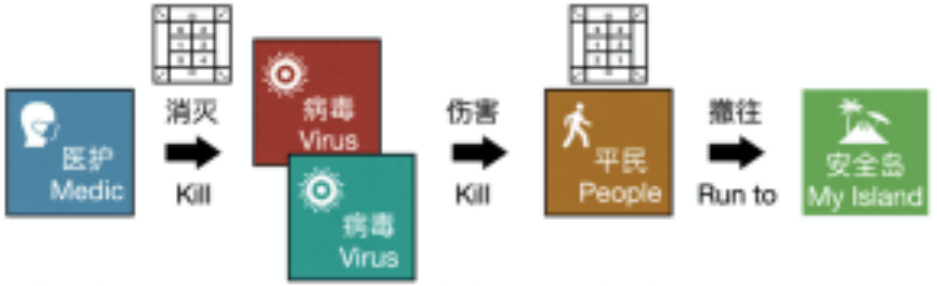
Print => Cut => Fold => **Play** => Share



Fighting Pandemic

Let's Play ~
Fighting Pandemic





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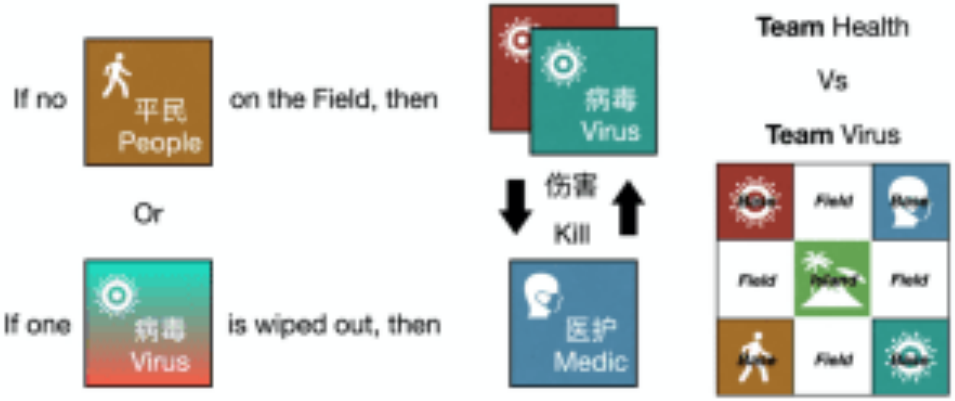


SuperCane

SUSTech Southern University of Science and Technology

仿生设计与学习实验室 Bionic Design & Learning Lab

Massachusetts Institute of Technology

A Soft Robot System of Supernumerary Robotic Limbs for Elderly Sit-to-Stand Assistance at Home

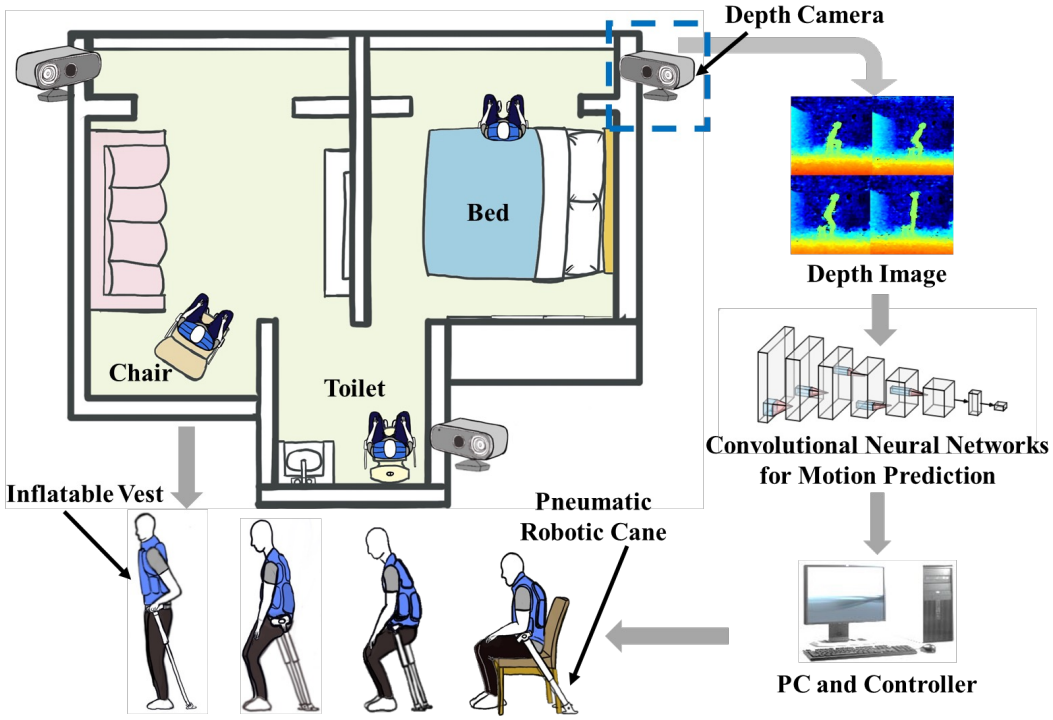
Xia Wu[1], Haiyuan Liu[1], Ziqi Liu[1], Mingdong Chen[1], Fang Wan[2], Chenglong Fu[1], Harry Asada[2], Zheng Wang[1], and Chaoyang Song[1*]

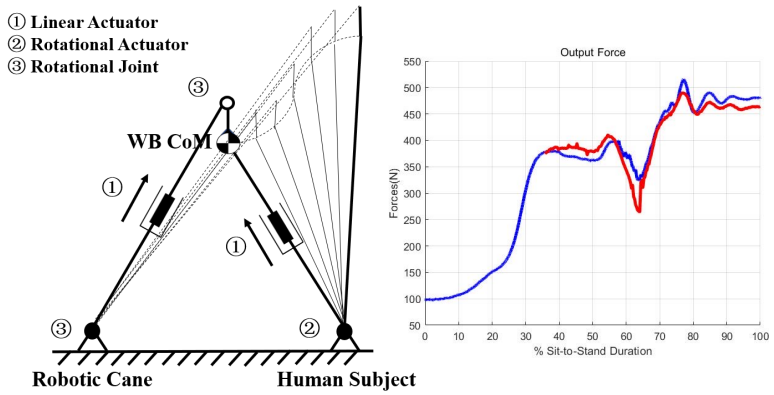
[1]Department of Mechanical and Energy Engineering, Southern University of Science and Technology, China

[2]SUSTech Institute of Robotics, Southern University of Science,China

[3]Department of Mechanical Engineering, Massachusetts Institute of Technology, USA

RoboCane: A Soft SuperLimb with Ambient Intelligence for Elderly Sit-to-Stand Assistance



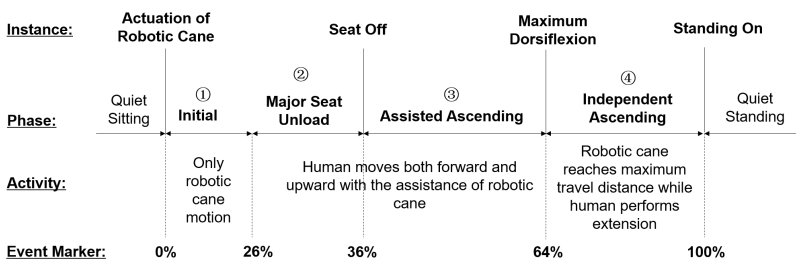


Modified telescopic inverted-pendulum model:

- Less demanding in inputs:
  - Trajectory of CoM, robotic cane input.
- Better accuracy.

Consist of 4 components:

- **Robotic cane** for lower limb support.
- **Inflatable vest** for force redistribution without hard push.
- **Depth camera** for privacy-safe intention detection.
- **Biomechanical Model** for assisted sit-to-stand motion.

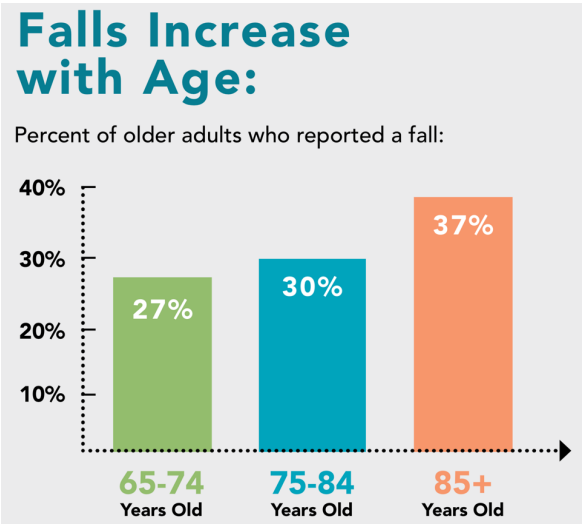


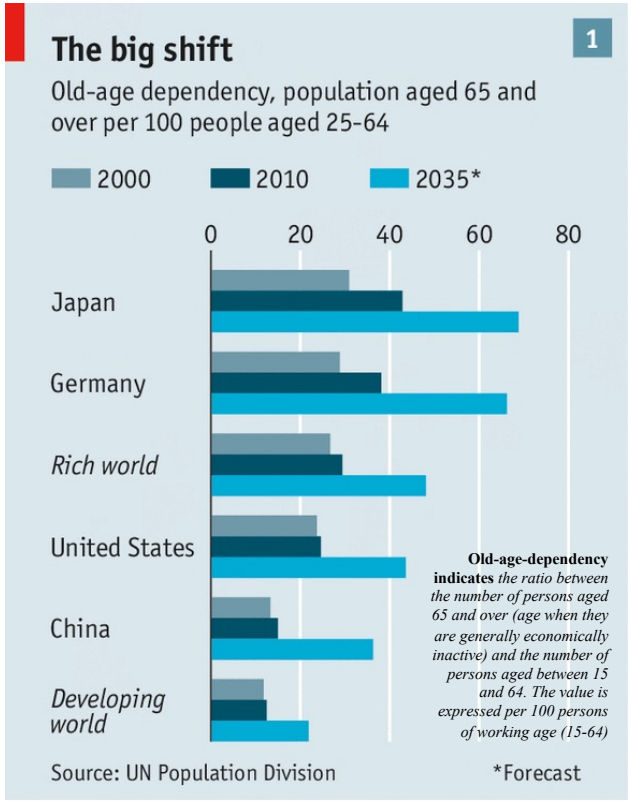
Relevant 4 phases of assisted sit-to-stand motion

Stand & Fall

A Social Challenge for Everyone, Especially the Elderly

"Challenge to balance or strength > Ability to stay upright"





1/5 falls causes a serious injury

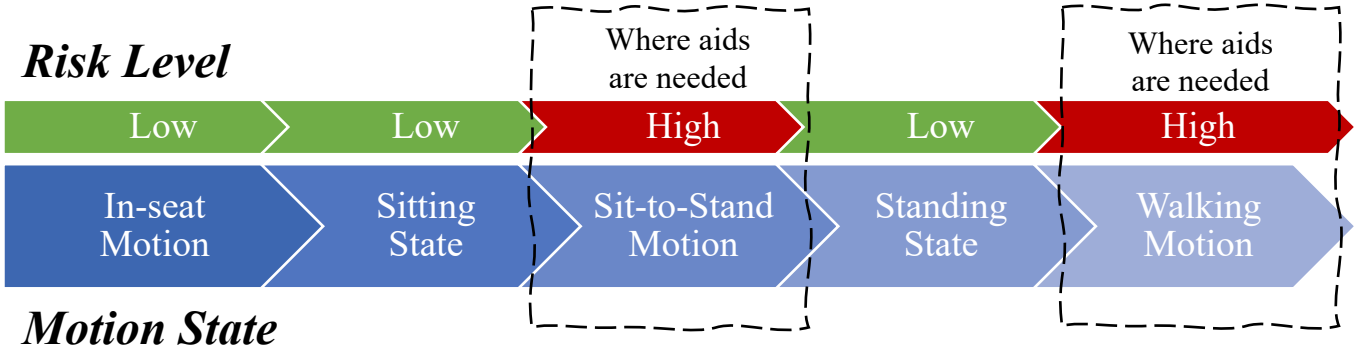
- a broken bone or head injury

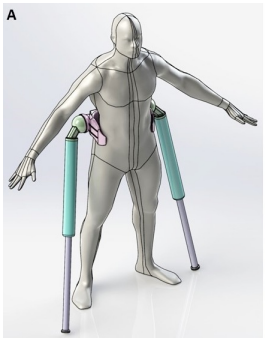
Fear of falling

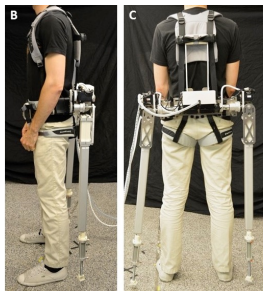
- seriously affect an aging adult's quality of life
- keep a person from being active and thriving

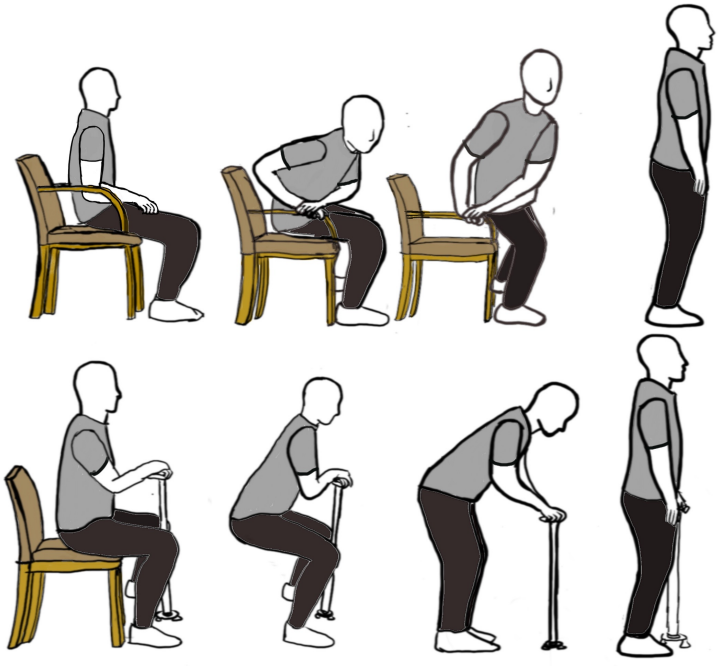
Falls Happen During Motion Transition

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









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.

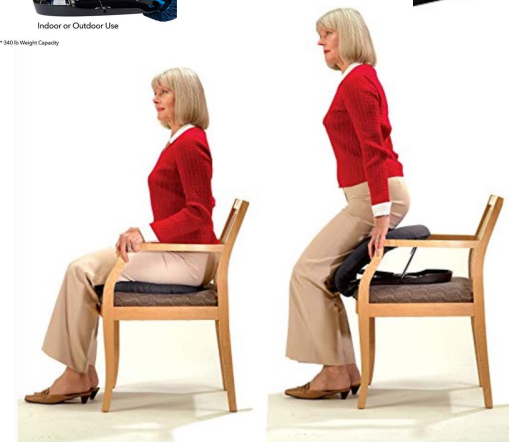
Assistive Tools for Sit-to-Stand

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).

Medline Bed Assist bar

Carex Upeasy
Seat Assist Plus



Able Life Universal
Stand Assist

Medline Toilet Safety Rails

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).

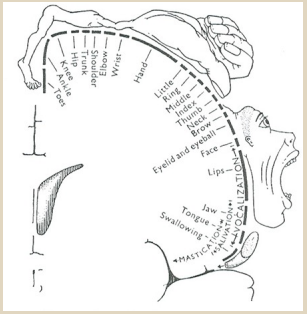
Table 1. Comparison of Assistive Devices

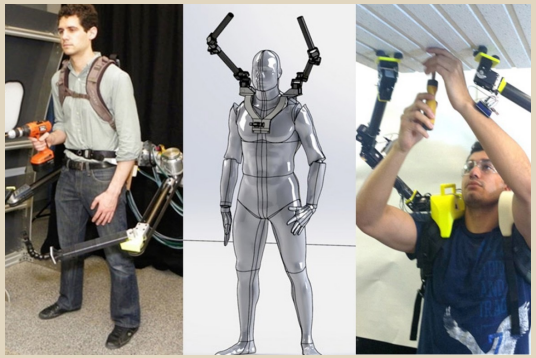
Assistive device	*Pros*	*Cons*	*Examples of conditions indicated for use*
Canes			
Standard/straight cane	Improves balance; adjustable	Should not be used for weight bearing; umbrella handle may cause carpal tunnel syndrome	Mild ataxia (sensory, vestibular, or visual); mild arthritis
Offset cane	Appropriate 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

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?

Geriatric Assistive Device Selection





SRL as a potential solution?

Does the patient need one or both upper extremities for weight bearing or balance?

- One
  - What frequency of weight bearing is needed?
    - Minimal → Standard cane
    - Intermittent → Offset cane
    - Often → Quadripod cane
- Both
  - What frequency of weight bearing is needed?
    - Minimal → Four-wheeled walker (rollator)*
    - Intermittent → Front-wheeled walker or forearm crutches
    - Often → Front-wheeled† or standard walker
    - Constant → Standard‡ or front-wheeled walker

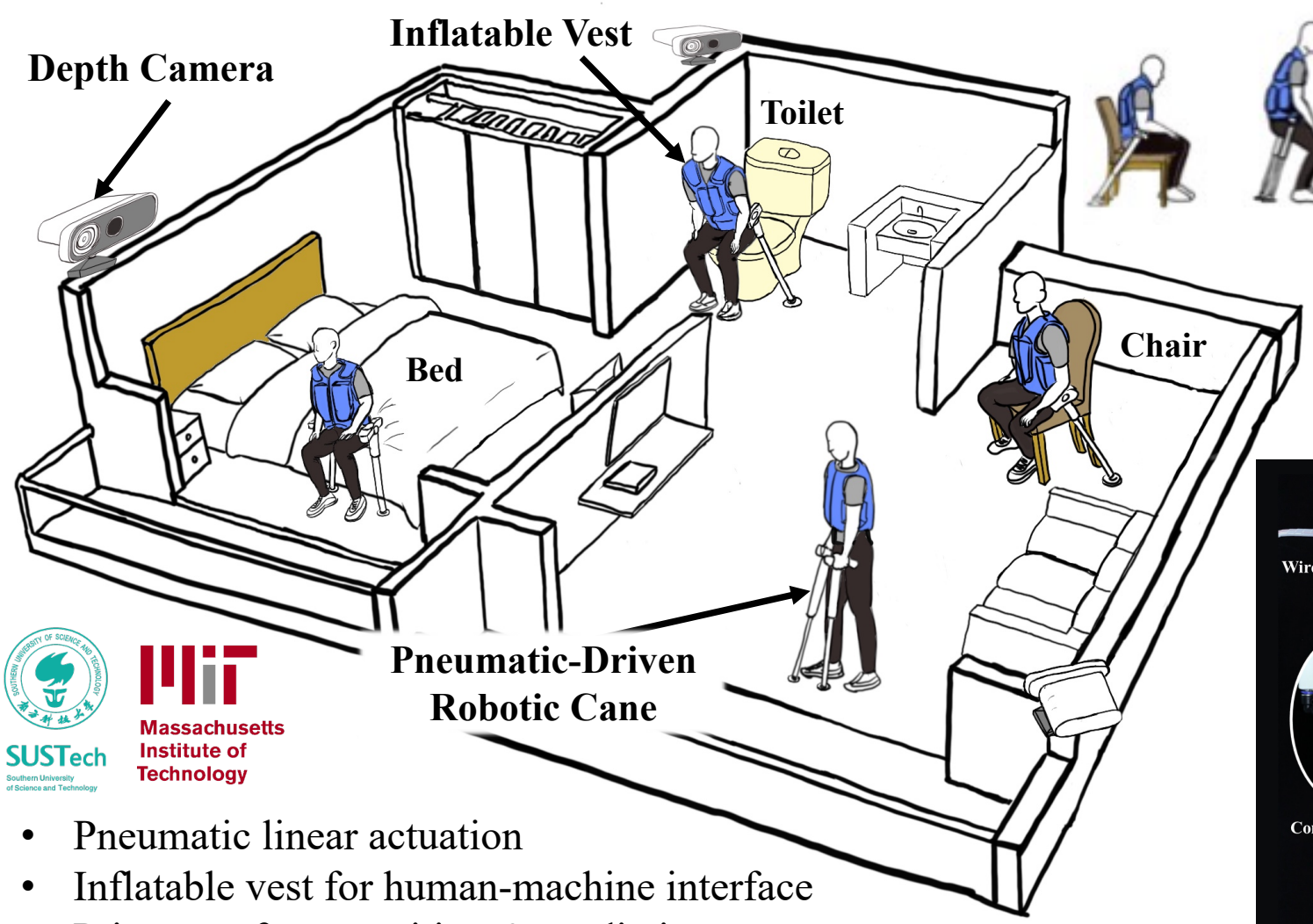
*—Use with caution; this type of walker is appropriate if balance or cognitive impairment is mild and the patient could benefit from having a seat.

†—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.

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

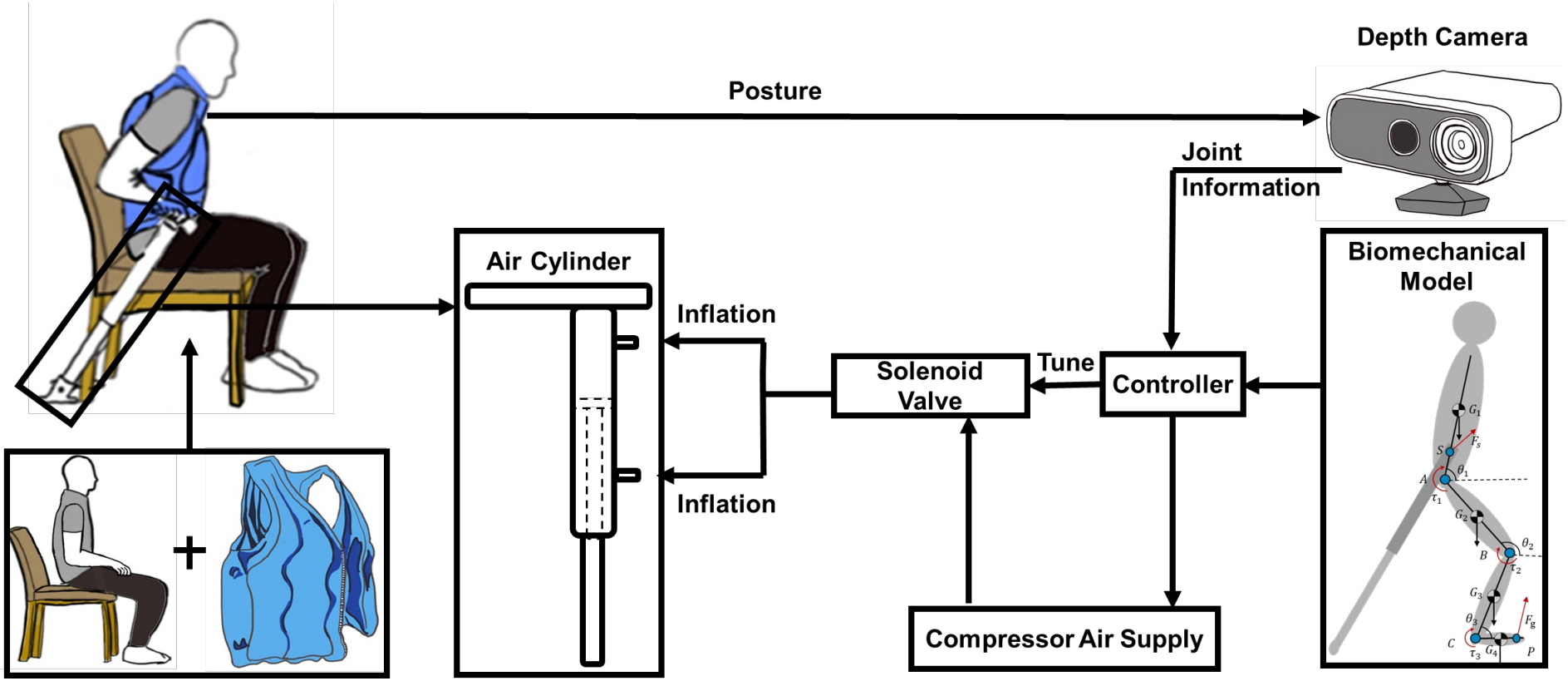
A Super-limb for the Elderly

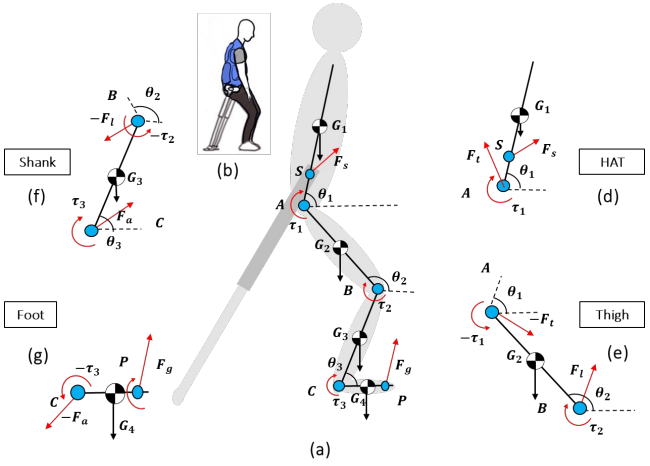


SUSTech Southern University of Science and Technology

Massachusetts Institute of Technology

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

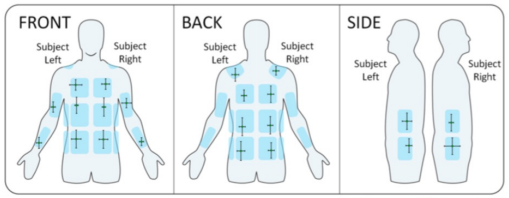


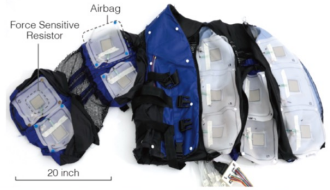


- Assistive Sit-to-Stand can be much more complicated than the current design
- Current progress establishes *the first steps* towards an autonomous assistive device

Inflatable Vest

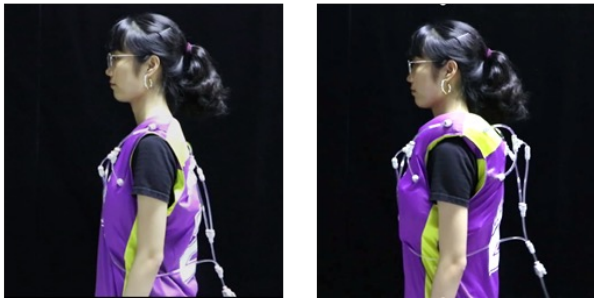
An inflatable swimming suit sewed inside a jacket with cane hooks under the arms





Before & After Inflation

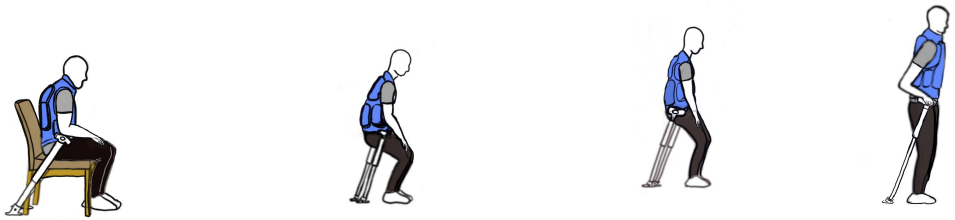
Before Inflation After Inflation

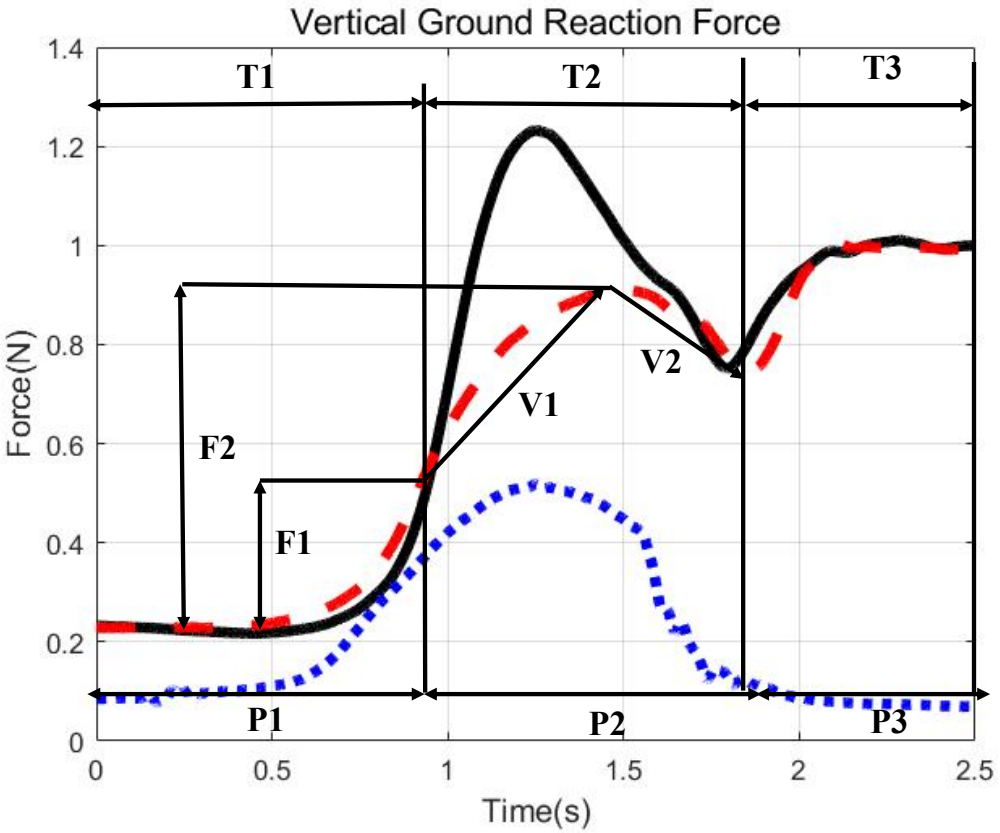


- Design issues with active assistance for the elderly as a wearable device
- Yet to be solved with a better design

Gradually Reduced Peak Force Exerted by Human Leg

Reduced Ground Reaction Force with a Robotic Cane

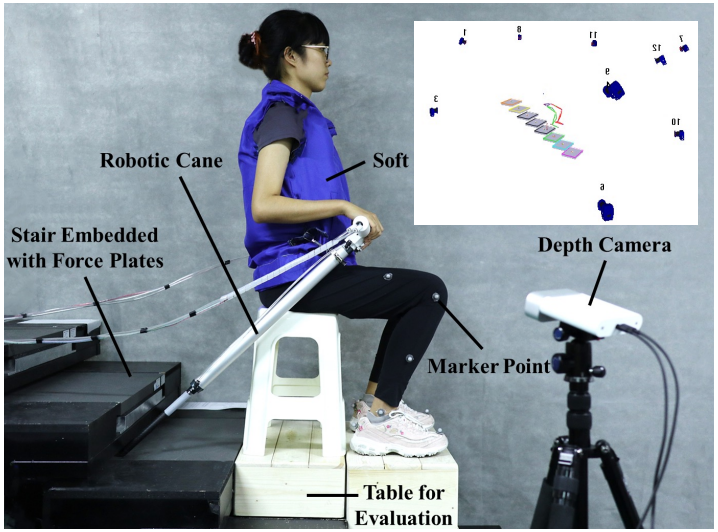


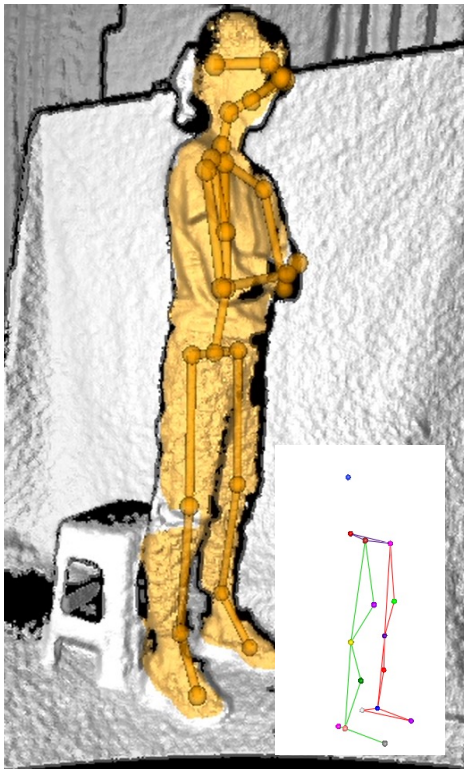


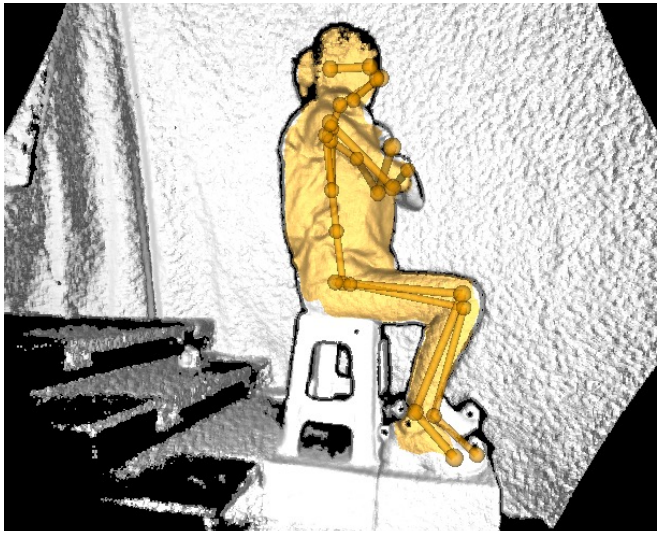
- Assistive Sit-to-Stand can be much more complicated than the current design
- Current progress establishes *the first steps* towards an autonomous assistive device

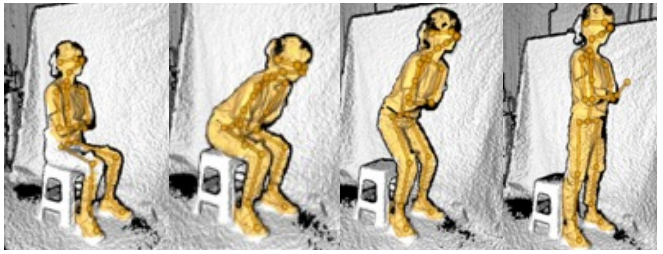
Depth Sensing for Ambient Intelligence

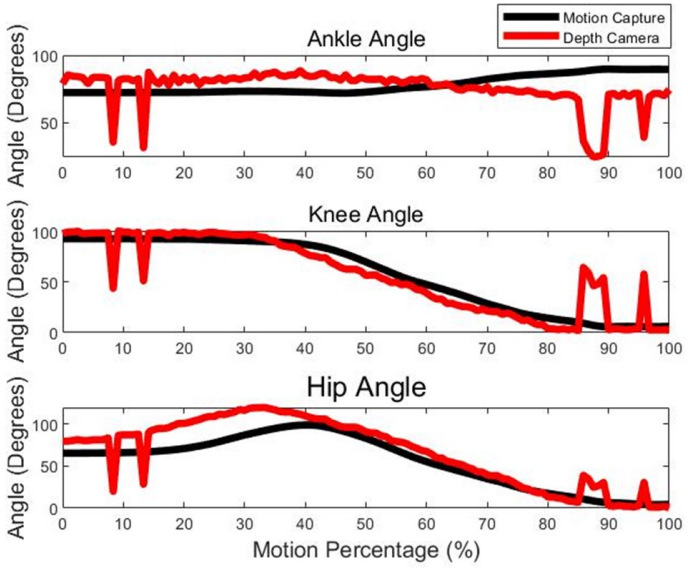
Towards an environment that satisfies our needs mostly without our having to think about it



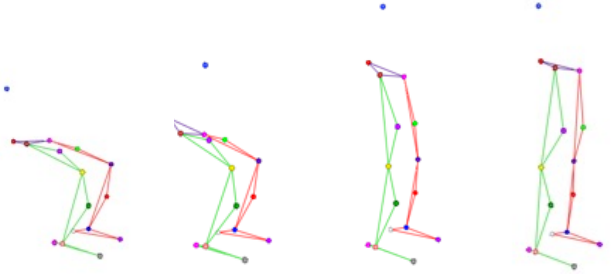






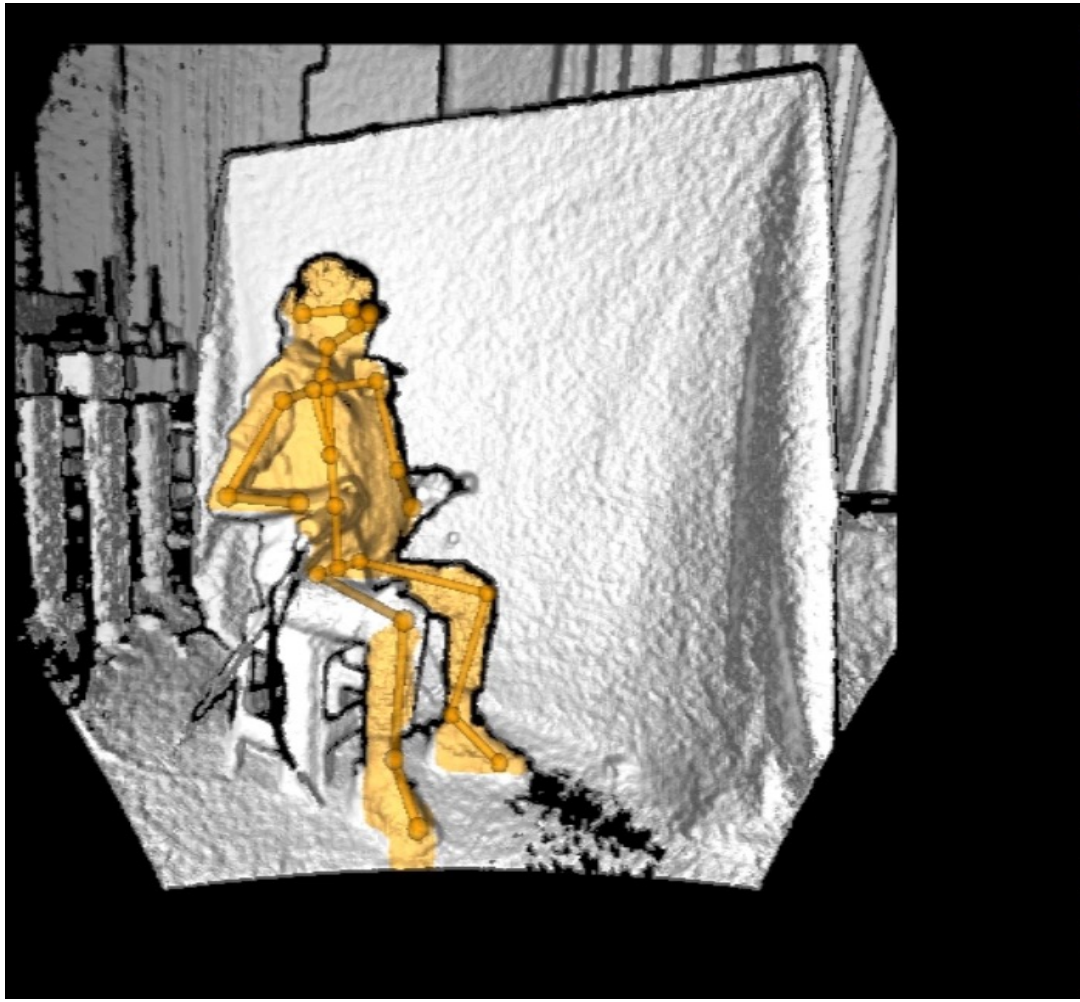


- Ambient control of assistive robot for the elderly requires rich motion data
- Consumer-grade depth sensing vs. Industrial-grade motion capture
- Future research on ambient control of super-limb robots for the elderly?

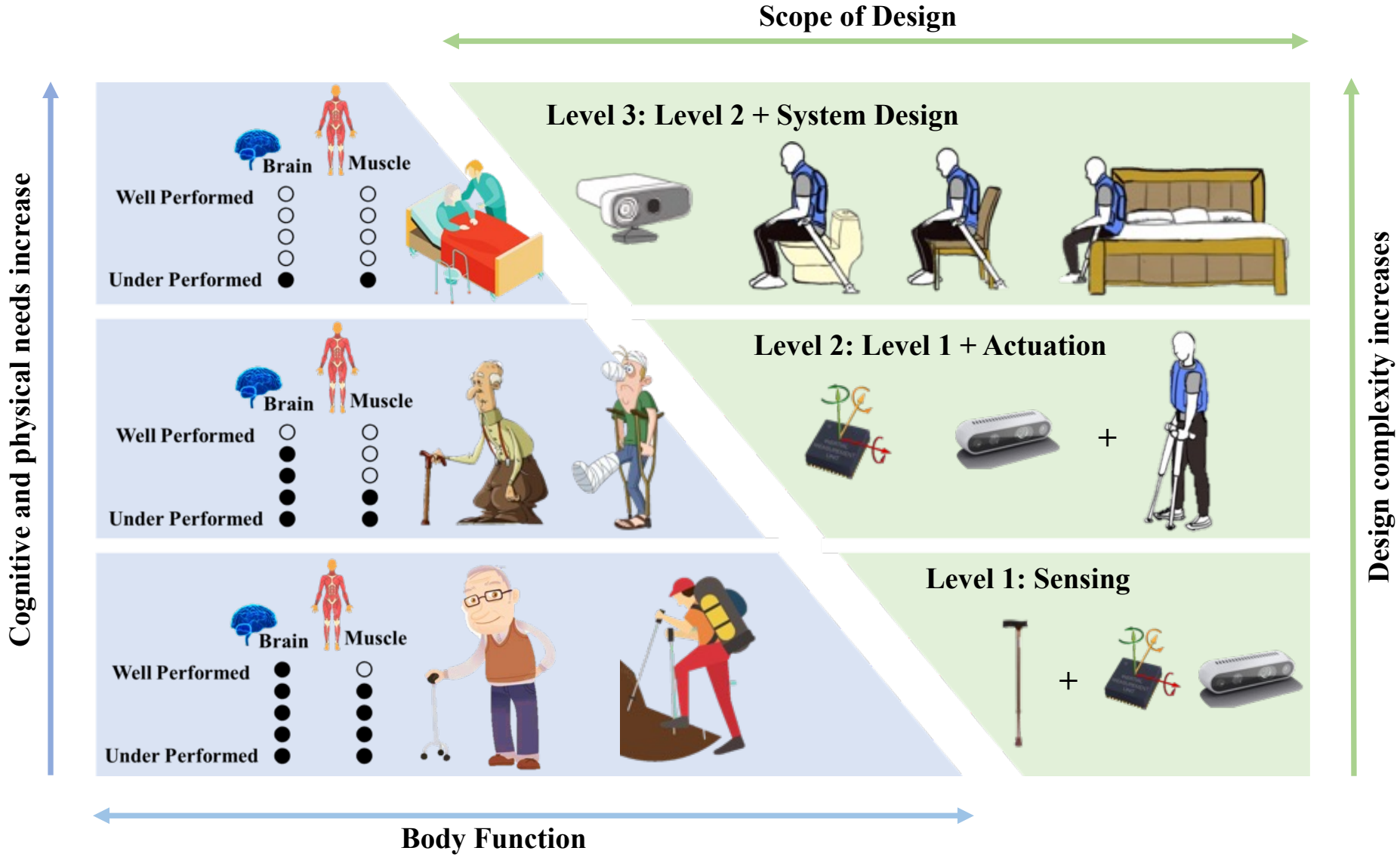


Experiment Setup

- Depth sensing for ambient motion recognition and intention detection



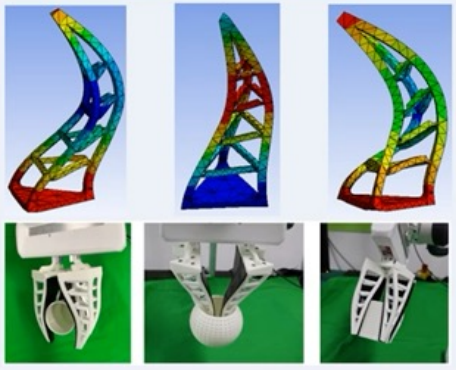
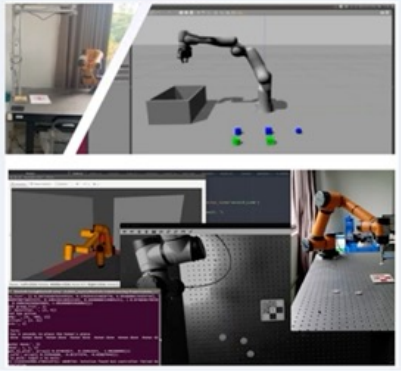
SRL Design for the Elderly

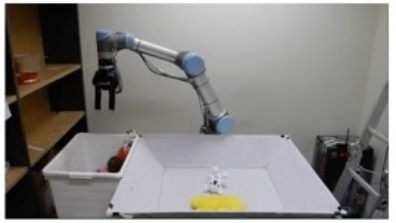


Soft Robot Learning

DeepClaw Robot Learning System

A Shareable & Reproducible Robot System for Learning and Benchmarking

非结构环境视触抓取与识别机理	生活垃圾的视触特征的数据化表征	智能软体机器人垃圾分拣系统集成
面向生活垃圾 抓取与识别的 视触感知软体机器人	建立非金属、中小尺寸 生活垃圾视触信息的 基准数据集	采用视触融合软体机器 人技术的垃圾分拣与 效率检测平台
		
• 全方向自适应软体机器人 • 低成本、高可靠柔性驱动 • 柔性触觉传感器集成阵列	• 垃圾视触特征的系统表征 • 垃圾视触分类基准数据集 • 无监督学习数据采集标定	• 机器人垃圾分拣系统示范 • 垃圾分拣的量化分析模型 • 经济效益集环境影响测试



Rigid-Soft Interactive Learning

Rigid-Soft Transferrability

Wasteless Themed Design Projects

Review of Challenges for Human Activities Underwater

The human musculoskeletal biology is **not** designed for activities underwater

- **Life** assistance: air, vision, body temperature, …
- **Motion** assistance: fins, gloves, …
- **Safety** assistance: dive suit, …
- **Cognitive** assistance: communication, …

- Human body is not designed for underwater work
- Many underwater work cannot be replaced by robots since many work requires humans dexterity.
- Underwater work is difficult, exhausted and dangerous.

→ Helping divers to keep balance and support their motion to save their metabolic energy consumption. Making underwater work safer and easier. → **Design a super-limb for underwater work**


Marine Biology

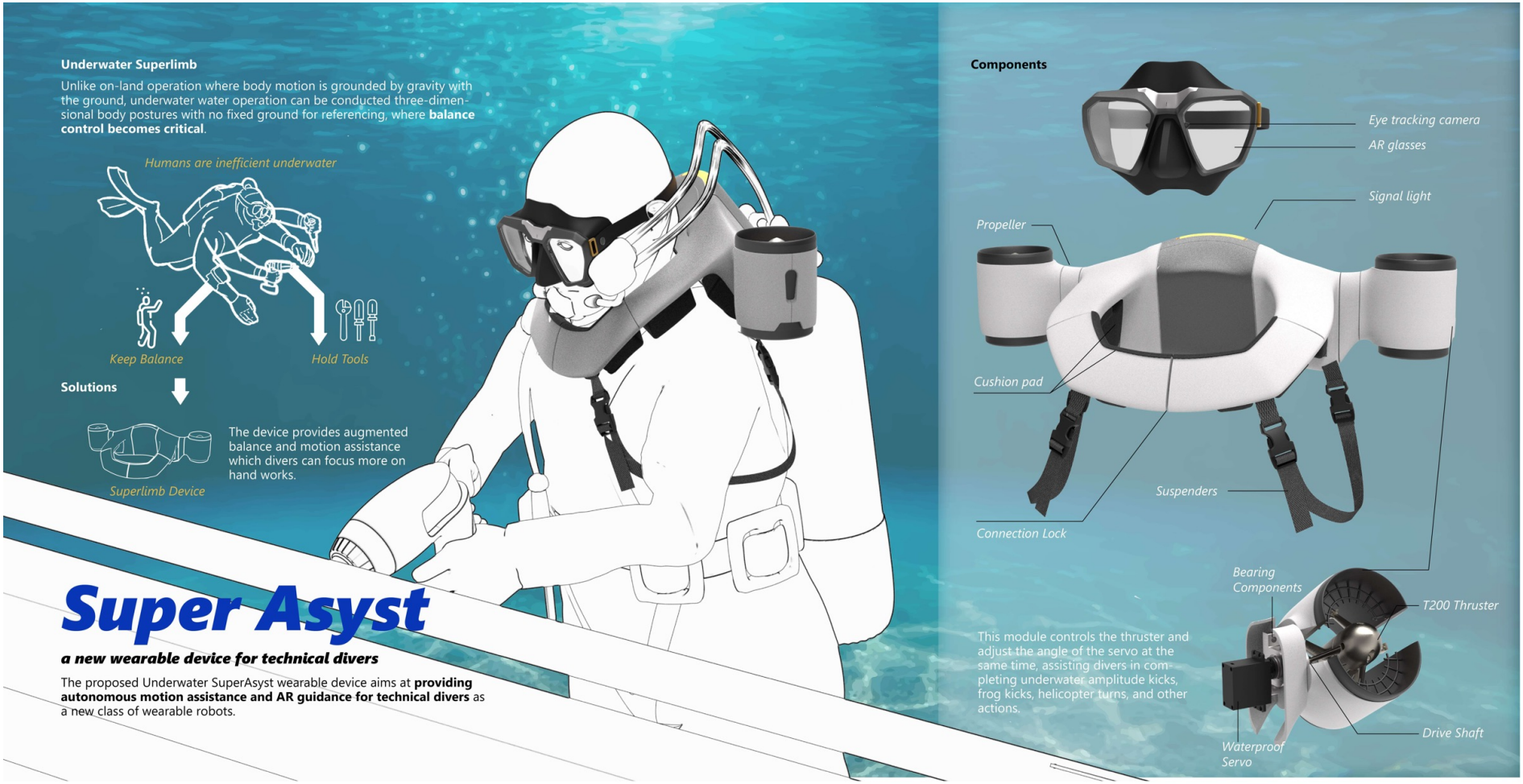

Underwater archeology


Paleontology


Underwater Welding

Han Yuanning

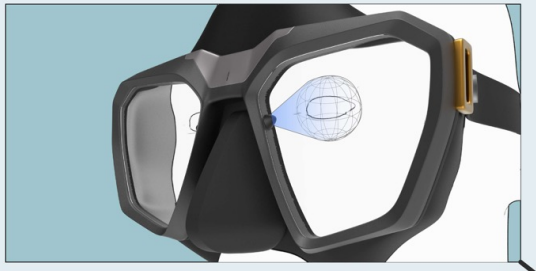
Super Asyst Concept Design



Designed by Chen Mingdong, Supervised by Wan Fang & Song Chaoyang

Super Asyst Concept Design

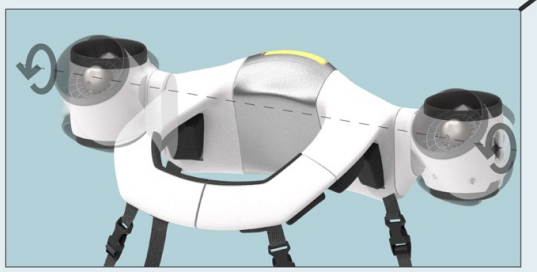
AR Goggles and Interaction



AR and Interacted Control

Enabling augmented reality experiences requires precise placement of augmented images-- where the user is looking. Besides the AR instructions, the fast and accurate eye-tracking camera system matches the divers' intentions to ensure the direction of the thruster.

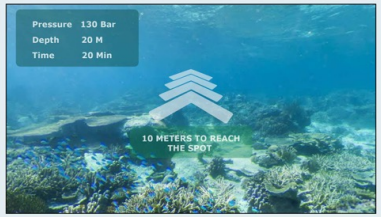
Adjustable Scubapack



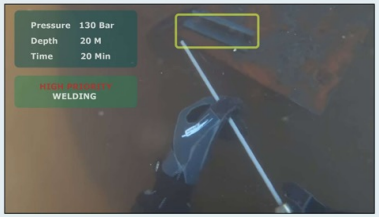
Rotatable Thrusters

The control box integrates the smallest and high-speed Arduino XIAO microcontroller, voltage power management module and electronic sensors, which are sufficient to control the thrust of the thrusters in real time and steplessly while adjusting the angle of the servos to the right angle.

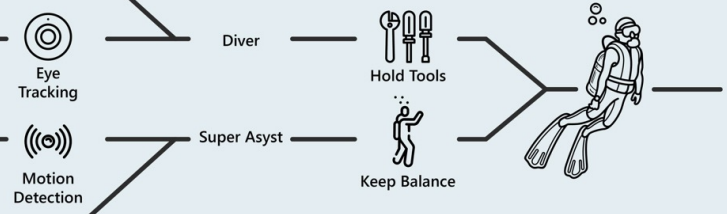
AR Instructions



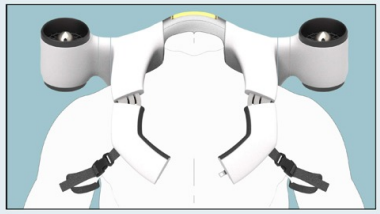
Route Guidance



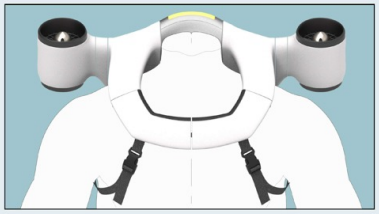
Task Instruction



Wearable Device



Step 1



Step 2

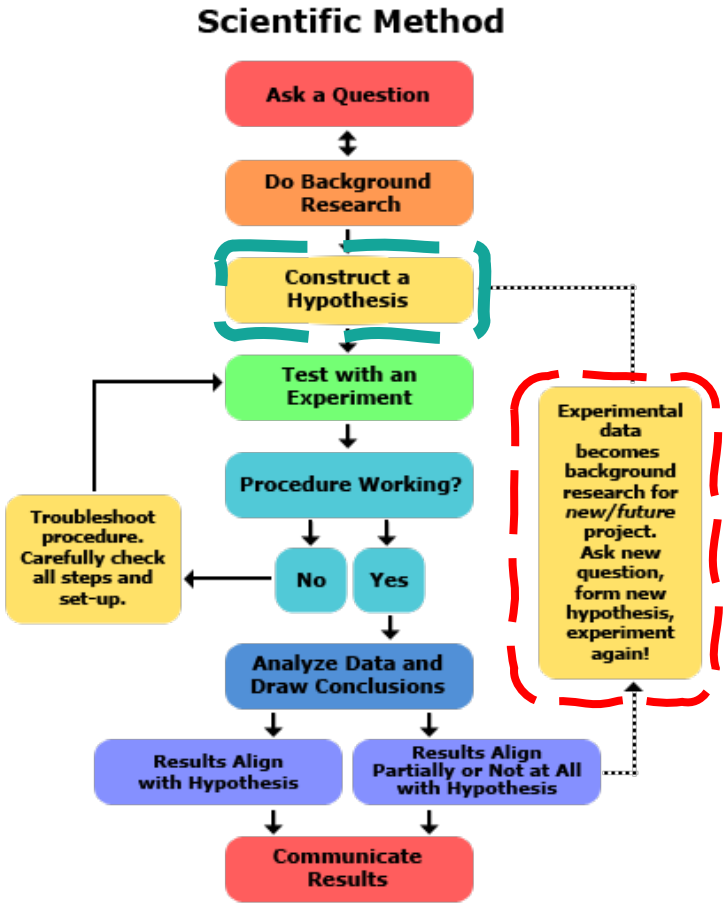
After the device is worn from the top of the head, the two ends are buckled and then the elastic cord is pulled tight.

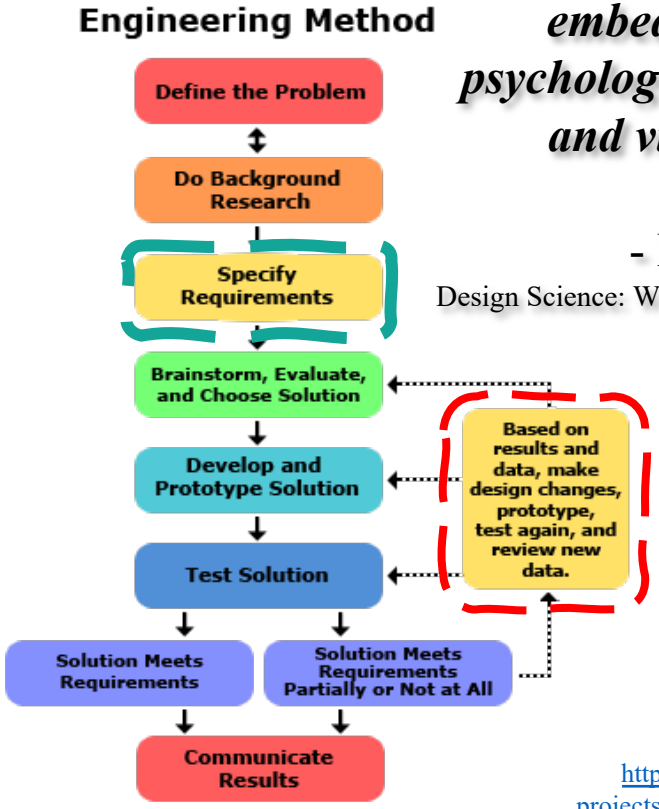
Scenarios

Designed by Chen Mingdong, Supervised by Wan Fang & Song Chaoyang

Design Science

- The Process of Identifying the Problem towards a Solution





"Design science studies the creation of artifacts and their embedding in our physical, psychological, economic, social and virtual environments."

- Panos Y. Papalambros

Design Science: Why, What and How, *Des. Sci.*, vol. 1, e1, DOI: 10.1017/dsj.2015.1

https://www.sciencebuddies.org/science-fair-projects/engineering-design-process/engineering-design-compare-scientific-method

Thank you~

Wan Fang
Southern University of Science and Technology