Plenary Talk, CCC2021
On-line, July. 27, 2021

Service Robot Technology

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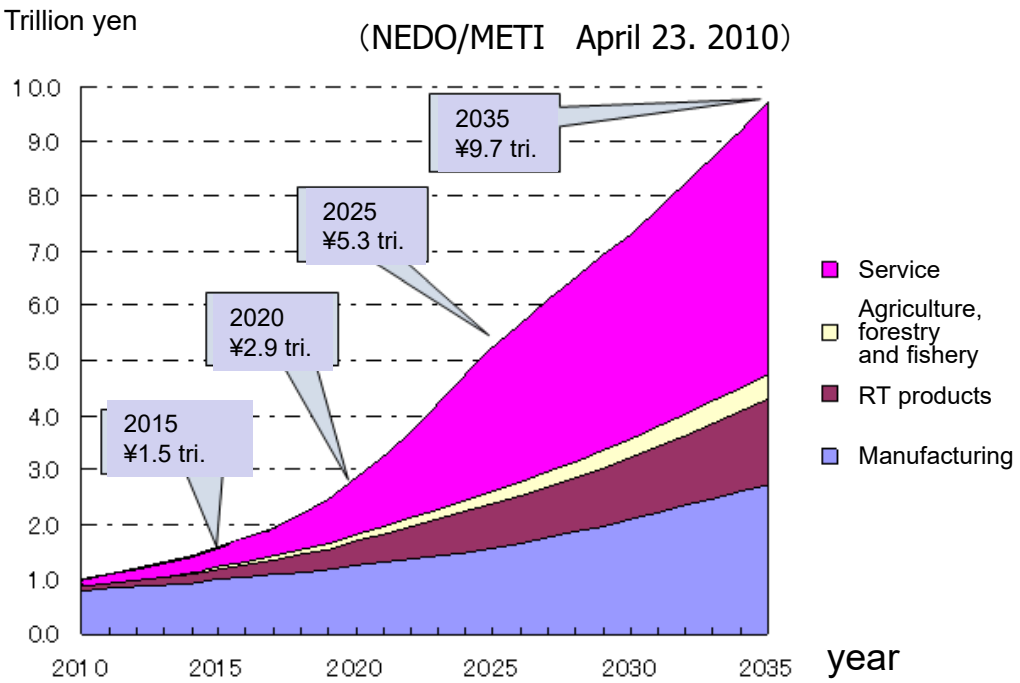
Market forecast in the future of robot industry for 2035



Personal Services

- Medicine (for surgery, rehabilitation, therapy)
- QoL Assist (for elderly, disabled, handicapped)
- Security
- Home services
- Guidance
- Education
- Amusement and Entertainment, etc

Public Services

- Maintenance of facilities
- Disaster response
- Construction
- Agriculture, forestry, fishery
- Demining, etc

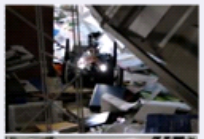
In 2035, the market can expand up to 9.7 trillion yen by dissemination of the robot technology in a new field including the service.

Trends of Robot Industry

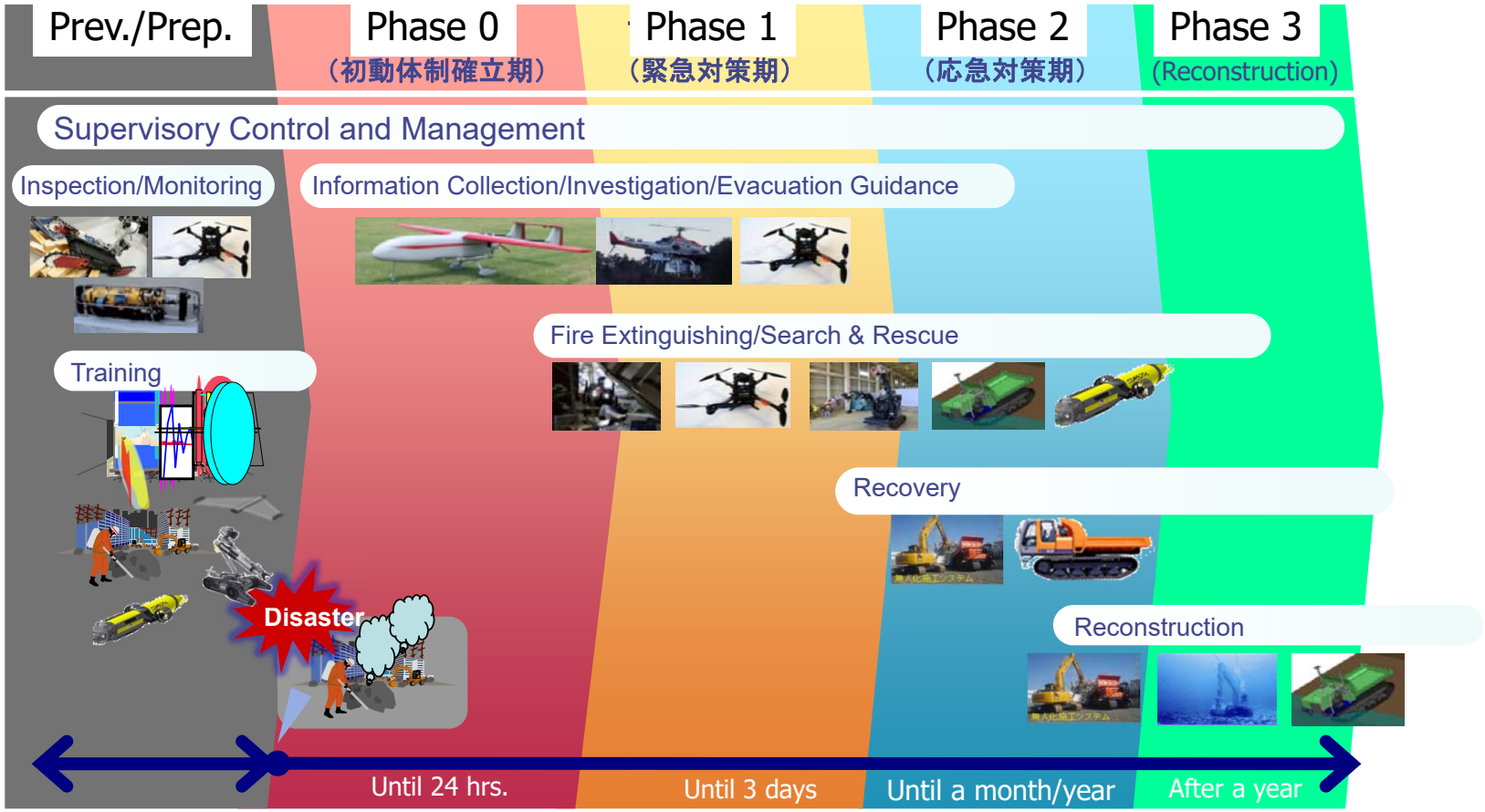
- From Human-exclusive system (automation)
  to Human-inclusive system (co-existing)

RT for public services

Robot Technology
Required in Disaster Prevention and Response

Aerial vehicles	【使用目的】 （1） 発災直後の広域被災状況の調査 （2） 孤立地域等の細部被害状況の調査 （3） 津波からの避難支援（局地の情報収集・伝達） 【期待する能力】 （1） 夜間、悪天候における情報収集 （2） 映像、位置、生体反応等の情報をリアルタイムに災害対策本部等へ伝送 （3） 津波からの避難に必要な情報・警報を住民に直接連絡	  
Ground vehicles	【使用目的】 余震・火災・水没等危険な時期・場所での調査・瓦礫除去・救助活動支援 【期待する能力】 （1） 生体反応の感知等捜索能力 （2） 瓦礫、浸水、高温・火災等環境下での機動力 （3） 瓦礫等重量物の除去能力	  
Underwater vehicles 水中探査ロボット	【使用目的】 津波発生後の海洋における調査・瓦礫除去・救助活動支援 【期待する能力】 （1） 瓦礫、汚濁等劣悪環境下の海洋での探索能力 （2） 同上環境下における機動力、瓦礫除去能力 （3） 被災者等の救助能力	  
津波避難支援ロボット	【使用目的】 津波からの災害弱者などの避難・誘導活動の支援 【期待する能力】 （1） 津波被害の予測・回避能力 （2） 避難住民を安全、迅速、努めて大量に輸送 （3） 居住地域、避難地域、避難経路の認識	

Operation Phases in Disaster Response



Remote Technology for Decommissioning of NPS

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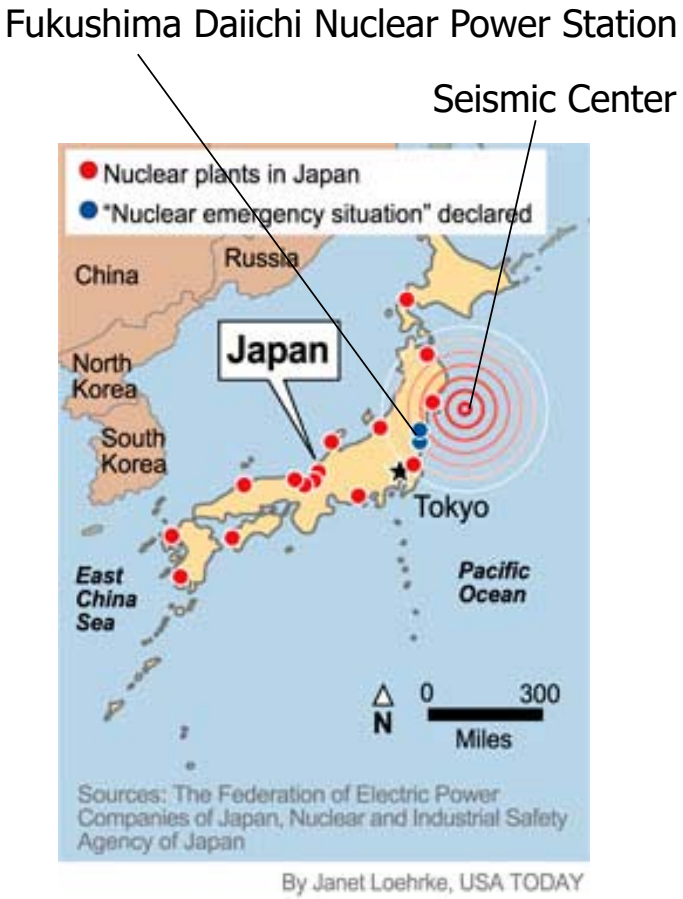
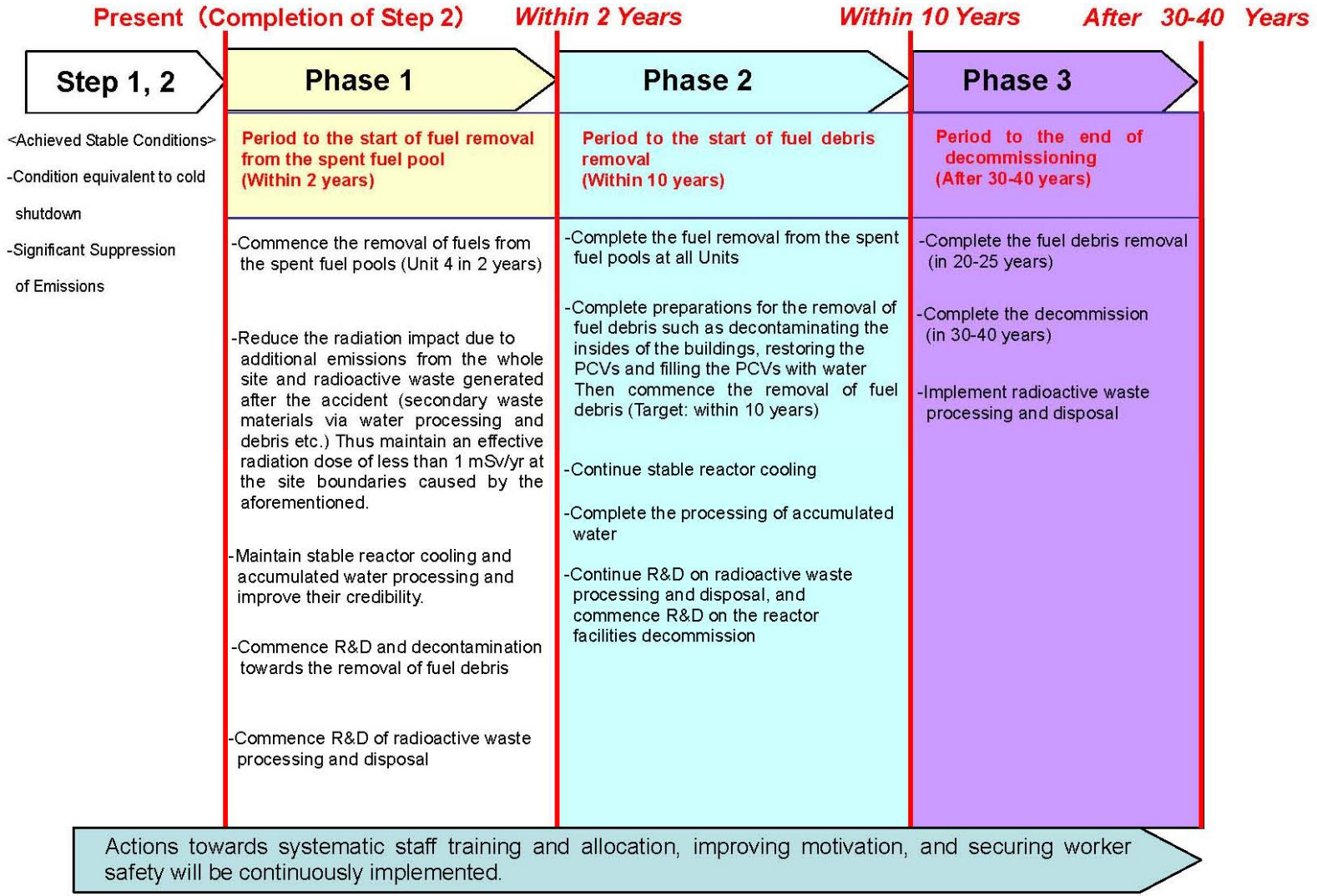
Accident of Fukushima Daiichi Nuclear Power Station

- Earthquake (14:47)
- Loss of Power Supply
- Activation of Emergency Diesel Generator
- SCRAM
  Stop Reactors
- Tsunami
- Damage of Fuel Tanks and Generators
- SBO (Station Black Out) (15:39)
- Failure of Cooling System of Reactors and Fuel Storage Pool
- Loss of Cooling Water
- Melt down
- Hydrogen Explosion (Mar. 12-15, Unit 1, 3, 4)



Mid-and-long-Term Roadmap Summary (TEPCO)



Needs (Tasks) for Remote Technology

- Water injection
- Removal and transportation of rubbles, fuels (including fuel debris), and contaminated water, etc. (Cutting, suction, handling)
- Investigation, measurement, and mapping (images, radiation, etc.)
- Sampling (dust, contaminated water, concrete core, fuel debris, etc.)
- Decontamination and Shielding
- Fixing of contaminated water leakages
- Handling, transportation, removal, setup of devices, instruments, equipments, etc.
- Waste and contaminated water management
- Dismantling of facilities

Remotely controlled Unmanned Construction System for Rubble Clearing-up From Apr. 6, 2011

TEPCO

処理前

コンテナ１個分の処理後

ガレキ積

コンテナふた

Crawler dumps

仮置き

ナ周辺約 2.5mSv/h）

Backhoes & Iron Forks

積み込み時配置

定置時配置

THE

na

ision Engineering

Tokyo

遠隔操作重機によるガレキ撤去作業

（コンテナ：3.2×1.6×1.1m、約4m^3）

1号　原子炉建屋周辺

（撤去前）

（撤去後）

（仮置の瓦礫収集コンテナ）

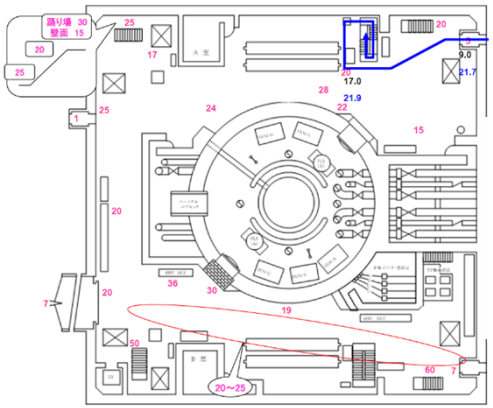
（東京電力提供）

Sampling of contaminated water and setting up of water level gauge by Quince from June 24, 2011

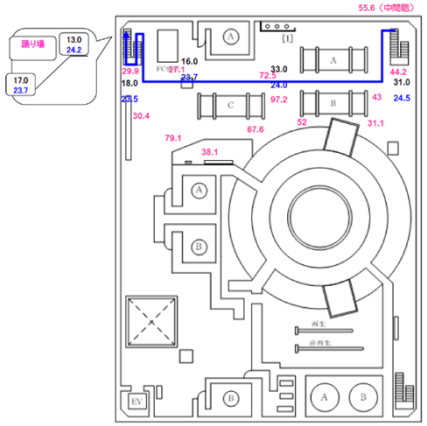
Investigation inside R/B unit 2 on Oct.20 by Quince

(TEPCO Oct. 21, 2011)

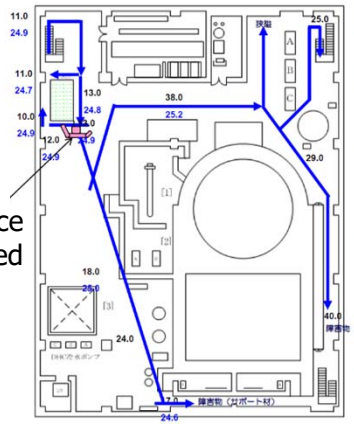
1st Floor



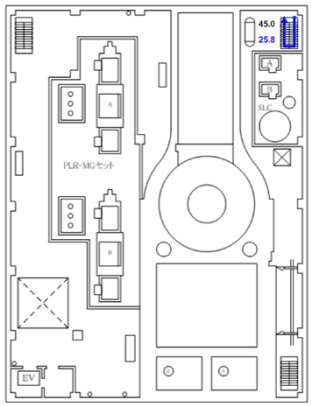
2nd Floor



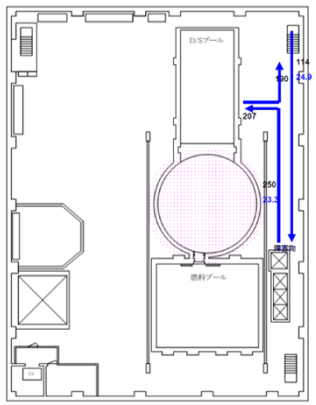
3rd Floor

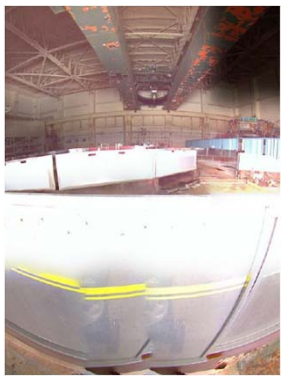


4th Floor



5th Floor





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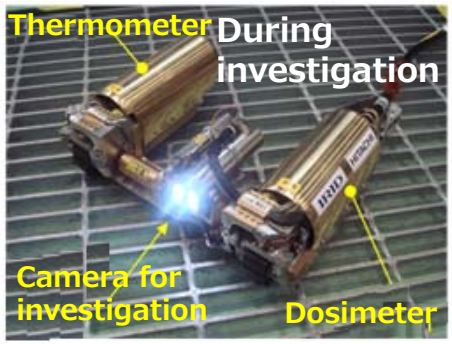
Investigation of 1st-5th floor inside Unit 2 R/B on Oct. 20, 2011 by Quince

Robots newly developed for Investigation of inside PCV

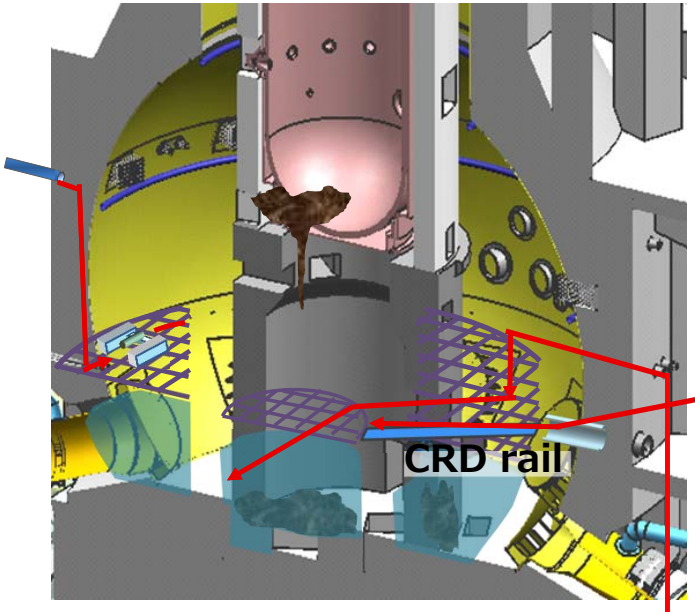
Two types of shape-changing, remote-controlled, crawler robots for investigation

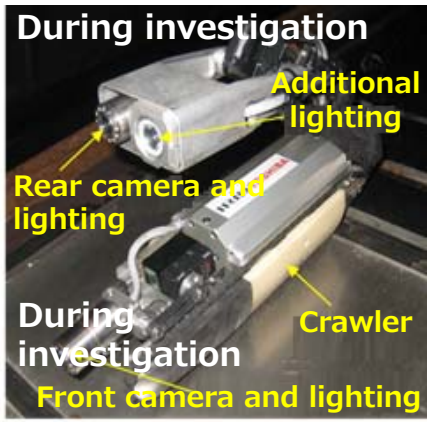
Investigation of outside the pedestal (Unit 1)

Shape changing

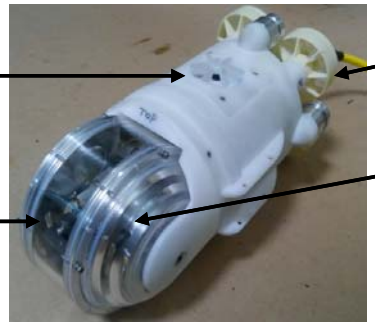


Investigation of inside the pedestal (Unit 2)





Investigation of inside the pedestal (Unit 3)

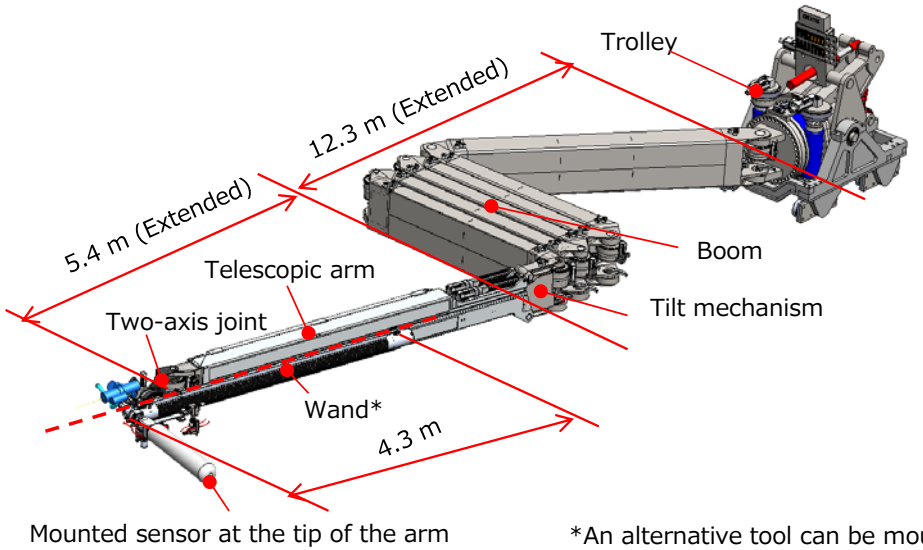


Hanging camera on extension rod (Telescopic type)

IRID

Arm Type Access Device

- An arm type access device has been produced, which can access on a wide range through the penetration of the primary containment vessel (X-6 penetration) for control rods maintenance.
  - Total length of the arm: Approx. 22m
  - An investigation device up to 10kg can be loaded.



Arm type access device

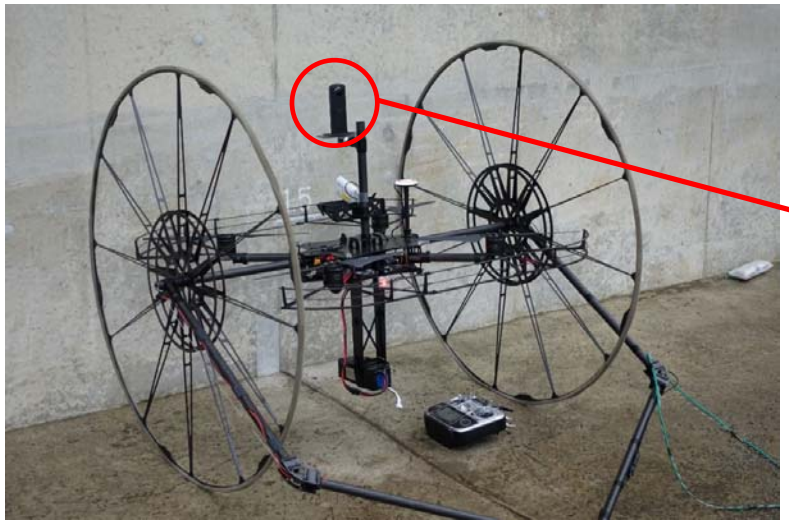
Inspection of Social Infrastructure

Bridge Inspection

- Drone (collaboration work Fujitsu, Nagoya Inst. Tech., Hokkaido Univ.)

Bridge Inspection

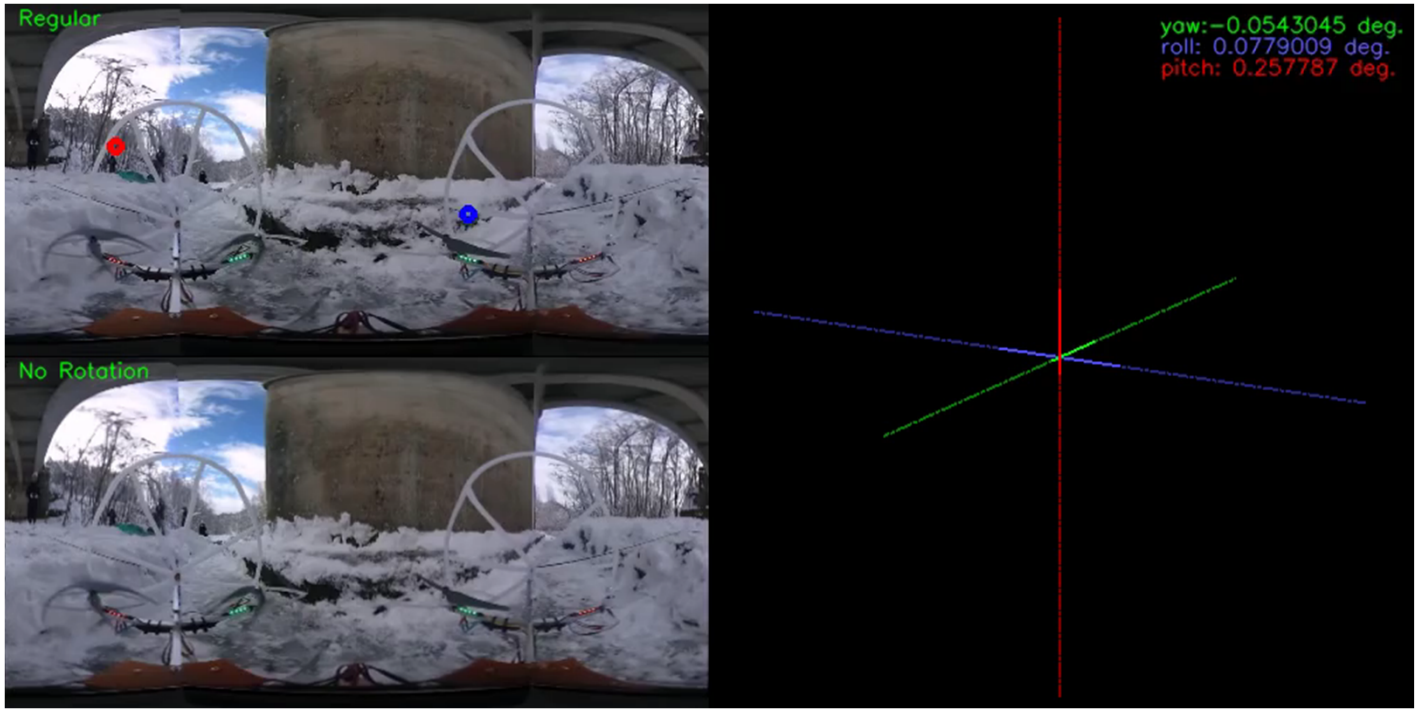
- Problem
  - GNSS signal is unstable under bridges.
- Approach: Localization using camera images
  - Estimate the drone pose (position and orientation) is only by the mounted camera on drone



Ricoh Theta
(Wide FOV camera)

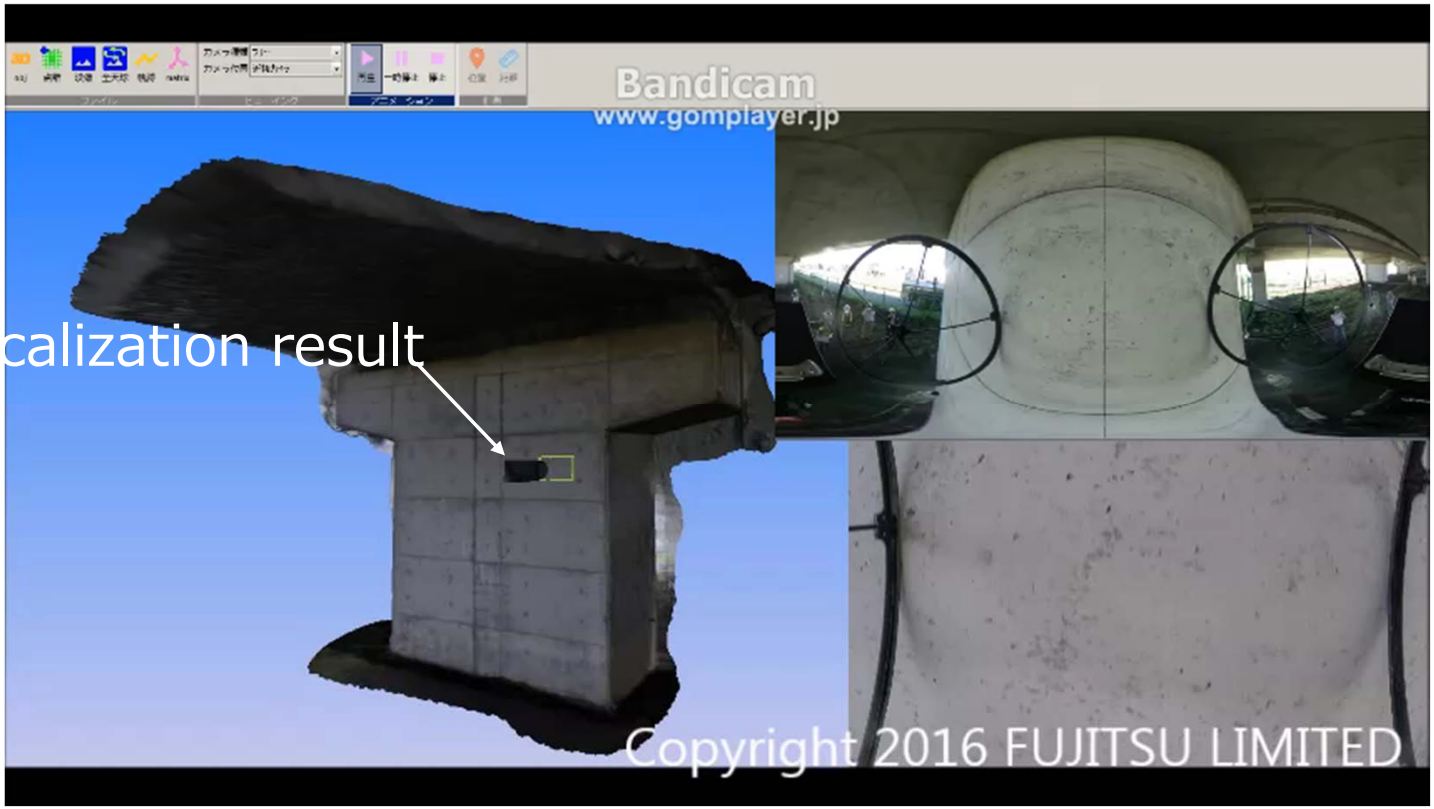
Robot Localization

- Localization result only by using images of spherical camera mounted on the drone



Bridge Inspection

- Generate database of bridge inspection



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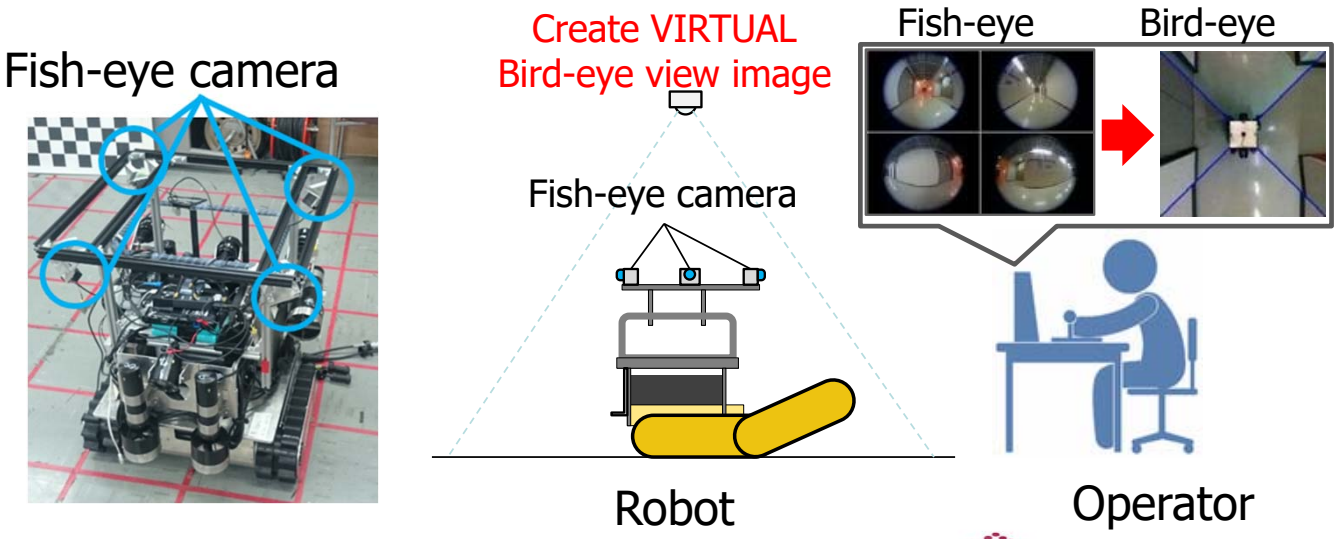
Bird-eye View

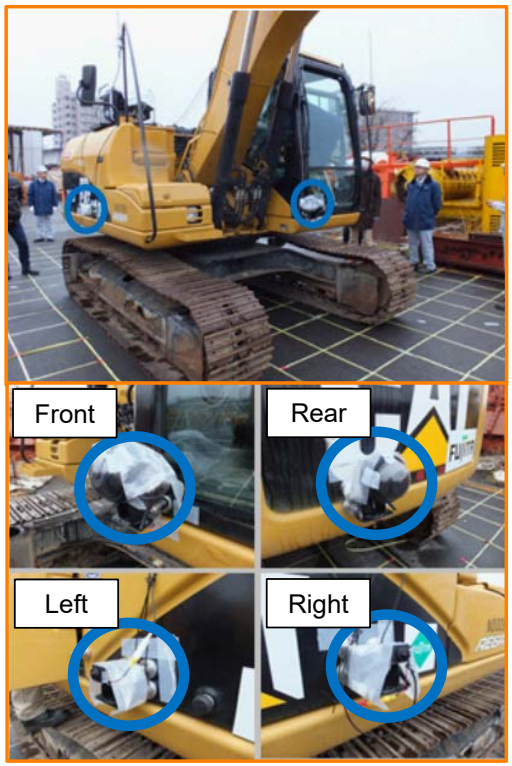
- Robot visualization method using third person view
  - Bird-eye view (third person view) are virtually created from four fish-eye (wide FOV) cameras on the robot.
  - We can easily understand the relation between the robot and the surrounding environment only from one bird-eye view image.



Bird-eye View

- Real-time visualization from top view using image processing technique.

Application to Unmanned Construction System



Construction machine

Teleoperation by an Operator

Front View

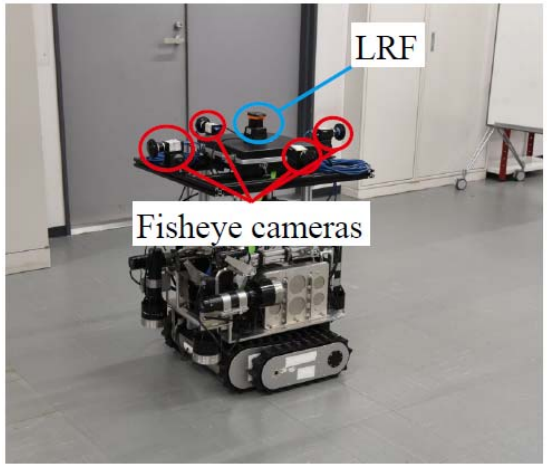
Bird-eye View

Teleoperation of Robot Using Bird-eye View

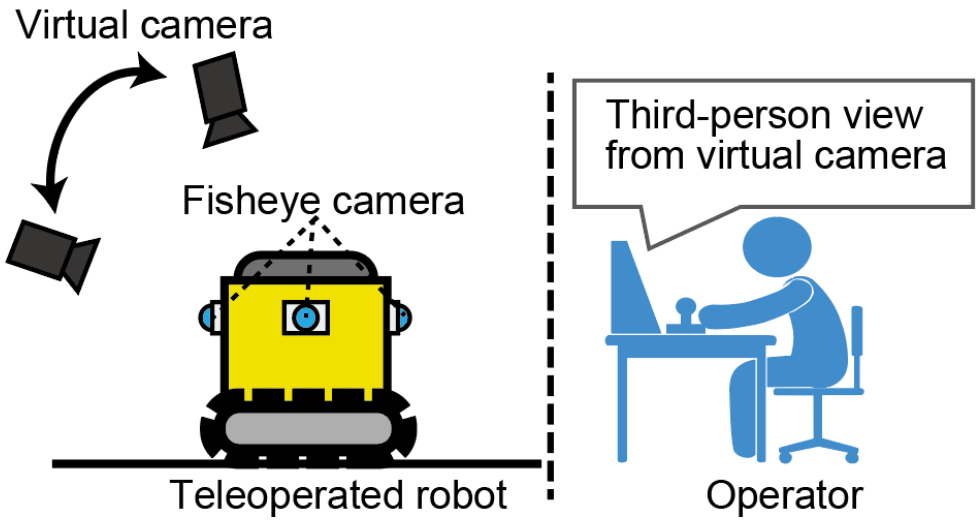
Third Person View Using Multiple Cameras

- Robot visualization method using third person view without external cameras
- Bird-eye view (third person view) are virtually created from multiple wide-FOV (fish-eye) cameras equipped on the robot

3D reconstruction of surrounding environment is required



Teleoperated robot

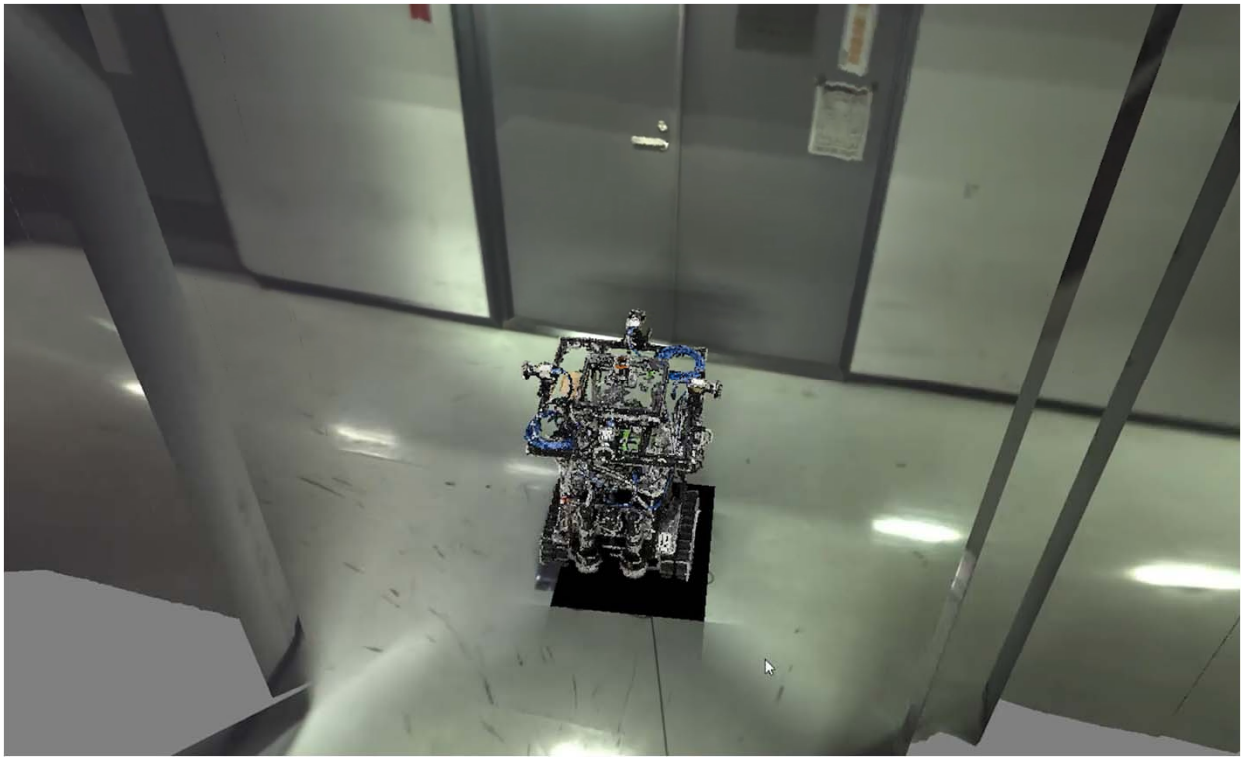


Concept of proposed method

Teleoperation of Robot Using Bird-eye View

3D Reconstruction of Indoor Environment Using LRF

- Using assumption that walls are perpendicular to floor
- LRF is used to measure distance between robot and walls



Visualize in real-time: 25 fps（=0.04 s） Vaio Z Core i7-6567U

RT for personal services

Assistive System for Rehabilitation (Stand-up motion)

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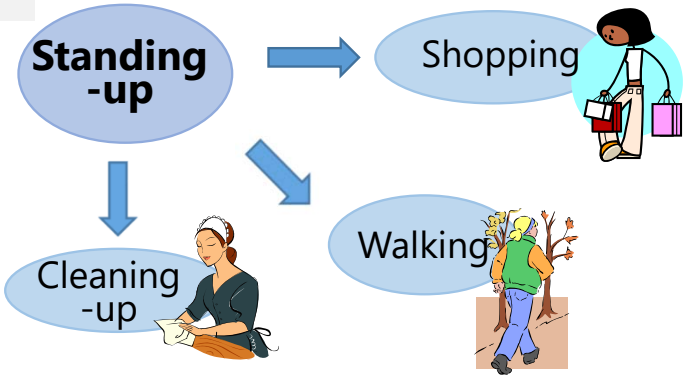
Background

- **Problem of Aging Society**
  - Increased social security cost
  - Burden to care givers
  - Declined QoL of the elderly



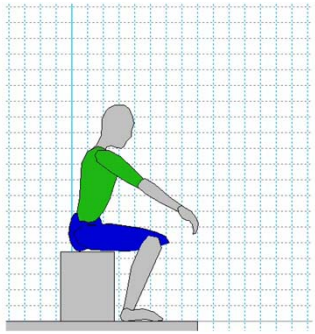
- **Standing up motion is an important basic activity**
  - Starting motion for activities of daily living [Guralnik JM '95]

Development of Assistive system for standing-up motion

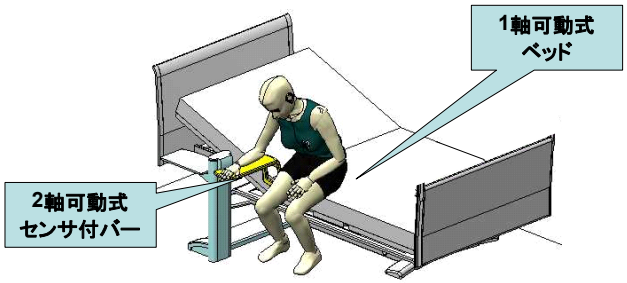
Measurement system for standing-up motion
(Motion Capture and force measurement)

Assistive motion by an expert

アシストバーとベッドの
連動により介護者の
起立動作を支援



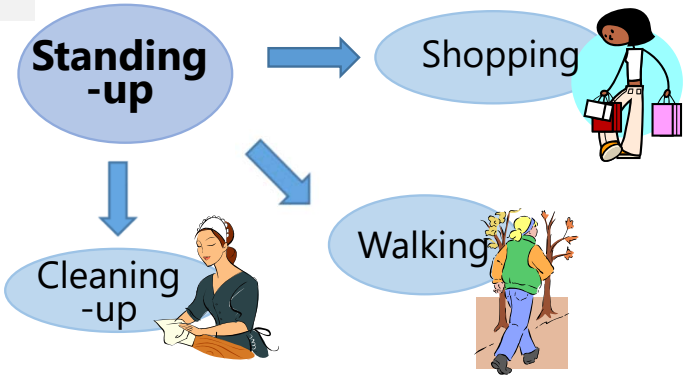
Dynamic simulation of standing-up motion



起立動作アシストシステム概観

Background

- **Problem of Aging Society**
  - Increased social security cost
  - Burden to care givers
  - Declined QoL of the elderly



- **Standing up motion is an important basic activity**
  - Starting motion for activities of daily living [Guralnik JM '95]

Necessary to understand mechanism of standing-up motion

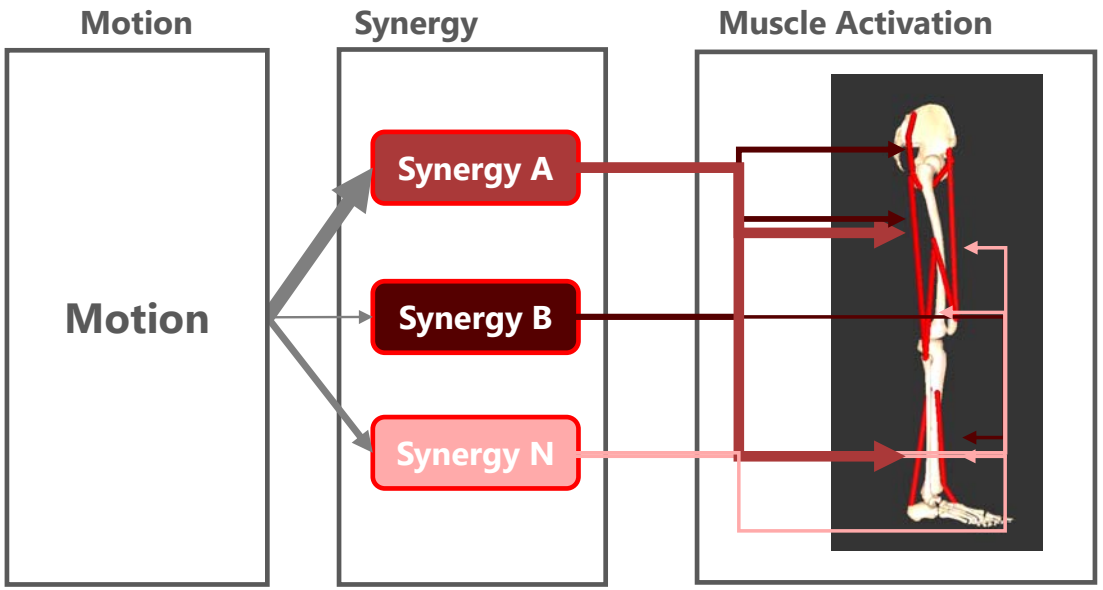
Muscle Synergy Hypothesis

For target motion, humans do not control individual muscles, but control modules of simultaneous muscle activation (synergy)

▶**Reduction of control input for redundant body DoF** [Bernstein '67]

-Muscle synergy in human walking, grasping, and posture control

[Ivanenko '05, Torres '07, Weiss '04]

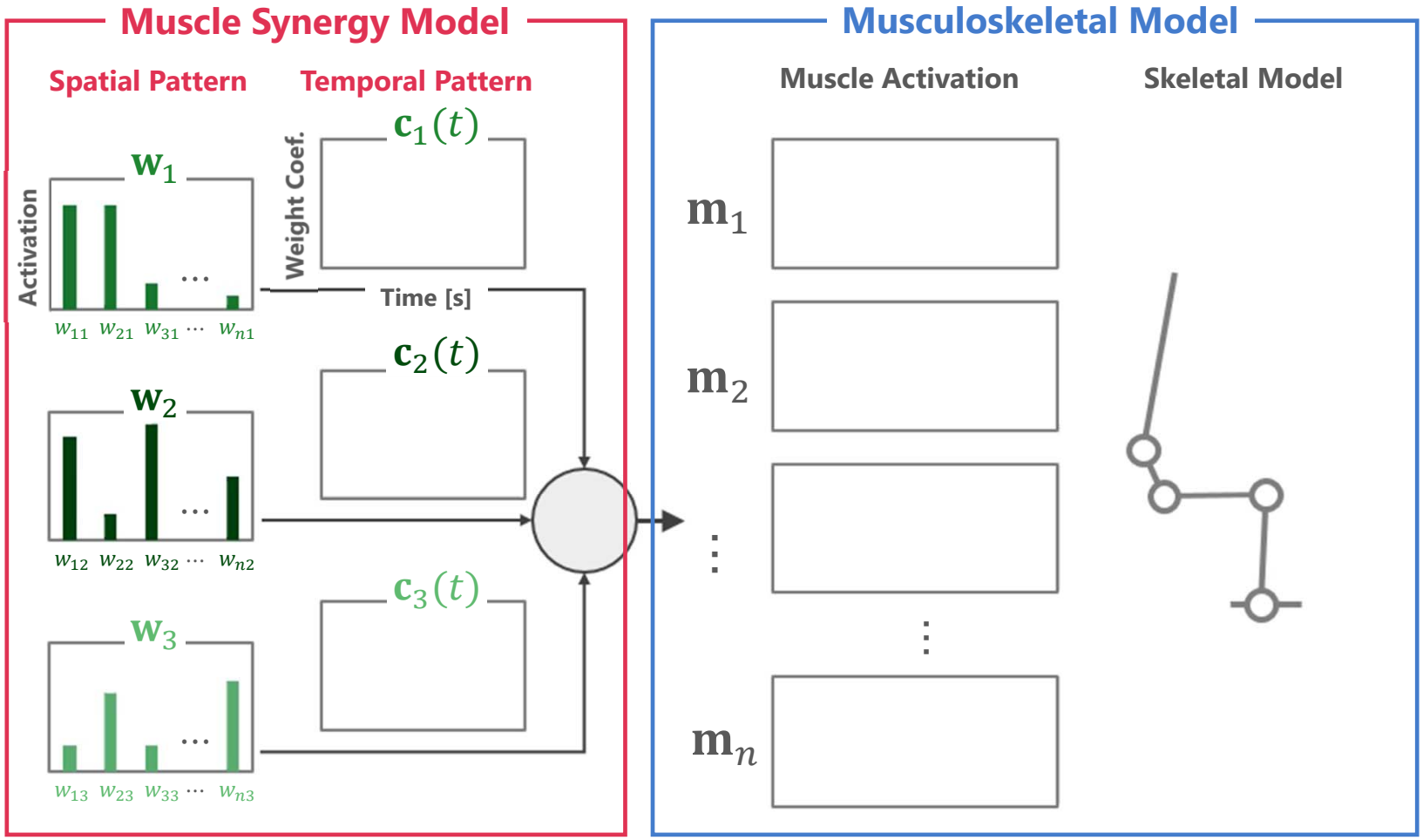


Objectives (Topics)

- What synergy structure humans have in standing-up motion
- Clarify how muscle synergies change in motor impaired patients
- How rehabilitation improves synergy structure

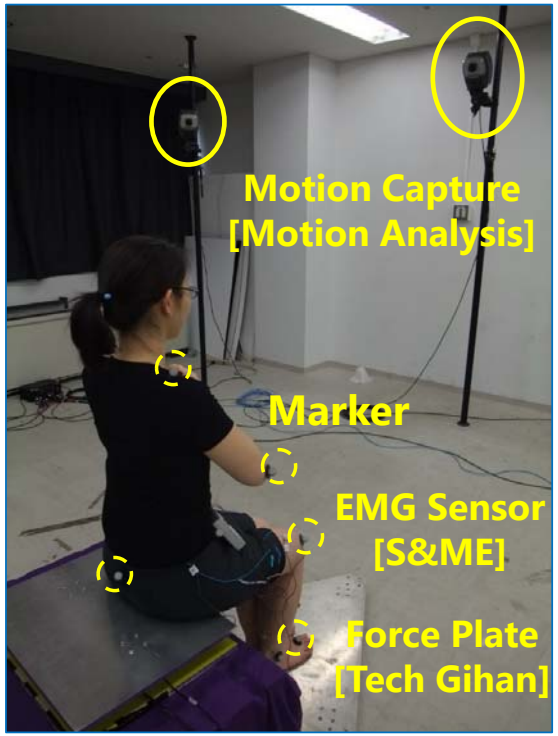
Muscle Synergy Hypothesis

- Coordination of synergies generate complex motion

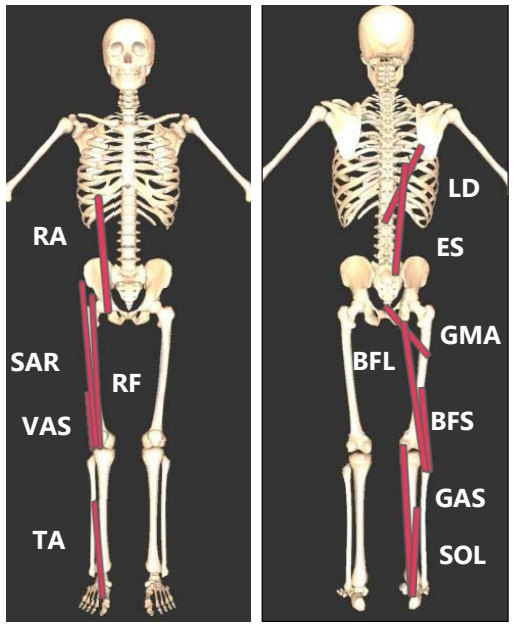


Experiment Setup

- Recorded muscle activity, kinematics and reaction force
- 7 Healthy male (24.3±2.1 yrs, 1.73±0.05 m, 71.7±10.3 kg)
  - 5 trials for every condition



12 muscles extend or flex
ankle, knee, hip, and lumbar



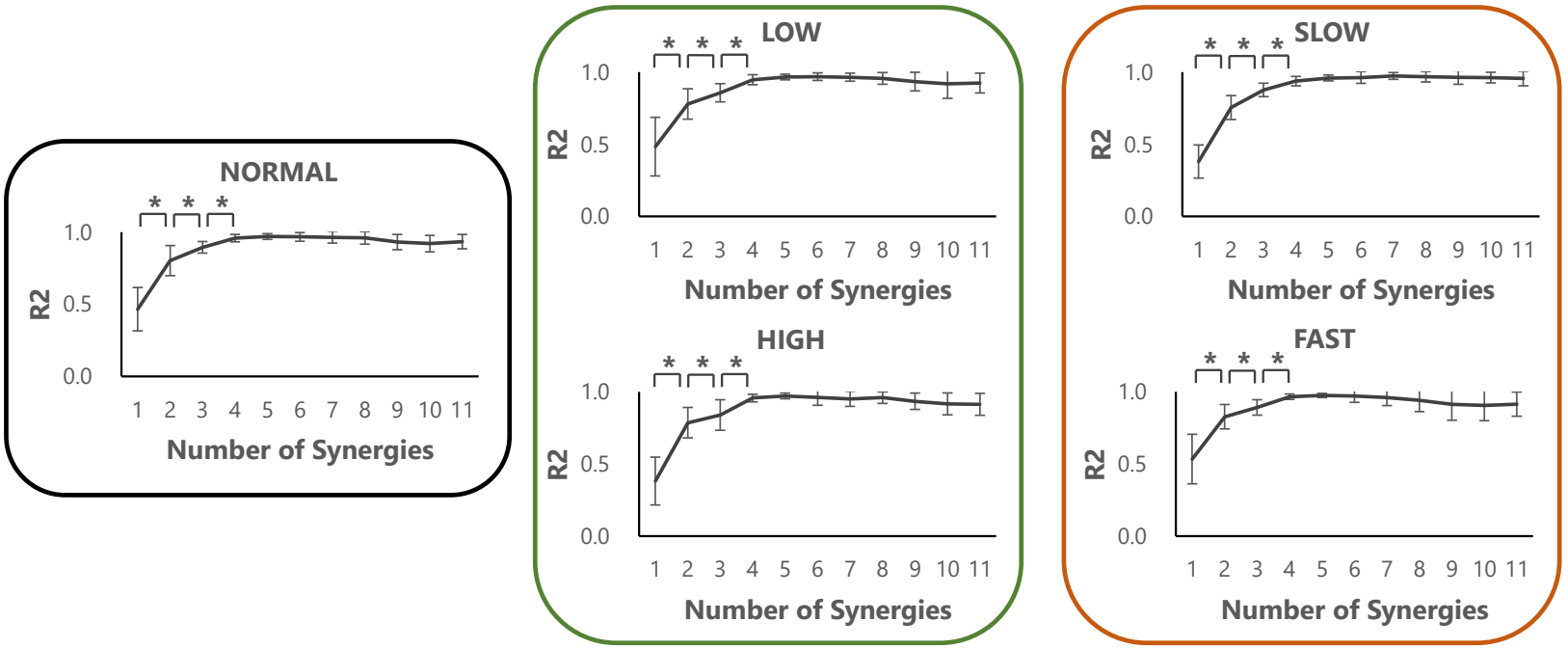
Front Back

Number of Muscle Synergy

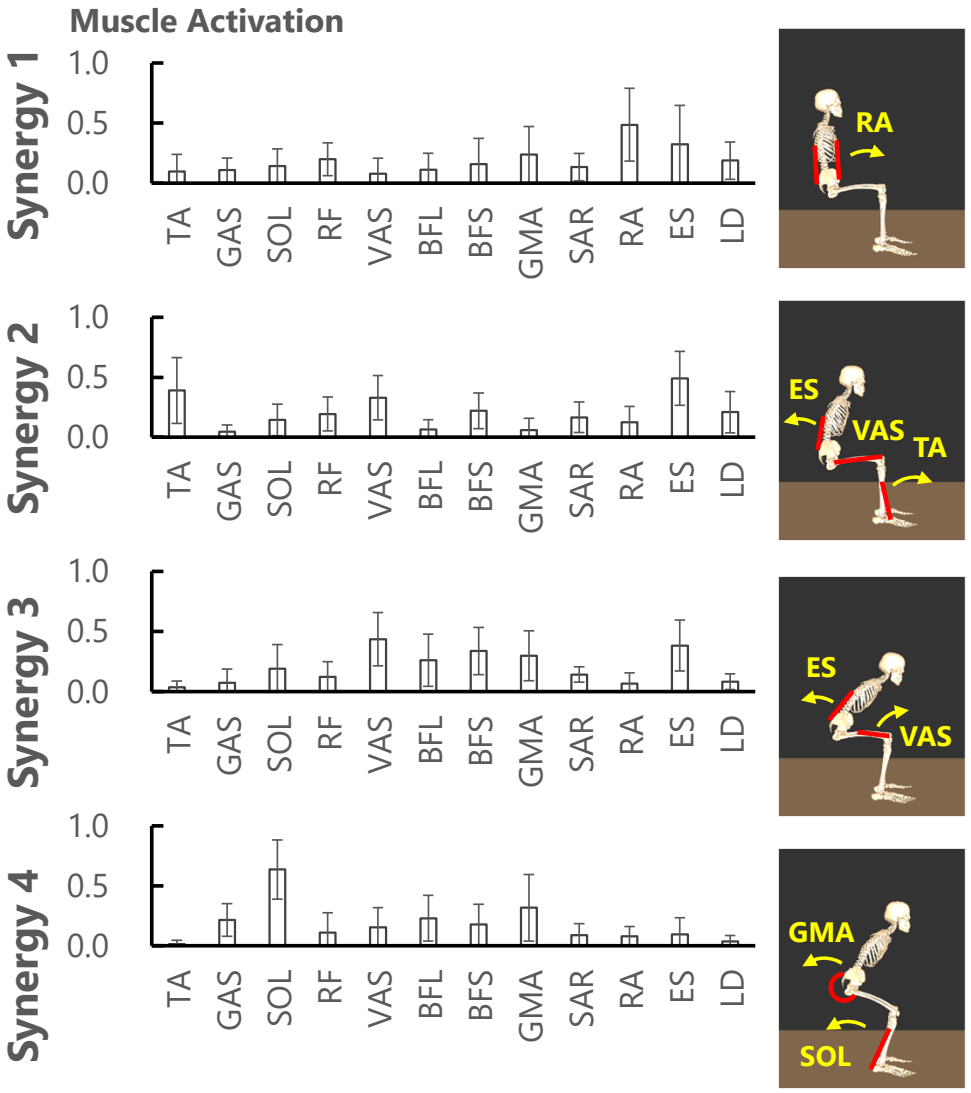
- ANOVA (Analysis of Variance) + post hoc test
  statistical significance between: 1～2, 2～3, 3～4 (p <0.05)
- Satisfies threshold of previous study: R^2 >0.95 [Ting '05]
  Coefficient of determination

Determine muscle synergy number as 4

Explanatory Variables



Spatial Pattern



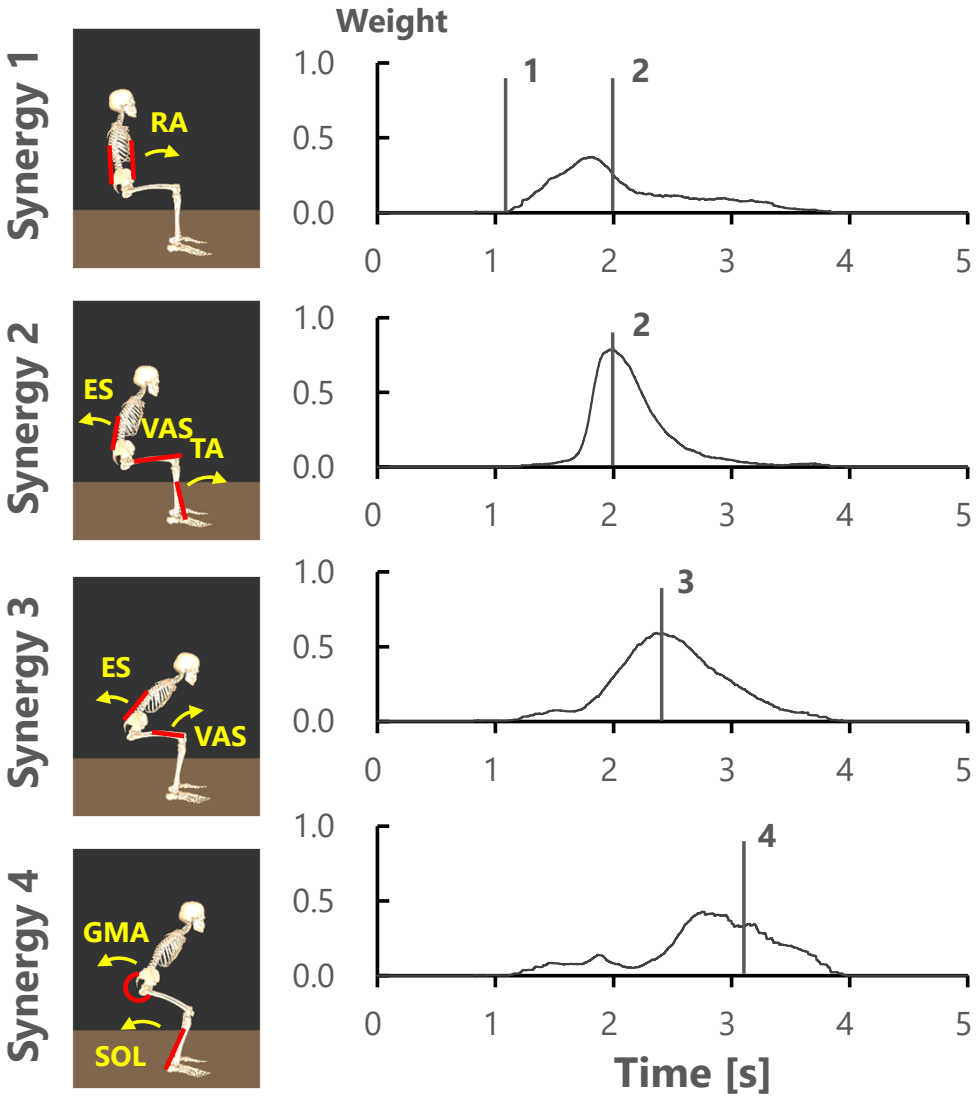
Bending Upper Body

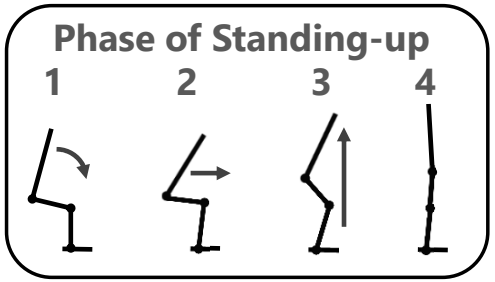
Rising Hip from Chair

Whole Body Extension

Posture Stabilization

Temporal Patterns





Corresponds to kinematic phase

Muscle Synergy Structure of Stroke Patients

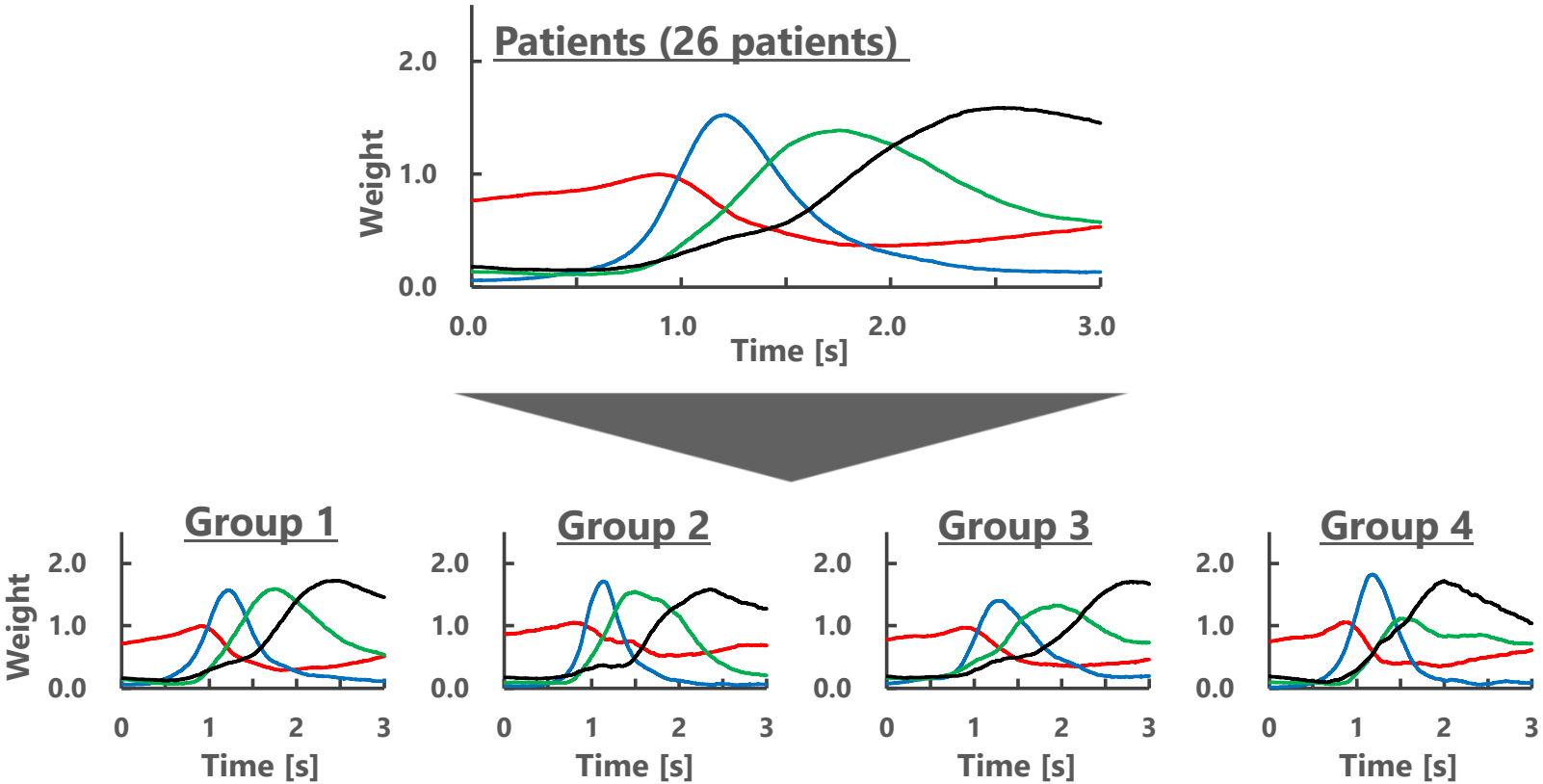
Aim: Clarify muscle synergy structure of stroke patients

- **Measure stroke patient with motor impairment**
  - Stroke Patient : 26 people (Morinomiya Hospital)
    - 58.9±12.7 yrs (22 male, 4 female)
    - Moderate-Mild (FIM: 74.3±8.4/91)
    - Analyze paralyzed side
  - Healthy Elderly: 8 people
    - 64.4 years±3.3 years, 8 male

- **Extract synergy from each patients and divide 26 patients divided into clusters based on temporal patterns**

Cluster Analysis

- 26 patients are divided into 4 groups considering clustering performance



Muscle Synergy in Stroke Patients

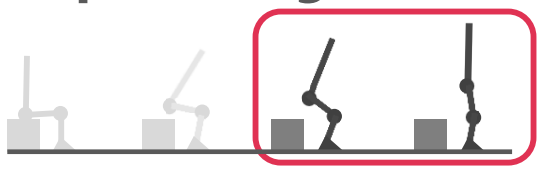
● Stroke patients have different synergy activation

Group 1: Relatively healthy group

Group 2: Longer activation of synergy 1

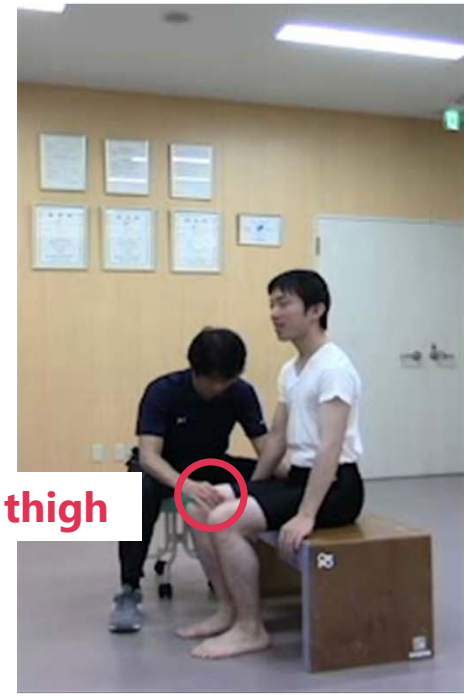
Group 3: Longer activation of synergy 2

Group 4: Merged activation of synergies 3 and 4



Intervention of Physical Therapist

- Physical therapist (PT) intervenes the affected side:
  - Distal front of thigh
  - Posterior pelvis

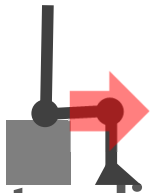


EMG Measurement of PT

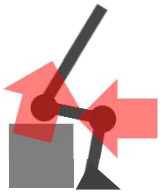
- Analyze EMG from upper limbs of physical therapist
- Clarify ***how*** and ***when*** they intervenes patients

Effect of PT Intervention

- PT intervenes the patient as follows
  - Pulling the distal thigh before buttocks leave



- Extending the knee and supporting pelvis



- PT Intervention improved muscle synergy structure
  - change activation timing earlier
  - shorten activation duration properly

Sense of Agency (SoA)

Temporal Delay in Tele-operation

Sensor data

Communication

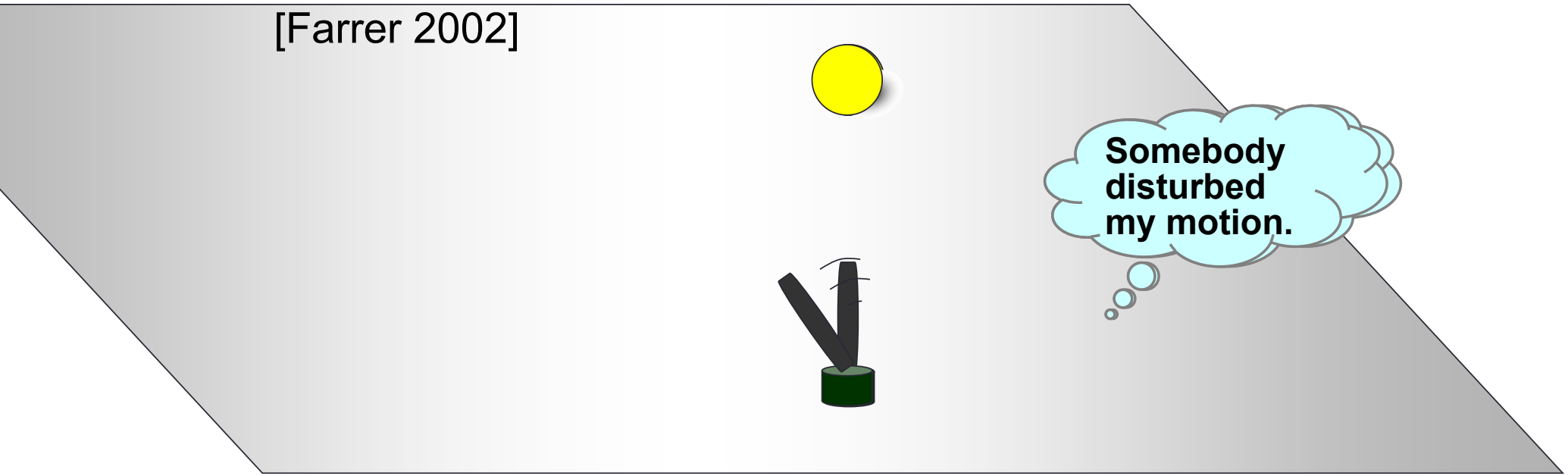
Control command

Machine

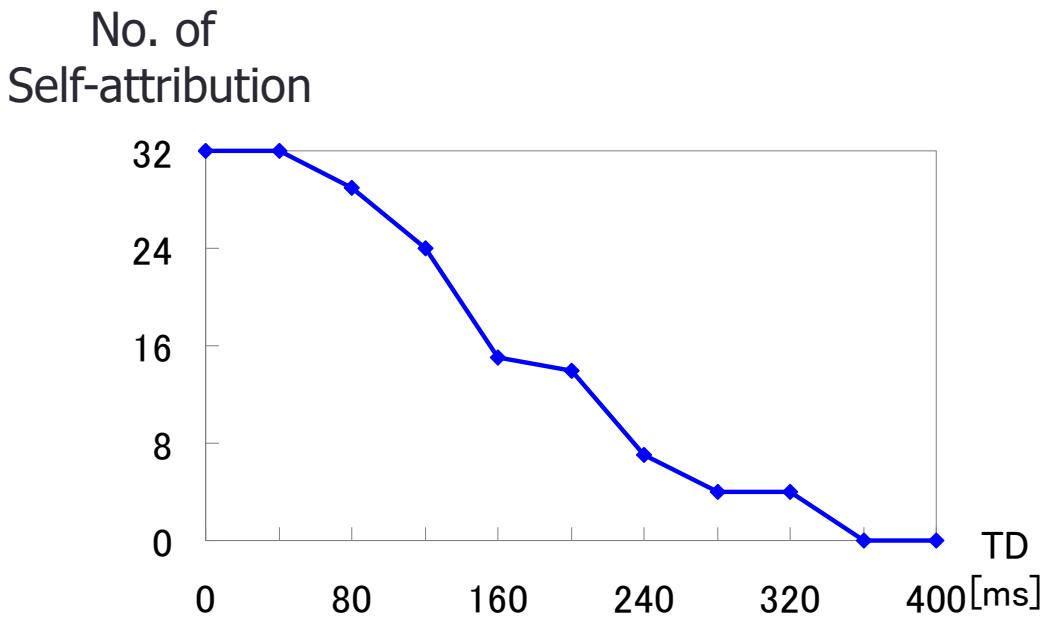
Operator

Sense of Agency (SoA)

- **The sense that the subject is the one who is causing or generating an action.**
  - Generated in the brain
  - Associated to the active motion of the subject

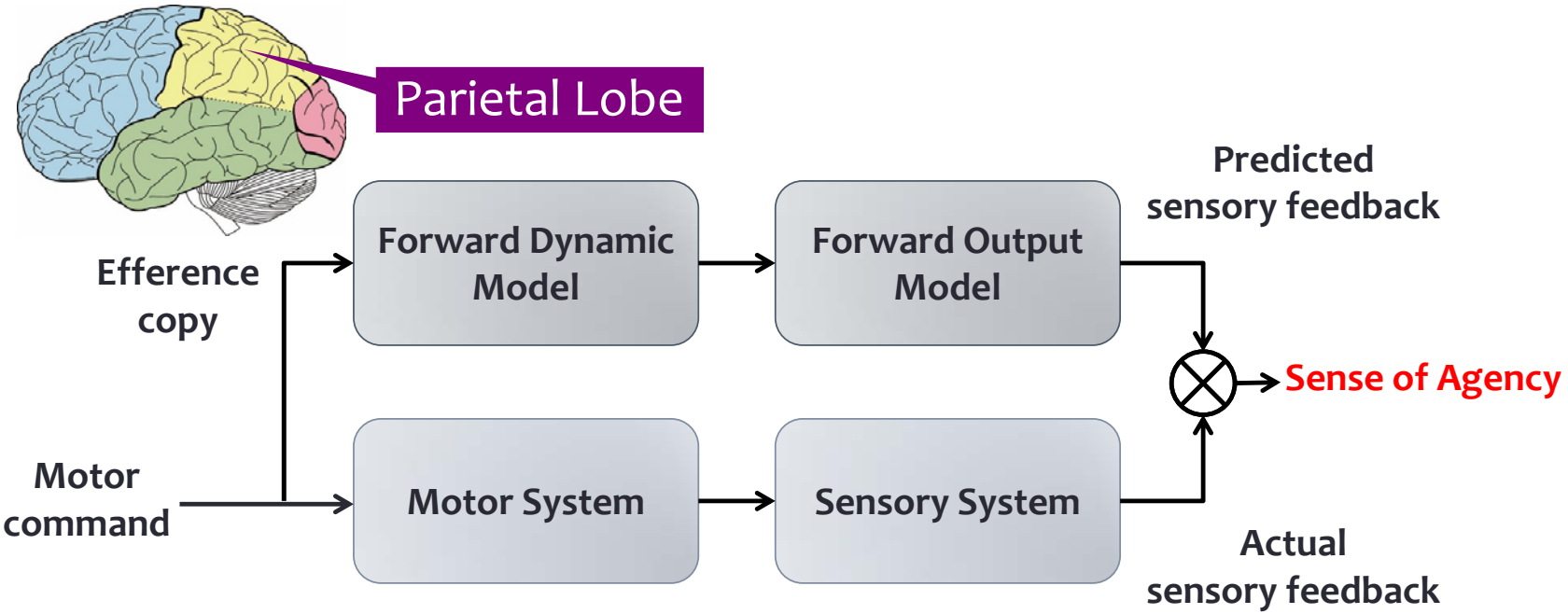


Results



Total of 8 subjects

Comparator Model

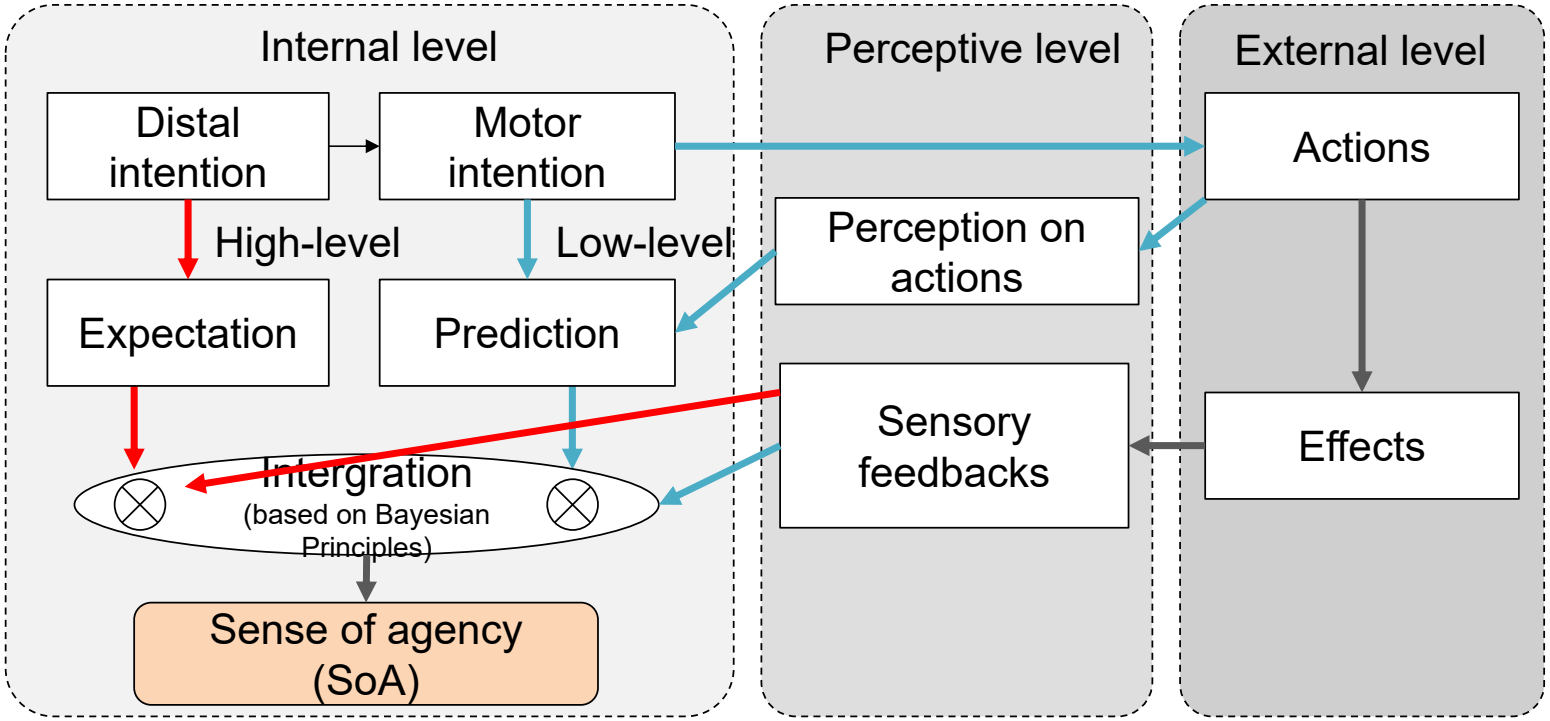


(Blakemore, 2003)

Difference is small: Motion is attributed to "self"
Difference is large: Motion is attributed to "others"

The Influence of High-level Cognitive Process on SOA

- Modified Comparator Model



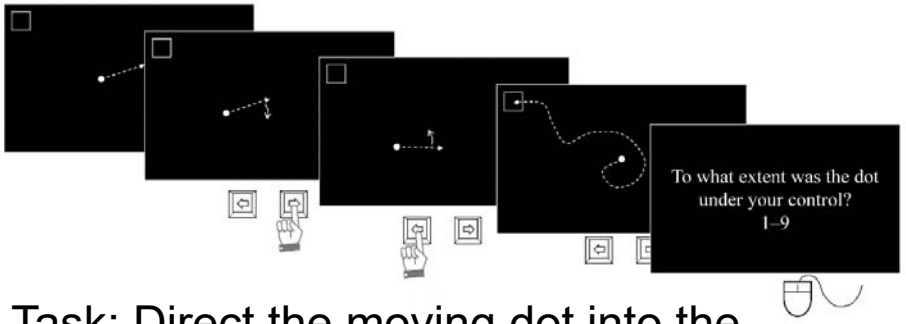
Sensory processes mentioned in the comparator model

High-level cognitive process (the present study)

Wen Wen, Atsushi Yamashita, Hajime Asama: "The Influence of Goals on Sense Control", Consciousness and Cognition, Vol.37, pp.83-90 (2015).

Embodied-Brain

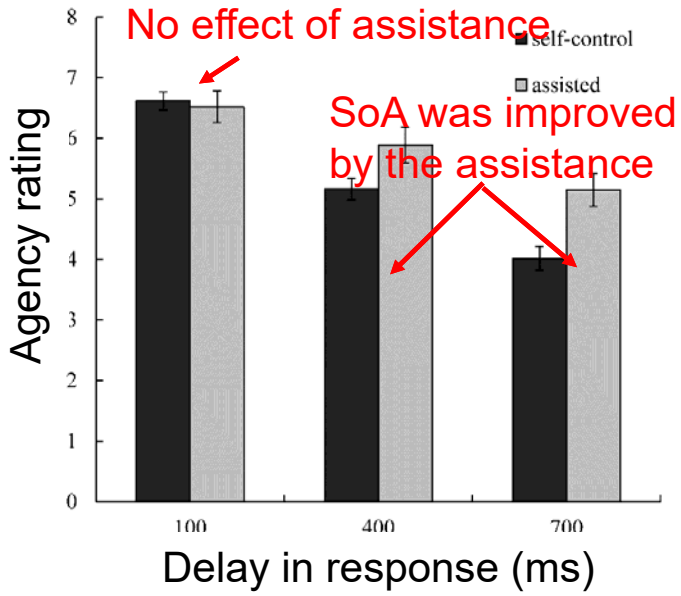
High-level vs. Low-level processes



Task: Direct the moving dot into the square as quickly as possible.

Independent variables
- Delay in response (100, 400, or 700 ms)
- Assistance of computer (Improving task performance by ignoring erroneous commands)

Assistance: Promotes high-level process (performance-based inference) while impairing low-level process (action-effect comparison)



SoA are influenced by both the high- and low-level processes, and the high-level process would be more dominate when the low-level process is less reliable.

Wen Wen, Atsushi Yamashita and Hajime Asama: "The Sense of Agency during Continuous Action: Performance is More Important than Action-Feedback Association", PLoS ONE, vol. 10, no. 4, e0125226, pp. 1-16 (2015).

Embodied-Brain

Rehabilitation taking account of SoA

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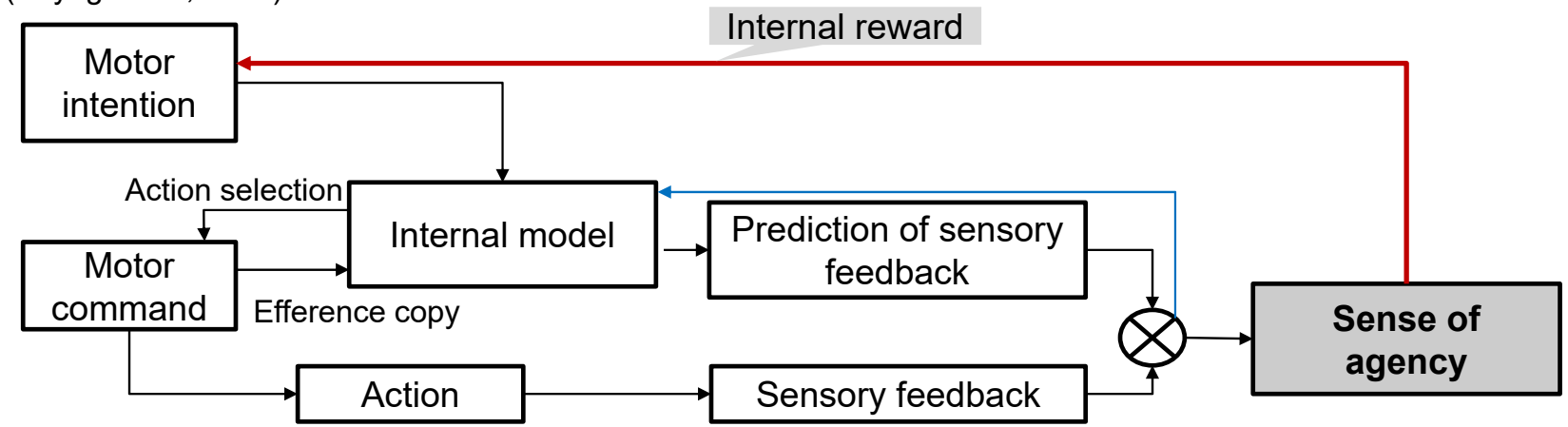
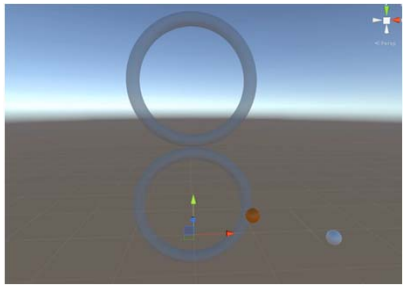
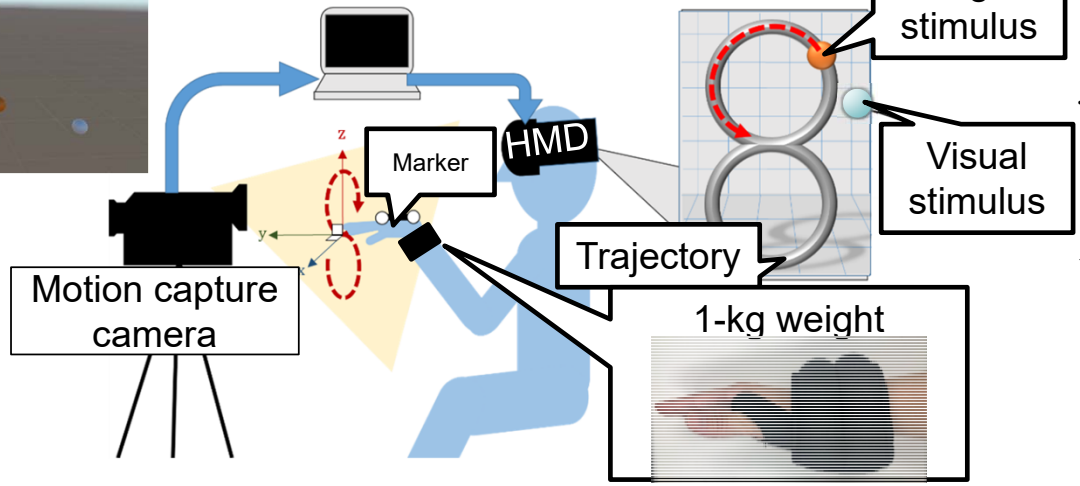
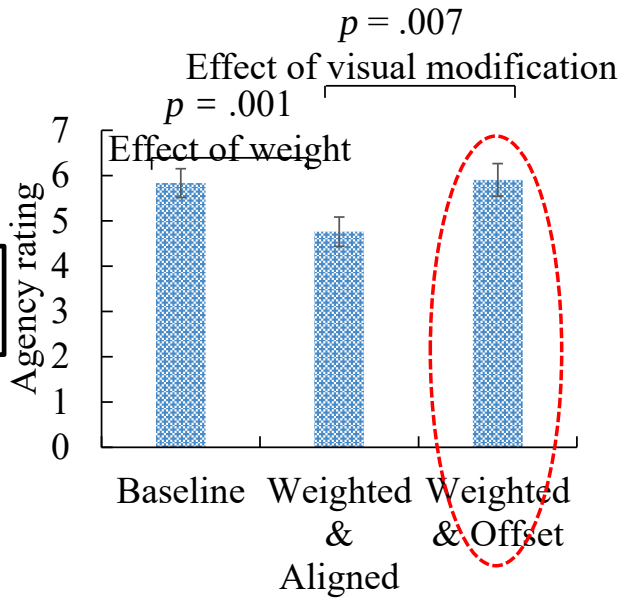
The role of sense of agency in motor rehabilitation

(Aoyagi et al., 2020)









Smartphone Zombie Detection and Avoidance

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Dept. of Precision Engineering
The University of Tokyo

Pedestrian trajectory data from Lidar data

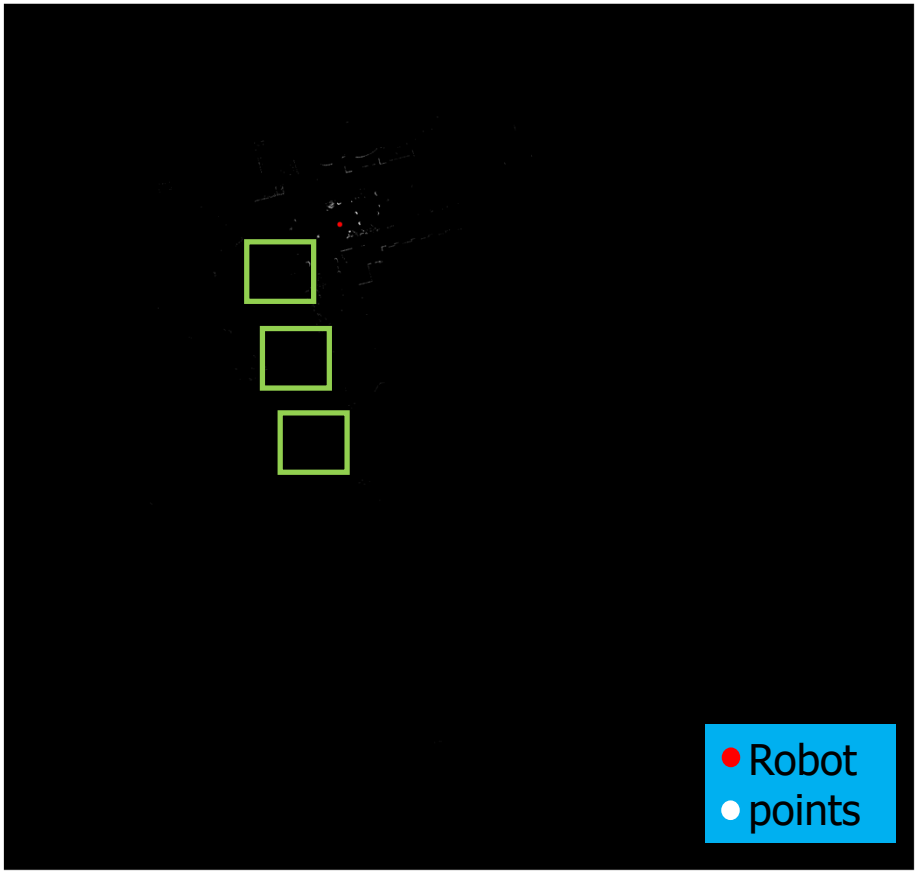


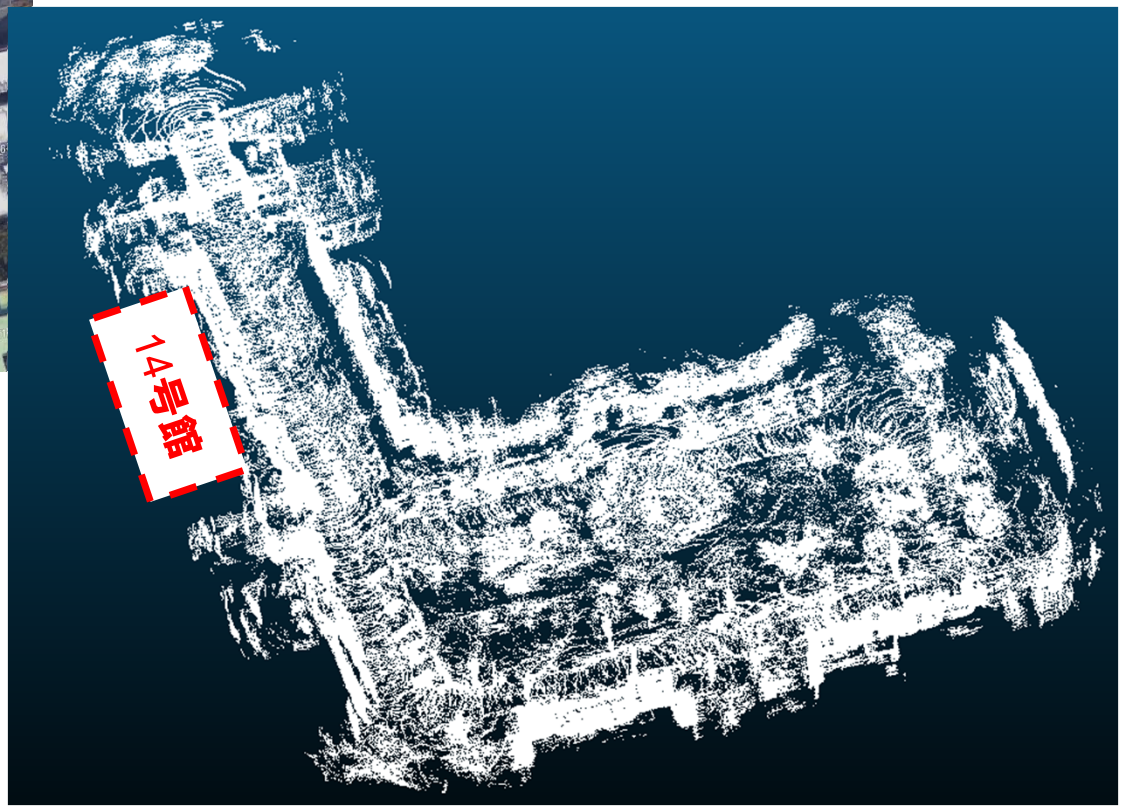
Fig. 5 projection of Lidar point cloud on x-y plane

- Thresholding z direction (eliminate ground)
- Project 3D point could to X-Y plane
- Quantize the point could to 2D grid map (an image)

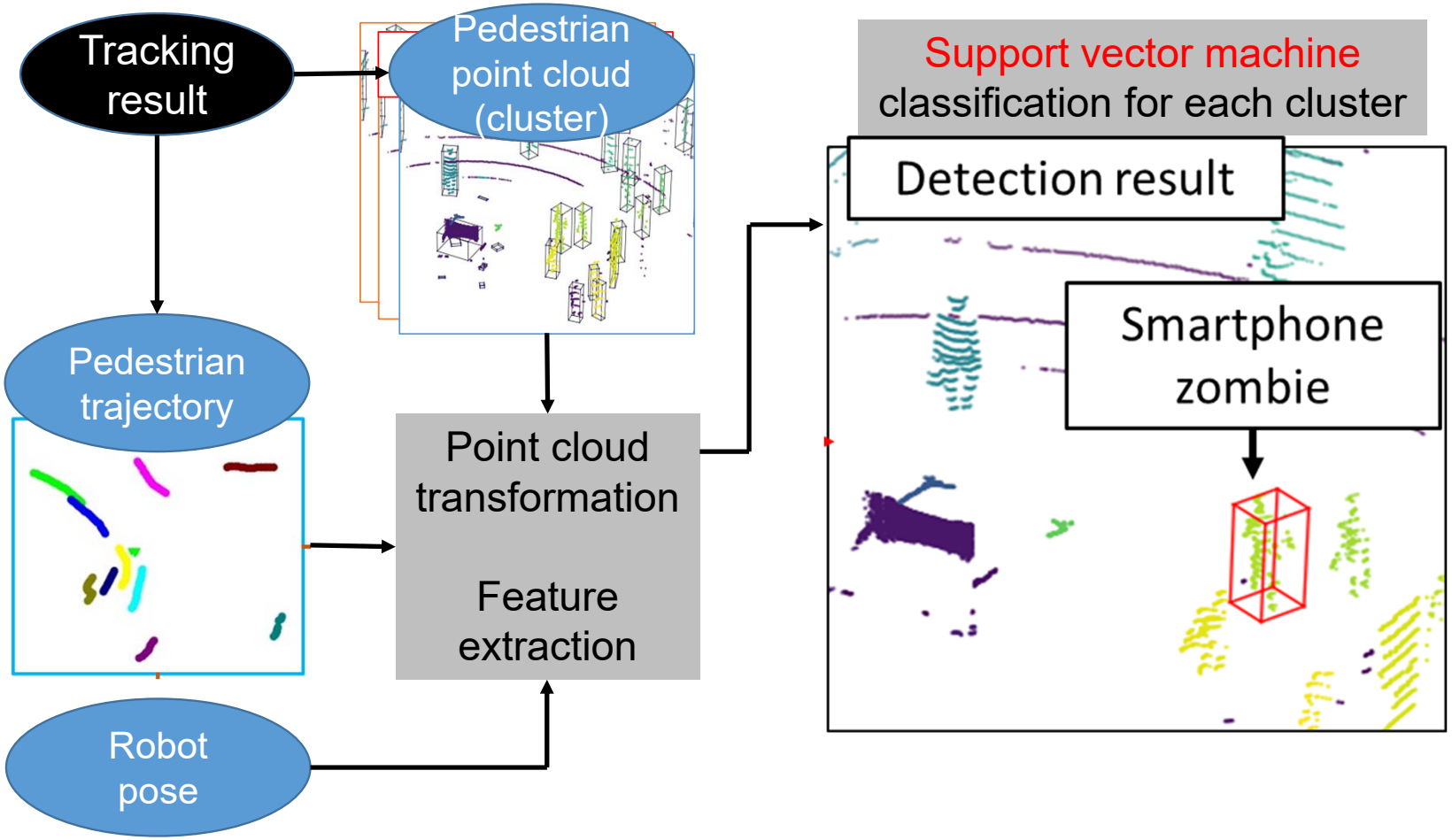
- Human trajectory is recognizable
- Tracking pedestrian in global view confront too many noise (leaves or other artifact)

Thresholding x, y direction to reduce noise
- Create a sliding window centered at robot

Mapping

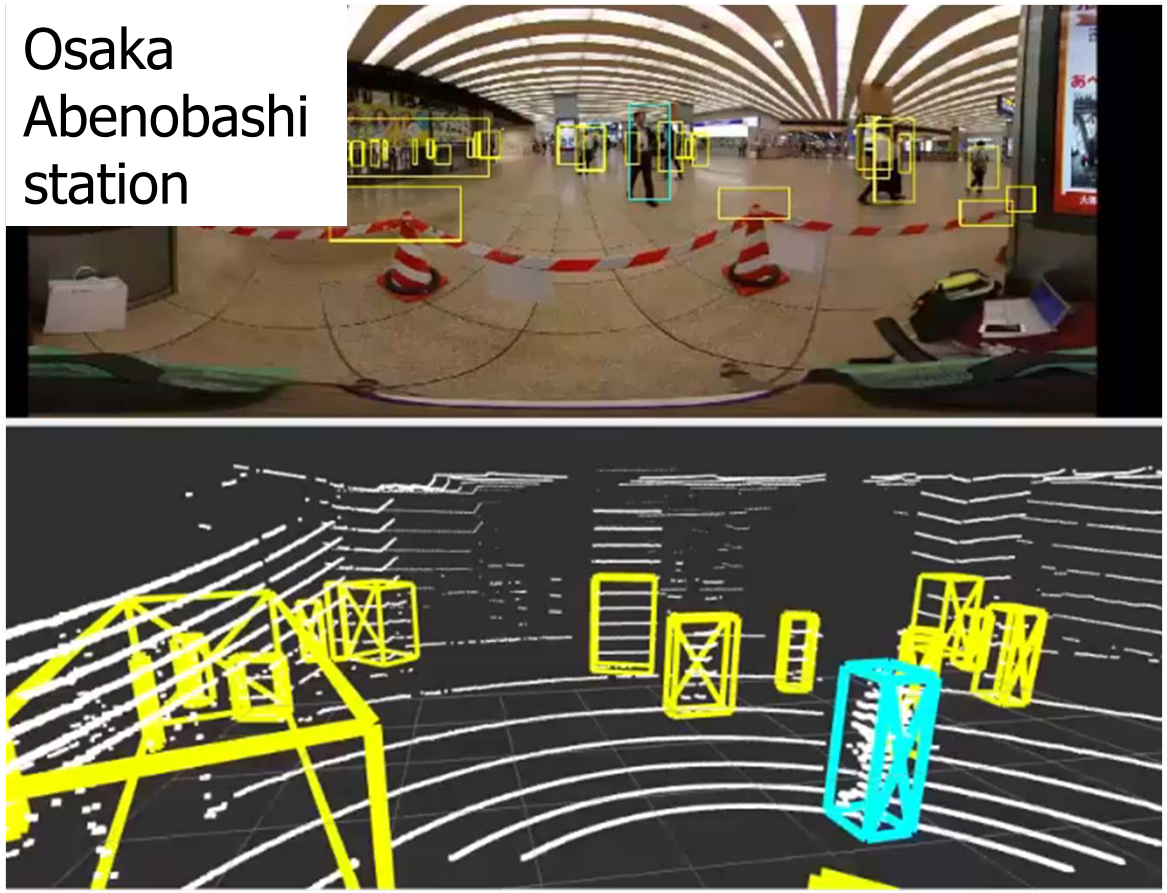


Overview of smartphone zombie detection



Data collection for training smartphone zombie detector

New dataset collected from two stations at 2019.2.21 and 2019.7.3



Other object

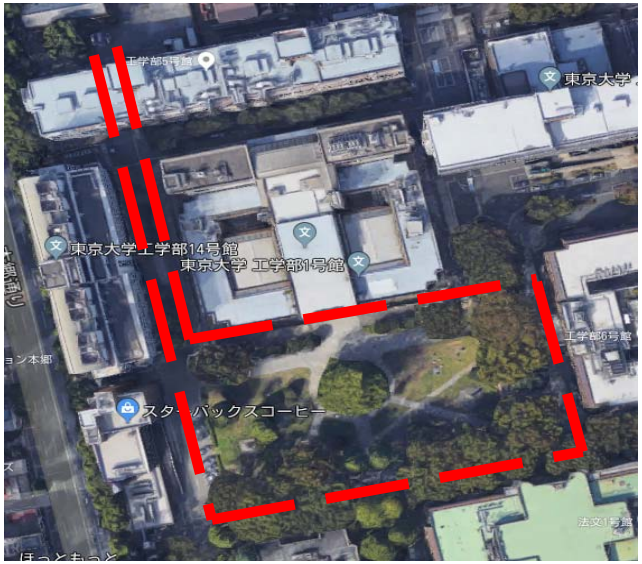
Smartphone zombie

- Point cloud: Velodyne LiDAR
- Image: spherical camera (Ricoh Theta V)
- Label: manual annotation

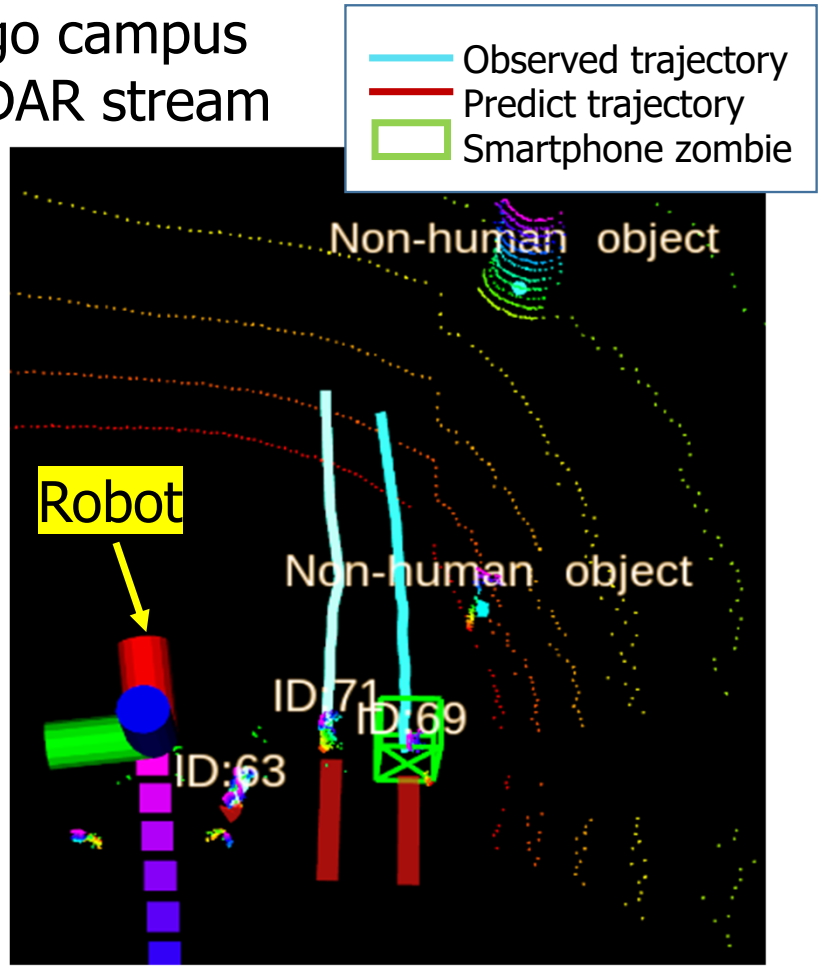
Experiments

- The robot moving inside Hongo campus

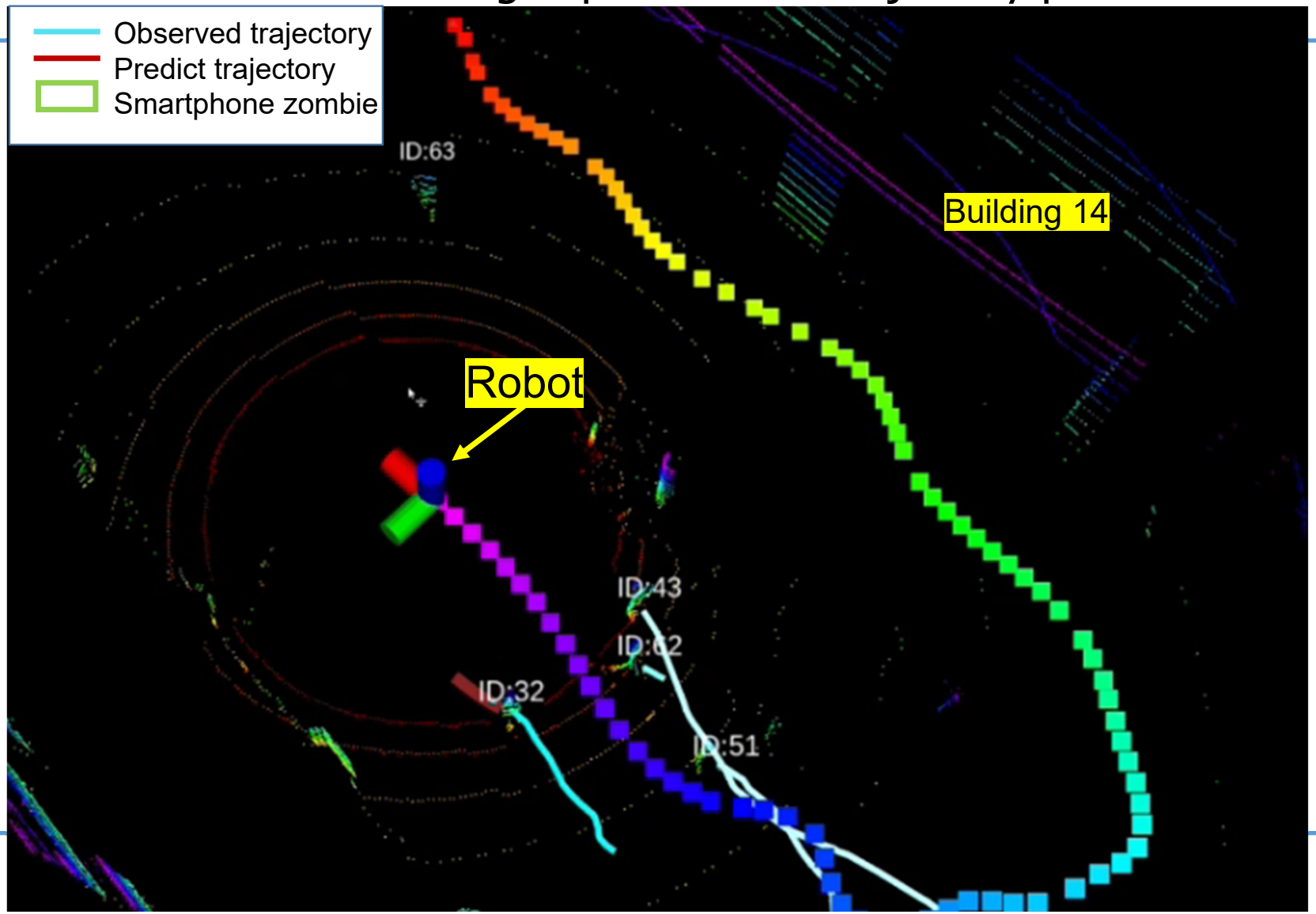
Approximately 15 minutes of LiDAR stream were used in evaluation



Experiment area in Hongo campus



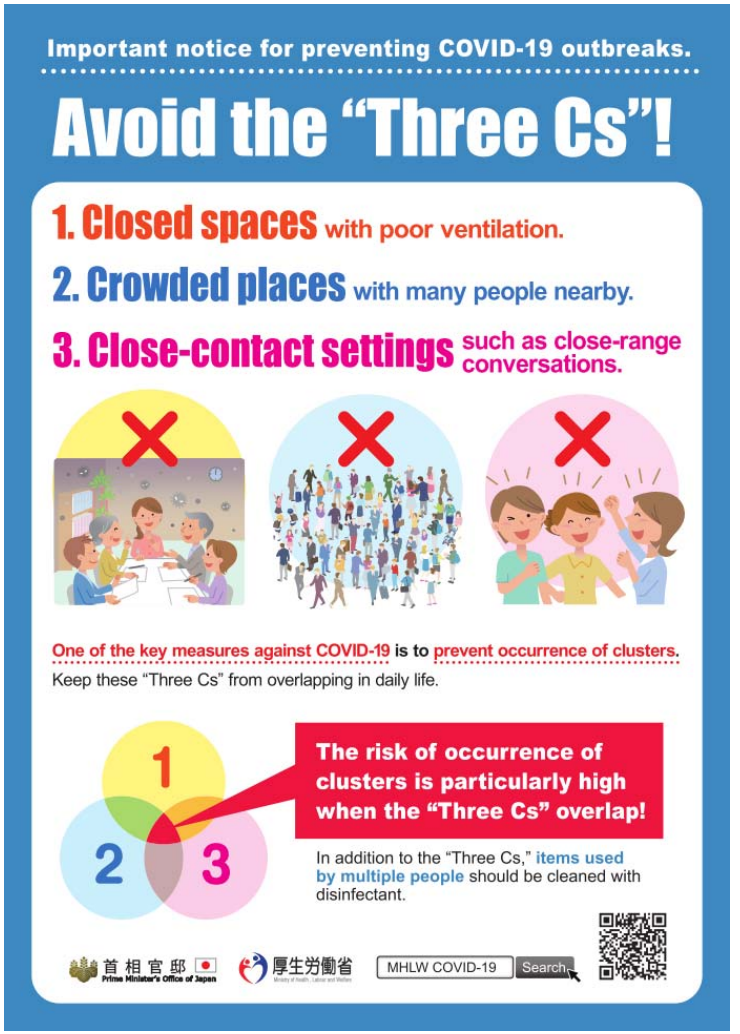
Video recorded during experiments – trajectory prediction



Video recorded during experiments – smartphone zombie detection

Needs of RT for response to COVID-19

- Avoid the Three C's
- Reduce contacts for Infection prevention



Needs of Robot Technology for Pandemic Disasters

Providing services without physical contact

- Direct Needs (Medical)
  - Medical treatment
  - Specimen collection, test, inspection
  - Transportation of patients, monitoring
  - Disinfection, sterilization, cleaning, pollutant treatment, disposal
  - Transportation (meal, medicine)
- Indirect Needs
  - Delivery, serving, transportation (meals, medicine)
  - Remote communication (including customer service, monitoring)
  - Disinfection
  - Temperature measurement

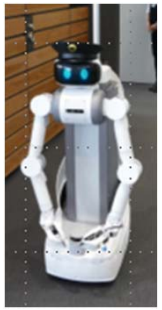
Case study of introduction / demonstration test

Disinfection, cleaning








Delivery, transportation








Measure-ment

Specimen collection, Test


Communication

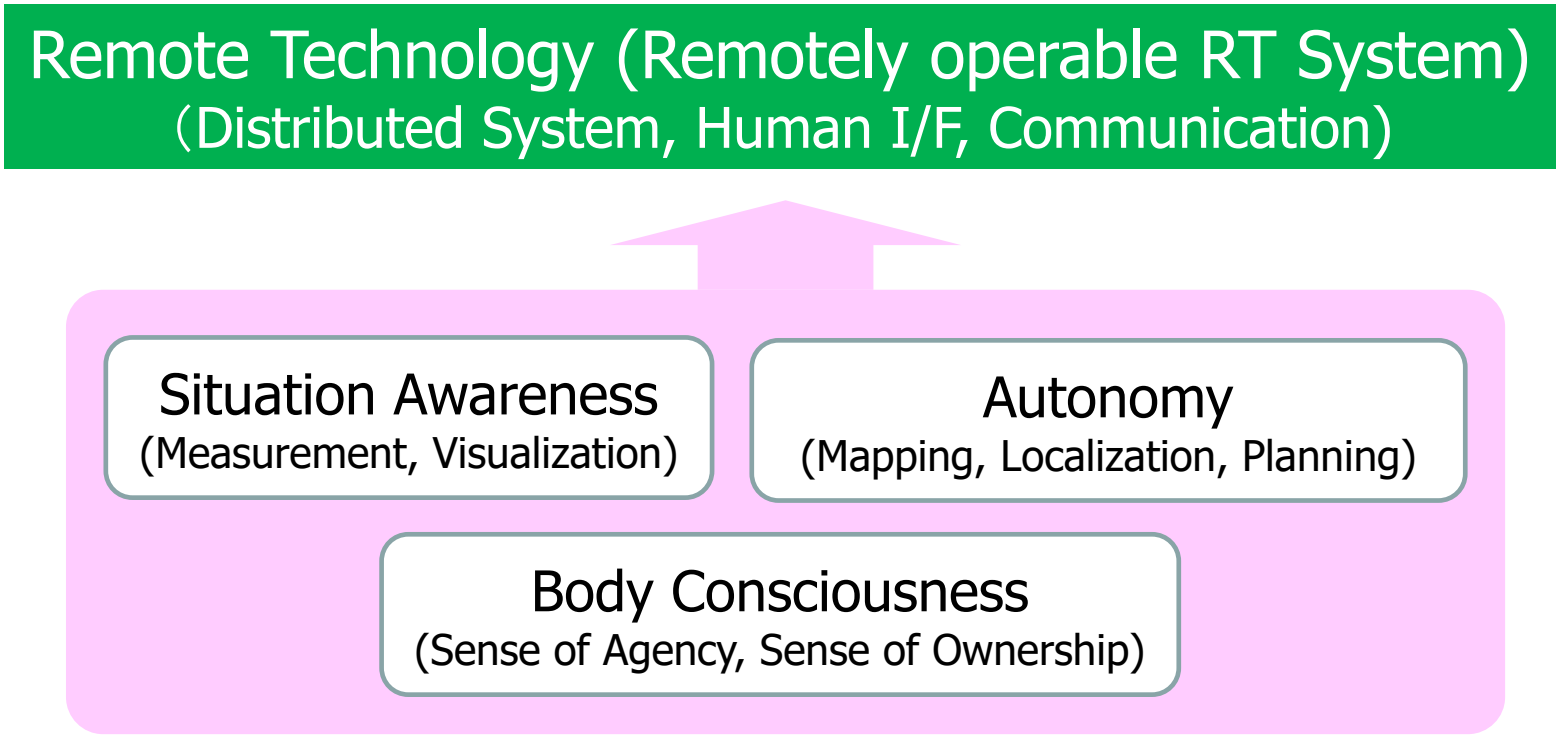



Customer service



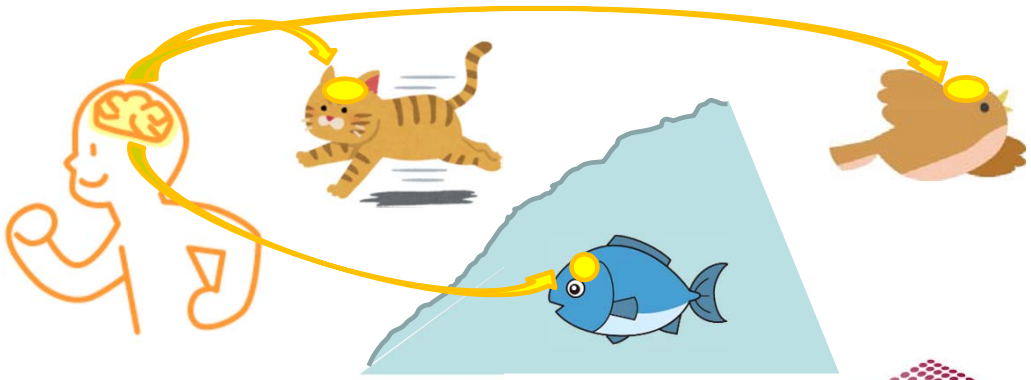
Monitoring


RT System Required at the Sites



Intelligence required for robots

- Can intelligent robots be realized only by mounting AI on the robot platforms?
  - Ill-defined, ill-structures, adaptive response to unknown situation
  - Noises, real-time
  - Blackbox, explainability, overfitting
- Intelligence required for motion control dependent on body
  - Is human brain functional if transferred on bird, cat, or fish?



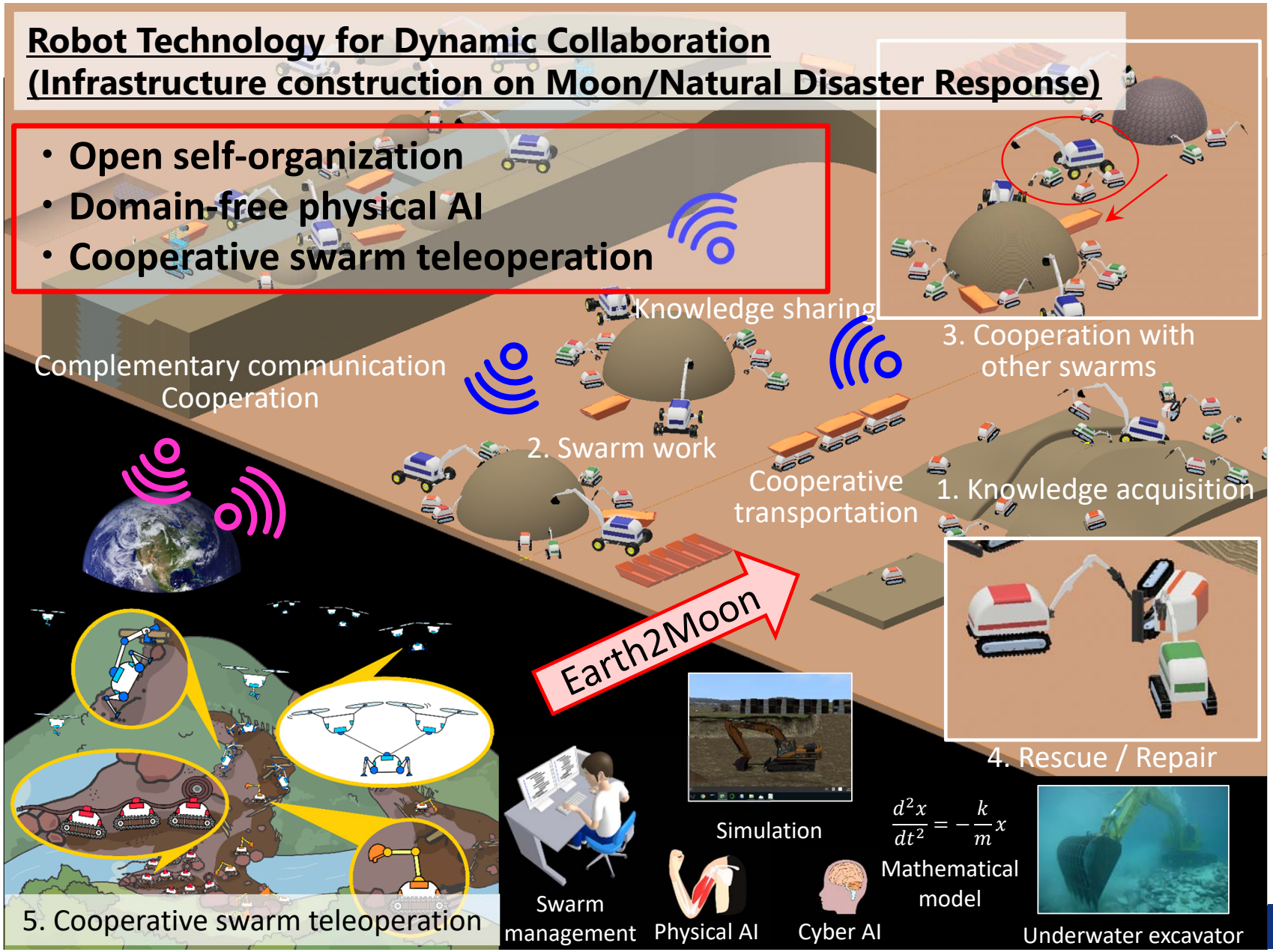
Moonshot Research and Development Program

The Moonshot Research and Development Program sets ambitious goals to attract people, and promotes challenging R&D projects with the aim of resolving difficult societal issues while bringing together the wisdom of researchers from all over the world.

- Moonshot Goal #3 (PD: Prof. Toshio Fukuda)
- Realization of AI robots that autonomously learn, adapt to their environment, evolve in intelligence and act alongside human beings, by 2050.
- Innovation in Construction of Infrastructure with Cooperative AI and Multi-Robots Adapting to Various Environments (PM: Prof. Keiji Nagatani)
- Robot Technology for Dynamic Collaboration

Robot Technology for Dynamic Collaboration (Infrastructure construction on Moon/Natural Disaster Response)

- Open self-organization
- Domain-free physical AI
- Cooperative swarm teleoperation



Summary

- Derive solutions (Needs-oriented R&D is necessary)
- Understand human (Humanity & social science, medical science)
- Systems theory and engineering (Means to design systems)
- Physical AI (Autonomous systems)
- Humanitarian viewpoint vs economic viewpoint
- International cooperation (Concentration of wisdom, Solidarity - Harmony)

IFAC
INTERNATIONAL FEDERATION OF AUTOMATIC CONTROL

IFAC2023 YOKOHAMA

22nd IFAC World Congress 2023

Yokohama, Japan

Jun-ichi Imura General Chair

Hideaki Ishii IPC Chair

IFAC Japan NMO

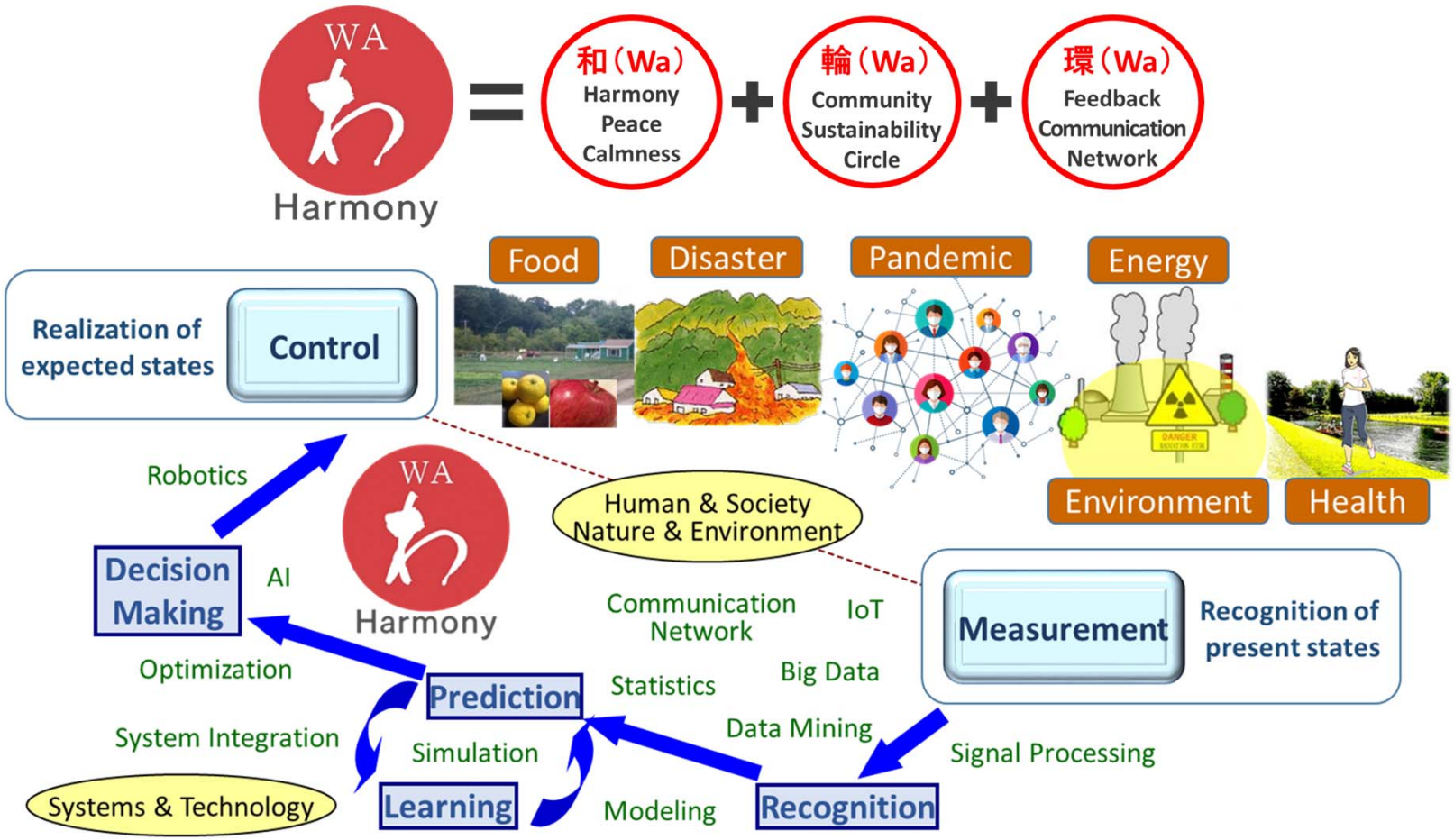
22nd IFAC World Congress 2023

Venue: PACIFICO Yokohama

Dates: July 9th (Sun) – 14th (Fri), 2023

PACIFICO Yokohama
(All-in-One Venue)

Control for Solving Societal Problems and Creating Societal Values



Congress Highlights: Industry

K. Asano (JFE Techno-Research Corp)

IFAC 2023 Industry Group (Chair: Kazuya Asano)

- 17 subgroups on various technical areas including more than 100 members (about half are affiliated with industrial companies in Japan)
- Goal: To identify societal problems that the industry faces and find control oriented solutions enhanced by new tools from Data Science, AI, DX, …
- Approach
  - Advertise IFAC activities to the industry
  - Encourage their participation in organizing events with TCs
  - Support presentation of their current problems and new developments
- In collaboration with Tariq Samad and Industry Committee of IFAC

17 subgroups

1. Mechatronic Systems (M. Hirata)
2. Power and Energy Systems (Y. Iino)
3. Machinery and Robotics (K. Osuka)
4. Steel Manufacturing Processes (H. Kitada)
5. Chemical Processes (H. Tanaka)
6. Automotive Control (Y. Yasui)
7. Smart Cities (M. Kohno)
8. Control in Agriculture (S. Hidaka)
9. Control in Construction (K. Nagatani)
10. Aerospace Technology (M. Sato)
11. Marine Systems (H. Yoshida)
12. Environmental Systems (M. Hashizume)
13. Biological and Medical Systems (K. Kawashima)
14. Systems Science and Technology (T. Kaihara)
15. Internet of Things (S. Takai)
16. Artificial Intelligence (K. Nakadai)
17. Measurement and Instrumentation (T. Tanaka)

Congress Highlights: Program

International Program Committee (Chair: Hideaki Ishii, Co-Chair: Yoshio Ebihara)


Hideaki ISHII


Yoshio EBIHARA

- Submission categories
  - Regular, Invited, Open invited tracks
  - Extended abstracts, Demonstrator
  - Discussion papers
    - For discussing specific topics by non-academic participants
    - Late deadline in February 2023
  - Dissemination papers
    - Papers recently accepted by IFAC journal can be presented at the congress
- Special sessions on the Congress Vision “Wa” in collaboration with the Industry Group

See you in Yokohama, Japan in 2023 !!

22nd IFAC World Congress

PACIFICO YOKOHAMA

9 July -14 July, 2023

20 July, 2020	22nd IFAC World Congress Promotional Video is now released.
9 July, 2020	22nd IFAC World Congress Official Website is now launched.

www.ifac2023.org

Thank you for your attention!

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