Introduction to the Mobile Robotics Lab
(OTA Lab)
2022

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Research Topics of the Mobile Robotics Lab (OTA Lab)

We have been studying multiple mobile robot systems since 1989. We consider intelligent systems as consisting of three factors: (a) multiple robots or intelligent machines (multiple agents), (b) human beings who operate or cooperate with multiple agents, and (c) working environments. Now we deal with "design of robotics system", "design of large-scale production/transport systems", and "human analysis, service, and hyper-adaptability science" based on motion planning methodology, evolutionary computation, control theory, and so on.

Our final target is to establish a design methodology for multi-agent systems including artificial agents, humans and working environments through clarifying the underlying structure and function in the intelligence and mobility (mobiligence) of these agents.

The details of our research are listed below.

Design of robotics system

- Development and manipulation planning of small mobile robot
- Contact state estimation using motion
- Measurement pose optimization in robot calibration using a hand-eye camera
- Design of mechanism using optimization according to task

Design and management of large-scale production, transport systems, and plants

- Proposal of a Task Assignment and Movement Planning Algorithm Considering Dynamic Characteristics of AGVs
- Skill Extraction of Expert Refinery Plant Inspectors Using Virtual Reality System
- Modeling of Manufacturing Systems for Expert Knowledge Description

Human analysis, service, and hyper-adaptability science

- Sway Analysis of Stroke Patients in Standing Posture
- Modeling Human Postural Control by Neural Controller Considering the Vestibulospinal Tract
- Motion Planning for Gait Initiation Focusing on Anticipatory Postural Adjustment
- Development of the wearable device for measuring finger joint angle
- Method to estimate the muscle activation pattern from MRI and EMG
- Development of Robot Patients System for Learning Wheelchair Transfer Skill
- Analysis of the Effects of Postural Feedback Training on Mental Health

Development and Manipulation Planning of Small Mobile Robot

Adopting robots in the manipulation of big-sized objects in domestic environments, human could be emancipated from such trivial works. However, big-scaled robots are not available in narrow domestic spaces. Owing to the small size and motion flexibility, small mobile robots are desirable for such tasks, because they can perform non-prehensile manipulation substituting manipulators by working cooperatively.

In our work, we adopted passive joints to design the mechanism of the multiple mobile robots [1,2], so as to realize the equivalent point—face contact model between the robots and the manipulated object. The costly controlling to maintain the object—robot contact could be avoided when manipulating the object. This simple contact model facilitated the manipulation planning, in which the contact state was required to be known to determine whether the robots provided adequate constraint for the manipulation.

In the manipulation planning, to deal with the distinct multi-level configuration space caused by the varying constraints in the robot-object system, a hierarchical method was adopted in our work. Defining a mode as a set of specific configurations that hold the same constraint, we specially focused on the modal planning, by which the manipulation action sequences could be determined to narrow down the configuration space for searching tasks [3]. Our proposed method determined the number of robots for manipulation stability, and investigated the mode transitions caused by the robots' motions and by the object's motions. With our method, the possible number of modes and their transitions was obviously reduced, and the determined mode sequences can be used to guide the further searching task for configuration planning.

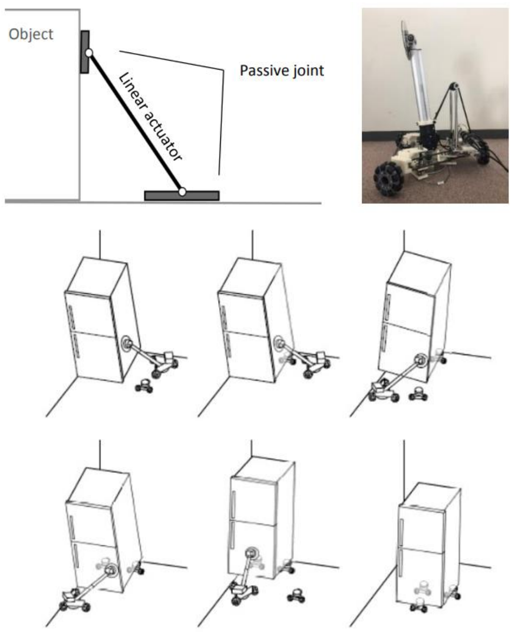

Figure 1. Constraints of the joints on the robotics leg using wires and non-circular pulleys.

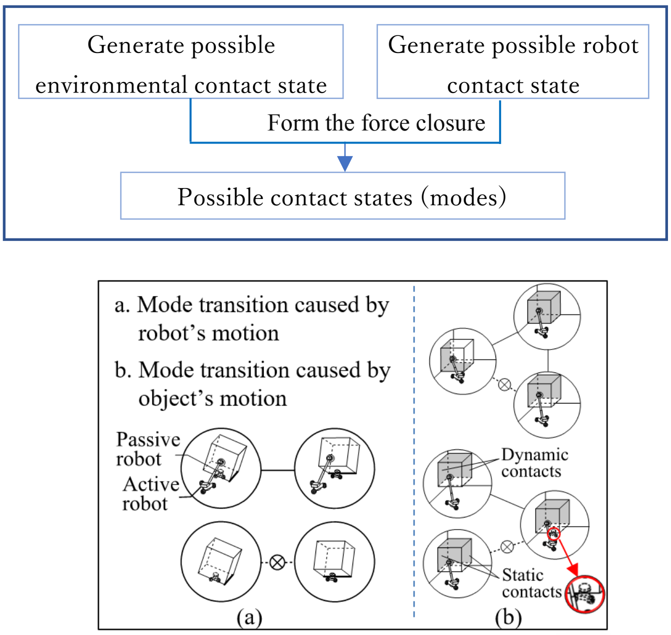

Figure 2. Mechanism to draw a letter on an egg-shaped object with less numbers of joints.

Keywords: mobile robot, simple contact model, manipulation planning, modal planning

References:

[1] S. Shirafuji, et al. Mechanism allowing large-force application by a mobile robot, and development of ARODA. Robotics and Autonomous Systems, 2018, 110: 92-101.

[2] T. Ito, S. Shirafuji, J. Ota. Development of a Mobile Robot Capable of Tilting Heavy Objects and its Safe Placement with Respect to Target Objects. In Proceedings of the 2018 IEEE International Conference on Roboics and Biomimetics (ROBIO2018), Kuala Lumpur, Malaysia, 12–15 December 2018; pp. 716–722.

[3] C. Fan, S. Shirafuji, J. Ota. Modal Planning for Cooperative Non-Prehensile Manipulation by Mobile Robots. Applied Sciences, 2019, 9.3: 462.

Contact State Estimation Using Motion

People can perform a variety of tasks by skillfully handling the contact between an object and its surroundings. For example, when loading and unloading goods in a warehouse, it is possible to save force compared to simply lifting the goods by sliding them. Such manipulation is also useful for robots.

To achieve such manipulation without applying unnecessary force, it is necessary to know the contact state (e.g., the surface or edge in contact) between the object and the environment. Therefore, it is important to estimate the contact state between the object and the environment based on the motion of the robot's hand.

In this study, we proposed a method for estimating the contact state between an unknown geometric object and an unknown geometric environment. We proposed an algorithm to estimate the contacting faces and edges from the motion of an object, and verified the method by experiments using a motion capture system.

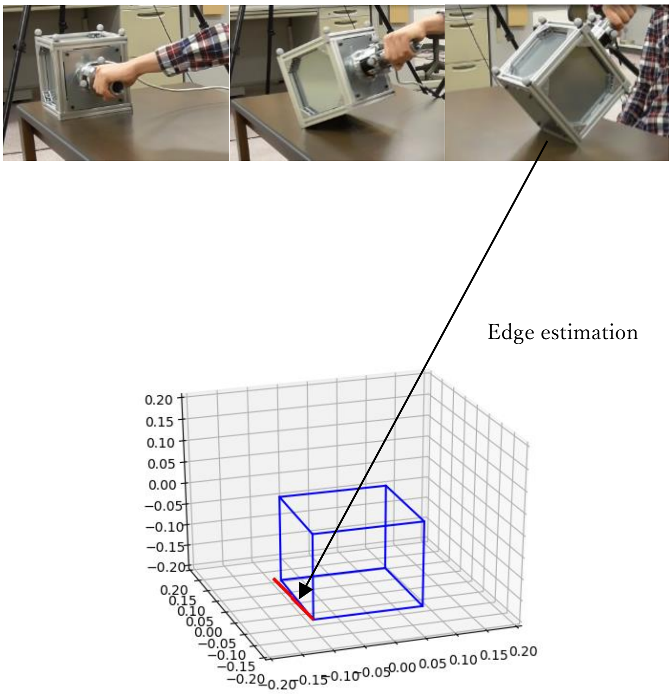

Figure 1. Experiment and result

Keywords: contact state estimation, compliant motion, manipulation

References:

[1] Seiya Ishikawa, Shouhei Shirafuji, and Jun Ota: "Objective Functions of Principal Contact Estimation from Motion Based on the Geometrical Singular Condition," Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems, Las Vegas, NV, USA (Virtual), pp.9465-9471, October, 2020.

[2] Ishikawa, S., Shirafuji, S. & Ota, J. (2019). Kinematics Analysis for Estimation of Contact Conditions in Teaching, Proceedings of the 2019 JSME Conference on Robotics and Mechatronics, Hiroshima, Japan, June 5-8, 2019

Measurement Pose Optimization in Robot Calibration Using a Hand-eye Camera

A kinematic model for controlling a robot is constructed based on kinematic parameters such as link length and joint offset. However, the kinematic parameters are subject to errors due to factors such as variations in robot processing and assembly and thermal expansion. Therefore, correction of the kinematic parameters, i.e., robot calibration, is necessary. In recent years, however, the use of hand-eye cameras has been attracting attention for its simplicity. However, the measurement accuracy of the camera is relatively low, and the calibration accuracy also decreases. In other words, there is a trade-off between the ease and accuracy of camera measurement.

On the other hand, it has been reported that the accuracy of robot calibration depends on the measurement pose, i.e., it depends on what pose the robot is placed in for measurement. In this regard, there is a study that optimizes the measurement pose under a certain constraint by sensitivity analysis of the relationship between the measurement pose and kinematic parameters. However, this method cannot be applied to robot calibration using a hand-eye camera, because the hand-eye camera must be able to capture the calibration marker, and the constraints of the robot hand change depending on the location of the marker.

Based on the above background, in order to achieve high accuracy in robot calibration using a hand-eye camera, we have proposed a method to optimize the measurement poses considering the constraints imposed by the hand-eye camera. By taking into account the effects of noise in the camera image on the estimation of the hand pose and the effects of errors in the hand-eye pose on the robot calibration, we can find a calibration pose that is less sensitive to the accuracy limitations of the hand-eye pose measurement by the camera through optimization. For example, simulation results show that an optimized measurement pose can be obtained as shown in Fig. 1, which confirms the improvement of calibration accuracy. Compared to conventional calibration using specialized equipment, this approach enables highly accurate robot calibration with a simple setup.

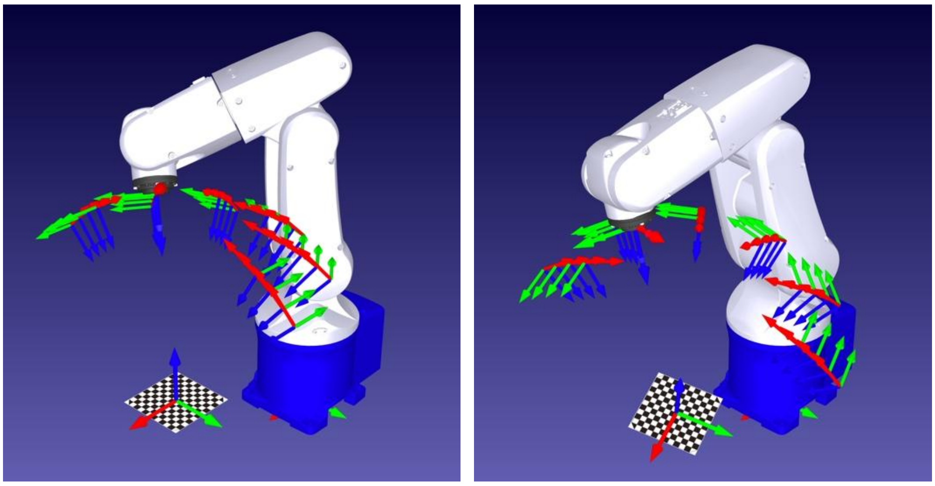

Fig.1 (Left) Initial measurement pose. (Right) Optimized measurement pose.

Keywords: robot calibration, optimization, hand-eye camera, absolute positioning accuracy

Design of Mechanism using Optimization According to Task

In the field of robotics, most of the studies focus on how to control the given mechanism to accomplish the target task. However, many tasks can be simplified or solved by preparing specified mechanism without sophisticated control method. Therefore, we are studying the methodology to derive the appropriate mechanism for a given task by calculation from the viewpoint of kinematics.

One of the outcomes of this study is the methodology to constrain the motion of a pair of revolute joints by a wire to generate the coordinated motion. We proposed the method to derive the shape of non-circular pulleys, which decides the route the wire, pass through, to realize the target coordinated motion of the joints [1]. An example of the applications designed by the proposed method is the leg mechanism of the robot, as shown in Fig. 1. This leg mechanism can move forward supporting its weight by the constraint on joints without controlling joints.

We also have proposed the methodology to decide the displacements of joints according to the task. We proposed the optimization method to decide the joint displacements of a manipulator that realizes the given target trajectory of its end-effector with less number of joints [2]. In the proposed method, the calculation of the errors between the target trajectory and resultant trajectory generated by design using the differential inverse kinematics realize the optimization with small calculation cost. Fig. 2 shows the manipulator, which we designed using the proposed method, can draw a letter on an egg-shaped object. This manipulator can draw the target letter on the curved shape only with three joints.

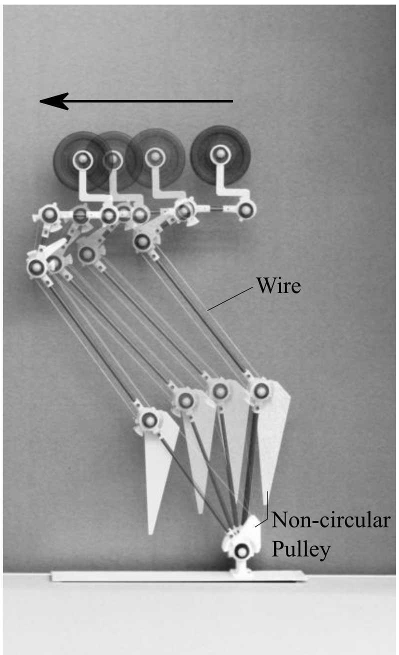

Figure 1. Constraints of the joints on the robotics leg using wires and non-circular pulleys.

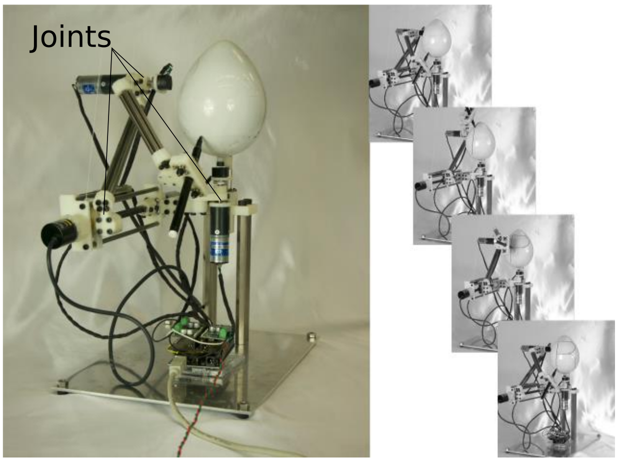

Figure 2. Mechanism to draw a letter on an egg-shaped object with less numbers of joints.

Keywords: robot design, optimization, kinematic synthesis, wire, non-circular pulley

References:

[1] Shouhei Shirafuji, Shuhei Ikemoto, and Koh Hosoda: "Designing Non-circular Pulleys to Realize Target Motion between Two Joints," IEEE/ASME Transactions on Mechatronics, vol.22 no.1, pp.487-497, 2016.

[2] Shouhei Shiarafuji and Jun Ota: "Kinematic Synthesis of a Serial Robotic Manipulator by Using Generalized Differential Inverse Kinematics," IEEE Transactions on Robotics, vol.35 no.4, pp.1047-1054, 2019.

Proposal of a Task Assignment and Movement Planning Algorithm Considering Dynamic Characteristics of AGVs

The use of Automated Guided Vehicles (AGVs) is expanding against the backdrop of the automation of logistics warehouses and the increasing flexibility of manufacturing lines. To operate a system consisting of multiple AGVs, it is necessary to solve two types of problems: the problem of assigning a material transfer request (hereinafter referred to as "task") to each AGV, and the problem of motion planning from the initial position of each AGV to its destination. It is important to complete each task as quickly as possible while avoiding collisions between AGVs. In general, AGVs run with a constant acceleration/deceleration pattern, and it is necessary to consider such AGV dynamic characteristics to avoid collisions between AGVs operating in the real world and to derive the optimal route. However, previous studies in this field have not optimized AGVs to reflect their dynamic characteristics. Therefore, the objective of this study is to design an algorithm for task assignment and motion planning that takes into account the dynamic characteristics of multiple AGVs.

Conflict-Based Search with optimal Task Assignment (CBS-TA) [1] by Hönig et al. with optimality and completeness is known as an algorithm for solving the task assignment and motion planning problems. In this study, we propose an algorithm based on the CBS-TA framework that performs task assignment and motion planning using multiple search trees. The proposed algorithm has the following features: 1.

(1) Optimization is performed based on the movement cost considering the dynamic characteristics of AGVs.

(2) Consistent optimization from task assignment to the completion of goods transportation.

The above is achieved by using a heuristic function that reflects the dynamic characteristics of the AGV to calculate the estimated cost in the search process, and by sequentially performing motion planning for picking up supplies and motion planning for transporting them. To verify the effectiveness of the proposed method, we solved the problem shown in Fig.1 using both the conventional and proposed methods and obtained the results shown in Table 1. By performing the optimization consistently, a solution that takes into account the effects of standby movements and turning was obtained over the entire time the AGV is in operation. In the future, we will investigate algorithms that can handle problems in which tasks are repeated or disturbances occur along the way.

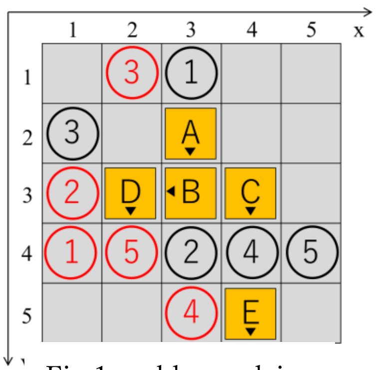

Fig.1 problem-solving

Table 1 Results

アルゴリズム	割り付け結果	全AGVの総移動時間 [s]	計算時間 [s]
CBS-TA + CBS	タスク1:A タスク2:B タスク3:D タスク4:C タスク5:E	197.20	1.53×10^{-1}
提案手法	タスク1:B タスク2:D タスク3:A タスク4:C タスク5:E	188.54	2.37×10^{-1}

[1] Hönig, W., Kiesel, S., Tinka, A., Durham, J.W., Ayanian, N.: Conflict-Based Search with Optimal Task Assignment. In Proceedings of the 17th International Conference on Autonomous Agents and Multi-Agent Systems (AAMAS). International Foundation for Autonomous Agents and Multiagent Systems, 757765 (2018)

Keywords: Multi-Agent Path Finding, Task Assignment, Motion Planning

Skill Extraction of Expert Refinery Plant Inspectors Using Virtual Reality System

A daily patrol inspection is conducted by human inspectors to prevent a serious accident from occurring in refinery. They walk through vast refinery area and try to find defects such as leakages or corrosions, and expert inspectors can find even the slightest one that would be overlooked by inexperience or novice inspectors by using their rich experiences. In this study, we developed the virtual reality (VR) system to extract the inspection skills of expert human inspectors. Previous studies which addressed the skill extraction of inspection task has mainly focused on visual inspection [1], and measured and compared the eye behavior of expert inspectors and novices (e.g., [2]). However, in refinery patrol inspection, it is difficult for inspectors to fit all targets in the field of view at once due to the large size of inspection target. Therefore, due to this unique nature of the refinery, measuring the eye behavior alone is not a suitable manner for extracting expert skills in refinery inspection task.

From these backgrounds, in this study, we developed the virtual reality system which can measure both eye behavior (gaze position) and motor behavior (head position) during refinery patrol inspection task (Figure 1) [3]. Specifically, we integrated a part of refinery model into the virtual environment and set some defects on it based on the accident cases' reports. The inspection behavior for the model can be measured from both viewpoints of eye behavior and motor behavior by using the eye tracker inside the head mount display and lighthouse position tracking system.

Using the VR system we developed in this study, we measured and compared the inspection behavior between experts and novices. As a results, we found that expert inspectors tend to 1. gaze the refinery from a father distance, 2. set their head in lower position than novices. These results suggested because the information inspectors get from the target is changed depends on the body states of inspectors such as distance from the target and head height, hence, expert get different information from novices due to the differences in these motor behaviors, and this may lead the differences in detection rate in inspection task. In our future study, we will add other kinds of information than visual such as haptic, olfactory and auditory, and achieve the "multi-modal" skill extraction system for understanding expert inspection skill more deeply.

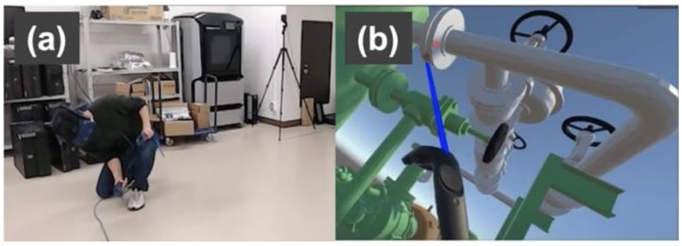

Figure 1. Virtual reality system for extracting skills of expert inspectors

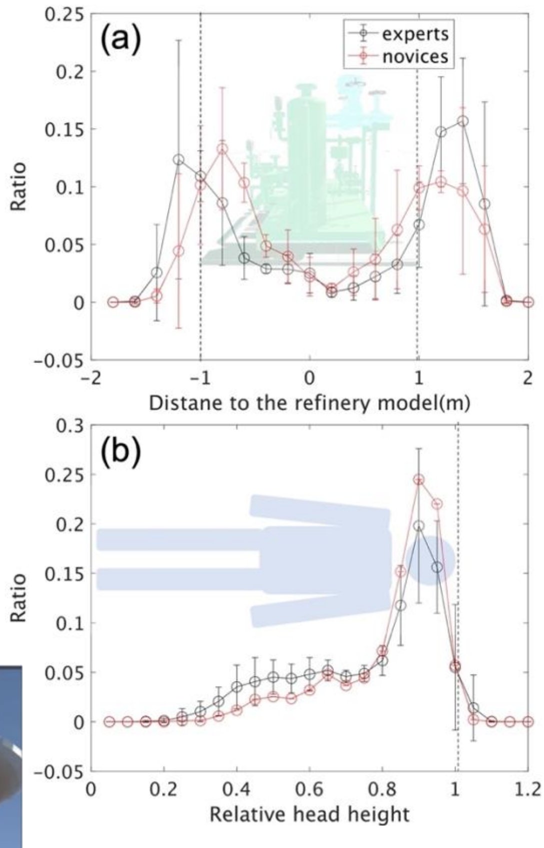

Figure 2. Results of our experiment, the differences between experts and novices in (a) distance from the model, (b) head height.

Keywords: Inspection, refinery, skill extraction, eye tracker

References:

[1] See, Judi E.: "Visual inspection: a review of the literature." *Sandia Report SAND2012-8590*, Sandia National Laboratories, Albuquerque, New Mexico, 2012.

[2] Dzeng, R. J., Lin, C. T., & Fang, Y. C. (2016). Using eye-tracker to compare search patterns between experienced and novice workers for site hazard identification. *Safety science*, 82, 56-67.

[3] Kurihara, S., Takamido R., Umeda, Y., Asama, H., Kasahara, S., Tanaka, L., … & Ota, J. (2022). Skill Extraction of Expert Refinery Plant Inspectors Using Virtual Reality System. Spring Meeting of the Precision Engineering Society 2022, H85. (in Japanese)

Modeling of Manufacturing Systems for Expert Knowledge Description

In recent years, many production systems, such as automatic assembly lines using robots, have become more complex due to their automation. In such systems, the workers on the shop floor often check the state of the production system and modify it to solve problems such as quality degradation and production inefficiency, as well as to improve equipment to cope with changes in plans based on their own experience. As systems become more complex as described above, how to efficiently perform such tasks with limited human resources will become important in the start-up and operation of manufacturing systems. In order to achieve this, it is necessary to have a mechanism to accumulate the experience and knowledge of expert workers and to be able to refer to the accumulated knowledge as necessary as the way that expert workers are doing in the shop floor today.

This study proposes a method of describing a model of a manufacturing system in terms of its elements and the order relationships among them. It is difficult to separate the knowledge of problem solving and improvements in manufacturing systems from the structure of the manufacturing system. Although various models of production systems have been proposed, it is desirable to use a model that can easily refer to the structure of the manufacturing system in relation to the knowledge in order to describe and refer to the knowledge of the manufacturing system. Furthermore, the knowledge of a person about a manufacturing system depends on how the person perceives the manufacturing system, and the knowledge of the manufacturing system abstracted in the mind requires a model that matches the level of the abstraction. The model of a manufacturing system proposed in this study describes the relationships among elements as simple ordered relationships, and we propose a mechanism to build this model based on the established system modeling language SysML. This description enables the construction of a model hierarchized by the aforementioned level of abstraction while maintaining the structure (ordered relations) of the described system, making it easy to trace the knowledge possessed by experts on the model of the system. We call this description "system lattice" and verify the proposed method by describing the process of an expert's identification of a problem occurring on an actual mock manufacturing line on the model of the system described by its system lattice. draw the target letter on the curved shape only with three joints.

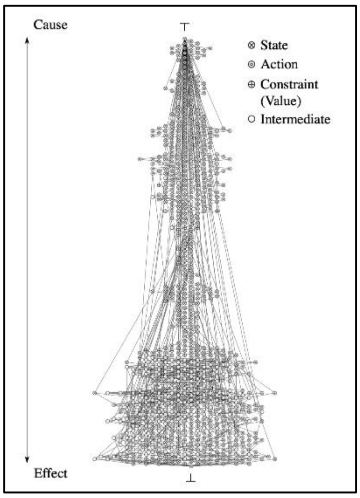

Figure 1. Target mock manufacturing line. **Figure 2.** System lattice of the system.

Keywords: Knowledge description, Manufacturing system, Modeling

Sway Analysis of Stroke Patients in Standing Posture

Stroke is a disease in which the brain's function is impaired due to a rupture or blockage of blood vessels in the brain, preventing blood from reaching the brain properly. It is known that the standing posture of stroke patients is more unstable than that of normal subjects, and the risk of falling is higher. Although the influence on standing postural control differs depending on the mechanism and site of stroke onset, and the appropriate rehabilitation and training methods may differ accordingly, detailed analysis has not been fully performed. We first focused on patients with cerebral infarction and cerebral hemorrhage, the two most common types of stroke, and investigated the differences in postural sway between them.

We used the dynamic time-warping method to cluster time-series data on the swaying of stroke patients in the standing posture [1]. As a result, the data were divided into different clusters mainly according to the number of days since onset. Among them, cerebral hemorrhage patients showed a clear transition between the number of days since onset and the cluster, whereas the relationship was not clear for stroke patients, indicating that there may be a difference in recovery with the passage of days between the two groups. The possibility of different postures during standing between cerebral infarction and cerebral hemorrhage patients has also been investigated [2]. In the future, we will analyze the findings of these studies in conjunction with the computational models we have constructed to clarify the differences in postural control mechanisms.

Keywords: Postural control, Stroke, Time-series clustering

References

[1] D. Li, K. Kaminishi, R. Chiba, K. Takakusaki, M. Mukaino and J. Ota, "Evaluation of Postural Sway in Post-stroke Patients by Dynamic Time Warping Clustering," *Frontiers in Human Neuroscience*, vol. 15, 2022, doi: 10.3389/fnhum.2021.731677.

[2] D. Li, K. Kaminishi, R. Chiba, K. Takakusaki, M. Mukaino and J. Ota, "Evaluating quiet standing posture of post-stroke patients by classifying cerebral infarction and cerebral hemorrhage patients," *Advanced Robotics*, vol. 35, no. 13-14, pp. 878-888, 2022, doi: 10.1080/01691864.2021.1893218.

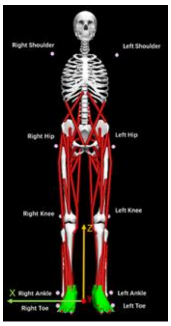

Figure 1. Marker positions used in the analysis. A total of 10 marker positions were recorded for the left and right sides.

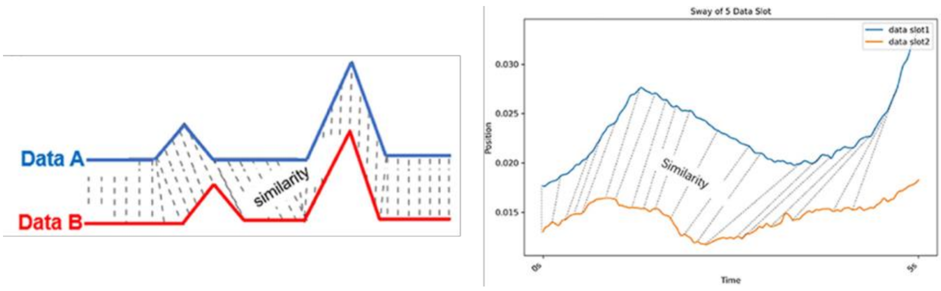

Figure 2. Conceptual diagram of the dynamic time-warping method and examples of similarities calculated with actual sway data.

Modeling Human Postural Control by Neural Controller Considering the Vestibulospinal Tract

Humans control their posture in their daily lives. When postural control is impaired by neurological diseases, their lives are restricted. It is essential to understand the postural control mechanism to reduce this restriction. The neural pathways play important roles in postural control. These neural pathways are the reticulospinal tract (RST) which controls stiffness (muscle tone) and the vestibulospinal tract (VST) which keeps their posture upright. However, the role of these neural pathways in human postural control has not been verified in detail. Therefore, we aim to verify the mechanism of human postural control by constructing a computational model focusing on these neural pathways.

We construct a computational model consisting of a musculoskeletal model with 17 degrees of freedom and 94 muscles and a neural controller model with controls based on the VST and RST. The validity of the computational model was verified by comparing simulation results to experimental results with human subjects. As a result, it was verified that control based on the VST enabled the musculoskeletal model to stand with lower muscle tone. In the absence of vestibulospinal tract-mimicking control, the postural sway was larger (Fig. 2). These results were similar to those obtained in actual human experiments. This confirms the validity of the constructed computational model [1]. By using this computational model, we aim to elucidate the mechanism of human postural control.

Keywords: Posture control, Vestibulospinal tract, Muscle tone

References

[1] Y. Omura, K. Kaminishi, R. Chiba, K. Takakusaki, and J. Ota, "A Neural Controller Model Considering the Vestibulospinal Tract in Human Postural Control," Front. Comput. Neurosci., vol. 16, 2022, doi: 10.3389/fncom.2022.785099.

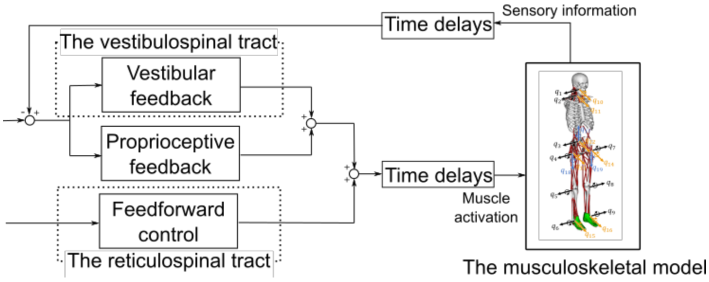

Figure 1. Computational model. The model consists of feedforward control based on the reticulospinal tract and feedback control based on the vestibulospinal tract. In addition, time delays due to information transmission and muscle activity are considered.

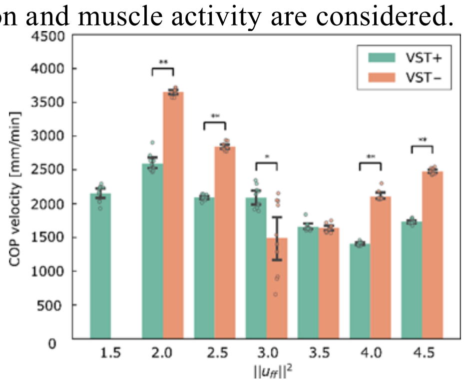

Figure 2. Center of pressure (COP) velocity. The green bar denotes COP velocity without VST. The orange bar denotes COP velocity with VST.

Motion Planning for Gait Initiation Focusing on Anticipatory Postural Adjustment

In the super-aging society, it is becoming increasingly important to solve the problem of human gait initiation. An anticipatory postural adjustment, in which the position of the center of plantar pressure (COP) moves backward during the stance phase, has been observed during gait initiation. Anticipatory postural adjustment has been observed in the elderly and Parkinson's disease patients, which is different from that in normal subjects, and is considered to be a cause of falls. Therefore, it is important to understand the action plan of anticipatory postural adjustment in the gait initiation in detail, but since anticipatory postural adjustment is an unconscious movement, it is not easy to investigate whether or not the patient falls without anticipatory postural adjustment in the gait initiation by a subject experiment approach. This has not been verified. In this study, we propose a simple mathematical model of gait initiation and show that anticipatory postural adjustment occurs, thereby deepening our understanding of action planning for anticipatory postural adjustment in gait initiation. A body model called a musculoskeletal model, which models the human body, is operated with a simple control model such as muscle length feedback. More than 1800 control parameters, such as feedback gains, are adjusted by optimization, and the anticipatory postural adjustment resulting from optimization is analyzed. The results show that the model can reproduce the movements from standing to gait initiation and gait, and reproduces the anticipatory postural adjustment that the COP moves backward, indicating that the anticipatory postural adjustment is effective for the gait initiation. We expect that these results will contribute to a better understanding of anticipatory postural adjustment during gait initiation, which is different from that of normal subjects in the elderly and people with Parkinson's disease, and the relationship between anticipatory postural adjustment during gait initiation and falls.

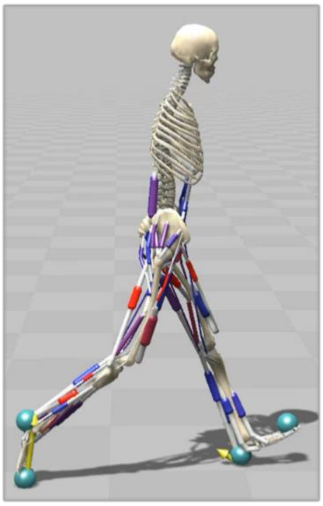

Figure 1. Musculoskeletal Model

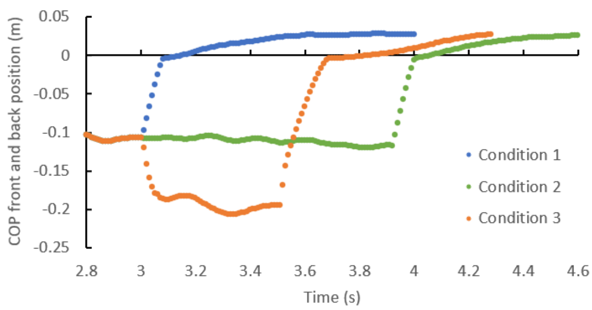

Figure 2. COP anterior-posterior position at the start of

Keywords: Gait initiation, Musculoskeletal model, Forward dynamics simulation, SCONE

Development of the Wearable Device for Measuring Finger Joint Angle

The measurement of finger movements using wearable devices have the potential to be used in various applications such as human-machine interface (HMI) and rehabilitation. However, wearable measurements using optical fibers and conductive inks, which are currently the mainstream, have the feature that the angle output by the sensor depends on the size and shape of the finger. Therefore, every time the measurer changes, time-consuming calibration is necessary to match the actual joint angle with the sensor output. In case a person with a hand disease cannot perform sufficient calibration, the sensitivity of measurement can be deteriorated and this prevents the measurements with high precision. Therefore, we research aiming to develop a wearable device that can measure the joints angle of fingers without depending on the dimension of the finger.

As a method, the joint angle can be estimated by overlapping the four tendons on the finger at regular intervals and measuring the displacement of them (Fig. 1). By utilizing the difference in the radius of rotation them at the joint part, the joint angle can be measured without depending on the dimension of the finger. By pinching layered belts made of soft polyvinyl chloride (PVC) between the tendons, they bend flexibly even when the fingers have a large curvature, and the intervals between the tendons are kept constant. In order to show the validity of this method, we developed a model miming the motion of flexion and extension of the finger by the serial link mechanism (Fig. 2). An experiment was conducted by placing tendons and belts on the model, and it showed that the proposed method can measure the joint angle with sufficient accuracy. In the next work, we will develop a glove-type device which can measure the finger joint angle based on the proposed method and knowledge obtained from the study so far.

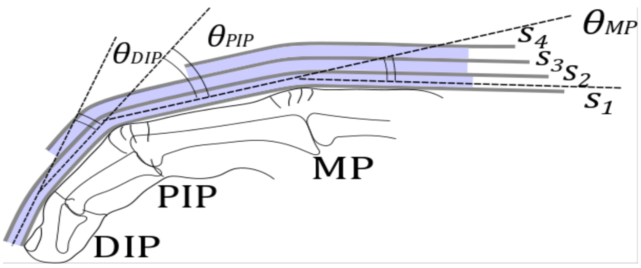

Figure 1. The configuration of tendons and belts on the finger. From the tip of the finger, finger joints are called DIP joint (Distal Interphalangeal joint), PIP joint (Proximal Interphalangeal joint), and MP joint (Metacarpophalangeal joint). From surface of the finger, the first and second threads are tensioned from on the nail, the third tendon is between from the DIP joint and the PIP joint, and the fourth tendon is from between the PIP joint and the MP joint. This configuration enables to measure each joint angle at the same time.

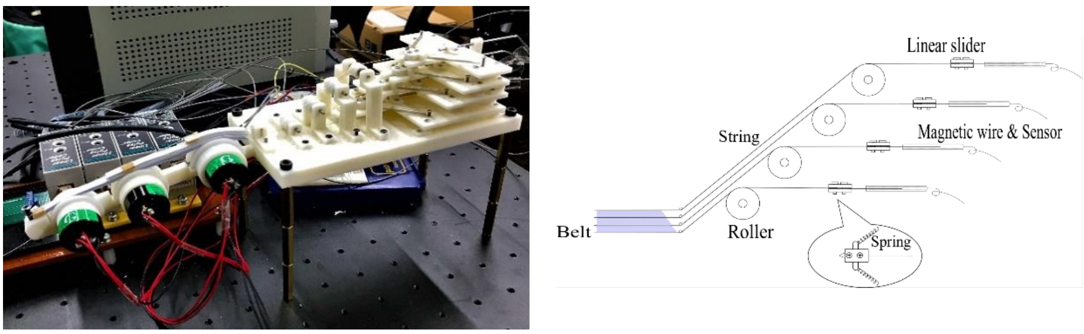

Figure 2. (Left figure) A model of the finger of the serial link mechanism used in the experiment. A potentiometer was incorporated in each joint to measure the ground truth of the joint angle. (Right figure) The pass of the tendons. Each tendon is connected to a linear slider via a roller. The linear slider has a role of connecting the tendon and the magnetic wire, and the displacement of the magnetic wire is measured by a sensor.

Keywords: data glove, wearable device, finger joint angle

Method to Estimate the Muscle Activation Pattern from MRI and EMG

In the study of neuromuscular degenerative disease and in the development of rehabilitation therapies to treat them, monitoring the activity of muscles is crucial to better understand the nature of the impairment and to have a feedback about the changes occurring after applied treatments. As a consequence of pathological conditions, it is also not so uncommon to observe changes occurring in the physical structure and in the behavior of muscles of impaired individuals. It is, therefore, crucial to have a full vision that simultaneously encloses the underlying morphology and the muscle activation behavior, in order to have a full understanding of the impairment status. At the state of the art, the gold standard method to depict morphological information is Magnetic Resonance Imaging (MRI), a diagnostic imaging technique that is used to represent the anatomy and physiological processes happening in the body. For the acquisition of time-related information about the muscle state instead, the most popular technique is electromyography(EMG) is a medical signal acquisition technique that read the potential variation caused by contracting muscles. State of the art method using EMG allow the estimation muscle activity up to motor unit level, but the estimation of deep muscles still remain a challenging problem.

Our group recently proposed a solution to merge the morphology obtained with MRI and the dynamic information from EMG to provide a direct estimation of deep and superficial muscles activities. The method exploits the morphological information contained in the MRI scan to build an electrical lumped model of the conductive volume that is then solved as an inverse problem using the sEMG collected from with a High density EMG electrodes wrapper around the forearm.

We believe that this method can be a valid way to overcome the limitations of the state of the art methods, allowing the estimation of muscle activation with temporal resolution of EMG, potentially improving the information quality for clinicians in the diagnostic process. In particular, we believe that the proposed method can make an important contribution in the field of rehabilitation allowing to track muscle activation pattern on impaired subject during rehabilitative cycles.

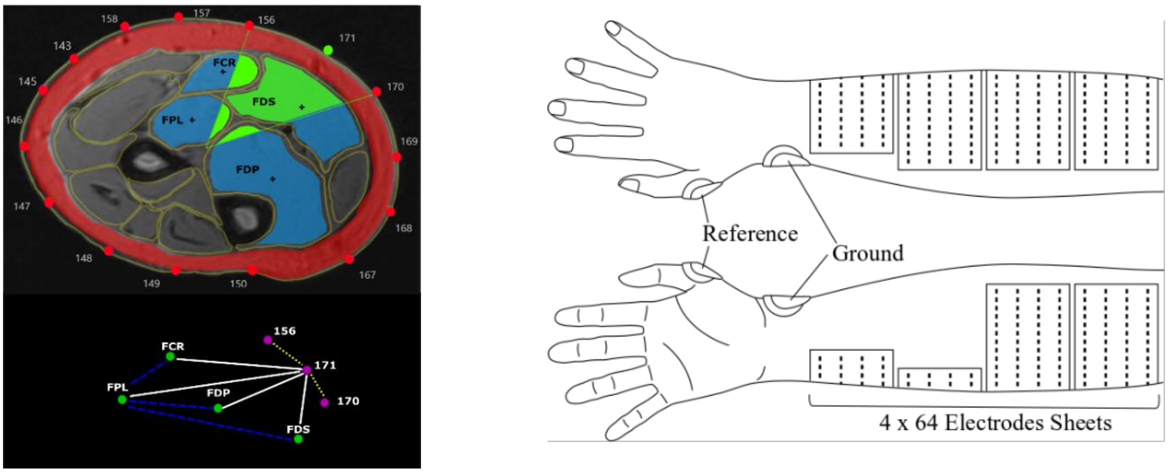

Figure 1. Left : Example of electric circuit construction from the morphological information of the MRI. Top: positioning of the electrodes on the arm.

Keywords: Neuromuscular control, electromyography, MRI, HD-sEMG, human machine interface

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Development of Robot Patients System for Learning Wheelchair Transfer Skill

One of the serious problems in current nursing education area is the reduction of student's experience of dealing with real patients due to the safety management and ethical issues. Our previous studies tried to solve this problem by developing the robot patient system for learning wheelchair transfer skill which is the typical skill in nursing movement [1][2]. Figure 1 shows the details of the robot patient system. Specifically, a force sensor attached to the robot's waist can measure and evaluate the force applied from nurse, and motors set in the ankle, knee, and hip joints of the robot are controlled according to it.

In this study, to achieve the "real patients like" robot motion, we measured the motion of the patient and the force applied from nurses in wheelchair transfer, and implemented the control theory based on it into the robot patient [3]. Specifically, first, we conducted the experiment to measure the motion of the patient and force applied from the nurse to the patient by using the experimental system consisting of optical motion capture camera system and a force plate. Then, we construct the control theory to achieve the real patient like motion in the robot patient, and, specifically, admittance control theory was adopted for modeling the relationship between the force applied from nurses to patients and patients' motion during wheelchair transfer movement. Owing to the nature of the admittance control theory to output the position or velocity based on the force as the input, we can express the human like patients' motion such as "falls forward when pulled with too large force" or "move slowly when weak force is applied" by using it. It is expected that nursing students learn the way of appropriate force interaction with patients through this robot.

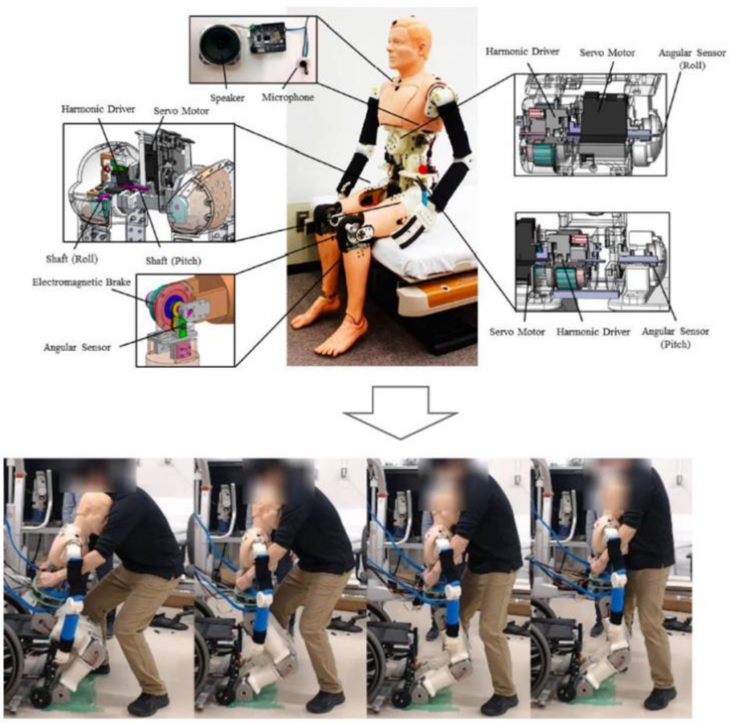

Figure 1. Details of the robot patient system

Finally, we conducted an experiment to verify the patient robot system we developed in this study. (Figure 1), and confirmed that the patient robot was able to discriminate between small and large forces applied by the nurse and provide feedback based on it (e.g., too large force). In the future, it is expected that we collect the data on patients with various symptoms, and implement it into the robot 's control theory and achieve the robot patient system for learning how to interact with patients with various symptoms.

Keywords: robot patient, modeling of human motion, nursing education

References:

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Analysis of the Effects of Postural Feedback Training on Mental Health

Maintaining mental health is an important issue in today's society. Exercises such as aerobic exercise, strength training, and yoga have been shown to be effective in maintaining and promoting mental health. However, not everyone can easily perform such exercises in their daily lives without special equipment or abilities.

Therefore, we focus on the maintenance of standing posture, which is one of the daily activities. It is well known that mental health status is manifested in posture and its sway, and the sense of body ownership formed by the organs that contribute to the maintenance of standing posture is thought to interact with mental health. We asked young healthy participants to perform postural feedback training in which they stood on a force plate and kept the position of the center of foot pressure displayed on a monitor within the indicated target. As a result, the training group showed a more relaxed state in the heart rate index during the calculation task immediately after the training, and improved values in the questionnaire assessing depression, anxiety, etc. during the 2-week training period. These results indicate that postural feedback training may contribute to the maintenance and improvement of mental health. In the future, we plan to increase the number of participants in the experiment to investigate the mechanism of the effect on mental health, and to propose a simpler training method.

Keywords: Postural control, Mental health

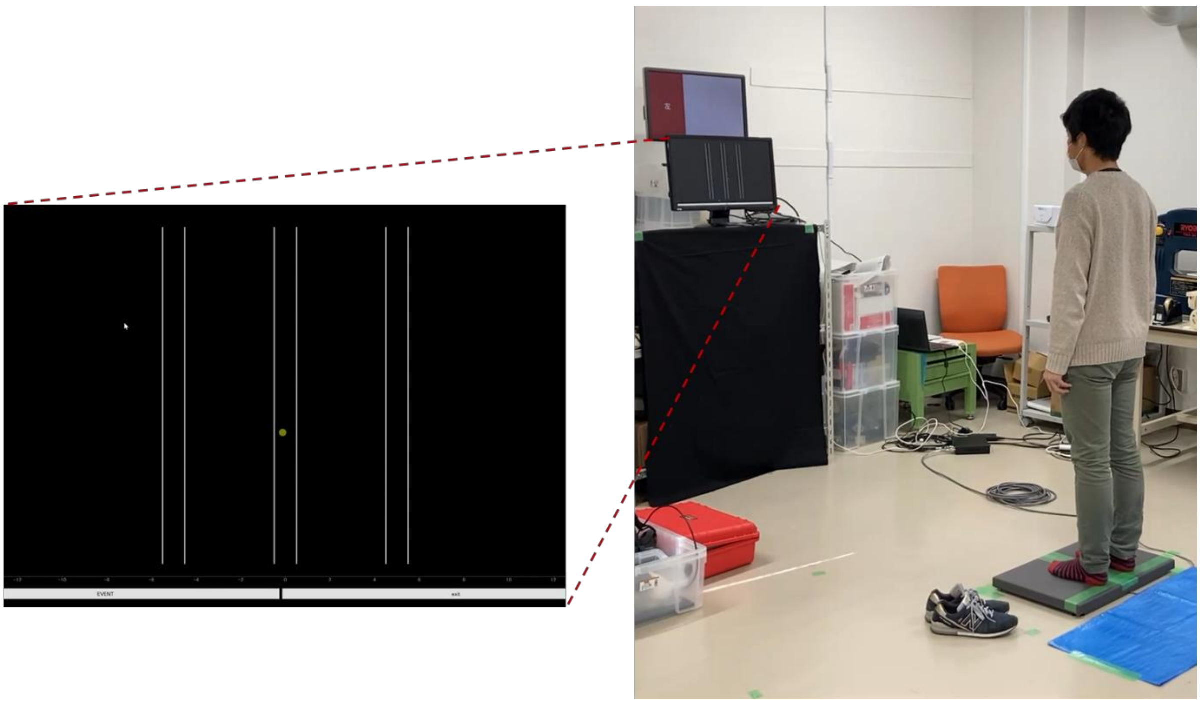

Figure 1. An example of postural feedback training. Three regions and the position of the center of foot pressure are displayed on the monitor, and the participant follows the instructions to keep the position of the center of foot pressure within each region.