Introduction to the Mobile Robotics Lab
(OTA Lab)
2016

Human-Artifactology Research Division,
Research into Artifacts, Center for Engineering (RACE) ,
The University of Tokyo

Research Complex 5F, Kashiwa Campus,
Kashiwanoha 5-1-5, Kashiwa, Chiba 277-8568, Japan

URL: http://otalab.race.u-tokyo.ac.jp

Members

Professor	Jun OTA
Research Associate	Taiki OGATA
Postdoc Researchers	Shouhei SHIRAFUJI, Jose RUBRICO, Huang ZHIFENG, Cong FEIYUN
Doctoral Course Students	Jorge David FIGUEROA HEREDIA, Ping JIANG, Nobutaka KIMURA, Veerachart SRISAMOSORN, Kohei KAMINISHI
Master Course Students	Takahiro KATAYAMA, Takumi SHIRAISHI, Hamdi SAHLOUL, Jingsi LIN, Taku ITO, Naotaka MATSUI, Becky SU, De Jong Anner WARRER, Shunsuke KANNO, Zhenyi CHEN, Yibing CHEN
Undergraduate Students	Tashuma ITO, Kazuki KIRIU
Research student	Yalcin AKIN, Peng ZERONG
Secretaries	Mika TAMURA, Ayako NAKAMURA

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 "multi-agent robotics and mobiligence", "design of large-scale production/transport systems", and "human analysis" 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.

Multi-agent robotics and mobiligence
Development of a Robotic Arm of Mobile Robot for Large Size Object Manipulation
Teaching Multiple Robots by a Human
Foreground Segmentation with Efficient Selection from ICP Outliers in 3D Scene
Automatic Face Tracking System using Quadrotors for Estimation of Elderly People’s Emotion

Design of large-scale production/transport systems
Automatic Design of Image Acquisition Environment and Recognition Process for Picking

Human analysis
Temporal Co-creation between Multi-People
Robot patient simulate different symptoms of paralysis for transfer Training
Stance postural control in consideration of neurological time delay based on a musculoskeletal model
Anxiety Prediction Using Smartphone Logs

Development of a robotic arm of mobile robot for large size object manipulation

Generally, it is difficult that a small mobile robot cannot exert a large force to the environment, although a small mobile robot can move in the narrow spaces. That is because a small robot has a risk of the robot tipping over or slipping by a large reaction force. If a small mobile robot can exert a relative large force to the environment, the robot can manipulate various objects including a large and heavy object even if a target object offers no gripping point. For example, the robot can tilt a large and heavy object to put a moving cart under it or turn a large and heavy obstacle over to remove it.

In our research, we analyzed limitations of forces which can be applied to the environment by a mobile robot caused by the mechanism of the robot and frictional forces between the robot and the environment to develop a mobile robot allowed to apply a large force. As a result, we proposed a mobile robot a linear actuator connected to the body of the robot via a passive joint as shown in Fig. 1. The robot has no risk of falling because the moment which rotates the robot is not conveyed to the body of the robot due to the passive joint. This makes it possible for the robot to manipulate an unknown object by trial and error without caring about falling of the robot. We demonstrated that the robot can find a direction of force which can be applied to an object without a slippage as shown in Fig. 2. Consequently, the robot could tilt a large and heavy object which weights 80.0 kg without slippage and falling of the robot.

Keywords: mobile robot, large force, pushing manipulation

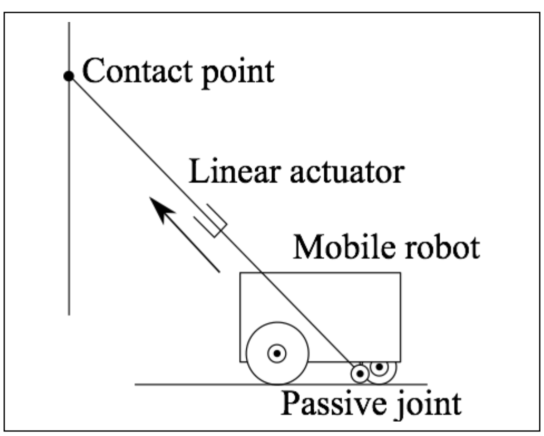


Fig. 1 Proposed mobile robot with a passive joint

Fig. 2 Experiment to tilt a heavy object by trial and error

Teaching Multiple Robots by a Human

In this study, we present a novel framework to address the problem of teaching a task performed by a single human to a set of multiple small robots [1]. Specifically, we focus on transferring information on how to perform manipulation tasks to multiple robots by a single human example. Data is extracted and then analyzed during a teaching process which consists in detecting human actions, classifying the task and deciding the number and type of robots to teach. Finally, according to the task requirements, robotics behaviors may be assigned in an independent or collaborative way into the created robots program. To illustrate the complete system, example of one manipulation task taught to multi-robots is shown in Fig 1.

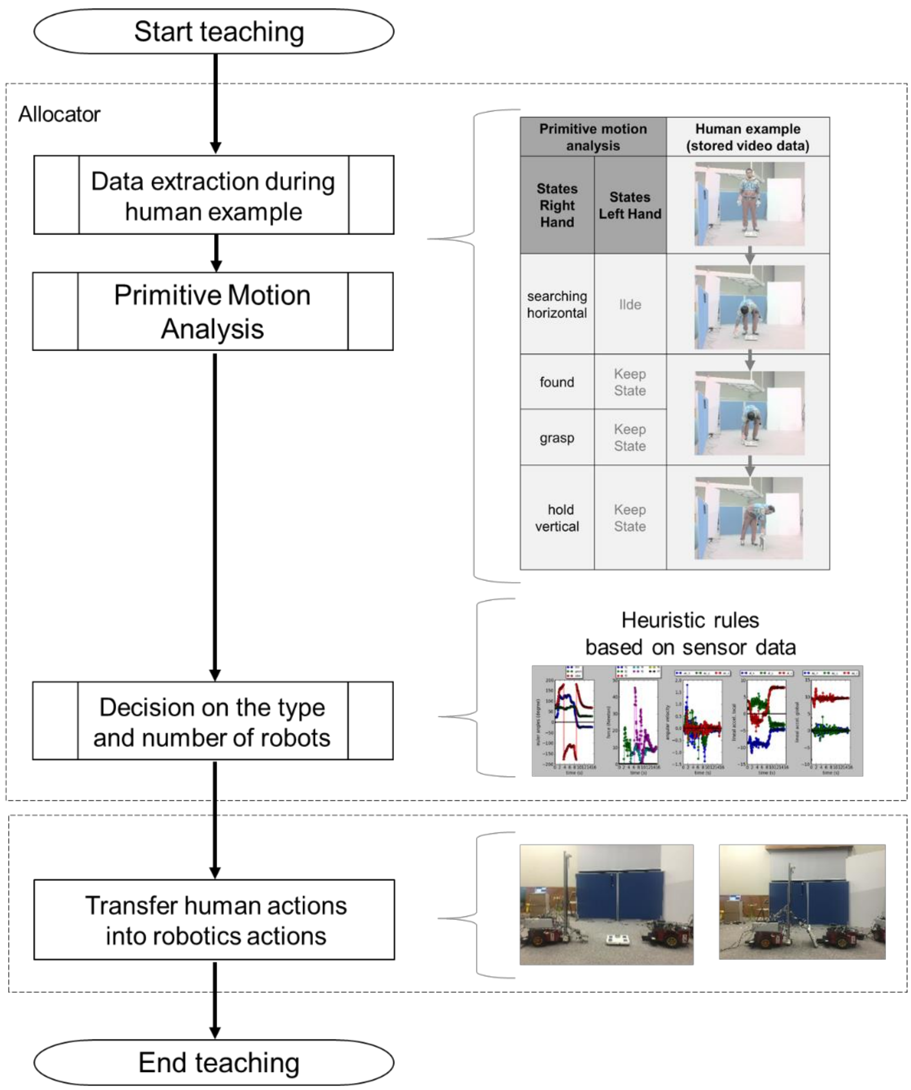


Figure 1. Manipulation task taught to multiple robots by a human example: flipping a bascule

[1]Figueroa Heredia Jorge David, Rubrico Jose I. U., Ota Jun, "Teaching multiple robots by a human", Proceeding of the ACM/IEEE International Conference on Human-Robot Interaction (HRI 2016), (pp. 613-614). Christchurch, New Zealand.

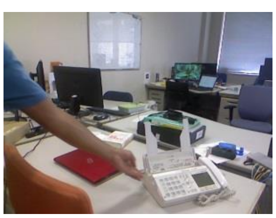
Foreground Segmentation
with Efficient Selection from ICP Outliers in 3D Scene

Foreground segmentation serves in reconstructing 3D models of moving objects in the scene. The foreground appears as a secondary outcome indicated by outliers of the Iterative Closest Point (ICP). To form the foreground, many studies have filtered outliers by noise-removal approaches such as morphological filtration or graph optimization. They have not considered constraints rejecting these outliers, and just handled ICP outliers all together.

This study constructs 3D reconstruction of the environment using a moving RGB-D sensor. Alignment of new frames to the fused surfaces is achieved by ICP algorithm. Foreground objects are recovered from ICP outliers (*Fig. 1.b*) after considering its most relevant segments. The segmented foreground could be tracked in separated volumetric fusion to construct foreground objects independent from the static reconstruction. This would enable interaction and virtual reality applications.

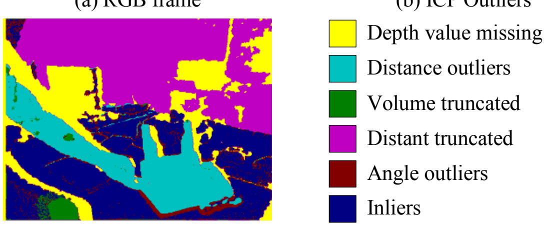
By tagging five different types of ICP outliers, we found out that noise-reduced foreground is located mainly in points violating distance constraint (*Fig. 1.c*). We propose a real-time method with an increase of 12% in quality (*Fig. 2*) using only bilateral filtration of distance outliers and distance truncation. Further details are available in the method's paper[1].

Our results suggest excluding distant depth points as well as angle/volume outliers from foreground segmentation to enhance processing time and quality. With that improvement, Graph-based refinements (e.g. GrabCut) are not required as well. Future work includes segmenting objects from the static environment once they start displaced.



(a) RGB frame

(b) ICP Outliers



(c) Noise reduction by sub-outliers selection

Figure 1. Dataset frames and ICP outliers resulting from depth-frame alignment. (a) An RGB frame capturing some objects in-motion. (b) Corresponding ICP outliers. (c) Colored map showing distance outliers (in eggshell-blue color) used in proposed method.

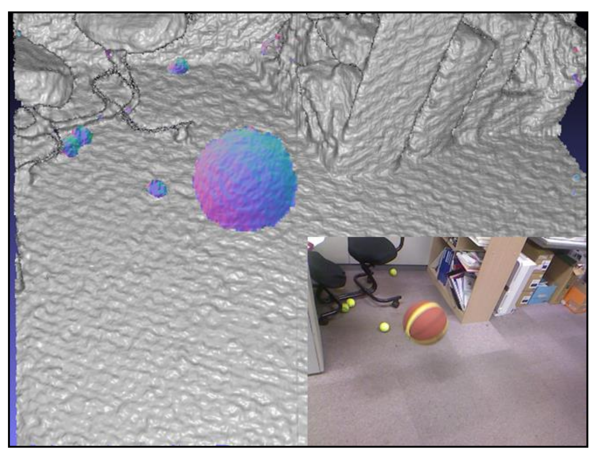


Figure 2. *Main*: A Phong shading surfaces of a reconstructed environment with the foreground represented as color-coded surface Normals. Proposed method results demonstrate a clean foreground of some balls while bouncing in the scene. *Side*: the corresponding RGB frame.

[1] Hamdi Sahloul, Jorge Figueroa, Shouhei Shirafuji, and Jun Ota, "Foreground segmentation with efficient selection from ICP outliers in 3D scene," in *2015 IEEE International Conference on Robotics and Biomimetics (ROBIO)*, Zhuhai, China, Dec 2015, pp. 1371-1376.

Automatic Face Tracking System using Quadrotors for Estimation of Elderly People's Emotion

For health care provided to elderly people or people with some mental disorders, patients' emotion needs to be observed regularly. The current practice uses a number of staff to observe their faces and use smile as the indicator. However, the ratio of staff to patients is not enough and the task require regular observation, resulting in inefficiency, ineffectiveness, and fatigue of the caregivers. Therefore, a system for tracking people's face and processing for their emotion is necessary for this task. This research proposes the use of environmental cameras together with mobile cameras to track people's face to obtain their facial images.

In the proposed method, quadrotors equipped with small video cameras are used to follow and track people's face (Fig. 1), where the facial images can be sent back and the emotion estimation can be performed. Xbox 360's Kinect cameras are installed in the environment to cover the area and detect the positions and orientation of each person in the space. The position and direction of the head is then used to set up the goal position for the quadrotor such that it is at a distance in front of the person and pointing the camera towards the face. The quadrotor's position is also detected from the depth image provided by the Kinect sensors, while its orientation is obtained from the onboard inertial measurement unit (IMU). Finally, the quadrotor is navigated to the goal position, where the camera can capture the person's facial images. Fig. 2 displays the tracking process in action for tracking of one person using 5 Kinects and one quadrotor, covering a 3-by-3.5 sq. m. area.

Keywords: quadrotor, Kinect, human tracking, face tracking

Reference

[1] Srisamosorn, V., Kuwahara, N., Yamashita, A., Ogata, T., and Ota, J. "Automatic Face Tracking System using Quadrotors: Control by Goal Position Thresholding". *Proceedings of the IEEE International Conference on Robotics and Biomemetics (ROBIO 2014)*, pp. 1314-1319, Dec 2014.

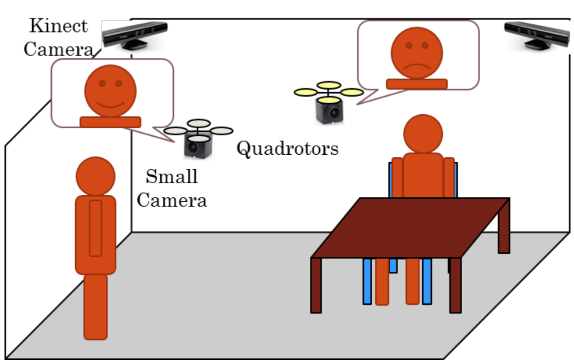


Fig. 1 System of quadrotors in elderly nursing home

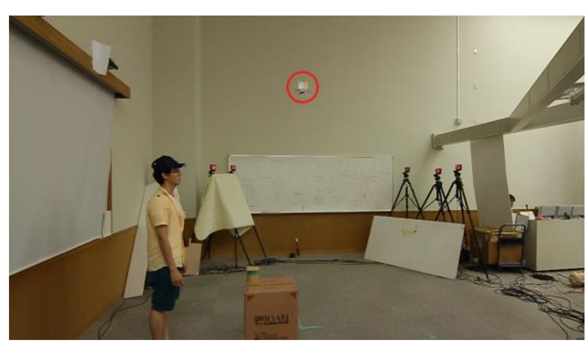


Fig. 2 Quadrotor tracking the person's face

Automatic Design of Image Acquisition Environment and Recognition Process for Picking

Recently, to increase production capacity and/or to reduce production cost, image recognition technique is actively used in manufacturing system such as product assembly and inspection. First, it is necessary to design image acquisition environment to construct the image recognition system. Then, the process to recognize target objects, such as type, position and angle is needed to design. The recognition process usually consists of three steps: image conversion, feature extraction and identification. There are vast amounts of combinations of parameters in image acquisition environment and recognition process. In addition, the parameters included in image acquisition environment and recognition process mutually depend. Therefore, it requires long-term to design whole recognition system even for experts.

The purpose of this study is to automatically design the image acquisition environment and the recognition process for picking system (Fig. 1). For picking, to recognize the kind, position and angle of target objects is necessary. The image acquisition environment included distance between target objects and camera and intensity of RGB light. For recognition process, we used method based on local features and targeted the automatic design of image-conversion-parameters and identification using the local features. This automatic design was formulated as optimization problem and the problem was solved by metaheuristic method. For the optimization calculation, the experiment-based optimization was used because there are some uncertainties of environment in the real world. For the uncertainties, it is too difficult to solve this problem only using theoretic and/or computational methods. Fig. 2 and 3 show conceptual image of the experiment and proposed algorithm of the experiment-based optimization respectively. As the results or evaluation experiment, sufficient recognition accuracy was obtained within a reasonable time.

Key words: automatic design, optimization, image recognition, image acquisition environment

Reference

[1] K. Tsujimoto, *et al.*: "Simultaneous Design of Image Conversion Parameters and Classifier in Object Recognition for a Picking Task," Proc. Int. Conf. Robotics Biomimetics (ROBIO2014), pp. 457-462, 2014.

[2] T. Yukisawa, *et al.*: Automated Design of Image Recognition System Including Image Acquisition Environment for Picking, Proc. JSPE Semestrial Meeting 2016 JSPE Spring Conference, Chiba, March, 15–16, p. 155, 2016 (*in Japanese*)

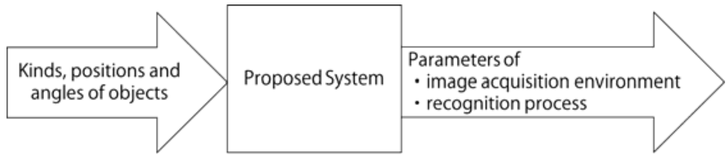


Fig. 1 Problem setting

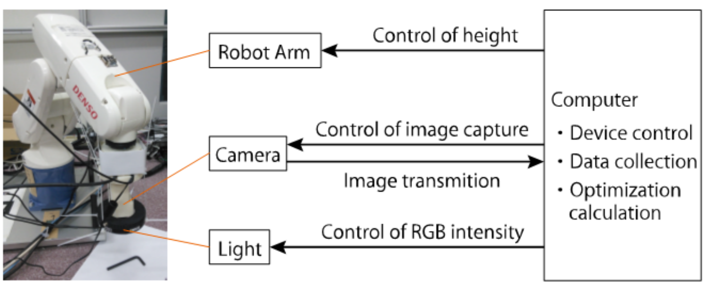


Fig.2 Conceptual image of proposed experiment-based optimization

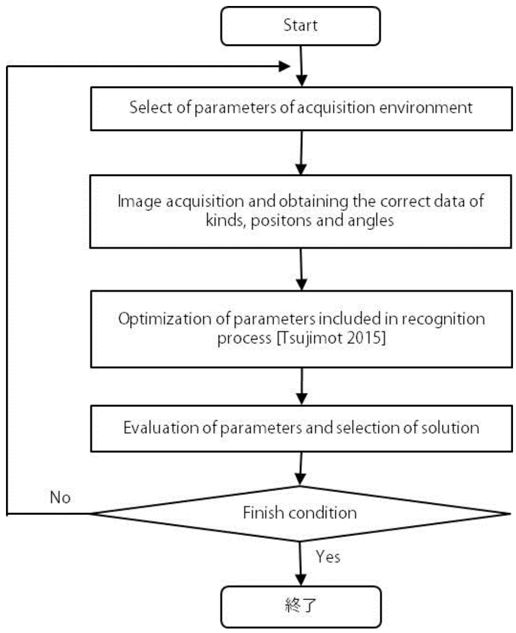


Fig. 3 Proposed algorisms

Temporal Co-creation between Multi-People

As evidenced in music ensemble, dance and sports, people cooperatively produce rhythm with other people. Such temporal co-creation between multi people includes many time delays: delays included in signal processing, multi-modal integration, sensory-motor coordination and cooperation with other people. Despite of such delays, people generate movement cooperatively with others in real time. To investigate the characteristics of temporal co-creation between people is important not only to understand human communication but also to achieve temporal co-creation between human and artifacts.

We conducted a psychological experiment. In the task, two mutually isolated followers simultaneously synchronized by finger tapping with a human leader or metronome producing constant tempo. The followers performed this task with or without tapping timing information of the other follower. The leaders were asked to tap their finger to keep constant tempo with or without the tapping time information of followers. Negative asynchronies (NAs) were observed under all leaders conditions. That is, the tap timings of the followers preceded those of the leaders. The amount of NA under human leader conditions was smaller than that under metronome condition. In addition, the followers predictively synchronized the human leaders while they synchronized the metronome to follow it up.

Keywords: Temporal co-creation, Multi-people communication, Cooperative rhythm production

References

1) T. Ogata, T. Katayama, Y. Miyake and J. Ota, Cooperative Rhythm Production between Three People through Auditory Signals. In Proceedings of 23rd International Symposium on Micro-Nano Mechatronics and Human Science, pp. 456—459, Nagoya, Nov. 2012.

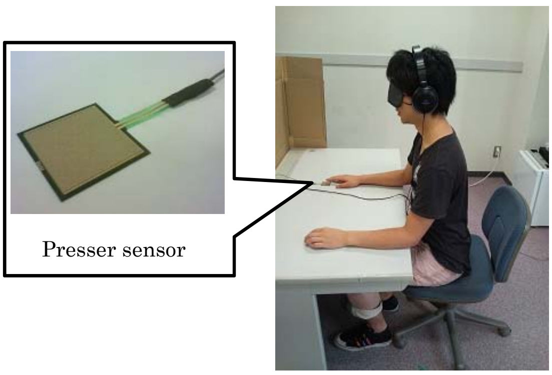


Fig. 1 The picture of a participant in the experiment and the presser sensor to measure the timing of the tapping

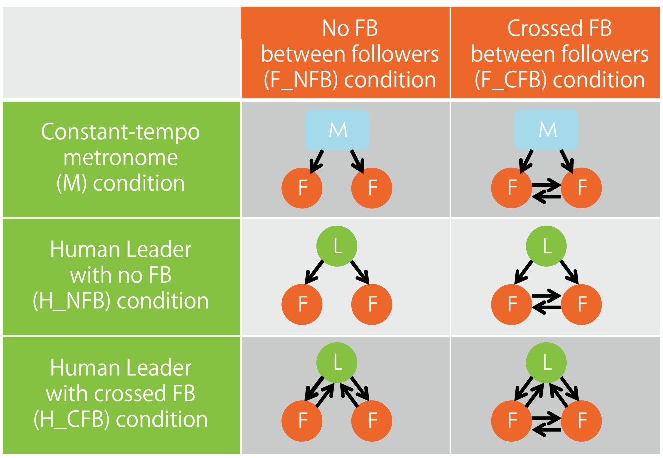


Fig. 2 The conditions of a leader who keeps the constant tempo and followers who cooperatively produce rhythm to synchronize with the leaders. The arrows indicate presentation of stimuli of metronome or other peoples' tapping timing. FB means feedback.

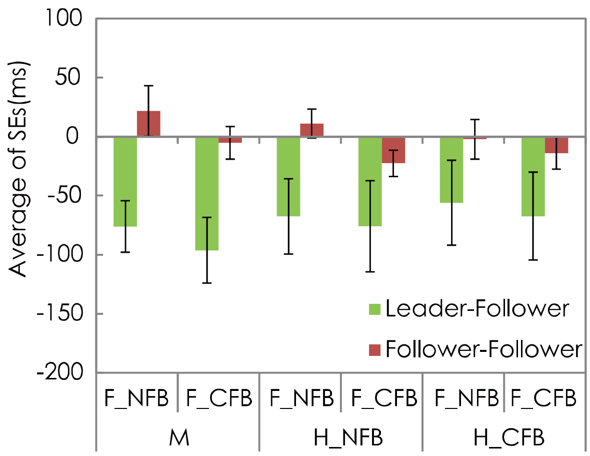


Fig. 3 Averaged synchronized errors (SEs). The followers tended to tap before the leaders.

Robot patient simulate different symptoms of paralysis for transfer Training

With the background that approximately 1 in 50 people have currently been diagnosed with symptoms of paralysis, it is important to train the nurse how to transfer of the different type of paralysis patients. The patient transfer is one of the complicated and difficult skills. To learn this skill requires plenty of practices and experience in manual patient handle [1]. However, in the school education, nursing students cannot practice the skill with real patients. Instead, they learn the skill with mock patients acted out by student or teacher who cannot precisely reproduce the paralysis patients. For example, the health people are hard to imitate the unstable falling down. Therefore, to improve this skill of nursing students, our study aims to develop a robot patient that enables to reproduce paralysis patient and apply into training.

To develop a robot patient which can accurately reproduce hemiplegia and quadriplegia patient, the prototype robot [2] should be improved. The prototype did not have the waist joint to reproduce the unstable movements of paralyzed patients [3], such as trunk's tilting toward paralyzed side and falling down. Therefore, we proposed the mechanical design of waist based on the compliant joint (Fig. 1). The reasons of utilizing the complaint joint were to reproduce the inherence compliance of human. In compliant joints, the springs were equipped and the springs enable the compliance feature as human. Fig. 2 shows the robot patients with the waist joints. The trunk moving of the robot can be seen in our demo video. For the future works, we intent to imitate more various patients via this robot to train the nursing student learn the transfer toward different patients.

Key Words: Robot patient, Education system, Nursing skill, Skill acquisition, Paralysis simulation

Reference

[1] *Kjellberg, K., Lagerström, M., & Hagberg, M. Patient safety and comfort during transfers in relation to nurses' work technique. Journal of advanced nursing, 47(3) (2004, 251-259.*

[2] *Huang, Z., Katayama, T., Kanai-Pak, M., Maeda, J., Kitajima, Y., Nakamura, M., & Ota, J. Design and evaluation of robot patient for nursing skill training in patient transfer. Advanced Robotics 29(19) (2015) 1269–1285.*

[3] *Ogata, T et al., Kanjano Tayouna Joukyouwo Kouryosita Kanja Robotono Kaihatsu (Development of Robot Patient Simulating Various Type Patients. Proc. 2015 Society of Servisology Domestic Conference, Kobe, Murch, (2016), 187–188.*

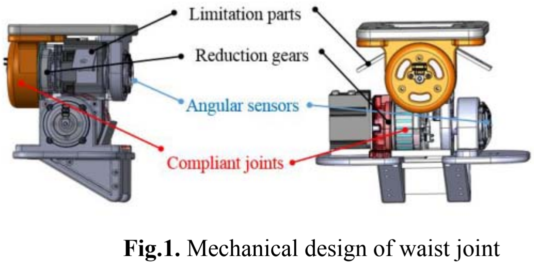


Fig.1. Mechanical design of waist joint

Fig.2. The robot patient for training

Stance postural control in consideration of neurological time delay based on a musculoskeletal model

Creating a physiologically plausible neural controller contributes to understandings on the nature of human postural control. Most previous studies simplified human body model to an inverted pendulum without muscles, which hinds our understandings how muscle activation contributes to the stance motion.

In this research, we adopted a musculoskeletal model incorporating 70 muscles and human anatomical data. We proposed a neural controller (Fig. 1) to maintain it standing under 140 ms delay. Through the forward dynamics simulation, we validated whether the proposed controller could keep musculoskeletal model standing. Furthermore, we muscle activations were investigated to validate whether our controller could simulate physiologically plausible activations.

Keywords: Postural control, Musculoskeletal model, biological simulation

References

[1] Jiang,P., Chiba,R., Takakusaki,K., & Ota,J. Generation of biped stance motion in consideration of neurological time delay through forward dynamics simulation. Proc. IEEE Int. MHS2015, pp. 205-208, 2015

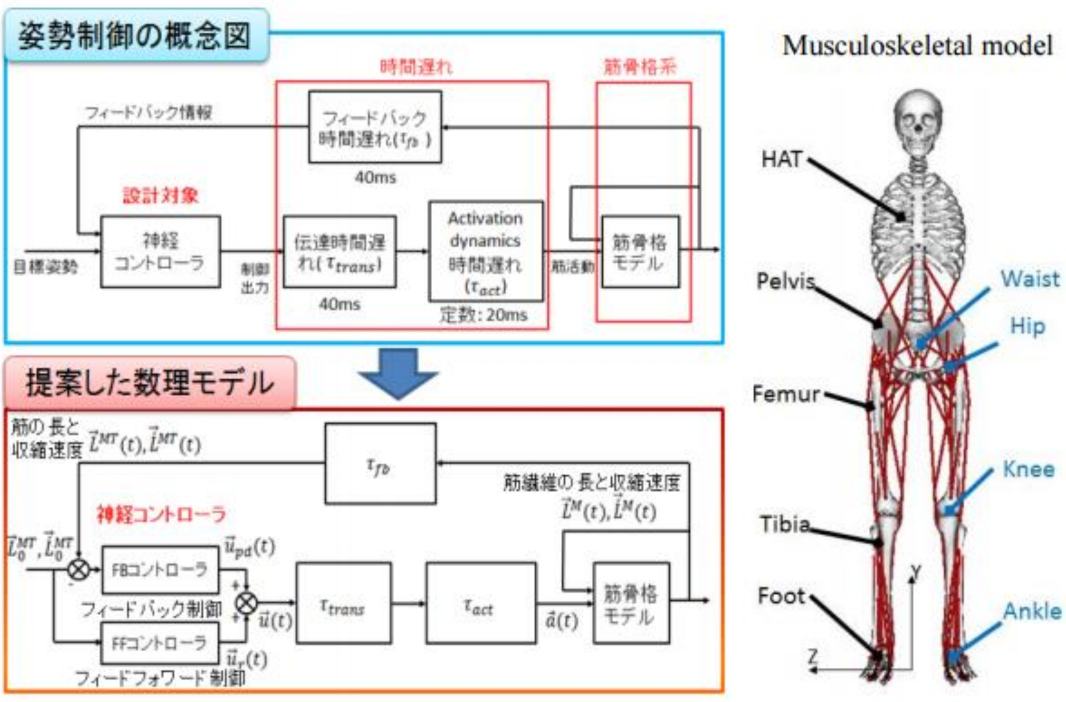


Fig. 1 Stance postural control model and musculoskeletal model

Anxiety Prediction Using Smartphone Logs

Lately, interest in mental health has increased. As of December 2015, companies with more than 50 workers are required to assess workers' stress, according to Japanese law. Maintaing workers' mental health has since been the focus. However, currently, stress is assessed once or twice a year through a questionnaire, and no continuous assessment has been conducted.

To enable continuous stress assessment without cost incurrence by workers, some researchers have focused on estimating the mental state though uses of smartphones. Since many people equip themselves with smartphones on a daily basis, use of smartphones as sensors can be less burdensome to users. In these studies, researchers extracted some feature values to estimate mental health states. It is necessary to extract feature values which reflect the change of use of smartphones dependent on the symptoms of mental health states. This is the challenging point.

In our research, we focus on the anxiety. We propose some feature values which is related to anxiety from sensor logs and application histories of smartphones, and aim to predict the anxiety state. We show the image of prediction of anxiety by smartphones in Figure 1. To predict the anxiety, there is a problem that of how many days should we learn the data to predict the anxiety in enough accuracy. We are investigating this problem now. We show the image of this problem in Figure 2.

We are going to present these results at a conference in May.

Key Words: Mental health, anxiety, smartphone, sensor logs, application history

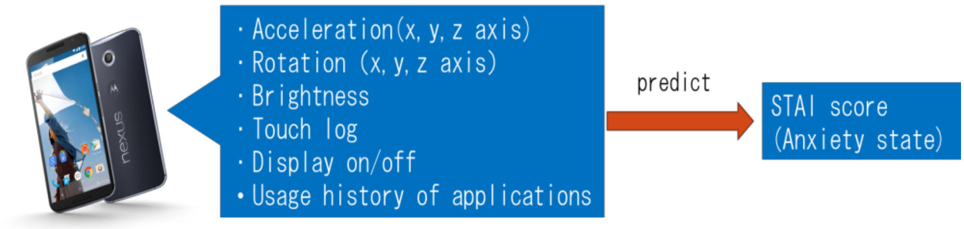


Figure 1: Prediction of anxiety by smartphones

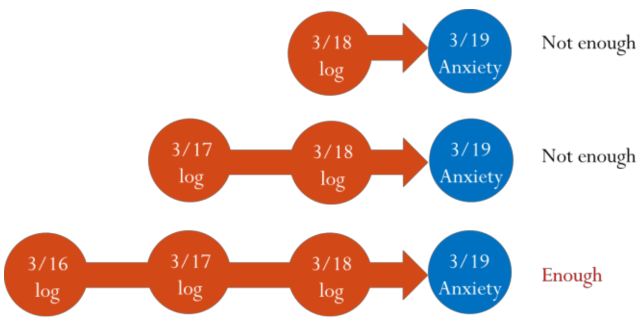


Figure 2: The image of anxiety prediction problem