

# Introduction to the Mobile Robotics Lab (OTA Lab) 2019

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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 "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 and manipulation planning of small mobile robot
- 3D Affine: An Embedding of Local Image Features for Viewpoint Invariance Using RGB-D Sensor Data
- Design of Mechanism using Optimization According to Task

### **Design of large-scale production/transport systems**

- Design of Buffer Size in Warehouse System

### **Human analysis**

- Musculoskeletal Simulation of Human Stance Postural Control
- Description of tissues interaction with a resistive network for the estimation of muscle currents from surface electromyography
- Study on Stress Estimation Using Smartphone Log
- Learning Patient Transfer Skill by Using a Robot Patient To Simulate Various Patients
- *(Following research topics are studied by the collaboration with Dr. Tatsunori Hara (Project Associate Professor of Graduate School of Media and Governance, Keio University and Senior Project Researcher of School of Engineering, The University of Tokyo))*
- Method of expressing customer psychology related to purchasing using physiological measurement
- Analysis of Study Tour Enhancing Social Concern of High School Students to Local Communities
- Review of Customization Research for the Development of PSS Customization
- Risk Assessment System of Human Activities in Order Picking Using IMU-based Motion Capture Device
- Actor Transformation and Zone Designing to Enhance Community Sustainable
- Analysis of Flight Attendants' Cognitive Skill during In-flight Service and Development of Learning material to support skill acquisition
- Utilizing Crowd Information of Tourist Spots in an Interactive Tour Recommender System
- Service Analysis in Home Delivery to Clarify the Effects of the Convenience in Service on Customer Psychology and Behavior

# 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 earlier work, we proposed the method to transport big object by using multiple mobile robots [1]. Based on that method, we developed a small-sized mobile robot [2-5], whose linear manipulator can exert a large force to push the object while robot flipping over can be avoided regardless the scale of output force. A group of our developed robot can conduct various manipulations to objects by working coordinatively, such as inclining, pushing, and pivoting.

To realize the cooperation among robots, manipulation planning is important. To deal with the distinct multi-level configuration space caused by the varying constraints in the robot-object system, a hierarchical method is 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 [6-8]. Our proposed method determined the number of robots for manipulation stability, and investigate 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.

**Keywords:** mobile robot, large force, manipulation planning, hierarchical planning, optimal placement

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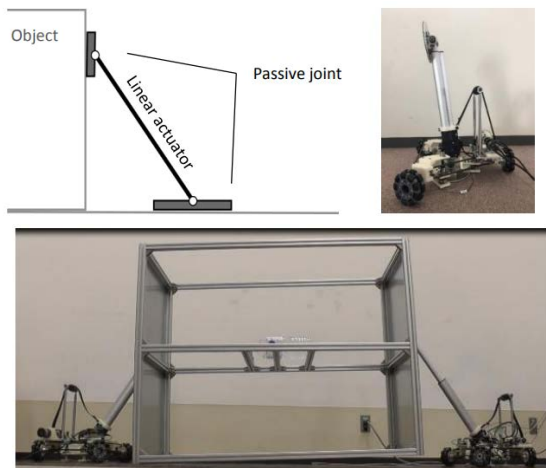


Fig 1. Developed mobile robot (above) and tilting manipulation using two mobile robots (bottom).

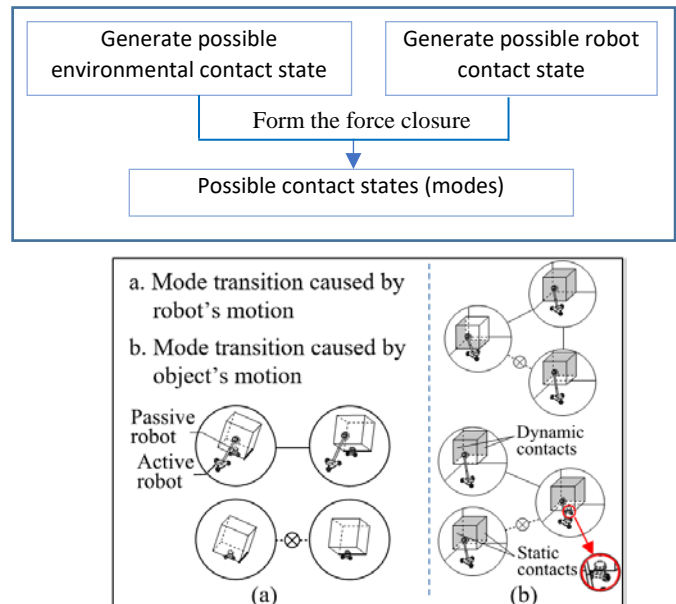


Fig 2. Modal planning for the robots' manipulation to the object (generating the modes and the principle for mode transition).

# 3D Affine: An Embedding of Local Image Features for Viewpoint Invariance Using RGB-D Sensor Data

Local image features are invariant to in-plane rotations and robust to minor viewpoint changes. However, the current detectors and descriptors for local image features fail to accommodate out-of-plane rotations larger than  $25^{\circ}$ – $30^{\circ}$ . Invariance to such viewpoint changes is essential for numerous applications, including wide baseline matching, 6D pose estimation, and object reconstruction.

For that, we proposed a general embedding [1] that wraps a detector/descriptor pair in order to increase viewpoint invariance by exploiting input depth maps. The proposed embedding locates smooth surfaces within the input RGB-D images and projects them into a viewpoint invariant representation, enabling the detection and description of more viewpoint invariant features (See Figs. 1-3). Our embedding can be utilized with different combinations of descriptor/detector pairs, according to the desired application.

While standalone local image features fail to accommodate average viewpoint changes beyond  $33.3^{\circ}$ , our proposed embedding boosted the viewpoint invariance to different levels, depending on the scene geometry. Objects with distinct surface discontinuities were on average invariant up to  $52.8^{\circ}$ , and the overall average for all evaluated datasets was  $45.4^{\circ}$ . Similarly, out of a total of 140 combinations involving 20 local image features and various objects with distinct surface discontinuities, only a single standalone local image feature exceeded the goal of  $60^{\circ}$  viewpoint difference in just two combinations, as compared with 19 different local image features succeeding in 73 combinations when wrapped in the proposed embedding. Furthermore, the proposed approach operates robustly in the presence of input depth noise, even that of low-cost commodity depth sensors, and well beyond.

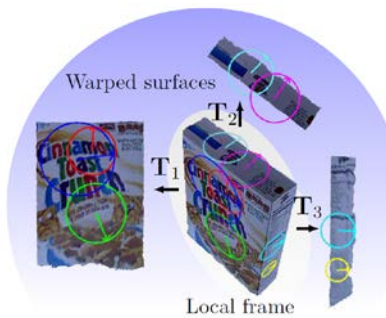


Figure 1: Keypoints are detected on the warped surfaces and remapped back to the original input local frame.



Figure 2: Before improving the viewpoint invariance of SIFT features.



Figure 3: After improving the viewpoint invariance of SIFT features.

**Keywords:** viewpoint invariance; local image feature embedding; wide baseline matching.

## References

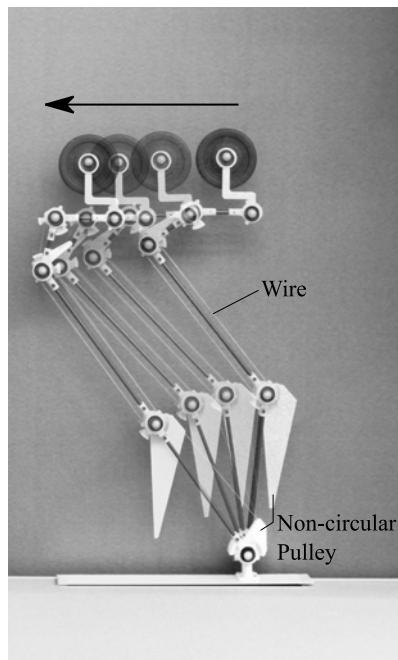
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## Design of Mechanism using Optimization According to Task

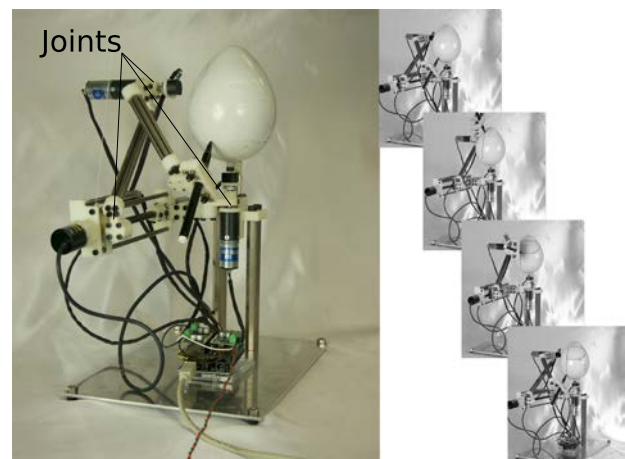
In the field of robotics, most of the studies focus on how to control the given mechanism to accomplish the target task. However, many tasks can be simplified or solved by preparing specified mechanism without sophisticated control method. Therefore, we are studying the methodology to derive the appropriate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

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## Design of Buffer Size in Warehouse System

Buffers that are temporary storage area for jobs handover in warehouse systems. Insufficient buffer size lead to much congestion, while excessive buffer size hampers the whole systems. To increase the working efficiency of the warehouse systems, proper buffers should be designed. However, jobs flow in real warehouse systems are complex and consistently variable, which make both the evaluation of the system performance and the design of buffer size become very difficult. In addition, other factors such as operation mechanism increase the analysis difficulty of the buffer size in the systems further.

The purpose of this study is to determine the size and location of buffers in warehouse systems. We used neighborhood search and drum-buffer-rope (DBR) methodology to determine the buffer location and update the buffer size. We proposed a throughput calculation approach to evaluate the effectiveness of the design buffer size efficiently. In the future, we will design numerical experiments and test the effectiveness of our proposed algorithm for the design of buffer size.

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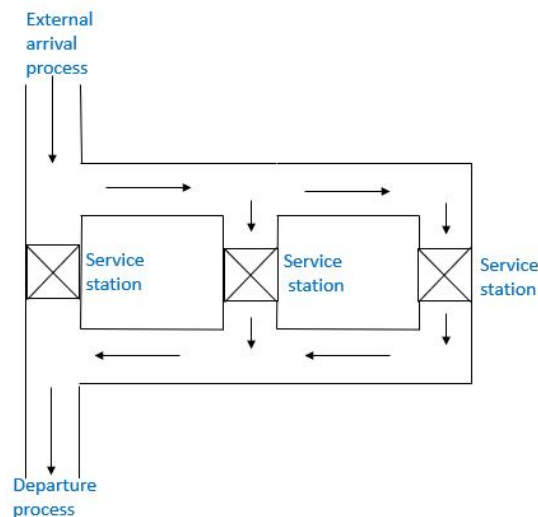


Fig 1. Example of a warehouse system

# Musculoskeletal Simulation of Human Stance Postural Control

Humans perform high-level stance postural control, which keeps their center of mass on their small base of support. Understanding the mechanism of control is essential to providing effective rehabilitation. In attempts to model human postural control, torque-driven inverted pendulum models have been widely used as a human body. However, internal forces contributing to posture maintenance are not represented when using a torque-driven model. Muscle forces and three-dimensional location information of skeletal bones are to be treated.

We propose a neural controller model (Fig. 1) to maintain a musculoskeletal model (Fig. 2) in a stance posture. This neural controller model consists of feed-forward control to send constant necessary muscle tonus for stance and feedback control based on sensory inputs. In simulations with the neural controller model, the contribution of muscle tonus at a stance posture was confirmed<sup>[1]</sup>, and the changes in muscle activations for different sensory inputs were reproduced<sup>[2]</sup>. This neural controller model could maintain a stance posture even under external forces, and the features of the magnitude of muscle activations and passive ankle stiffness were consistent with experimental results in previous studies. We are trying to understand what kind of change occurs in behavior when body change occurs through predictive simulations.

**Keywords:** postural control, musculoskeletal model, biological simulation

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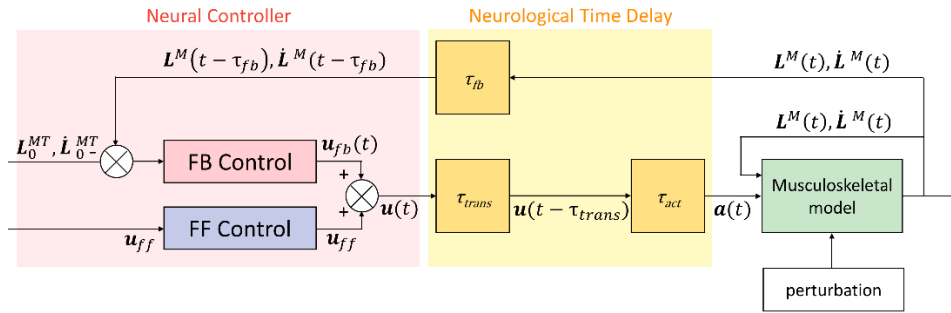


Fig. 1 Neural controller model. It consists of feedback control based on muscle length and lengthening speed and feed-forward control of constant value.

$\mathbf{u}$ : total control,  $\mathbf{a}$ : muscle activation,  $\mathbf{L}^{MT}$ ,  $\mathbf{L}_0^{MT}$ : current and objective muscle length,  $\dot{\mathbf{L}}^{MT}$ ,  $\dot{\mathbf{L}}_0^{MT}$ : current and objective muscle lengthening speed,  $\tau_{trans}$ ,  $\tau_{fb}$ ,  $\tau_{act}$ : transmission, feedback, and activation time delay.

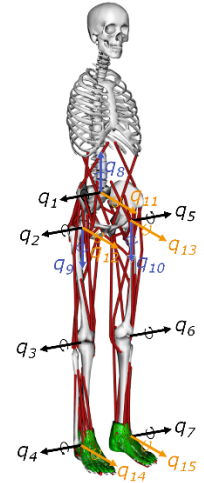


Fig. 2 Musculoskeletal model.



## Description of tissues interaction with a resistive network for the estimation of muscle currents from surface electromyography

Designing and development of better control paradigm for robotic prosthetics are topics that has been increasingly gaining the interesting of the scientific community. Big steps forward has been done from several point of views, from the design of smaller and lighter components to the development of smarter and more accurate control strategies. The most recent control systems, in particular, exploit the neuromuscular information obtained from surface electromyography (sEMG) to interpret the intended movements. At the state of the art the commercially available prosthetics are based on classifiers that trigger a particular movement where a specific sEMG pattern is detected. Direct control of prosthetics still presents reliability issues that preclude its application to a large scale.

We started a study in collaboration with Prof. Piovesan (Gannon University, USA), on a method that exploits the simplicity and linearity of resistive network to model the interaction between the different muscles and tissue identified from a single magnetic resonance imaging (MRI) slice through a segmentation process. This modeling approach aims to overcome the complicated tissue interaction previously described with Finite Elements, reducing the number of interaction modeled to the minimum.

The results obtained from a preliminary application on few isometric contraction of small number of forearm muscles (Fig.1) show that the method is able to correctly estimate the involved muscles and to explain the variance of the input sEMG with a high precision (Fig.2) [1][2]. Further study will be conducted on non-isometric movements involving an increasing number of muscles as well as using time series of sEMG readings to validate its validity for real time estimation of muscle activity.

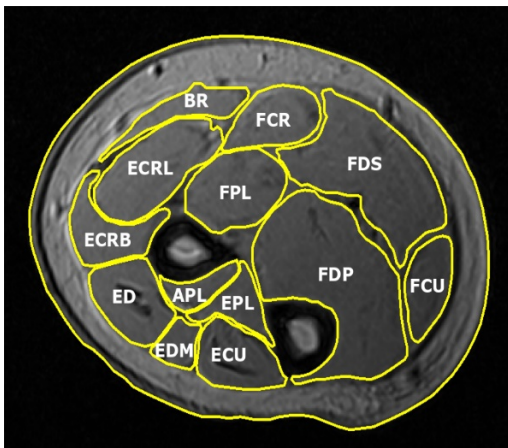


Fig.1 Regions of muscles in a MRI image.

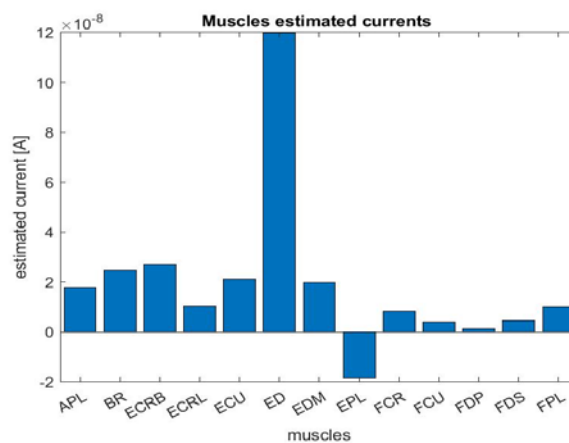


Fig. 2 Estimated current in muscles.

**Keywords:** Electromyography, Graph Theory, Forearm, Signal Processing, Inverse Problem

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# Study on Stress Estimation Using Smartphone Log

Recent years, interest in mental health care is increasing. In 2015, Ministry of Health, Labor and Welfare has made stress checks obligated. This study aims to encourage individuals to understand the degree their stress in order to promote self-care and prevent mental disorders in advance. We propose a method to estimate owner's stress from smartphone log. Figure 1 shows the overall flow of the method. Each data of smartphone is acquired, and the feature is calculated based on the behavior related to stress. We created clusters between participants with similar behavior, implementing machine learning for each cluster. Feature values which are considered to be effective for estimation are selected for each cluster, and LF / HF (used as a stress index) for each day is set to 1 while above the average of participants or to 0 while below the average. Then, we performed machine learning with the correct data. Here, we used the result of pervious research shown in Table 1 to design feature values. The emphasis here is on regular exercise information and interpersonal communication. The flow of feature extraction is shown in Fig.2. It is difficult to measure the conversation with a smartphone so that we use an estimation model. Through the experiment with 19 people, we achieved an accuracy of 67.9%, which has demonstrated the effectiveness of the proposed algorithm.

**Keywords:** Stress, Smartphone, LF / HF, Interpersonal exchanges

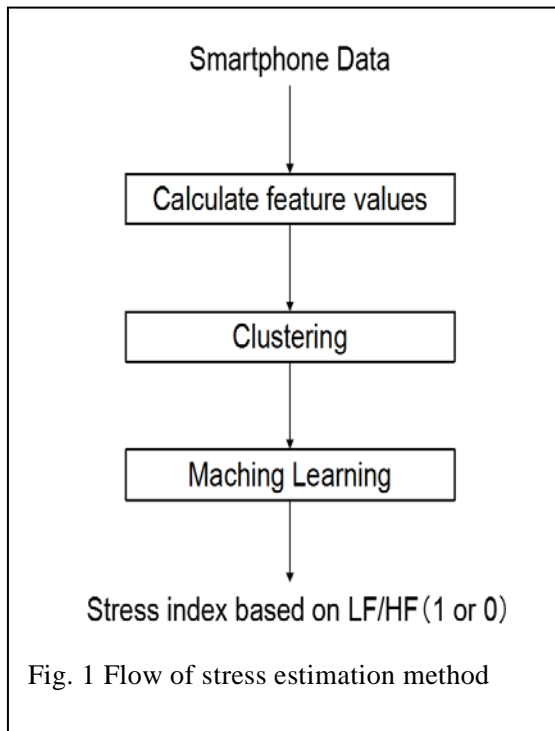
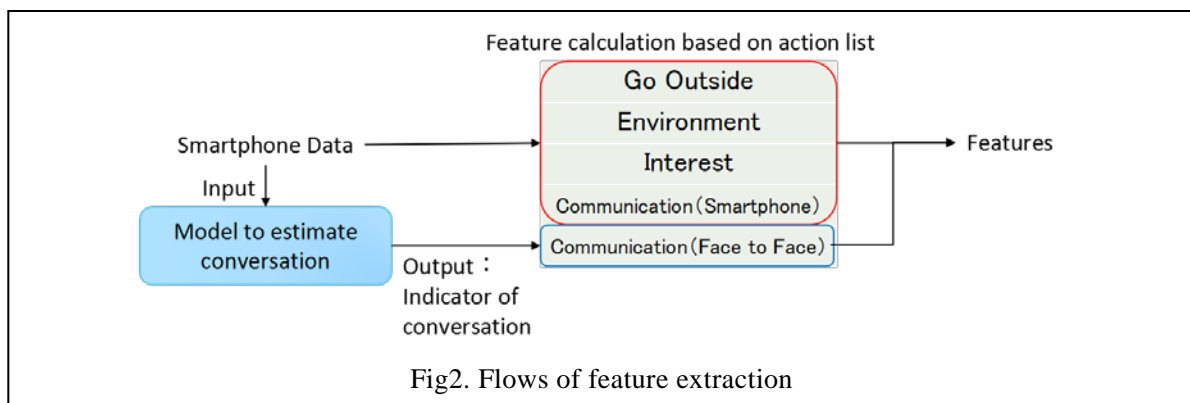


Table 1 Behavior index used as feature value

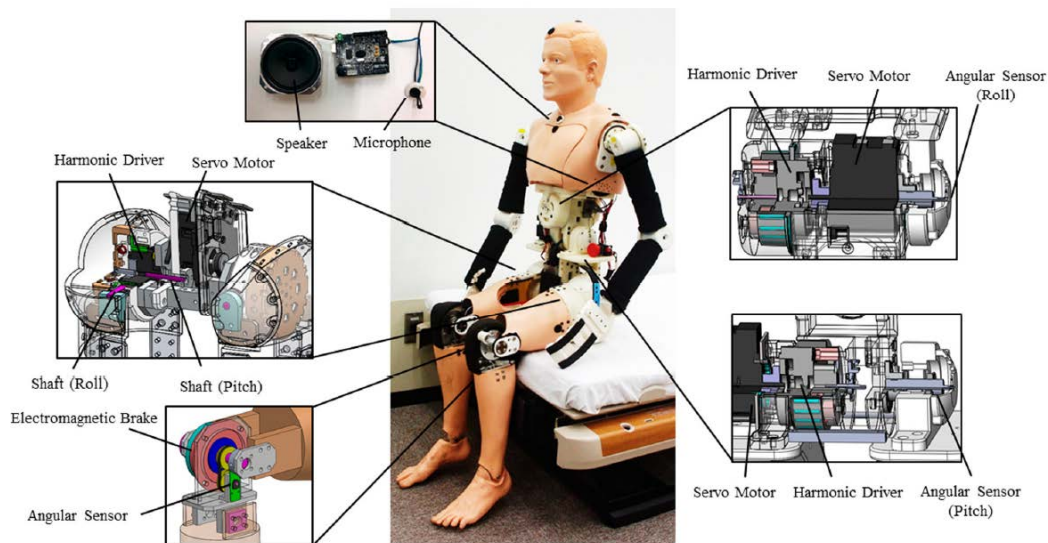
Category	Examples of actions and indicators related to stress
Go Outside	Go out? On foot? Place visited
Environment	How about the ambient brightness? How about the pressure?
Interest	Enjoy hobbies and play? Enjoy the day off?
Communication	Communication on smartphone Talked face to face?
Meal	Number of meals and time,



# Learning Patient Transfer Skill by Using a Robot Patient To Simulate Various Patients

Nowadays experienced nurses play a vital role at hospitals to take care of seniors and patients. However, many statistics reveal that the learning at schools are inadequate, because the students have few accessibilities to obtain the practical experience from actual patients. As the progression of technology, many researches proposed simulators for education propose. But most of the proposed simulator only can reproduce single type of patient which cause inefficiency to learn variability of patient. Moreover, the learning effectiveness has not been measured from the trainees. Therefore, this study aims to develop a robot patient simulating two types of patient for the nursing student to learn patient transfer skill, and also evaluate the learning effectiveness.

Patient transfer is determined as a goal to be improved in this study because of its difficult interaction between nurse and patient, and also the importance to maintain patient's daily life. Two types of patient: injured arm with painful sensation and expression, and hemiplegia were decided to be target patient based on the discussion of nursing teachers. One is related to the painful sensation from the injuries; and the other is related to the behavioral problems. A robot was developed with trunk and four limbs was employed to observe the learning effectiveness on the nursing students. An evaluation method of checklist is proposed by nursing teachers. All the checkpoints are referred to the nursing materials and nursing teacher's clinical experience. An experiment comprised by pre-test, practice, and post-test was conducted by nursing students (n=4). In the pre- and post- test, the students were tested by both types of patient. And during the practice, they were asked to practice three trails of injured arm patient, and also three trails of hemiplegia. The experimental trails at pre- and post- tests were recorded as videos, which were reviewed and evaluated by experienced nursing teacher based on the checklist.



**Figure 1.** Configuration and mechanical design of robot patient.

**Keywords:** robot patient, nursing education, mechanical design

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## Method of expressing customer psychology related to purchasing using physiological measurement

In product and service design, human-centered design has been popularized. Interviews and questionnaires conducted after specific experiences are a basic way to understand user psychology. However, it is difficult to grasp accurately the change in psychological state during the experience of consumers by using those methods. Based on the progress of physiological measurement technology, The purpose of this research is to evaluate sequentially the psychological state of consumers by brain activity measurement and to develop a quantitative analysis method of measurement data.

First, we conducted a user experiment targeting the purchase experience using the online supermarket. In the experiment, in order to measure the subject's subjective evaluation, we developed a subjective evaluation input device that enables sequential subjective reporting in the task execution process. Physiological information was measured in real time by simple electroencephalogram measurement and eye gaze measurement as an objective evaluation index. After the purchasing experience, retrospective interview was conducted based on the post-questionnaire on the purchasing experience and the recorded and measured data from the experiment.

We analyzed the similarity of the purchase experience, taking into account both subjective and objective indicators for the recorded and measured data. We used multiple alignment, which is a sequence analysis method, and the neighbor connection method, which is a cluster analysis method. From the analysis results, we extracted the feature in the appearance pattern of the physiological index when the user is (satisfied) / (dissatisfied) with shopping.

**Keywords:** Consumer Psychology, Physiological Measurement, Sequence Analysis, Emotion

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Fig. 1 Experiment Device



Fig. 2 User Experiment

# Analysis of Study Tour Enhancing Social Concern of High School Students to Local Communities

Due to the depopulation and the aging of the population, there is a shortage of leaders in community development in rural areas. To solve this problem, it is necessary to motivate young people (high school students) living in urban areas to participate in community development. As a means to do so, we focus on study tours through school trips. The purpose of this study is to clarify the influence of learning outcomes in the study tour on the interest in community development of students.

After classifying the learning experience into implicit learning and explicit learning based on the SECI model (Fig. 1), a hypothesis model was built on the influence of the learning experience on the learning outcomes, and a questionnaire survey was conducted. We used structural equation modeling for the analysis.

From the analysis results, it was clarified that students raises interest in community development by acquiring knowledge about regional issues through study tour. Furthermore, this effect is promoted by enhancing self-efficacy from co-creative learning in study tours. Our model can be widely applied in Project Based learning (PBL).

**Keywords:** Tourism, Knowledge Co-Creation, Project Based Learning

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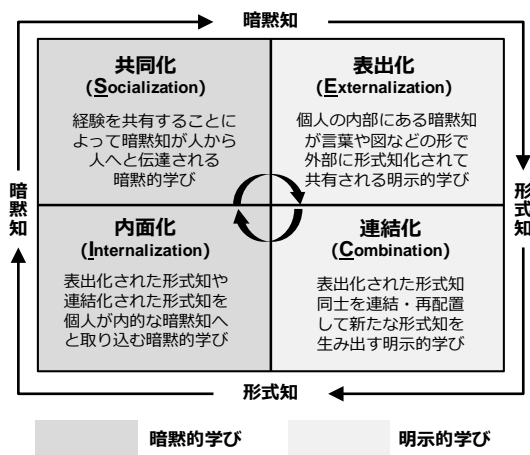


Fig 1. SECI Model

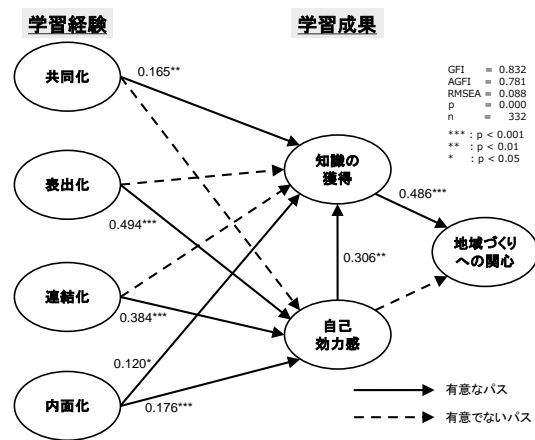


Fig 2. Analysis Results

# Review of Customization Research for the Development of PSS Customization

In the manufacturing industry, in order to produce higher value-added products, customization of product/service system (PSS) combining tangible products and intangible services is attracting attention. However, what should be discussed in the design of PSS family has not been clarified. Therefore, through the literature review, we clarified the points to be studied in the customization of PSS.

Specifically, we investigated papers on the family design of products, services, and PSS, and compared them in terms of "design object" and "design method". In order to systematically compare the literature in each field, we created Concept Matrix based on the model used in the PSS design for product, service, and PSS. Figure 1 shows the words used in keywords search used and the obtained results.

From the results, it was pointed out that there is a need to promote research on module design in PSS. It has been found that service module design, which has already been researched, should be referred to in the context of PSS module design since both of them has similar characteristics.

**Keywords:** Customization, Product/service system (PSS), Integrated solution, Design science, Platform, Literature review, Modularity

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フェーズ		PSS	Service customization	PSS customization	Product customization
検索	タイトル	"service" "hybrid offering" "PSS" "integrated solution"	"customization" "service family design"	"customization" "PSS family design" "hybrid offering family design" "integrated solution family design"	"customization" "product family design"
	トピック	"CAD"	"service"	"product service system" "hybrid offering" "integrated solution"	"product"
	研究分野	"engineering" "computer science"	"engineering"	None	"engineering"
	文献の種類	"article"	"article"	"article"	"review article"
検討文献の選出	必要条件	本研究との文脈との一致 計算機上での実装があるか	明確なモデルを提示し, 設計研究の観点を有するもの	明確なモデルを提示し, 設計研究 の観点を有するもの	設計理論に基づく研究を広範囲に 調べたもの
結果					
検索された論文→ 選出された論文		PSS 40→3	Service customization 44→4	PSS customization 5→3	Product customization 5→4
選出論文		(Komoto and Tomiyama 2008) (Hara, Arai et al. 2009) (McKay and Kundu 2014)	(Jiao, Ma et al. 2003) (Sakao, Shimomura et al. 2007) (Fogliatto and da Silveira 2008) (Moon, Shu et al. 2010)	(Ming and Liyue 2011) (Kuo 2013) (Song and Sakao 2017)	(Simpson 2004) (Jiao, Simpson et al. 2007) (Fogliatto, da Silveira et al. 2012) (da Silveira, Borenstein et al. 2001)
コンセプトマトリクス を用いた比較	設計対象 ・入力情報 (ペルソナ・制約) ・設計物 (ニーズ・機能) ・実体 (製品・サービス) 設計方法 ・入力方法 ・設計方法 ・評価方法				

Figure1 : Condition of literature search and research result

## Risk Assessment System of Human Activities in Order Picking Using IMU-based Motion Capture Device

Warehouse, used to store or buffer products, plays an important role of supply chain's performance. Warehouse contributed to about 20% of firms' logistics costs. In order to serve customers well, order picking (OP) is considered as the highest priority area for productivity improvement. However, human factors were less considered in previous research of OP design while the activities of OP are high labor-intensive. And most of previous research used self-report or video-based method to investigate the health situation of operator, which are subjective. Therefore, this research is aimed at developing an assessment system for not only posture but also human activities during OP process.

IMU sensors (Fig.1) are used to collect posture information of operators and then joint angles are estimated based on these data for Rapid Entire Body Assessment (REBA) usage of posture risk assessment. REBA is a postural analysis tool sensitive to musculoskeletal risks in a variety of tasks and it is originally applied to health care field. The posture part of REBA need body joint angles for computation. We also recorded human activities contents by camera. Finally, risk assessment of every kind of activities during OP process such as picking, holding, pushing and pulling is carried out following KIM standard.

**Keywords:** order picking, human factors, IMU sensors, risk assessment system, REBA

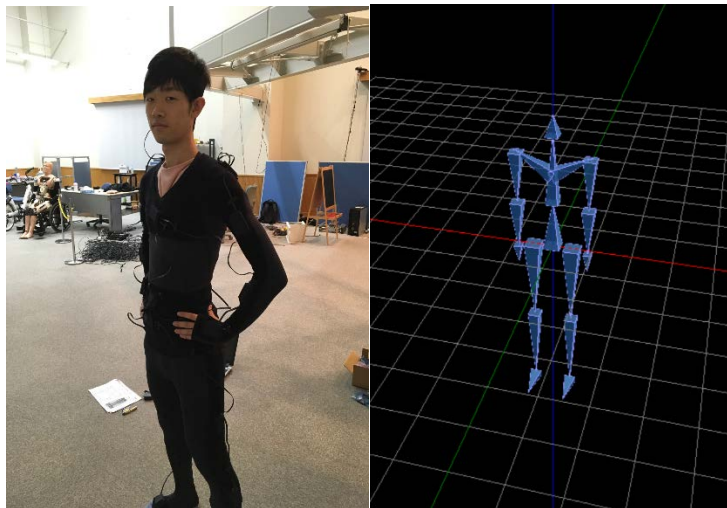


Fig. 1 (a) Motion capture device (left) (b) Motion capture software (right)

# Actor Transformation and Zone Designing to Enhance Community Sustainable

Due to aging and population centralization, there is concern about the decline of the local community. It is difficult to sustain the living of local communities with public services of the administration which only can provide uniform services. Therefore, community support services for supporting residents' living are needed, and participation of residents in those services is essential.

In this study, we proposed the "service topos model for actor transformation" that indicates that residents' participation in community activities is promoted through the use of community support services (Fig. 1). The residents in the recipient state who only consume value are transformed into generic actors who participate in the value proposition for the local community through the state of quasi-actor who transfers resources.

Furthermore, a modeling method based on goal-oriented requirements engineering is used, and based on the case analysis of community support services, a method is drawn out that depicts local communities as a service ecosystem. This is a method of zone design that enhances the sustainability of local communities that do not rely on traditional administrative divisions by describing the dependency relationships between a single resident and a community as its group.

**Keywords:** System Design, Actor Transformation, Community Development

## Reference

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状態	受容者 	準行為者 	ジェネリックアクター
欲求	物質的な欲求	社会的な欲求	感情的な欲求
行動	資源消費	資源伝達	資源統合
場の意味 (トポス)	実践の場	集合の場	家庭の場
提供支援	手段的支援	関係構築	感情的支援
獲得する価値	機能的価値	社会関係価値	情緒的価値

Fig 1. Service Topos Model for Actor Transformation



# Analysis of Flight Attendants' Cognitive Skill during In-flight Service and Development of Learning material To support skill acquisition

In recent years, it is required to train flight attendants efficiently since the number of flight attendants hired by airline companies is increasing. In the light of this trend, this research aims at developing a learning material which enables junior flight attendants to learn skilled flight attendants' skill efficiently.

First of all, in order to understand what is the skill of skilled flight attendants, we created service-process model. In addition, we extracted the cognition about "Why did you provide the particular service ". In order to extract cognition, experiments with flight attendants were conducted, and retrospective interview data were analyzed using the grounded theory approach. Result show that, in comparison with the junior flight attendant, the skilled flight attendant had deeper consideration of possible service he/she could provide and the passenger's psychology such as request, situation, and action he/she might take.

After integrating the above findings, we summarized the service process model and developed a training material for junior flight attendants to support the acquisition of service skills. From the experiment to evaluation the learning effect of the training materials, we clarified the process of acquiring service skills which is the consideration of passengers' psychology such as the demand of the passenger.

**Keywords:** Flight Attendant, Cognitive skill, Grounded Theory Approach, Learning Materials

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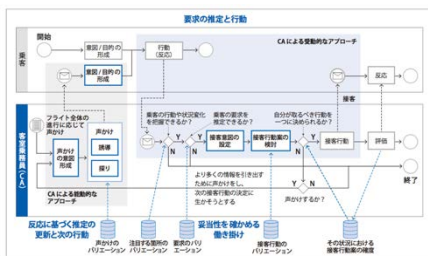


Figure1 : Service Process model



Figure2 : Retrospective interview

# Utilizing Crowd Information of Tourist Spots in an Interactive Tour Recommender System

The development of information and communication technology has enabled tourists to make detailed travel plans. However, it is difficult for many tourists to visit popular spots due to a crowd. The tolerance for a crowd differs from person to person. Furthermore, the effect of the crowd differs depending on the purpose of a trip (Fig. 1). This study aims to develop a tour planning support method through interactive presentation of crowd information in order to capture individual preferences and demand.

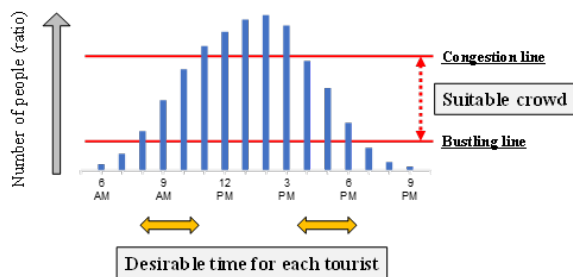
We developed a system that reflects feedback in the plan through user selection. To tourist spots selected in the plan, the system shows crowd information and options dealing with the crowd (Fig. 2).

We conducted user experiments to verify the proposed method. Results show that the plan which coped with the crowd was able to be presented without decreasing the utility for tourism preference largely. Additionally, we found that the decrease in utility due to crowded situation during sightseeing were prevented if users recognized crowdedness in advance.

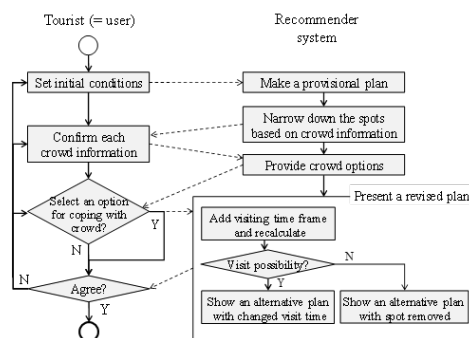
**Keywords:** tourism, recommender system, crowding data

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**Fig. 1.** Model of tourists' perception of crowd



**Fig. 2** Interactive process of the proposed system

# Service Analysis in Home Delivery to Clarify the Effects of the Convenience in Service on Customer Psychology and Behavior

Since the number of redelivery in home delivery is increasing, home delivery service providers are exhausted. Through the two studies, the effect of service options in home delivery on customer psychology and behavior was analyzed.

First, we used structural equation modelling (SEM) for questionnaire of consumers in home delivery service to identify the effect of customer psychology toward customer behavior. The results showed that customer's psychological ownership does not decline a lot of the amount of redelivery, whereas it strongly promotes customer participation behavior which is necessary behavior for the success of service delivery.

Secondly, in order to clarify what prevents customer's psychological ownership from declining the amount of redelivery, the systematic analysis in home delivery service system was conducted by a goal-oriented requirement engineering modeling called i\* (Figure.1). We clarified factors which prevent customer's psychological ownership from declining the amount of redelivery.

**Keywords:** Service Modelling, Service Design, Customer Behavior

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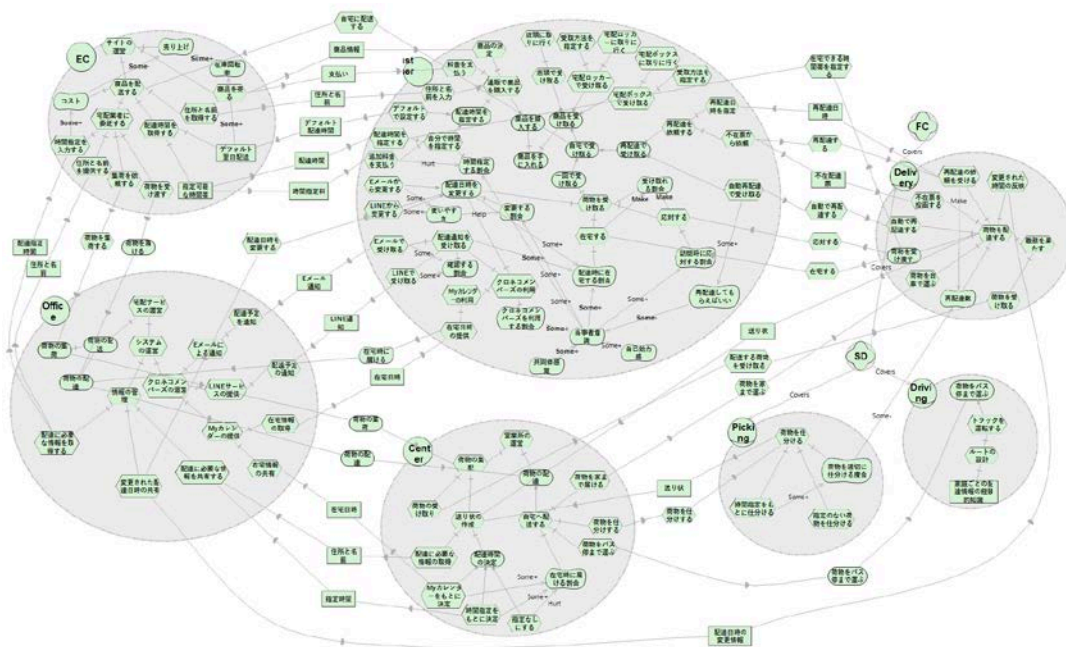


Figure 1. The modelling result of home delivery service by i\*