Introduction to Mobile Robotics Lab.
(OTA Lab.)
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Research Topics of 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, evolutionally computation, control theory, and so on.

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

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Interactive Methods for Specifying Grasping Points to Robots

A semi-direct teaching method for specifying information for grasping objects in home or office environments through the generation of a teaching data is proposed in this research. Information specified during the teaching process includes: object’s shape, grasping force, grasping position, and orientation. To achieve this data indication in our approach, we propose the use of a teaching tool created by us and which has the same mechanism as the hardware (gripper) placed on the robot Pioneer 3 (Fig. 1). This enables our system to carry out the teaching process without using the robot. The challenging point is how to easily obtain information on shape, grasping force, grasping position, and orientation to be used as teaching data.

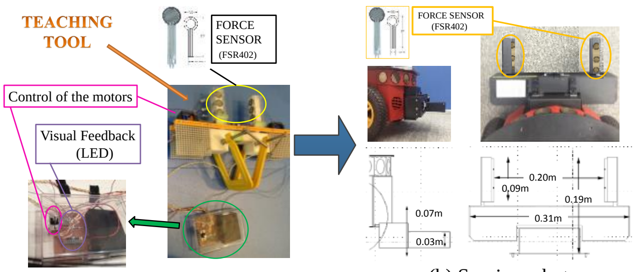
In the proposed method (refer to the flowchart Fig. 2), we use an RGB-D device to get information regarding the height (in meters) relative to the flat surface of the desk and the arm of our teaching tool. The system also provides us with information about how deep (in meters) the arm of our teaching tool went into the cube. With this information, part of the teaching data is generated.

In the teaching tool, we are using force sensors to obtain the measurement of applied force (in newtons) by the teaching tool at the moment of grasping the object, but also to measure the stability of the object once it is lifted. An overview of the method approach is shown in Fig. 3.Our approach method was evaluated to determine the quality of the measurements obtained, the result of the data generated in one of our experiments it is shown in Fig. 4.

Keywords: Robot teaching, RGD-B sensor, Grasping.

Reference

[1] J. Figueroa, T. Sakuyama, Y. Miyazaki and J. OTA, Interactive Methods for Specifying Grasping Points to Robots, Prepr. 30th Annual Conference Robotics Society of Japan, RSJ2012AC4D2-5, 1/3 (2012).



(a) Teaching tool (b) Service robot

Fig.1 Teaching tool and the robot

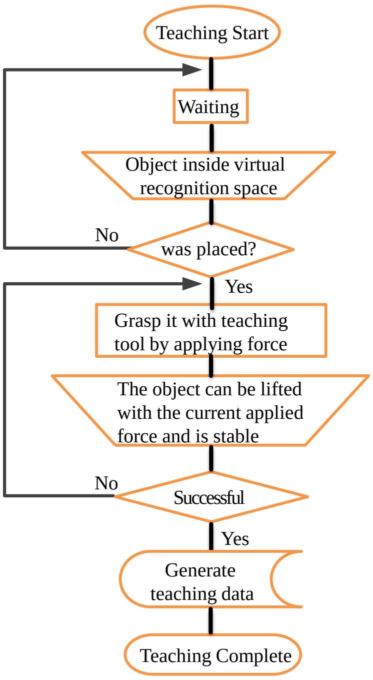


Fig.2 Flowchart showing the process of teaching

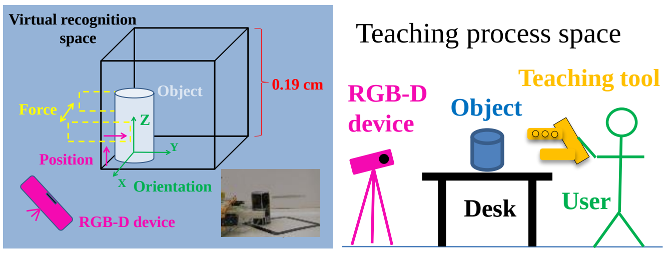


Fig.3 Overview of the method

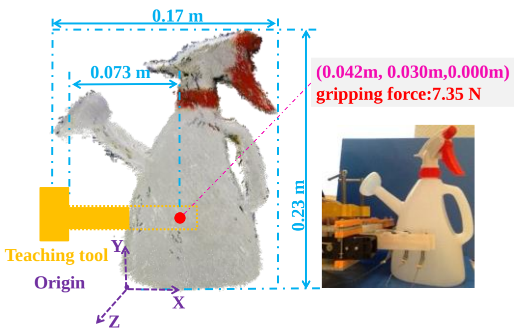


Fig.4 Teaching data generation

Transportation of a Large Object by Mobile Robots Using Hand Trucks

To transport a large object by small mobile robots, it is important to reduce the load on the mobile robots. As a solution for this problem, this research proposes a new methodology for object transportation by mobile robots using hand trucks.

In the proposed method, the object is loaded onto small hand trucks by two mobile robots in the following steps (Fig.1). First, a robot equipped with an end-effecter tilt (robot A) an object to provide the space between the object and ground. Then the other robot (robot B) inserts two hand trucks into the provided space. The robot A moves to the opposite side of the object to tilt it again, and the robot B insert the rest of the hand trucks.

For motion planning of the robots, it is necessary to decide "where to insert the hand trucks" and "where to push by the end-effector to tilt the object" considering the operating procedure of the mobile robots. This problem is formulated as an optimization problem. The stability of the object in the final state in which the object can be transported is used as an evaluation function. The penalty method and multi -start local search method were chosen to acquire the optimization solution.

In the simulation, it was confirmed that the proposed algorithm is applicable to objects of arbitrary shape (Fig.2). And the result shows that mobile robots can transport heavier objects in this method than the conventional method in which robots lift up the object coordinately (Fig.3).

Keywords: Mobile robot, Object transportation, Hand truck

Reference

[1] T. Sakuyama, J. Figueroa, Y. Miyazaki and J. Ota, Transportation of a Large Object by Small Mobile Robots using Hand Carts, In Proceedings of the 2012 IEEE International Conference on Robotics and Biomimetics (ROBIO2012), 2108/2113 (2012).

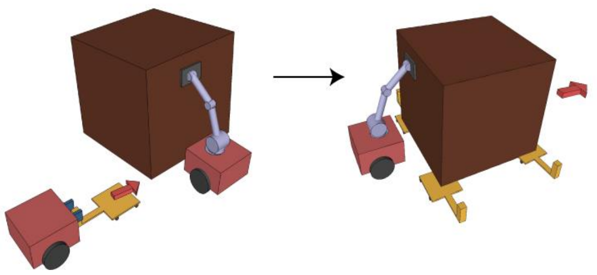


Fig. 1 Image of the proposed method

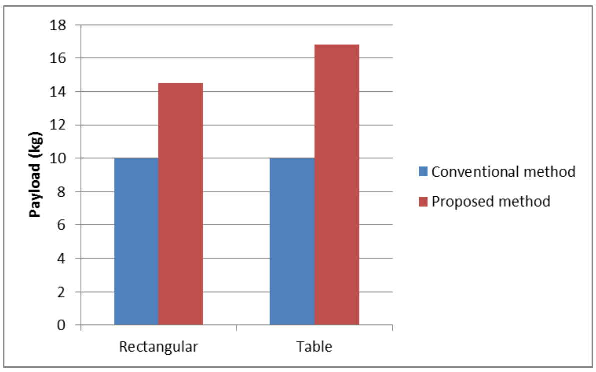


Fig. 3 Comparison of the payload

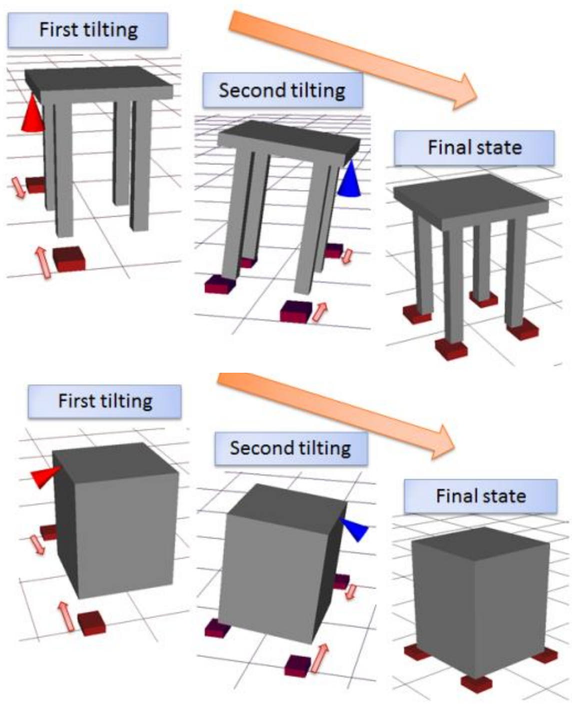


Fig. 2 Simulation result

Real-time Robot and Spacecraft Actuators Fault Diagnosis and Motion Estimation

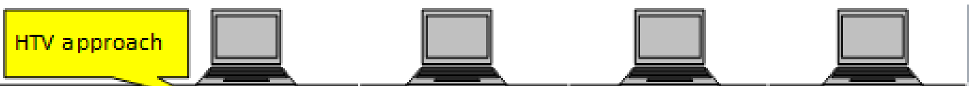
In recent years, the fault diagnosis of electro-mechanical robotic systems has been performed in widespread applications, including grand vehicles, unmanned aerial vehicles, and spacecraft. According to the IFAC SAFEPROCESS Technical Committee defined terminology, there is an absolute necessity to identify unexpected changes (faults) in a system before they lead to a complete breakdown (failure) [1]. It is also worth noting that actuator fault detection is particularly important in space applications, as thruster faults occurred in 12% of 129 searched spacecraft launched between 1980 and 2005 [2]. The functionality to supply computational redundancy for a robotics system to be sustained is fault diagnosis – the computational utilization of mathematical relations between measured or estimated variables to detect possible malfunctions that we want to realize with few extra conventional motion estimation procedures.

We propose improved particle filtering-based approaches, adaptive resampling for the fault states, and state-segmentation. The ordinal approaches such as State Observer and Kalman Filtering can *detect* faults but *diagnose*. This means it can detect something is wrong, but cannot find which component has been failed and how. Particle Filtering is an excellent frame work for modeling faults so it may diagnose faults. However, the ordinal Particle Filter requires tremendous amount of "particles," each of which represent dynamics and fault mode. The goal of this research is to reduce amount of particles (or computation). The adaptive resampling involves resampling timing as well as the use of a reward-punishment function constructed from the actuator input information. As another novel approach to particle filtering, both a continuous state vector and fault states are segmented. For each segmented space, an attempt is made to construct a corresponding posterior distribution independently, resulting in a reduction in particles.

Keywords: Fault Diagnosis, Particle Filtering, Failure Detection and Recovery, Redundant Robots, Space Robotics

Reference

[1] R. Isermann and P. Balle, Trends in the application of model-based fault detection and diagnosis of technical processes, Control Engineering Practice, vol. 5, no. 5, 709/719, 1997.
[2] M. Tafazoli, A study of on-orbit spacecraft failures, Acta Astronautica, vol. 64, no. 2-3, 195/205, 2009.



Method #	#1: State Observer	#2: Kalman Filter	#3: Ordinal Particle Filter	#4: Improved Particle Filter
Noise tolerability	Sensitive to sensor noise & modeling error	Robust to noise	Robust to noise	Robust to noise
Can fault detect?	Yes	Yes	Yes	Yes
Can fault diagnosis?	No	No	Yes	Yes
Is computable?			No	Yes

Fig. 1 Comparison of Actuator Fault Detection/Diagnosis Methods

Part Dispatching Rule-Based Robust Multi-Robot Coordination against Goal Variation in Pick-and-Place Task

In a pick-and-place task, goal variation occurs because the parts on the conveyor are fed following a certain probability distribution with various random seeds. To make the manipulator system complete the task reliably and efficiently, the robust solution should be obtained against goal variation.

In this study, we propose a method (Fig. 1) to obtain a robust solution against goal variation in a pick-and-place task. The multi-robot conveyor system is used to complete the task (Fig. 2). The part flow is considered as the performance index. The combination of part dispatching rules is set as the design variable to coordinate the actions of robots. In the proposed method, the greedy randomized adaptive search procedure (*GRASP*) is utilized to search for the appropriate combination of part dispatching rules [1]. The Monte Carlo strategy (*MCS*) is used to estimate the minimum-maximal part flow for one combination of part dispatching rules. The proposed method (*GRASP+MCS*) is verified to be effective and practical through a comparison with two methods through simulations. The task completion success ratio derived by the proposed method can reach 99.4% for 10,000 patterns (the process of feeding parts on the conveyor following a given probability distribution with 10,000 different random seeds), which is improved by 73.3% and 19.6% relative to that derived by *O_GRASP* and *GRASP+GA*, respectively (Table 1).

Keywords: Part dispatching rule, Multi-robot conveyor system, Robust optimization, Goal variation, GRASP, MCS

Reference

[1] Y. J. Huang, R. Chiba, T. Arai, T. Ueyama and J. Ota, Part Dispatching Rule-Based Multi-Robot Coordination in Pick-and-Place Task, In Proceedings of the 2012 IEEE International Conference on Robotics and Biomimetics (ROBIO2012), 1887/1892, (2012).

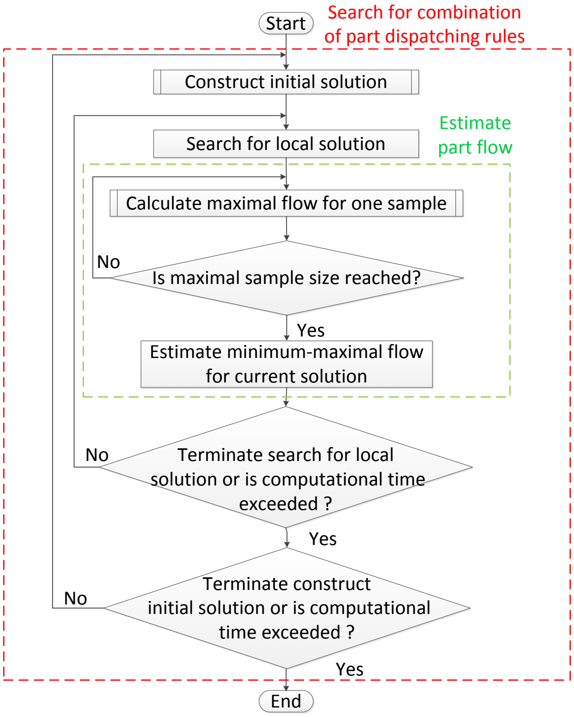


Fig. 1 Proposed method

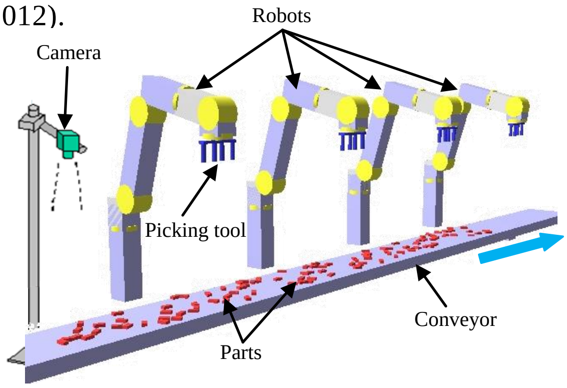


Fig. 2 A multi-robot conveyor system that consists of multiple robots, a moving conveyor, a picking tool with multiple absorbers, and a camera.

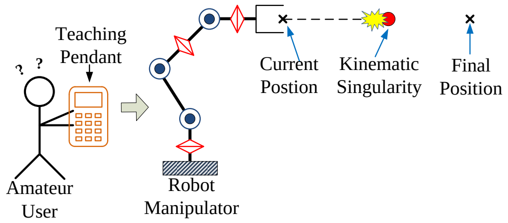
Table 1 Solution obtained by using three different methods

Method		*O_GRASP*	*GRASP+GA*	*GRASP+MCS*
Obtained solution	Obtained combination of part dispatching rules	(SR, SR, SR, FIFO)	(SPT, SPT, SPT, FIFO)	(SPT, SPT, SPT, FIFO)
	Estimated part flow (piece/s)	17.1	17.0	15.8
Task completion success ratio		26.1%	79.8%	99.4%
Computational time (h)		0.3	10.0	10.0

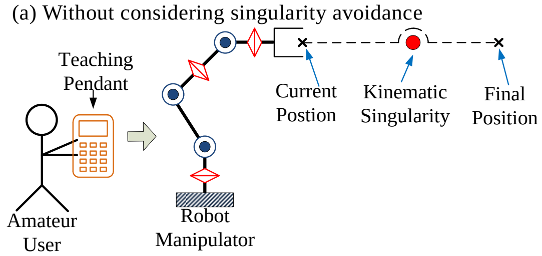
Teaching-Playback Robot Manipulator System in Consideration of Singularities

Normally, in the industrial robot teaching-playback system, a teaching pendant is used as a portable console in order to teach the robot, and there are many technicians who do not have expertise about robotics but still doing the teaching task to the industrial robot. For robot manipulator, a kind of singular posture in which the end-effector locality loses the ability to move in arbitrary direction. For those users who do not have the knowledge about that, it is difficult for them to consider the singular posture of robot; as a result, the end-effector will be difficult to be moved. Hence, the performance of the robot teaching system will be worse, and even cause some problems (as shown in Fig. 1(a)). The purpose of this study is to design a teaching-playback robot manipulator system that allows these non-expertise users to move the end-effector of robot manipulator from point-to-point by using teaching pendant without worrying about singular posture. In other words, when user move the end-effector come nearby the kinematic singularity, the end-effector will avoid the kinematic singularity automatically (as shown in Fig. 1(b)). The proposed methods of singularity avoidance will be taken account into non-redundancy and redundancy DOF robot manipulator system. Here, we compare the three systems obtained by adding a system that does not consider singularity avoidance. The trajectories of end-effector pass through the shoulder singularity (Fig.2. (a) system without considering singularity avoidance, (b) non-redundancy singularity avoidance system, (c) redundancy singularity avoidance system) and wrist singularity (Fig.3. (a), (b), (c) are same description as Fig.2) are verified in the experiment. The result shows that both of the proposed algorithms also can perform better than the system without considering singularity avoidance

Keywords: Robot manipulator, Singularities avoidance, Inverse kinematic, Jacobian Matrix

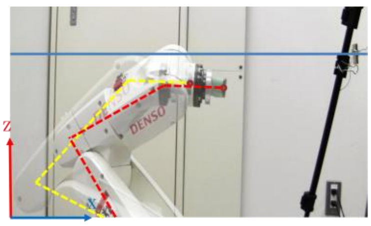


(a) Without considering singularity avoidance

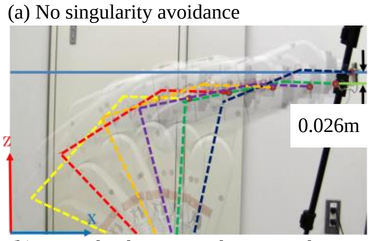


(b) With considering singularity avoidance

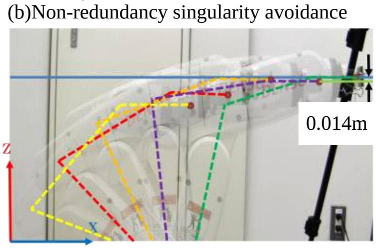
Fig. 1. Motion-teaching robot manipulator



(a) No singularity avoidance

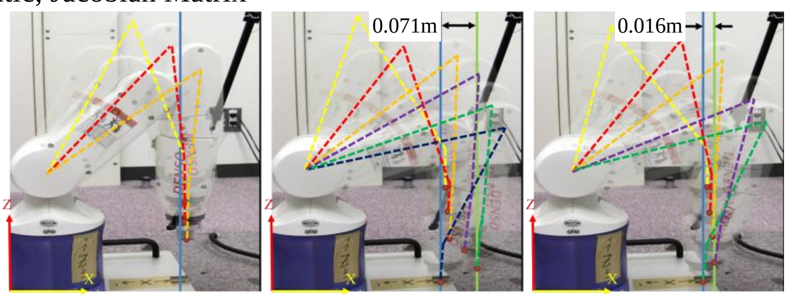


(b)Non-redundancy singularity avoidance



(c) Redundancy singularity avoidance

Fig. 2.Trajectory of end-effector moves from initial point to final point in shoulder singularity test using teaching pendant



(a) No singularity avoidance (b)Non-redundancy singularity avoidance (c) Redundancy singularity avoidance

Fig. 3. Trajectory of end-effector moves from initial point to final point in wrist singularity test using teaching pendant

Modeling and Design of Conveying System

The role of warehouse in the distribution trade is not only to keep products in good conditions but also to manage and arrange the stock to ship them as soon as they are ordered. As shopping through the Internet has got more popular recently, the demanded capacity and performance for the warehouses have become higher. Thus the distribution system is being mechanized and controlled electrically and machines are widely used in warehouses. However, the design of automated warehoused has relied on by skillful system engineers' experience and there was no formulized method established up to now. Thus the design results differ upon the people. It was inefficient not only because the calculation took a lot of time but also because there are so many reworks for a design. Especially, the size of buffer, which is used as temporary storage area for machines to pass loads to another, is difficult to estimate because to know the actual operation situation at design phase is usually impossible.

In this study, a mathematical model called "queuing network theory" is adopted to calculate the size of buffer as well as the number of machines. In the proposed method, warehouse system is modeled a network; nodes represents machines and loads go around the network. The result implies that without any constraint there is a possibility that the necessary size of buffer is too large. And through simulations, the buffer proved to be large enough to temporarily storage loads, which suggests the appropriateness of the proposed method.

Keywords: Queuing network theory, Automated warehouse, System design, Conveying system

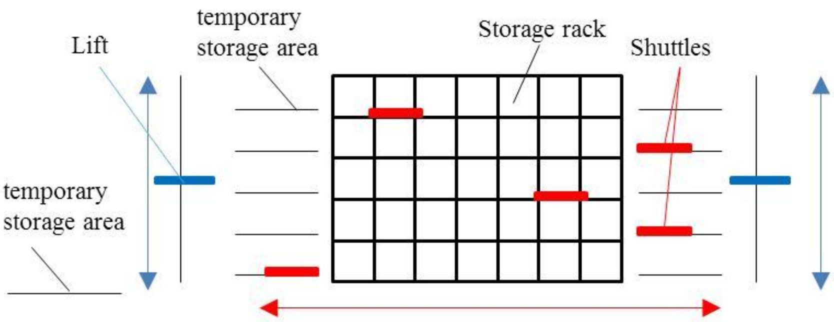


Fig. 1 An example of automated warehouse system. Lifts and shuttles convey loads and buffers are necessary among them.

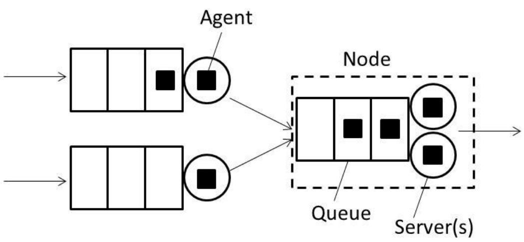


Fig. 2 Outline of queuing network. Loads wait in the queue until they go to the front of it and are conveyed by machines.

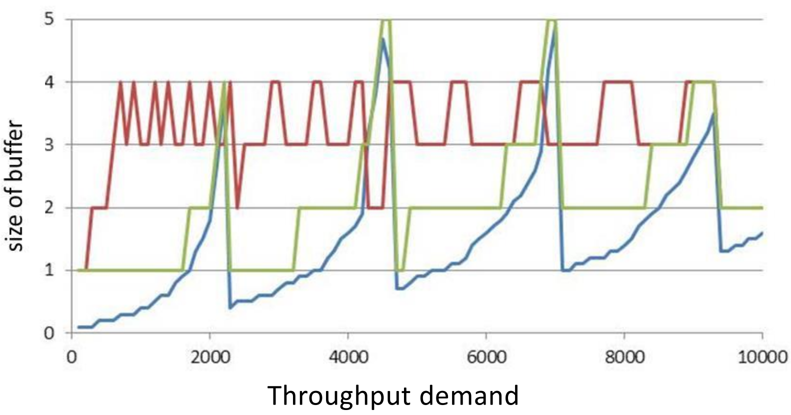


Fig. 3 Change of buffer size according to the throughput demand

Rule Generation for Multi-agent System

The system, which is composed of decision-making entities (agent) and completes difficult problem by not an action of one agent but cooperation of some agents, is called “Multi-agent System.” Multi-agent system exists in many scenes. For example, in a restaurant, some clerks cooperate and cope with many customers for a purpose of the whole system like improvement of customer satisfaction. Many examples of multi-agent system modeled by researcher exit, and these systems were analyzed how these system work when the action rule of each agent is defined. However, a few studies to inquire into how each agent should work for accomplishing purpose of the whole system exist. Especially, There are few studies to generate rule which is simple for people to understand and robust to accomplish purpose in unknown environment. Scheduling problem, in which the process some agent observe environment and determine their action is repeated, are target in this research. And generating simple and robust rule for multi-agent system is defined as the purpose of this research.

In this research, rule of agent is dealt with divided into condition part (what each agent should do in how is the environment) and combination (what a kind of order some condition parts should be considered in). Condition parts are optimized using SAP, and Combination is optimized using PADO. SAP and PADO are one of simulation-based evolutionary computation algorithms. However, in former studies, the problem which computation time becomes enormous happens when robust solution are tried to be calculated using simulation-based algorithm. Therefore, in proposed method, the algorithm which extracts constrains of solution from simulations repeating in a computation and generates candidate solutions using these constrains is proposed. this algorithm can reduce the number of simulation.

Proposed method is evaluated using the problem of taxiing control at a large airport. Figure 1 express perspective of simulation, and solutions which does not generate dead-lock like Figure 2 but total taxiing time of aircrafts is not so much are calculated using proposed method. In addition, the algorithm extracting constrains can make computation time lessen one twentieth

Keywords: Rule Generation, Simulation-based optimization

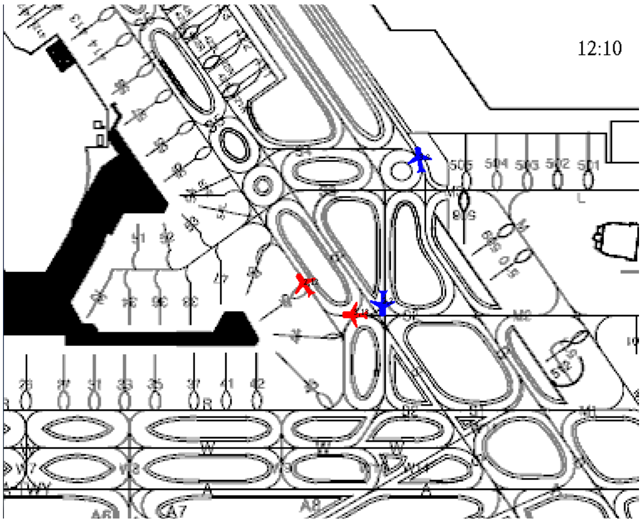


Fig.1 Perspective of simulation

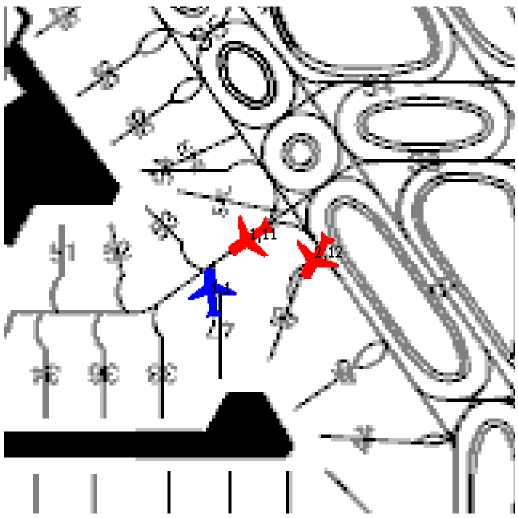


Fig. 2 Dead-lock

Nursing Self-Training System

Recently, it is required more and more nursing care service, as the seriousness of aging problem is increasing. However, the requirement is prevented by the shortage of nursing teachers. One way of solving this problem, is to provide a self-training system which is able to automatically measure the performance of the trainee and provide the evaluation results as almost the same precision with the nursing teachers' (Fig.1).

In the research, we forced on patient transfer and bed making which are the fundamental and the heavy nursing tasks (Fig. 2). In the proposed system, the Kinect sensors (Microsoft co., Ltd.) which are able to provide color and depth images are applied. The trainee's performances, such as posture, body joints' spatial positions and the bed's state were measured by the combining with color and depth data. The system evaluated the trainees' performance in each evaluation items by indicating right or wrong. Then trainees are able to correct their error performance by reviewing the system's evaluation results and the demo video.

The performance of the system is examined by the controlled trials. The average accuracy of the system's evaluation results was 81.4% in patient transfer training and 80.0% in bed making training. In addition, Fig. 4 depicted the training effectiveness of patient transfer.

Keywords: Self-training system, Nursing skills, Skill Evaluation, Kinect sensor

Reference

[1] Z. Huang, A. Nagata, M. Kanai-Pak, J. Maeda, Y. Kitajima, M. Nakamura, K. Aida, N. Kuwahara, T. Ogata and J. Ota, Posture Study for Self-training System of Patient Transfer. In Proceedings of IEEE International Conference Robotics and Biomimetics (ROBIO2012), 842/847, (2012).

[2] Ayanori Nagata, Z. Huang, M. Kanai-Pak, J. Maeda, Y. Kitajima, M. Nakamura, K. Aida, N. Kuwahara, T. Ogata and J. Ota, Supporting System for Self Training of Bed-Making Using Image Processing with Color and Distance Information, In Proceedings of IEEE International Conference Robotics and Biomimetics (ROBIO2012), 2102/2107, (2012).

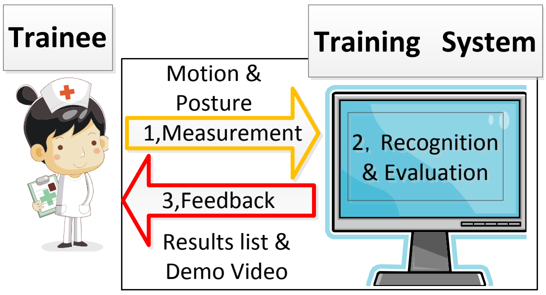


Fig.1 System Image

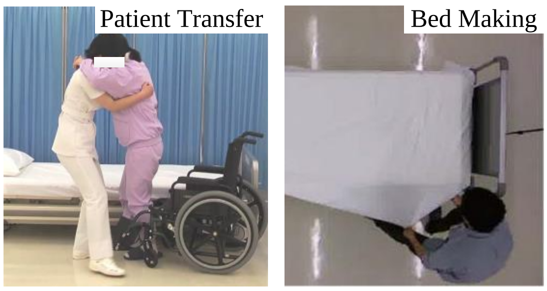


Fig.2 Patient transfer and bed making

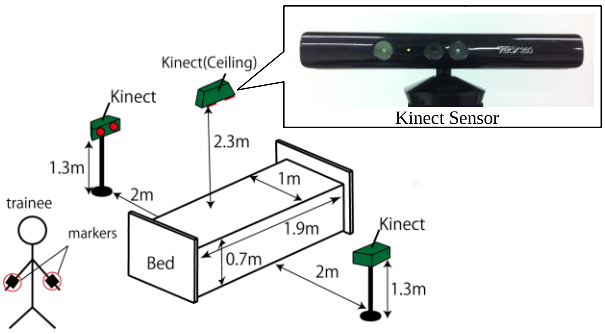


Fig.3 Camera system

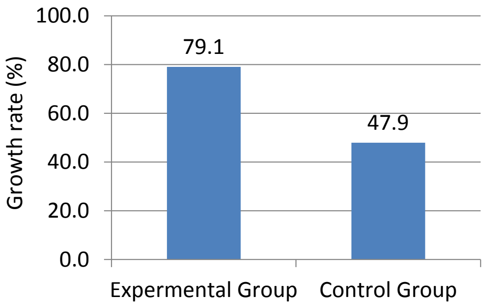


Fig.4 Comparison of training effectiveness

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, 456/459, (2012).

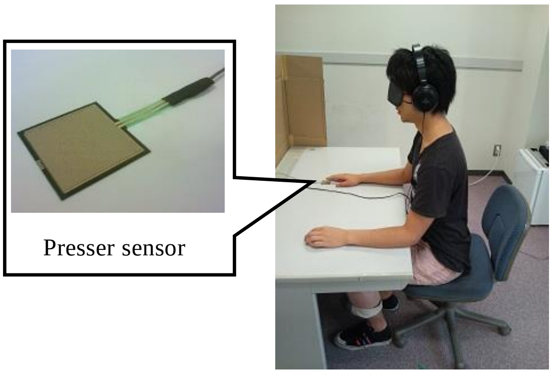


Fig. 1 The picture of a participant in the experiment and the presser sensor to measure the timing of the tapping

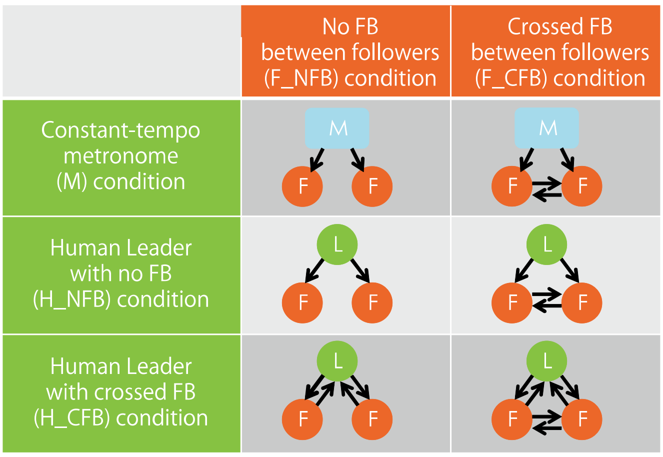


Fig. 2 The conditions of a leader who keeps the constant tempo and followers who cooperatively produce rhythm to synchronize with the leaders. The arrows indicate presentation of stimuli of metronome or other peoples' tapping timing. FB means feedback.

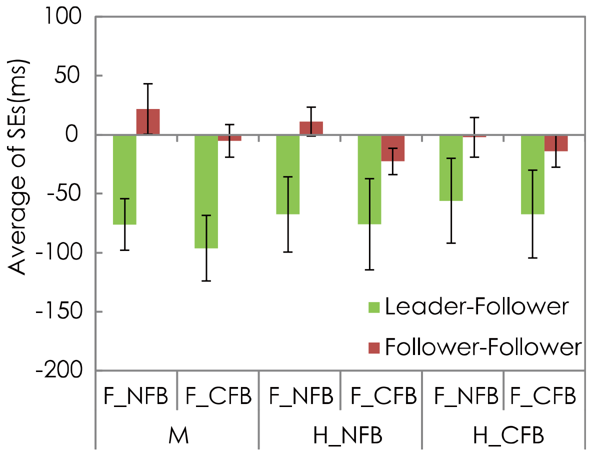


Fig. 3 Averaged synchronized errors (SEs). The followers tended to tap before the leaders.

Modeling of Quiet Standing Postural Control

Human beings achieve postural control through the coordination of whole body muscle activities under the control of sophisticated nervous system. Clarification of standing postural control mechanism makes significant contribution to the field of physiology. We found that the composition of muscle tension includes not only tension for keeping balance but also one for exciting whole body's muscle activity. However, the model of it hasn't been created yet.

The purpose of the research is to model brain cortex – reticular formation – spinal tract control system for postural maintenance during the quiet standing. We hypothesized that both balance control system, constructing the muscle synergies, and feed-forward control system, increasing whole body's activity, exist for standing postural control. Control model which represents the function of them is to be presented.

To achieve the goal, a simulator has been created based on musculo-skeletal model which is able to represent the motion of quiet standing in order to evaluate function of balance control system and simple feed-forward control system quantitatively. In addition, according to the physiology knowledge, frequency of body's tremor during postural control is 10HZ, so that whether postural control can be realized when sample time of balance control system is 100ms is to be validated. Then, the function of reticulospinal tract during postural control is able to be evaluated quantitatively based on motion commands of muscle synergies which are responsible for balance control, whole body's excitatory activity， and sample time of balance control system.

The simulator with essential joints and segment, shown in Fig.1, was developed in OpenSim. As the first step of the research, feed-forward control system, without balance control system, was simulated to validate the motion output of the simulator.

Keywords: Postural control, Musculo-skeletal model, Reticulospinal tract model

Reference

[1] R. Chiba, H. Ogawa, K. Takakusaki, H. Asama and J. Ota, Muscle Activities Changing Model by Difference in Sensory Inputs on Human Posture Control, Advances in Intelligent Systems and Computing, vol. 194, 479/497, 2013.

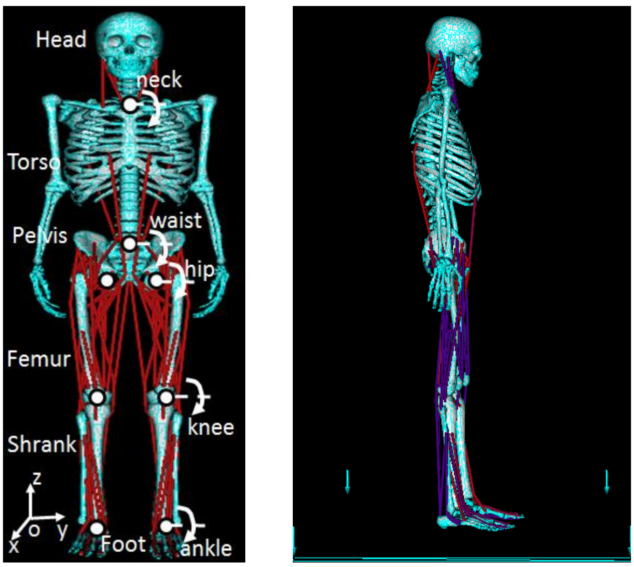


Fig.1 Simulator based on musculo-skeletal model

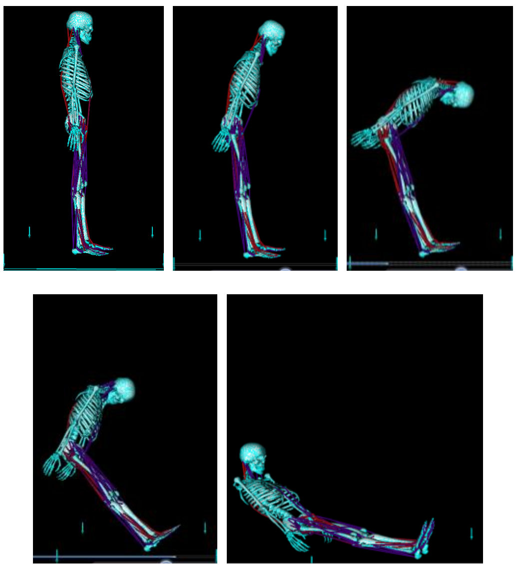


Fig.2 Simulation for body increasing activity model

Activity-Aware Recommender System Exploration using Twitter Data

In everyday life, we keep receiving recommendations from others either by words of mouth, press print, or multi-media such as TV advertising. Nowadays, recommender systems are entering our life online: advertising about something you searched the other day in Google appears in the right side of your current searching page; Amazon always tries to guess what you would be interested in and give some similar items as recommendations; content sites such as StumbleUpon provide information in particular areas which you set before.

This research will serve for recommender systems by focusing on capturing people's activities from tweets to find the associated preference topics. Such recommender system is supposed to provide more targeted information with accompanied comprehensive recommendations. The research priority is to build a categorized database for activity-based preference reference. We use twitter posts that contain "new year's resolution" as our raw data, and extract word pairs as users' activity expressions. Then, by the newly-developed word-pair LDA (wpLDA) model, these activities are clustered under different topics. Fig.1 shows the flow chart of the creation of categorized activity database, and Fig.2 is the conceptual design of wpLDA model.

Keywords: Intuitive expressions, Connection lattice, Tweets, LDA model, Association rules

Reference

[1] D. Zhu, Y. Fukazawa, E. Karapetsas and J. Ota, Analysis of New Year's Resolutions Extracted from Twitter Post to Capture User's Long Term Goals, IEICE SIG Notes, WI2-2012-13, 41/42 (2012).
[2] D. Zhu, Y. Fukazawa, E. Karapetsas and J. Ota, Long-Term Goal Discovery in the Twitter Posts through the Word-Pair LDA Model, Hitoshi Isahara, Kyoko Kanzaki (Eds.): Advances in Natural Language Processing, In Proceeding of 8th International Conference on NLP, 262/267 (2012).
[3] D. Zhu, Y. Fukazawa, E. Karapetsas and J. Ota, Intuitive Topic Discovery by Incorporating Word-Pair's Connection into LDA, In Proceeding of 2012 IEEE/WIC/ACM International Conferences on Web Intelligence and Intelligent Agent Technology, 303/310 (2012).

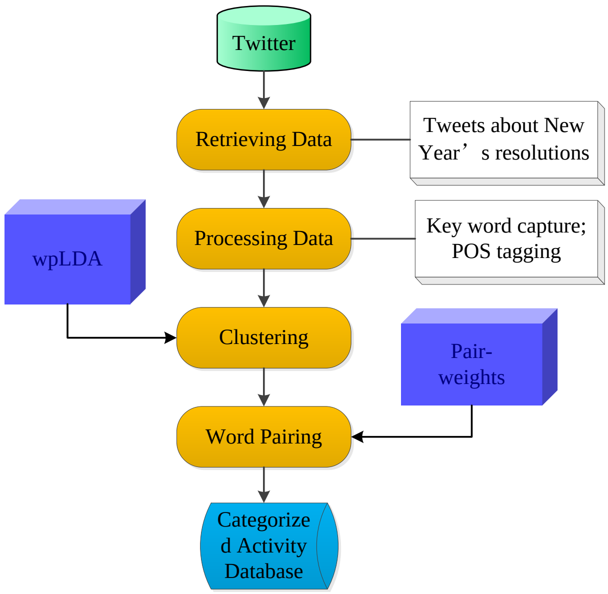


Fig. 1 Flow chart of creating categorized activity database

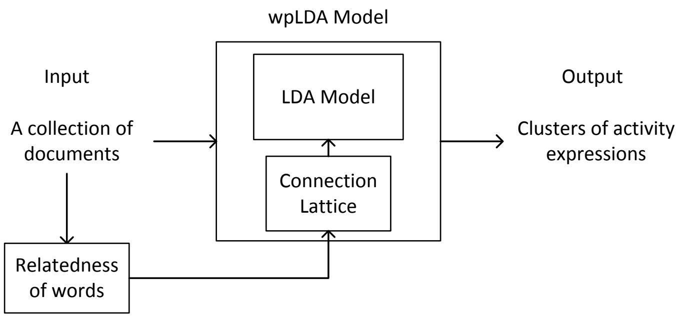


Fig.2 Conceptual Design of wpLDA model