Introduction to Mobile Robotics Lab.
(OTA Lab.)
2012

Service Engineering Research Division,
Research into Artifacts, Center for Engineering (RACE) 5F

The University of Tokyo
Kashiwanoha 5-1-5, Kashiwa, Chiba 277-8568, Japan

TEL:

Professor's room (509):		+81-4-7136-4252
Laboratory	(559, 561):	+81-4-7136-4260
	(534-A):	+81-4-7136-4276
FAX:		+81-4-7136-4242

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

Members

Professor Jun OTA

Doctoral Course Students

Yanjiang HUANG, Zhifeng HUANG, Dandan ZHU, Hiroki KATO

Master Course Students

Takuya SAKUYAMA, Eiko YOTSUI,
Eleftherios KARAPAPETSAS, Baron Yoon Seong YONG, Jorge David FIGUEROA HEREDIA, Ayanori NAGATA, Hiroyuki YAHAGI, Motoyuki OZAKI, Ping JIANG

Undergraduate Students

Takahiro KATAYAMA, Yuta MIYAZAKI

Secretaries

Mari HIRATA
Mika TAMURA

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.

Grasping of Unknown Objects by Multiple Mobile Robots

In this work, we present a method involving the fast grasping of an unknown object by a mobile robot with a parallel-jaw gripper [1]. Three 2D range sensors are installed on the robot at an inclined angle to acquire partial shape information regarding the unknown objects as shown in Fig. 1. The candidate grasping points for an unknown object can then be determined by directly extracting features from this partial shape information. After object grasping and lifting, whether the object can be lifted is judged. If the robot fails to lift the object, then detects other candidate grasping points and performs grasping trials until the object is lifted. Detailed procedure of the proposed algorithm is shown in Fig. 2. The path for the robot to find the grasping points is also designed. The grasping time can be decreased without the need for acquiring and processing all of the object information.

Experiments are conducted. The results are shown in Fig. 3. Grasping time of 3D model construction only include the time of scanned data acquisition and object grasping. And the time of 3D model construction is not included. Therefore, the comparison is conducted no matter what concrete method of 3D model construction is used. Grasping time for the proposed method is obviously shorter than the time for 3D model construction. It is approximately 45% faster than the 3D model construction, thus confirming the statement that the proposed method can realize the grasping of an unknown object as quickly as possible.

We also deal with the problem of cooperative transportation of two mobile robots [2].

Keywords: Feature extraction, partial shape information, fast grasping of unknown objects

Reference

[1] Zhaojia Liu, Lounell B. Gueta, and Jun Ota, Feature Extraction from Partial Shape Information for Fast Grasping of Unknown Objects, Proceedings of the 2011 IEEE Int. Conf. Robotics and Biomimetics (ROBIO2011), 1332/1337 (2011).

[2] Zhaojia Liu, Hiromasa Kamogawa and Jun Ota, Motion Planning for Two Robots of an Object Handling System Considering Fast Transition between Stable States, Advanced Robotics, to appear (2012).

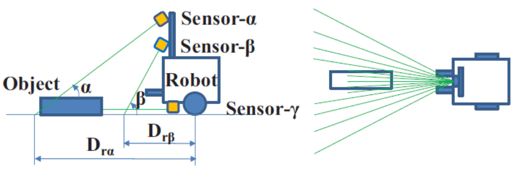

Fig. 1 A mobile robot with two 2D range sensors.

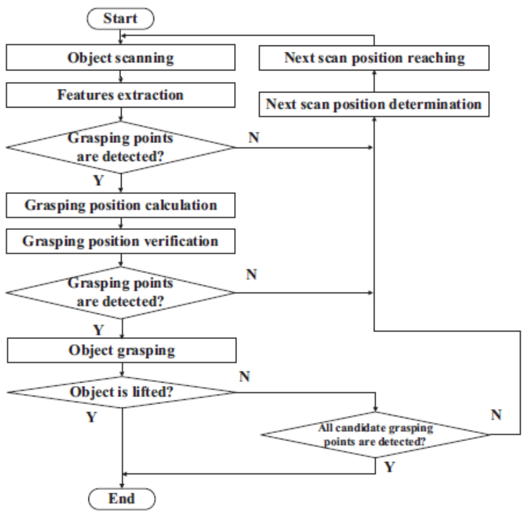

Fig. 2 Proposed approach.

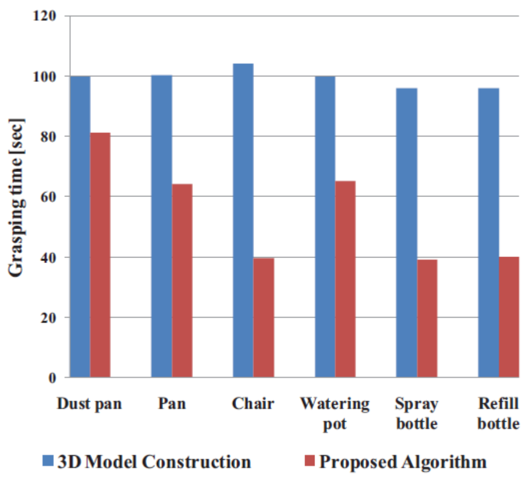

Fig. 3 Comparison of the grasping time of every object by using the proposed method and 3D model construction.

Exploration of a Mobile Robot in a Boundary Environment with Unknown Obstacles Using Reaction-Diffusion Equation on a Graph

A new exploration re-planning framework for a mobile robot is proposed integrating with Reaction-Diffusion on a Graph (RDEG) for exploration in a boundary environment with unknown obstacles. The robot must plan a path that can completely coverage all unknown area, this is done by utilizing the boundary information in order to create more efficient exploration plan, however, there are chances encountering unexpected obstacles and when this occurs the predefined path cannot handle this situation and it is necessary an efficient path re-planning as shown in Fig.1.

Using an exploration algorithm that arranges observation points by the reaction-diffusion equation on a graph the boundary area is covered with a minimal number of circles (hard computation problem). After the observation points are arranged, the effective exploration path is generated by connecting all these points, for this research Lin-kernighan heuristic (LKH) is used, the distances between 2 observation points are calculated by using A* Algorithm.

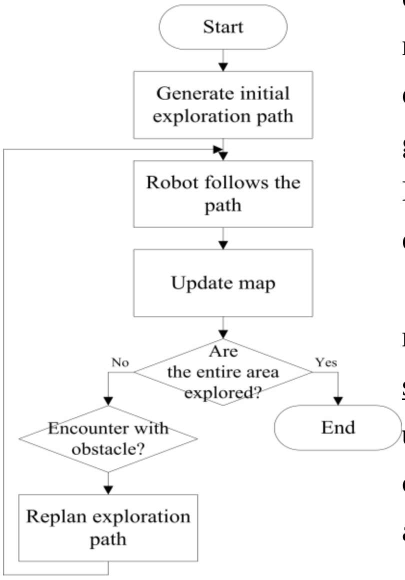

Fig.1. Overview exploration plan flowchart

In the proposed framework a grill is used as our spatial representation, each grill cell is represented with one of three states: **occupied cell** (could be obstacle area or boundary area), **unexplored cell** (the cell that has not yet been explored) and **free cell** (area already sensed by robot and it did not found obstacles) as shown in Fig. 2.

From this spatial representation, a detection process analogous to region extraction in computer vision is used to find the obstacle region. This information is used in the rearrangement of the observation points in the case that the robot encounters an unknown obstacle during its movement along the created path while updating the exploration map. In this case the robot must decide whether it cans recognize the complete shape of the obstacle or not by calculating the connected-component labeling. If shape and area can be decided this changes the state of the occupied cell. Otherwise, we made consideration that the movement of observation points follows the Reaction-Diffusion Equation, the further the distance from the place where change has occurred, the smaller the magnitude of the movement. After the observation points are rearranged the new path is generated as mentioned previously as show in Fig. 3.

Reference

[1] Theeraphol Wattanavekin and Jun OTA, "Exploration in a Boundary Environment with Unknown Obstacles Using Reaction-Diffusion Equation on a Graph", Proc. IEEE International Conference on Robotics and Biomimetics, 1332/1337 (2011).

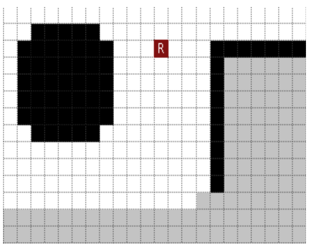

Fig.2. Occupied cell (Black), Unexplored cell

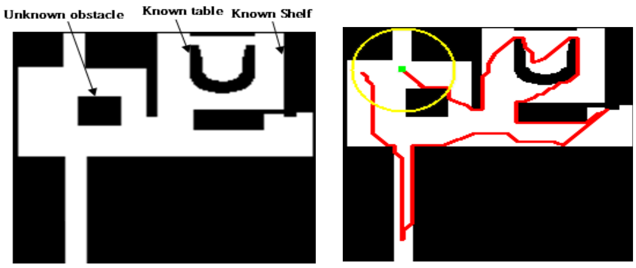

Fig.3. Simulation's practical experiment map and RDEG (proposed)

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

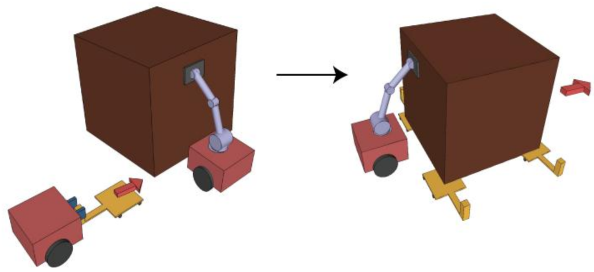

Fig. 1 Image of the proposed method

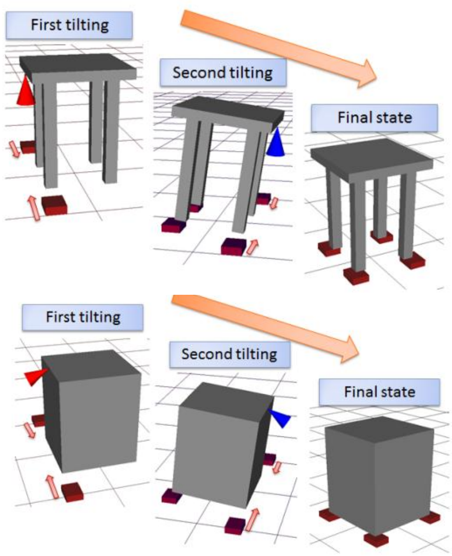

Fig. 2 Simulation result

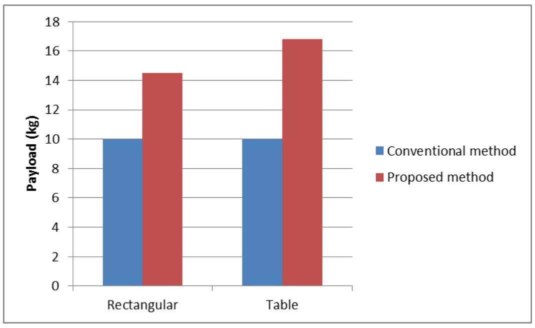

Fig. 3 Comparison of the payload

Selection of Manipulator System for Multiple-Goal Task by Evaluating Task Completion Time and Cost with Computational Time Constraints

Task completion time and cost are two significant criteria for the selection of manipulator system. For a given task, several Pareto solutions of manipulator systems should be derived based on evaluation of these two criteria. However, a large computational time is required to evaluate these two criteria for all candidate manipulator systems.

In this study, we propose a method (Fig. 1) that can select Pareto solutions of manipulator systems by evaluating task completion time and cost within the desired computational time [1]. Selection of manipulator is taken into account in manipulator system selection since task completion time and cost are affected greatly by the selected manipulator. Each candidate manipulator system consists of a 6-DOF robot arm, a 1-DOF positioning table, and a tool (Fig. 2). The structure configuration of manipulator system (connective relationship among system components) is taken into account. In the proposed method, multiple objective particle swarm optimization (MOPSO) is employed to search for appropriate manipulator systems with structure configuration from a set of candidate systems. Location optimization and motion coordination are integrated to derive the task completion time. We employ particle swarm optimization (PSO) for location optimization and use nearest-neighborhood algorithm (NNA) for motion coordination. The proposed method is proved to be effective in a comparison of 3 methods that involve a random search algorithm for 5 different tasks. The computational time for each method is 1 hour. Retrieval performance evaluation (*F* value) is used to evaluate all methods. The *F* value derived by using the proposed method is improved on average by 72.4% relative to the results of the other methods (Fig. 3).

Keywords: Manipulator system selection, MOPSO, task completion time, location optimization

Reference

[1] Y. J. Huang, L. B. Gueta, R. Chiba, T. Arai, T. Ueyama, M. Sugi and J. Ota, Manipulator system selection based on evaluation of task completion time and cost, in Proc. IEEE/RSJ Int. Conf. on Rob. and Sys. pp. 4698-4703 (2011)

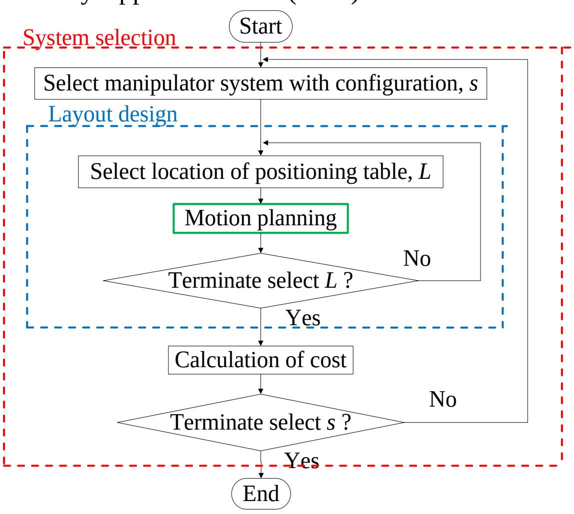

Fig. 1 Proposed method

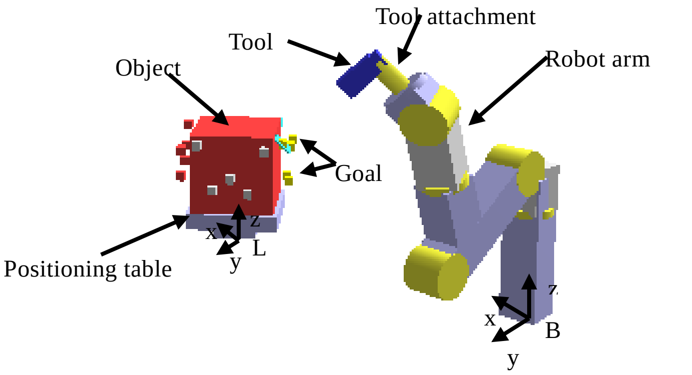

Fig. 2 A system with a robot arm, a positioning table and a tool

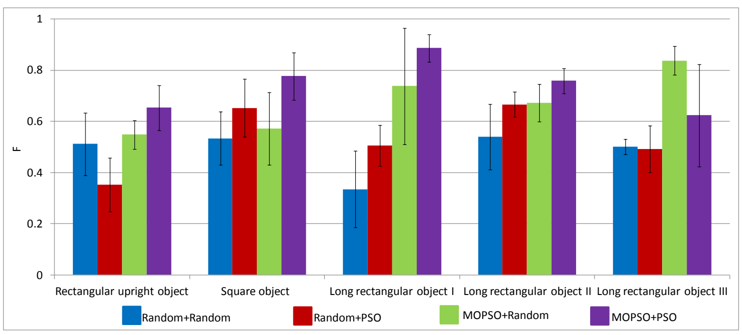

Fig. 3 The F value derived by 4 different methods for 5 tasks

Motion Planning of Two Stacker Cranes in a Large-Scale Automated Storage/Retrieval System

We propose a method for reducing the computational cost of motion planning of warehouse equipped with two stacker cranes (Fig.1). There is a former research studied the motion planning of an automated storage/retrieval system with two independent stacker cranes [1]. While the loading efficiency of the algorithm it proposed is satisfied, calculating the feasible trajectory requires a significant amount of time, which does not satisfy the requirement of industry. In other words, the load to be transported is assigned randomly, so we cannot do trajectory calculation beforehand.

We propose a method for reducing the computational time of motion planning for stacker cranes [2]. Most automated storage/retrieval systems are only equipped with one stacker crane. However, this is logistically challenging, and higher work efficiency in warehouses, such as those using two stacker cranes, is required. In this paper, a warehouse with two stacker cranes working simultaneously is proposed. Unlike warehouses with only one crane, trajectory planning in those with two cranes is very difficult. Since there are two cranes working together, a proper trajectory must be considered to avoid collision. As transport works in automated storage/retrieval systems are occurring randomly, motion planning cannot be conducted in advance. Planning an appropriate trajectory within a restricted duration would be a difficult task.

As a solution, we propose a “free-step” and a method to choose trajectories that are more likely to avoid collision. We thereby address the current problem of motion planning requiring extensive calculation time. For employment in an actual industrial warehouse, we must reduce the calculation time of the automated storage/retrieval system.

References

[1] Hisato Hino, Yoshimasa Kobayashi, Toshimitsu Higashi and Jun Ota, Control Methodology of Stacker Cranes for Collision Avoidance Considering Dynamics in a Warehouse, Proceedings of the 2009 IEEE International Conference on Robotics and Biomimetics (ROBIO 2009), 983/988 (2009).

[2] Yiheng Kung, Yoshimasa Kobayashi, Toshimitsu Higashi, and Jun Ota, Motion Planning of Two Stacker Cranes In A Large-Scale Automated Storage/Retrieval System, Proceedings of the 2011 IEEE Int. Conf. Robotics and Biomimetics (ROBIO2011), 168/173 (2011).

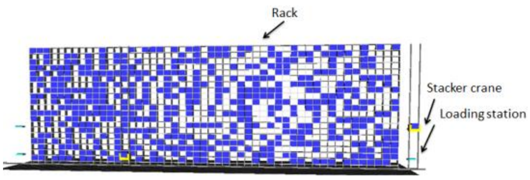

Fig. 1 Automated storage/retrieval system with two stacker cranes

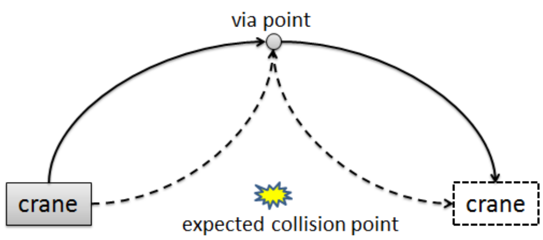

Fig. 2 Derivation of the order of collision verification in a detour avoidance trajectory

Analysis of Congestion of Taxiing Aircraft at a Large Airport

At large airports, a large number of aircraft are taking off and landing every day. Congestion during aircraft taxiing (going from terminal to runway) can still occur because of several factors such as the concentration of aircraft and bad weather. (Fig. 1) Therefore, it is essential to clarify the causes of congestion and to propose a plan of action to ease congestion. Taxiing aircraft at Tokyo International Airport (Haneda) (Fig. 2) are simulated and analyzed by using actual data for taxiing and operations.

Various parameters needed for the operation modeling of aircraft are acquired. The time and speed of aircraft taxiing were measured. For a departing aircraft, it moves from spot, to taxiway and finally to runway. Since aircraft cannot move in reverse, pushback is carried out to push it backwards using a pushback truck. The pushback time are measured with a stopwatch. Arrivals are given priority over departures when using the taxiway and pushback lanes. These parameters are used for simulations of aircraft movement. The service diagram on May 10, 2010 is used. The situation of Tokyo International Airport in a simulation at about 8:30 a.m. is shown in Fig.3.

The arrival rate at the runway is constantly distributed so that the average queuing time is the shortest. The service diagram of the departure aircraft is changed so that the interval of the departures in the service diagram can be steady in Strategy 1. The departure time of each aircraft is changed to 218 seconds on the average, and it changes to a maximum of 884 seconds. The service diagram is not changed but the timing of departures is adjusted and changed in Strategy 2. By monitoring the real-time situation of the arriving aircraft as well as the departing aircraft, the adjustment in the departure order and take off order can be conducted similarly in real time. About 43% was reduced, and congestion was reduced with regard to the maximum taxiing time in Strategy 1. In addition, the average taxiing time was reduced significantly, by about 28%. In Strategy 2, the maximum taxiing time was reduced to at least 10%.

***Keywords*:** Taxiing aircraft, easing congestion

Fig. 1 Congestion at around 8:00 a.m. (five aircrafts are queuing up).

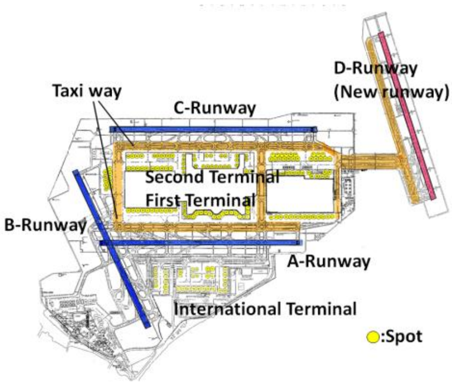

Fig. 2 Building layout of Haneda Airport

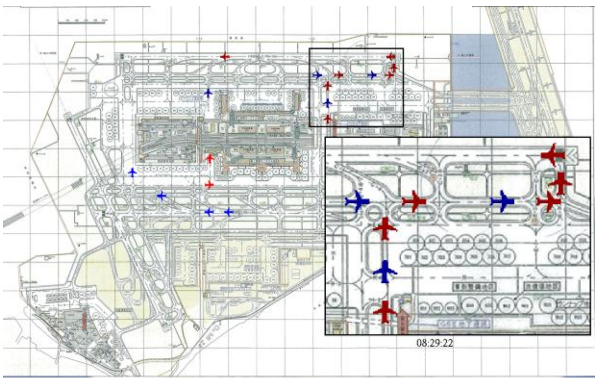

Fig. 3 Simulation of aircraft taxiing at approximately 8:30 a.m.

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 train and provide the evaluation results as almost the same precision with the nursing teachers' (Fig.1). In nursing activities, to master the appropriate procedures is quite important for not only the patient but also the nurse to prevent from injury, especially in heavy tasks. Since of that, to automatically distinguish the appropriate and inappropriate procedures is requested. For the purpose, we established the camera system with depth camera sensors Kinect(Microsoft co., Ltd.) for nursing activities training of transferring patient from bed to wheelchair. In addition, we used color information to deal with the problem of image overlap between the trainee and the patient(Fig.2). The evaluation item is defined by the discussed with the nursing teacher and the reference form text book and the evaluate criteria of each item is quantified by experiment. The performance of the system is examined by the controlled trials. The average accuracy of transferring training is up to 85.8%. Also, the effect of system is examined (Fig. 4).

***Keywords*:** Self-training system, evaluation, kinect

References

[1] Zhifeng.Huang et al: Development of a Nursing Self-training System for Transferring Patient from Bed to Wheelchair. (SICE 2012) (to appear)

[2] T. Yonetsuj et al.: A Measurement and Evaluation Method of a Support System to Teach How to Improve Transferring Patients. Proc.2011 IEEE Int. Conf. Robot. and Biomim (ROBIO 2011), 908-913, 2011.

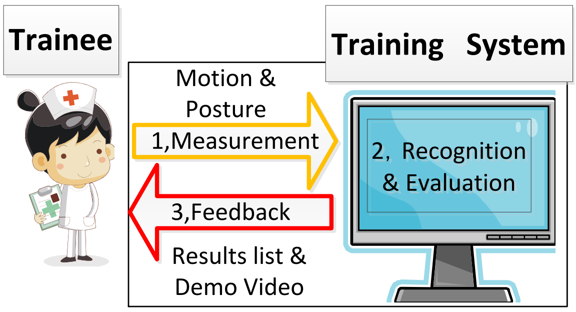

Fig. 1 System Image

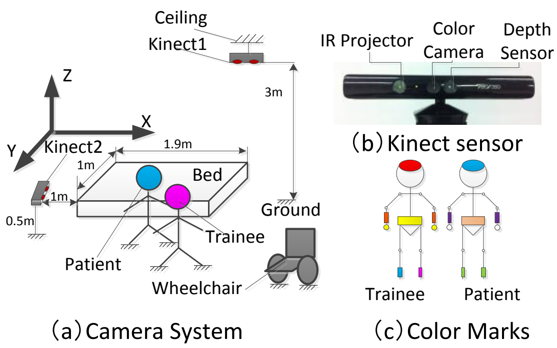

Fig. 2 Camera System

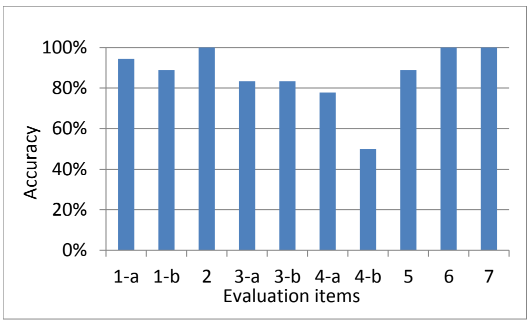

Fig. 3 System accuracy

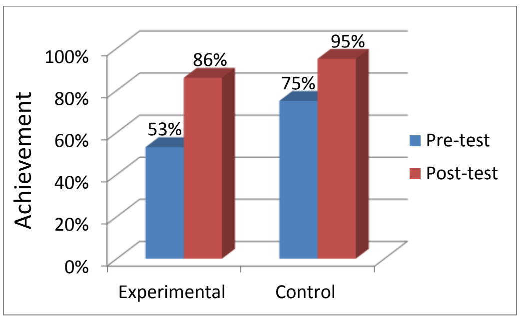

Fig. 4 Training effect

Multimodality Analysis for Modeling of Human Posture Control

Humans control their posture by controlling the muscular activity of the whole body with the cranial nervous system using multi-sensory inputs. The construction of sensory inputs and muscular activity model has a significant meaning medically and biologically because this model leads us to understand how the brain functions. For the modeling of the posture control, it is important that the brain controls the redundant muscles using multimodal sensory inputs. And it is also important that the muscular activity measurement can make it possible to consider not only torque activity to maintain their posture but also internal activity by antagonist muscles.

Therefore, the purpose of this study is obtaining changes in muscular activity by changing sensory inputs and finding the existence of the internal activity in human standing posture control.

One of the important things is how to change the sensory inputs. We propose a method for it by inhibiting or stimulating three senses which are related to the posture control as follows: A) visual sense is inhibited by closed eyes, B) vestibular sense is inhibited by a caloric test with pouring cold water into the ear cavity, and C) somatosensory sense is stimulated by touching a part of the body. And the existence of the internal elements is observed with muscular activity difference between the state in the inhibited or stimulated senses and the normal state.

Experiments were performed with the proposed method. When Subjects' senses were inhibited or stimulated, they tended to change their posture as follows: A) when only the vestibular sense was inhibited, subjects were able to maintain the standing posture (Fig.1A); B) when both visual and vestibular senses were inhibited simultaneously, subjects leaned (Fig.1B); and C) when both visual and vestibular senses were inhibited and somatosensory sense was stimulated, subjects recovered its standing posture (Fig.1C). From the results, the muscular activities can be observed more than the torque elements to maintain the posture when both visual and vestibular senses were inhibited. This finding indicates the possibility of new human posture control model in which torque elements are given with PID control from the sensory inputs, and also internal elements control make both antagonist muscles activate for the increase of stiffness from the sensory inputs (Fig.2).

Keywords: Mobiligence, standing posture control, sensory inhibition, multimodality analysis

Reference

[1] Hiroaki Ogawa, Ryusuke Chiba, Kaoru Takakusaki, Hajime Asama and Jun Ota, Method for obtaining quantitative change in muscle activities by difference in sensory inputs about human posture control, Proc. Int. Symp. on Adaptive Motion in Animals and Machines, 9/10 (2011)

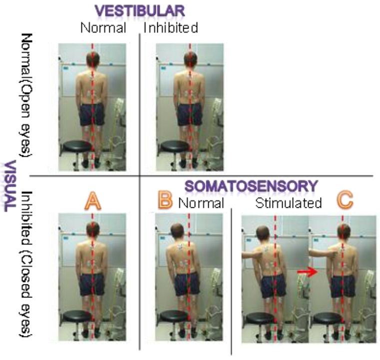

Fig.1 Postural changes

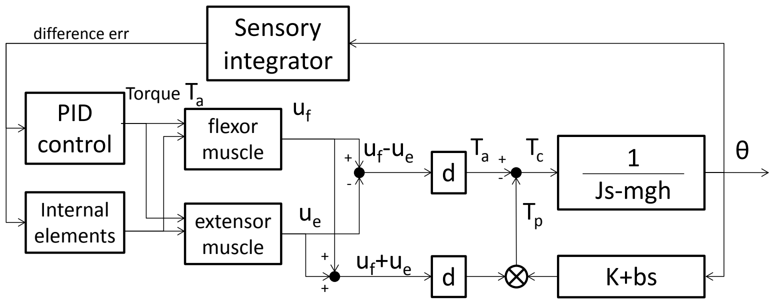

Fig.2 Posture control model with internal elements

Exploring the Web for Real World Activities Related to User's Query

The web is full of information concerning activities. An activity is something a person can accomplish or something one can create. This information is concentrated on websites called How-To or DIY websites, where you can find articles detailing methods to accomplish any action a person can imagine, from the simplest to the really complicated ones. People can search for these activities in the traditional way using a search engine.

What our research focuses on is how we can allow a user interested in a general query to search for activities to accomplish related to that query. For example a user searching for the query coffee can find among others the activity "Wake up and exercise in the morning". It is an activity that does not directly contain the search query but is conceptually related to it.

We accomplish this by creating a system that performs Query Expansion on the search query, employing a knowledge base created by MIT called ConceptNet. The query is expanded and we obtain related words that are tagged depending on the relation to the original query and with every relation getting a different weight parameter. Then the How-To websites are searched with these related words and the resulting activities are returned to the user.

The order that the activities are presented in is important and for that we have employed optimization using genetic algorithms. We conducted a small experiment where we gathered data for a large set of queries and constructed the so called gold standard list for each query, which is the perfect order of activities for that query. The genetic algorithms optimize the relation weight parameters so that the final order of the resulting activities is as relevant as possible to the original by attempting to converge to the gold standard.

Finally we conducted a small evaluation comparing our optimized system with its un-optimized equivalent and simple web search of the How-To websites and it was concluded that in both cases the optimized system was superior to the other two. For the future we are planning to tweak the genetic algorithms implementation and conduct more experiments and finally perform a bigger evaluation of the system in its entirety.

References:

[1] Karapetsas E. Fukazawa Y. and Jun O. 2011. Retrieving Information about Real World Activities from the Web. IPSJ SIG technical reports 2011-MBL-59(2), 1-7, 2011-08-29

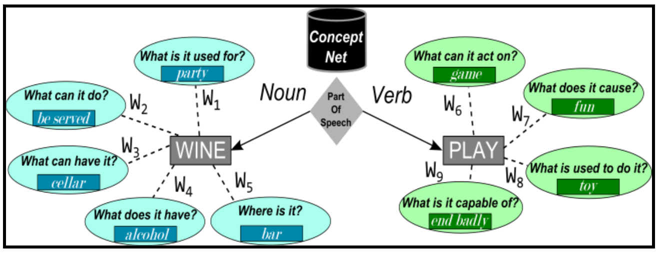

Fig. 1 ConceptNet and relation weights

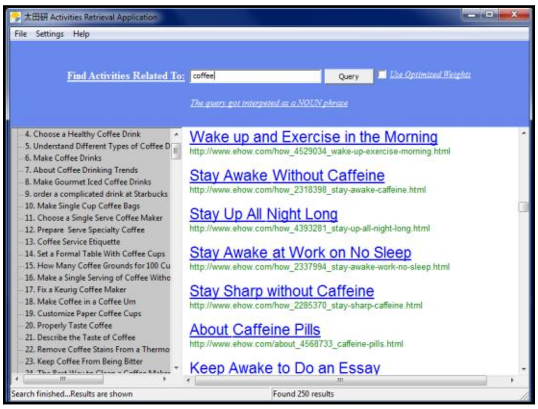

Fig. 2 - The GUI of the system

Long-term Goal-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 since people depend more and more on computers to solve problems of various kinds. We can come across them almost everywhere on the internet: 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.

Here, we are planning to build a special recommender system, called "long-term goal aware recommender system", which would differ from traditional ones as providing recommendations according to the users' long-term goals. It is supposed to be able to serve people in a more comprehensive way and in long haul, by providing them an excellent package of recommendations to reach their long-term goals.

So, the first phase is to build a long-term goal dictionary to be referred to, which is also what we are doing now. We use twitter posts that contain "new year's resolution" as our raw data, and extract key words as users' long-term goals. Then, by using LDA algorithm, these long-term goals are clustered under several different topics, so the basic dictionary of long-term goals is built. The next is to refine it. We may use external sources to extend it into large-scale dictionary.

For the future work, another difficulty is how to choose appropriate recommendations to different people. We tend to build another dictionary, a recommendation dictionary, which is used for recommendations' online searching. The framework of our system shows as Fig.2.

Keywords: Long-term goals, twitter, topic modeling, clustering

Reference

[1] D. D. Zhu, Y. Fukazawa, E. Karapetsas and J. Ota, Analysis of New Year's Resolutions Extracted from Twitter Posts to Capture User's Long Term Goals, Web Intelligence and Interaction (SIG-WI2), pp.41-42(2012)

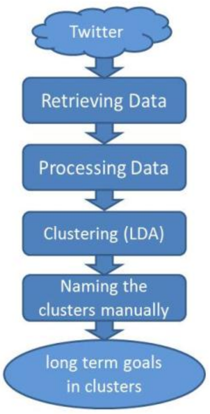

Fig. 1 Flow chart of creating long term goal dictionary

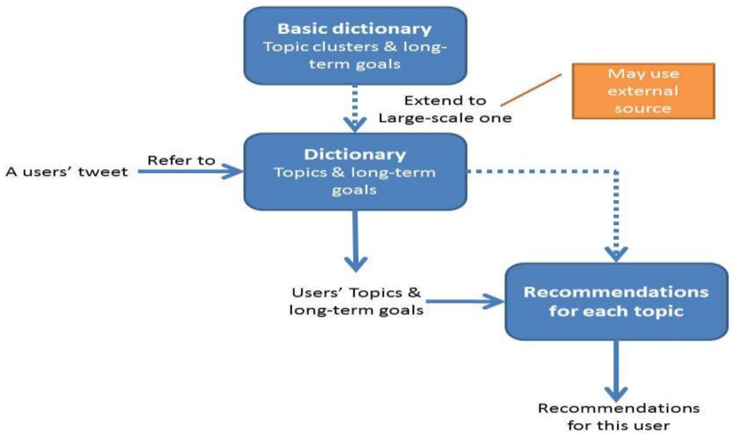

Fig. 2 Overall flow of long term goal based recommendation