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.

A Strategy for Fast Grasping of Unknown Objects using Two 2D Range Sensors and Partial Shape Information

Fast transportation of objects is important for productivity and efficient improvement in factory operations. Therefore, fast grasping of unknown objects is important. To improve the grasping efficiency, we propose a method for a mobile robot with a gripper to grasp an unknown object quickly based on partial shape information from two 2D range sensors.

The objects can be grasped and lifted by a gripper if the following three conditions are satisfied: ①There are flat parallel surfaces or parallel tangent planes on the objects. ②The distance between parallel flat surfaces or parallel tangent planes is not larger than the maximum opening width of the gripper. ③There is no obstacle near the grasping part when a robot is grasping objects. The conditions given above can be defined as three features, depth differences, flat surfaces or parallel tangent planes, and gripper insertion space, all of which are used to identify the grasping point. The 2D range sensor scans the object *N* times while the robot is moving forward to acquire the partial shape information of an object. The features are then extracted from the scanned data of partial information of an object. Whether a pair of grasping points is included in the scanned data is determined on the basis of these features. If no grasping points are detected, the robot moves to the next scan position to detect a possible grasping point. Otherwise, if a pair of grasping points exists in the scanned data, the grasping position is calculated. Finally, the robot moves to the grasping position and grasps the object.

The proposed approach is tested with experiments. A mobile robot with a parallel-jaw gripper can successfully grasp a wide variety of objects. The grasp success rate is about 90%. The grasping time of the proposed approach is 49% shorter than that with the 3D model construction method.

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

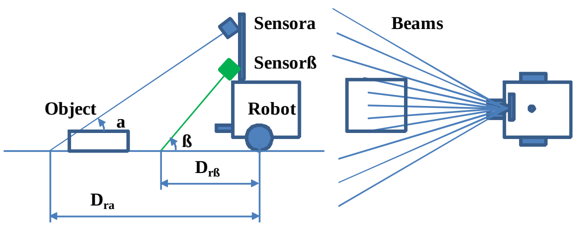

Fig. 1 A mobile robot with two 2D range sensors.

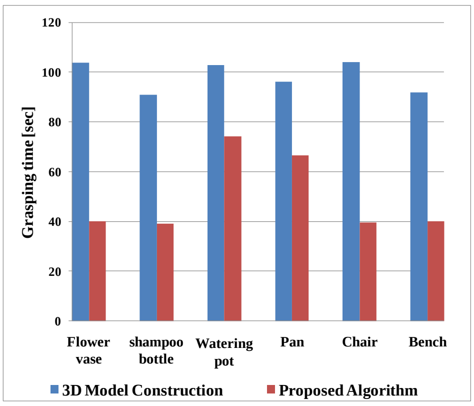

Fig. 3 Comparison of the grasping time of every object by using the proposed method and 3D model construction.

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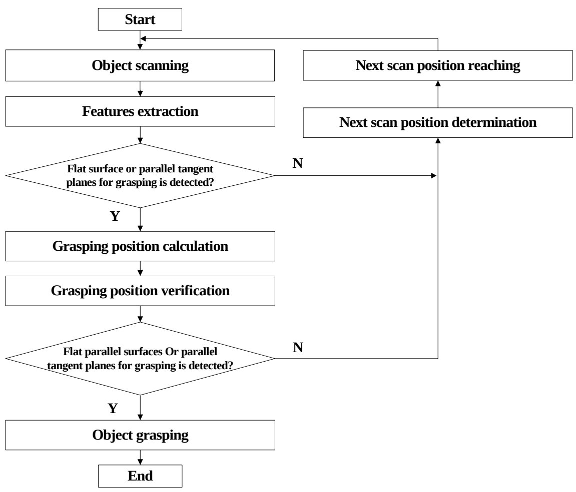

Fig. 2 Proposed approach.

Motion Planning for Multiple Robots of a Object Handling System Considering Fast Stable State Transition

Fast transition from a stable initial state to a stable handling state is important when multiple mobile robots grasp and transport a bulky and heavy object. We focus on the problem of fast transition from a stable initial state to a stable handling state and propose a strategy for two mobile robots to grasp and lift an object in a minimal amount of time.

In order to realize the transition from a stable initial state to a stable handling state, a object handling system consisting of a gripper robot and a lifter robot was designed. A gripper robot moves to the grasping position and grasps an object. Then a gripper robot lifts one side of the object and transits grasping finished message to the lifter robot. This provides space between the object and ground which can be used by the lifter robot. The lifter robot moves to the lifting position and inserts the lifter into the space under the object after receiving message from the gripper robot, then lifts the other side of object and transits the lifting finish message to the gripper robot. Finally, two mobile robots perform circular motion at same time, so the stable handling state can be realized by using the object handling system designed.

Trajectory generation of two robots to minimize the transition time from a stable initial state to a stable handling state can be formulated as an optimization problem. The goal is to acquire the velocity of left/right wheel of the gripper robot and the lifter robot to realize fast transition from the stable initial state to the stable handling state. The penalty method and multi-start local search method were chosen to acquire the optimization solution.

The experiments were conducted with two real robots and the objects which are used in daily life. Two robots can realize fast stable state transition cooperatively.

Keywords: Motion planning, a object handling system, fast stable state transition

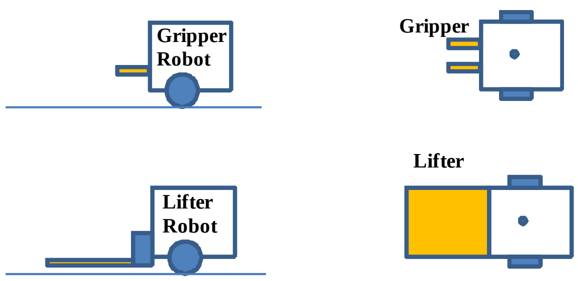

Fig. 1 A object handling system

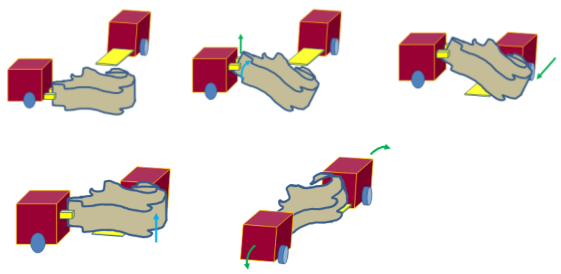

Fig. 2 Fast stable state transition using a object handling system

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1) Z.J. Liu, H. Kamogawa and J. Ota, Manipulation of an Irregularly Shaped Object by Two Mobile Robots, Proc. 2010 IEEE/SICE Int. Symp. System Integration, 228-223 (2010).

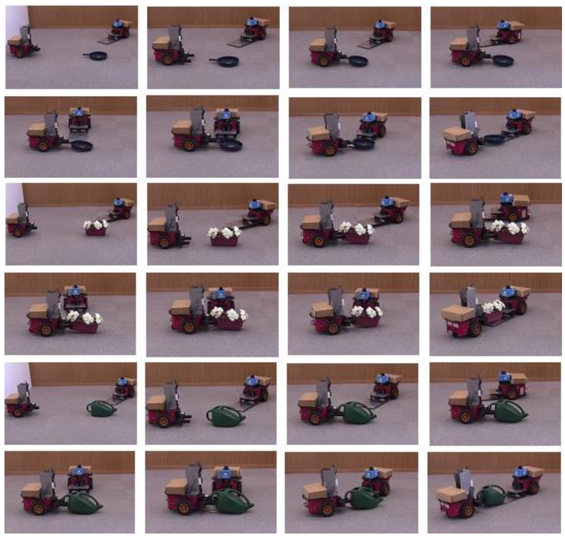

Fig. 3 Experiments of fast stable state transition.

Rearrangement Task using Multiple Mobile Robots

Rearrangement tasks involving multiple objects are the fundamental for mobile robots. Robots transport objects from an initial to a goal configuration as shown in Fig.1. These tasks have various applications, for example, production system, transfer machine, room cleaning machine, etc. The goal is to realize the fast and effective rearrangement tasks in the environment with many obstacles such as objects and walls.

To solve the problem, there are 2 important points to be considered. (a) the method in determining the delivery positions, (b) the method in deciding efficient task assignment and path planning. In order to cope with (a), delivery positions are set up in the neighborhood of narrow corridor where only on robot can pass by to reduce extra delivery tasks. For (b), we derived a Meta-Heuristic based on Simulated Annealing method to find sub-optimal solution in practical time. The task completion time is used as an evaluation function. The rearrangement problem is modeled as k-Stacker Crane Problem (k-SCP). Then, an order of tasks and paths of robots are determined by using heuristics to solve k-SCP as shown in Fig.2.

In the simulation, the proposed method is compared with 2 kinds of methods which are continuous transportation method and Territorial Approach. The simulation results indicate that the proposed method achieves the least task completion time in all simulation environments. The results of simulation using 3 robots with 10 objects are shown in Fig.1. Moreover, the real experiment show that our system can still operate accurately even there is the sensor error from sensing the environment. These results reflect the effectiveness of our proposed method.

Keywords: Rearrangement problem, Multiple mobile robots, Multiple objects

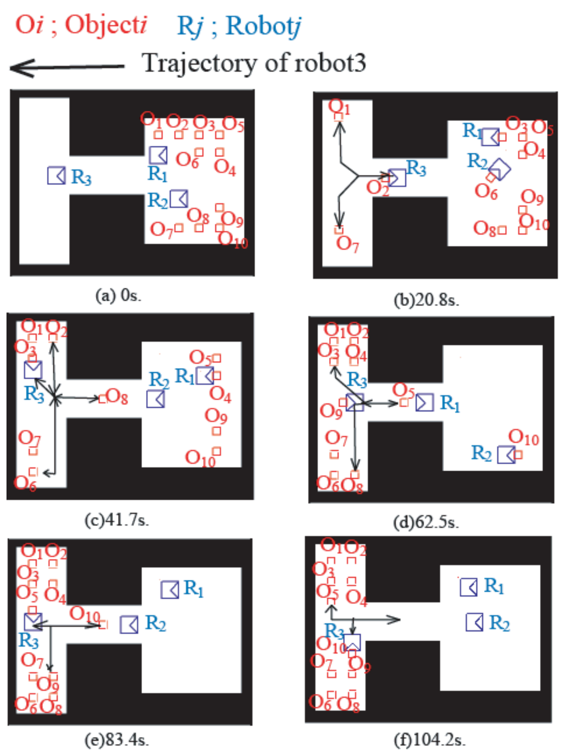

Fig. 1 An example of rearrangement tasks using the proposed method

Reference

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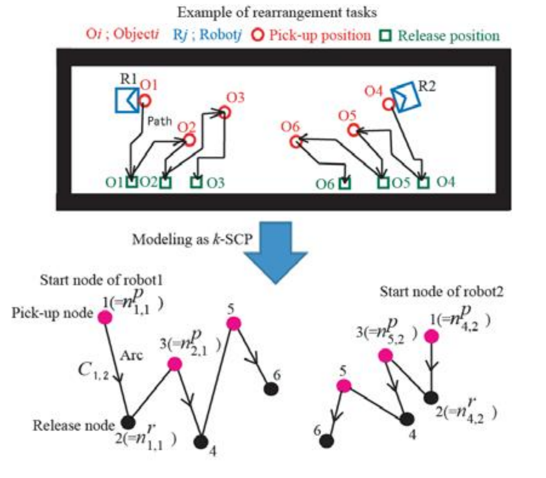


Fig. 2 k-SCP problem in the rearrangement task

Manipulator System Selection Based on Evaluation of Task Completion Time and Cost

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 calculation 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 calculation time. 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 system consists of a 6-DOF robot arm and a 1-DOF positioning table (Fig. 2). In the proposed method, multiple objective particle swarm optimization (MOPSO) is employed to search for Pareto solutions of manipulator 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 through a simulation under 3 types of tasks. The proposed method is compared to a comparative method which evaluates all candidate systems. The calculation time for these two methods is shown in Fig. 3 and the derived Pareto solutions are shown in Fig. 4.

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

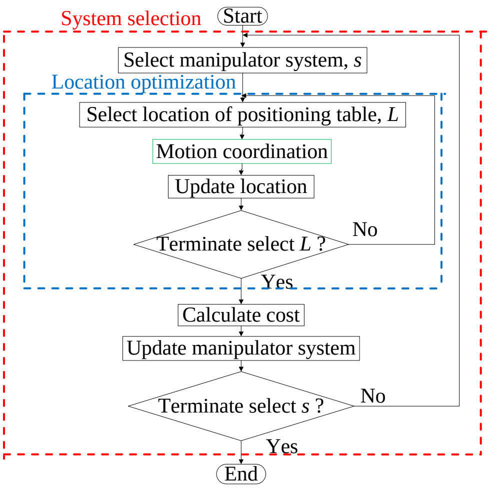


Fig. 1 Proposed method

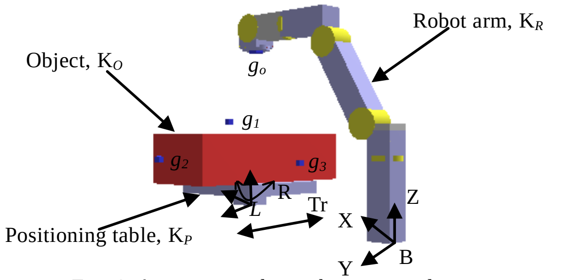


Fig. 2 A system with a robot arm and a positioning

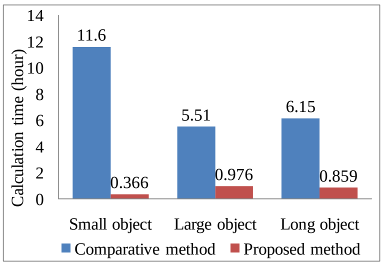
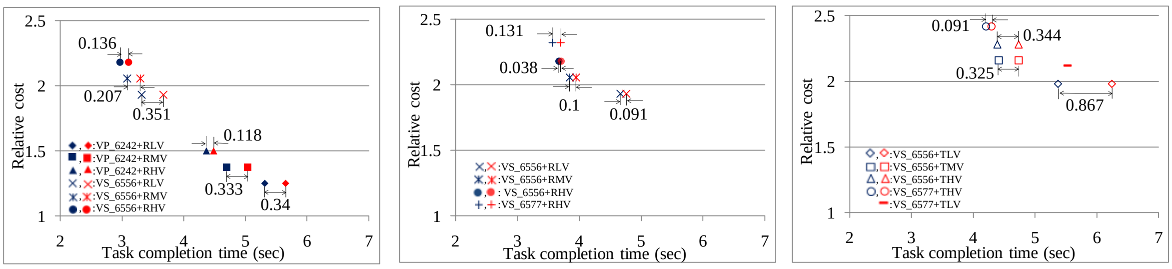


Fig. 3 Calculation time



(a) For a small object (b) For a large object (c) For a long object

Fig. 4 Derived Pareto solutions of manipulator systems by using proposed method and comparative method. The red symbols are the systems derived by using proposed method, the blue symbols are the systems derived by comparative method.

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

We propose a method for reducing the computational time 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. While the loading efficiency of the algorithm it proposed was satisfying, 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. For employment in an actual industrial warehouse, we must reduce the calculation time of the automated storage/retrieval system.

There are two reasons which make the calculation time longer. For not colliding with other crane, we have to do collision verification for each trajectory candidate. Those works will take much calculation time, especially for large-scale warehouse.

For a specific start position and target position, there are infinite trajectory candidates. To find an efficient and safety one from those candidates will also take much calculation time.

To solve these problems, first, we devise a new algorithm for collision verification which uses information of position and velocity of cranes to get a time span (free step) for not doing collision check in order to reduce the calculation time of a collision check. By using free step, we can do collision check only when the time collision may happen, thus we can reduce the calculation time (Fig. 2).

Second, we propose a method for faster selection of a trajectory with a higher probability of avoidance from a quantity of trajectory candidates. We use the information of position and of cranes to speculate a feasible trajectory.

In the simulation, we assigned 200 tasks randomly of the simulation environment of 256rays 128levels. The simulation result is much better than the former research. While the maximum trajectory calculation time in this simulation is 13.33s, the maximum trajectory calculation time in this simulation is 0.03s. Furthermore, the working time in a former study and that in the proposed method are almost identical. Therefore, we can understand that the proposed method is useful here.

Keywords: Warehouse, motion planning

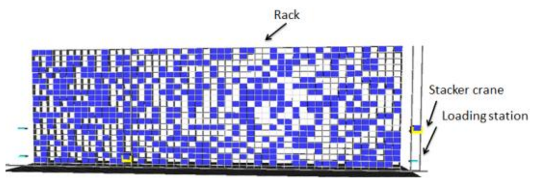


Fig. 1 Automated storage/retrieval system with two stacker cranes

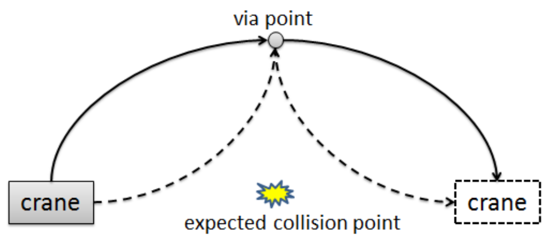


Fig. 2 Derivation of the order of collision verification in a detour avoidance trajectory

Analysis of Congestion of Taxiing Aircraft at a Large Airport

In large airports, a large number of aircraft are taking off and landing daily. Congestion during aircraft taxiing (going from terminal to runway) can still occur and is affected by several factors such as the concentration of aircraft and 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 necessary 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).

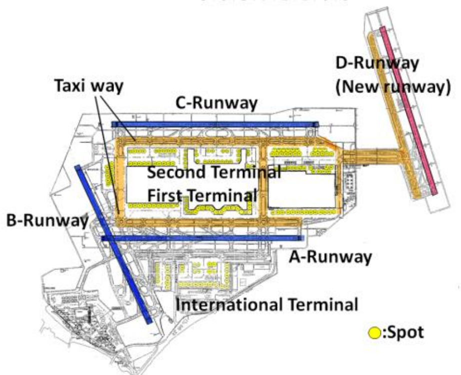


Fig. 2 Building layout of Haneda Airport

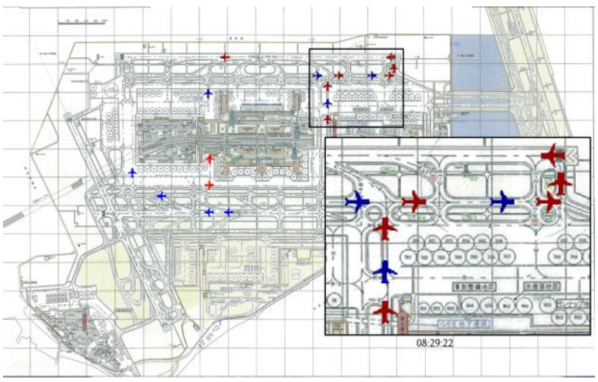


Fig. 3 Simulation of aircraft taxiing at approximately 8:30 a.m.

Basic Research for Constructing a Model 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. Thus, it is important to examine the relationship between senses and muscular activity as the first steps in constructing this model. Therefore, purpose of this study is obtaining changes in muscular activity by changes in sensory inputs.

To achieve this purpose the method to change sensory inputs is a challenging point. We propose a method of changing sensory inputs by inhibiting or stimulating three senses (visual, vestibular, and somatosensory senses) which are related to posture control. Concretely, A) the visual sense is inhibited by closed eyes, B) the vestibular sense is inhibited by a caloric test pouring cold water into the ear cavity, and C) the somatosensory sense is stimulated by touching a part of the body. Muscular activity is measured by electromyography (EMG) when subject's senses are inhibited or simulated by the method mentioned above. It is considered that the variety of muscular activity influenced by change in sensory inputs is observable by comparing measured muscular activities.

Experiments were performed on 5 subjects using the method mentioned above. Subjects tended to change their posture when their senses were inhibited or stimulated: A) if only the vestibular sense was inhibited, subjects were able to maintain the standing posture (Fig. 1A); B)if both visual and vestibular senses were inhibited simultaneously, subject leaned (Fig. 1B); and C) if both visual and vestibular senses were inhibited and somatosensory sense was stimulated, subject recovered its standing posture (Fig. 1C). The probability of variation of muscular activity by inhibiting or stimulating senses was calculated. The muscles which change in a probability above 0.5 compared with normal condition were colored in Fig. 2. By the difference of the visual sense, activity changes of gluteus maximus muscle in one side in uninhibiting vestibular sense and no muscle in inhibiting vestibular sense were observed. If the vestibular sense is inhibited; gluteus maximus muscle and quadriceps femoris on water-poured side, and hamstring on the other side increase their activity. By the difference of the somatosensory sense; activity changes of gluteus maximus muscles, and tibialis anterior on pouring water side were observed. Therefore, it is confirmed that changes in muscular activity by changes in sensory inputs in standing posture are observable.

Keywords: Mobiligence, posture control, sensory inhibition, standing posture.

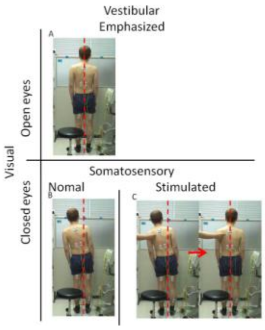


Fig.1 postural changes

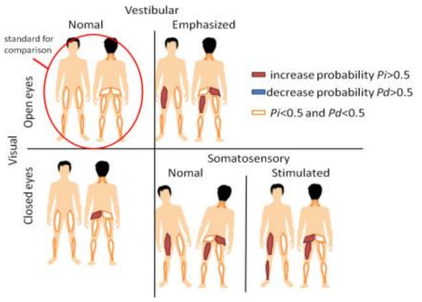


Fig.2 muscle activity compared with normal condition

References

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A Support System for Self Training in Transferring Patient

Transferring patient is a kind of typical nursing activities which is to move and turn the patients' body, for an instance, to transfer from bed to wheelchair. Since the operations relate to the patients' status, such as height, weight and the states of body, the qualities of this kind of nursing activities is mostly depended by the practice experiences. Also, comparing with other operations, accidents and hurt is more easily happen on not only the patients but also the nurses during transferring patient, because there are lots of interaction motions. However, limiting by the number of the teacher and the lack of practice of training, traditional education is inefficiency. In this research, for the object of improve of the training efficient, we propose an innovational self training support system to give trainees enough feedback training (Fig. 1).

In order to evaluate the qualities of the trainees' performance, in the first step of this research, we established a multi camera system to detect their motions (Fig. 2) Through this camera system, the key motions of the operation are extracted by the algorithm and compared with the veteran nurses' motions. Through the experiment in simulated transferring patient form bed to wheelchair training (Fig. 3), we evaluated the accuracy and have proved the efficient of this system (Fig. 4).

Keywords: Transferring patient, self training, camera system

References

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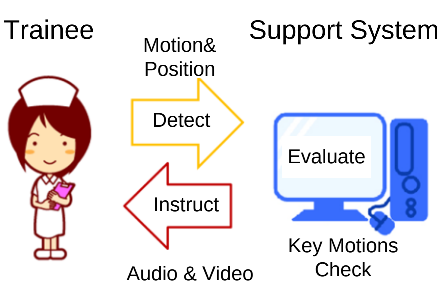

Fig. 1 Support system for self training

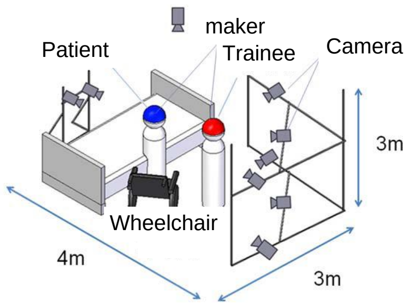

Fig. 2 Multi camera system

Fig. 3 Bed to wheelchair transferring

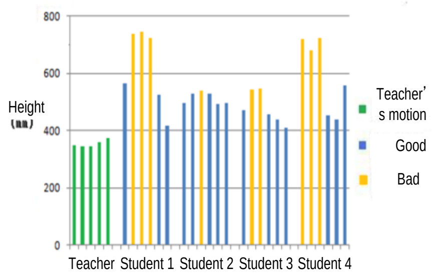

Fig. 4 Experimental results

Automatic Modeling of User's Real World Activities and Its Application

The mobile Internet is expanding dramatically, such as the number of subscribers and the volume of mobile contents. As the mobile Internet gains in popularity, information retrieval must be made easier and more efficient. Towards this goal, we investigate the automatic modeling of users' real world activities from the web. Concretely, to estimate the hierarchical relationships present in the activity model with the lowest possible error rate, we propose a method that divides the representation of activities into a noun part and a verb part, and calculates the mutual information between them[1][2]. The result shows almost 80% of the hierarchical relationships can be captured by the proposed method. Fig. 1 shows learned task-model.

In our research, we incorporate learned task-model into content-based recommendation algorithm, by representing both content profile and user's profile by set of learned tasks[3]. From the user test, the obtained precision-recall curve is higher than that obtained by existing content-based recommendation algorithm which uses noun-based features for both user profile and content profile.

In addition, we have incorporated learned task into map interface for mobile video navigation[4]. This interface allows the user to find videos that are related to the activities around the user’s current location (Fig. 2). Activities are expressed by pairs of sightseeing spot names and 3,300 kinds of verbs extracted from the Blog. A user’s evaluation test shows that the proposed interface increases the number of videos watched by about 3 contents compared to video linked map interface by Google in 40 minutes user test. Especially at the area where user has never visited, number of videos watched increases twice, and this shows the efficiency to make user interested in unknown place through mobile video navigation.

Keywords: Web mining, task model, recommendation, semantic search

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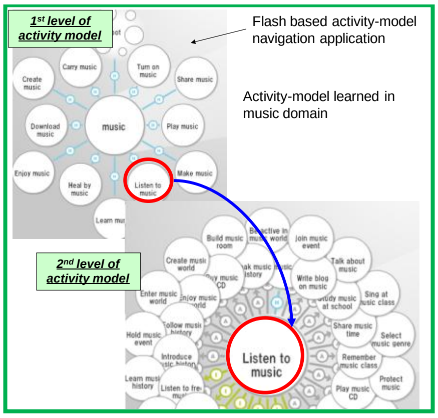

Fig. 1 Learned Activity model

Fig. 2 TaskGuideRoid’s main screen image