Introduction to Mobile Robotics Lab.
(OTA Lab.)
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Research into Artifacts, Center for Engineering (RACE)

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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

Rearrangement Task by Multiple Mobile Robots

Rearrangement tasks involving multiple objects are fundamental for mobile robots. Robots transport objects from an initial to a goal configuration. These tasks have various applications within production systems. These production systems can be more flexible than traditional AGV system because robots develop by themselves the order of transportation and moving paths. At first, robots develop their motion plans, and then they realize these plans. It is unfeasible to apply former methods to rearrangement problem because rearrangement problem is very complex involving multiple robots and movable object. The search space is exponentially large in the number of robots and objects. Furthermore, there exist many kinds of difference between a real world and simulation. To realize rearrangement plan, we must deal with these difference.

To solve rearrangement problem and generate motion plan, we divide the entire complicated problem into multiple simple sub-problems; Project Scheduling Problem (referred to here as a PSP) and the path planning problem for single mobile robot [1)]. PSP and motion planning problem for single robot is relatively easy and have been studied many years. To deal with between a real world and simulation, we divide developed plan into several "behavior". Each behavior is designed to deal with some differences to achieve each sub-goal [2)]. For example, to localize robot's positions, we give some information about arrangement of walls and landmarks beforehand. And each robot specify position so that arrangement of landmarks which is measured by robot itself and those of which is given in advance.

Keywords: Multiple mobile robots, rearrangement task, environmental model.

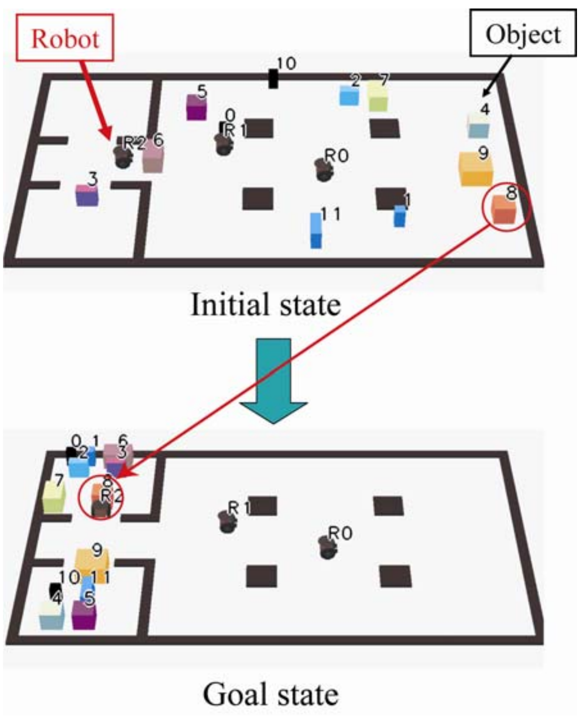

Fig. 1An example of Rearrangement Task.

References

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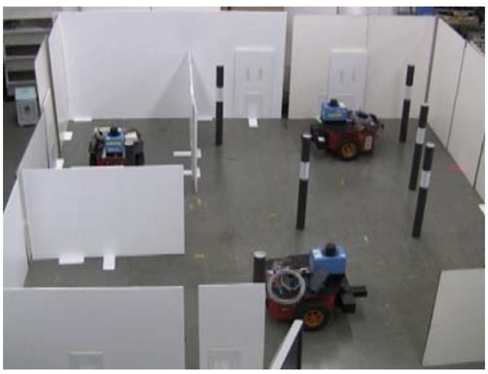

Fig. 2 An experience in real environment.

Estimation of Muscle Fatigue for Human Workers

Muscle fatigue is defined as the condition where the muscle is no longer able to maintain certain level of force. Monotonous or repetitive works as practiced by assembly workers are one of the risk factor for muscle fatigue. Long time exposure to muscle fatigue will cause injury to the workers. This problem can be prevented by monitoring the level of muscle fatigue. However, as muscle fatigue is not a physical value, it can only be measured indirectly by analyzing to the other measurable parameters. The commonly used parameter is the myoelectric signal, which is generated during muscle contraction. In terms of practicability, the surface Electromyography (SEMG) is preferred due to its non-invasive property, where sensors are attach on the surface of the muscle.

We propose a dual frequency-band wavelet analysis technique, which able to monitor the level of force and the degree of muscle fatigue simultaneously [1)]. Two endurance handgrip tasks (static and dynamic muscle contraction) are performed in order to evaluate the effectiveness of this technique. The SEMG signal is recorded from Flexor Carpi Radialis (FCR) muscle. From the observation, it can be concluded that the Root Mean Square (RMS) of high frequency band, 65Hz - 350Hz, is correlated to the force level (Fig. 1). Since both tasks are performed until exhausted, it is assumed that the degree of muscle fatigue will increase throughout the experiment. Therefore, we conclude that the RMS of low frequency band can be used to represent muscle fatigue.

Keywords: electromyography, muscle fatigue

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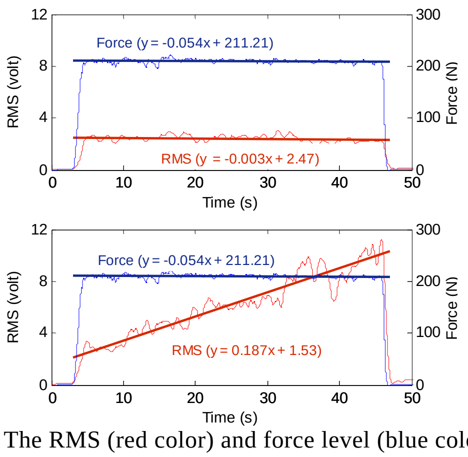

Fig. 1 The RMS (red color) and force level (blue color) of HF (top) and LF (bottom) of FCR muscle. The data is captured during static contraction experiment and is fitted with a linear regression line.

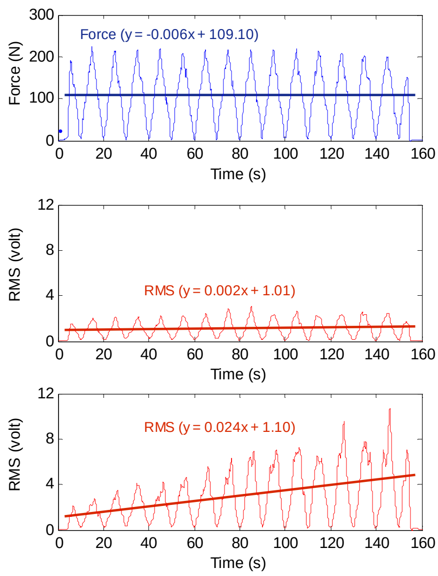

Fig. 2 The results of cyclic dynamic contraction and the changes of force level (top) from FCR muscle of one subject. The RMS of HF (middle) and LF (bottom) calculated and fitted with a linear regression line.

Attentive Workbench: An Intelligent Production Cell Supporting Human Workers

In recent years, manufacturers are required to maintain wide variety of product lineups according to diversifying consumer trends. Instead of conventional manufacturing lines, cell production systems, in which a single human worker assembles each product from start to finish almost manually, have come into wide use in order to accommodate diversified products and production quantity. With negative and zero growth of the population and the tendency of young people avoiding manufacturing jobs, we will face a shortage of skilled workers, and hence a great difficulty in maintaining the cell production system. To meet diverse needs with fewer labor forces, we propose attentive workbench (AWB), shown in Fig.1, together with researchers in the University of Tokyo, such as Prof. Takamasu in the Dept. of Precision Engineering and Lecturer Kotani in School of Frontier Science. AWB recognizes the intention or the condition of a worker through cameras and vital signs monitors, presents the information through projectors, and supplies assembling parts to the worker using self-moving trays. This informational and physical assembly support may result in a higher yield rate and productivity. The present system has been implemented (Fig. 2), and physical support of simple product assembly using self-moving trays has been demonstrated (Fig. 3). We have proved the effectiveness of the present system through subjective experiments.

Keywords: Cell Production System, Attentive Workbench (AWB)

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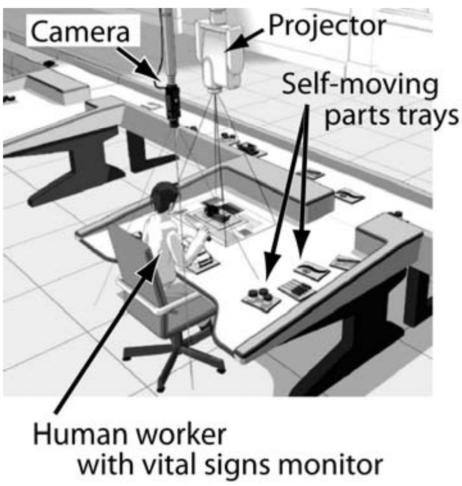

Fig. 1 Overview of Attentive Workbench

Fig. 2 Prototype Model

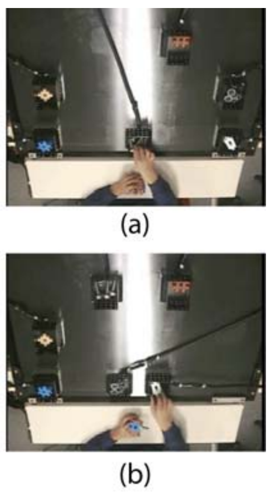

Fig. 3 Demonstration of Physical Assembly Support

Estimation of Neural Network in Silk Moth

When a male silk moth senses sexual pheromone of a female partner by using its antenna, it repeats certain series of walking pattern and arrives to the partner (Fig. 1). This walking pattern is generated in lateral accessory lobe (LAL) domain which controls physical exercise. The LAL domain is consist of about 400 neurons and this neural network is transmitting information. Therefore, in this study, we elucidate the process of this behavior by constructing a neural network model of the LAL domain.

If we estimate every individual neural connection, it will be too huge and complex to solve. Therefore, i) we build a model that treats some numbers of neurons as one neuron and ii) estimate strength of each connection between 2 neuron representatives of neuron groups. Concretely, at i), we divide the LAL domain into 10 sub domains (Fig. 2) and at ii), Genetic algorithm (GA) is applied to solve the large-scale problem estimating 45 connection values. We also use the sequence of zigzag walking pattern as an evaluation function. Figure 3 is one example of estimation results. The arrows mean strong connections; the blue allows are excitatory connections and the white ones are inhibitory. In conclusion, it is shown that this approach is appropriate to estimate the neural network which generates zigzag pattern.

Keywords: Mobiligence, neural network

References

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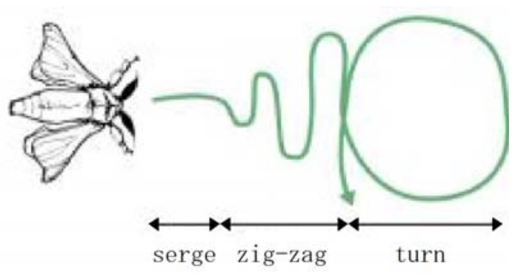

Fig. 1 Walking pattern of silk moth
(Provided by Prof. Kanzaki)

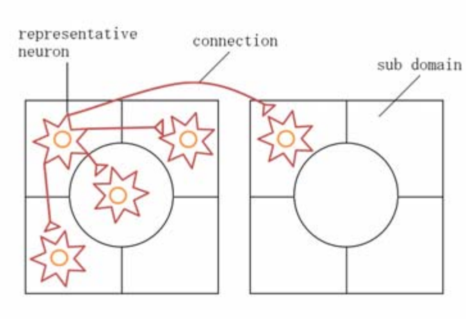

Fig. 2 Model of LAL domain

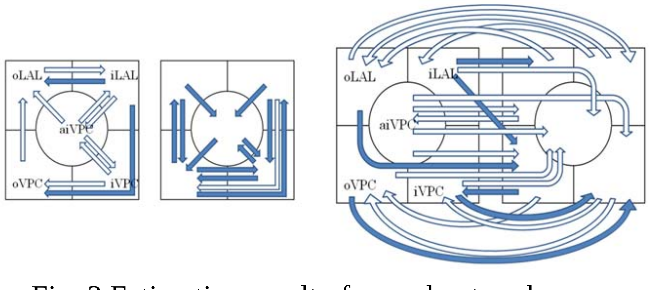

Fig. 3 Estimation result of neural network

Modeling of adaptive behaviors in crickets

Insects provide good model systems to investigate neuronal mechanism underlying adaptive behavior (Fig. 1). Aggressive behavior of male cricket is released by cuticular substances on the body surface of male cricket and the aggression levels escalate until one of male crickets evacuate from the fighting. This agonistic behavior establishes social status between two male crickets (Fig. 2). We have been investigated how animals behave in the social population. Cricket agonistic behavior must be a good model system to understand the mechanism of social status formation. Here we perform mathematical modeling of the male-male interaction among cricket population to investigate how animals organize sociality (Fig. 3). Individual interaction among crickets was simulated by constructing artificial cricket model (Fig. 4). This model was constructed by observation of cricket behaviors in a population and probability P of a behavior pattern was given where P is dependent on a component of time decay and memory which we determine as α. Using this simulator we examine the effect of social population on the crickets behaviors. When the population of cricket was low density, fighting behavior showed rather random pattern. When the population was middle density, only one of crickets did beat other crickets to keep dominant status. When the population was high density, almost all crickets always moved to avoid interaction. This modeling could simulate mechanisms underlying social behavior in insects and that in turn must help us to understand neuronal mechanisms underlying adaptive behaviors.

Keywords: artificial cricket, sociality, social behavior

References

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Fig. 1 Fighting behavior of male crickets

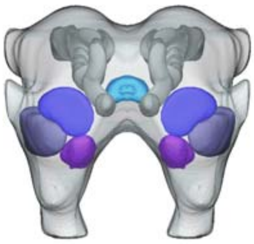

Fig. 2 Image of Cricket Brain

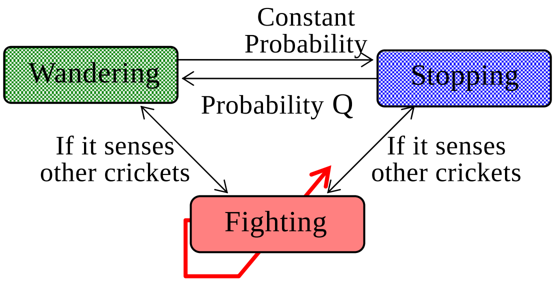

Fig. 3 Finite automaton model of cricket's behavior

Fig. 4 Simulate of Artificial Crickets

Multiple-Goal Task Realization of Robot Arm with Rotating Table

Multiple-goal task such as inspection and spot-welding is essential in manufacturing industries. Previous research works mostly focused on methods for motion planning and collision avoidance; some research works, on the other hand, proposed methods on designing a specialized robot arm for a given task. Selection of these methods is crucial to ensure that a method or combination of methods is applicable to several tasks and can effectively minimize the task completion time.

In this study, we utilize a system consisting of a 6-DOF standard robot arm and a 1-DOF positioning table (Fig. 1), which is applicable to several tasks. The robot arm has to reach goals while the table positions an object. In minimizing the task completion time, we propose a hybrid design composed of hardware-based and programming-based methods (Fig. 2). The hardware-based method involves designing a tool attachment (TA), which is a fixed linkage attached on the robot arm end-effector. In programming-based method, we incorporate base placement (BP) design, goal rearrangement and motion coordination. The proposed method is evaluated under various numbers of goals; its performance against other methods is shown in Fig. 3. A comparison of derived configurations of robot arm and table is shown in Fig. 4.

Keywords: Multiple-goal task, manipulator, design method.

Reference

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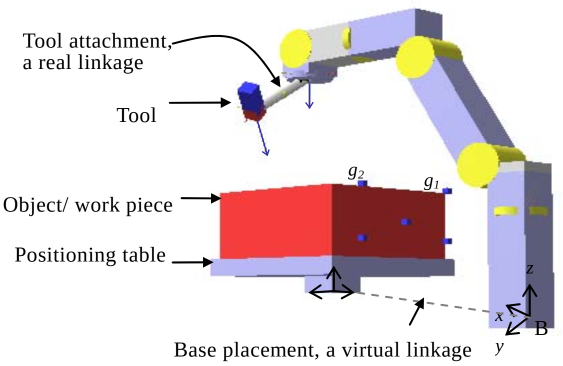

Fig. 1 A system consisting of a robot arm and a positioning table.

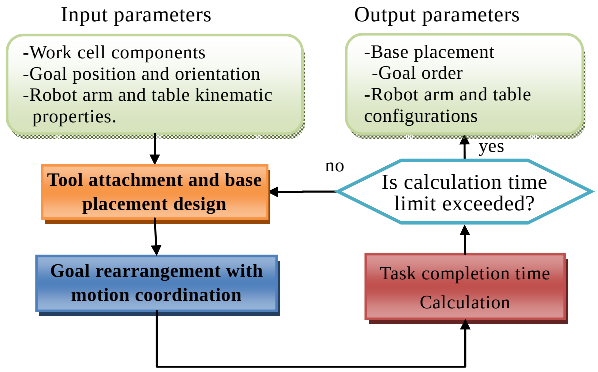

Fig. 2 Proposed method.

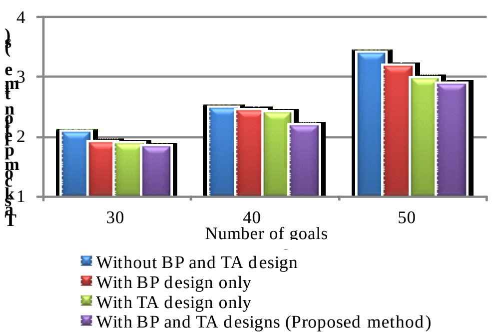

Fig. 3 Performance of compared methods.

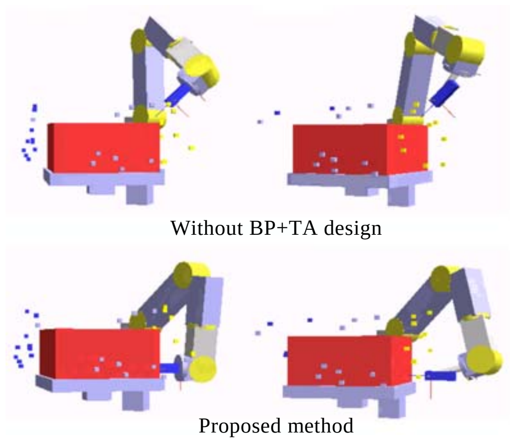

Fig. 4 Derived configurations of robot arm and table with 30 goals.

E-Nightingale - Analysis of Nurses' Action Rules

Nursing is characterized as a cycle management of patient conditions within the PDCA (Plan Do Check Action) conceptual framework. Due to *(i)* shortage of nurses and *(ii)* improving complexity of cares for the old, nursing is regarded as the most challenging profession in Japan. Therefore, an effective nursing induction system for high quality cares is practically mandatory. As we know, the nurses with lower staffing levels tend to have higher rates of poor patient outcomes, which is partially resulted from their action rules to provide nursing cares. Consequently, we proposed a new analysis method to quantitatively elucidate nurses' action rules on their provision of nursing cares [1)]. Different with the traditional analysis method mainly based on the dialogues, we hypothetically modeling the nurses' action rules in the abstract nursing flow model (Fig.1) as a set of candidate dispatching rules; and then, by evaluating the similarities of the planned nursing cares with observed ones, we quantitatively elucidate nurses' action rules from the most similar rules.

As shown in the results of the similarity on time (a measure representing the proportion of the difference of execution times in planned cares and actual ones to total working time) in Fig.2, we find that nurses generally define the processing orders of the nursing activities based on a rule similar to the dispatching rule of EDD, which mainly references the information of evaluated processing time of the preparation tasks and the upper bound of the expected execution time in worksheets [1)]. Next, we described the nursing care scheduling problem, and modeled it from the viewpoint of the similarity with the job shop scheduling problem. Moreover, based on the simulated annealing algorithm, we propose an effective scheduling method for nursing care scheduling problems [2)]. Last, through the experiments in simulated nursing conditions, the proposed dynamic scheduling system is verified to be highly applicable to practical nurses' work environments.

Keywords: Nursing care, nurses' action rule, dispatching rule, scheduling.

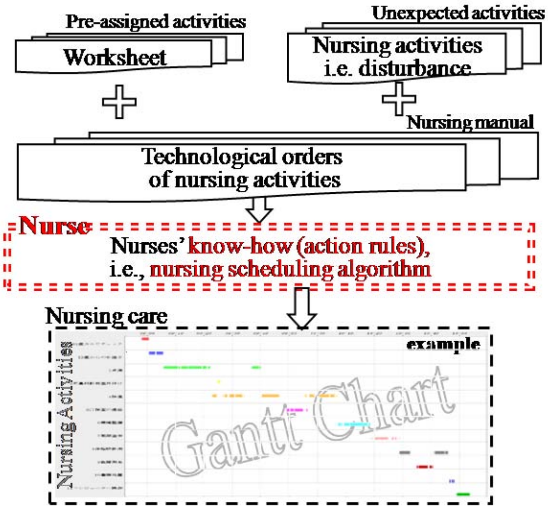

Fig. 1Abstract nursing flow model

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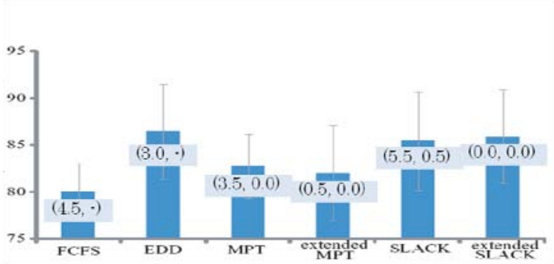

Fig. 2 Similarity on time