ARAI – YOKOI – OTA LAB

Introduction to Intelligent Systems Division (ARAI Lab., YOKOI Lab., OTA Lab.) 2006

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Intelligent Systems Research Group

Lab. for Advanced Robotics with Artificial Intelligence (ARAI Lab.)

Lab. for Developmental Cognitive Machines (YOKOI Lab.)

Mobile Robotics Lab. (OTA Lab.)

Research Projects in Lab. for Advanced Robotics with Artificial Intelligence

(mainly supervised by Prof. T. Arai)

Research Projects in Lab. for Developmental Cognitive Machines

(mainly supervised by Prof. H. Yokoi)

Research Projects in Mobile Robotics Lab.

(mainly supervised by Prof. J. Ota)

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Development of Artificial Intelligence for Legged Robots on RoboCup Soccer Environment

(Prof. T. Arai and Mr. R. Ueda)

RoboCup (robot soccer world cup) is nowadays an international joint project to promote artificial intelligences that act in this actual environment. Team ARAIBO, the united team of Univ. of Tokyo and Chuo Univ., has participated in RoboCup four legged robot league since 1999. In this league, SONY's quadruped robots, ERS-7, are used as shown in Fig. 1. Our team has achieved 2nd and 3rd prizes on the technical challenge, which has been held with soccer games, since 2003 to 2005.

We have proposed various novel methods that enable robots to work in the real world. Lately, the resetting method for kidnapped robot problems on self-localization1) (Fig. 1) and the real-time Q-MDP value method for decision-making under uncertainty of recognition2) are developed from our team. Moreover, software for adjustment of color recognition from color images, auto-generation algorithms of gates, and a simulator that can simulate the characteristics (noise, blur, and so on) of color cameras 3).

Our team will take a step in development of autonomous robots that work in home and office environment in this year. Our products in RoboCup will accelerate the challenge.

Keywords: RoboCup, Pet Robots, Particle Filters, Simulator, Real-Time Q-MDP

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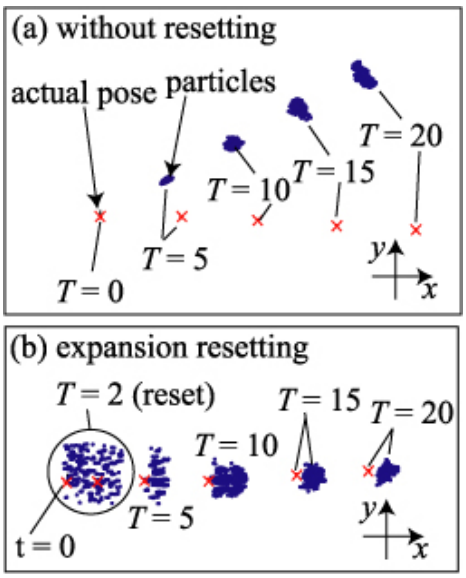

Fig. 2 resetting method

Fig. 1 RoboCup 2005 in Osaka

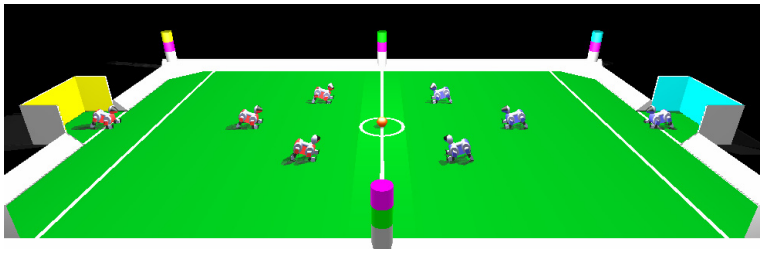

Fig. 3 ARAIBO simulatior

Decision Making by State-Action Map and Its Application (Prof. T. Arai and Mr. R. Ueda)

When a robot must decide its behavior in real-time, a look-up table that contains appropriate behavior for every state in the environment and the robot is useful. That is because the robot can choose its behavior only by a reference of memory at every moment. We have studied creation of the look-up tables, which are called state-action maps with dynamic programming. Then, various offspring of the method have been proposed also (e.g. compression method of state-action map1), real-time Q-MDP method2)).

In Fig. 1, a robot (ERS-7 made by SONY) approaches to the ball with a state-action map. The robot iterates map reference at every step of walking with self-localization result and measurement of the ball, and creates the sequence of actions as shown in the figure. A state-action map is used for a goalkeeper in Fig. 2. In this map, the pose of the robot, the velocity and position of the ball are considered. The goalkeeper can judge its strategy (blocking at the goal, seizing the ball, etc.) from the state-action map. Our current challenge in this study is to create cooperative behavior of two robots without heuristics. In Fig. 3, two robots behave on simulation with a huge state-action map, which contains actions of 610 million states. We have obtained the huge map within one week with a computer that have 3GB RAM and a 3.6GHz Pentium 4 CPU.

Keywords: Dynamic programming, Vector Quantization

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1) K. Takeshita, R. Ueda and T. Arai: “Fast Vector Quantization for State-Action Map Compression,” Proc. of The 9th International Conference on Intelligent Autonomous Systems (IAS-9), pp. 694-701, 2006.
2) R. Ueda, T. Arai, K. Sakamoto, Y. Jitsukawa, K. Umeda, H. Osumi, T. Kikuchi and M. Komura: “Real-Time Decision Making with State-Value Function under Uncertainty of State Estimation -Evaluation with Local Maxima and Discontinuity,” Proc. of IEEE ICRA, pp. 3475-3480, 2005.

Fig. 1 Behavior for Obtaining the Ball

Fig. 2 Goalkeeper Behavior

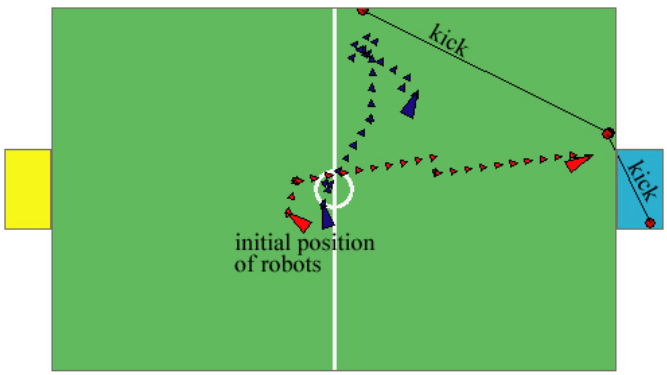

Fig. 3 Cooperative Behavior of Two Robots on Simulator

Vector Quantization for State-Action Map Compression (Prof. T. Arai and Mr. R. Ueda)

Dynamic Programming (DP) has been proposed by Bellman in the 50s as a direct method for solving optimal control problems. Though computational complexity of DP is huge, its application range is expanding thanks to the development of computers.

We have utilized DP for planning of behavior for a small soccer robot, which is show in Fig. 1. When we create a control policy, which is written on a huge memory array and is called a state-action map, by DP on a powerful computer, a problem occurs: the small robot does not have enough memory to unfold the state-action map. We think that this problem is common to systems that are controlled by small computers if DP is applied to them.

Under the circumstance, we have the motivation to try compressing state-action maps. The vector quantization technique is used for the compression. As shown in the figures below, this method has been applied to decision making for soccer robots, the puddle world task, and the Acrobot that are standard problems of artificial intelligence and robotics. In the tasks, we have verified that the compression method can reduce size of state-action maps with high compression ratio (1/10 – 1/1000).

Keywords: dynamic programming, vector quantization, RoboCup, puddle world task, the Acrobot

References

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2) R. Ueda, T. Arai, and K. Takeshita: "Vector Quantization for State-Action Map Compression - Comparison with Coarse Discretization Techniques and Efficiency Enhancement," Proc. of IEEE/RSJ IROS, pp. 166-171, 2005.
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Fig. 1 behavior of a robot with DP result

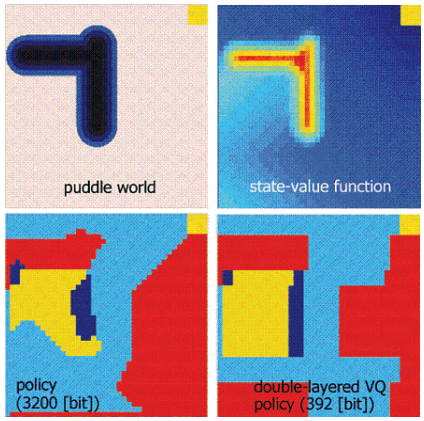

Fig. 2 compression of a policy for the puddle world task

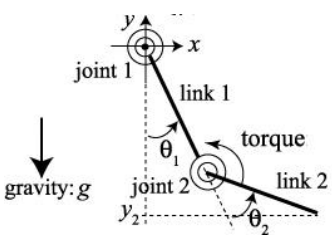

Fig. 3 the Acrobot and its compressed control policy

Design of Force Control Parameters for Cycle Time Reduction

(Prof. T. Arai and Prof. Y. Maeda (Yokohama National Univ.))

Recently, in manufacturing industry, robots are required to achieve complicated assembly operations like those human workers perform. Force control plays a significant role in robotic assembly operations, in which manipulated objects contact with the environment. In order to achieve successful operations, force control parameters must be designed appropriately. Here, it should be noted that reducing a cycle time, which is the time required to complete an operation, is very important in industrial applications. Therefore, force control parameters that can reduce the cycle time and achieve operations successfully are desired greatly.

In this research, we have proposed a method for designing force control parameters considering the cycle time. In the method, sub-optimal control parameters are obtained through iterative simulations of assembly operations because it is difficult to calculate the cycle time analytically. This method is formulated as a nonlinear constrained optimization problem whose objective function is the cycle time (Fig. 1).

We applied the method to peg-in-hole operations and clutch assembly. First, we developed simulators based on preliminary experiments (Fig. 2, Fig. 3). Then, we solved the optimization problem using the simulator and obtained sub-optimal control parameters that can reduce the cycle time. The validity of the obtained parameters has been demonstrated by experimental results.

Keywords: Cycle Time, Force Control, Admittance, Robotic Assembly, Optimization

References

1) Natsuki Yamanobe, Yusuke Maeda, Tamio Arai: “Designing of Damping Control Parameters for Peg-in-Hole Considering Cycle Time,” IEEE Int. Conf. on Robotics and Automation, 2004.
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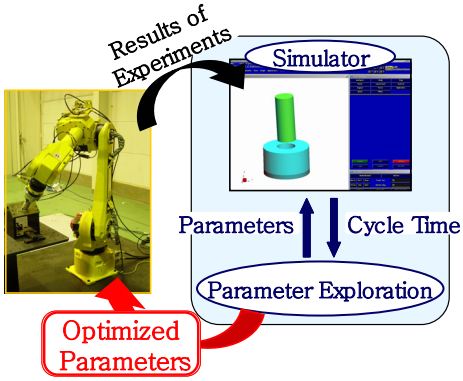

Fig. 1 Schematic View of Designing Force Control Parameters

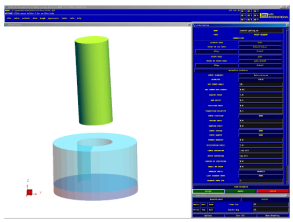

Fig. 2 Simulator for Peg-in-Hole Operations

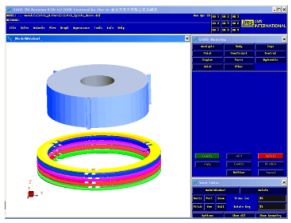

Fig. 3 Simulator for Clutch Assembly

Analysis of Complex Assembly with Dynamic Simulator (Prof. T. Arai)

In present manufacturing scene, one of the requirements that arise is the use of general-purpose robots for complex tasks like engine assembly. In order to achieve these tasks, we need a deeper understanding of the tasks, for example, the relationship between the robot behavior and the change of the task states. However, it is difficult to analyze the complicated tasks by geometrically or statistically based methods. Therefore, we use a dynamic simulator to analyze the tasks in order to gain such understanding. Using the simulator for analysis allows us to measure phenomena that are too fine to be perceived in reality.

We analyze the clutch assembly which is highly required in manufacturing industry (Fig. 1). The clutch assembly is a complicated assembly task that needs a searching motion to insert a toothed clutch axis through a series of movable clutch plates with errors of translational position and angle against the axis. In our research, we especially investigate the qualitative relationships between searching motion and task efficiency. Analyzing the simulator's data (Fig. 2), we obtained that an increase in the searching speed shorten the time to achieve the assembly. However, increasing the searching speed makes the parts hard to fit in simultaneously, decreasing the efficiency (Fig. 3). Our results indicate the existence of an appropriate searching speed that will allow us to perform the tasks efficiently. We expect to use this analysis approach in various different complex tasks.

Keywords: Analysis, Dynamic Simulator, Robotic Assembly, Force Control

References

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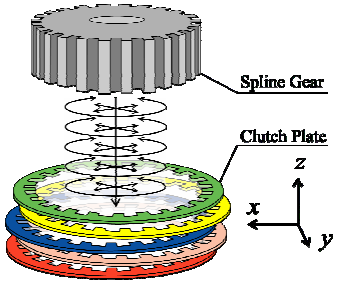

Fig. 1 Clutch Assembly

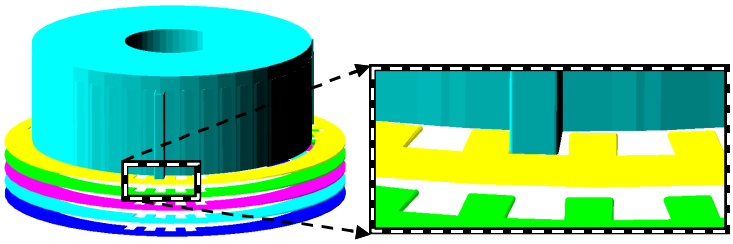

Fig. 2 Simulator of Clutch Assembly

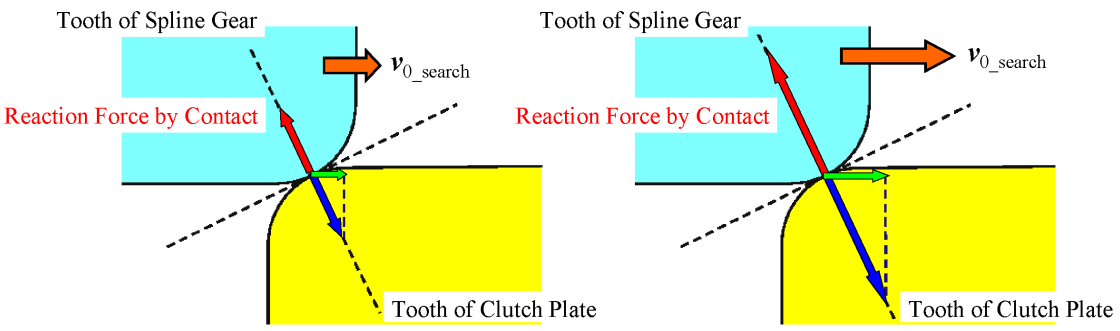

Fig. 3 Analysis of the Operation

Motion Planning of Multiple Robots by Considering Robot Fatigue (Prof. T. Arai)

Robot manipulators used in industrial lines are required to work continuously for long durations. In order to develop a stable system comprising robots, an important factor that needs to be considered is the heat generated at the actuators of robots. Because of high-speed and continuous motion of the robots, this heat increases with their movement. If some actuators get overheated, the robot halts; this causes a drop in the efficiency of the system.

In this study, we consider a high-speed handling system comprising multiple robots (Fig. 1). Further, we optimize robot motions and a task allocation algorithm in order to control the actuator heat and improve the efficiency of the entire system. Because of the short durations of the robot motions in this system, a state-action map is used; this map comprises a lookup table that connects the state of a robot and the system to an appropriate robot action. The state-action map is developed in advance so that the robot can decide its actions by just referring to the map. The appropriate motion for picking up a component is determined by optimizing the initial and final positions of the robot's hand using dynamic programming. The task allocation algorithm is optimized by reinforcement learning in order to balance the task load between the robots and control the heat generated while performing the allocated task. The efficiency of the system improves by 70% when the developed state-action map is used.

Keywords: Robot fatigue, State-action map, Dynamic programming, Reinforcement Learning

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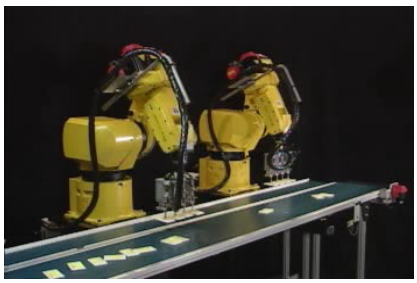

Fig. 1 Handling system with multiple robots

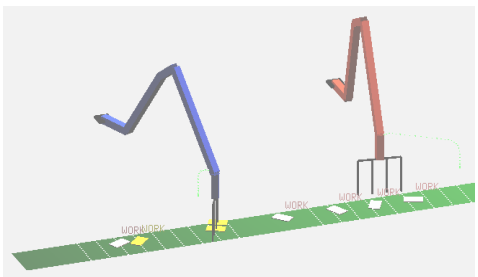

Fig. 2 Simulator of a handling system

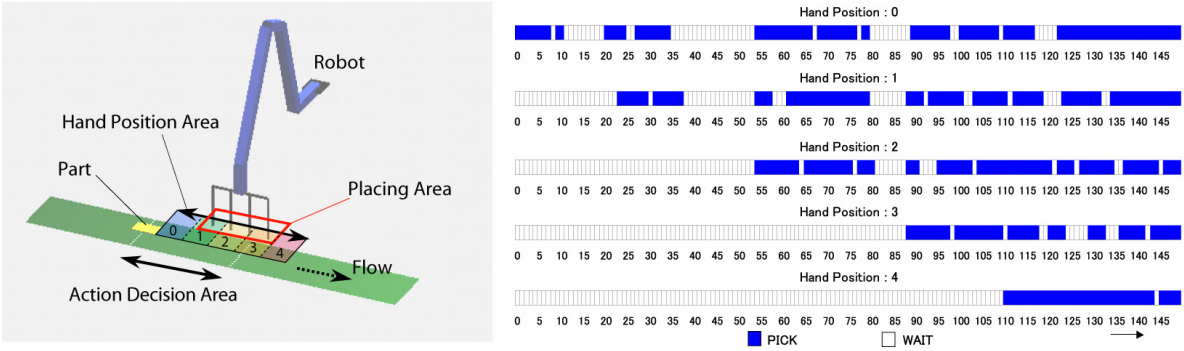

Fig. 3 Developed state-action map for picking up a component

Robot Motion Planning by Integrating Multiple Rules (Prof. T. Arai and Mr. R. Ueda)

The programming of robot motions is an arduous task. Typically, specialists design and implement a robot motion for each particular task with a cut-and-try approach. In addition, reprogramming is indispensable to deal with even a slight change in tasks and work environments since robots cannot adapt their motions to the changes. The difficulty in motion planning is a major hurdle to automating various complex tasks with robots.

In this study, we propose a method for planning appropriate robot motions by integrating various task-relevant rules: programs for similar tasks; human demonstration data; expertise for the task and the robot. Determining the conditions for effectively applying the rules to a target task is difficult, and some parts of the applied rules would conflict with others. In addition, the rules exist in different forms. In our method, we represent a control policy for robots with a state-action map in order to exploit various rules; this map denotes a lookup table that connects a state of a robot to its action. First, all rules are included in the map. Then, robot motions feasible for the whole task are efficiently developed by modifying the policy for the states where no rule is written or when the rules result in failure. We applied the proposed method to rearrangement tasks of multiple objects and developed the feasible control policies by integrating programs for similar tasks and a simple rule for the task process. In addition, we address appropriate task segmentation in order to express human demonstration data as a rule.

Keywords: Multiple Rule Integration, Policy Modification, State-Action Map

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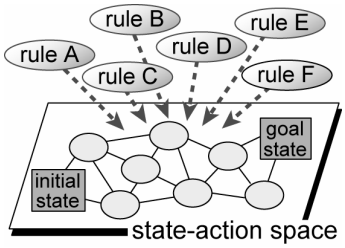

Fig.1 State-action map developed by integration of multiple rules

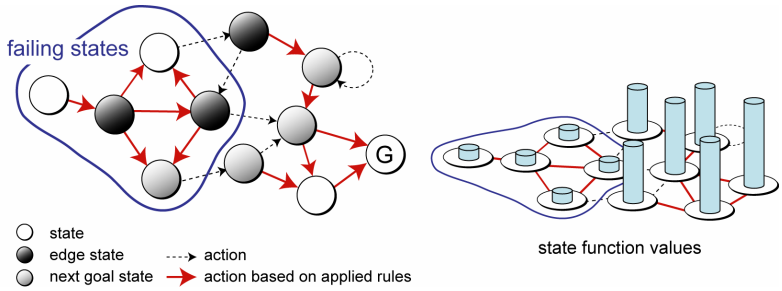

Fig.2 Failing states detection

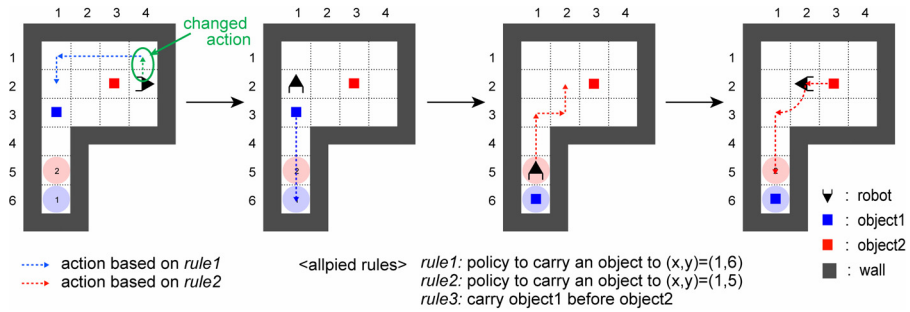

Fig.3 Result of rearrangement task using developed state-action map

Service Engineering and Design Support System for High Creativity (Prof. T. Arai and Prof. Y. Shimomura (Tokyo metropolitan University))

It is well known nowadays that mass-production of artifacts does not link directly to happiness of human beings. Society, however, cannot get out from the paradigm of mass-production. The mission of engineering needs to be reformulated. Under this context, an objective of the "artifactual engineering" is the investigation of a new style of engineering, which would increase directly the happiness of mankind and our environment. A key of "artifactual engineering" is design of artifacts as devices to transfer, supply and amplify services. In the past engineering activities we focused only on the function of artifacts, but from now on we design consumers' satisfaction rather than designers' interests. "Service engineering" is an engineering technique to yield increased value and satisfaction by providing services as defined in Fig. 1; it is also leading to a cost reduction, useful not only for service sectors, but also to the manufacturing sectors as a method to increase added-value.

We have proposed a "service CAD" called Service Explorer, which gives an aid for engineers in the design procedure of service. The purpose of the CAD is to serve as a design environment for the development of a service that would be difficult to develop with the designer's knowledge alone. This CAD system supports designers by storing knowledge about existing service designs in its database and applying various operation rules of service design.

A novel CAD system is implemented to describe the relationships among various agents whose parameters are evaluated. To realize this system, a method for creative design is introduced using dynamically integrated knowledge in different design domains. We argue that abduction for integrating theories can be a basic principle to formalize such design processes. Based on this principle, Prof. Shimomura and his research group have proposed "Universal Abduction Studio, "a design environment in which designers combine different theories to arrive at better design. In this new approach to computational support of conceptual design, the system should offer various types of abductive reasoning from which designers can select an interesting design method.

Keywords: Service Engineering, Service Design , Service CAD

References

1) Arai, T. and Shimomura, Y., Proposal of Service CAD System -A Tool for Service Engineering-, Annals of the CIRP, 53-1, (ISSN 1660-2773), (2004), 397-400.

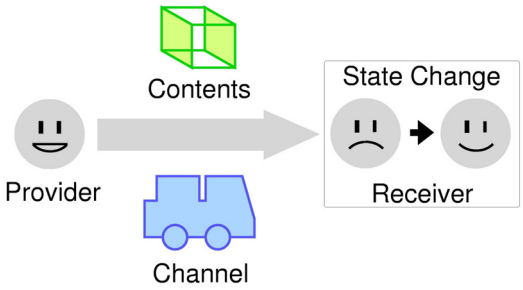

Fig. 1 Definition of a service

Service CAD System
(Prof. T. Arai and Prof. Y. Shimomura (Tokyo metropolitan University))

In our laboratory, we are carrying out research in service engineering by focusing on service as an element that adds more value to any product. Service engineering aims at providing engineering methods for analysis, design, and development about service. And also, as an application of service engineering, we propose a service CAD(Computer Aided Design) system(Fig.1)[1], which supports engineers to design services. A prototype system of the service CAD, which is called "Service Explorer," (Fig.2) has been developed.

Service Explorer is an integrated development environment for service design on a computer. The concept of Service Explorer is based on conventional CAD systems, which are mainly used for physical products. By introducing research result of service engineering, Service Explorer can make service visible, can simulate a behavior of service, and can provide a framework to manage knowledge about service. Furthermore, a reasoning function which is based on analogy is available in order to support creative service design.

A service case described on various view points is stored in a service case base, and then the data can be used as information among designers and as material for a later service design. In addition, a designer is able to evaluate the service multilaterally. For example, to calculate the customer satisfaction or to analyze the importance of the service elements by using the customer requirements. In order to support decision making, mathematical techniques such as Logistic Function, AHP(Analytic Hierarchy Process) method, and Dematel method are employed in these evaluations. A designer is able to improve the service by using the result of evaluations.

Keywords: Service Engineering, Service Design, Service CAD

References

1) Arai, T. and Shimomura, Y., Proposal of Service CAD System -A Tool for Service Engineering-, Annals of the CIRP, 53-1, (ISSN 1660-2773), (2004), 397-400.

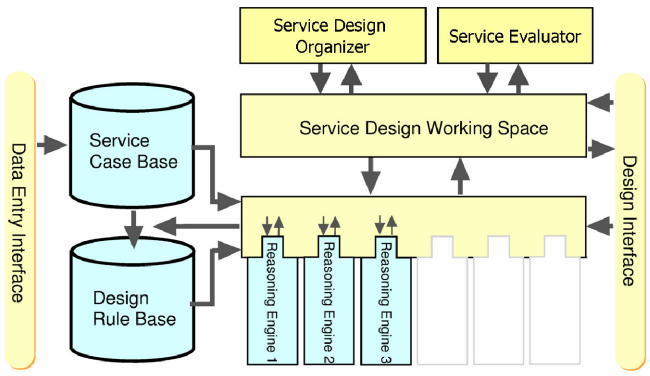

Fig1. A Concept Scheme of Service CAD System

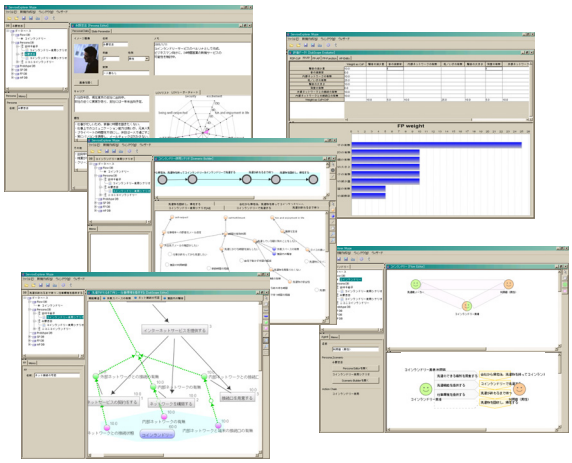

Fig2. Screenshots of Service Explorer

Customer Value Evaluation Method for Service

(Prof. T. Arai and Prof. Y. Shimomura (Tokyo Metropolitan Univ.))

In recent years, manufacturing companies needs to be changed to sell not only their products but also products with service. Therefore, added to current evaluation methods of Engineering, we need a new method to evaluate customers' value created by a service. In this laboratory, we propose the method for service designers to evaluate customer satisfaction. In the process of making this method, we made a model of customers' evaluation processes, for example, how a customer recognizes service value and decides to receive a service. This method allows service designers to determine realization structures of services optimally when they create new services or modify current services.

In Service Engineering, functions of a service are described in the framework called "the parameter model."(Fig.1.) In the parameter model, functions are described as parameters called "Function Parameter (FP)" and these have a tree structure and the root of this structure represents the service receiver's state parameter called "Receiver State Parameter (RSP)". A FP has a concrete attribute value which represents the property of the function such as "20 minutes, for delivering Pizza". RSP is, in the other words, requirement of the service receiver. This structure means the service receiver's satisfaction comes up with change of RSPs occurred by functions of the service. Therefore, the value of RSPs is very difficult to know for the service designer, although the value of FPs is easy to know.

Consequently, we supposed there were functional relations between the service receiver's satisfaction and each FPs which constructs the service, and defined these relations as "Satisfaction – Attribute Value Function (S-AV Function)" (Fig. 2). By the way, we proposed a method to find S-AV functions approximately using "logistics function." This method allows obtaining S-AV functions settling a few parameters.

Keywords: Service Design, Service Engineering, Customer Satisfaction

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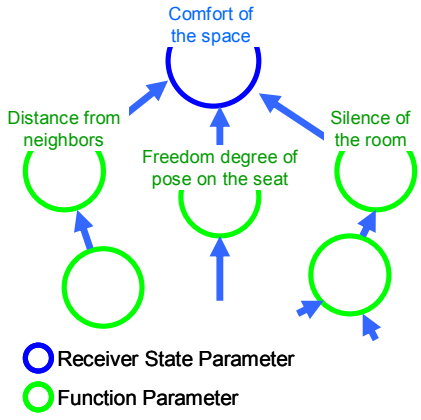

Fig. 1 A Parameter Representation of Service

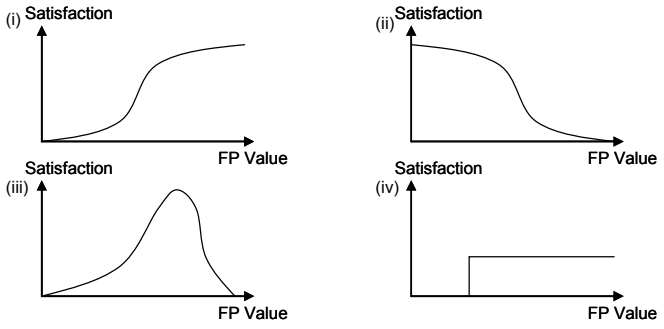

Fig. 2 Examples of S-AV Function

Mutual Adaptation among Human and Machines
(Prof. H. Yokoi and Prof. T. Arai)

Surface electromyogram (EMG) is an electrical action potential of muscle detected on the skin surface and it can be recorded by a non-invasive electric measurement. EMG is a bio-signal which includes the information of the motion dynamics, so it is used to estimate the motion intention of an amputee for controls of the prosthetic hand. However, there are several problems on using EMG: High nonlinearity, individual variation and non-stationary. In order to solve these problems, we have proposed a control method for multi-D.O.F prosthetic hand using adaptive learning as information processing. These methods succeeded to recognize many hand motion patterns. In the field of this study, we aim to clarify the aspect of mutual adaptation among human and machines by investigating adaptive human action.

Adaptable Control for Individual Characteristics: Using concept of machine learning, the method for acquiring mapping between EMG and hands motion pattern is effective. We called this method "Adaptable control for individual characteristics" (Fig.1) and have developed. In the present research, by using the self organization clustering way of thinking, we analyze the human adaptation process. We propose an adaptive learning method to maintain the fingers movement identification performance when using EMG signal dynamical patterns.

Brain function analysis for investigating human adaptation process to EMG prosthetic hand:

In this research, we analyzed the human adaptation process to EMG prosthetic hand using f-MRI. Through the previous research, it is clear that amputee's activation of primary motor area (M1) and primary somatosensory area (S1) were widely growth after sufficient training (Fig. 2). This fact means that"the more strongly subjects recognize that motions of prosthetic hand are hand motions of their own, the more strongly the activation of M1 and S1 is".

Keywords: EMG, Adaptable Control for Individual Characteristics

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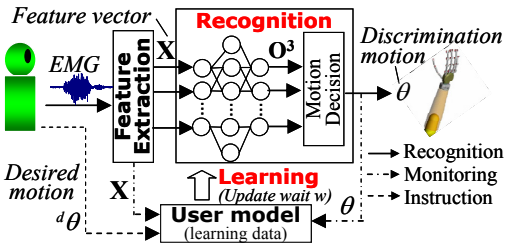

Fig.1 Overview of proposed adaptable EMG-to-motion classifier for Individual characteristics.

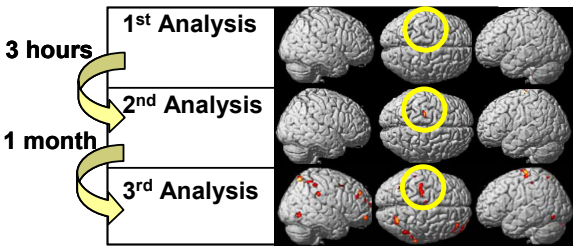

Fig.2 Brain activities for amputee in adaptation process

(yellow circle shows M1 and S1 area of right hand)

Development of Multi-DOF High Torque Joints Light Weight Robot Hand (Prof. H. Yokoi and Prof. T. Arai)

This research aims to the development of an externally powered myoelectric (EMG) controlled robot hand fit for daily life activities. The myoelectric upper limb prosthesis is a function recovery device for the hand, which functions goes from simple griping tasks to more complex activities. Moreover, the prosthetic hand must be lightweight as well as waterproof. The hand uses two wires in parallel configuration for the interference driven joint mechanisms, which allow us to provide high grip power transference with a light structure. The hand has 18 joints and 13 control DOFs (Fig.1).

1. The Interference driven joint mechanisms imitates the human hand

The hand uses the wire driven mechanism at the fingers (Fig.2(a)), imitating the human hand structure. When the wire W3 is pulled, the MP joint curl. The wire W2 can curl not only the DIP joint and PIP joint but also the MP joint. Because the wire W2 passes through the wire guide that corresponds to the fiber sheath, this mechanism allows us to provide MP joint with a high grip power.

2. Interference driven joint mechanism using sliding materials

We developed an interference drive joint mechanism at the wrist joint and the thumb MP joint (2 DOFs). The main objective is to design a mechanism with lossless bearing power transmission. Fig.2(b) shows the mechanism developed in our laboratory with oil less bearing for the rotating axis forming a guide for the actuators wires, resulting in a 2 DOFs high torque joint.

Keywords: Multi-D.O.F. Prosthetic Hand, Interference Driven Link based on Parallel-Wire Mechanism

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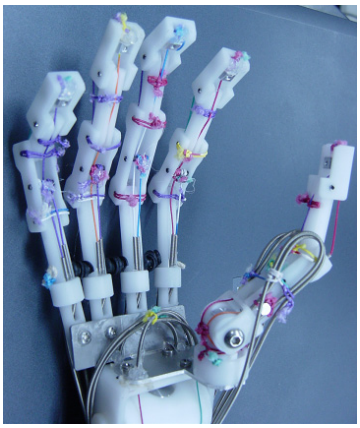

Fig.1 Five-fingered robot hand with interference driven finger and wrist.

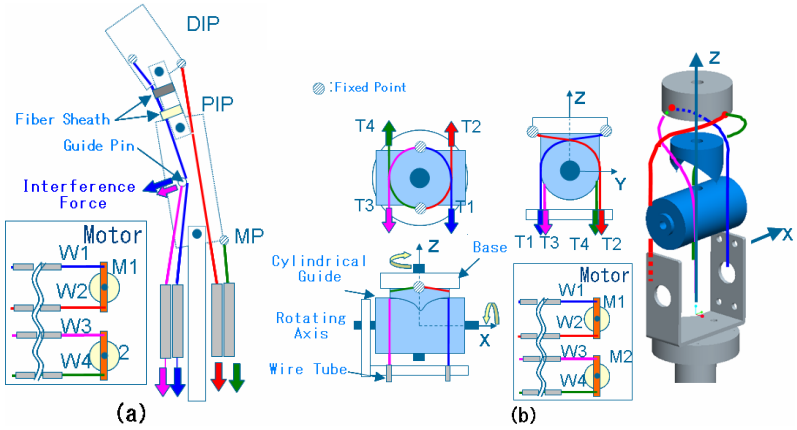

Fig.2 Proposed interference driven finger(a) and wrist(b) based on parallel-wire mechanism.

Biofeedback by using Electrical Stimulation
(Prof. Dr H. Yokoi)

Man-machine interfaces are leading into an era where the intelligent devices are becoming part of our every day lives. In our laboratory we work in the development and implementation of a biofeedback interface for an electrically powered electromyography (EMG) controlled prosthetic hand (Fig.1). One of the major problems for the prosthetic devices is the lack of feedback to the human body that will help in the recognition of the device, facilitating its control. Having only visual feedback, and lacking of any form of proprioception, the prosthetic's users requires of a conscious effort in order to control the prosthesis.

Providing with an interface that allows the user to interact directly with the device will increase its controllability. In our laboratory we use functional electrical stimulation (FES) (Fig 2) to supply the user with tactile information by translating pressure into electrical stimulation. In the current development, we use conductive rubber based pressure sensors that provide the interaction between surrounding environment and the machine. The signal acquired is then translated into a duty cycle controlled pulse based stimulation signal to interact with the human body. We expect that the biofeedback signal applied directly to the system's user will allow the subject to have direct interaction with the environment, reduce the effort generated by the use of only visual feedback, and increase the acceptance rate in the prosthetic hand use. Our research also includes the measurement of the biofeedback effects using fMRI (Figure 3)

Keywords: EMG control, Biofeedback, subconscious control, extended proprioception.

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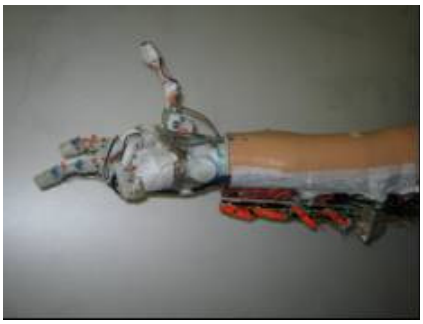

Fig. 1 EMG controlled Prosthetic Hand

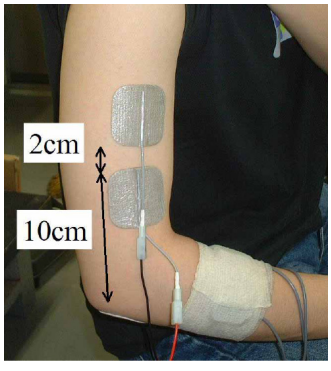

Fig. 2 Electrical Stimulation Electrodes

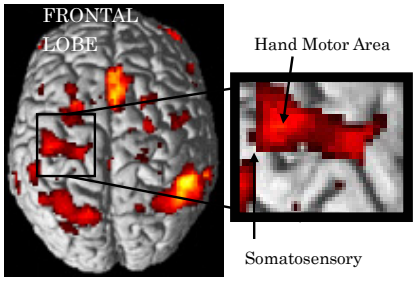

Fig. 3 Stimulation "Ilusion" (fMRI)

Evolutionary Robotics: Coupled Evolution of Controller and Morphology for Dynamically Stable Locomotion

(Prof. H. Yokoi and Prof. T. Arai)

Recently, there have been a lot of research efforts on the development of various assistive devices for replacement of motor function attuned to patient's needs and body. However, when patients use most of these assistive devices, they are required to receive long training to use them. These generate unnecessary burden on the users. To reduce the burden we propose an interface that can directly catch users' motion intention. One challenge we face is that humans are likely to change their motion features while using the assistive devices. If the assistive devices could not follow the motion feature changes, it would be difficult to replace motor function stably by the assistive devices. Therefore, in order to develop useful assistive devices, we should analyze the changes in the user's motion patterns and let the devices change their features accordingly.

In this research, we measured EMG signals during motion, extracted useful information about motion and analyzed skill acquisition process to develop a system where users and devices adapt to each other for restoration of motor function (Fig.1, Fig.2). Which information about motion should be extracted from EMG is also a problem to be solved, so we develop the frequency extraction method (Fig.3). And not only skill acquisition but also muscle fatigue may cause changes of motion pattern, thus we analyze muscle fatigue using EMG signals.

Keywords: Mutual adaptation, EMG, motor learning, Frequency analysis, Muscle fatigue

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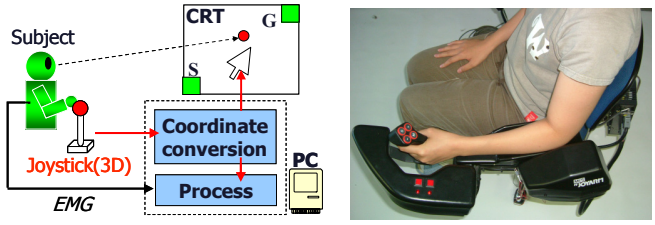

Fig. 1 Experimental System

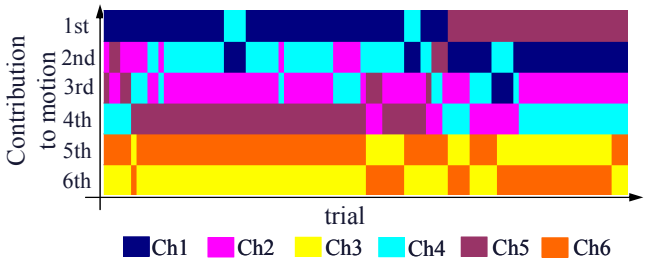

Fig. 2 Each muscle's contribution to arm reaching motion

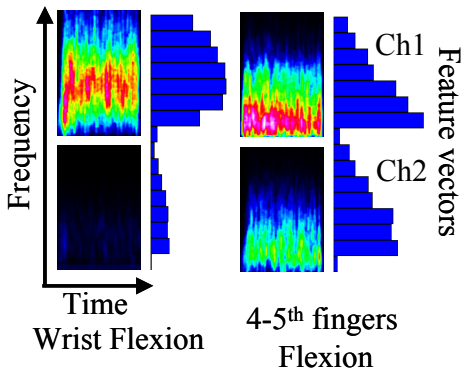

Fig. 3 Feature Vectors (Spectrum) from EMG Signals

Brain Activation when using an EMG Controlled Prosthetic Hand (Prof. H. Yokoi and Prof. T. Arai)

1. This study focus on the measure of the effects due to the use of the EMG controlled Prosthetic hand developed at our laboratory. In order to measure those changes, we use a functional Magnetic Resonance Imaging (fMRI) device. The fMRI use for measurement purposes in a non-invasive form is wide spread in different disciplines, like medicine, rehabilitation and sports. However, the fMRI environment is surrounded by strong magnetic forces, which affects the EMG acquisition process; also, no metallic parts can be put inside the room. In order to overcome such difficulties we use the system as showed in Fig.1. This study aims to the development of an easier to use myoelectric prosthetic hand that allows a more natural control of the device to the amputee's based on the data acquired from the fMRI.

2. FMRI measurement experiment using myoelectric upper limb prosthesis

We perform a series of experiments involved in the comparison between healthy subjects and an amputee. We used a Siemens 1.5T MRI device for the measurement, and the statistical parametric mapping (SPM2) version 2000 for the image processing. The experiment follows the next conditions:

[1]To hold and object with the myoelectric prosthetic hand using only the EMG signal acquired from the right hand. When the system use only the EMG signal to interact with the myoelectric hand, we found the activation of the motor area (M1) related to the hand, but no activation whatsoever related to the somatosensory area related to the right hand.(figure 1)

[2]Use electrical stimulation to provide tactile feedback (left upper arm) from the hand together with the EMG signal (right hand) discrimination to control the myoelectric hand to hold an object. In this case our experiments show how the motor area related to the right hand is activated accordingly, but even though the stimulation is performed on the left arm, the somatosensory area for the right hand is activated, for both the amputee and the healthy subjects.

Keywords: fMRI, EMG, Prosthetic hand, FES

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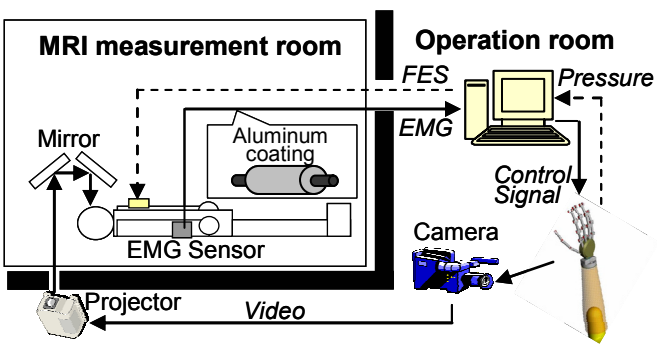
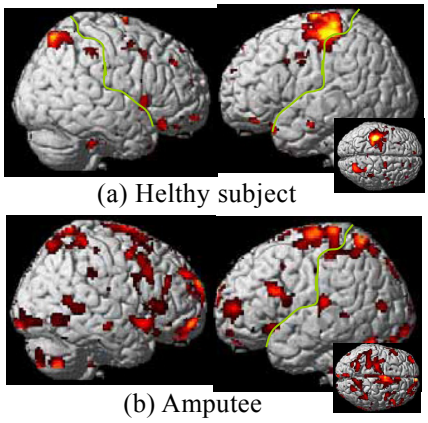


Fig.1 fMRI measurement system for using EMG prosthtic hand.



(a) Helthy subject

(b) Amputee

Fig.2 fMRI data in condition II.

Theoretical Approach in the Development of Multi-Modal Sensory Feedback Controller for the SMA Actuator

(Prof. H. Yokoi and Prof. T. Arai)

INTRODUCTION - Shape Memory Alloy (SMA) is known as a metal that keeps its geometry - after it is deformed, it regains its original geometry by heating at higher ambient temperature, and, in the field of engineering, it is used as an actuator because of light weight, high tensile force, easy heating by giving electrical current directly to SMA. However, SMA has the characteristic of large hysteresis so that it causes slow response problem. Thus, establishment of temperature-regulation system for quick response of SMA is a major issue on development of SMA actuator. Therefore, in our research, we propose two methods: heat sinking mechanism and high current pulse control.

HEAT SINKING MECHANISM is proposed as an efficient cooling mechanism. This is based on the assumption that increase of heat-radiation area by covering a SMA wire with high heat transfer materials causes cooling down the SMA wire in the mechanism more efficiently than a normal SMA wire. Therefore, we built a SMA wire, which is inserted into a metal tube and filled up with silicon grease, as known high transfer semi-solid material, in the tube (fig.1). For the verification, we have built a thermodynamic model in simulation (fig.2) and the experimental equipment in real world. As results, the mechanism in both virtual and real world realized more quick response.

HIGH CURRENT PULSE CONTROL is proposed as an efficient temperature control algorithm. This is based on assumption that surplus heat energy causes low response speed in SMA. Thus, we applied high current pulse (50Hz) as a control algorithm to a SMA wire for the purpose of preventing from overheating (fig.3). As a result, the control realized 2Hz oscillatory response of a SMA wire (the experimental equipment is the same as fig.2). Moreover, we applied the SMA actuation system to a robot hand and, as results, it achieved motions. It indicates that the SMA actuation system has potential in weight-saving, miniaturization, mobilization of the robot hand.

Keywords: Shape Memory Alloy, heat sink, high current pulse control, robotic finger actuation

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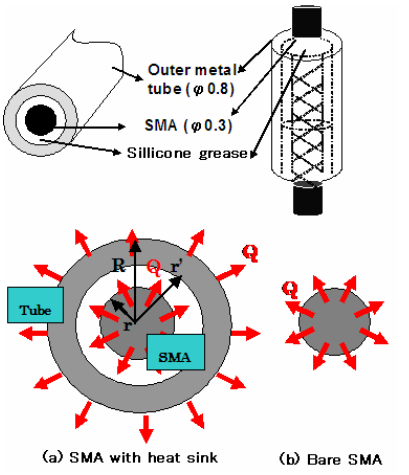

Fig.1 proposed heat sink with the SMA wire.

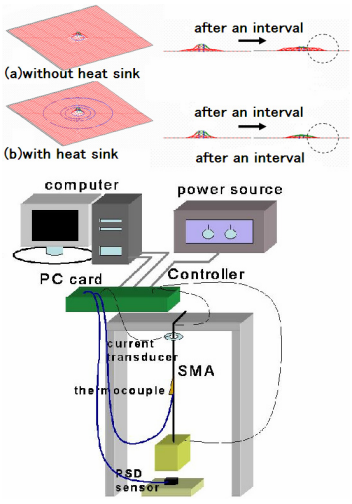

Fig.2 Heat transfer model based on FEM and Experimental equipment

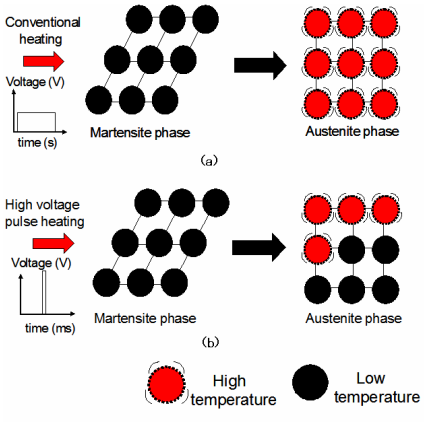

Fig.3 High current pulse control

Evolutionary Robotics: Coupled Evolution of Controller and Morphology for Dynamically Stable Locomotion

(Prof. H. Yokoi and Prof. T. Arai)

Evolutionary robotics is regarded as an auto-design method of robot system and is modeled with an engineering viewpoint of biological evolution. As a main advantage, this approach is excluding as much human bias on design as possible. In other words, designers do not have to implement desired behaviors by their own and, however, unplanned behaviors can be emerged by evolutionary computation. Thus, this approach is suitable to designing autonomous robot system.

In our research, we mainly focus on "inter-dependence between controller and morphology" and, therefore, applied coupled evolution of controller and morphology in order to design locomotive robots, which achieve dynamically stable locomotion such as running and jumping:

(i) For the investigation of relationship between controller, morphology, and dynamical stability, we conducted coupled evolution of controller and morphology on legged robots in three-dimensional simulation. As results, designed robots tended to acquire triped and quadruped locomotion even with five-and-six legged morphology as shown in fig.1 and those also tended to acquire high fitness. Moreover, those robots tended to acquire two kinds of gaits similar to trot gait and gallop gait in biological system.

(ii) An important issue in the filed of evolutionary robotics is to solve "reality gap" problem. This problem indicates that robots, which designed in virtual world, do not always work in same way in real world. In our research, we interdependently conduct evolutionary design, which eliminate human bias, and heuristic design, which utilize human skills (as shown in in fig.2) order to clarify necessity information on fitness function, reality constrains, and effective design components for dynamically stable locomotion.

Keywords: Evolutionary Robotics, Legged Locomotion, Dynamics, Morphology.

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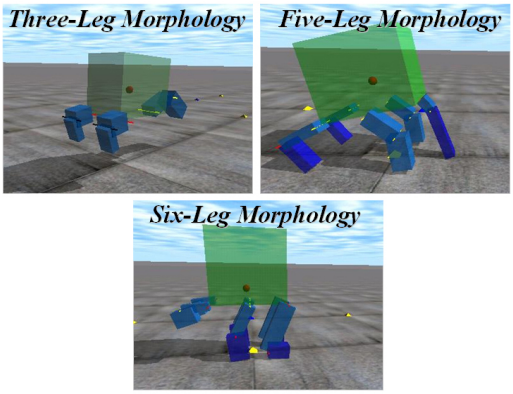

Fig. 1 Legged Robots

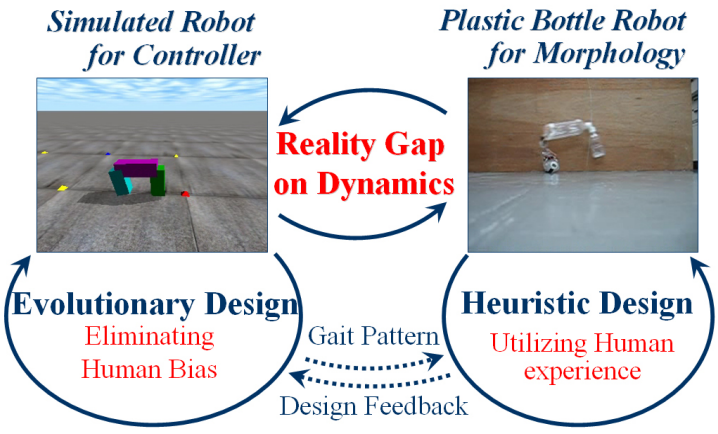

Fig. 2 Desgin System for Reality Gap

Development of Walking Assist Machine (Prof. H. Yokoi and Prof. T. Arai)

INTRODUCTION - Gerontology becomes significant research in recent rapidly-aging society for the purpose of supporting elderly people on life self-reliance. Even the field of robotics contributes to the research issue with developing assist machines for elderly persons and paralyzed patients.

In our research, we mainly focus on walking-assist system for difficulty-walking people such as muscle-weaken persons and leg hemi-paretic persons. At the present stage, we measure walking of a leg hemi-paretic person with surface electromyographic (EMG) sensor, angular sensor, accelerating sensor, and ground reaction force sensor and analyze its walking characteristics. On the basis of the analytical results, we develop two assisting devices for walking improvement: functional electric stimulation and power assist machine.

FUNCTIONAL ELECTRIC STIMULATION is a method to activate leg muscles in paralysis with electric stimulation from an external device. For the purpose of walking in leg paralysis, FES has an advantage on utilizing impaired motor function and, therefore, it is not necessary to build actuation system. In our research, we focus on establishing system, which feedbacks bio-information (surface EMG signal, joint angle, and ground reaction force) representing walking characteristics of a leg paralyzed patient, and, then, assist walking by giving stimulation to appropriate muscles at appropriate time.

POWER ASSIST MACHINE is leg-wearable design as shown in fig.1 and purposes to assist weaken muscles by pulling wires as muscle mechanism. The advantage of this wire actuation is to adjust assist positions corresponding to characteristic of users.

Keywords: Functional Electrical Stimulation, Power Assist, Gerontology.

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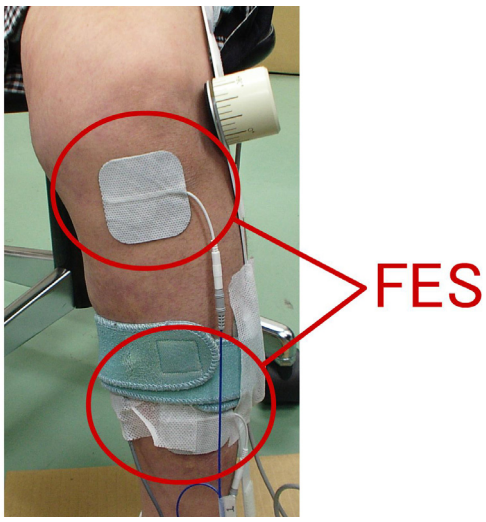

Fig. 1 FES System

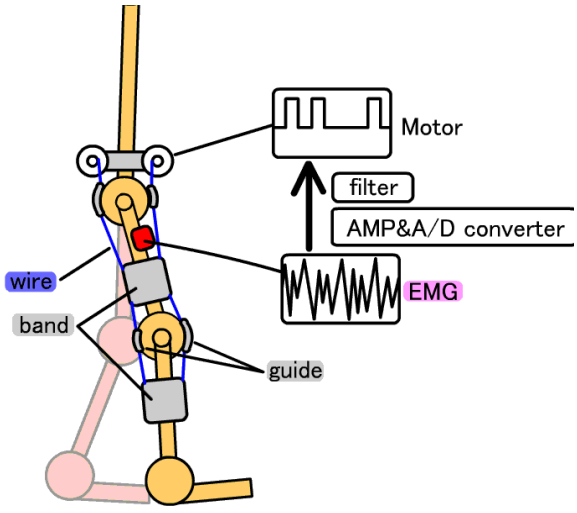

Fig.2 Power Assist Machine

Multiple Mobile Robot Surveillance
(Prof. J. Ota and Prof. T. Arai)

This research aims to deal with the fundamental problems that arise in surveillance missions for multiple mobile robots, where the shortest cyclic path of the robots is aimed as a result of the iterative operation.

In this task setting, robots are first sent out in an exploration phase by distributed sensing at observation points and complete coverage strategy using the Reaction-Diffusion Equation on a Graph (RDEG)-based surveillance planner. In surveillance mission it requires the iterative search of events over and over in the target environment. In the iterative operation, the robots monitor their individual coverage areas and update their local maps to account for environmental changes. In order to quickly respond to such changes, the observation points are dynamically assigned to the robots. The assignment is made by utilizing the proposed real-time task assignment planner.

Keywords: multiple mobile robots, surveillance, task allocation

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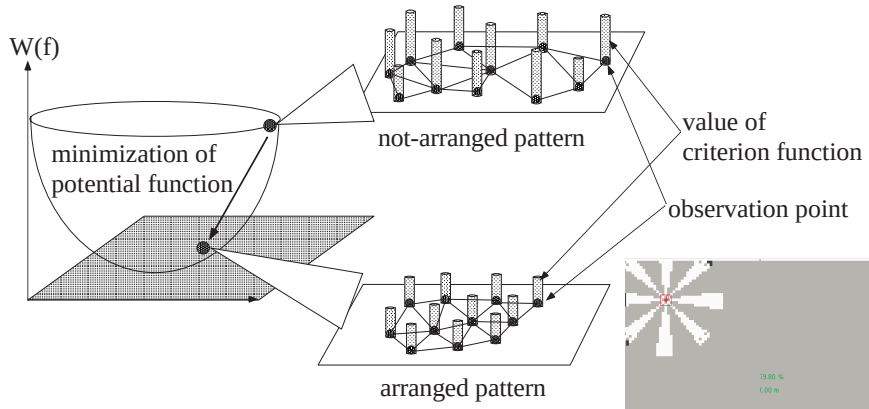

Fig. 1 Arrangement of Observation Points

Fig. 2 Surveillance Task Realization by Real Mobile Robots

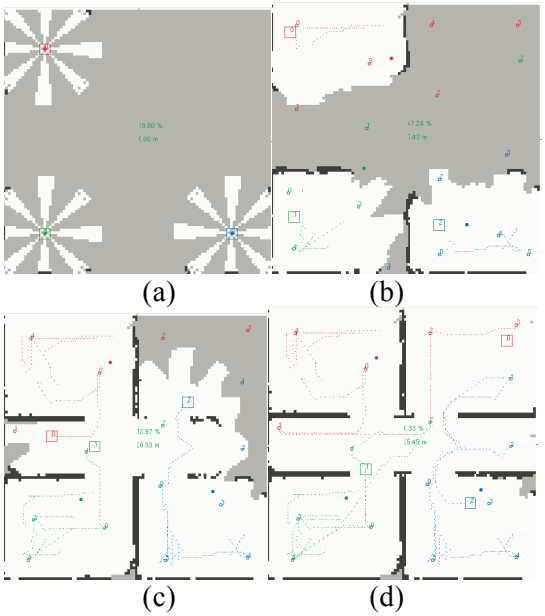

Fig. 3 Simulation Results of Three Robot Surveillance Task Realization

Rearrangement task using multiple mobile robots
(Prof. J. Ota)

A rearrangement of multiple objects is a basic manipulation task. The applications of a rearrangement system are numerous, such as manipulating objects and assembling parts. Generally, distributed autonomous systems using multiple robots are considered superior to others in terms of reliability, expandability, and flexibility.

The cost for a robot to convey a specific object depends on the configurations of objects other robots are conveying, all robots and objects, and the environment (e.g., walls). In some cases, there are constraints among tasks, which require a sequential execution. Because of very high computational complexity, it is infeasible to calculate all constraints beforehand.

Much research has been conducted on this subject, which can be classified into two main topics: (a) variation of the basic motion planning, (b) multi-robot cooperation. Approaches in (a) assume several (not more than 5) objects and that environmental information is always completely known to the robot. Researchers in category (b) have focused on rearrangement projects with a low degree of complexity. However, as far as we know, no research has been conducted on a rearrangement task requiring multiple robots in a dynamic environment. We developed a rearrangement system using multiple robots in an iterative manner of planning and execution.

To decrease the computational complexity, we classified task constraints into three groups and a different strategy is applied for each group as shown in Fig. 1: (I) constraints that can be calculated by the initial and the goal configuration of objects, (II) constraints that require path planning repetition before they can be detected, and (III) constraints depending on the relationship between robots. Group (I) has low computational complexity; therefore, a robot attempts to locate this group at every allocation process. Group (II) requires a higher computational complexity; therefore, robots accept these kinds of constraints only in cases in which allocated tasks are inachievable. Group (III) requires the highest degree of computational complexity to determine its influence. The proposed system has been tested in a simulated environment (Fig. 2).

Keywords: Multi-robot cooperation, Task constraints, Rearrangement problem, Movable objects, Mobile robots

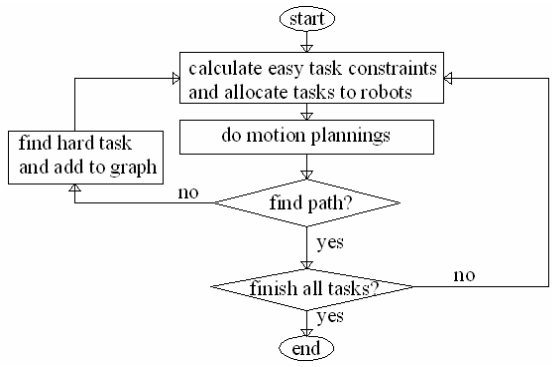

Fig. 1 An overview of the system

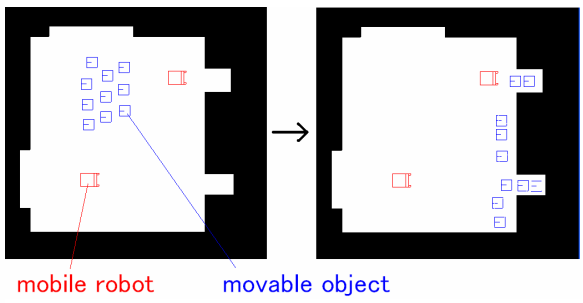

Fig. 2 A rearrangement task with two robots and ten object

Searching methodology with goal state optimization considering computational resource constraints (Prof. J. Ota)

Searching methodology with goal state optimization considering computational resource constraints is proposed. The three topics shown in Fig. 1 should be solved here. Combination of extended graph searching methodology and parallelization of task execution and on-line planning makes it possible to solve the problem. The proposed method is evaluated with the rearrangement problem of twenty movable objects, Comparison of the goal configuration with respect to the demanded task completion time is shown in Fig. 2. The goal state is changed depending on the demanded time, which consists of the time for offline planning, that for online planning and that for task execution only. Balancing among the three classes is made adequately depending on the demanded time. The time for offline planning is very short (almost reactive) when the demanded task completion time is short, and the ratio of the time for offline planning becomes large with respect to the realized task completion time when the task completion time is long. These results show the effectiveness of the proposed method.

Keywords: graph searching, resource constraints, parallelization of action and plan, rearrangement planning

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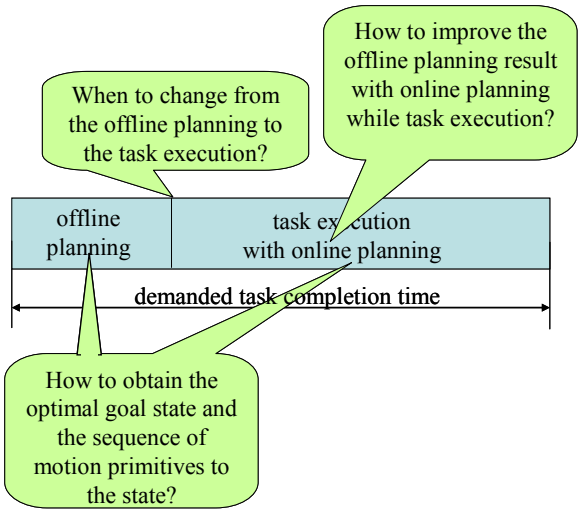

Fig.1 The structure of the problem

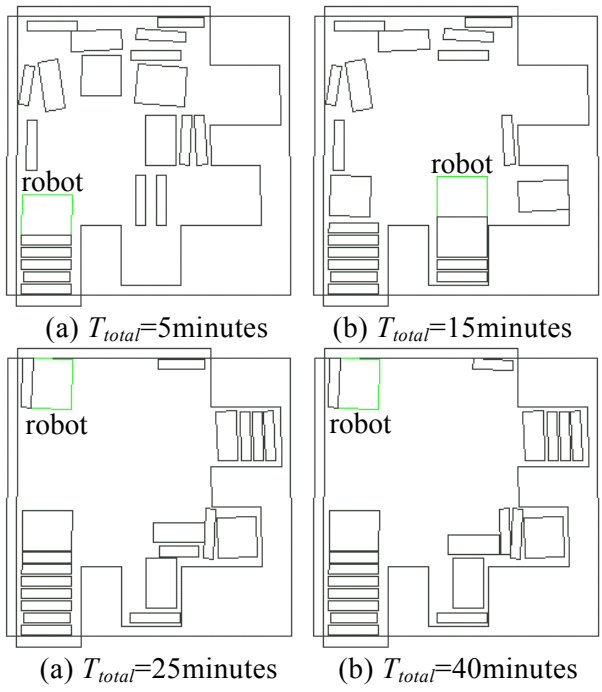

Fig. 2 Comparison of final arrangement with respect to the demanded time

Attentive Workbench: An Intelligent Production Cell Supporting Human Workers

(Dr. M. Sugi, Prof. J. Ota and Prof. T. Arai)

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 Profs. Takamasu, Yamamoto, Kimura, and Dr. Kotani in the Dept. of Precision Engineering, Prof. Suzuki in Research Center of Advanced Science and Technology, Prof. Sato in Institute of Industrial Science, Prof. Shin in Dept. of Mathematical Engineering and Information Physics. 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 assembly using self-moving trays has been demonstrated (Fig.3).

Acknowledgements This research is partly supported by the 21st century COE program “Information Science and Technology Strategic Core” from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

Keywords: Cell Production System, Attentive Workbench (AWB), EnhancedDesk

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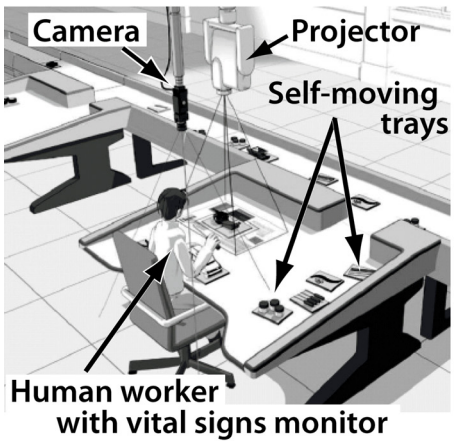

Fig. 1 Overview of Attentive Workbench

Fig. 2 Prototype Model

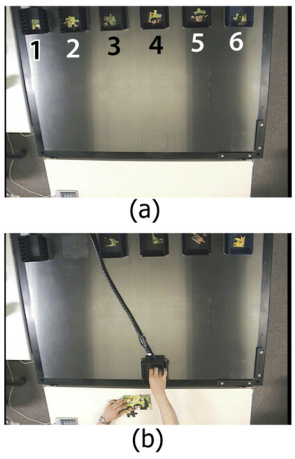

Fig. 3 Demonstration of Physical Assembly Support

User-Adaptive Deskwork Support System
(Dr. M.Sugi, Prof. J.Ota, and Prof. T. Arai)

In our daily life, people typically spend a significant amount of time at their desks. Therefore, supporting individuals who work at desks by using an intelligent robotic system could have a great deal of benefit. We have proposed "Attentive Workbench (AWB)," a deskwork support system that helps a user from both physical and informational viewpoints.

The objective of this study is to realize a support system that delivers necessary objects to a user based on user's pointing gestures (Fig.1). To meet this end, the system must estimate the target.

In this study, we adopt following three approaches:

(1) Estimating the user's subjective pointing directions based on a linear model using the user's finger directions (Fig.2).

(2) Integrating sensory information obtained from the user's pointing gestures and contextual information as the user's action sequences.

(3) Arranging the target candidates as appropriate according to the user's characteristics.

The system can estimate the target object appropriately based on the user's pointing gesture by integrating these approaches (Fig.3).

Keywords: Attentive Workbench (AWB), pointing gesture, epistemic action

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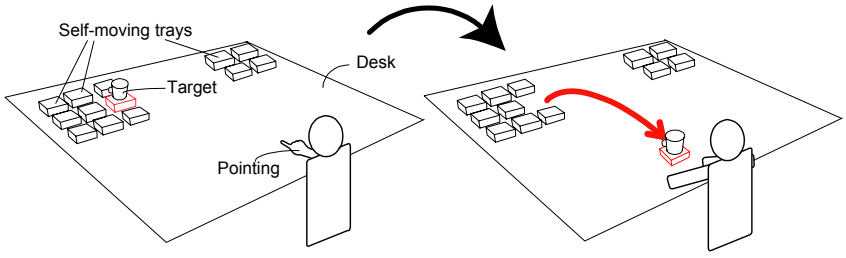

Fig.1 Overview of deskwork support with self-moving trays

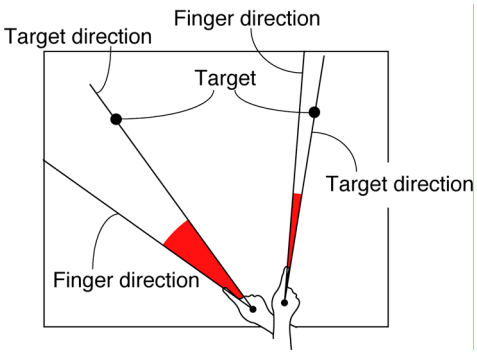

Fig.2 Relation between target direction and finger direction

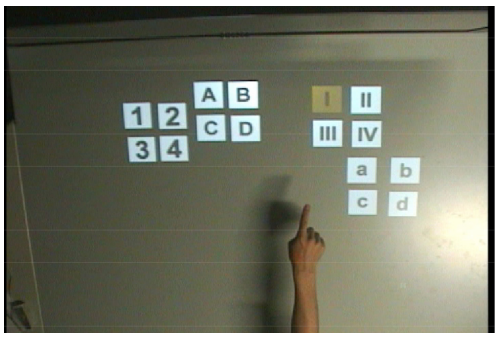

Fig.3 Target estimation based on pointing gesture

Modeling of adaptive behaviors in crickets
(Prof. J. Ota and Prof. H. Aonuma (Hokkaido Univ.))

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 among other crickets. 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

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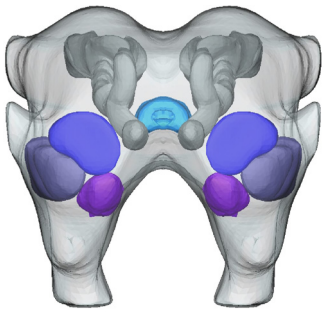

Fig. 1 Brain of Cricket

Fig. 2 Fighting Behavior of Male Crickets

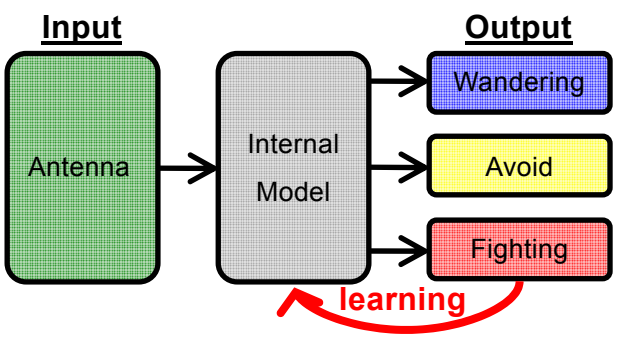

Fig. 3 Finite automaton model of cricket’s behavior

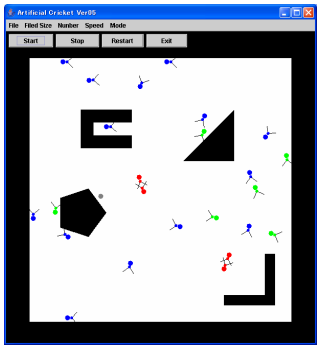

Fig. 4 Simulate of Artificial Crickets

Online Rescheduling in Semiconductor Manufacturing (Prof. J. Ota and Dr. M. Sugi)

Semiconductor manufacturing is mainly characterized by the production of diversity of products on different process flows. It is extremely difficult to solve manufacturing rescheduling problems in real time due to high occurring frequency of disturbances (about 1 time/1 minute). Along with the traditional performance measure on due date, schedule stability, represented by degree of unsimularity (the variation of processing orders from the original schedule), is another important measure for rescheduling method. We have proposed a new online rescheduling system for semiconductor manufacturing by a dual rescheduling process as shown in Fig.1. Once a disturbance occurs in facilities, the rescheduling process revises the original schedule in real time by the transmission of disturbance information among the arcs on a disjunctive graph as shown in Fig.2 - it obtains a new feasible schedule with the high schedule stability. During the execution of manufacturing along the revised schedule, the improving process then performs a quick local search in an acceptable computation time (i.e. the minimal cycle time of disturbances) based on the permutations of processes on the semi-critical paths as shown in Fig.3, which obtains a good feasible solution on the compliance of due date. The proposed method is evaluated through the simulation of several semiconductor manufacturing problems with the actual size of about 200,000 processes in facilities. The results show that this method can effectively accommodate disturbances in less than 1 second, and obtain a better executable schedule in less than 1 minute, and that it is more effective for rescheduling (especially on the performance of schedule stability) by a comparison with conventional dispatching-rule based methods, some of which have been actually applied in many facilities (Fig.4).

Keywords: Online rescheduling, schedule stability, permutation, semiconductor manufacturing

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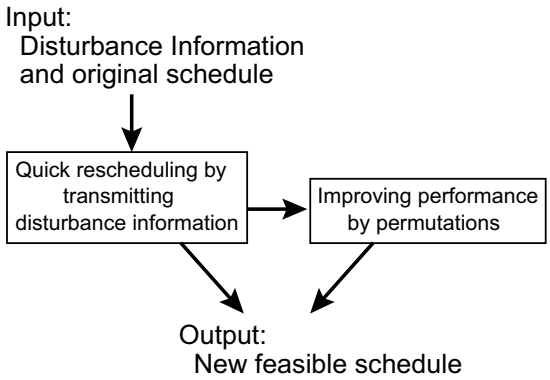

Fig.1 Online rescheduling system

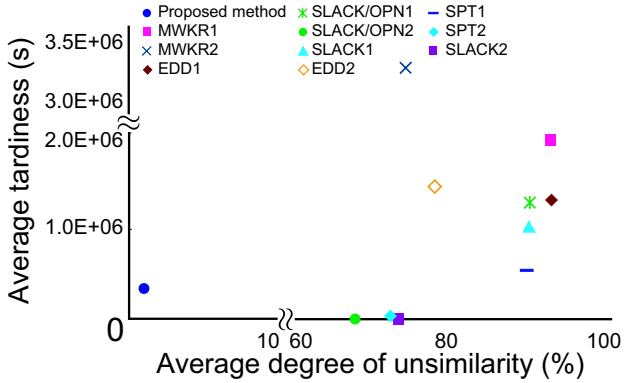

Fig.2 Comparison between traditional and proposed methods

Design of Robust Systems using Competitive Co-evolution
(Dr. R. Chiba, Prof. J. Ota and Prof. T. Arai)

Recently, material-handling systems with Automated Guided Vehicles (AGVs) are being used in manufacturing factories. These programmable AGVs circulate on a guide-path and transport materials in factories (Fig.1). Design process of robust AGV systems is proposed in this research. One of the important design problems associated with the development of AGV systems is a flow-path network design problem.

When the task changes to another task, the flow-path network should be designed again from the beginning in previous works. The flexibility is one of the strong merits in AGV system. Therefore, the robust AGV system is the more efficient transportation system than other systems. However, for this robust flow-path, the number of possible tasks is very large in AGV systems, therefore it is impossible to test the promising flow-path network against all of possible tasks.

The problem is solved by the method of difficult task design with Genetic Algorithm (GA) and an effective flow-path network is designed with GA simultaneously, because the difficult tasks depend on the flow-path networks. Both the network and the task evolve competitively as in Fig2 and a robust network and difficult tasks are finally designed. The robust network means that the minimum number of conveyance is large with the network to some tasks.

Results of the designing are shown through AGV transportation simulations (Fig.3) and the designed flow-path network (Fig.4) makes it possible to complete 10000 tasks that are generated randomly. This shows that the network is robust against tasks and our method is effective.

Keywords: Competitive Co-evolution, AGV Transportation System, Flow-path Network Design

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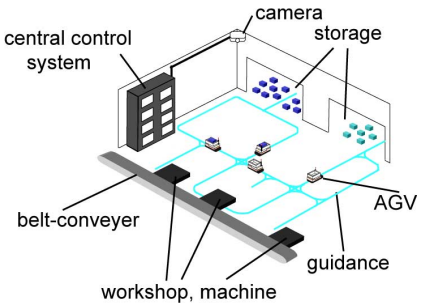

Fig. 1 AGV Transportation Systems

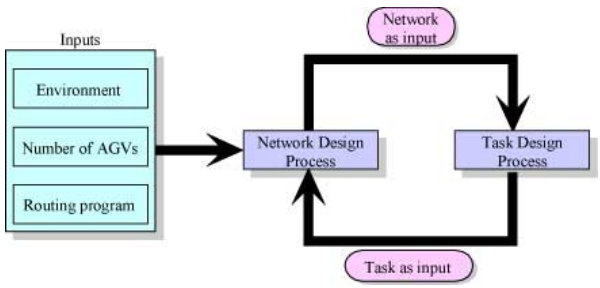

Fig. 2 Design Process with Co-evolution

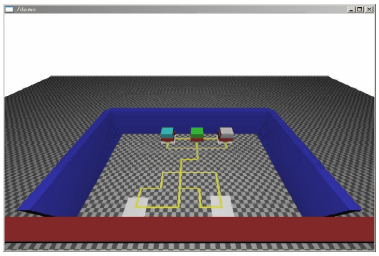

Fig. 3 Simulation for AGV Systems Design

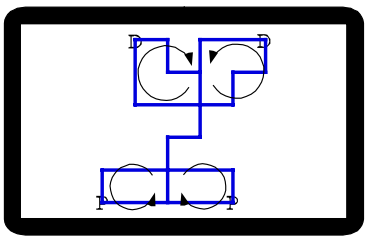

Fig. 4 Designed Network and AGV behiviors

Environmental Design for Palletizing Tasks with 6DOF Manipulator

(Dr. R. Chiba, Prof. J. Ota and Prof. T. Arai)

Palletizing tasks (Fig.1) play important roles in manufacturing systems. It is necessary for the manufacturing to design the effective systems, because the tasks should be essential in several processes. In this research, a method of environment design is proposed to reduce cycle time in the palletizing tasks.

The cycle time can be reduced with an effective design of the working environment such as 1) placement of manipulator and 2) shape and position of pallet. The effective these environment parameters can be designed with nearest neighbor search. In this method, the parameters should be evaluated the summation of takt-time of all products to be placed. Moreover, the dimension of the search space is very high, because the number of the parameters is very large. Therefore, it will take long time to design the proper environment.

In this research, the problem is solved with 1) motion planning with passing point (Fig.2), 2) reduction of the dimension with proper parameters and 3) evaluations with some represented place points in place of all products

Though simulation experiment (Fig 3), the effective environment can be obtained (Fig.4) and the result shows the effectiveness with the proposed method increase by no more than 59 % compared with an empirical method. The design time is within 8 minutes in this experiment.

Keywords: Palletizing Task, Environment Design, Manipulator Placement

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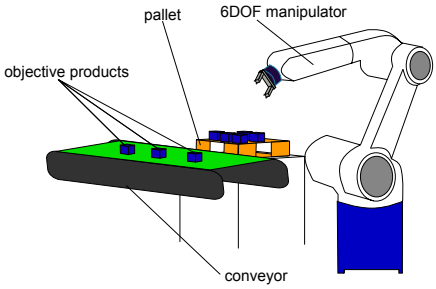

Fig. 1 Palletizing Task

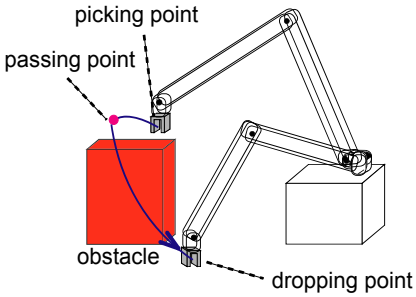

Fig. 2 Motion Planning with Passing Point

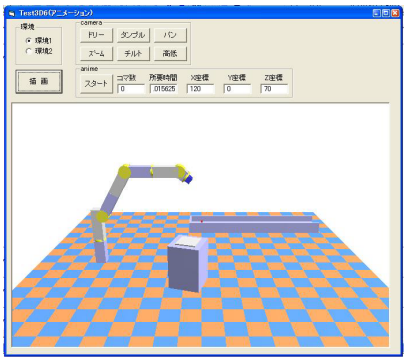

Fig. 3 Simulator for Palletizing

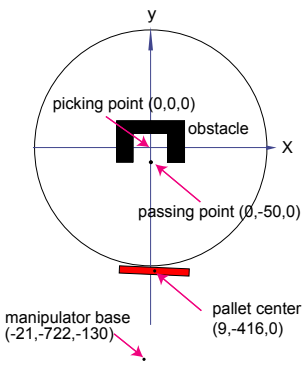

Fig. 4 Result of Environment Disgn

System Design of Large-Scale Port Transportation System Using Multiple Automated Guided Vehicles (AGVs)

(Prof. J. Ota)

The explosive growth in recent years in the volume of freight has resulted in heavier workloads at seaports. In this regard, there are several investigations that have attempted to realization of automation of the container transportation system. For this issue, we have considered machines for loading/unloading/transportation/storage as the multi-robot that have intelligence, then, dealt with the system as AGV transportation system in an automated container terminal (ACT) in Fig. 1.

We need to consider the following problems to construct the AGV transportation system: (I) optimal design of the AGV transportation system, (II) evaluation of the system characteristic, (III) highly management of the AGV transportation system. The problem (I) represents how to design the parameters such as the number of inputting robots and layout. We have proposed a hybrid design methodology with the use of the queuing network theory and simulation as shown in Fig. 2. As for the problem (II), a careful evaluation of the performance based on the system characteristic is needed if there are some considerable systems. The result has shown that the horizontal-type system is more cost-effective. For the problem (III), we have proposed a management methodology using heterogeneous multi-robot behavioral designing, container storage scheduling, and container transportation planning. Finally, it has noticed that the system constructed with the use of the proposed management methodology can be designed effectively than the system that is constructed with the use of the conventional management methodology.

Keywords: Multi-Robot, AGV, Transportation System, Optimal Design, System Management

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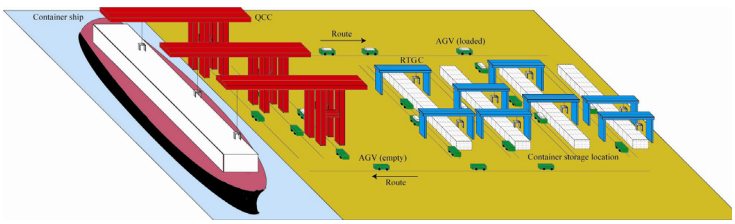

Fig. 1 The Horizontal AGV Transportation System in Automated Container Terminal

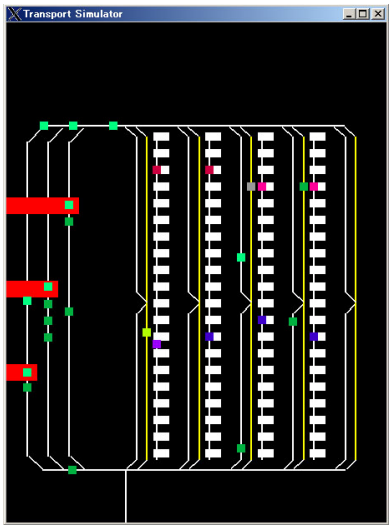

Fig. 2 The Modeled AGV Transportation System

Development of Design Algorithm for Delivery Center
(Prof. J. Ota)

Delivery centers are facilities for making shipment of many kinds of products from factories to commission agents or retail shops. In this research, we deal with a design problem of material flow in the delivery center. The problem can be expressed as follows: determining the sizes of the automatic warehouses, the number of warehouse cranes, that of depalletizers and robots, and the flow volume among these equipments.

An overview of a delivery center, and design objects are shown in Fig.1. In recent years, some delivery centers have been completely automated to improve the operational costs and shipping efficiency.

We propose an extended network flow model in which each device represents a node of the network flow and the conveyed products correspond to the flow within the model. Figure 2, 3 represent the proposed model. When designing a delivery center, it is necessary to determine the appropriate number of devices, the flow among the devices, device-layout, etc. while holding the costs down and satisfying the demand throughput. In the proposed network flow model, several binding clauses exist between nodes and arcs. These clauses are represented as linear constraints. Under these constraints, the number of machines and the flow volume should be optimized. This problem is formulated as a mixed integer problem.

To validate the effectiveness of the proposed model and algorithm, we designed a delivery center using actual shipping data. The result shows that our proposed method can get feasible design results within a few minutes.

Keywords: Warehouse management, Material flow, Logistics

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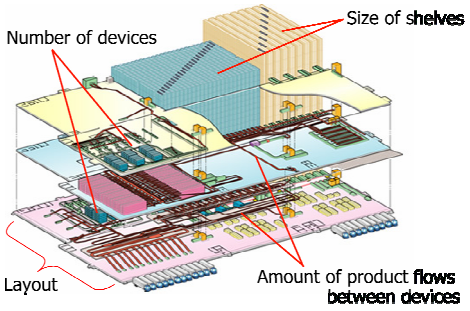

Fig. 1 Warehouse design object(Firure taken from the website of Murata Macninery, LTD. http://www.muratec-l-system.com/en/)

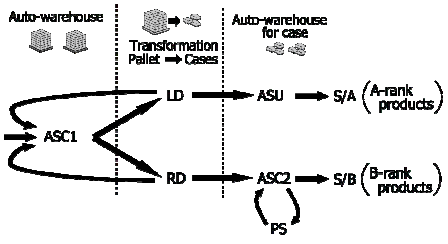

Fig. 2 Network-flow model

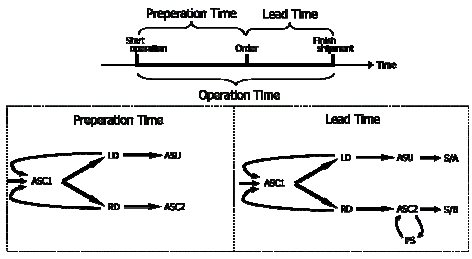

Fig. 3 Operation time and lead time

Scheduling Multiple Agents for Picking Products in a Warehouse (Prof. J. Ota)

The picking problem is a complex, NP-Hard problem wherein orders from a warehouse must be efficiently picked by agents that begin and end their picking sequences (trips/routes) from a common shed. The objectives are to minimize the total number of trips the agents make and the total operation time (makespan). We have proposed to breakdown the picking problem into sequential stages to reduce its overall complexity as shown in Fig.1. The Route Generation (RG) stage creates a set of trips from the orders made on the warehouse – it does this with the aim of minimizing both the number of trips and the total distance covered by the trips. The Route Assignment (RA) stage then assigns the generated trips to a given number of agents that are tasked with picking the products. The aim of RA is to assign the trips such that there is maximal equity of tasks among the agents, i.e. it tries to minimize the difference between the longest and shortest operation times. By ensuring load balancing, the maximum agent operation time is also minimized. The final Dispatching stage, which is our main interest here, is concerned with a) the sequence in which agents are dispatched one after the other and b) the order by which routes assigned to a given agent are traversed. We formulate a model for the dispatching problem and show that it has a non-polynomial complexity with respect to the number of agents and number of routes. We then propose an effective simulation-based scheduling procedure to solve the problem with the aim of reducing agent interactions such as collisions or queues. We simulate a real warehouse environment (Fig.2) and show that the said dispatching procedure is able to keep delays caused by collisions and queues significantly low, and that it makes large improvements over the case when no dispatching policy is applied to the agents (Fig.3).

Keywords: multiple-agents, routing, warehouse automation, scheduling

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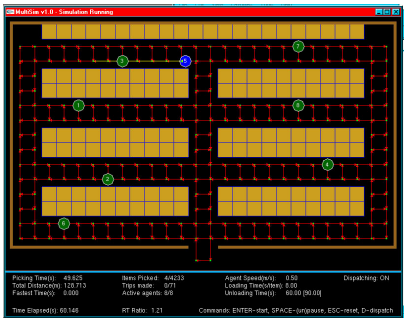

Fig. 2 Simulation software for the warehouse picking problem

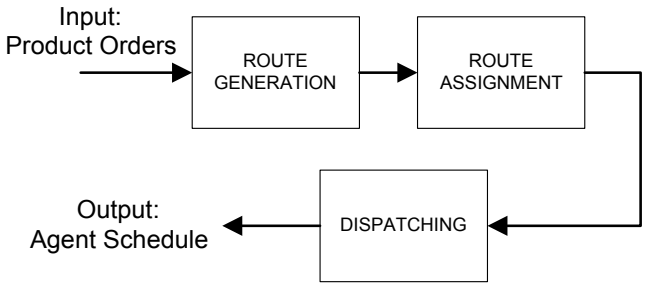

Fig. 1 Multistage solution to the picking problem

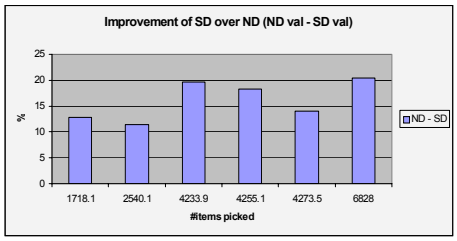

Fig. 3 Improvements gained from the dispatching procedure

A Study on Immersive Hand Manipulation for VR Systems

(Prof. J. Ota and Dr. N. Miyata@AIST)

In large item small scale production, the following two points are very important: (1) product design generating customer satisfaction, (2) shortening product design cycle. Designing products based on the shapes of user's bodies leads to satisfy customers with good usability of product. But it is difficult for designers to do this because the body shape of a designer differs from users. On the other hand, initial evaluation tools of software simulation are useful to reduce the number of mockups of product, and to shorten design cycle. However, these tools for hand manipulation are almost never available, instead of the fact that most of the products are operated directly by human hand. And a designer can't improve product design viscerally without the mockup. This is a trade-off problem of with/without mockups.

Therefore, we are collaborating with Digital Human Research Center of AIST on developing the VR system by witch a designer can evaluate virtual products with experiencing various hand shapes (Fig. 1), and finding out the condition necessary for the system. We are approaching this issue on a condition of sensory stimuli with rich reality as usual because there is a relationship of chicken & egg problem between developing the system and finding the condition.

The experience of hand is confirmed in terms of analogous hand shape as a special case of various hand shapes by using the optical equipment shown in Fig. 2. We investigate the effect of delayed vision on the experience of hand which is inevitable in VR systems by using camera-display system (Fig. 3,4), and it is clear that visual delay up to about 150[ms] is allowable.

Keywords: Various Shapes of Hands, VR System, Product Design, Initial Evaluation

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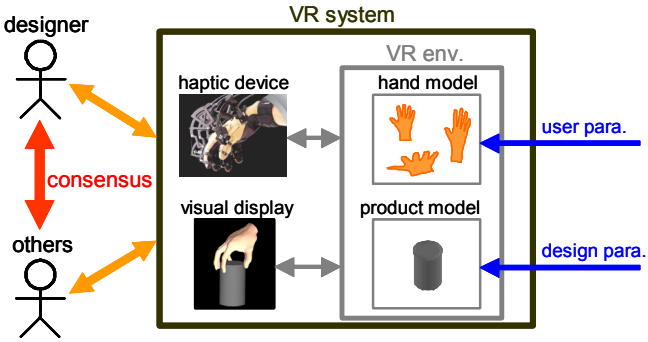

Fig. 1 Overview of Immersive Hand Manipulation System

Fig. 2 Wearable Optical Equipment

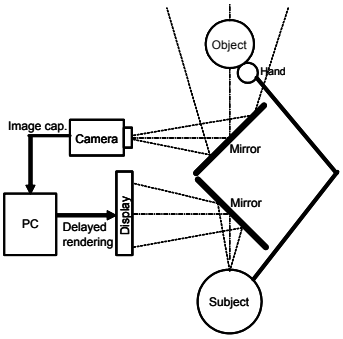

Fig. 3 Concept of Delayed Vision System

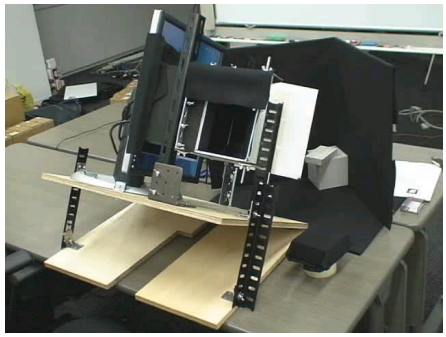

Fig. 4 Implementation of Delayed Vision System

Strategy to operate Cylindrical Interface

- Operation difference according to the size of the cylinder and that of the hand -

(Prof. J. Ota and Dr. N. Miyata@DHRC,AIST)

Various types of switches or levers (interfaces) are available to realize the same function such as switching the discrete status or adjusting continuous value. When people are in a hurry, they are apt to operate the given shape of interface as induced by the interface itself. Therefore the control failure occurs if the interface requires different operation from what it induces people to do, which results in serious accident. From the viewpoint of avoiding control failure based on such inconsistency, it is important to estimate human's intuitive operation of the given interface in the stage of design.

As a first step of the research, we observed how people operate different cylinders with various height and diameter (size) when they assume them as an interface "to switch discrete two statuses" or "to adjust continuous quantity." The operation difference boundaries were examined with respect to the cylinder size change and the hand characteristics in size. Five kinds of operations were observed; pushing, rotating, sliding, tilting, and pulling. (Fig.1) The boundary between the tilting operation and others was found to be related to an aspect ratio, the proportion of the diameter to the height. (Fig.2) Also the direction to approach cylinders was found to change from top to side according to the height increase and the boundary height of operation change was related to the palm width. (Fig.3)

Keywords: Human-Interface, Affordance, Ergonomics, Design

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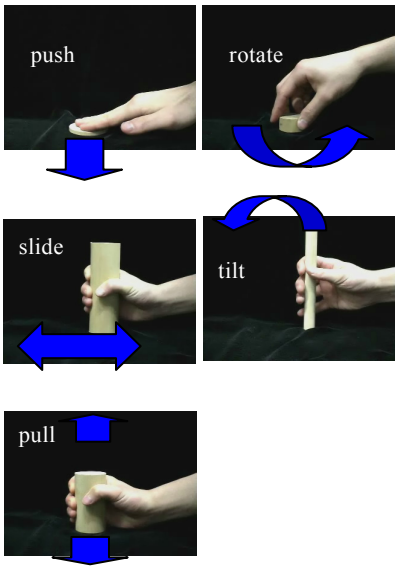

Fig.1 Various Ways to Operate Cylinder-Shaped Interface

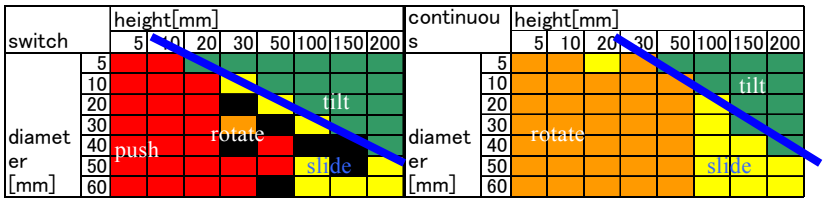

Fig.2 Boundary of the “Tilt” Operation from Others

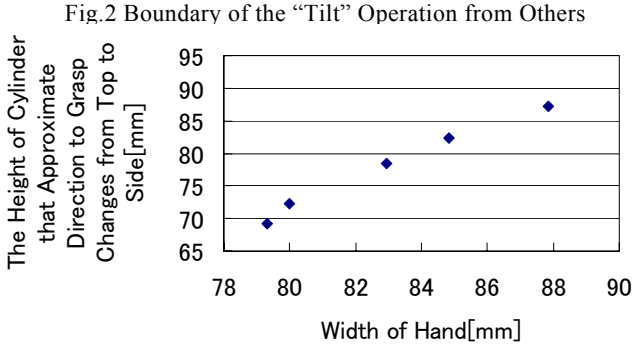

Fig.3 The Height of Cylinder that Approximate Direction to Grasp Changes from Top to Side according to the Hand Width