Introduction to Intelligent Systems Division (ARAI Lab., YOKOI Lab., OTA Lab.) 2005

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ARAI – YOKOI – OTA LAB

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)

- Development of Artificial Intelligence for Legged Robots on RoboCup Environment (Prof. T. Arai and Mr. R. Ueda)
- Real Time Behavior with State-Action Map (Prof. T. Arai and Mr. R. Ueda)
- Self-Localization with Panoramic Image (Prof. T. Arai and Prof. E. Pagello (The Univ. of Padua))
- Design of Force Control Parameters for Cycle Time Reduction (Prof. T. Arai and Lecturer Y. Maeda (Yokohama National Univ.))
- Analysis of Complex Assembly with Dynamic Simulator (Prof. T. Arai)
- Motion Planning of Multiple Robots Considering Robot Fatigue (Prof. T. Arai)
- Analysis and Planning of Graspless Manipulation (Prof. T. Arai and Lecturer Y. Maeda (Yokohama National Univ.))
- Service Engineering and Design Support System for High Creativity (Prof. T. Arai and Prof. Y. Shimomura (Tokyo Metropolitan Univ.))
- Service CAD System (Prof. T. Arai and Prof. Y. Shimomura (Tokyo Metropolitan Univ.))
- Service Model using Petri Nets (Prof. T. Arai, Prof. G. Tian (Visiting Prof. from Shandong Univ.) and Prof. Y. Shimomura (Tokyo Metropolitan Univ.))

Research Projects in Lab. for Developmental Cognitive Machines

(mainly supervised by Prof. H. Yokoi)

- Mutual Adaptation among Human and Machines (Prof. H. Yokoi and Prof. T. Arai)
- Development of a Multi-DOF High Torque Joints Light Weight Robot Hand (Prof. H. Yokoi and Prof. T. Arai)
- Biofeedback by using Electrical Stimulation (Prof. H. Yokoi and Prof. T. Arai)
- Theoretical Approach in the Development of Multi-Modal Sensory Feedback Controller for the SMA Actuator (Prof. H. Yokoi and Prof. T. Arai)
- Evolutionary Robotics: Co-evolution of Controller and Morphology for Locomotion Functionality (Prof. H. Yokoi and Prof. T. Arai)

ARAI – YOKOI – OTA LAB

Research Projects in Mobile Robotics Lab.

(mainly supervised by Prof. J. Ota)

- Action Acquisition of Multiple Intelligence Agents in Real World (Prof. J. Ota and Prof. T. Arai)
- Attentive Workbench: An Intelligent Production Cell Supporting Human Workers * (Dr. M. Sugi, Prof. J. Ota and Prof. T. Arai)
- User-Adaptive Deskwork Support System (Dr. M. Sugi, Prof. J. Ota and Prof. T. Arai)
- Controlling Large Scale Systems by Reaction-Diffusion Equation on a Graph (Dr. M. Sugi, Prof. J. Ota and Prof. T. Arai)
- Design of Robust Systems using Competitive Co-evolution (Dr. R. Chiba, Prof. J. Ota and Prof. T. Arai)
- Large-Scaled Transportation System Using Heterogeneous Multi-Robot (Prof. J. Ota)
- Development of Design Algorithm for Delivery Center (Prof. J. Ota)
- Scheduling Multiple Agents for Picking Products in a Warehouse (Prof. J. Ota)
- Digital Hand – Identification of Position and Orientation of Hand Bones from MRI Images – (Prof. J. Ota and Dr. N. Miyata (AIST))

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ARAI – YOKOI – OTA LAB

Development of Artificial Intelligence for Legged Robots on RoboCup Environment

(Prof. T. Arai and R. Ueda)

RoboCup (robot soccer world cup) is nowadays an important standard problem for development of artificial intelligences that act in this actual environment. Team ARAIBO, the united team of Univ. of Tokyo and Chuo Univ., has participated RoboCup four legged robot league since 1999. This robot uses quadruped pet robots ERS-7 made by SONY. Team ARAIBO has achieved 2nd and 3rd prizes on the technical challenge that is held with soccer games.

We have handled some kinds of elemental research that enables robots to work in the real world: motion planning with dynamic programming, vector quantization of the result of dynamic programming, modification of particle filters for noisy sensor readings, and real-time Qmdp value method for decision making under uncertainty of sensor readings. Moreover, we have developed software for adjustment of color recognition, auto-generation algorithms of gates, and a simulator that can simulate the characteristics (noise, blur, and so on) of color cameras.

Our current interest is to make ERS-7s be home use with the results on RoboCup.

Keywords: RoboCup, Pet Robots, Dynamic Programming, Vector Quantization, Particle Filters

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1) Kazunori ASANUMA, Kazunori UMEDA, Ryuichi UEDA and Tamio ARAI: "Development of a Simulator of Environment and Measurement for Autonomous Mobile Robots Considering Camera Characteristics," RoboCup 2003: Robot Soccer World Cup VII, pp. 446-457, 2004.
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3) Ryuichi UEDA, Tamio ARAI, Kohei SAKAMOTO, Yoshiaki JITSUKAWA, Kazunori UMEDA, Hisashi OSUMI, Toshifumi KIKUCHI and Masaki 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 ERS-7

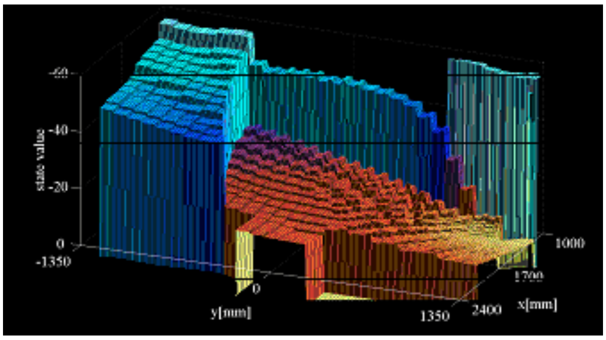

Fig. 2 value function for goalkeeper behavior

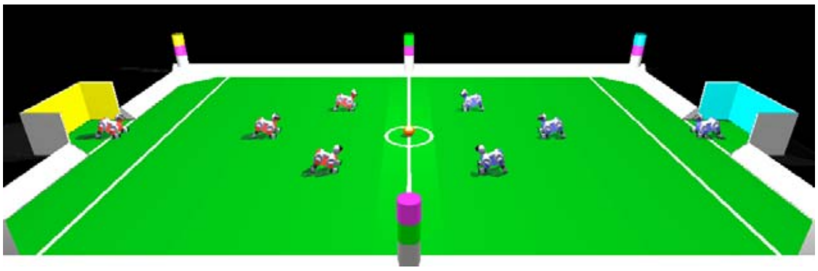

Fig. 3 Soccer Simulator

Real Time Behavior with State-Action Map

(Prof. T. Arai and R. Ueda)

Our purpose of participation in RoboCup (Robot Soccer World cup) is to study image processing, decision making, and the other methods that enable a small quadruped robot, ERS-7, to behave wisely in the constraint of real time computation.

For real-time behavioral decision of robots, we have used a state-action map, which records appropriate behavior for every state of the robot and its surroundings. A robot which is installed a state-action map decides its behavior very quickly by referring to the map.

We have used dynamic programming (DP) for building a state-action map. Fig. 1 shows the behavior of a forward robot, which approaches the ball to become an advantageous position for the shot, with a state-action map.

However, a state-action map is too large to be loaded on the memory of common robots. To solve this problem, we have used vector quantization (VQ) method for compression of the state-action map. Fig. 2 shows an example of State-Action Map (2D Map) compression with VQ. In this example, the original State-Action Map is compressed to about 30% size.

Keywords: Dynamic programming, State-Action Map, Vector Quantization

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2) Ryuichi Ueda, Takeshi Fukase, Yuichi Kobayashi and Tamio Arai: "Vector Quantization for State-Action Map Compression," *Proc. of ICRA2003*, Taipei, Taiwan, 2003.
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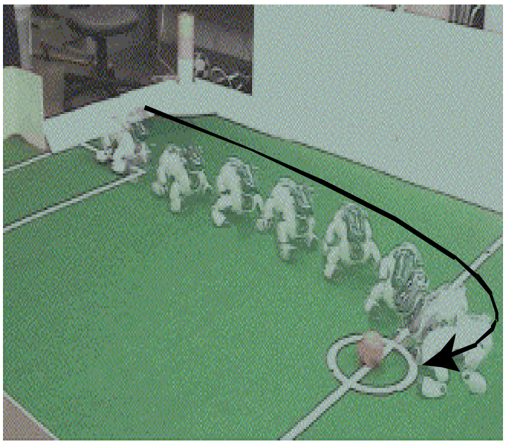

Fig. 1 Behavior of a forward Robot

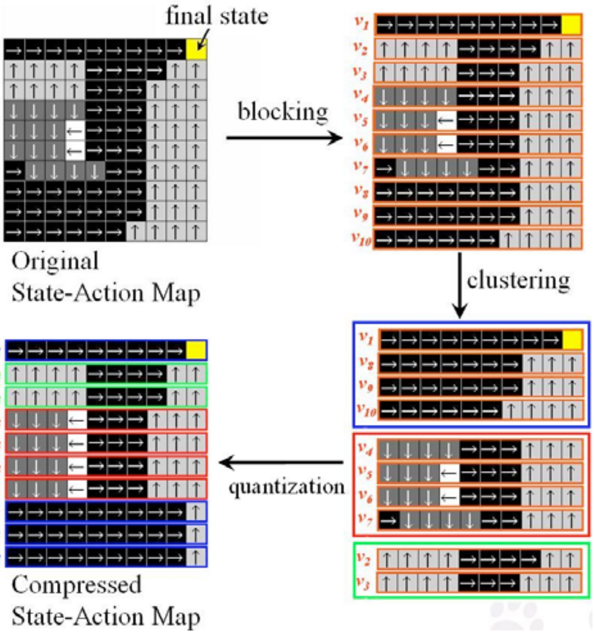

Fig. 2 VQ for State-Action Map(2D) Compression

Self-Localization with Panoramic Image

(Prof. T. Arai and Prof. E. Pagello (The Univ. of Padua))

For the self-localization of a mobile robot, methods which compare an input image with reference images taken beforehand on known positions and estimate robot's position according to the result of the comparison have been proposed. We have developed a method which localizes the position of a robot with a 180 degrees panoramic (semi-omnidirectional) image taken by panning a perspective camera.

The outline of the method is as follows. First, reference images are collected previously on observation points (Fig. 1). On each point, two images of opposite directions are taken. Then, an input image is compared with reference images and the similarities are calculated. The similarities are considered to indicate the probability of the existence of the robot.

This method needs the information of the direction of an input image, but the direction is unknown when self-localization is needed. Therefore we jointly use the Monte Carlo localization method which approximates the probability density function of the robot's position by the distribution of sample particles. This fusion will open a way to practical use.

Keywords: Self-Localization, Panoramic Image, Monte Carlo Localization

References

1) Ryuichi Ueda, Takeshi Fukase, Yuichi Kobayashi, Tamio Arai, Hideo Yuasa, and Jun Ota: "Uniform Monte Carlo Localization - Fast and Robust Self-localization Method for Mobile Robots," *Proc. of ICRA-2002*, pp. 1353-1358, 2002
2) Ryuichi UEDA, Tamio ARAI and Kohei SAKAMOTO, Toshifumi KIKUCHI and Shogo KAMIYA: "Expansion Resetting for Recovery from Fatal Error in Monte Carlo Localization - Comparison with Sensor Resetting Methods," Proc. of IEEE/RSJ IROS 2004, pp. 2481-2486, 2004.

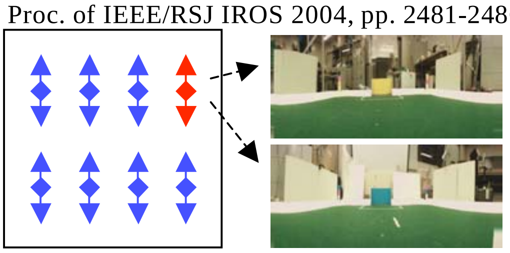

Fig. 1: Reference images

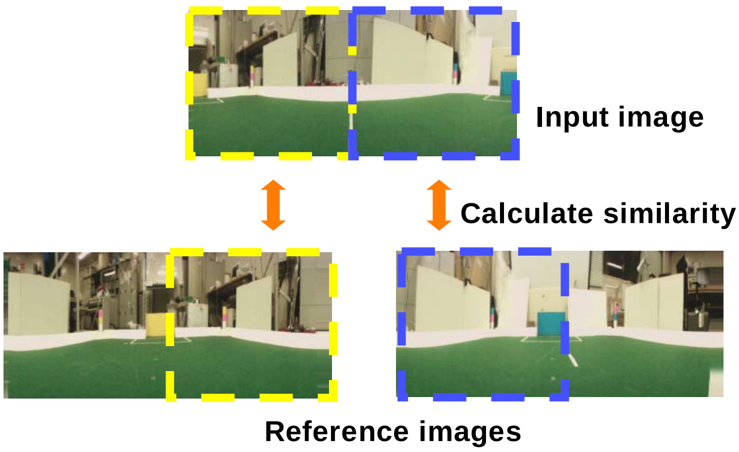

Fig. 2: Calculation of similarity between an input image and reference images

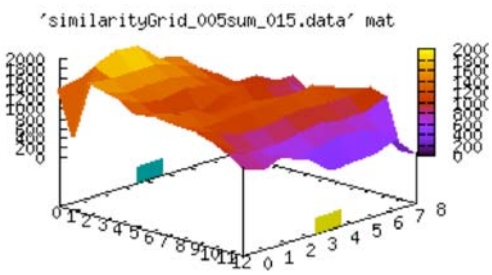

Fig. 3: Calculated similarity for each position

Design of Force Control Parameters for Cycle Time Reduction

(Prof. T. Arai and Lecturer 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.
2) Natsuki Yamanobe, Yusuke Maeda, Tamio Arai, Tetsuaki Kato, Takashi Sato, Kokoro Hatanaka: "Design of Damping Control Parameters for Peg-in-Hole by Industrial Manipulators Considering Cycle Time," IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, 2004.

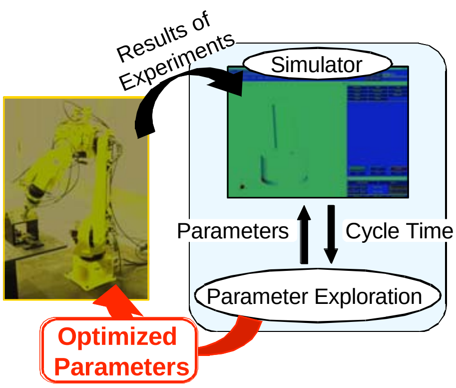

Fig. 1 Schematic View of Designing Force Control Parameters

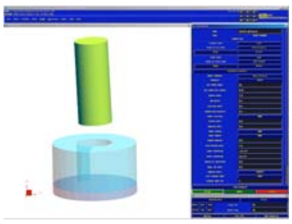

Fig. 2 Simulator for Peg-in-Hole Operations

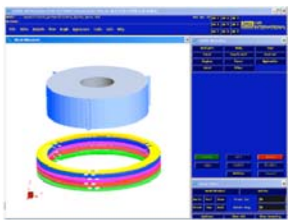

Fig. 3 Simulator for Clutch Assembly

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

1) Hiromitsu FUJII, Natsuki YAMANOBE, Tamio ARAI, Atsushi WATANABE, Tetsuaki KATO, Takashi SATO, and Kokoro HATANAKA: "Construction of Clutch Assembly Simulator and Its Application to Analysis of the Task," The Japan Society for Precision Engineering, Graduation Research Meeting, 2005. (In Japanese)

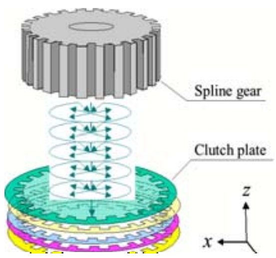

Fig. 1 Clutch Assembly

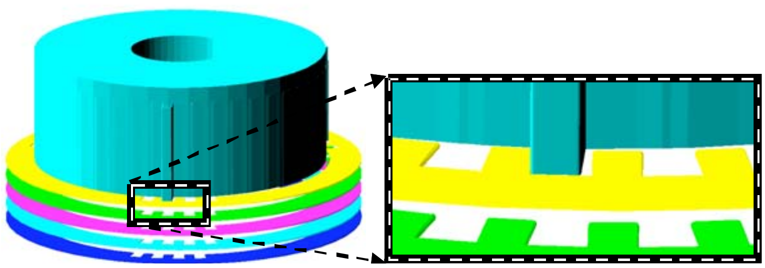

Fig. 2 Simulator of Clutch Assembly

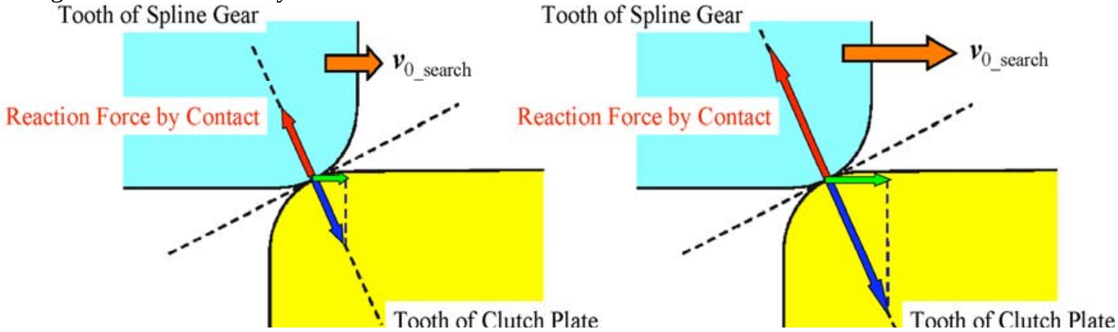

Fig. 3 Analysis of the Operation

Motion Planning of Multiple Robots Considering Robot Fatigue

(Prof. T. Arai)

Recently, robot manipulators used in automated lines at plants are expected to keep working long term. In order to make a stable system with robots, actuator heat must be considered as an important factor. Each actuator gets heat as a robot moves, and because of high-speed and continual motion of the robots, the actuator heat causes line stop eventually. Therefore it is required to optimize robot motions and a task assignment algorithm in order to reduce the torque generated at the actuators and give the robots a rest for radiation.

In this research, we consider a handling system that consists of a conveyor and multiple robots used to pickup parts on the conveyor (Fig. 1) and optimize robot actions in order to control robot fatigue and improve the efficiency of the system. We use a state-action map, which determines a robot action for each state, since the intervals of robot motions are very short. The state-action map can be made beforehand so that robots just refer the map to decide their actions while operating. We generate a state-action map using reinforcement learning in simulation of the handling system. Fig. 2 shows the obtained map. The efficiency of the system was improved with this map.

Keywords: Robot fatigue, State-action map, Reinforcement Learning, Motion Planning

References

1) Koki Kakamu, Natsuki Yamanobe, Tamio Arai, Atsushi Watanabe, Tetsuaki Kato, Koji Nishi: "Task Assignment of High-Speed Handling Operations to Multiple Robots Considering Robot Fatigue," Digital Engineering Workshop, 2005.
2) Koki Kakamu, Natsuki Yamanobe, Tamio Arai, Atsushi Watanabe, Tetsuaki Kato, Koji Nishi: "A State-action Map for Handling Operations with Plural Robots Considering Robots' Fatigue," The 2005 Spring Meeting of The Japan Society for Precision Engineering, 2005. (In Japanese)

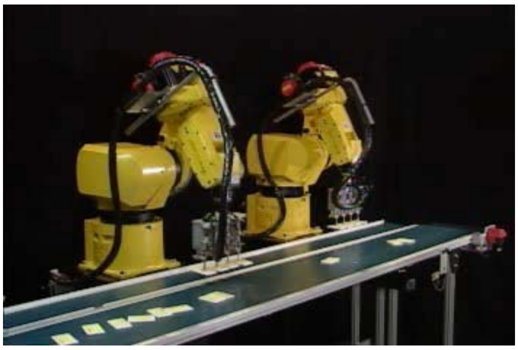

Fig.1 Handling system with multiple robots

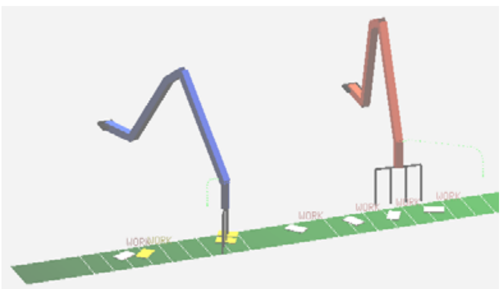

Fig. 2 Simulator of handling system

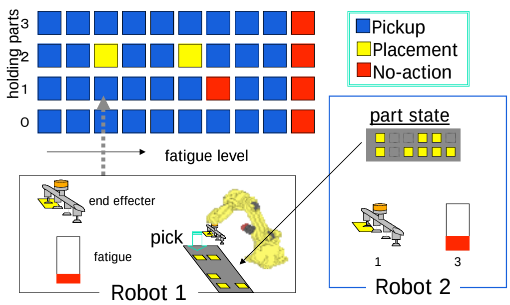

Fig. 3 Obtained state-action map system

Analysis and Planning of Graspless Manipulation

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

Graspless manipulation is to manipulate objects without grasping. That includes pushing, tumbling, pivoting, and so on (Fig. 1). Graspless manipulation enables robots to manipulate objects with smaller load and enhances their dexterity. However, we have difficulties in planning of robot motion for graspless manipulation. In planning of graspless manipulation, we have to consider mechanics in addition to geometry, because motion of the manipulated object depends on mechanical conditions such as friction. Moreover, a robot may be able to push an object but may not be able to pull it because of the unilateral nature of contact forces. The irreversibility of manipulation caused by mechanics makes planning more difficult.

We have developed an algorithm to plan general graspless manipulation by robot fingers and a theory of mechanics required for the manipulation planning. We conducted mechanical analysis on manipulation stability and internal force in graspless manipulation. In consideration of the stability of the manipulation, motions of the fingers including regrasping were obtained as the optimal solution (Fig. 3). By sampling C-Space adaptively, we can shorten the planning times. An example of execution of planned manipulation is shown in Fig. 4.

Keywords: Manipulation Planning, Graspless Manipulation

References

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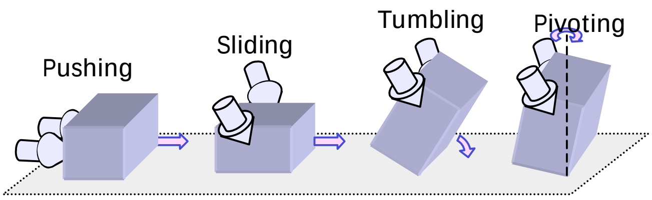

Fig. 1 Graspless Manipulation

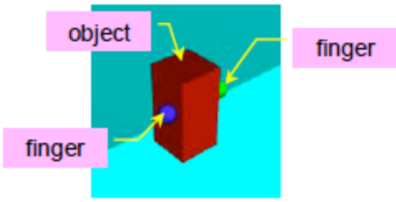

Fig. 2 Model of Graspless Manipulation

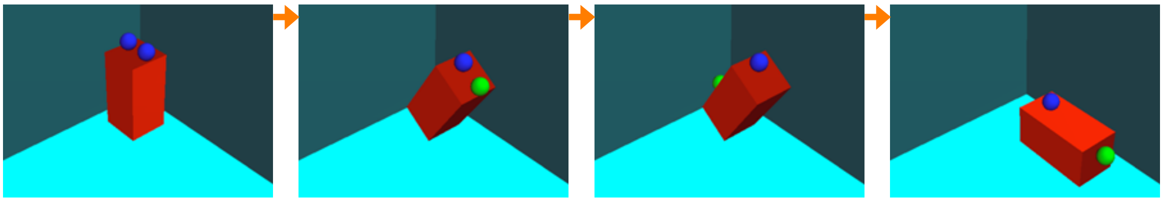

Fig. 3 Planned Tumbling Operation with Regrasping

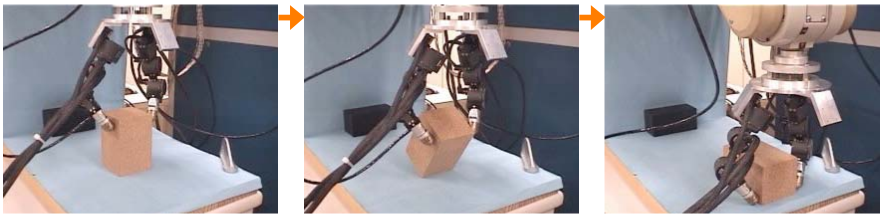

Fig. 4 Execution of Planned Tumbling Operation by Multi-Fingered Hand

Service Engineering and Design Support System for High Creativity

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

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"[1)] 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.

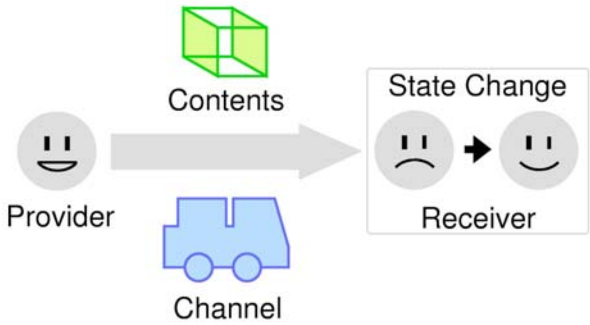

Fig. 1 Definition of a service

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 CAD, Design Methodology, Abduction

References

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Service CAD System

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

In our laboratory, focusing on service as an element that realizes to develop more added-value product, we are carrying out researches of service engineering, which provides engineering methods for service design, development and manufacturing. As an application of service engineering, we aim at developing a service CAD (Computer Aided Design) system (Fig.1)[1], which supports engineers to design services. The prototype system of a service CAD, which is called “Service Explorer,” (Fig.2) has been developed.

By using Service Explorer, a designer can arrange and describe a service by means of the concept of sub models which are called flow, scope and view model [1]. The described service is registered in a service case base. It is expectable that the data is used for information among designers and material for later service design. In addition, by evaluating the service based on QFD (Quality Function Development), the importance of customer’s needs are decomposed to the importance of each component of the service. Mathematical techniques such as AHP (Analytic Hierarchy Process) method and Dematel method are employed in the evaluation. A designer is able to improve the flow and/or realization structure of the service by using the evaluation result.

At a moment, the following researches are studied from the view point of supporting service design.

(1)Develop a framework which enables to obtain knowledge about service design from service case base and to manage them properly.

(2)Propose other evaluation methods that include various mathematical technique in order to support decision making in service design.

(3)Develop a mechanism that gives us new design solutions by applying various reasoning to service cases and/or service design knowledge in the database.

Keywords: Service Engineering, Service Design, Service CAD

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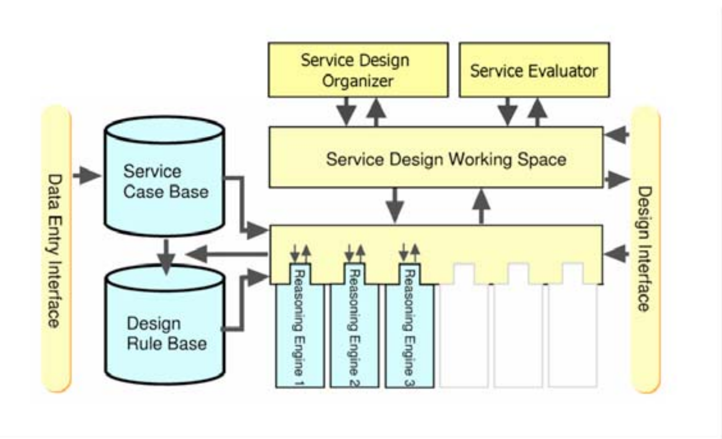

Fig1. A Concept Scheme of Service CAD System

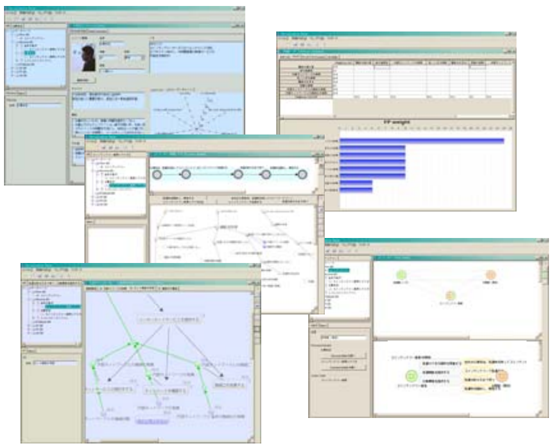

Fig2. Screenshots of Service Explorer

Service Model using Petri Nets

(Prof. T. Arai, Prof. G. Tian (Visiting professor from Shandong Univ.), and Prof. Y Shimomura (Tokyo Metropolitan Univ.))

A novel engineering paradigm called *service engineering* is proposed to change our modern society in order to achieve "appropriate production, appropriate consumption, and least waste" rather than "mass production, mass consumption, and mass waste" [1]. *A service* is defined as *an activity that changes the state of a service receiver.* A service model consists of three sub-models: scope model, view model and flow model [2].

We present a research framework for service engineering based on a kind of high-level Petri Nets—Hierarchical Colored Petri Nets[3]. In this framework, a flow model is presented in top level net so as to describe the structure of a target service as a chain of agents existing in the service (see Fig.1). Then the sub pages corresponding to the substitution transitions of the top level net give the inner structure, which determines the sub services including all agents as receivers (see Fig.2). Thus the sub pages show a scope model. Moreover, there are also substitution transitions in the scope model; the sub pages corresponding to them give the view models expressing the relationships among the RSPs (Receiver State Parameters), CoPs (Content Parameters), and ChPs (Channel Parameters) (see Fig.3).

In this framework, we can represent information of material flow, and deal with RSPs for the complicated service system with hierarchy and modularity method:

- In the top level net, we can give the flow model to describe the whole service structure coarsely and crudely, but in this way we can represent the complicated relationship clearly for a large scale of services.
- In the sub-page of a flow model, we can give the scope model to determine sub service which we are interested in.

It will be very helpful in intensifying, improving, and automating the whole service, including service creation, service delivery, and service consumption.

We illustrate the development procedure by studying some service cases — Restaurant Service, Consumer Electronics Rental Service, the optimizing and scheduling problems of material distributing centre of one of the important parts of the supply chain, using CPN—TOOLS simulation software

Keywords: service engineering, hierarchical colored Petri nets, modeling

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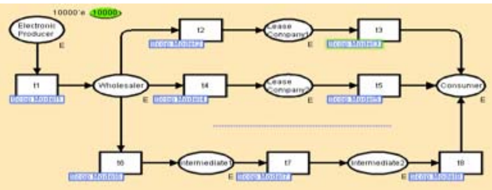

Fig.1 Flow model of Producing-Consuming System

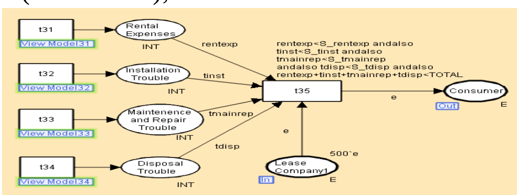

Fig.2 Scope model of Consumer Electronics Rental Service

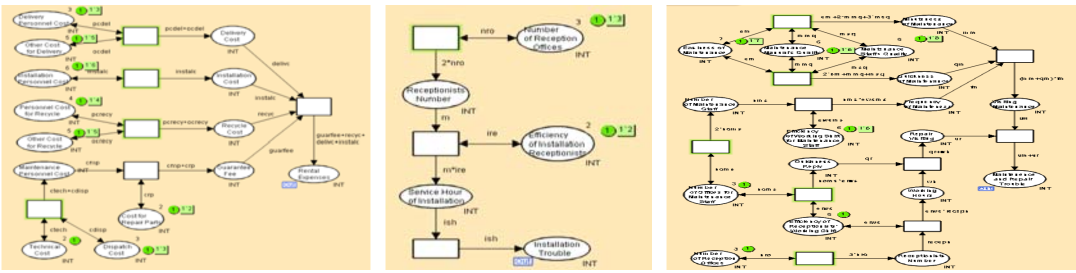
Fig.3 View models of Consumer Electronics Rental Service

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.

Multi-D.O.F. Hand and Adaptable Control for Individual Characteristics: An input for controlled multi-D.O.F. hand is also a mechanomyogram, muscle tension and so on. 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.

Keywords: EMG, Adaptable Control for Individual Characteristics

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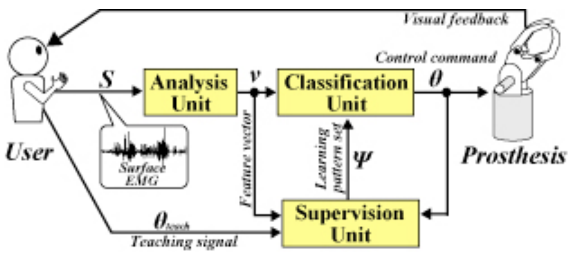

Fig. 1 EMG classification method.

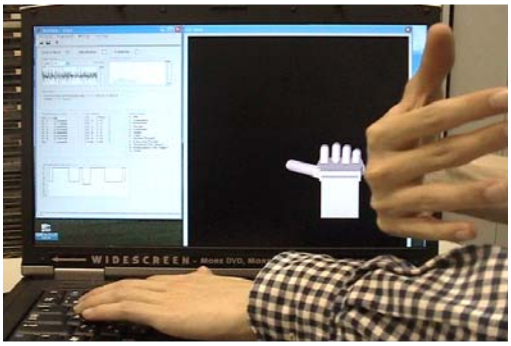

Fig. 2 Inputting instruction signals from the keyboard.

Development of a 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 light weight as well as water proof. The hand uses the interference drive mechanism for a torque adaptive joint at the fingers, which allows us to provide a high grip power with a light structure. The wrist joint uses the parallel wire type interference for a 3DOF joint with high torque.

1. Interference drive type adaptive joint method

Fig. 1 shows the interference drive type adaptive joint. When the wire guide is close to the joint (a), it works as a passive joint transmitting no power. Because the wire route is close to the joint, the moment arm is small allowing for low torque & high speed movements (b). But when the wire guide parts from the joint the momentum arm increases, turning the joint into a high torque & low speed configuration(c).

2. Parallel wire type interference drive joint method

We developed a parallel mechanism that works by making two or more actuators cooperate together transmitting the power with two or more wires to control the object, allowing for high torque equal to the sum of actuators. As a result, we achieve an actuation with 3DOFs with high power transmission in any configuration. The main objective is to design a mechanism with lossless bearing power transmission. Fig. 2 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 3 DOFs high torque joint. Fig. 3 shows the application in our prosthetic hand.

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

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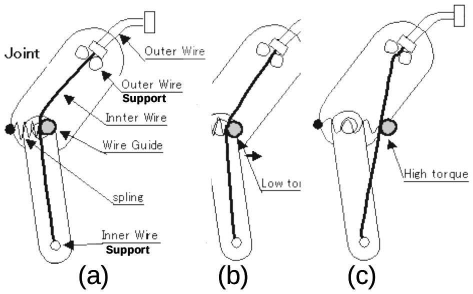

Fig. 1　Adaptive Joint Mechanism.

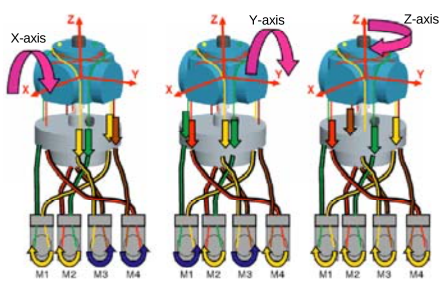

Fig. 2　3 DOF Joint System.

Fig.3 Multi-D.O.F. EMG prosthetic hand

Biofeedback by using Electrical Stimulation

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

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 device.

We believed that 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.

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

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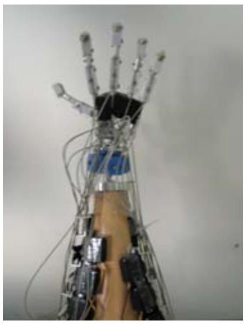

Fig. 1 EMG controlled Prosthetic Hand

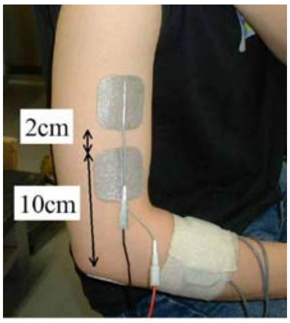

Fig. 2 Electrical Stimulation

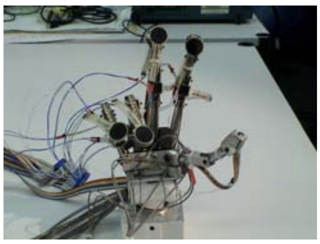

Fig. 3 Pressure Sensors

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

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

1. Introduction The Shape Memory Alloys (SMA) are materials that exhibit the characteristics of the shape memory effect which takes place when it is at low temperature. The SMA mostly remains in the form of the crystalline structure of martensite, which displays an elastic nature. When heated, the crystalline structure transforms to the austenite structure, which is less elastic thus strain induced to the SMA at the lower temperature martensite phase can be recovered in the austenite phase. One major disadvantage of the SMA is its slow response speed in actuation. In this research, we describe the effort taken in quickening the rate of heat dissipation from the SMA wire in an ambient environment together with a fast and optimum heating method for the control of the SMA.

2. Heat sinking in increasing response We propose the application of a simple, new heat sink that consists of a combination of a stainless outer tube together with silicon grease. A heat model was constructed, and the Finite Element Method was used to analyze the dissipation of heat to the environment from the SMA (Fig.1). Experiment results (Fig.2) showed that the proposed heat sink is effective as a heat sink and widens the application of the SMA wires as actuators.

3. Actuation of the prosthetic hand Currently, the SMA incorporated with the outer metal tube is used in the actuation of the prosthetic hand, a project in the research state in our laboratory (Fig.3). SMA is now being used as an alternative approach to using conventional servo-motors in actuating the fingers and wrist of the prosthetic hand, making the usage on a prosthetic easier and lighter.

Keywords: Shape Memory Alloy, heat sink, response, robotic finger actuation

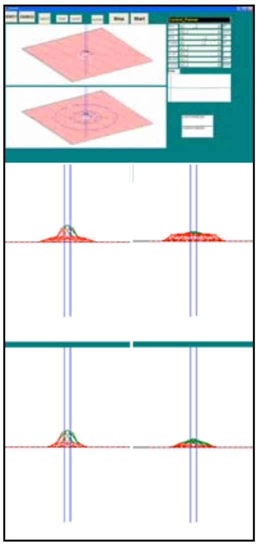

Fig.1 Heat model

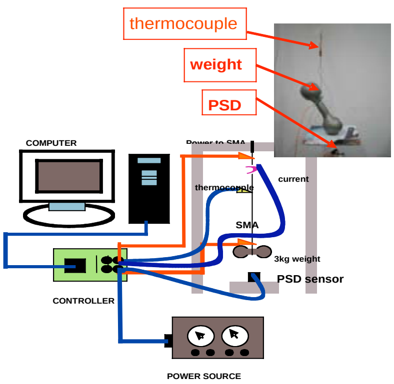

Fig.2 Experiment setting

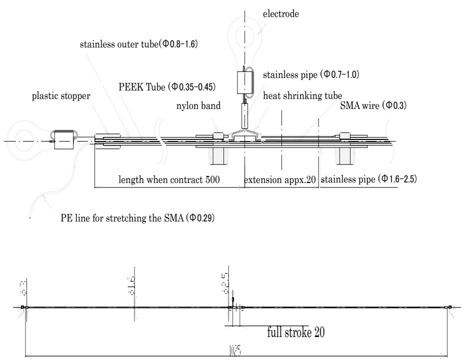

Fig.3 SMA actuator

Evolutionary Robotics: Co-evolution of Controller and Morphology for Locomotion Functionality

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

Evolutionary robotics is a method of auto-design for robot system. This approach imitates the mechanism of biological evolution from an engineering point of view and the main advantage is that the designer does not need to implement the desired behaviors of the robot system because unexpected behaviors can emerge from the interaction between controller, morphology and environment. Therefore, this approach has been applied to designing autonomous robot system. In our research, two evolutionary approaches are conducted to designing and investigating locomotors in both virtual world and real world: (a) controller and morphology of robots are co-evolved with genetic algorithm to achieve forward locomotion in three-dimensional simulation. With the results, “effective dimensions” are discussed in point of “locomotion functionality” (Fig.1); (b) some “morphological parameters” of a biped robot with minimum controller are evolved in three-dimensional simulation. As the results, the robot acquires pseudo-passive dynamic walking, which exploits it own dynamics. Moreover, the real robot “bendy” is built with the results and examined the characteristic of its walking. As the result, it has shown stable walking and indicated the possibility that morphology reduces computation resources of its controller (Fig.2).

Keywords: Evolutionary robotics, Genetic Algorithm, Morphology, Locomotion

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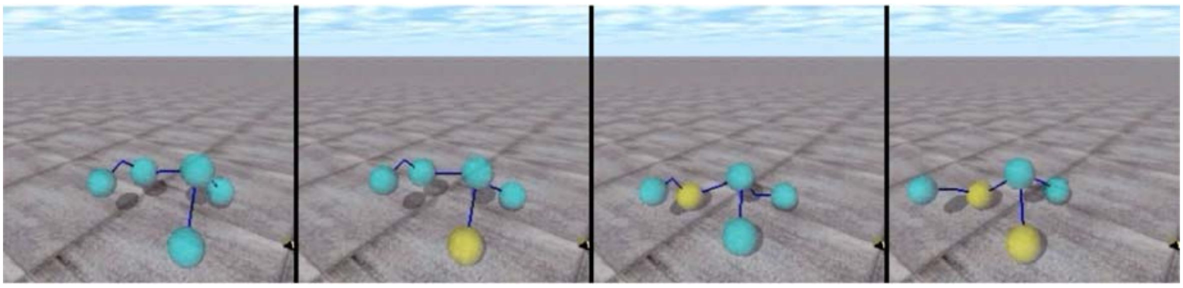

Fig. 1 Co-evolution of morphology and controller

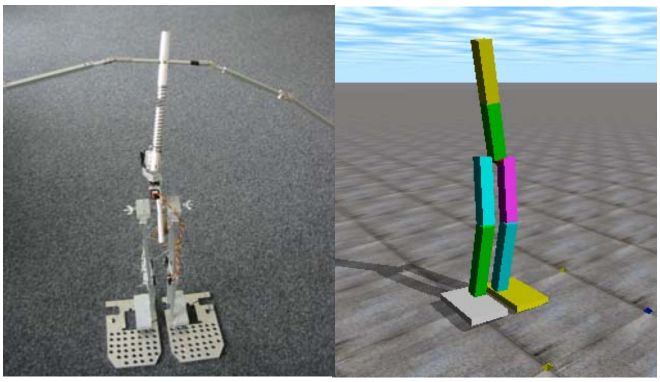

Fig. 2 Pseudo-Passive Dynamic Walker

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Action Acquisition of Multiple Intelligence Agents in Real World

(Prof. J. Ota and Prof. T. Arai)

In this research, the actions of our agents are to be generated by the interaction between the agents themselves and the world. In the situations that the agents to accomplish tasks without control of human operator, the agents must be able to interact with the outside world and acquire the proper actions to accomplish tasks. Our intelligence agents are designed to be able to use only little local sensor information in which to make the decisions to act. As shown in Fig.1, our agents interact with the world through their sensors. The simulation shows that our agents can achieve their goal without collision.

In Fig.2 shows the actual mobile agents avoid collision in the experiment. From the experiment, we can prove the robustness of our method. The autonomous navigation as in our research has several applications, such as security patrol or floor cleaning. The autonomous navigation is also known to be fundamental function needed to realize mobile robot system in real world.

Keywords: Multiple Mobile Robots, Exploration, and Navigation

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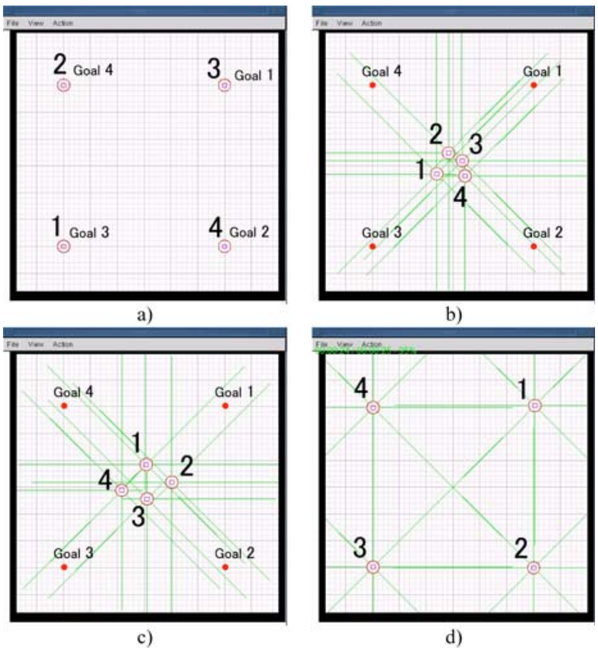

Fig. 1 Simulation of Distributed Mobile Robots Navigation

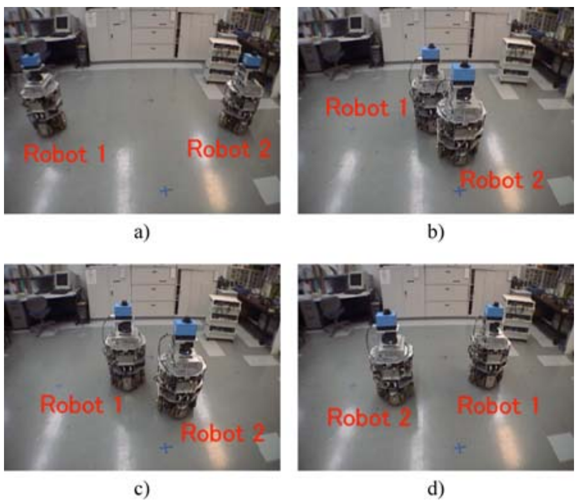

Fig.2 Experiment of 2 Mobile Robots

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), Augmented Reality

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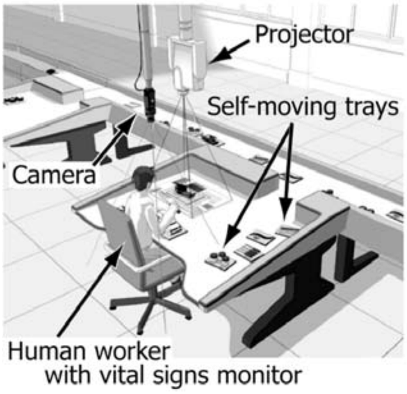

Fig. 1 Overview of Attentive Workbench

Fig. 2 Prototype Model

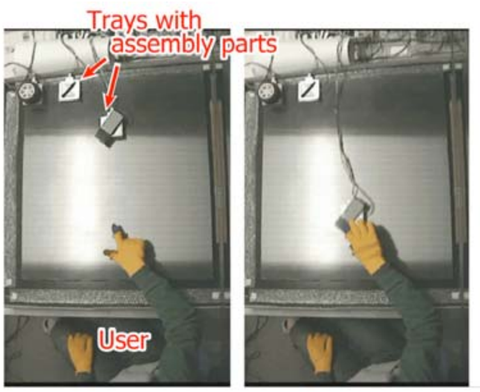

Fig. 3 Assembly Support by Trays

User-Adaptive Deskwork Support System

(Dr. M. Sugi, Prof. J. OTA, and Prof. T. ARAI)

In our daily life, people spend a great deal of time at a desk. It is therefore especially important to support deskwork by intelligent systems. We have proposed "Attentive Workbench (AWB)," a deskwork support system that helps a user from both physical and informational viewpoint.

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

In this study, we adopt following 3 approaches: (1) To improve the accuracy of recognition of the direction of pointing by estimating the user's subjective pointing direction from little information (Fig.2). (2) To decrease the influence of the error of pointing gesture by integrating the spatial information from sensors with the temporal information from the user's action sequences based on the dynamic Bayesian network. (3) To reduce the load on the estimation by arranging the self-moving trays according to the user's action sequences and pointing property.

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, Dynamic Bayesian Network

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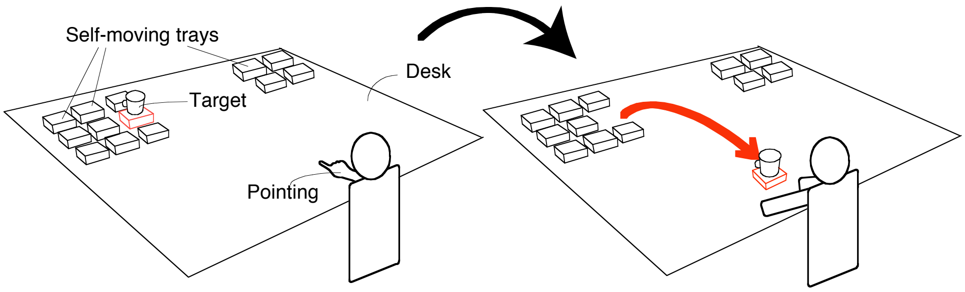

Fig.1 Overview of deskwork support with self-moving trays

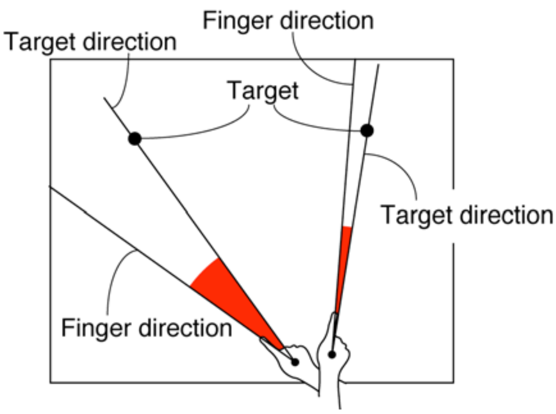

Fig.2 Relation between target direction and finger direction

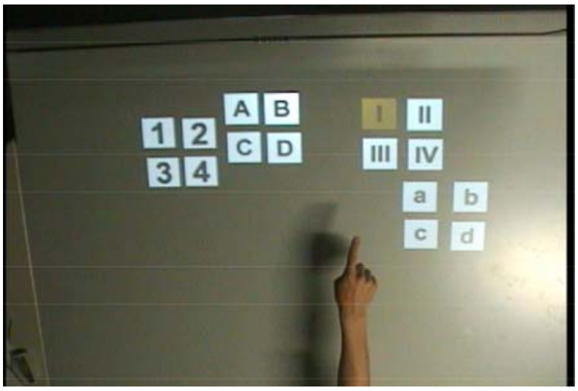

Fig.3 Target estimation based on pointing gesture

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Controlling Large Scale Systems by Reaction-Diffusion Equation on a Graph

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

Yuasa proposes a method for modeling autonomous decentralized systems by reaction-diffusion equation on a graph. The whole system is represented as a graph, with each autonomous agent and the interaction between two agents corresponding to a vertex and an edge, respectively. The objective of the whole system is given as a potential function on a graph, and the behavior of each agent is governed by a gradient system of the potential. Having high generality, this model can be applicable to various research fields concerned with large scale systems. Currently we are studying the following two applications.

Controlling traffic signal network: The control of traffic signals has been researched as one of the countermeasures to improve traffic conditions. We have proposed a new method for controlling a large number of traffic signals in a decentralized manner. Traffic signals forming a network are modeled as a nonlinear coupled oscillator system. The behavior of each oscillator is governed by a reaction-diffusion equation on a graph. Each signal determines its parameters (i.e. split, offset, and cycle length) from its local traffic conditions. Simulation results have shown high stability in a stationary environments and a high adaptability in dynamic environments.

Job shop scheduling problem: We deal with a large scale job shop scheduling problem with various disturbances (e.g. addition or removal of jobs, delay of processing time, etc.) and practical constraints (e.g. release time constraints, setup time constraints, etc.) taken into account. Operations are regarded as autonomous agents, and the constraints are represented as potential functions. A feasible schedule is obtained by the dynamics of the gradient system along the potential functions. Combining the present method with the schedule improvement based on the permutation of operations, we aim to obtain a good feasible solution in a short time.

Keywords: Reaction-Diffusion Equation on a Graph, Traffic Signal Control, Job-Shop Scheduling

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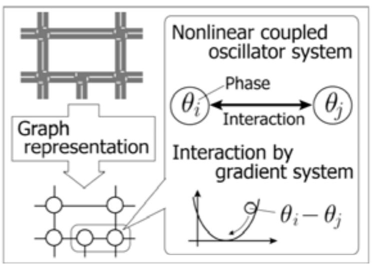

Fig. 1 Overview of Traffic Signal Control

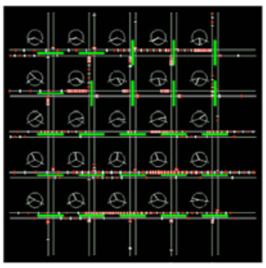

Fig. 2 Traffic Simulation

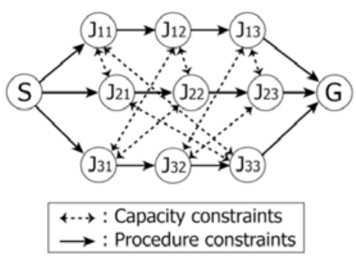

Fig. 3 Sample of Constraints with 3-job 3-machine problem

ARAI – YOKOI – OTA LAB

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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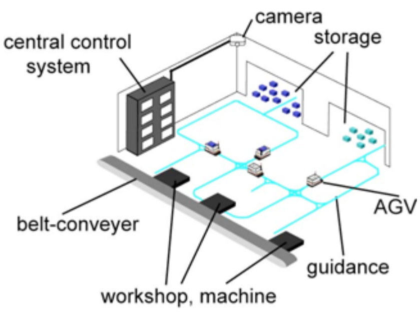

Fig. 1 AGV Transportation Systems

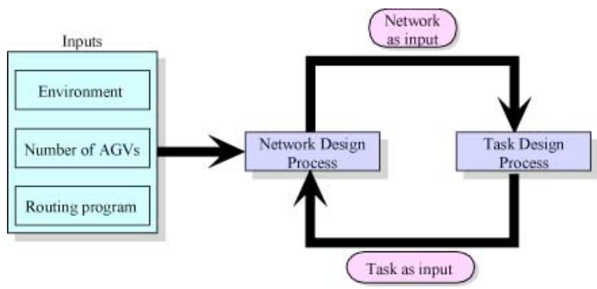

Fig. 2 Design Process with Co-evolution

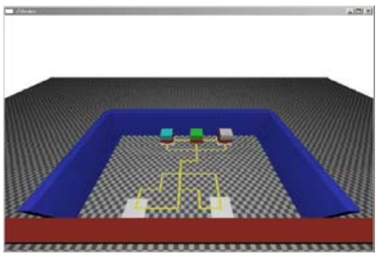

Fig. 3 Simulation for AGV Systems Design

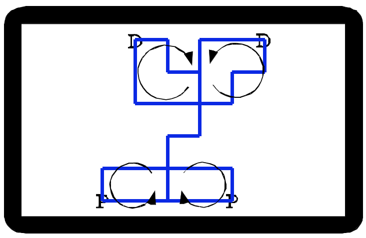

Fig. 4 Designed Network and AGV behiviors

Large-Scaled Transportation System Using Heterogeneous Multi-Robot

(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 the automated guided vehicle (AGV) transportation system in an automated container terminal (ACT) as shown 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 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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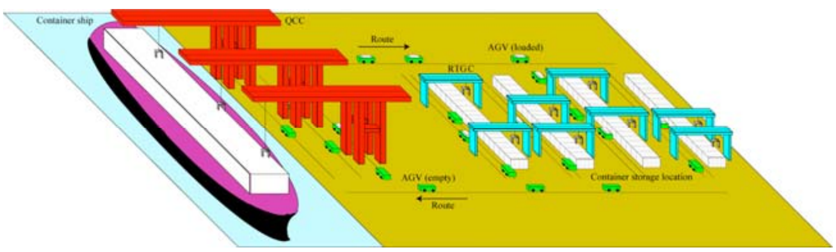

Fig. 1 The Horizontal AGV Transportation System in Automated Container Terminal

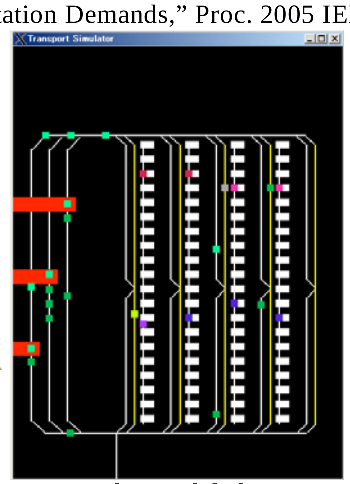

Fig. 2 The Modeled AGV Transportation System

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.

Flow in the delivery center is shown in Fig.1: (1) the pallets of the products from factories enter in the automatic warehouse. (2) Depalletizers and/or robots divide the pallets into the cases. (3) The cases temporally enter in the automatic warehouses for cases, and (4) the demanded number of cases are delivered outside of the center. We propose three time-constant flow models as shown in Fig.2 to Fig.4. Here, the products are divided into rank A and rank B products from the viewpoint of the amount of the delivered products. Flow of the rank A products is again divided into two based on the time slots of transportation: flows during the order and the delivery completion (Fig.2), and those during the delivery completion and the next order (Fig.3).The flows for the rank B products are shown in Fig.4. The design problem is solved by integrating the three flow models, and by solving it as mixed integer programming problem. The algorithm is implemented for an Intel Pentium M 900 computer. The effectiveness of the proposed algorithm is shown by using real transport data. Calculation costs are only about 5 minutes for about 50 various lead time inputs.

Keywords: Warehouse management, Material flow, Logistics

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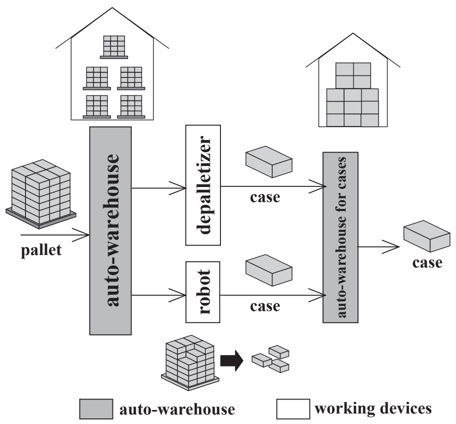

Fig. 1 material flow in the delivery center

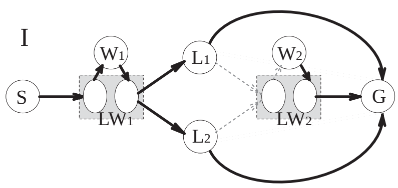

Fig. 2 flow model for rank A product (Order - Delibery)

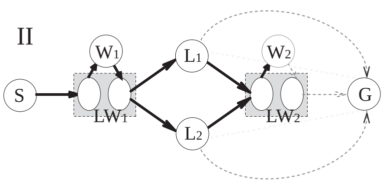

Fig.3 flow model for rank A product (Delibery - Next order)

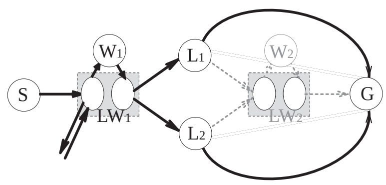

Fig. 4 flow model for rank B product

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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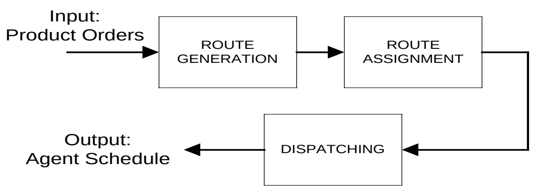

Fig. 1 Multistage solution to the picking problem

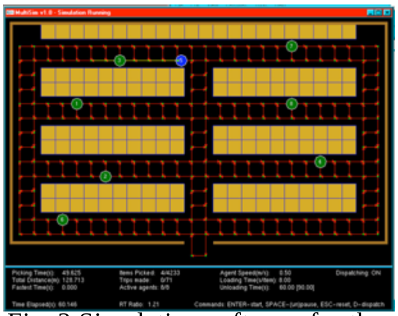

Fig. 2 Simulation software for the warehouse picking problem

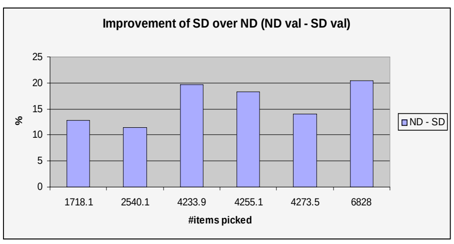

Fig. 3 Improvements gained from the dispatching procedure

Digital Hand
–Identification of Position and Orientation of Hand Bones from MR Images-

(Prof. J. OTA and Dr. N. MIYATA (DHRC, AIST))

Recently, a computer manikin, which is a tool to assist designing human-friendly products, has been attracting increasing attention. It is a CAD system with human models and can evaluate products by virtual users. However, current computer manikins do not have adequately precise hand model, instead of the fact that most of the products are operated directly by human hand.

Therefore, we are collaborating with Digital Human Research Center of AIST on developing the technologies for a hand-specific computer manikin, Digital Hand (Fig. 1). In order to capture and model human hand motion accurately, the more detailed and accurate link structure (i.e. the centers and rotation axes of joints) needs to be modeled. The hand link structure is derived from relative movement of bones, measured in 3D medical images (MRI), between different poses of a hand. So we are developing a method to derive the precise position and orientation of each bone from MR images of multiple poses of the same subject.

We use MRI instead of CT, because it is preferable to avoid unnecessary risk of radiation exposure. However, in MR images, the contour of the bone region is obscure. So manual segmentation, which is a time consuming task, is unavoidable, because automatic segmentation using simple method such as thresholding cannot be used. Therefore we have proposed the model-matching method as follows, and succeeded in getting the valid position and orientation of a bone in a short time compared with processing all the data manually. (1)Bone surface polygon is generated as a bone model by manually extracting the bone region from one of the MR scanning data. (2)Initial configuration of the bone model is settled manually in MR volume data of different poses (Fig. 2). (3)The bone model is aligned in MR volume data to maximize the performance index that sums the brightness inside the bone model.

Keywords: Human, Modeling, Computer Manikin, Hand Bones, Registration, Medical Imaging

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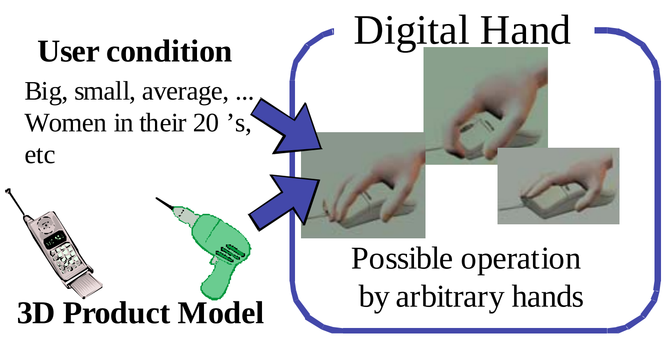

Fig.1 Outline of Digital Hand

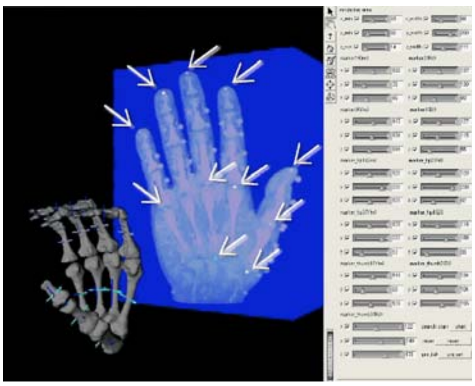

Fig. 2 Initial Configuration Settlement