**News**

# Micro System Control Laboratory in Nagoya University*

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## 1. Introduction

NAGOYA is known as the center of automobile, machine and aerospace industries in Japan and has many electro-mechanical industries such as Mitsubishi, Toyota and their allied companies. The Laboratory of Micro System Control belongs to the Department of Micro System Engineering and Mechano-Informatics and Systems, Nagoya University, and was established in 1989. Our laboratory currently has five faculty staffs, one engineer, four visiting researchers, thirteen Ph.D. course students, eighteen master course students, twelve undergraduate students, and visiting research fellows from industries (see **Fig. 1**). The main characteristic of this laboratory is to have strong collaboration with industries and other research institutes. We are also involved in many national large-scale projects, such as Micro-machine Technology, IMS (Intelligent Manufacturing System) and New Energy and Technology Development Organization (NEDO) of MITI.

## 2. Major Research Topics

The followings are the major research topics in our laboratory.

### 2.1 Cellular robotic system

Cellular robotic system (CEBOT) is an abbreviation of Cellular Robotic System that is a self-organizing robotic system proposed by myself. The CEBOT consists of many robotic units with a simple function, named cell (see **Fig. 2**). The CEBOT can reconfigure the whole system depending on given tasks and environments and organize collective or swarm intelligence. The concept of the CEBOT is based on biological organization constructed by enormous natural cells. Several prototypes of the CEBOT have been developed and demonstrated under this project. This research project includes the development of a new CEBOT system and several issues related to mutual communication between cells, the optimum dynamic knowledge allocation among cells, the reconfiguration strategy of the system and the artificial-life such as the cooperative behavior modeling of ants. This invokes many interesting research problems, such as dynamic decentralized planning, dynamic distribution and coordinated control system as well as hard ware systems. Many applications are under considerations: space, agricultural, medical, and construction applications, including the distributed inspection, monitoring, and surveillance system.



**Fig. 1** Professor Fukuda (fourth from the left in the forefront sequence) and his staffs



**Fig. 2** CEBOT

### 2.2 Microrobotic system and micromechatronics

This topic includes the analysis, the development and the control of microactuators, micro mobile robotic system and micromanipulators. Micro mobile robotics systems in a small pipe and micromanipulators with multi-degrees of freedom have been developed in this laboratory. We have joined the member of the advanced research center, which is one of the facilities of Nagoya University and has three clean rooms and microfabrication facilities of silicon, such as a Chemical Vapor Deposition Machine and Reactive Ion Etching Machine. They are now available for the development of micromachine and microrobotic systems. Our laboratory organizes the International Symposium on Micromechatronics and Human Science regularly every year with the support by the city of Nagoya and other organizations. Micro Line Trace Robot and programmable Micro

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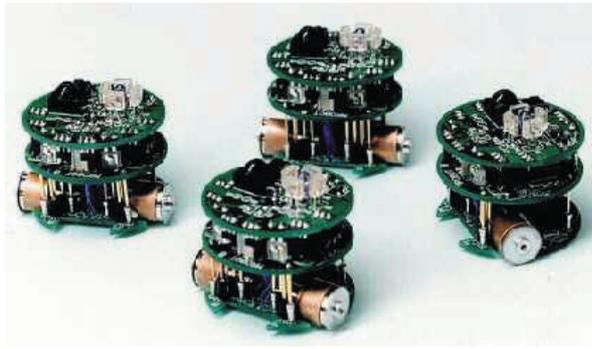
**Fig. 3**   MARS

Autonomous robotic System (MARS) is also produced (see **Fig. 3**).

### 2.3  Bio-micro manipulation system

This project aims at developing the manipulation system of micro objects such as the biological cell with directly contact manipulation and non-contact manipulation. The biological cell is so small and flexible that it is difficult to handle by manipulator with fingers directly. Therefore, non-contact manipulation with optical power and field power such as electrostatic field is considered to be effective to handle it. This project approaches to achieve the three dimensional manipulation system by the constructing the micromanipulator using optical and electric field power and operating system using virtual reality technology.

### 2.4  Telesurgery system for intravascular neurosurgery

Goal of this project is to develop a medical assistance system which supports doctor's operation and decision making while a medical treatment. Our target field is the intravascular neurosurgery using a catheter that is a thin tube made of soft plastic. This softness of the catheter disturbs operator's appropriate maneuvering and this causes fatigue of patients and doctors and elongating of the operation time. Therefore, a novel medical assistance system is needed.

Our approach is; first: developing new surgical devices using micro technologies and installing these devices in the intravascular surgical tools. We have developed a small force sensor (see **Fig. 4**) that is installed in the tip of catheter. The diameter is 1.2 mm and the length is 5 mm. This small force sensor measures the contact force between the catheter and blood vessels. This information is an alternative tactile sensation that doctors had never felt. Second: integrating these micro devices into teleoperation system appropriately. Third: developing new control strategies that enable doctors to operate intravascular surgical tools easily. The new sensation is useful when the teleoperation system displays that information appropriately to the operator. So a new control strategy is needed.

### 2.5  Machine learning of intelligent robotic system

The adaptability to various environments of humans and animals by themselves is far more superior to robots developed up to now. In order for the future robots to play an active part in our life space like living creatures, it is desir-
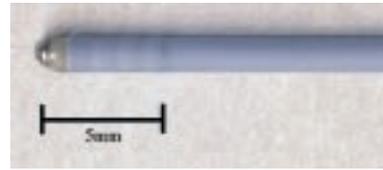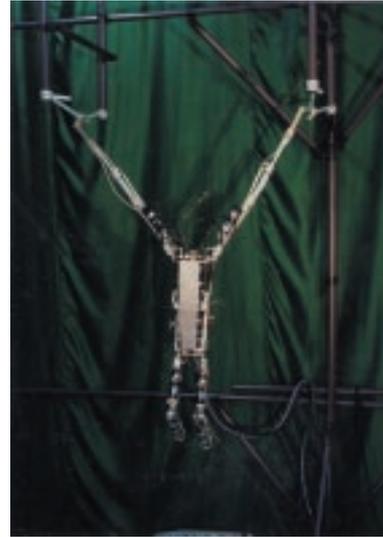


**Fig. 4**   Micro force sensor



**Fig. 5**   13-link brachiation robot

able that they could realize better performance than preprogrammed movements and work in more various environments than in preprogrammed ones. In this research, control architecture for robot motion learning is studied and applied to a brachiation robot (see **Fig. 5**), which moves like a gibbon from branch to branch by its arms, both in simulations and experiments.

### 2.6  Intelligent human machine interface considering interactive adaptation

This project proposes Interactive Adaptation Interface to an operation system of rough terrain crane. The system assists human operation with various types of operational assistance information based on sensor's output and an automatic control theory. The VR technology enables the system to express more effective and easier to understand with visual display, tactile display, auditory display, etc. The system has a function that infers human's states (e.g. operational skill level) with Recursive Fuzzy Inference. To apply this function, we focus on tactile display because the system can change the strength of operational assistance. We made a VR crane simulator, which includes the proposed operational assistance system. Operational experiments were performed to confirm the effect of the proposed system. The aim of the experiments is to suppress payload's swing with 2 DOF joystick. The joystick has tactile display devices in its grip. Subjects control the joystick to suppress payload's swing with referring tactile display which shows proper control method. The results clearly show the effect of the proposed operational assistance system.

**Fig. 6** Four-fingered robot hand

## 2.7 Intelligent control by soft computing

A baby learns various basic behaviors: walk, catch, and throw, by his own evaluation and some visual information after many trials. After that, a child learn more complex behaviors in less iterations by connecting objective behavior with some fundamental behavior learned in past experiences. After much experience, human can learn more complicate behaviors based on them. Using this procedure, a robot can gradually get more complicate behaviors after some steps, unless designer needs making huge programs and adjusting its parameters. In this research, behavior acquisition and behavior coordination algorithm is studied. About behavior acquisition, we use genetic algorithm, evolutionary programming, and reinforcement learning. About behavior coordination, we proposed hierarchical behavior-based architecture, which enable for a robot (see **Fig. 6**) to perform some complex behavior coordinating the obtained fundamental behaviors.

## 2.8 6-leg omnidirectional walking robot with manipulator

This walking robot consists of 6 legs and it can walk on rough terrain. There are great demands for omnidirectional walking robot, which can be applied into the any environments. This system will be used in many fields such as construction sites, civil engineering sites and for planet exploring. The present project is the task scheduling by the Hierarchically Structural Robotic System with walking mechanism and manipulator.

## 2.9 Image processing using KANSEI engineering

Human being often judges based on KANSEI of himself. This research aims at analysis of mechanism of decision making based on KANSEI and realization of KANSEI model using self-tuning fuzzy inference.

## 2.10 Emotional Robotic System

Human being changes his motion and performance according to his decision making and emotion. Robotic System changes its strategy based on the algorithms programmed by operator. Besides, the robotic system has to adapt itself into the variable environments since the robots are applied into the various applications by its higher quality. The emotion is considered to be one of the parameters to adjust the condition and performance of robot. This project is the approach to the design the group robotic system to improve its performance based on the emotion-like parameters.

## 2.11 Study on dynamically dexterous robots from a nonlinear control point of view

A growing number of robotics researchers have taken an interest in building in dynamically dexterous robots—machines that are required to interact dynamically with an unactuated environment in order to achieve a designated task. We wish to understand how such dynamically dexterous tasks can be achieved using physical insight into the task and intrinsic dynamics of the system. Brachiating robots take an interesting place within this larger category of machines that juggle, bat, catch, hop and walk in effort to achieve dynamically dexterous behavior analogous to that of humans and animals. We confine our attention to the control of a simplified two-link brachiating robot from a nonlinear control point of view. In the longer run, we are hopeful that the brachiation task may lend significant insight into general locomotion systems as well as wider problems requiring dynamical dexterity.

## 3. Past Projets

In addition to the current projects listed above, we had also following past projects:

- Robot Applied Under Hazardous Environment
- Hierarchical Intelligent Control by Fuzzy, Artificial Intelligence, and Neural Networks
- Sensor Integration System
- Manipulator/Vehicle System
- Parallel Link Manipulator
- Man-Robot Cooperation Type of Manipulator System
- Skill-Based Control of Manipulator
- Single-Master Multi-Slave Manipulator System
- Teleoperation
- Optical Servo System
- Neural Network Using Incremental Learning
- Force/Impact Control of Robotic Manipulator
- Image Processing for Bio-Engineering Technology
- Self-Organizing Manipulator System.

A part of them is now still studying in other universities or institutes by the former students or other researchers. As a result of these projects, I have produced over 30 Ph.D. students and could publish about 900 transaction and journal papers and international proceedings from 1989 to 1999.

## 4. Conlusion

If you will have a chance attending to any international conference or symposium held in Japan or surrounding countries, please don't hesitate to contact me in order to visit my laboratory.