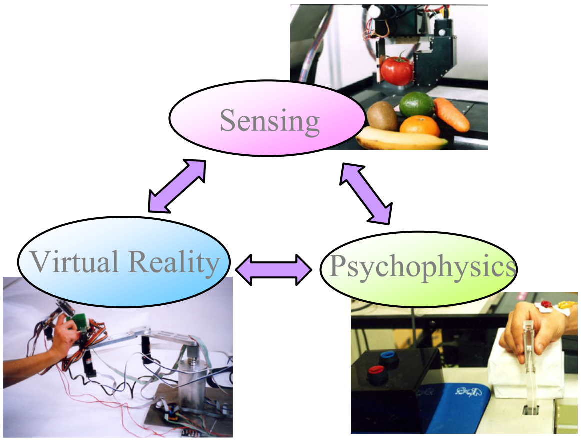
Nagoya University, Graduate School of Information Science Ohka Lab.

April, 2007

Three major projects



In our laboratory, we are focusing our study in sensing, psychophysics and virtual reality, which are cooperatively progressed.

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Themes for master and doctoral theses

●Psychophysics on human tactile sensation

Human capability of sensing pressure and shearing force

Human perceptive ability of the tactile coordinate

●Tactile sensors

A tactile sensor using CT algorithm

An optical three-axis tactile sensor

A tactile sensor using stochastic resonance

●Tactile displays

Two-axial micro actuators

Combined presentation of tactile and force

Combined presentation of pressure and shearing force

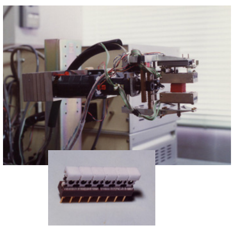
●Mobile robots

Cooperative behavior of collecting robots

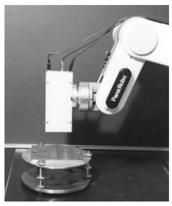
Environment recognition of humanoid robots using tactile sensing

A brief history of three axis tactile sensor

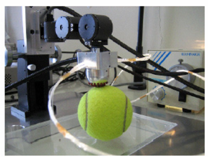
Almost two decades are spent before we successfully developed a three axis tactile sensor using semiconductor processing, which was the first succession in the world. In the present, we are expecting that the three-axis tactile sensor is able to apply to a dexterous hand.



1986-1993
Semiconductor processing
In Fuji Electronic Research and Development, Ltd.



1993-2003
Optical waveguide typed I
In Shizuoka Institute of Science and Technology



2004-the present
Optical waveguide typed II
In Nagoya University

Self-introduction

Department of Complex Systems Science

Complex Systems Computing
Associate Professor

Engineering Dr.

OHKA, Masahiro

Human Sensation Modeling towards Robotics

Intelligent robotics, Sensor and actuator system, Psychophysics on human tactile sensation

Current Research

Introduction

Robots are highly complex systems comprised of several actuators. This complexity arises because both the characteristics of components and the relationships between components are nonlinear. Complex Science Computing provides appropriate solutions for integration of multi-sensor and actuator system such as data acquisition and recognition of environments, planning of navigation, and object handling. Observations on human sensations can be used to advance complex science computing toward robotics.

In our laboratory, human sensation mechanisms, especially for tactile perception, are being investigated, and mathematical models are being formulated on the basis of the mechanism. This work aims toward robotics and mechatronics, human-robot communication, virtual reality, human health, and medical applications. We study tactile sensors, micro-actuators for tactile displays, and psychophysics on tactile sensation as follows :

- Collection robotics
- Navigation of Humanoid Robots Using Tactile Sensing
- Affordance on Tactile Sensation
- Tactile Sensor using Stochastic Resonance
- Tactile Virtual Reality
- Tactile Sensor Based on Computerized Tomography
- Human Tactile Sensation Mechanism

Human Tactile Sensation Mechanism

We have developed several apparatuses such as a fine step-height presentation device and a slippage force display. Furthermore, we have performed a series of psychophysical experiments to obtain subjective equalities and differential thresholds, which are important parameters for investigating human tactile sensation. Surface unevenness was acquired by Fast Adaptive Type I unit (FA I), and no difference was found between active and passive touch on discrimination of surface unevenness, while the unevenness amplitude felt by a human subject increased with an increase in the finger's sliding speed.

Tactile Sensor and Tactile Information Processing

Since not only pressure but also slippage force sensing determines dexterous robotic handing, we developed three-axis tactile sensors. We obtained Best Paper awards from the Japanese Society of Mechanical Engineers (JSME) in 1998 and 2002 and the Excellent Achievement award from Machine, Design and Tribology of JSME in 2004.

Using the three-axis tactile sensors, we made progress in tactile information processing. In our series of studies, we studied object recognition using artificial intelligence and Fuzzy inference to perform object recognition and control finger configuration according to the slippage caused on robotic fingers. We formulated equations of a neuron's activity caused by human tactile sensation and incorporated them into a robot equipped with the tactile sensor to recognize subtle unevenness on a surface.

Micro Actuator Array for Tactile Display

We developed several tactile displays according to our findings on human tactile sensations. Using the tactile displays, we are developing a tactile virtual reality system, which comprises a master hand having two sets of tactile displays with a

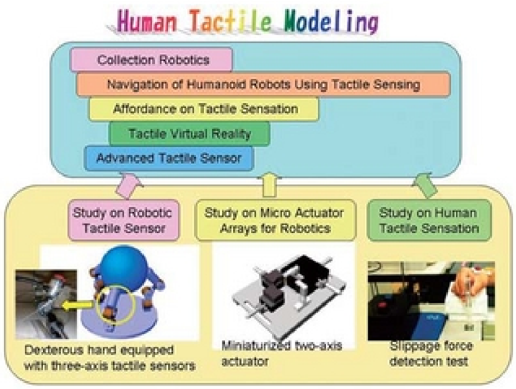


Figure : Scheme of our study on tactile sensation modeling

4-by-6 array of stimulus pins and an articulated manipulator, as part of the Japan Scientific Research of Priority Areas 438 "Next-Generation Actuators Leading Breakthroughs" program. Since diameter discrimination and insertion precision of the virtual peg were increased by tactile information, tactile presentation was effective for the peg-in-hole task in the case of a relatively large clearance.

Future Work

In future work, we will advance the present study to multi-modal sensation of visual, auditory and tactile perceptions. Furthermore, we intend to develop a new computational method inspired by our studies.

Career

1986, Dr. Engineering, graduated from Graduate School of Engineering, Nagoya University ; 1986, Fuji Electric Research and Development Co., Ltd. ; 1992, Assistant Prof., Faculty of Engineering, Nagoya University ; 1993, Associate Prof., Shizuoka Institute of Science and Technology ; 2003, Associate Prof., Nagoya University.

Academic Societies

JSME, SICE, RSJ, Japan Ergonomics Society, JSAEM

Publications

[1] Sensing characteristics of an optical three-axis tactile sensor under combined loading, Robotica, vol. 22-2, 2004.

[2] An experimental optical three-axis tactile sensor for micro-robots, Robotica, vol. 23-4, 2005.

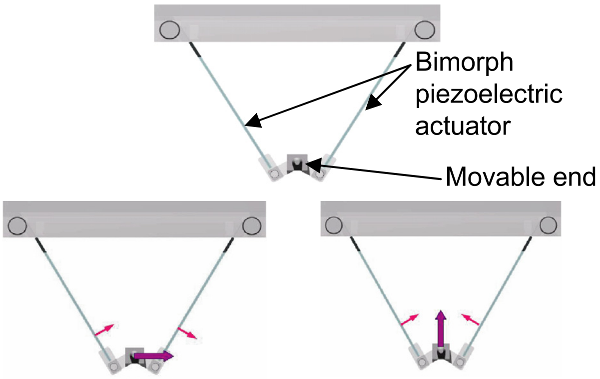
[3] A tactile recognition system mimicking human mechanism for recognizing surface roughness, JSME International Journal, Series C. Vol. 48, No. 2, 2005.

Two-axial micro actuator

Objectives

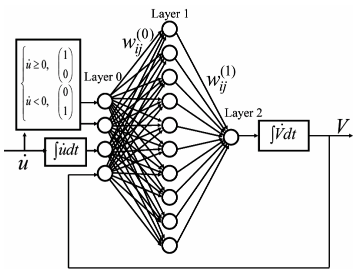
We are attempting to develop a high-end tactile display capable of presenting pressure and slippage force caused on human finger surface. The two-axial micro actuator is used as a key part of the tactile display.

Principle of the actuator

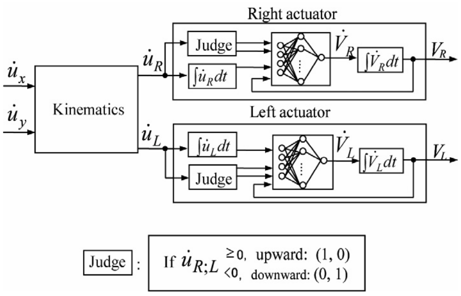


Vertical and horizontal movement are generated by in-phase and out-of-phase applied voltages, respectively.

Neural control

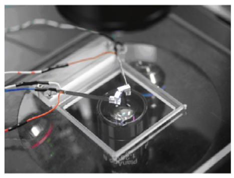


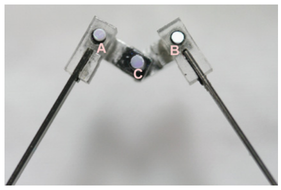
The present neural network is featured with integral elements and a feedback connection.



Since characteristics of the left and right actuators are different, two neural networks are incorporated into the control system to drive independently the left and right actuators.

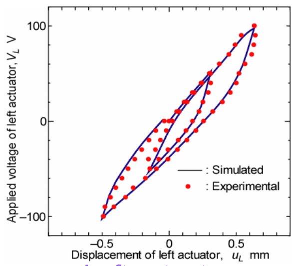
Measurement



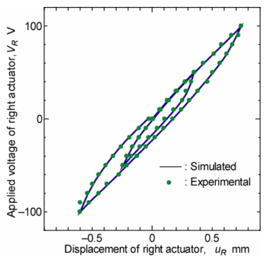


Displacement of the movable end is measured by image data processing obtained by a micro scope.

Experimental results



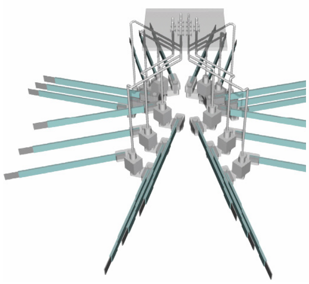
Left actuator

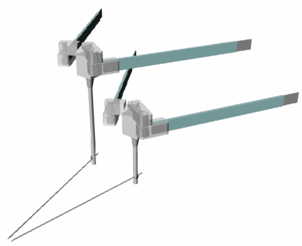


Right actuator

The difference between the left and right actuators is well presented with the two neural networks.

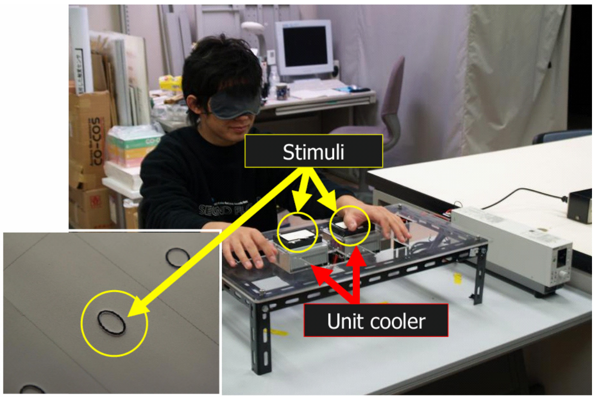
Applications





A tactile displace is composed of large number of the present actuators. A micro hand is composed of a pair of the present actuators

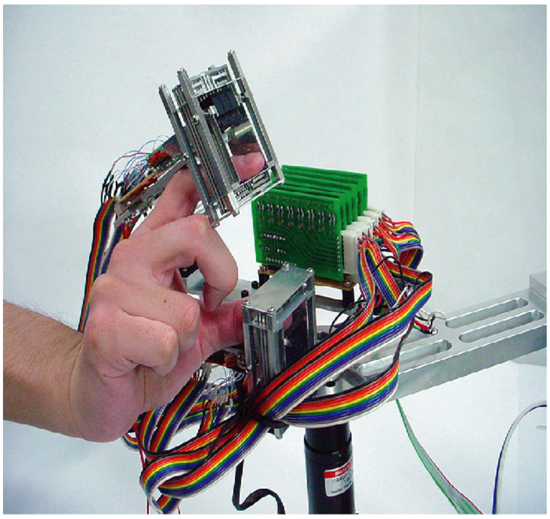
Psychophysics on human tactile sensation

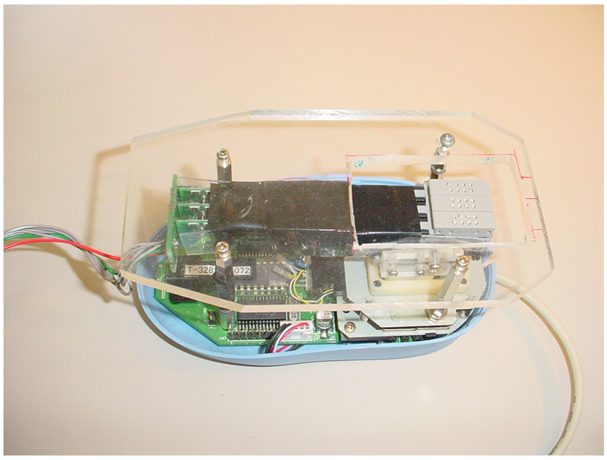


Type	Density	Temperature dependence
FA I	High in finger tip	Weak
FA II	Low and constant	Marked
SA I	High in finger tip	Weak
SA II	Low and constant	Marked

As shown in the above table, human mechanoreceptive units, FA I, FA II, SA I, SA II, have different temperature dependence. Difference of density between finger tip and thenar depends on the type of mechanoreceptive unit. Using these characteristics, we examine psychological response of mechanoreceptive unit caused by several stimuli and difference of environment condition. Remarks obtained by this study is utilized for evaluation of tactile display and modeling of human tactile sensation.

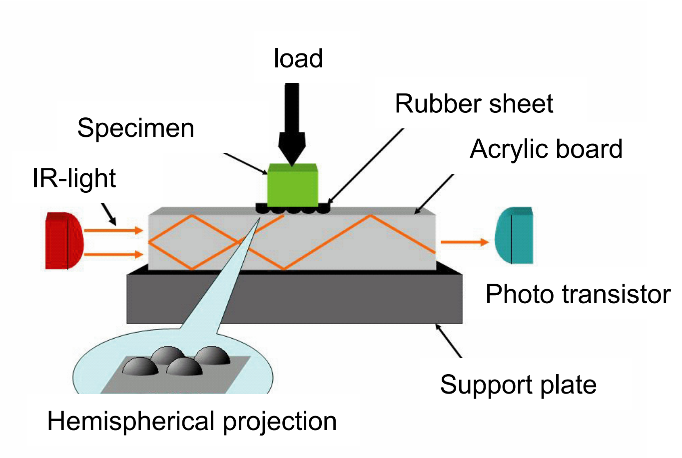
Tactile display

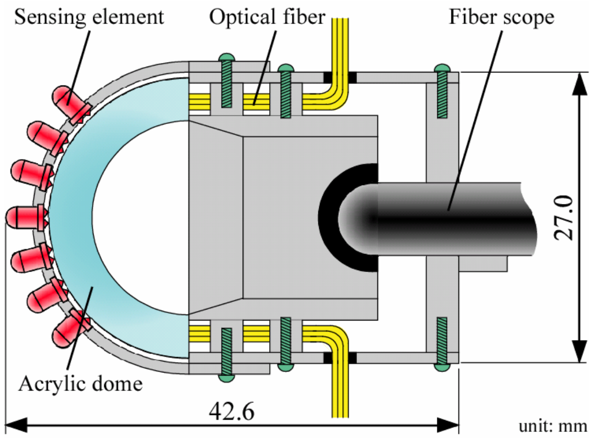




We have developed several tactile display composed of bimorph piezoelectric actuators combined with a master manipulator (the left figure) and a tactile mouse produced by Fuji-Xerox (the right figure). These tactile displays are utilized for experiments of virtual reality such as virtual peg-in-hole and virtual texture recognition.

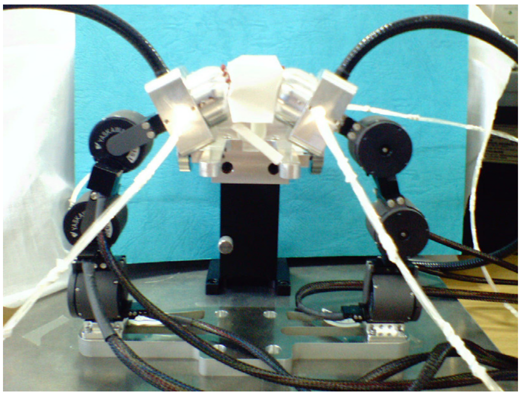
Tactile sensor

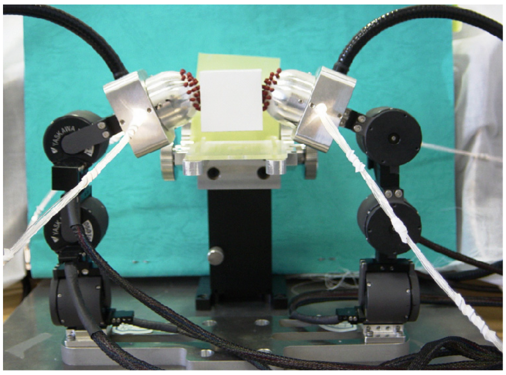




In the left sensor, IR-light absorption caused between an IR-diode and a photo-transistor is measured to identify the applied force. One dimensional distribution of the absorption is reconstructed according to computer tomography algorithm to obtain pressure distribution. The right panel shows an optical three-axis tactile sensor, which is attempted to be attached on a fingertip of a robotic finger. 41 red rubber feelers arranged on the hemispherical finger tip measure distribution of three-axial force.

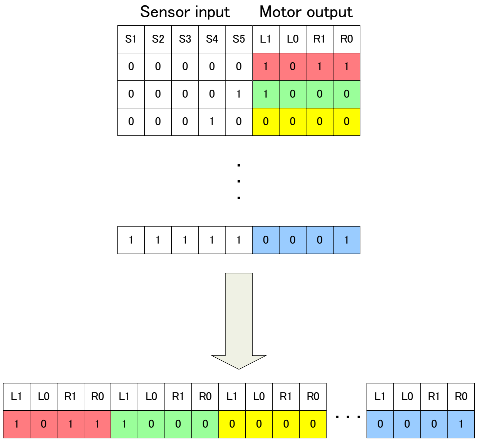
Multi-fingered hand



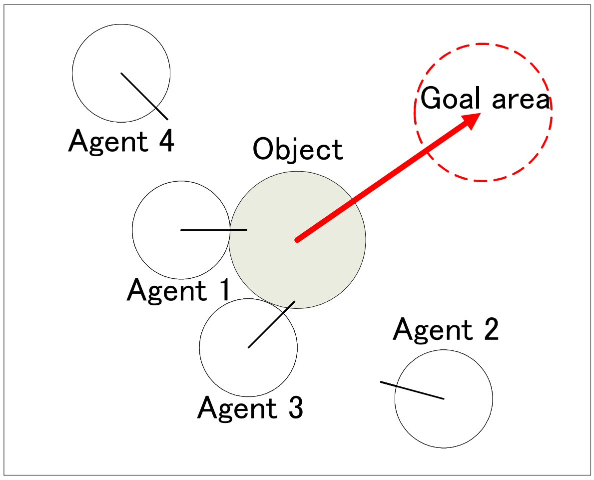


Since the three-axis tactile sensor can measure not only normal force and but also shearing force, the robot can grasp an object without dropping the object. However, if the robot grasps any object with same grasping force, the robot crushes a soft object as shown in the left panel. To overcome this problem, the robot measures hardness of the object at first touch, and grasps the object with adjusted grasping force according to the hardness as shown in the right panel

Collective robotics

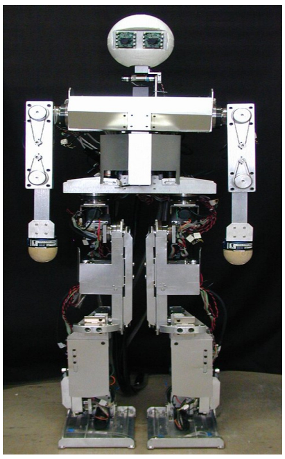


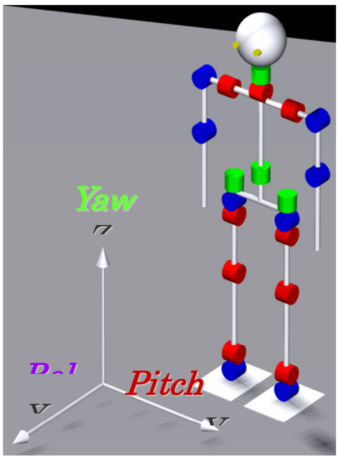
Length of gene locus : 32 × 4 = 128 [bit]

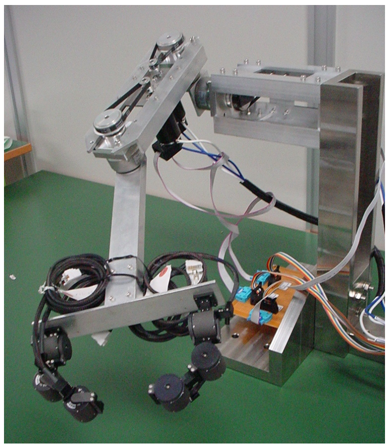


In this project, we are developing an artificial mechanism to make a robot acquire autonomously its behavior pattern. We define a gene comprised of sequence of 1 and 0 (128-bits), which represents multi-sensor status and multi-actuator status as shown in the left panel. We evolve the gene using GA（Genetic Algorithm) to make collective robots convey efficiently an object to a specified place. The right panel shows that 4 robots equipped with the optimum gene covey cooperatively an object to a goal.

Humanoid robotics







We are using tactile sensation in a dark place, when we search a switch on the wall. In this project, we are examining a method to make the robot acquire environmental information using tactile sensing. The left panel shows a humanoid robot BontenMARU II produced by Nasu Lab. in Yamagata University, which is used in this project. The right panel shows an arm unit, which is used for a testing and equipped with robotic fingers.