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Featured in this issue is Assistant Professor Norihisa Miki who challenges the development of MEMS-based devices, which have heretofore been impossible to develop with existing technologies.

# Creating New Devices with MEMS

## Opening up new horizons of manufacturing

**Imagine a bedridden patient, who wants to drink a cup of tea, can communicate his/her intention to others by simply turning his/her eyes to a pot and tea cup. If we can understand what the elderly and small children tend to look at while moving around town, it will contribute to safety-assured urban planning. Or if consumers can get a feel of products shown on a display screen, possibilities for Internet shopping will greatly expand ...**

**Attempts are now being made to digitize sensory information (visual sensation, tactile sensation, etc.) for application in communication. MEMS (Microelectromechanical Systems) plays the central role in the manufacturing of such key devices. In this issue we listened to Assistant Professor Norihisa Miki, Department of Mechanical Engineering, Keio University Faculty of Science and Technology, who is actually making such devices using MEMS.**

### MEMS technology plays an active role in the industrial world

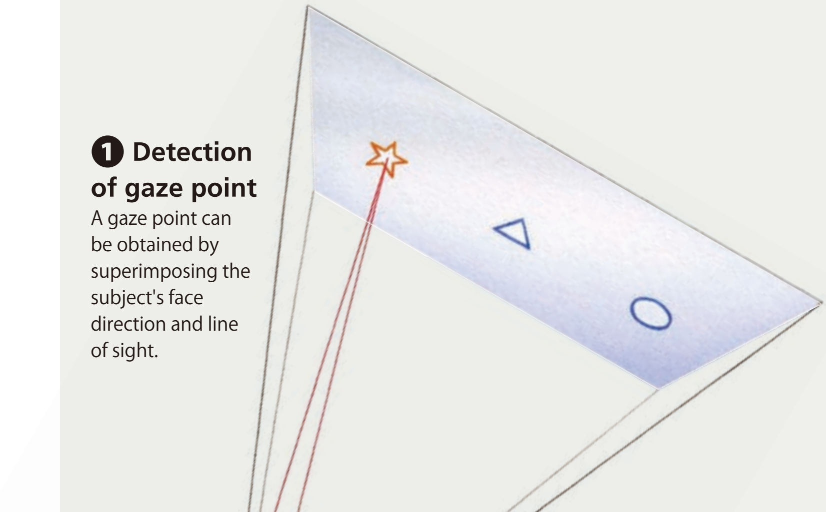
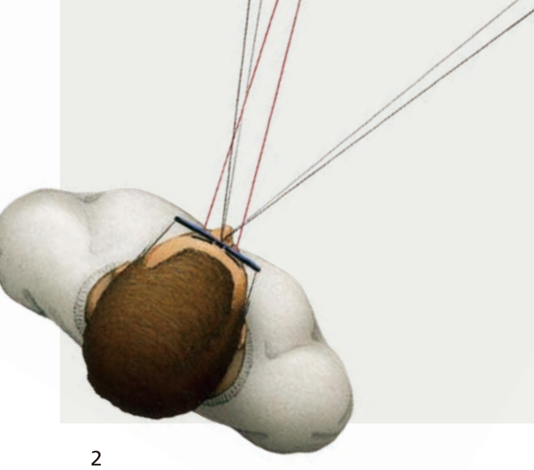
Some two decades has passed since AT&T's Bell Telephone Laboratory in the United States launched in 1987 a silicon micro gear less than 0.2mm in diameter. During this period, MEMS (Microelectromechanical Systems) has steadily evolved and grown into a technology indispensable for today's industrial world. A fine example of a MEMS-applied product in our daily life is portable electronic game consoles. For example, as you incline a game console, a ball drawn in the screen begins to roll. But the rolling ball comes to a halt as you bring the console back to a horizontal position. MEMS technology can make such sensory movements more realistic. It is also applied extensively to many other fields that impact our lives, including automobile air bag motion control.

"MEMS technology is contributing immensely to innovation of the measuring instrument technology that covers impact detection sensors, acceleration sensors and flow rate sensors. Indeed, its application ranges from automobiles to cellular phones. Perhaps you may know of a game played by swinging a controller like a baseball bat or tennis racket. This game incorporates MEMS technology," remarks Dr. Miki.

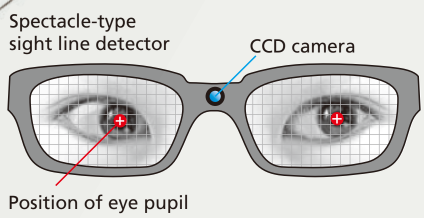
MEMS is a technology indispensable to "manufacturing" activities that require precision of a micromillimeter. Taking advantage of this technology, the Miki Laboratory is pursuing the development of devices that offer truly innovative functions.

### Detecting our lines of sight

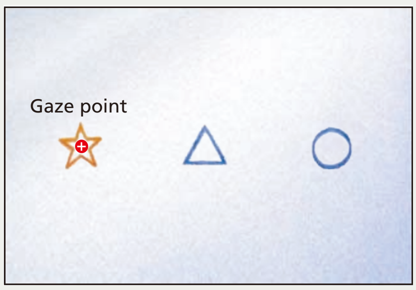
The Miki Laboratory addresses a wide scope of research fields ranging from information/communication to medical care and welfare. This extensive scope reflects the wide range of MEMS applications. One of the research endeavors at the Miki Laboratory is an attempt to make human line of sight as an interface device in place of keyboards

**❶ Detection of gaze point**
A gaze point can be obtained by superimposing the subject's face direction and line of sight.




**❷ Locating eye pupil positions**
Optical sensors arranged on the lenses of a spectacle-type sight line detector are used to locate the eye pupil positions of the right and left eyes. The line of sight is determined from the positional relationship between the eye pupils.




**❸ Superimposing the subject's front-face image and his/her line of sight**
A CCD camera is used to obtain the subject's front-face image, upon which the line of sight detected in ❷ is superimposed.

and touch panels.

"Many studies have been conducted so far on detection of human line of sight. However, most of these endeavors involved the use of large-scale equipment like setting a camera in front of the subject, which often caused mental stress on the subject. This is why I wanted to develop a system that allows us to conduct such experiments as naturally as possible while significantly reducing the burden on the subject."

When conceiving how to detect line of sight, a concrete image of an application Dr. Miki had in mind was the "scouter" appearing in the popular animation "Dragon Ball." The scouter is an advanced tool resembling the monocle that was in fashion in Europe in the 19th century. If one stares at an object through the lens, the scouter recognizes the object in front of the line of sight. It then digitalizes pieces of information such as the object's battle capability, the distance and direction from the scouter to the object, and displays the information on the lens.

"Equipment almost comparable to the scouter wouldn't only be a dream if we had a technology capable of accurately determining human line of sight. Convinced that such equipment would blossom into a promising technology, I made up my mind to develop a line of sight detecting device based on MEMS. This detector would allow one to complete the process of information acquisition only by looking at the object. For example, the line of sight would point to the object, staring for a single click and two winks for a double click," says Dr. Miki delightfully. But he is actually serious and highly motivated, saying "I conceive like an amateur and achieve the project with professional technology."

The Miki Laboratory thus embarked on the development of a spectacle-type line of sight detection system. A new method was devised to locate the eye pupil positions. In this method, transparent micro optical sensors are arranged at regular intervals on the left and right lenses. Information from these sensors is analyzed to detect the line of sight.

The task of arranging micro sensors on glasses - extremely difficult with the existing technology - could happen thanks to MEMS, which led to the development of a spectacle-type, easy-to-wear line of sight detection system. Much is expected of this system as an innovative communication tool and human interface device.

## Reproducing tactile sensation

Application of the MEMS technology is not limited to digitalization of human sensibility as the line of sight detection system does. It is also applied to the development of devices that allow stimuli to be input directly into the human skin. One such example is the tactile sensation display.

"Although visual and audio programs that stimulate human visual and auditory senses have been highly developed, the field of tactile sensation has long remained dormant. This is because physical stimuli had to be applied directly to the skin. Tens to some 100 microns of change in momentum is required for a human to feel a stimulus. However, MEMS, which is geared to handling a stimulus in units of several microns, is not good at handling momentum changes in units of tens of microns. This posed a problem."

In order to solve this problem, he developed an actuator by applying the principle of a hydraulic system - a system capable of amplifying momentum of several microns to 100 microns. This led to the development, though at the lab level, of a highly practical braille display system.

"Recent studies indicate that the human skin can feel a stimulus with much less energy if you apply the stimulus with fine vertical vibrations, rather than simply pressing it against the skin. I'm now engaged in research one step ahead, assuming that even less energy would be required if spatial vibrations - horizontal and vertical - were added. Fine motion is a field MEMS is good at, you know ..."

Based on these achievements, Dr. Miki plans to bring to light how humans will recognize tactile sensation through various kinds of stimuli given.

## What "manufacturing" means in the world of MEMS

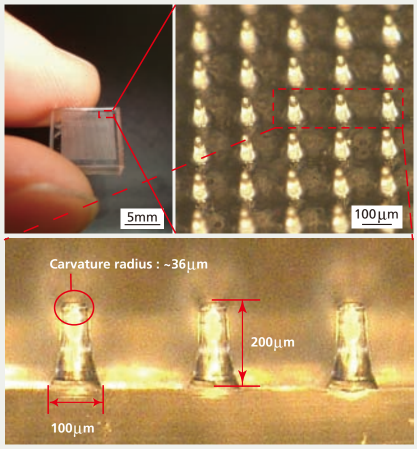
Methods of human interface come in various forms, such as digitalization of visual information and the technology to convey external information as tactile sensation. The ultimate form, Dr. Miki thinks, will be the Brain-Machine Interface (BMI). "I'm interested in the BMI study Dr. Ushiba (Department of Biosciences & Informatics) is addressing. Both of us joined forces to create an electrode needle to detect brainwaves based on MEMS (for details of BMI, please refer to issue #1 of "New Kyurizukai"). The needle, only 200 microns in length, can break through the horny layer of skin that impedes electrical information, but does not reach the pain spot. It has a "moderate" hardness as its point can stick into the skin and yet cannot be broken or come off even when the person moves. The pursuit of "moderate balance" in the microscopic world has not been systematically studied so far. As such, it's an intriguing theme even from the viewpoint of mechanics. We are now promoting joint research with the Material Strength Mechanics Laboratory of the Department of Mechanical Engineering.

Because of the fineness it deals with, MEMS sometimes encounters difficulties like the inability to adapt to rules of "ordinary manufacturing" including changes in characteristics due to scale effects. On the other hand, such difficulties seem to offer exciting challenges as Dr. Miki says. Expectations are high for MEMS with vast potentials despite its small appearance.

(Reporter & text writer: Kaoru Watanabe)


### Basic mechanism of the tactile sensation display

Although the surface of the tactile sensation display is normally flat, stimulus-presenting elements pop up as the micro actuator begins to move, which give stimuli to fingertips or the skin. MEMS is used in the manufacture and control of this micro actuator. In the foreseeable future, the display is expected to be applied, in addition to braille display systems, to fields such as the reproduction of the feel when one touches a cloth, and reproduction of the feel of coldness and warmth.




### Micro electrodes to detect brainwaves

These easy-to-fit micro electrodes can read brainwaves accurately. MEMS was instrumental in the development of the electrodes.