Solutions for today's challenges

Sensors Answering the Call!

The Tokyo Gate Bridge is nicknamed the "Dinosaur Bridge" because of its unique shape. If you look at the bridge, you may find that it looks like two dinosaurs facing each other.

Not only is its shape unique. Did you know that the giant bridge has a fine nerve network? In fact, this nerve network is attracting attention as a step towards solving various social issues facing Japan at present.

The nerve network is a "sensor-based monitoring system." Various sensors are installed below the roadway surface at the center of the bridge to check the structural soundness of the entire bridge by measuring displacements, vibrations, tilts and other small changes.

This fiscal year, the Ministry of Economy, Trade and Industry (METI) launched a "Project to Develop Sensor Systems for Responding to Social Issues." The project aims to "research and develop energy saving microsensors and control systems." The goal is to solve social issues plaguing (1) social and public infrastructure, (2) agriculture, (3) healthcare, and other areas.

Specifically, these sensor systems may be used for the following sorts of applications:

(1) Discovering anomalies and damage to bridges, roads, buildings and other structures to "manage infrastructure"

(2) Monitoring agricultural conditions including temperature and humidity to "appropriately control agricultural products," and

(3) Measuring blood pressure, blood glucose and other biological indicators to "detect the three major diseases (and others) at an early stage and prevent these diseases from worsening." The monitoring system for the Tokyo Gate Bridge represents one of these applications.

Why are sensors required for such purposes? What kinds of sensors are required? What are present sensors like? We have tried to explore the overall picture of the project from a variety of perspectives.

Visualization Can Make a Difference in Social and

Public Infrastructure Maintenance

Tokyo City University Professor Chitoshi Miki describes the development of a bridge monitoring system as “the installation of a nerve network and a brain on a bridge.” Prof. Miki has long been engaged in research on infrastructure design and maintenance. We interviewed Prof. Miki on the present status, directions and challenges of sensor systems.

The deterioration of social and public infrastructure, including bridges, tunnels and roads that support social activities, has recently become a problem. This is because Japan’s social and public infrastructure development was concentrated in the high economic growth period of the 1960s and 1970s. “The massive concentration of development over such a limited period is unique in the world,” said Prof. Miki. Data from the Ministry of Land, Infrastructure, Transport and Tourism indicate that about 40% of road bridges and tunnels in Japan will become more than 50 years old in the next decade.

Shifting from Movement Observation to “Preventive Maintenance”

“At present, the designed service life of bridges is globally set at around 100 years. Appropriate maintenance can provide bridges to continue working for such a long time. But structures built in the 1960s have begun to gradually develop damage due partly to later dramatic increases in traffic. Effects of earthquakes are also a major issue. How to secure the same level of ‘safety’ and ‘security’ for all social and public infrastructure is the challenge we face now.”

Chitoshi Miki, Vice President of Tokyo City University and Professor at its Advanced Research Laboratories. Born in Tokushima Prefecture in 1947, he graduated from the Tokyo Institute of Technology Graduate School in 1972. He assumed his present post in 2012 after serving as assistant at the Tokyo Institute of Technology, associate professor at the University of Tokyo, dean and professor and vice president of the Tokyo Institute of Technology. He also chairs the Road Maintenance Subcommittee of the Social and Public Infrastructure Development Council at the Ministry of Land, Infrastructure, Transport and Tourism.

Prof. Miki has investigated fatigue in bridges since the 1980s. He has also engaged in research on the maintenance of bridges for Shinkansen railways, metropolitan expressways and major national roads in that time. About 10 years ago, Prof. Miki launched a study on how to use sensor technologies to check for structural deterioration. He developed an optical fiber sensor monitoring system which is attached to the opening of the lower deck (Route 357) of the Yokohama Bay Bridge.

“Attempts have been made over a long time to use sensors to check the condition of structures. But previous attempts focused on movement observation to check whether bridges work as designed. We have come up with a new optical fiber sensor technology and a new concept of “preventive maintenance” to manage the integrity of bridges,” he said.

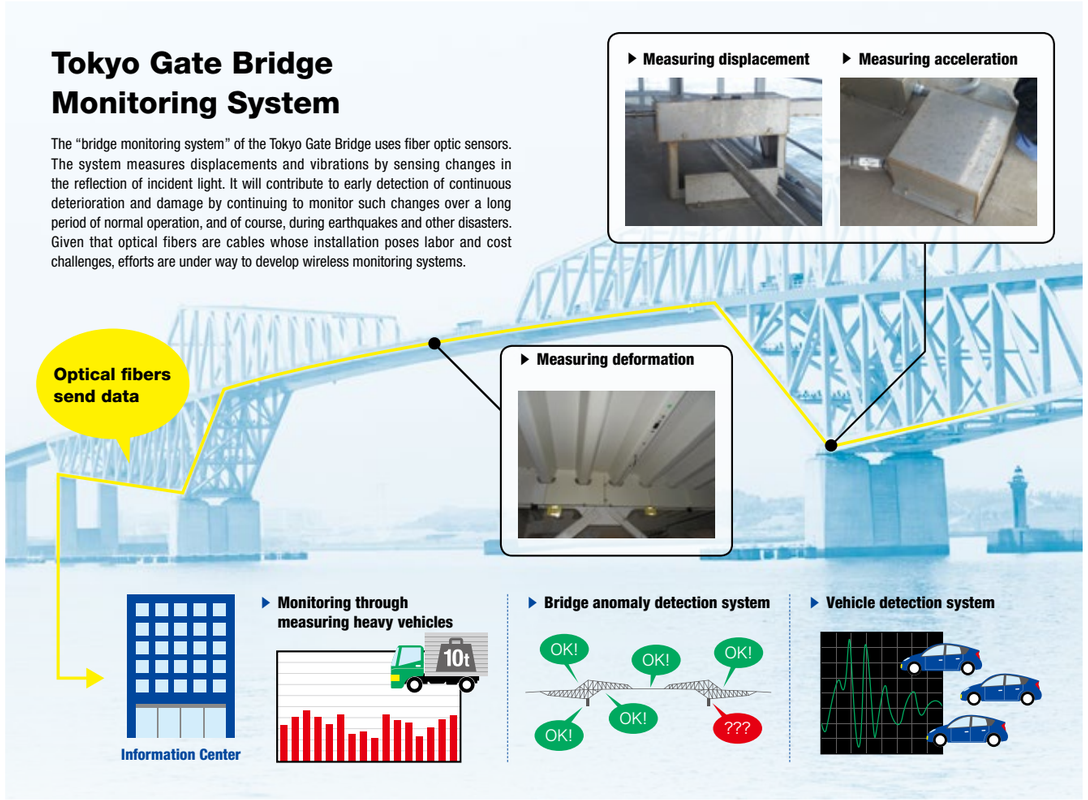
In parallel with the construction of the Tokyo Gate Bridge, various sensors, including deformation, acceleration and displacement meters were developed and installed, according to a “bridge deterioration scenario.”

The scenario includes estimates of degrees of damage caused by strong earthquakes, which have been projected with the latest analysis techniques. A wide range of expertise and know-how in the structural design as well as in maintenance and conservation is required in the development of preventative maintenance systems. The know-how is used for determining “what and how many sensors should be installed where, and to collect what data.”

Massive amounts of data on displacements, vibrations, tilts and other changes are sent and received in real time. An information center collects and analyzes this data. Prof. Miki explained: “Sensors work as the nerve system and computers as the brain. They are connected through sophisticated information and communications technology. Thanks to the evolution of these three technologies, the present monitoring system is possible. But there are still multiple problems for the future.”

Discussions on “Cost-Benefit Ratios” are Indispensable

One of the challenges cited by Prof. Miki is the performance of sensors. The performance includes the battery life of sensors.



Prof. Miki said: “The battery life is reported to be around one year. But regular inspection work on a bridge is conducted only every five years. Battery life may have to be extended to at least this level.”

The METI project aims to develop “energy saving (independent electricity source, wireless communication and maintenance-free)” microsensors. Given that sensors may be installed at locations that are difficult for humans to check, independent power sources which convert heat and light energy into electricity are indispensable.

Another key point is the price of sensors. Prof. Miki said: “Building a monitoring system constructed with current optical fiber sensors costs around 10 million yen. The cost is unrealistic for nationwide bridge maintenance. At present, MEMS (microelectromechanical systems) technologies are making sensors cheaper. With performance and cost taken into account, research in this field will be critical in the future.”

One more important point is that the largest challenge is the “cost-benefit viewpoint.”

“How much should be spent on social and public infrastructure maintenance and management? Who would shoulder the cost? It is important for all stakeholders to discuss and share in the costs including investment in maintenance research and development,” said Prof. Miki.

“If a road bridge on the metropolitan expressway system is replaced, societal losses including losses associated with traffic closures may far exceed 100 billion yen.” In fact, there is an abundance of ageing infrastructure in need of replacement in Japan. Societal losses from the aging of bridges and roads are far more costly than we assume.

“We must also consider creating new business models. Historically, priority in construction technology has tended to be given to new infrastructure development rather than maintenance. Unless we cooperate with the business community to develop mechanisms to secure returns on investment in maintenance, it may be difficult for private sector enterprises to enter the infrastructure maintenance business.”

There are many challenges to be solved before establishing new sensor systems. METI plans to begin the project by determining these “problems” and “on-site needs” and cooperate with sensor users in demonstration research.

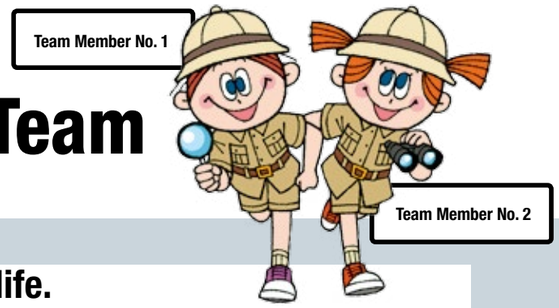
“I hope that I will someday hear that Japan’s infrastructure has been successfully restored thanks to sensors.’”

The potential of sensors will continue to increase.

CLICK! ●Tokyo Gate Bridge ●Tokyo City University

Investigating Simple Questions Thoroughly!

Sensor Exploration Team



**Sensors are everywhere in everyday life, although we are seldom conscious of them.
What are these reliable sensors? What functions do they have, and where are they?
We interviewed two experts on everything from fundamentals to future potential!**

Sensors are everywhere in everyday life. Toward a Society Protected by Sensors

No. 1: Automobiles, air conditioners, digital cameras, smartphones… Sensors are used in many different devices.

No. 2: What roles do sensors play?

Fujimaki: A kettle tells us water is boiling by whistling. A doorbell informs us of a visitor. Although sensors are thought of as devices sending radio signals, there are also other kinds of sensors. In brief, sensors sense something for us, inform us, or tell machines to do something on our behalf. That's what sensors are!

No. 1: I see! Sensors represent an extension of human senses.

Fujimaki: Yes. The word "sensor" originates from the word "sensing." Sensors are devices that visualize and more accurately detect what humans cannot see. We are actually usually in the presence of various kinds of sensors. Sensors are in fact already widespread and have the potential to contribute to solving various social issues.

No. 2: What sort of convenient sensors can we expect to see in the future?

Fujimaki: I am researching biosensors to detect proteins in the body. As you probably know, lifestyle-related diseases have become a major problem. While diseases develop without being detected by humans, it is widely known that some small changes are seen in the initial phases of the development of a disease. So, more sensitive sensors may be able to detect such small changes and prevent the development of such diseases. At present, blood samples are taken by sensors to monitor body data. In the future, sensors may be developed which enable diagnosis without invasive blood samples being taken.

No. 2: Sensors will also be useful to maintain a healthy life!

Fujimaki: We are approaching a world where humans will be passively and naturally protected by sensors.

CLICK! ●**National Institute of Advanced Industrial Science and Technology**

Sensors visualize what humans cannot see

Dr. Makoto Fujimaki

← Planning Officer, Research Planning Office for Information Technology and Electronics, National Institute of Advanced Industrial Science and Technology. As a Doctor of Engineering, he has been engaged in developing sensors since 2004.

Sensors Chatting with Each Other!?

No. 1: What do you think are the key words for future sensor development?

No. 2: I've heard about the word "miniaturization."

Imanaka: Yes. That is one of the key points. First, let's review how sensors have advanced. Some sensors can decide whether specific data are necessary or not. These sensors that discriminate necessary data from other data are called "smart sensors." Ultra-smart sensors with advanced data discrimination functionality can chat with each other.

No. 1. Oh! What do you mean?

Imanaka: For example, one cleaning robot can handle cleaning a small room. In a large space, however, multiple robots can be used to increase efficiency. Then, sensors send and receive messages between the robots, informing them "this part has been cleaned." In this way, sensors can work collaboratively with chatting each other.

No. 2: Sensors are cooperating with each other very well! Is this related to the sensor network system you are currently researching?

Imanaka: Our NMEMS Technology Research Organization has been developing a system that reduces energy consumption in society using compact and low-cost sensors with energy harvesting and wireless communications functions. This technology may be used for a wide range of areas including public infrastructure, factories and office buildings. Of course a single sensor may break down or lose power, so it is important to install multiple sensors with energy harvesting functions to enable continuous monitoring.

No. 1: Prices may have to be lowered to allow for a large number of sensors to be used.

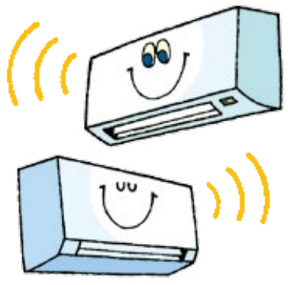
Imanaka: Yes. I would like to realize such systems as early as possible. I'm confident that sensors have the potential to enable a more secure, safe and efficient society.

CLICK! ●**NMEMS Technology Research Organization**

Sensors have the potential to change society

Dr. Koichi Imanaka

→ Chairman of NMEMS Technology Research Organization and Doctor of Engineering. Before taking up the current post in 2011, he was engaged in developing sensing devices at Omron Corp.



▶ Air conditioners

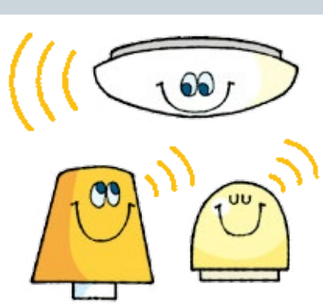
Recent air conditioners are equipped with not only temperature sensors but also infrared sensors that can detect the presence or absence of humans. They control heating and cooling depending on room conditions.

▶ Cars

Check engine revolutions, measure distances from other vehicles and control braking. Sensors are installed at various locations to support a safe car-based life.

▶ Smartphones

Smartphones indicate walking directions and provide games that can be played by tilting the handset. They are also mounted with acceleration sensors to provide a wide variety of functions.



▶ Lighting

An infrared sensor senses human movements and automatically controls lighting. Sensors are useful for not only energy conservation but also for security. Automatic doors also depend on sensors.

▶ Integrated Circuit Cards for Transportation

Various integrated circuit cards support smooth movement of passengers using trains and buses. Sensor technology works to send and receive data stored on cards with data readers.

▶ Digital Cameras

Sensors are indispensable for digital cameras to measure light levels. Digital camera autofocus devices are also a type of sensor.

Attempts Have Already Been Made to Use

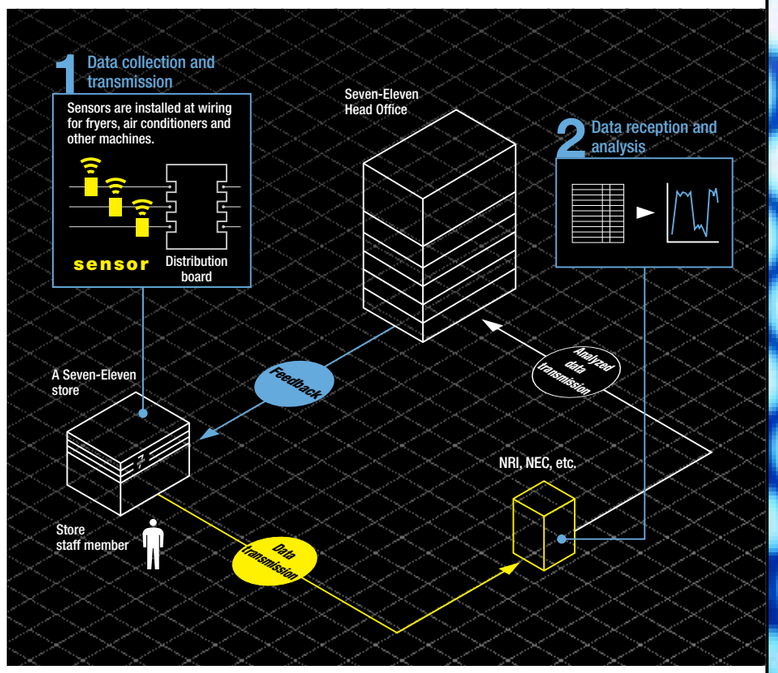
Sensors to Conserve Electricity!

**Energy saving and cost reduction are challenges that any enterprise must deal with constantly.
The emergence of sensors has led to a rise in new ideas for solutions.
We would like to introduce two enterprises that have made positive efforts to that end.**

Sensors Visualize Work Conditions!

Seven-Eleven Japan Co., Ltd.

Seven-Eleven Japan Co. has more than 15,000 convenience stores across Japan and has been increasing the number of stores every year. The largest convenience store chain in Japan is socially responsible for reducing carbon dioxide emissions and conserving electricity. CO2 emission reduction and electricity conservation are great business goals. In fact, the entire chain's CO2 emissions annually reach 1 million tons and its annual electricity charges totaled about 34.4 billion yen in 2010. Taking necessary measures to address this situation were required.
The measures Seven-Eleven Japan had implemented to this end included the adoption of commercially available ammeters to determine the amount of electricity consumption at the stores. Upon discovering that an ammeter costs as much as 400,000 yen, however, the company began searching for more economical methods. In 2010, it found a small wireless electricity sensor under joint research and development by the National Institute of Advanced Industrial Science and Technology (AIST) and NEC Corporation.



Demonstration Test Results Led to Substantial Electricity Conservation

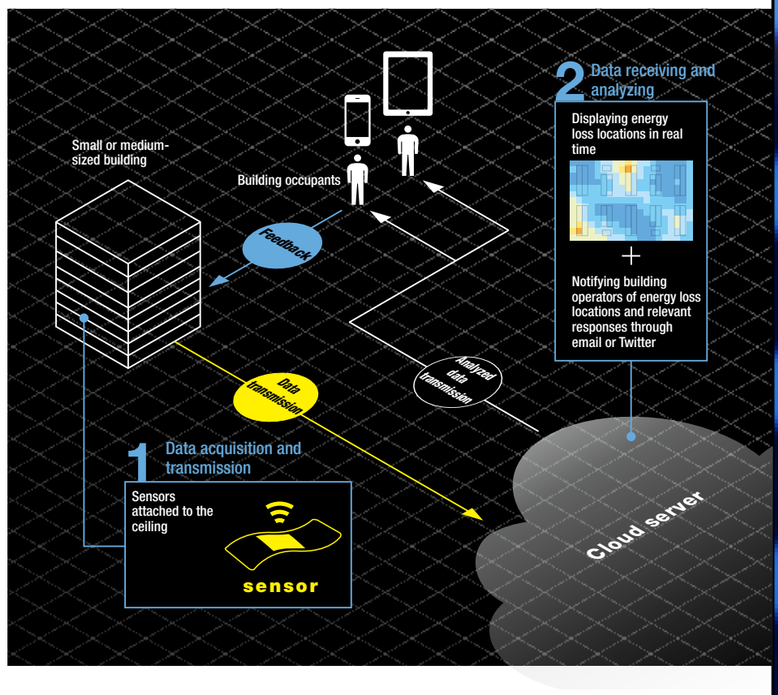
When the thumb-sized, easy-to-install sensors were installed on distribution boards to measure the electricity consumption of in-store lighting, air conditioners, fryers for fried food and the like, various findings were made. For example, the power save modes of fryers were not being used. Filters for air conditioners were not being cleaned. These failures made a greater contribution to electricity consumption than expected. When inspectors visited stores that used more power consumption for air conditioners, they found that these stores left entrances open to allow for frequent customer visits. These findings meant that sensors visualized electricity consumption as well as each store's business situation.
In response to the results of the demonstration test that Seven-Eleven conducted jointly with AIST and NEC, the convenience store chain implemented thorough utilization of the power save mode for fryers, stricter lighting controls, modified operation manuals for refrigerators etc., and has successfully and substantially reduced electricity consumption. The achievement has been shared with Seven-Eleven stores throughout Japan to encourage their electricity saving. The convenience store chain is now further improving its energy consumption efficiency by installing environmental sensors to measure temperature, humidity and atmospheric pressure levels in addition to electricity sensors. Miniature sensors encouraged innovation in the company.

CLICK! ● Seven-Eleven Japan Co., Ltd.

Promoting Energy Saving in Small and Medium-Sized Buildings!

Daikin Industries, Ltd.

Many small and medium-sized buildings have failed to make progress in saving energy. One factor behind the failure is that these buildings differ from larger buildings subjected to stricter legal regulations and lack operators with expertise. Operators of small and medium-sized buildings also fail to identify the sources of energy loss or promptly devise improvements. These actions are difficult to be taken for such buildings.
Daikin Industries, Ltd. wants to provide tools and offer services that overcome such weak points of small and medium-sized buildings. Daikin, whose main business is air conditioning equipment manufacturing, is striving to establish an energy management system that is easy to operate, affordable and easy to install. Daikin has teamed up with sensor suppliers (Omron Corporation, Rohm Co., Ltd., Hitachi Ltd., and NTT Data Corporation) to form a task force with the following concept; "to visualize energy losses in real time by only attaching sensor terminals to ceilings" and "propose countermeasures to promote energy saving."



A further 10% energy saving by using a "bird's-eye view" of rooms

In this demonstration test, Daikin has newly developed an infrared array sensor to monitor not only the temperature, but also the location of occupants. Since a tiny PV panel was integrated with the wireless sensor, wiring installation for power supply and communication were eliminated. The sensor is very small; the size is at only 2 cm x 5 cm.
With multiple sensors, the entire room can be overlooked. For instance, optimum air conditioning can be controlled, because the monitor displays the number of occupants in the room as well as the locations from which the areas do not need air conditioning and ventilation can be determined at a glance. Based on the real time data measured at other office buildings, we estimated the effect of energy saving by introducing this system, and obtained data that shows an approximately 10% reduction of energy consumption can be expected, even in buildings that have already taken energy saving measures.
Daikin is expected to take further steps to commercialize sensor systems that can not only measure data but also "process data into a meaningful form."

CLICK! ● Daikin Industries, Ltd.

A New Future Guided by Sensors

How will our life change with the advancement of sensors?
Let's look at some of the changes!

Temperature, water levels and other environmental information, electricity consumption, chemical substances, etc. Sensors have a massive range of potential uses and the scope for sensors is continuing to expand. If ongoing research efforts by various enterprises and organizations successfully improve the sensitivity of sensors and further miniaturize them, solutions that have been historically viewed as excessively difficult will grow more realistic.
As shown above, new devices will be manufactured to support human health promotion in the future. Higher-quality farm products will be produced more efficiently. Sensor technology will make our lives more affluent and could generate greater effects by being connected with manufacturing. Sensors have the potential to "improve Japan's international competitiveness."
In order to accelerate such efforts to develop sensors, METI is promoting "Sensor System Development Projects Responding to Social Issues." Under the projects, METI will provide subsidies while considering feeding back the research results so that they could be adopted to the reform of relevant institutions and regulations, and also plans to develop arrangements to support private enterprises.

CLICK! ●**Outline of the Sensor System Development Projects Responding to Social Issues (cited from NEDO's information on invitation for applications)**