Human-oriented Research and Development

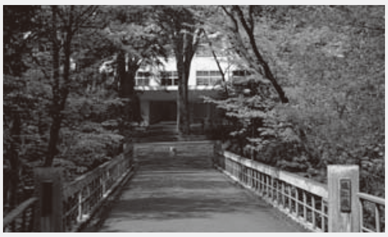
Haruo Takeda, Dr. Eng.

RETURN TO HUMAN-RELATED RESEARCH

THE phenomenon whereby a group of intelligences can be more powerful than the sum of the individual intelligences that make up the group has been observed across the full range of biological activity from microbes to human beings. The example of ants teaming up to bring a large piece of food back to their nest is frequently quoted when explaining this phenomenon. There is no doubt that the ability to exchange information between individuals by some means plays an important role in this process.

In human society, IT (information technology) had by the end of the 20th century evolved into the Internet, Web, and search engines, suddenly expanding information exchange between people to a global scale. The hardware and software businesses that supplied the PCs (personal computers), networks, data storage devices, and other tools of this technology became drivers of the global economy. It is certain that this century will see a completely new intelligence comprising the entirety of human society being built on the infrastructure for information exchange that this expansion has produced. To understand the nature of this new intelligence, it is considered important that fresh attention be paid to research about human beings.

Since its formation in 1910, Hitachi has expanded its business activities into various fields including electrical goods, machinery, transportation, materials, home appliances, electronics, medical equipment, information, and services. To provide a high level of technical strength to drive these businesses forward, the group established its first research section in 1918 and this was followed by the establishment of the Hitachi Research Laboratory in 1934 and the Advanced Research Laboratory in 1985. The group now has six different research laboratories under the direct control of headquarters (see Fig. 1). The group has been accelerating its global expansion in recent years in particular, and by 2007 had reached 10 trillion yen in sales and a total of 390,000 employees. Given the extensive scope of its business activities



Central Research Laboratory

Advanced Research Laboratory

Hitachi Research Laboratory

Systems Development Laboratory

Mechanical Engineering Research Laboratory

Production Engineering Research Laboratory

Fig. 1—Six Research Laboratories Directly Managed by Hitachi Headquarters.
Research and development at Hitachi started with the establishment of a research section in 1918. Hitachi currently has six research laboratories under the direct control of Hitachi Headquarters.

and the depth of the technologies that underpin them, Hitachi sees one of the missions for itself and its research and development as being to take maximum advantage of how it brings all of these together under the same roof and management structure in a large organization to gain an overview of human society in the 21st century and anticipate what directions it will take. By extending the analogy of the biological activities referred to in the opening sentences and considering each business and each technology as a separate intelligence, a broad-based electrical equipment manufacturer should be able to achieve extensive synergies.

This feature consists of 10 articles, including this one, that describe the results of human-related research work carried out by research and development at Hitachi.

Following this introduction, the next four articles deal with core technologies that relate to different business areas. The second and third articles describe technologies for human measurement, with the second article describing approaches to the internal direct measurement of human brain activity and the third article looking at external observation of human behavior. The fourth and fifth articles describe techniques for artificially simulating human beings, with the fourth article describing approaches to using information processing to simulate intelligence and the fifth article describing approaches to simulating body action using robots. These articles dealing with core technologies attempt to understand the trends in the various internal and external techniques that have been developed over many years.

The next four articles describe human-oriented application technologies from fields with which the core technologies are associated. The sixth article looks at transportation and the seventh, eighth, and ninth articles give an overview of human-oriented directions in the home, office, and industry domains that are linked together by transportation. These application articles aim to give an overview of internal and external applied technologies that covers the extensive business activities of Hitachi, Ltd. and the Hitachi Group. The tenth and final article introduces a focus on health issues and looks at the potential for human-oriented technology across our entire lives, including time.

The remainder of this current article aims to model and visualize the broad trends discussed in the remaining nine articles.

Hitachi Hyoron (the Japanese version of Hitachi Review) was first published in 1918 at the same time as the first research section was established at Hitachi and one of the principles laid out in the inaugural issue[1] was innovation through the open publication of information in order to "bring about an alignment in the opinions of producers and consumers." Through the Japanese and English editions of these articles, we hope that publishing the potential directions for its human-oriented technology will encourage feedback from around the world, and that cooperation based on this feedback will make it possible to convert this potential into reality at an early stage.

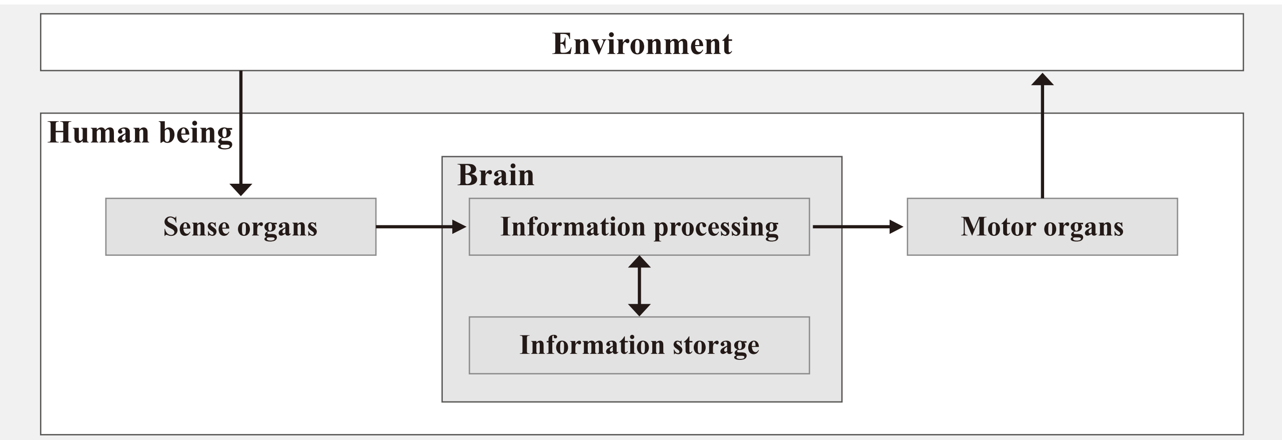


Fig. 2—Simplified Model of Human Being.
The sense organs obtain information from the environment which is then processed by the brain and leads to actions being performed on the environment by the motor organs. In processing this information, the brain uses its own individual characteristics as well as past experience, and the results of this information processing in turn accumulate in the form of new experiences or characteristics.

HUMAN MODEL AND CORE TECHNOLOGIES

As a simplified model of a human being, a system consisting of sense organs, a brain, and motor organs can be considered in terms of its relationship with the external environment (see Fig. 2). In this system, the sense organs obtain information from the environment which is then processed by the brain and leads to actions being performed on the environment by the motor organs. In processing this information, the brain uses its own individual characteristics as well as accumulated past experience that it stores internally, and the results of the processing in turn continuously update the brain's experience and characteristics. Although it is probably impossible to elucidate this entire system for an actual human, the following four approaches are essential to the aim of providing partial explanations.

The first is measurement of brain function [see Fig. 3 (a)]. The discovery of X rays by Röntgen in 1895 made it possible to see the two-dimensional shadows that are produced when X rays pass through a living body, and a mathematical proof of the ability to reconstruct a two-dimensional internal structure from a single-dimensional shadow in infinite directions was demonstrated in 1917 by the formulation of the Radon transform. This was realized in an actual machine in 1979 with the invention of CT[a] which resulted in the awarding of a Nobel Prize[2], and the static structure of the living brain was progressively elucidated over the course of the 20th century. Entering the 21st century, the technology for obtaining an understanding of dynamic brain function has made significant advances. These include the invention of MRI[b] which, rather than using invasive X rays, works by controlling an externally applied magnetic field and measuring the resulting changes in the body's magnetic field which can then be used to construct a three-dimensional map of the density of water molecules inside the body, and the development of optical topography[c] which uses near infra-red light to make direct measurements of changes in the volume of hemoglobin contained in blood in the surface regions of the brain. Another development was magneto-encephalography[d] which can directly measure the magnetic fields produced by the electric currents that flow along nerves inside the brain and use this information to generate images.

It is anticipated that the elucidation of dynamic brain function will have some role in the prospects for society in the 21st century. Hitachi has been engaged in research and development of the CT, MRI, optical topography, and magneto-encephalography techniques described above from an early stage. The second article in this feature ("Measuring Brain Function") outlines the status and future prospects for research and development at Hitachi.

The second approach is the measurement of human behavior [see Fig. 3 (b)]. Whereas the brain measurement techniques described above aim to measure brain functions directly, behavior measurement involves external observation of the behaviors that people perform or otherwise output to the environment in response to the information that they input from the environment. Semiconductor integrated circuits and their associated miniaturization technologies have undergone rapid development since they first appeared in the 1960s. By using MEMS[e] and other devices made possible by this technology, it has become possible to carry around sensors, computers, and radios unobtrusively[3]. The infrastructure for information networks allows real-

(a) CT
Abbreviation of computed tomography. A device that uses radiation, typically X rays, to scan internal organs and produce a visual image. The device generates X rays as it rotates around the subject and a computer processes the collected data to reconstruct cross-sectional images. In recent years, advances in image processing technology have also made it possible to display three-dimensional images.

(b) MRI
Abbreviation of magnetic resonance imaging. A device that exposes the human subject to an electromagnetic field generated by a superconducting magnet, permanent magnet, or similar to capture images from inside their body. MRI works by utilizing the resonance of hydrogen nuclei in the subject's body that occurs when radio waves at a specific frequency are applied to a subject placed in a static magnetic field. The internal structure of the body is detected as a weak signal which is used to generate images.

(c) Optical topography
A non-invasive technique for imaging and measuring brain function that uses light shone through the scalp to measure changes in the densities of oxygenated and deoxygenated hemoglobin resulting from the changes in blood flow caused by brain activity.

(d) Magneto-encephalography
A method for measuring the extremely weak magnetic fields generated by the activity of nerve cells in the brain (intracellular currents) from outside the head. Measurement of the magnetic fields generated by intracellular currents requires even greater time and space resolution than is needed for electro-encephalography.

(e) MEMS
MEMS is an abbreviation of micro-electromechanical system and refers to devices that combine miniature mechanical structures with an electric circuit. Example uses include acceleration, pressure, flow, and other sensors, optical switches, inkjet print heads, and DNA (deoxyribonucleic acid) chips. MEMS is expected to be used in a wide range of applications in the future.

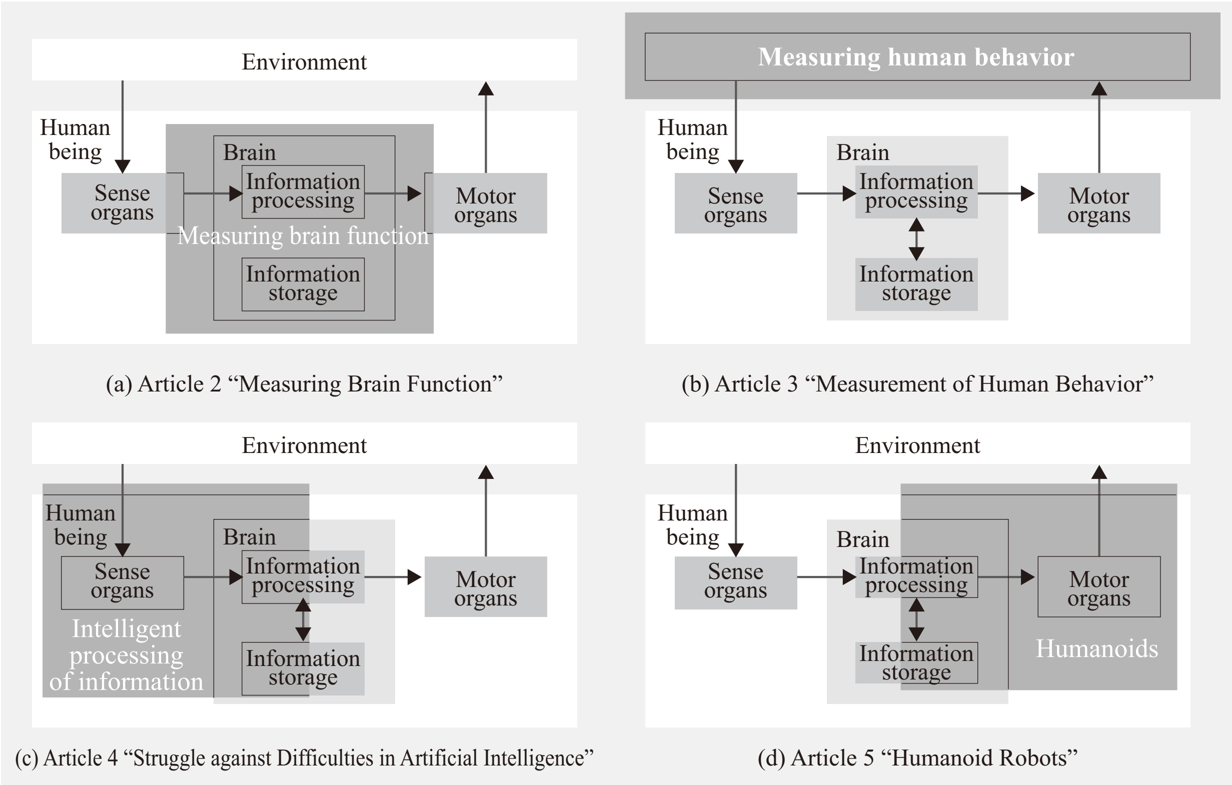


Fig. 3—Role of Core Technologies Described in Articles 2 to 5 of this Feature.
Articles 2 and 3 (top) deal with technologies for human measurement and articles 4 and 5 (bottom) with technologies for artificially replicating human beings.

time information exchange from anywhere in the world. If all of the information provided by portable sensors and placed on the international network infrastructure via wireless communications could be made available, there is no doubt we would obtain significant knowledge about the behavior of the entire human race.

Hitachi has been actively researching topics such as semiconductors, MEMS and other types of sensors, information networks, and data mining of the huge volumes of information generated by the world around us. The group has also in recent years engaged in research and development to determine the status of an organization from the behavior of the individuals of which it is comprised, and to find ways to increase the value of the overall organization. The group has already established a behavior database covering 30,000 person-days and is building up know-how on how to process this data. The third of these feature articles ("Measurement of Human Behavior") outlines the current status and future potential of this research and development with a special emphasis on ways of understanding people.

The third approach is the intelligent processing of information [see Fig. 3 (c)]. Here, the expression "intelligent processing of information" refers to the use of computers as a substitute for humans in the role of observing the environment and processing the information obtained. This area was first established as a fully fledged research field in 1956 by a conference held at Dartmouth in the USA[4]. Of the various problems for which the goal of approaching human levels of performance was established at that time, some such as board games and inference have already surpassed human abilities. Other areas have reached a level where they can provide support for human tasks. Examples of these include the use of visual recognition functions in the automation of industrial inspection or to improve vehicle driving safety, and the use of natural language processing in machine translation. On the other hand, use of computer processing to perform intelligent dealing in financial products risks triggering a financial crisis caused by computer software programs interacting in unanticipated ways. Computer functions are still limited in areas such as abstraction and imagination. Investigating the current differences between the abilities of computers and people and considering whether or not these can be bridged by advances in computer performance should be of great significance in predicting the sort of world we will face in the 21st century.

In pursuing the development of computers and various different application systems over the last fifty years, Hitachi has made progress on the computerization of human intelligence. The fourth feature article ("Struggle against Difficulties in Artificial Intelligence") looks back at this experience and outlines the future potential of this work.

The fourth approach is the humanoid [see Fig. 3 (d)]. Here, the term "humanoid" is used to indicate a particular type of mechanism for performing actions on the environment based on the results of information processing that is implemented in the form of a robot that resembles a human being and uses simulated human motor organs. An example from the past is the designs by Leonardo da Vinci for armored warrior robots[5], while in the modern era the dream of robots replicating human motor functions in human form appears to be alive and well in Japan at least judging by how often they appear in literature, movies, and other media.

This field has seen rapid technical progress in recent years, including control of bipedal walking, mainly due to the dramatic increase in computer processing performance and advances in real-time control software that take advantage of this performance.

Hitachi has been involved in robotics research and development from an early stage against a background of demand for such systems in fields such as factory automation and performing work in extreme environments. Recently, new humanoid robots have been produced based on the key concept of "symbiotic coexistence with humans." The author of this article has also spent some time on research and development in the fields of intelligent processing of information and autonomous mobile robots[6]. The fifth article in this feature ("Humanoid Robots") gives an overview of past research and development in the field of humanoid robots and summarizes the current situation.

SOCIETY MODEL AND APPLICATION TECHNOLOGIES

A system in which the home, office, and industry spaces are linked by transportation space can be considered as a simplified model of human society (see Fig. 4). In this model, the home space is the center of human movement, the industry space is the center of merchandise movement, and the office space is the center of the movement of information including money. Whereas human-oriented technology in the industry space revolves around the points of contact between people and goods, the principal axis in the office space is at the points of contact between people and information and the model considers the clear differences between the functions of the sense organs and motor organs in the human model in Fig. 2. The article uses the businesses operated by Hitachi to give an overview of human-oriented application technologies for the four spaces in this model of society.

The first of these is human-oriented technology for transportation [see Fig. 5 (a)]. In addition to core technologies for transportation comfort and safety, functions for providing information for work and leisure while commuting are also recognized as having become part of the human-oriented direction in recent years. Hitachi businesses involved in the transportation domain include rail systems (driving control and manufacture of rolling stock), automotive equipment and components including navigation systems, lifts (elevators, escalators, and travelators), construction machinery, defense systems, and monorails. A basic model common to all of these business fields is to use sensors fitted to a mobile vehicle to detect information such as the surrounding environment, the movement of the vehicle relative to the environment, and the activity of the people riding on the vehicle, and then to process this information

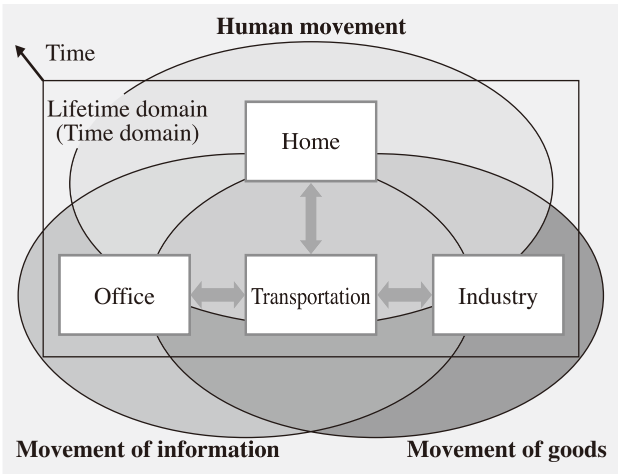


Fig. 4—Simplified Model of Human Society.
Homes are primarily a place for human activity, industry is primarily a place for the movement of goods, and offices are primarily places for the movement of information including money. These spaces are linked by transportation and extend across the lifetime domain (time domain).

based on existing knowledge and other factors and apply the results to operational control in real-time and also supply it to the people riding on the vehicle. Based on this model, the sixth article in this feature ("Toward Human-oriented Transportation") gives an overview of the current status of application technologies for the key human-oriented axes described above.

The second is human-oriented technology for the home [see Fig. 5 (b)]. In addition to making our lifestyles more comfortable and reducing the cost of living, human-oriented technologies in recent years have also been directed towards ensuring health and safety. In the home domain, businesses in which Hitachi is involved include electrical products as well as information systems and services used in daily life. Hitachi electrical products include refrigerators, air conditioners, washing machines, vacuum cleaners, and cooking appliances, and also televisions, cameras, and the AV (audiovisual) equipment for storing the data used by televisions and cameras. A proposed common model for these businesses is the concept of a society of ambient information. Based on this model, the seventh article in this feature ("Toward Human-oriented Home") gives an overview of the current status of application technologies for the key human-oriented axes described above.

The third is human-oriented technology for the office [see Fig. 5 (c)]. In addition to key issues from the past such as the improved response of office IT equipment due to better processing performance, recent years have also seen a strong trend toward more sophisticated data security functions against a backdrop of demands from society relating to concerns such as the protection of personal information and the prevention of information leaks, and it is anticipated that more sophisticated ways to collect information to support intellectual activity by office workers and data mining functions for this information will play a central role in human-oriented technology in the future. In the office domain, businesses in which Hitachi is involved include data storage [RAID (redundant arrays of inexpensive disks) and HDD (hard disk drives)], servers, networks, information systems, services, and data centers. The proposed underlying model common to all these businesses is the KaaS[f] concept based on the idea of turning knowledge into a service. The eighth article in this feature ("Toward Human-oriented Office") follows this concept and gives an overview of the current status of application technologies for the key human-oriented axes described above.

The fourth is human-oriented technology for industry [see Fig. 5 (d)]. This overview of the trends in human-oriented technology focuses on the points of contact between people and goods in industrial

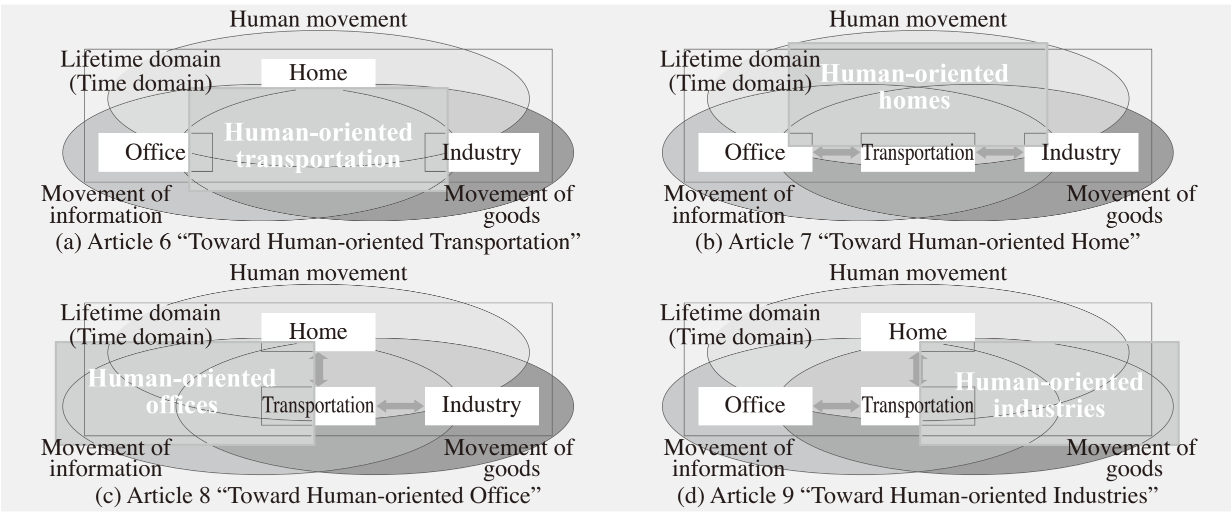


Fig. 5—Role of Application Technologies Described in Articles 6 to 9 of This Feature.
These articles outline how human-oriented application technologies are manifest in the transportation, home, office, and industrial domains.

(f) KaaS
Abbreviation of knowledge as a service. A service model in which large volumes of log, sensor, and other data collected from actual work are collated and analyzed to transform them into added-value knowledge (intelligence) that can be supplied or returned to customers.

processes from design through to production, distribution, and maintenance. As well as being a producer itself of end products in specific industries, Hitachi also produces industrial plant and equipment for a wide range of different fields. Based on this model, the ninth article in this feature ("Toward Human-oriented Industries") gives an overview of the current status of application technologies for the key human-oriented axes described above.

As well as encompassing the above four domains, human life also extends across the time domain as shown in Fig. 4 where it is called the "lifetime domain."

Finally, the tenth article ("Toward Human-oriented Life") adds the concept of time, introducing "health" as an additional axis that encompasses both the four articles describing human-oriented core technologies and the four articles describing application technologies. Using prevention, diagnosis, and treatment as specific examples, this article seeks to identify the directions being taken by human-oriented technologies in this area.

OVERVIEW OF HUMAN-ORIENTED RESEARCH AND DEVELOPMENT

This article has defined models that respectively cover the entirety of the core technologies and application technologies dealt with by human-oriented research and development with the aim of identifying the underlying elements. For the core technologies, the article has proposed a model of an individual human being and outlined the future for the underlying elements thus identified based on an historical overview. For the application technologies, the article has proposed a model of the entirety of human society and outlined the future for the identified underlying elements by giving a cross-sectorial overview covering the specific business areas in which Hitachi is active. The article then concluded by touching on the overall outlook for these areas in terms of the lifetime domain that encompasses the above topics and also extends across time.

REFERENCES

(1) K. Baba, "Thoughts on the Inaugural Edition of Hitachi Hyoron," Hitachi Hyoron **1** (Jan. 1918) in Japanese.

(2) G. N. Hounsfield, "Computed Medical Imaging," Nobel Lecture (Dec. 1979).

(3) "ACM Transactions on Sensor Networks" (2005).

(4) J. McCarthy et al., "A Proposal for the Dartmouth Summer Research Project on Artificial Intelligence" (1955).

(5) M. Taddei, "Leonardo da Vinci's Robots" (2007).

(6) H. Takeda, et al., "Planning the Motions of a Mobile Robot in a Sensory Uncertainty Field," IEEE Trans. Pattern Analysis and Machine Intelligence **16**, No.10, pp.1002-1017 (1994).

ABOUT THE AUTHOR

Haruo Takeda, Dr. Eng.

Joined Hitachi, Ltd. in 1980, and has held various posts including General Manager of the Strategy Center of the Research & Development Group. He is currently the General Manager of the Advanced Research Laboratory. His specialist fields include applied mathematics, information science, video and image processing, and management of technology. Dr. Takeda is a visiting professor at The University of Tokyo and a member of the IEEE.