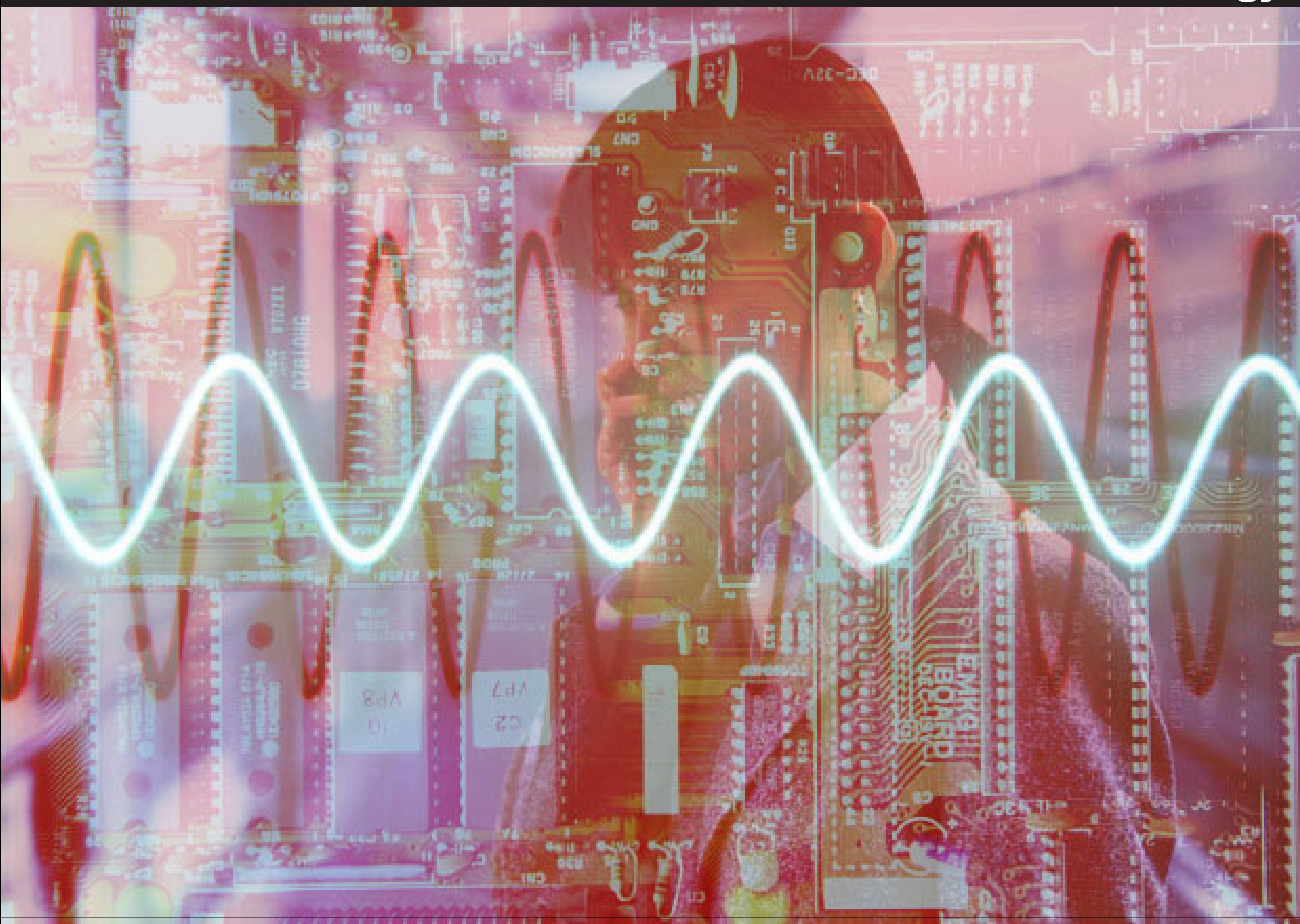
ISSN 1349-3531

NICT NEWS

9
SEP. 2006
No.366

National Institute of Information and Communications Technology



Seeing the Dreaming Brain
Development of a Brain-Wave-fMRI Simultaneous Measurement System

Satoru Miyauchi, Masaya Misaki, Shigeyuki Kan, Takashi Abe, Takahiko Koike, Kazuki Iwata, Sachiko Takahama
CREST Brain Function Imaging Team, Kobe Advanced ICT Research Center

A Third of Our Life is Spent Asleep

Humans sleep six to eight hours every day, and as it is often said, we spend a third of our lives asleep. Is sleep just a “process of resting”?

Recent studies in neuroscience have begun to reveal that this is not the case, and that the brain activity that takes place during sleep closely associated with waking activities. Through this activity, the information we have memorized or learned during the day is spontaneously reprocessed in our brain during sleep, and fixed into long-term memory. However, studies dealing with the reprocessing of the memorized and learned information during sleep have all been conducted on rats; to date, few studies are available on humans, where the cerebral cortex is significantly more developed than in rats.

Development of a System for Simultaneous Measurement of Brain Waves and Functional Magnetic Resonance Images

In 1993, NICT installed an MRI (Magnetic Resonance Imaging) unit with the aim of incorporating advanced information-processing functions of the brain into info-communication technologies, followed by studies on non-invasive measurement of human brain functions using fMRI (functional Magnetic Resonance Imaging). In 1990, the principle of fMRI was discovered by Doctor Seiji Ogawa (presently at the Ogawa Laboratories for Brain Function Research), and it is a method of precise, non-invasive measurement of the active regions of the human brain, detected by changes in blood flow (Fig. 1). However, with fMRI, it is not possible to determine directly whether the subject is excited, relaxed, or asleep. In contrast, brain waves—recordings of neural activities in the human brain taken by attaching electrodes to the head—cannot precisely determine the active region of the brain, but will clearly show the status of the subject, whether he or she is awake, asleep, and even how deeply the subject is asleep (Fig. 2). Therefore, to observe brain activity while asleep using fMRI, brain waves must also be recorded at the same time. Under normal conditions, the measurement of brain waves is simple. However, in fMRI, a localized magnetic field is inclined relative to a static magnetic field generated by a superconducting magnet that is several tens of thousands times stronger than the Earth’s magnetic field; the local field is rapidly inverted to scan the subject’s head with electromagnetic waves of around sixty to approximately one hundred and thirty Megahertz (Fig. 3). The effects of these changes on the magnetic field, and the effect of strong static magnetic fields and electromagnetic waves cause the recording of brain waves (which are on the order of several tens of micro volts) to be contaminated with noise an order of a magnitude larger than brain waves (Fig. 4), rendering it extremely difficult to perform simultaneous measurements of brain waves and fMRI.

Since 2002, the CREST Brain Function Imaging Team of NICT’s Kobe Advanced ICT Research Center has embarked on the development of a simultaneous measurement system for brain waves and fMRI, and after some attempts at modification of the hardware and software, we have succeeded in removing the effects of noise on the recorded brain waves associated with fMRI imaging, thus obtaining stable brain wave recordings. In addition to the simultaneous measurement of brain waves and fMRI, we have established work on a system for recording the eye and body motions of the subject using an infrared camera (Fig. 5). We are now conducting studies on the reprocessing of memorized and learned information during human sleep using this system.

Dreams: The Brain’s Ultimate Virtual Reality

One may acknowledge that the activities of the brain during sleep are associated with memory and learning during waking hours, but be forgiven for wondering why a research institute for communication should be interested in sleep. Human sleep can be largely divided into REM sleep, during which the eyes move rapidly, and NREM sleep, during which the eyes remain still (Fig. 2). It is during REM sleep that humans frequently dream. The duration of REM sleep depends on the person’s age, but generally for adults, about one-fourth to one-fifth of the time asleep is spent in REM activity. So if we assume that we spend a third of our lives asleep, then we can say that we spend one-twelfth to one-fifteenth of our lives in a dream, as it were. Of course, during dreams, there is no sensory input from the eyes. Thus, dreams may be regarded as the ultimate virtual reality, created spontaneously by the brain. Our brain creates a virtual reality that is indistinguishable from reality, one that even a virtual-reality laboratory equipped with the largest screen and the most sophisticated surround-sound system could not reproduce, and this is accomplished even without stimulus from the outside world. The language, image, and audio information (physical energies of light and sound) used in current communication systems can only be input through sensory

Life and Technology

Q: Is the present research for resolving the mechanism of brain functions applicable to the field of medicine?

A: Yes, it is. Non-invasive brain function measurement in the past has involved measurement of brain activities with respect to a pre-designated response (task) by presenting a subject with a visual stimulus, for example. In the case of certain disorders, such as dementia, subjects are unable to perform the given tasks. Thus, the doctor will be unable to determine whether a certain brain region is not activated because the patient cannot perform the task or because the brain region itself is not functioning. However, the brain-wave-fMRI simultaneous measurement system will permit observation of regions of the brain showing spontaneous activity such as brain waves and eye movement. In the future, it should therefore be possible for a subject simply to take a nap inside an MRI unit to enable diagnosis and prognosis of any of a variety of brain disorders.

organs such as the eyes and the ears. However, our brain creates all of these sensations—including the visual and auditory senses—and even emotion, in our dreams. We could say that every night each of us plays the role of Keanu Reeves in The Matrix. We believe that the brain-wave-fMRI simultaneous measurement system developed by our team will close in on the mechanism through which this takes place: researchers are dreamers, aren't they?

NICT's future plans to promote R&D on info-communication technologies include those approached from the standpoint of neuroscience, as in this example.

Fig 1. Example of measurement with fMRI. The human brain is viewed from the right side; the region colored in yellow to red is the active region of the brain associated with eye movement.

Fig 2. Example of human sleep cycle.
Human sleep can largely be divided into REM (Rapid Eye Movement) Sleep and NREM (Non-Rapid Eye Movement) sleep. NREM sleep is further categorized according to the depth of sleep, in stages 1, 2, 3, and 4. Deep NREM sleep tends to appear in the first half of sleep, and REM sleep, shown in green, appears more often in the second half of sleep.

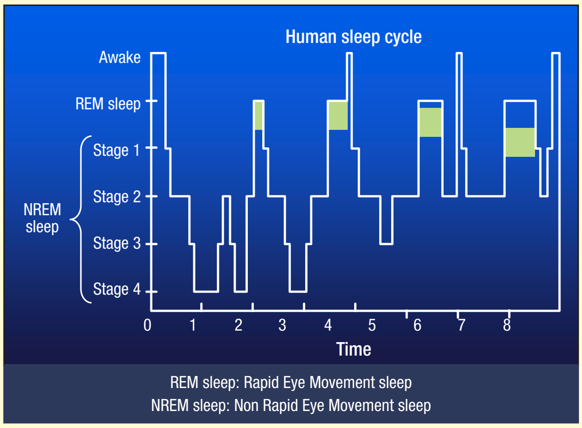


Fig 3. Schematic diagram of MRI instrument and a photograph of MRI instrument at NICT

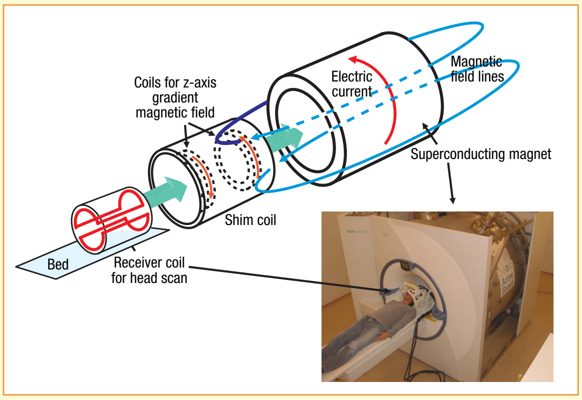


Fig 4. Brain wave and electrocardiogram recorded for a subject inside the MRI unit

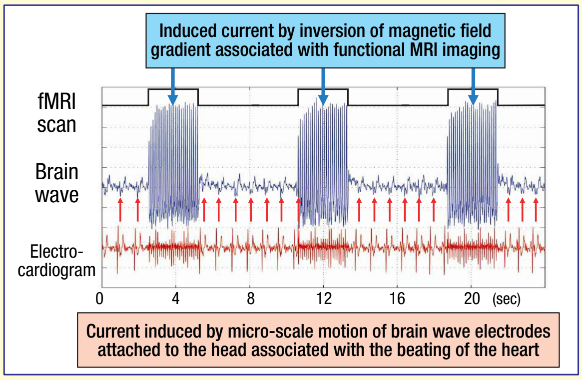
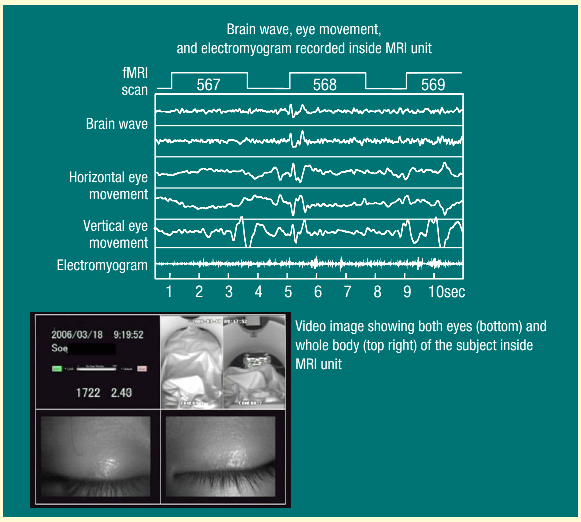


Fig 5. Brain wave, eye movement, and electromyogram of the mentalis muscle (muscle of the chin) (top) and video image of the subject asleep inside the MRI unit (bottom). The deflection in eye movement show movements during REM sleep.



Researcher

Satoru Miyauchi
CREST Brain Function Imaging Team
Kobe Advanced ICT Research Center
Research Department 1

After completing his graduate course, studied at Brown University in the U.S. and the National Institute for Physiological Sciences (NIPS) of the National Institutes of Natural Sciences (NINS) in Japan; joined the Communications Research Laboratory (presently NICT) in 1993. Currently involved mainly in research and development of non-invasive brain function measurement systems such as fMRI, brain waves, and neuromagnetic imaging. Doctor of medical sciences.

This month's key concept

[fMRI (functional Magnetic Resonance Imaging)]

The "f" in fMRI stands for functional, and the "MRI" stands for magnetic resonance imaging. This is a method for visualizing neural activity within the living body (especially the brain) using magnetic resonance. In contrast to MRI, which obtains a structural image of the brain, fMRI images the neural activities of the brain with high spatial resolution using the changes in the magnetization of the blood associated with changes in blood flow. Thus this method is referred to as functional magnetic resonance imaging. By performing continuous observation while a subject is performing a task, it is possible to examine the active regions of the brain without discomfort to the subject, rendering this method an ideal tool for cognitive neuroscience studies.

Research

Application and Utilization of ICT in the Fields of Medicine & Health — Towards a More Fruitful Society —

Establishment of a Medical ICT Group

The 2nd Middle-Term Plan at NICT have begun. In line with these plans, the Medical ICT Group was established within the New Generation Wireless Communication Research Center as the main body for R&D on wireless body-area communication technologies for internal and external communication processes in the human body. NICT has also initiated research on a ubiquitous medical network using satellite and ground-based infra-networks, and well as research on updating and regulating technological standards for wireless communication systems targeted at the medical field. This article will introduce the relationship between ICT and the fields of medicine and health, and will also address the roles of the Medical ICT Group.

Wireless Body Area Communication Technologies

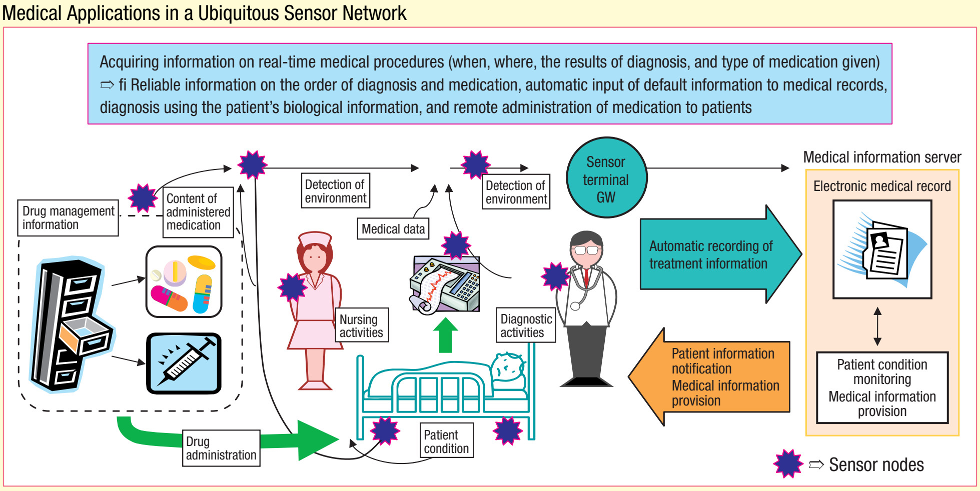
Wireless body-area communication technologies include ultra-small antenna technology for wireless transmission within and exterior to the human body, the construction of a wide-band radio propagation model for the human body at frequency bands greater than 1 GHz, modification of the applicable communication methods (UWB, Bluetooth, Zigbee, etc.), and basic technologies for wireless transmissions within and near the human body. Our practical goals revolve around R&D, standardization, and regulation of a body area network (BAN) and medical RFID. In our aging society with a falling birthrate, medical ICT is expected to have a great impact on a number of fields, such as medicine and health-care, and is receiving widespread attention from both foreign and domestic institutes.

On the other hand, the computerization of medicine has been the subject of study since the Ministry of Health, Labour and Welfare drew up its “Grand Design for Computerization in the Health-Care Field” in December 2001, with the establishment and pursuit of various quantitative goals for electronic medical record keeping systems and on-line management of receipts. Furthermore, priority will also be given to a theme presented as one of the overarching goals of the 3rd Science and Technology Basic Plan, launched this year: the protection of health and safety. We will also focus on the theme of promoting the use and application of ICT to medicine, as set forth in the u-Japan policy of the Ministry of Internal Affairs and Communications.

Expectations for Medical ICT

To respond to these demands in priority research areas, R&D on the basic technologies for constructing a ubiquitous network (such as RF tags and UWB technologies) has formed the subject of intense study among the advanced technologies under investigation in the ICT field. The application of these technologies is expected to bring about a new era of “ubiquitous medicine” in the field of computerized medicine. The introduction of wireless technologies into medical equipment is also expected to permit doctors to automatically receive information on the health of patients in remote areas by wireless communication and to allow patients to receive continued health diagnoses and long-term advice from their doctors. These developments may also allow doctors to treat patients with serious conditions via remote control of syringes or fluid delivery systems, allowing automatic injection of drugs in a much more time-efficient manner.

Medical Applications in a Ubiquitous Sensor Network



The Role of Medical ICT Group

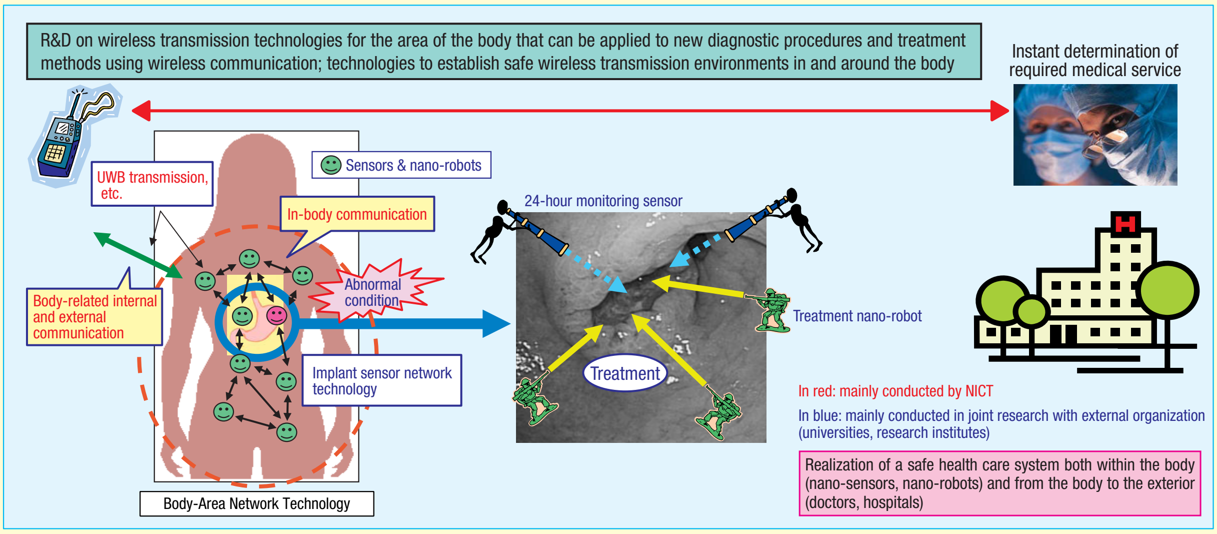
Two approaches must be taken if we are to bring medical ICT to fruition — the micro-scale approach, in which the performance of the individual technologies involved are modified and improved, and a macro-scale approach, in which various combinations of the numerous applicable technologies in existence are examined for new uses. Based on these approaches, NICT has decided to establish a Medical ICT Group,

Life and Technology

Q: How will R&D on wireless body-area communication technologies benefit us in terms of health care?

A: Health information will be automatically sent to hospitals and recorded, with diagnoses performed as we go about our normal lives. Physicians will automatically step in when there are signs of abnormal health. Furthermore, “medical robots” may even become reality, which could be remotely controlled from the hospital, allowing for the automatic prescription and administration of medication.

Future themes for the Medical ICT Groups



which will re-examine the achievements of NICT's past R&D efforts in related technologies and conduct R&D on medical ICT-associated fields. The following themes will comprise the group's main pursuits.

(1) R&D on BAN and Implant Sensor Network

This subject includes technologies such as wearable sensors and implanted sensors within the body that will collect biological information, such as induced electrocardiograms and heart rates. This area also encompasses the technology required for constructing a specialized sensor network for the body that will minimize the adverse effects of treatment on the patient's body through the remote instructions of a doctor.

(2) R&D on a Ubiquitous Medical Network

These technologies will offer medical services that can be administered away from a medical facility, through the transmission of biological and treatment information collected via RFID and BAN using satellite communication, cellular phone systems, and the Internet.

Biological information contains private individual information, and will require the utmost caution in handling. Therefore, a secure system will have to be established to send such information over wireless and wired networks, to prevent this data from eavesdropping; research on such systems will thus form an important focus.

On the other hand, standardization of these systems will also be required. The Medical ICT Group has actively worked to promote such standardization, taking part in the foundation of a group for BAN studies at the International Standardization Organization IEEE802.15. In Japan, we have established a commission that will play the central role in the establishment of a "Medical Consortium," in collaboration with over 20 private businesses and universities; the activities of this commission are now coming into full force. In the future, we hope to standardize the elementary technologies proposed by NICT, helping to create successful medical ICT businesses with the cooperation of the consortium participants.

Pioneering Future Medicine

Medical ICT is an integrated innovation of advanced technologies aimed at pioneering medical applications of advanced ICT technologies and future medicine using advanced ICT. We believe this area of study will create new markets and trigger technological innovations in the ICT industry. Furthermore, the results of these efforts are expected to have an enormous impact on our social lives as well. The Medical ICT Group thus hopes to contribute generally to society through its R&D related to medical ICT.

Researcher

Ryuji Kono
Group Leader, Medical ICT Group
New Generation Wireless Communications Research Center, Research Department 1

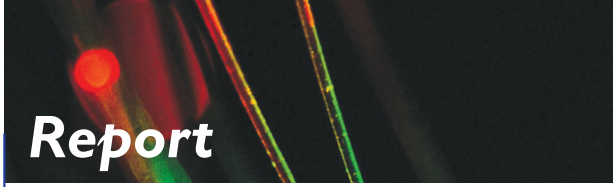
Joined NICT in 2002; Group Leader for the UWB Technology Group prior to taking current position. Professor at Yokohama National University; fellow of the Institute of Electronics, Information and Communication Engineers.

This month's key concept

[Medical ICT (Medical Information and Communication Technology)]

Generally, "medical ICT" refers to the application and utilization of info-communication technologies in the field of medicine. In the basic policies of the nation presented this year*, the anticipated roles of medical ICT included the improvement of the quality of medical service, reduction in workload and increased efficiency, improvement of the safety and public trust in medical service, and the provision of a so-called "patient-first" service. In this context we must recognize that it has been pointed out that progress in medical ICT in Japan is significantly lagging behind that of other advanced countries.

* Report by the "Commission on the Application and Utilization of ICT in Medical Fields" (Presented by the Ministry of Internal Affairs and Communications on April 18, 2006)



Report on Summer Science Camp 2006

Yoshiki Arakawa, Project Promotion Office, Knowledge-Creating Communication Research Center

The Summer Science Camp 2006* was held at NICT's Knowledge-Creating Communication Research Center from Wednesday, August 9 to Friday, August 11, 2006. This year's theme was "Let's Experience Future Communication." 12 high school students coming from all parts of Japan joined in the camp (Photo 3).

On Day 1, after the opening ceremonies, the Computational Linguistics Group headed the camp with their theme, "Chat and translation systems, and new-generation browsers." Through chat with foreigners using the machine translation system and practice on collecting information from foreign sites, the students had a rare opportunity to experience firsthand the translation technologies and the system developed by NICT (Photo 1).

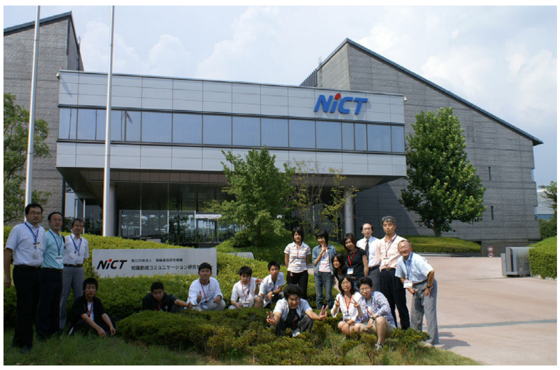
On Day 2, the Spoken Language Communication Group gave a course on speaking with foreigners using an automatic voice translation system. A lecture was given on the automatic voice translation system, and then students had some time to speak with foreigners using the system. The students also made a study tour of the Advanced Telecommunications Research Institute International (ATR). In the evening, a barbeque party allowed everyone to get acquainted.

On Day 3, under the theme of the ubiquitous sensor network, the Universal City Group gave a lecture on ubiquitous sensors (specifically, an ultrasonic sensor) and the students did an experiment to determine positions using the sensors (Photo 2). A closing ceremony was held in the early afternoon, and certificates of completion of a course were handed out to the students by the Center's Deputy Director, Dr. Igi.

Normally, the researchers at our center have the opportunity to discuss these issues only amongst specialists, and so the camp was a refreshing experience for us, giving us direct contact with fresh-minded young people eager to share whatever views and questions that pop into their minds. We also enjoyed being able to present our achievements and ongoing research activities; in short, the camp represented very productive outreach for the Center.

(Photo 1) Collecting information from foreign sources using the machine translation system

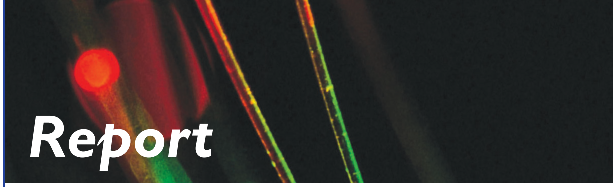
(Photo 2) Experiment to determine positions using ultrasound sensor



(Photo 3) Participants and staffs

* Science Camp

The camp is sponsored by the Japan Science and Technology Agency and managed and operated by the Japan Science Foundation. National testing and research institutions and independent administrative agencies accept high school or technical college students at their facilities for the science and technology experience camp. The aim of the camp is to cultivate interest in science and technology and nature though courses and experiments that reflect the activities of the Institute, as well as simply to promote friendship among



Performance Result Report of Open Demonstrative Experiment regarding Sponsored Research Promoted by NICT

<Expectation for Safety and Security of New Services Linking Conveniences Stores and Inhabitants>

Shingo Shoji, Sponsored Research Promotion Division, Research Department Promotion, NICT

A new technology has been created in the Sponsored research promoted by NICT. The research theme was entitled “R&D on Authentication Roaming between Different CAs”, which was contracted with Tepco Systems Corporation and Mitsubishi Electric Corporation in 2005, and “Authentication Roaming” is the developed technology which permits sharing the results of authentication among the existing societal infrastructures. In practice, the authentication information was coordinated between two entities, a convenience store and a university, and therefore, its open demonstrative experiment succeeded in the result that a student registration and graduation certificate issued by the university could be retrieved at a convenience store.

In August 30, 2006, the press conference and demonstration regarding the technology concerned was held at the headquarters of Seven-Eleven Japan in Kojimachi. The press conference held in the first half of the appointed day was attended by Dr. Kato, Vice President of NICT, Mr. Kyuma, Standing Executive Officer and Vice president of Development Division of Mitsubishi Electric Corporation, and Mr. Hirai, President and C.E.O of Tepco Systems, Mr. Yamaguchi, President and C.O.O. of Seven-Eleven, adding Dr. Ohashi, Professor, Dean of Faculty of Policy Studies, Chuo University. Dr. Kato, Vice President of NICT, made a speech on the synopsis of the Sponsored research system and introduced the unique role of NICT as an organization to support the public, and finally he added, “I am very pleased that the research Sponsored by NICT has produced results which can contribute to inhabitants’ convenient life, expecting its future evolution.” The others made a speech on the role played in their respective organizations and future perspective in the present research and development.

After that, the event site was changed into the Seven-Eleven Store in front of Kojimachi Station, which was crowded with many people during the lunch time. And in there, an open demonstrative experiment was performed. Inside the store, users logged into the certificate issuance service at the university with their mobile phones, and then selected a certain branch of the convenience store as the site to issue the certificate, and finally obtained the printed certificate from a multi-functional copy machine in the store. Like this, these sequential steps were carried out on site, and its success made an appeal for being able to realize authentication processes in safe and secure collaboration. On that day, a great deal of people related and the press gathered for the open demonstrative experiment. Consequently, it was attested that they got a great societal interest to the technology concerned. The scenes of the open demonstrative experiment were broadcasted in detail by various TV networks and described in various newspapers. Moreover, NICT has received a lot of inquiries about the future possibilities for the technology from external organizations. Nowadays, the race to provide better services is heating up in the ever-increasing competition between convenience stores and between mobile phone companies. Thus, this research performance was indeed very timely and extremely relevant to current demands of the society.

More demonstrative experiments for this research are planned to continue through March, 2007 in order to increase the security of this technology, aiming to create new business models.

Open: Demonstrative Experiment regarding Sponsored Research Promoted by NICT
Date: August 30, 2006
Venue: Headquarters of Seven-Eleven Japan Co., Ltd.

NICT Vice President, Dr. Kato, addressing the press conference

Scene from the conference hall

Validation experiment inside the convenience store

Journal of the 2006 IEEE/EMC SOCIETY
Report on the “Most Outstanding Paper of the Year” Award

Kazuo Morita, Manager, Collaborative Research Management Group, Collaborative Research Department

A paper presenting the results of research at the Sendai EMC Research Center*1 has been awarded the “2006 Richard Schultz Transactions Prize Paper Award” at the “2006 IEEE*2 EMC SOCIETY Symposium” held in Portland, Oregon, U.S., on August 14–18, 2006.

The award was established in 1973, in memory of the late R.B. Schultz contributing editor to the academic journal EMC Transactions. Every year, the single most outstanding paper among the nearly 80 papers appearing in the IEEE EMC SOCIETY journal is awarded this prize; the current award is the first to be given to a Japanese group.

The Sendai EMC Research Center conducted its R&D project from FY 2000 to FY 2004*3, with the goal of establishing a technology for the quick and detailed observation of radio wave leakage, succeeding in the visualization of leakage from electronic devices; this leakage had been the source of numerous obstacles in electronic device design. With these results the Center has contributed to the overarching goal of establishing a safe electromagnetic environment.

The paper that received the prize introduces one of the achievements of this project, discussing the modification of an optical magnetic field probe that can measure high-frequency magnetic fields with high precision using optical beams and optical crystals. The paper also discussed the achievement of higher-frequency measurement relative to conventional probes — which make use of $LiNbO_3$ (lithium niobate) crystals — through the adoption of CdTe (cadmium telluride) crystals and more compact optical components. Our improved probe enabled the measurement of radio wave leakage up to significantly higher frequencies, representing an innovative technology that can contribute to resolving the problem of inter- or intra-device electromagnetic interference in electronic devices that involve frequencies in the increasingly utilized GHz band.

This award would not have been possible without the cooperation of many people both within and outside our institute who assisted us in these R&D efforts.

The achievements of the project have been passed on to a new R&D project, which began in 2005*4, through which we intend to continue our efforts and to produce even more innovative results.

*1: [Paper title] Optical Magnetic Field Probe Working up to 15 GHz Using CdTe Electrooptic Crystals
[Authors] Eiji Suzuki, Satoru Arakawa, Hiroyasu Ota (Researchers at the Sendai EMC Research Center), Kenichi Arai (Project Sub Leader), Risaburo Sato (Project Leader)
[Journal] IEEE EMC-T, Vol.47, No.2, pp.344-351, May 2005

*2: The official name of the IEEE is the “The Institute of Electrical and Electronics Engineering, Inc.,” and stands as the largest organization of engineers in the electrical and electronics field, with its headquarters in the U.S. In Japanese, this organization is normally referred to as the IEEE (the Electrical and Electronics Engineering Society). This non-profit organization consists of over 377,000 members from 150 countries around the world and plays a leading role in a wide range of technological fields associated with electrical, electronics, and communication technologies.

*3: “Research and Development Project to visualize Electromagnetic Fields Emitting from Electronic Devices with Three Dimensional Images” (Sendai EMC Research Center, FY 2000–2004)

*4: “Research and Development on Highly Sensitive Electromagnetic Field Measurement Technology for Wireless Security” (Sendai Research Center, FY2005–2009)


IEEE

IEEE Electromagnetic Compatibility Society

takes pleasure in presenting the

2006 Richard Schultz Transactions Prize Paper Award

to

Eiji Suzuki

For the paper co-authored with Satoru Arakawa, Hiroyasu Ota, Ken Ichi Arai, and Risaburo Sato entitled, “Optical Magnetic Field Probe Working up to 15 GHz Using CdTe Electrooptic Crystals” published in the IEEE EMC-T, vol. 47, no. 2, pp. 344-351, May 2005.

Andrew L. Drozd
President
EMC Society

Bruce Archambeault, PhD
Chairperson
EMC Awards Committee

EMC SOCIETY

Journal of the 2006 IEEE/EMC SOCIETY—“Most Outstanding Paper of the Year” Award
This is a photo of the diploma of merit received by each of the co-authors, with Dr. Eiji Suzuki’s shown here.

NICT NEWS

Published by:
Public Relations Division, General Affairs Department
National Institute of Information and Communications Technology

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