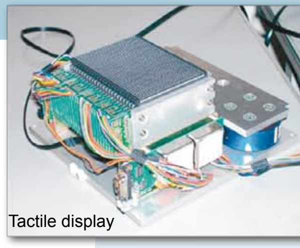
Information Technology on Five Senses

Research on the Five Senses by AIST is making great strides

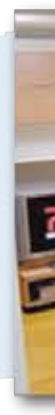
Information Technology on Five Senses



Tactile display

Research on the Five Senses by AIST is making great strides

System of remotely acquiring image data in an ambulance



Michitaka Hirose Research coordinator (Information Communications)

Information Technology of the Five Senses seen from the social perspective

During the last several years, the terminology of “Information Technology on Five Senses” has garnered attention from various areas. As far as I remember, that wording was first used in a report submitted by the Electrical Communications Technology Meeting: “Basic Plan on Information Communications Research Development”. My recollection of that time paints it as a suggestion that we would need to investigate such a new field and to explore it because we had entered into a situation in which new information interface technologies, such as virtual reality (VR) technology, were beginning to be introduced. More than four years have passed since then, and this wording now seems to imply that this technology is rather closer to the industrial world in addition to its recognized importance as a keyword in research work.

We could say that one background in which these changes are occurring is that our society is now more mature than ever. People now demand not products made based only on functionality and effectiveness, but those products that penetrate into our sensations. Now, five senses technology is required to produce such products to satisfy people’s demands.

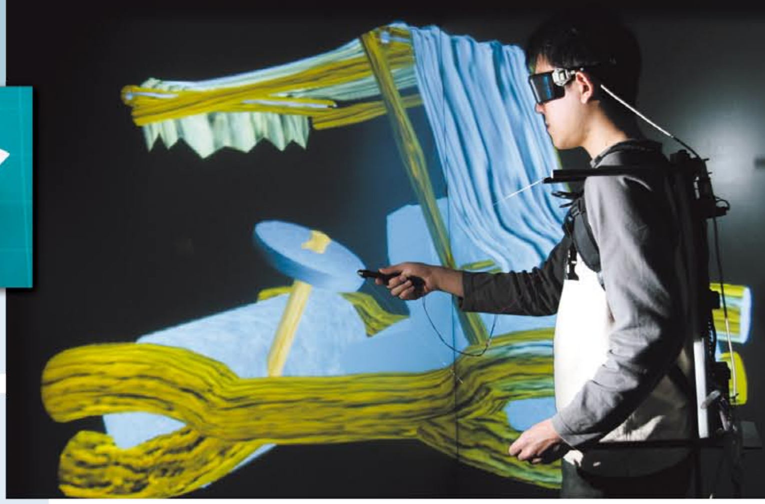
One more interesting aspect of technology is that information technology itself has changed to a mobile-type: it is becoming much clearer to everyone that we are facing a new phase of technology. Mobile-type information processing can function while the user is moving physically from one place to another. Therefore, we require new types of interfaces that differ starkly from ordinary visual interfaces. The Information Technology of the Five Senses is thus requested to exist in the sense of multi-level modality.

AIST’s research topics that are fully associated with Information Technology of Five Senses

One field that is associated with this technology in AIST is the information communications field. However, it is certain that the Information Technology on Five Senses is now leading the field to a new direction. Now that information processing technology is greatly progressed, say, to the extent of what it can achieve, it is more important to discuss what we might construct on top of that foundation. In other words, what could we possibly need in the upper levels of human structure? Research exploring Information Technology of the Five Senses is similar to that exploring human sensations. We could say that such subjects are closely related to the upper levels of human structure.

Remote support system for visually impaired persons

Thin-film pressure sensor



Wearable type tactile display (provided by Research Center for Advanced Science and Technology of Tokyo University)

Medical and welfare industry

Industry of various sensors

Mobile audiometer

Color rendering equipment

Industries supporting businesses of education, culture, and leisure

Life supporting robot system

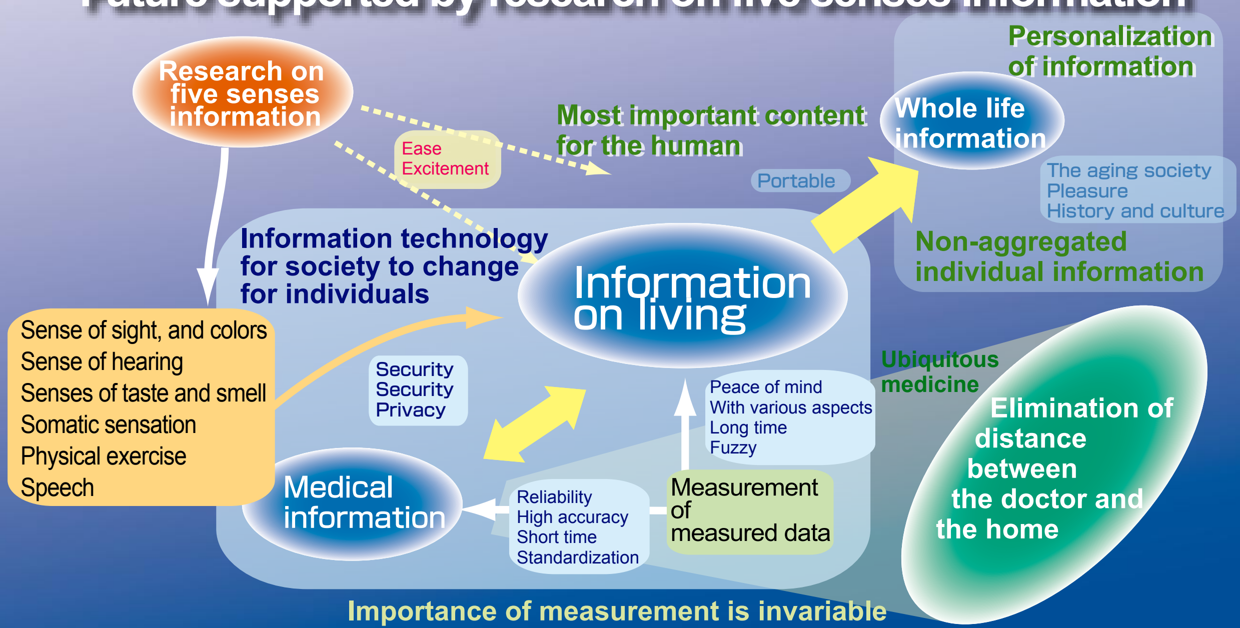
Safe driving support system

Wearable type olfactory display (provided by Research Center for Advanced Science and Technology of Tokyo University)

Another field that is associated with research on the five senses is life science. The Information Technology of the Five Senses is a new research field that functions astride the studies of information technology and life science. Especially, it implies the possibility that it brings basic research work of life science to IT industries in a wholly different context. What is interesting in life science research work is the fact that new techniques like genetic research are beginning to be added dynamically to traditional research on human sensation. For instance, some new genes have been found for the sense of smell, which has been said to be a relatively enigmatic sense. In this manner, new knowledge is added gradually.

I feel sure that Information Technology of the Five Senses is the vanguard of a new current in our industrial world that has tended toward a standstill.

Future supported by research on five senses information



figures : by Takashi Hiraga (Principal Research Scientist of Photonics Research Institute)

Focusing on multiple sounds using super-distributed microphones and speakers

Satoshi Kagami Humanoid Interaction Team Leader , Digital Human Research Center


Photo: 128ch Microphone arrays allow five people to each listen to a different sound

Listen and recognize a sound, then emit it to wherever intended

Our environment always includes a vast number of flowing sounds. We human beings listen unconsciously to what we think we need. Robots, however, would be incapable of picking up only the information they need out of the sounds captured by a microphone. In addition, no technology has yet been established to provide a sound to a specific place at home or in the office. In light of these facts, we are researching, using numerous microphones and speakers, a means to allow us to provide sound only to those places that need it, or to catch sounds that exist only in the place we specify.

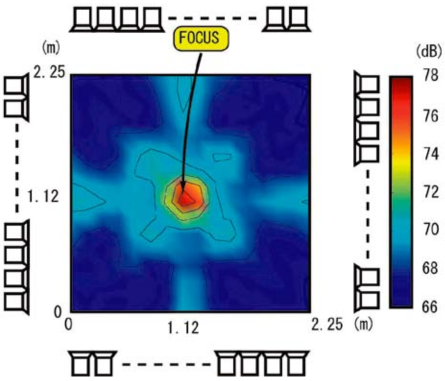


Figure: 128ch Diagram showing actual measurement of the sound field with one sound focus using speaker arrays

Super-distributed microphones and speakers, and sound focusing

Super-distributed microphones and speakers are sound devices comprising several hundred microphones and speakers, each of which is aligned in an array form (positioned in a regular disposition). Inside the array, we can capture sound that is focused on any arbitrary point, or otherwise capture sound out of that position, both of which can be accomplished by adjusting the phase of the wavelength or the amplitude of the sound waves emitted from each sound device. At that focal point, we can differentiate and separate the sounds that come not only from one sound source, but also from multiple sound sources. A system that is set up in this way consists only of inexpensive sound devices and a PC, which are then controlled by software with a real-time based OS so that no problem obstructs its use for various environments.

Sounds pass through air at about 340 m/s. Therefore, with many sound devices placed in that air, the time every sound reaches each device varies depending on the distance from the focus. Knowing and using this fact, it is possible to select one sound and intensify it specifically by setting a sound focus at one location and adding the time difference of each sound coming from that point to compensate.

What can we do with super-distributed microphones and speakers?

A set of super-distributed microphones can capture and recognize one sound from all the different sounds that are audible from various directions. Therefore, it can be used as a robot ear, for example. Development of a system that can record the minutes of a meeting automatically is now underway. Using super-distributed speakers, the sound can be heard only at its focus position. Therefore, such a system could be used to listen to, for example, only the right-guided voice at the right exhibit in a museum, or to change the voice alternately for a group of adults and for a group of children. Another example is that it might be possible that only some groups in a living room could hear and appreciate television or the movie while no others in the room would be able to do so, or be bothered with doing so. With these examples of applications in mind, a room-sized prototype system is under development.

Industry forum on five senses

Toward horizontal unity among studies of the five senses

Yasuhiro Nishida Assistant Director, Osaka Science & Technology Center

Osaka Science & Technology Center has made the “Industrial Forum on Five Senses” take off in 2004 after it had spent longer than a year on the runway.

Five senses technology (technologies related to any of the five senses such as sensors or information on sensation) as well as systems and products made using such technologies are steadily improving to create a “high-quality, safe, secured, and healthy society.” On the other hand, the important necessity is not the achievement of superficial convenience, but firmly based technologies, systems, and products to recognize and address the differences of each individual of every generation in every activity. From that vantage, it seems to be a requirement that five senses technologies apply to improvement of human life and society from a social scientific perspective: we should seek a new paradigm for these technologies’ development.

Based on the background described above, the forum has been established to allow a new industry (Five Senses Industry) to start and extend to seek a high level of amenity, and perform the following practical activities to assist people to:

Organic device in ubiquitous information society

Kiyoshi Yase Deputy Director, Photonics Research Institute

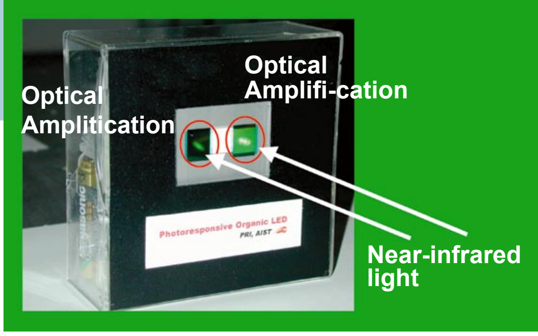


Figure 1: Photo of light-responsive organic EL device when illuminated

As information society is becoming more advanced, more needs are demanded for ubiquitous information household appliances, which allow users to access information at any time from any place. Among others, organic devices, as represented by organic electroluminescent (EL) devices and the thin film transistors (TFT) are expected to apply more for soft and flexible information electronic devices such as electronic newspapers. Organic materials have "light and soft" characteristics in contrast to non-organic materials. The organic EL display has been already commercialized and used for cell phones and displays for digital cameras.

Development of organic EL devices that capture outside light efficiently

Our research group is working on development of "photo-responsive organic EL devices" by putting a layer of a photoelectric transducer (organic photo conductor (OPC)) into an organic EL device. Emitting light to that device, photo carriers are produced at the OPC layer. The carriers are then injected into the organic EL layer, thereby improving its intensity.

Figure 1 illustrates that light radiation. Emitting near-infrared light (780 nm) to a device with 3–6 V applied, only the emitted portion radiates green light (in the switching mode: left side of Fig. 1). Applying 6 V or more to the device, the entire device radiates green light and the radiation intensity increases at the place where the near infrared light is irradiated (in the amplification mode: right side of Fig. 1). In the future, we anticipate developing a "lighting apparatus responding to brightness" by having a higher sensitivity around the visible range of the OPC layer so that it can recognize the environmental brightness. Consequently, it will be irradiated with low intensity in a dark place and with high intensity by absorbing light in clear weather outside, for example.

Development of n-type organic TFT of high performance by applying spin-coating method

In addition, organic TFT is now receiving attention for use in RF-ID tag or organic EL, which is driven by organic TFT circuit. Particularly, the development of organic semiconductors that are soluble in solvents is becoming more popular recently because, if done successfully, it would allow production of organic TFTs with a large area at low cost by the associated printing law.

Our research group newly developed the C60 derivatives(C60MC12). Using an alkyl chain, which can become soluble in the solvent, we can produce a highly crystallized thin film using the spin-coating method. Figure 2 shows characteristics of the C60MC12-TFT. The electron mobility is 0.09 cm^2/Vs, which shows the best value of all the n-type organic TFTs produced by the spin-coating method.

Based on this success, we accomplished the same level of electron mobility as of p-type semiconductors (polythiophene) that were made using the spin-coating method, which means that both p-type and n-type of organic semiconductors became available. As a consequence, not only has that circuit designing become more flexible, but organic devices can also now be produced even on a soft and flexible base like plastic, which is allowed by the new printing law. It is expected that the actual use of in the real world would be accelerated by the use of this new technology.

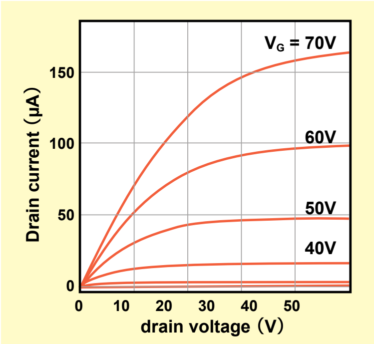
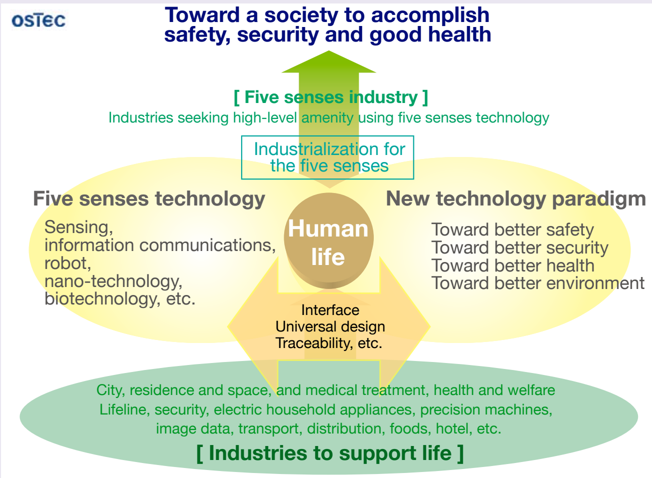


Figure 2: Characteristics of C60MC12-TFT produced by spreading method

- Create a personal network and a research community across fields of technical aspects or social life aspects with respect to the five senses;
- Exchange information regarding five senses technology and its needs;
- Plan and promote various research and development projects regarding five senses technology;
- Establish a vision for the five senses industry;
- Investigate and advise on aspects of five senses technology and industry to work on a new promotion policy or to plan a new base creation.

Up to the end of December 2004, we have opened the forum five times with 800 participants in all. In addition, we have forum members of nearly 250 people from over 200 companies who have joined at present, meaning that cooperative activities made by industry and by academic and government organizations are steadily and passionately moving forward to support "Five Senses Industry" in its establishment and growth.



Haptic Displays - Information Displays for the Sense of Touch

Juli Yamashita Institute for Human Science and Biomedical Engineering Skill Research Group

Haptic display

What does the word "display" make you think of? We must look at a "visual display," such as a "liquid crystal display" to "see" or understand information processed by a computer. In other words, a visual display is a device that presents information to our vision.

A "haptic display" is a device that enables us to "touch and feel" information in a computer. The word "haptic" means "relating to or based on the sense of touch." A haptic display allows us feel such information as an object's hardness, viscosity, and warmth that would be difficult to see on a visual display.

Haptic ≃ Cutaneous + Kinesthetic ?

The eye is the only organ of vision that accepts light signals. In contrast, the sense of touch is a very complex and unified sensation felt by many kinds of receptors in the body. In this article, let us divide "haptic" into two categories, "cutaneous" and "kinesthetic."

The cutaneous sense is mainly felt by the skin, which is the largest haptic organ and contains several different kinds of receptors responding to pressure, temperature, skew, and tension. With this sense, we recognize the roughness of a surface, or surface texture, vibration, and temperature of an object.

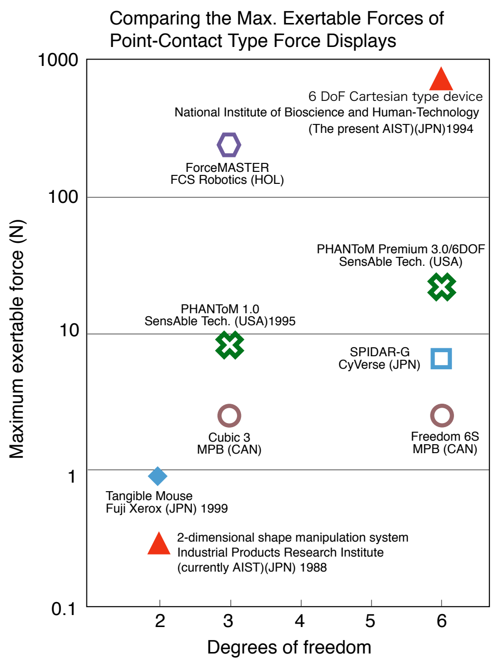


Figure: Comparing the Max. Exertable Forces of Point-Contact-Type Force Displays
The point-contact type is the most widely used force display (commercial products are shown as outlined symbols).

The kinesthetic sense, or kinesthesia, is a sense mediated by receptors located deep inside the body, such as muscles, tendons, and joints, and stimulated by bodily movement and tension. We use this sense to recognize the physical shape and softness of an object in the hand; we capture its shape through joint angles and feel its softness by the tension of associated muscles or the force we apply.

These two categories actually are not so clearly separated, however; for example, it is reported that skin stretching or shrinking (i.e. cutaneous sense) around a joint affects the sense of its angle (kinesthesia).

Various haptic displays

In the last two decades, many kinds of haptic displays have been researched and developed. The variety of devices is a consequence of the complex nature of this sense and the mechanisms to artificially stimulate it. Cutaneous displays showing surface texture by stimulating the skin can be implemented using an array of thin rods that vibrate or poke out (Photo 1), a thin film with well-controlled vibrations, and even an electromagnetic stimulator of skin receptors.

The basic idea of a kinesthetic display, or a force display, is to immediately evoke the "right" reaction force when the user touches a virtual object. Displays in this category can also vary widely, including an "exoskeleton" type (the user wears an "armor suit" device controlled by motors and computers to

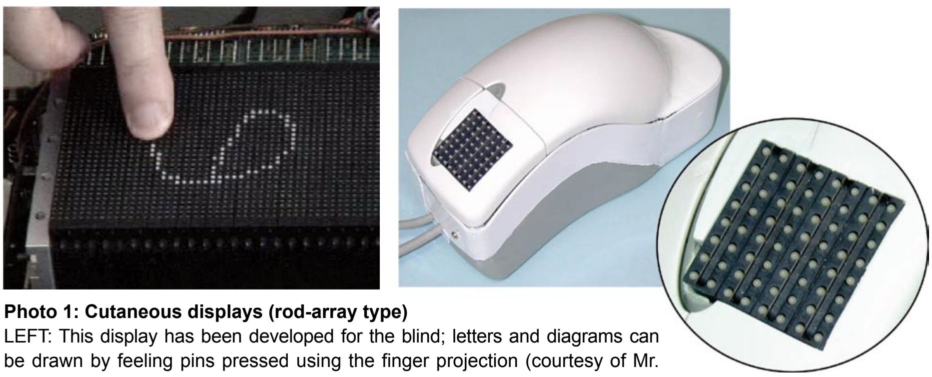
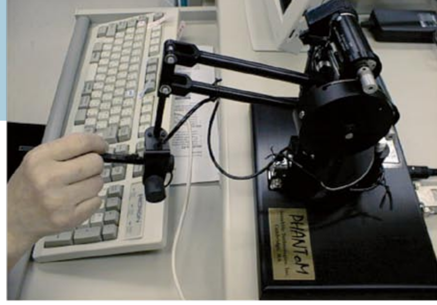
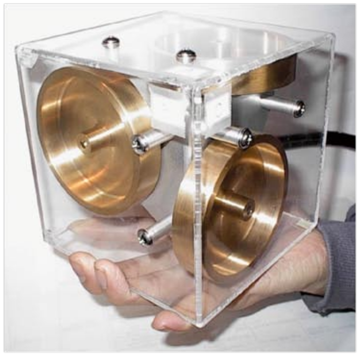


Photo 1: Cutaneous displays (rod-array type)
LEFT: This display has been developed for the blind; letters and diagrams can be drawn by feeling pins pressed using the finger projection (courtesy of Mr. Shinohara, Human Science and Biomedical Engineering, AIST, Japan).
RIGHT: A computer mouse equipped with a small pin-array display (see enlarged image in the circle). A user can feel information around the mouse cursor through level-controlled pins (courtesy of Prof. Shimojo, The University of Electro-Communications).

Photo 2: Examples of "Force Display"
LEFT: Six degrees-of-freedom (DoF) Cartesian-type force feedback device (National Institute of Bioscience and Human-technology (currently AIST), 1994.) "DoF" indicates the number of directions in which force can be rendered by the device. In the three-dimensional world in where we live, six is the maximum DoF (three each for parallel and rotation). The device is a point-contact type force feedback device with six DoF with the largest exertable force (see Figure).
Right Top: PHANToM Haptic Interface (SensAble Technologies, Inc., U.S.A.) This is the most commercially successful device in the world (point-contact type, 3 DoF), developed in the MIT AI Laboratory in the early 1990's. With this device, you can touch a virtual object with the tip of a stylus in your hand.
Right Bottom: GyroCube (AIST, Japan, 2001.) This is a torque display of three DoF, developed as a portable direction pointer (courtesy of Dr. Nakamura, Human Science and Biomedical Engineering, and Prof. Fukui, University of Tsukuba).





create reaction forces through the armor), a "point-contact" type (making the user touch a virtual object using the tip of a "tool" in his hand; the "tool" is controlled to show a reaction force to the user so that he can feel the tip touching the object; Photo 2), and a "torque" (a force that produces rotation or torsion) display (Photo 2). Among these, the point-contact type has already been commercialized (see Figure). Since the late 1990's, point-contact-type force displays have been used as three-dimensional input/output devices in computer-aided design systems, virtual surgical simulators, and rehabilitation systems.

At AIST, we conduct research into the display of haptic information by measuring and clarifying the haptic characteristics of humans and the development of haptic devices.

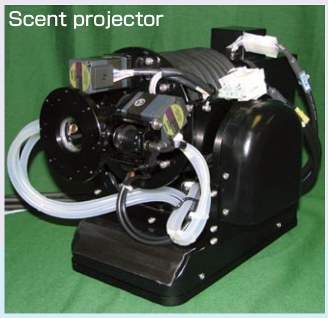
Research and development of olfactory displays

Yasuyuki Yanagida
Meijo University /
Advanced Telecommunications Research Institute International (ATR)

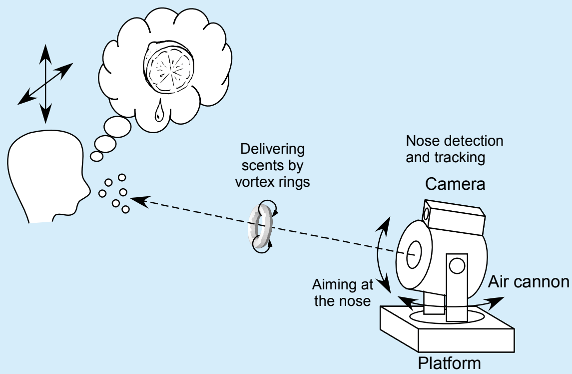
Recently, researchers of the information-related technology have come to join research and development work on olfactory displays; new approaches are now being pursued in this field. These researchers aim at using smells as computer-controlled media, as well as using olfactory displays as tools for aromatherapy or for research on the sense of smell. Various trials are now underway, for example, to use smells as an implicit information output from computers, or to add an odor to the world of multi-media applications and virtual reality (VR).

Among others, VR-oriented olfactory displays are actively pursued in Japan. For example, a wearable olfactory display has been developed at the University of Tokyo that can supply odors to a person who walks around in a VR space. An arm-mounted interactive olfactory display has been developed at Nara Institute of Advanced Science and Technology, focusing on the behavior when a person tries to pick up something to smell. In ATR, a scent projector, which delivers the odor locally to the nose without requiring a user to wear anything on the face, has been developed.

These types of olfactory displays are capable of providing smells synchronously with other interactive contents, so that they are expected to stimulate people to find a new way of using odors.

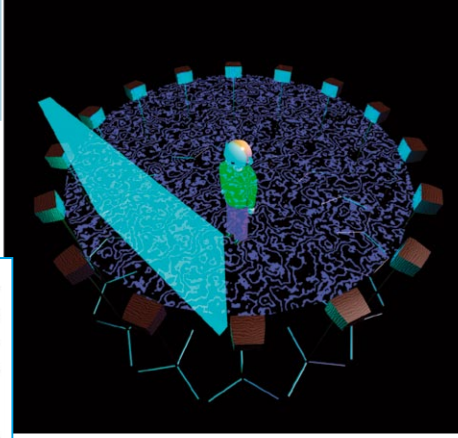


System concept



Obstacle perception training system for rehabilitation use

Yoshikazu Seki
Accessible Design Group, Institute for Human Science and Biomedical Engineering



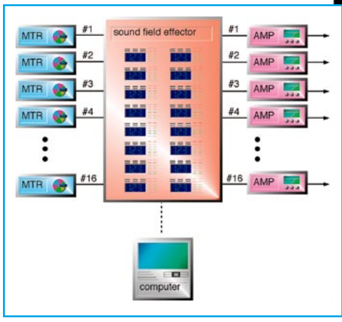


Figure 1: Obstacle Perception Training System
A virtual obstacle is reproducible so the beginner can readily learn

Perception to recognize a silent object

"Obstacle perception" is the ability to sense the existence of an object (like a wall, for example) that makes no sound. It is achievable using hearing based on the reflection or insulation of other sounds in the environment, which is an important environmental perception capability used by visually impaired persons. Training to have visually impaired people perceive obstacles around them is an important factor in the education or rehabilitation to allow them join and participate in society. However, that acoustic mechanism remains little understood. For that reason, current training must rely mostly on as much experience as they can get.

Obstacle perception training system

Against that background described previously, we aggressively investigated this issue to elucidate the acoustic mechanism for obstacle perception. We developed a new training method to utilize acoustic technology ahead of the rest of the world so that training can be accomplished more scientifically.

The first developed "Obstacle Perception Training System" is capable of calculating the activity of an acoustic field surrounding an obstacle. Based on that, it can artificially reproduce an identical situation in which virtual obstacles are represented by the associated sounds. Therefore, even a novice can learn obstacle perception easily (Fig. 1). In a situation in which an obstacle exists, the listener can be reached by the "direct sound" coming from the sound source in addition to a "reflected sound" that comes after the direct sound hits the obstacle and is reflected. Using a computer to calculate each sound's direction, along with the delay time of the reflected sound, then reproducing each sound emitted from loudspeakers placed in each associated direction, we produced a sound field that made us feel as if there were an obstacle even though nothing existed physically in that location (Fig. 2).

Using this technology, we can alter the direction, size, and distance of the obstacle. In addition, we can produce a new situation that would normally be impossible to have in the real world merely by adding or removing environmental sounds, and intensifying the reflected sound. Thereby, we can reproduce virtual obstacles any time so that beginner to learn obstacle perception without difficulty.

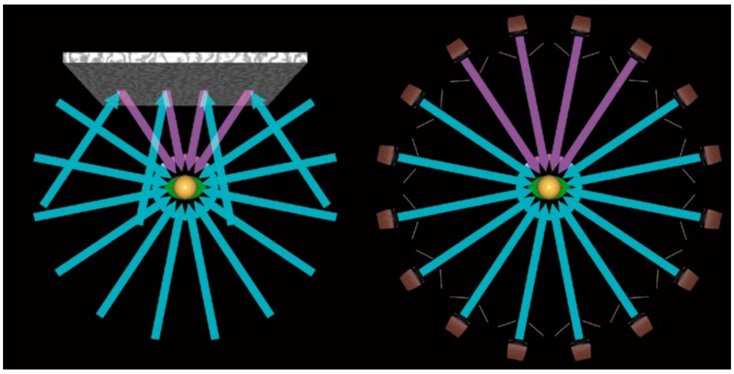


Figure 2: Reproduction of a sound field (left in diagram) artificially in which a wall exists using a loudspeaker array (right in diagram).

Introduction of a rehabilitation system for home use

One problem is that the resultant "Obstacle Perception Training System" is so expensive and large-scale that it is difficult to use in the real world where training for visually impaired persons is conducted or where rehabilitation is taking place. To surmount that obstacle, we have developed and are providing an "Sound Field CD for Obstacle Perception Training" which is recorded with acoustic data that reproduces a virtual obstacle so that the training can be accomplished at home using an ordinary home audio device (Fig. 3).

Currently, a simple version of the "Obstacle Perception Training System" is placed at National Rehabilitation Center for Persons with Disabilities. It is used as a training material for rehabilitation workers for the blind. As many as 200 copies of the current version, Ver.1.0, of the "Sound Field CD for Obstacle Perception Training" are now available and provided free of charge for visually impaired persons and other interested parties.

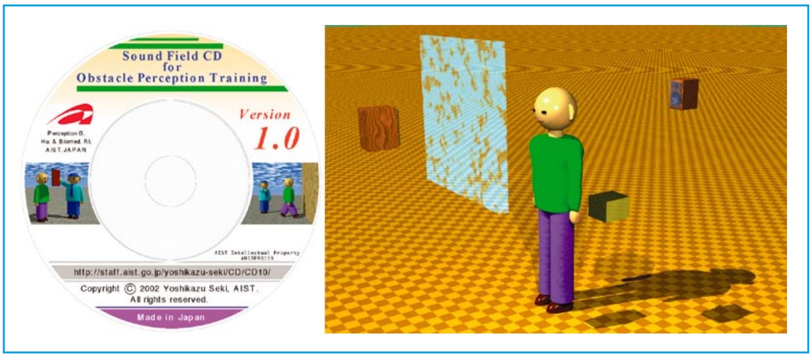
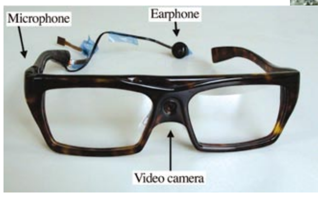


Figure 3: Sound Field CD for Obstacle Perception Training. Training can be accomplished using a home audio device.

Remote support system for visually impaired persons

Iwao Sekita
Advanced Semiconductor Research Center

Special glasses inconspicuously attached with a small video camera and so on.



PC connected to the internet or cellular phone (PHS)

System supporting daily lives of visually impaired persons

Visually impaired persons often need quick and on-the-spot assistance in their daily lives; For example, (1) When wanting to read liquid crystal displays on measuring devices, remote controls and touch panels, or to read mails and manuals. (2) When wanting to check contents of freezer, to peel fruits completely, or to select clothes of particular color. (3) When wanting to search something dropped on the floor.

But it is difficult to promptly dispatch a human helper in every case, because a helper is dispatched based on a plan and usually supports at least for 30 minutes.

The remote support system allows a visually impaired person to send images of his situation together with his assistance request to a remote supporter and to receive voice assistance via the wireless network based on a cellular phone or PHS. The remote supporter can provide eyesight support to a visually impaired person using the system.

Outline of the system

As the system does not require a special infrastructure, the points of development are software for transmitting video images and voice signals, and a wearable video camera.

Software for transmitting video images and voice signals

A data compression technique is necessary to transmit video images and voice signals via the wireless network based on a cellular phone (PHS). We have developed and are improving an adaptable BTC compression technique that has a characteristic of keeping shapes of characters even in strong compression because character information is important for assistance. We are also improving the adaptive technique for adjusting to legible brightness of images.

Wearable video camera

We are developing the special glasses which have a small video camera, a microphone, and an earphone inconspicuously attached. The glasses can provide inconspicuous and hand-free assistance. We are performing improvement of the system from the following aspects: Speaker system, image quality, and wire annoyance. We plan to adopt a bone conduction speaker so as not to obstruct the ears.

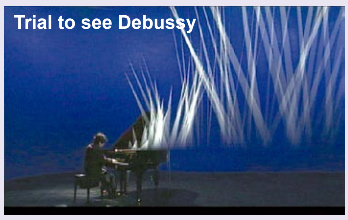
Conclusion

Through the non-profit organization: "Shirogame for visually impaired persons" we have learned very much. For example, is it true that a visually impaired person becomes to have more sensitive sensations except sight? How much stress would be given if a visually impaired person walks alone who is accustomed to walking independently? What would the characteristic of walking be like if no visual information were provided? What information would be important for independent traveler? What would be a good way to sighted guide technique? The system development would not be accomplished without understanding visually impaired persons well.

We continue to research and develop this system further so that anyone can be supported from a remote supporter at anytime, anywhere whenever assistance is necessary.

Relationships and exchange among the five senses: barrier-free and media art

Tohru Ifukube Research Center for Advanced Science and Technology at Tokyo University



Trial to see Debussy

Research on barrier-free access to anyone with impairment of one of the five senses is based upon technologies of converting audible information like voices and visual information, like characters, over to stimulation of other senses. It is also based upon research for the science of recognition in terms of how the thus converted stimuli would be recognized. Naturally, the objective of this research work is to assist people who have lost or are reducing their sensations. However, to establish a truly helpful technology, we must confront cerebro-physiology, which has many unknown factors involved. Such technology may not be able to be developed sufficiently because the need for it is too small.

Recently I have had the pleasure of holding a seminar class with media artists; I am surprised there that what they are seeking really agrees with the subject being researched for the five senses barrier-free in many aspects. During the seminar, I enjoy the essence of the research work by which we are released from stricture and practicality: I feel as if I can run freely in the world of imagination. I am intoxicated with new and unusual ideas popping up. After the seminar class, I always wished that both research workers of barrier-free and media arts could communicate further with each other, and that we had more chances to exchange the unique characteristics that both of us are have in our fields of work. With these two fields combined, I am sure that the research work for the five senses, which should bring a good benefit to the society, can be expanded further.

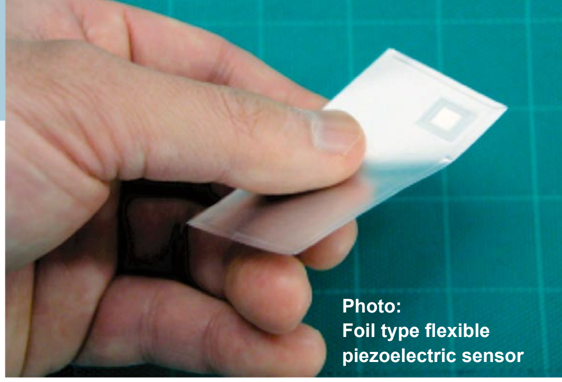


Photo: Foil type flexible piezoelectric sensor

Tactile sensor based on a thin-film semiconductor

Michiru Sakamoto Director of On-site Sensing and Diagnosis Research Laboratory

Touch is the first stage of human sensation: it is said that any human being would check to ensure its bodily existence by attempting to touch itself. Apart from other sensations, the sense of touch would not allow definition of the object to touch beforehand. Such a sensor, therefore, which would be reproduced artificially, must be equipped with a sufficient protective mechanism against the environment, such as a heat-proofing feature. In addition, to attach it to various devices and equipment, it would be required to be thin, finely made, flexible, and to cope with a wide and dynamic range of sensation. We have researched and developed a thin film of aluminum nitride (AlN), which has a number of splendid features to satisfy these requirements to use as a sensor device. Its technical characteristics dictate that we can have a wide selection of substrates for production of a thin membrane from metal foils to high polymer films, for example.

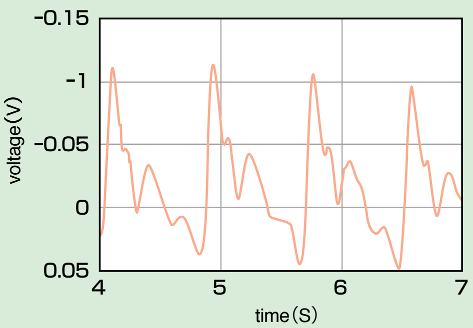


Figure: Example of detecting artery pulses

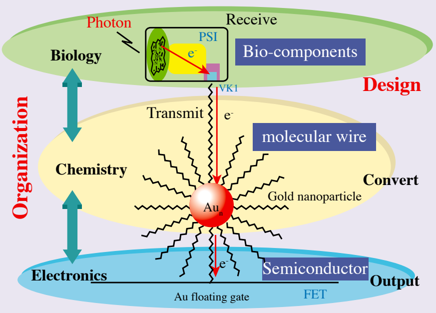
Development of foil-type flexible piezoelectric sensors

We have researched and developed various types of tactile sensors using piezoelectric thin foil of AlN. We are attempting to measure possible impacts to living bodies while placing it in an actual environment for everyday life. Thickness of the soft and flexible piezoelectric sensor (see the photograph) of the aluminum foil sheet that is used as a substrate is 50 µm; its electrodes are structured with five-layered laminates – yielding a high signal to noise (S/N) ratio. It is not merely an ordinary tactile sensor. As shown in the diagram, it can measure pressure variation rendered on a human body surface even when passed over clothing; thereby, it can detect arterial pulses that are used to diagnose arteriosclerosis, cardiomyopathy, or heart-valve defects or disease.

This sensor is thin, soft, and heatproof. It can be used easily in an everyday life environment such as to place in a bathroom, for example. Unlike image data measurement using a camera, nobody would notice the existence of the sensor itself. In other words, it is not an overstatement that the system is not invasive of the personal privacy of those living in such an environment. Therefore, it is expected to be applicable and useful for a medical monitoring system placed in the home, which can be used for the emerging aging-society. In addition, because such a tactile sensor can be incorporated easily into a universal design, we are trying to make it contribute to create a safe, secured and comfortable society.

Imaging sensor incorporating “Bio-components”

Takashi Hiraga Principal Research Scientist of Photonics Research Institute



Grand Design:Bio-conjugate Photosensitive Nanomaterial

Only the best-fitted living bodies have been chosen to survive in this world during the past 4 billion years of natural selection process. Therefore, living bodies, on the whole, represent a system of functionalities that are beyond the level that we can reproduce artificially. However, we might extract minimum units of living body functions (“Bio-components”) to process them while retaining its original functionality. We can then use those components in combination with artificial materials (molecules and semiconductors) to construct hybrid systems or components. Consequently, we can make a system of high functionality that has never been possible through any method. Based on this concept, we produced a super microscopic light acceptance unit (bio-conjugate photosensitive nanomaterial) that can efficiently and reliably detect single photon even at room temperature. It was realized using molecular wires to reconstitute a photosynthetic unit (photo system I) that can achieve photoelectric conversion with a 100% efficiency to be joined with the nano-sized gold particles that can be counted in every electron level, and then to align them to connect on a gate of FET. The success of this research dictates that a third way of nanotechnology is newly opened as the minimum functioning unit of a living body that can be used as one part of the system. Currently this technology is being developed and used as a visual sensor. Later, along with other “Bio-components” that can detect other human senses, this technology can be readily expanded as a general level sensor to augment or substitute for all five senses. Thus, this technology is expected to grow and expand.

(This research was made through cooperation of Tokyo University of Science, Tokyo University, Shizuoka University, and Tokyo Institute of Technology in addition to funds given for the promotion of science and technology.)

A robot arm with a universal sense of touch

Aiming to produce robots that live with humans

Takashi Suehiro Task Intelligence Research Group of Intelligent Systems Research Institute

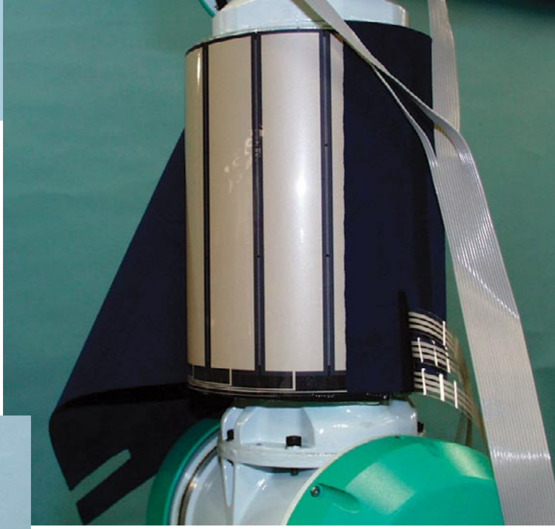


Photo 1: Sensor sheet and the fourth link cuticle

Characteristics of the sensor sheet attached are:
(1) It does not hinder arm movement, and is easily worn.
(2) Contact information and the contact force information are obtainable in a wide range.
(3) Location of the robot arm and how strongly it was contacted can be known.
(4) It offers high amenity for humans because it is covered with soft materials.

Tactile sensing of a robot is an important factor to make robots work safely to support disaster support or nursing care functions, for example, especially when the surroundings are not well-equipped or when contact with human beings is unavoidable. An overall body tactile sensing system has been developed and produced for testing robot contact with humans or other objects safely and without incident.

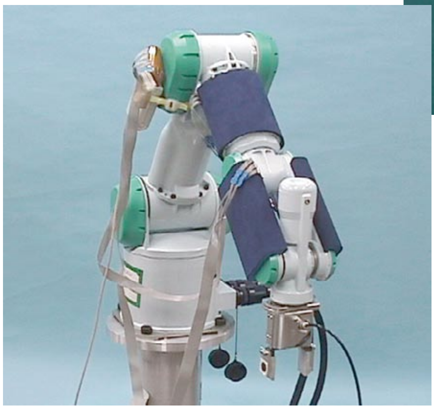


Photo 2: Robot arm with a sense of touch

Development of whole-body type tactile sensor

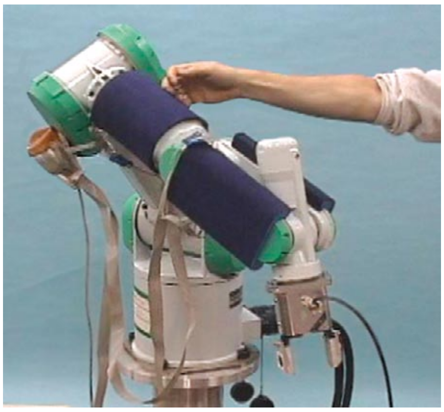
The whole-body type tactile sensor we have developed here allows the exploration of variable resistance occurring at each cross point on a pattern that is printed horizontally and longitudinally using inductive pressure sensitive ink. The pattern detects the force exerted at each contact point. We have developed a robot forearm with seven degrees of freedom covered with 72 areas of tactile sensing detection capability (see Photo 2). A tactile force rendered at every area can then be detected and measured.

The sensor sheet is located between the spacer and the cuticle, which looks like a sandwich. That sensor is then attached to the robot arm. Figure 1 shows the cuticle of the sensor (artificial skin of dark blue) as partially peeled off. Shown inside is the horizontal and longitudinal pattern that is printed with inductive pressure-sensitive ink. This type of tactile sensor is readily applicable without arm movement interference; it can get information on the location of touch and force rendered all throughout the area. It is of high affinity for humans because it is covered with soft materials.

“Dodging” movement implemented to avoid danger

An excellent example of whole-body tactile sensing using this system is that we implemented a dodging movement to avoid being touched. Making a motion in the opposite direction – away from each point where a touch is detected – the entire robot arm flinched, as if it were avoiding the touch. The arm’s avoidance movement at each point of tactile sensing while allowing the arm to do normal work in parallel determines the instruction to give to the motors placed in it. Which of the two movements has more priority is adjustable by adding a weight to either of the parallel equations associated. Photo 3 shows that the arm has detected contact by a person and is trying to move away from it while its fingers continue doing the same work continuously. Implemented touch avoidance movement has such characteristics that multiple movements can be unified using a globally integrative method; moreover, multiple touches can be handled in parallel simultaneously.

This system has proved that it can accomplish whole-body tactile sensing usefully and effectively.



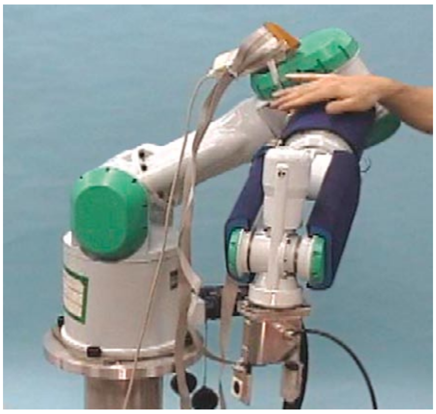


Photo 3: Contact-avoidance using the sense of touch

Measuring brain sensation and recognition of odors

Robots and TVs sensing odors expected in the near future

Mitsuo Tonoike Living Informatics Group of Human Science and Biomedical Group

Photo: Whole head type MEG

Odor information transmission has begun

Among other senses, the olfactory sense and the gustatory sense are called chemical sensations. In the past, our common sense told us that chemical sensations needed “something to be given” or “something to give” to activate. Therefore, it was deemed impossible to transmit or receive information of chemical sensations as with others such as sight or hearing. In fact, in terms of the sense of smell, it is said that roughly 400,000 different materials produce some odor. Therefore, it was deemed impractical to control and transmit a sense of smell as with other senses using those 400,000 different materials.

However, the recent development of science and technology is astonishing. Getting into the 21st century, the situation has greatly changed. Last year’s Nobel prize for medical science and physiology was given for clarification of the odor acceptance mechanism (i.e., the organic function that captures and accepts odors the first time); recently, virtual reality handles odors, and a trial of sending odors through the internet has been tried. On the other hand, it is widely known that many animals use odors as communication and an important survival tool. With these facts in mind, we can notice that even human beings use odors as important tools to pass information in everyday life.

Mechanism by which a human being senses odors

We have been involved in research to elucidate how the sense of smell is perceived and have recognized when the smell stimulation is received. Odors are received in the nose, which is the olfactory organ. However, it is the brain that recognizes and interprets odors, so we inferred the importance of scientifically measuring the status of the brain first.

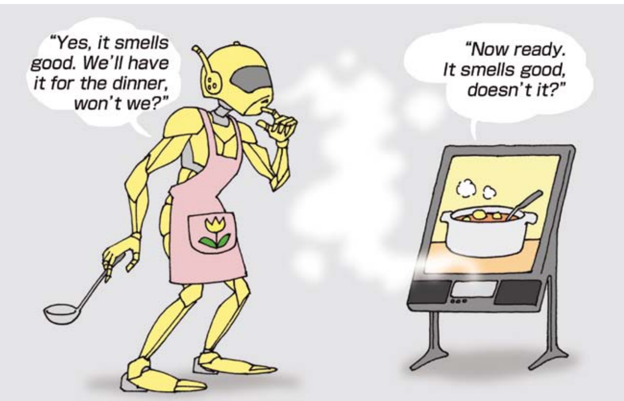
Realistically, we would be unable to apply similar techniques to humans in terms of physiology or anatomy to those we are using for experiments with animals. Therefore, we must find a way to observe the interior status of the brain indirectly when we examine the human brain. Because of this we are doing our research work using a highly technical measuring device (see Photo) called a magnetoencephalogram (MEG), which allows us to measure the magnetic field activities of nerves throughout the entire head at one time using many sets of superconducting sensors (SQUID: Superconducting Quantum Interference Device). With MEG, we merely have a subject sit in a chair and smell: we can then visualize the changing brain state over time with millisecond accuracy.

Indirect measurement of odor sensation

In this study, we specifically recognized the central part of the brain (frontal eye field) that is activated when an odor is perceived. Furthermore, as shown in the diagram, we found that the perceived odor information was subsequently sent to another part of the brain (called the association cortex) within a tens of milliseconds to hundreds of milliseconds time frame after odor perception. Lastly, the odor is recognized in another part of the brain (upper lobe). Thereby, we indirectly measured the “mechanism of perception and recognition of odors” for the first time in the world.

Future of information systems using odors

Once we clarify how information on odors is processed in the brain, we will become able to “give odors” or “receive odors” easily in any way desired. In the near future, it will no longer be merely dreams in which we have a robot that can smell or a TV that can provide odors.



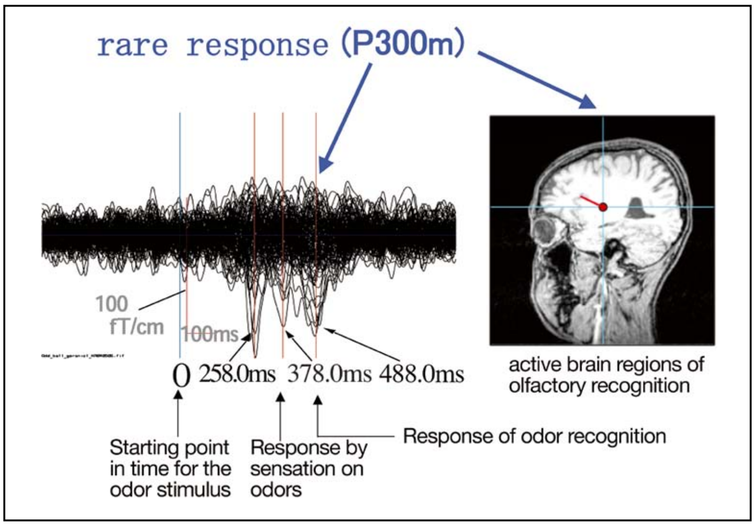


Figure: MEG depicts the brain state after stimulation by an odor and until it is perceived and understood by looking at every magnetic response, thereby visualizing the change of responses by time

New information transmission using a colored illumination equipment

Shigeharu Tamura Photonics Research Institute

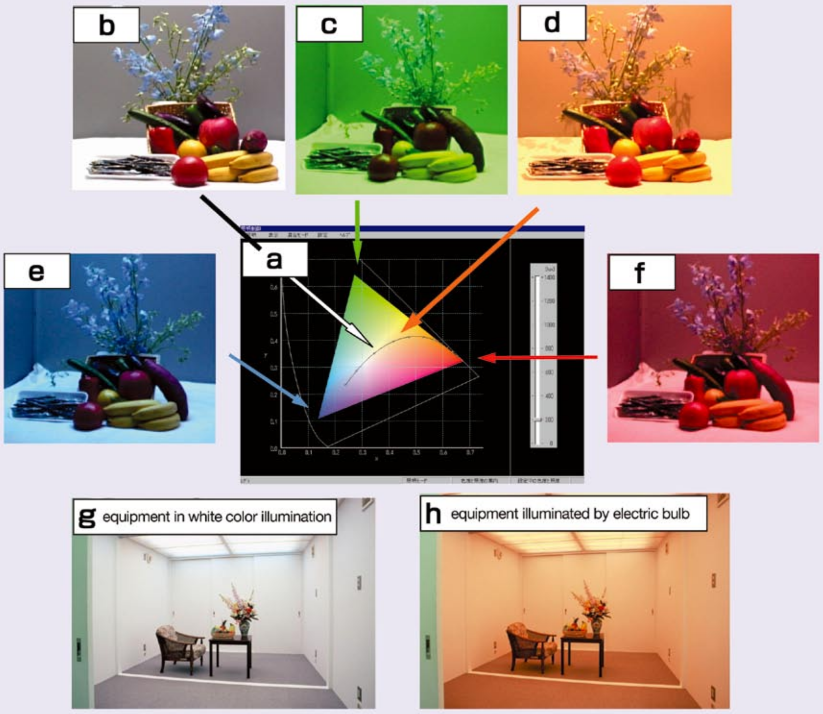


Figure: Variously illuminated space achieved using a color illumination device
(a) Color diagram on control screen; (b)–(f) Color of the object under illumination of white light, green light, electric bulb light, blue light, and red light; (g) Inside the equipment in white color illumination; and (h) Inside the equipment illuminated by an electric bulb

Technically improved visual information

Visual information is one communication method that has been used for a long time along with audible information. Consequently, among all five senses, a high level of technology for that to develop is highly expected. As far as colors are concerned, we can note that many types of color images are used in various fields such as in commodity trading, remote medical treatment, architectural designing, and so on. It is therefore necessary to establish a technology that can pass exactly the same information to another person as it is visually recognized by human beings. For commodity trading, visual information using colors is more frequently passed than ever in the world: color information of products may play a more important role in evaluation when purchasing than information about the quality or material itself.

Information and benefits of illumination

For the basic technology of sense information communication, it is important not only to understand what impact a stimulus gives to humans, but also to establish a technology to produce stimuli to give to humans. In terms of color information, the AIST has been paying attention to illumination, and working on formalizing to how humans gain impressions about an object's color under various colors of illumination, while simultaneously developing various types of color-controllable illumination equipment.

Human eyes have a function that can change the sensitivity for every color received based on the color of each illumination. It is called "chromatic adaptation." For communication of color impressions that a human receives by seeing, this chromatic adaptation must be considered. Equipment developed at AIST is designed to facilitate the understanding of this function of chromatic adaptation so that it can produce any arbitrary color of illumination.

Illumination of the equipment uses fluorescent light. We can mix three basic colors of light: red, green, and blue. Later, to obtain higher intensity in the white color domain, a new white color fluorescent light was added to use as a source of light. Improving further on its hardware and its controlling software, the current capabilities of this equipment have been achieved.

Our laboratory is 12 m^2 (3 m × 4 m) and 2 m high. There, a person can experience the same level of illumination space as normally encountered in everyday life. In the hue range of fluorescent lights like daytime color or white color, intensity of 300 lux or over a maximum of 1000 lux can be accomplished. A color diagram (Fig. a) is displayed on the control monitor screen. Clicking the mouse at a desired point on the color diagram, or entering the numerical value of the point on the coordinates, the same color of illumination as selected at that associated point on the coordinates can be lit with the highest intensity available. It is also possible to change the illumination in various ways: one can change the hue with the intensity unchanged, or change the intensity with the hue unchanged, or change the hue automatically along the black body locus selected.

You can experience how an object can be viewed under colors of red, blue and green in addition to other illumination of white light or electric bulb light, as shown in Fig. g and Fig. h, allowing examination of how human eyes would function. The laboratory is divided into two compartments that are separated by a curtain with a small window: each compartment can receive a different color of illumination.

Possible technology expansion available using color illumination equipment

One available benefit color illumination equipment thus developed is that it can be used to simulate a city view, office spacing, or residential spacing; it may be available for the remote medical treatment among multiple medical facilities using image data.

Capturing "colors"
Development of a neural circuit producing colors

Yoichi Sugita Cognitive and Behavioral Sciences Group of Neuroscience Research Institute

Neural mechanism to capture "colors"

Even if wavelength components of light radiation vary largely, humans are able to recognize objects' colors correctly. Assume that we illuminate the diagram shown on Fig. 1 from three sources of light only (S: short wavelength, M: middle wavelength, and L: long wavelength). Rectangle A looks green and is located at the center of the diagram on Fig. 1A. It is reflecting light by each of the three sources of 1, 4.5, and 4 (units), respectively. On the other hand, rectangle B appears yellow of 1, 5, and 9 (units), respectively. Now presume that we change the intensity of the light sources so that green rectangle A reflects respectively 1, 5, and 9 (units). Therefore, the light entering our eyes should be the same as the reflected light at the yellow rectangle B. Notwithstanding, this rectangle B still looks green: it never appears as yellow.

Thus even if the characteristics of light coming into our eyes change to a great degree, we retain "color consistency," by which we can recognize the color of an object correctly. That fact indicates that the light itself that

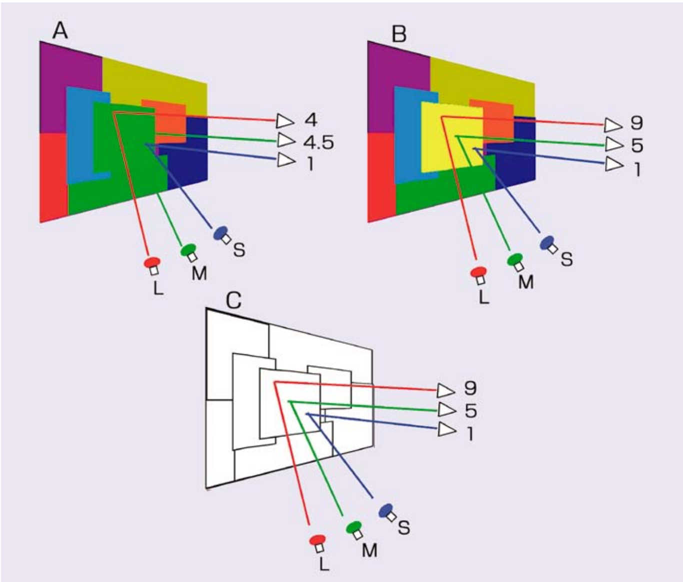


Figure 1: Color consistency
Squares of green (A) and yellow (B) embedded in a Mondrian figure (geometrical abstract figure). We illuminate this form of the figure using lights from three sources, each of which is having a different wavelength. The green square reflects the light of short wavelength S, middle wavelength M, and long wavelength L respectively by 1, 4.5, and 4 (units), while the square B appears yellow by respective illumination of 1, 5, and 9 (units). We next adjust to intensify the middle wavelength light by slightly more, and long wavelength light by more than double so that the reflective light from the green square A becomes equal to that from the yellow square. Then would the square A appear as yellow?

Seeing "taste" in the brain

Professor **Takashi Yamamoto**
Graduate School of Human Science Research at Osaka University

The research in which food tasting is understood as part of brain function is underway. As a simple experiment, we tend to use sweet and good-tasting sugar solution or bitter and bad-tasting quinine solution. In the primary gustatory area (the area from the frontal operculum to insula), which recognizes taste, every different part is activated depending on the quality of the taste given. The amygdala and the anterior orbitofrontal cortex become strongly activated when a person tastes something delicious, the posterior orbitofrontal cortex and the anterior cingulate gyrus get strongly activated when a person tastes something bad-tasting.

Odor also plays an important role in taste. The combination of odors and tastes for every food image is determined based on each person's eating experience. In the experiment we have, we first have the examinee smell a food odor such as that of a banana. Next, we show an image of a banana or strawberry, for example. Subsequently, we take a measurement using MEG. Activities at the occipital lobe and the temporal lobe become intensified if the banana image is combined with an actual banana odor, or if the strawberry image is supported with an actual strawberry odor – in other words, if anything expected appears (see Figure).

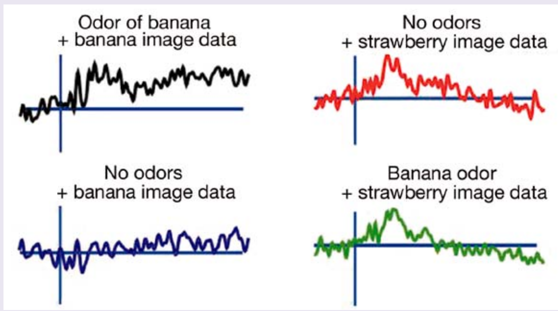


Figure: MEG responding waveform taken from the back of the head.
Cumulative data of 100 times obtained from the same examinee (20-year-old female). The analysis time period is 200 ms before and 1000 ms after the image was presented, as shown by the longitudinal lines.

Consequently, when you smell a good odor first, see the food next, and put it in your mouth to taste to feel good, the various parts of your brain become activated. Once the cerebral mechanism becomes better clarified in terms of identification of taste quality, and emotion of good tasting or bad tasting, the true objective evaluation on tasting would be put into effect so that it would be expected to help apply it for development of much better tasting food.

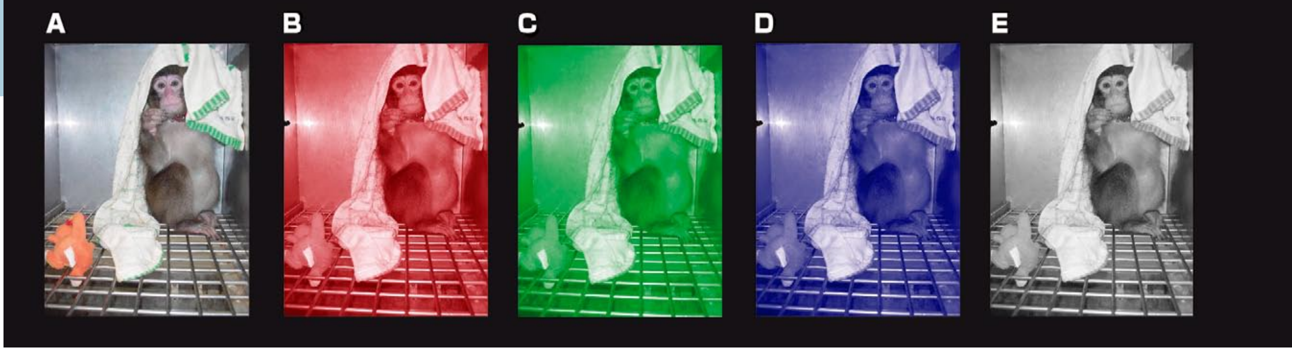


Figure 2: Imaging photograph of monochromatic illumination
(A): The photo under the normal illumination (A). Imaging photo of illumination with (B): Long wavelength (red), (C): Middle wavelength (green), and (D): Short wavelength (blue). If illuminated with monochromatic light, none of the colors of the monkey, the red necklace worn, and the picture on the towel, or the color of the doll would be recognized, just as if you were looking at a black-and-white picture (E).

comes into our eyes does not include "color" information. The "color" of an object can be identified without much difference, even if the wavelength components of the light that comes into our eyes change to a great extent, because the "color" is created when the color information passes in the chain of neural link from the eye's retina to reach the cerebral cortex. The neural function to produce "colors" (the sense of color) has been conceptualized as genetically provided in humans, but the actual structure and function of the neural circuit network are not yet clarified.

Experiment on monkeys' "sense of color"

We raised a monkey from birth until it became one year old, allowing it only the monochromatic illumination that we provided so that it was unable to recognize any color. During that time, however, we changed the wavelength of the monochromatic light to red, green and blue alternately every minute, so that all three kinds of color acceptance cells (visual cortex) in the retina became active. Then we examined the monkey's sense of color. We found that it had difficulty in discerning color similarity and color consistency. After we trained it for a long time to make it capable of choosing the right object of the same color as that of a sample, the monkey finally achieved the same level of ability of normal monkeys. However, for color similarity testing, in which it was required to choose a nearly similar color to the sample one, he had a totally different score from what the other normal monkeys did.

This result tells us that the monkey raised only in a monochromatic light classifies colors differently from other normal monkeys. Furthermore, the result of the test in which the monkey selected one color out of several different colors varied to a great extent by every condition in which the illumination was given. The monkey raised only with a monochromatic light was not provided with any "color consistency."

These results all mean that the "sense of color" is not something that is genetically given, but can be given through experience. By more fully examining the neural activities of the monkey with the color-sensing problem, we expect to clarify more of the structure and the function of the neural circuit network, which are the bases of "color consistency."

Competition between the bottom-up and the top-down flows

Professor **Takao Sato**
Graduate School of Humanities and Sociology at University of Tokyo

When you think about the mechanism of human vision, i.e., "how we perceive objects and the environment," you might think that the information received by the eyes is processed sequentially through various stages. However, our vision is not accomplished by such a sequential flow alone. Various pieces of knowledge and assumptions about objects in the external environment and the environment itself are stored in the higher parts of the brain that reside beyond the primary visual cortex, which is responsible for early visual information processing. When an object is seen, the bottom-up information coming up from the eyes to the brain, and the top-down information that comes down from the database reside in the higher levels of the brain, meet, compete, and compromise with each other in one way or another. Only after such a compromise, an object can be perceived and understood.

For example, when you look at the inside of a mask with two eyes, it looks concave. However, when you look at it with only one eye, you see it concave at first, but if you keep looking, it eventually starts to appear convex. The depth information (binocular stereopsis information), which functions when looking with two eyes, does not function with only one eye and the depth information becomes ambiguous. In such occasions, the top-down information, that "face are convex" becomes predominant, and you perceive the inside of the mask convex although it is actually concave.

I am trying to understand the mechanism of the visual perception through psychological experiments. However, to explore the nature of such a complex mechanism, it is important to interact with researchers from various research fields such as neuro-physiologists who study brain mechanism, researchers in brain imaging, modeling people who study theory, and experts in computer vision who attempt to build artificial vision systems.

Information Technology on Five Senses

Research on the Five Senses by AIST is making great strides

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