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Image Sensing

from Keio's Faculty of Science and Technology

A new world opened up
by advanced image recognition technology

Yoshimitsu Aoki

Associate Professor
Department of Electronics
and Electrical Engineering

Featured in this issue is Associate Professor Yoshimitsu Aoki, who pursues research into image information sensing for application to a wide range of fields.

I'd like to obtain useful information from visual images and use it to benefit society

Understanding contexts from human, object and spatial information

Our modern daily lives are brimming with all kinds of visual images and image information thanks to the spread of digital cameras, security cameras and the like. To put it another way, these visual images and information are serving as our vital sensors on understanding society. Associate Professor Yoshimitsu Aoki focuses his energy on the effective use of leading-edge image sensing technology to develop systems beneficial to society. We asked Dr. Aoki about a variety of advanced technologies he is working on at his lab.

A desire to develop a "quick-witted" artificial intelligence system based on image sensing technology

Dr. Aoki of the Department of Electronics and Electrical Engineering is currently engaged in an attempt to apply visual images from digital cameras and video cameras for sensing. He says he is interested in developing a system that allows meaningful pieces of information to be extracted automatically, which he wants to use for the benefit of society.

For example, functions such as extracting a particular individual's facial features to automatically focus on them and functions for recognizing one's own child and bringing the camera into focus on the child have already been put into practical use with digital cameras and video cameras. Furthermore and steps ahead, he aims to enable the computer to understand a move a subject is going to make, a given situation and even the meaning or import of a whole particular scene.

"I'm targeting not only humans but also recognition of colors and shapes of objects as well as spatial and environmental recognition. In other words, I'm trying to understand the whole of a given scene by using images to recognize the three – human, object and spatial – elements. By combining multiple pieces of information, I think it'll be possible to understand the context of what's going on there. Suppose there is a person who is extending his hand. Context understanding in this case means distinguishing whether he is going to shake hands with someone else or is trying to get hold of something," remarks Dr. Aoki.

Almost everyone carries a smart phone or a tablet device now, casually taking snapshots and videos and uploading them on the Internet. Out on the streets, security cameras are installed everywhere, replacing human eyes. Sensing these images and using them to develop an intelligent sensing system with human-like senses, sensitivity and thinking, something that can comprehend complex matters and make forecasts . . . this was Dr. Aoki's motive to take up this research theme.

But why images . . . ? He explains as follows: "The primary merit of using images lies in that images allow us to conduct simultaneous, wide-range measurement of more than one person. Another advantage is that, unlike common sensors, images do not have to be carried by the persons concerned, thus placing no restrictions on their actions.

On the other hand, the use of images can involve privacy problems. Images are also useless unless the target can be captured by camera due to blind spots and so on. Furthermore, it is difficult to process moving images in real-time because of their large volume of information. In this age of overflowing image information, why can't we make full, more effective use of images? . . . This is the ever-stronger voice from the real

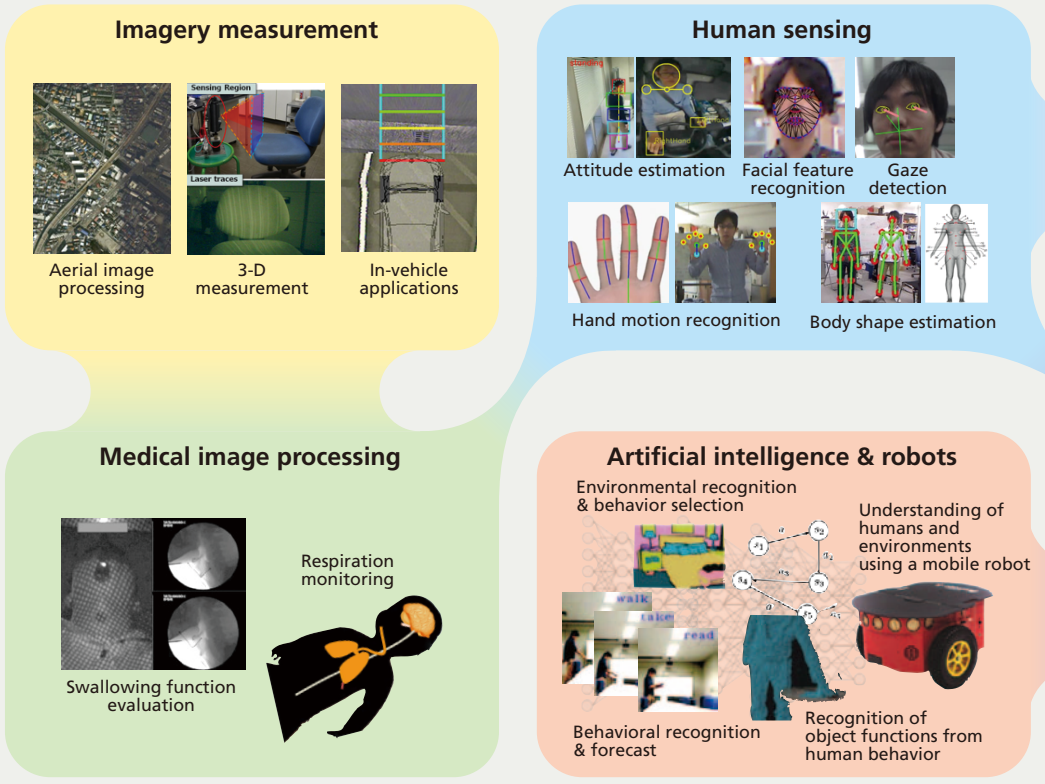


Fig.1 Image sensing technologies from Aoki lab
Aoki lab's core technologies cover: a variety of sensing technologies targeting humans for measurement and recognition; and imagery measurement and recognition technologies targeting objects and spaces. Results of sensing thus obtained are applied for automatic image analysis, scene understanding, extraction of sensitivity information, and medical diagnosis support systems, among others.

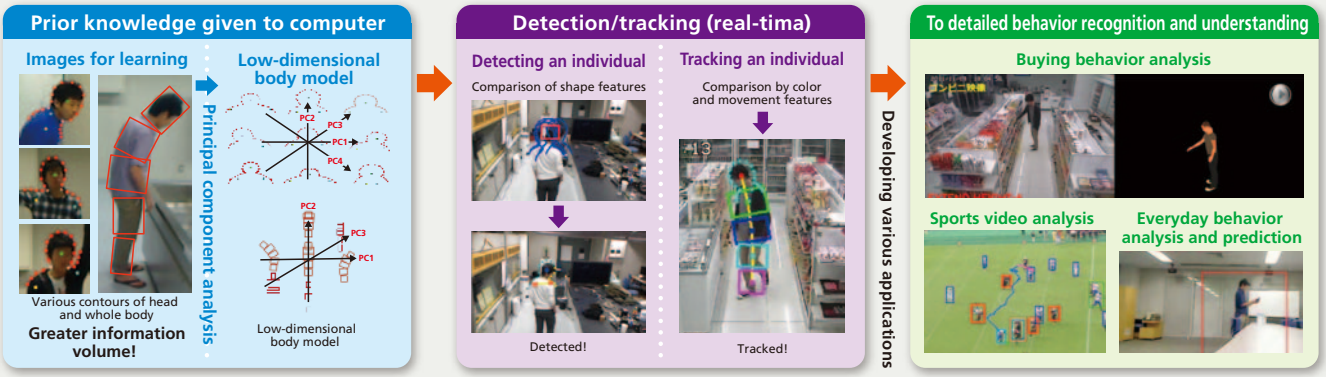


Fig.2 Flow of human behavior recognition from image information
This process begins with modeling of an individual's features based on a limited amount of information. The modeled features are given to computer as prior knowledge and are compared stochastically with features obtained from visual images. This enables detection and tracking of a target that has human-like features. Expectations are high for applying this technology for a wide range of fields, such as analysis of buying behavior at shops, analysis of sports tactics, recognition of everyday behavior, and even the prediction of next actions to be taken.

world."

Recognizing and understanding individuals under various situations by detecting and tracking their behavior

Above all, Dr. Aoki focuses on a technology with the ability to detect and track a particular individual in images. "By applying this technology to security cameras, it will become possible to identify a suspicious person or detect a lost person. If used with security cameras at convenience stores, for example, it will recognize what product items customers are interested in – an application for marketing research."

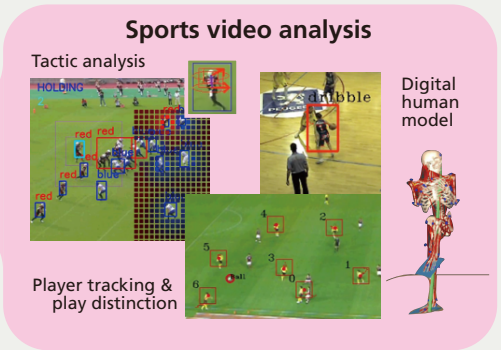
Dr. Aoki is also tackling a more challenging theme in relation to sports events such as soccer or American football games, where players of each team wear the same uniforms with different numbers. The challenge here is to detect movements and/or positions of a particular player (or the ball) from among many players, relying on his number only. These technologies can be applied for the understanding of tactics and prediction of plays. In fact, Dr. Aoki is receiving business inquiries from pro sports teams, TV stations, game software makers and so on.

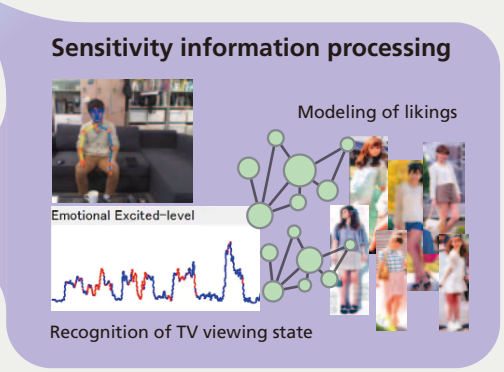
"For this technology, we employ a method based on modeled human postures, which allows the computer to learn beforehand information about how positions of a person's body parts, e.g. from the head to shoulders, will change. In doing so, we compress the information volume significantly by using a technique known as 'principal component analysis,' which is the secret," continues Dr. Aoki.

Principal component analysis is a mathematical technique to show in a limited number of indices the features of given multidimensional data without destroying important information. By using this technique, it becomes possible to express an individual's body shape features from a limited volume of information. Furthermore, by establishing a link model for a human body from the upper to the lower halves, it is also possible to track an individual's movements and postures in real-time and robustly.

"Thanks to this technology, I can now obtain more detailed information about human postures, such as determining to what product on a shelf a person is trying to extend his/her hand. In addition, by applying this knowledge I could successfully develop an innovative technology capable of instantaneously restoring one's three-dimensional body shape from only two pieces of image showing his/her front and side," he says.

In this manner, the excellence of Dr. Aoki-initiated technologies lies in that they can speedily process highly complex movements and shapes using an extremely limited volume of information, which can be applied to actual systems.





Aiming to put the technologies into practical use in entertainment, fashion and medical fields

The essence of Dr. Aoki's research initiatives can be described as pursuit of real-time processing of information using minimal volume of information. What lies beyond? . . . It should be practical application of the research results. What he has in mind as application outlets for his research results are fields, such as sports, entertainment, apparel, medical and social welfare.

Examples of potential medical application are measurement systems for the detection of babies' respiratory failures and for the swallowing ability of the elderly. For the former, the system is intended to measure subtle up-and-down movements of the chest, and for the latter it will measure movements of the Adam's apple. The greatest advantage is that both of these measurement systems will have no invasiveness.

Another feature of the Aoki lab is that it engages in research into a sensitivity information processing system designed to measure human sensitivity. For example, suppose one accesses an EC (electronic commerce) web site. In this case, the system will estimate the user's personal taste for clothing and recommend a product most suited for his/her sense or liking.

"At my lab, 60 to 70 percent of the research activities are joint projects with businesses. This means expectations are high among businesses for our image sensing technologies," concludes Dr. Aoki. Being close to our everyday life, it seems only natural that expectations continue to grow for practical application of these technologies.

(Reporter & text writer : Madoka Tainaka)

Associate Professor Yoshimitsu Aoki

I've always done my best in everything, whether it is study, sports or hobbies. What I am today is nothing less than the result of this way of life

Brought up as the first son of an electrical shop owner in town, Dr. Aoki spent his childhood familiarizing himself with all kinds of electrical appliances and PCs. In his high school and college days, he was extremely active in extracurricular activities such as judo, rugby, band and so on. Indeed, throughout his life he has tackled study, sports and hobbies with all his might and produced a number of achievements in research as well. He is one of the teachers who enjoy an overwhelming popularity among Keio students. How did Dr. Aoki become a researcher? We asked him about his personal background and his career as a researcher.

We heard that you were born in a family running an electrical shop in Takasaki City, Gunma Prefecture. Is that right?

Right. My parents were running an electrical appliance shop. Whenever my father opened his mouth, he talked only about electrical appliances – even at home! It was only natural that I became interested in electrical appliances. What's more, my father liked novelties. An electrical shop is a community-oriented business by nature, but my father's shop seems to have been a trendsetting one.

Another example typifying my father's shop was that it was quick to handle PCs and opened to visitors the whole of its second floor as a PC-dedicated space. On my way from elementary school, I often visited the PC floor together with my friends in the neighborhood, enjoying time programming games while referring to the "Basic Magazine." It was in those days that I vaguely felt that I would choose the scientific course in the future.

In the meantime, I loved sports of various kinds. As an elementary school boy, I took up soccer and swimming; when I entered junior high school, I joined the volleyball club eventually to become the captain.

You then advanced to a high school attached to Waseda University, didn't you?

Being a high school attached to Waseda University meant that there would be no university entrance exam, so I was able to adsorb myself in extracurricular club activities. In fact, my school life was extremely busy – setting up a cheering party together with my seniors; playing active roles as a judo club member; beating a drum at a light music club; at the school cultural festival, I held positions in three different bands, and then appeared on cheering party's stage during the night festival.

That said, I also studied as hard as other students. Incidentally, the theme of my high school graduation thesis was: "Energy toward the 21st century – The necessity of solar energy as an alternative energy in place of fossil fuels." In those days, I was convinced that petroleum would be completely depleted by the dawn of the 21st century.

Did you go on to the scientific course without worrying about the choice?

Actually not. When I was in the third year of high school, I was a bit in doubt as to which course to choose, the Faculty of Political Science and Economics or Faculty of Science and Engineering. But I finally carried out my original intention and chose the latter. What attracted my interest was the study of space physics, so I chose the Department of Physics and Applied Physics.

That said, I became absorbed in sports again. I joined the faculty's rugby club; I spent the first one and a half years of the campus life with practice, games and drinking parties day in, day out. In September when I was a sophomore, however, I had a neck bone broken when I was making a tackle during a game

The lab has a simulated living environment equipped with image sensors that can capture human movements and object shapes. This environment is useful in promoting research on behavioral recognition under a real environment.

against the University of Tokyo. It was the first cervical vertebra. But it were the second cervical vertebra or any of the lower neck bones, one half of my body would have been paralyzed.

I was confined in hospital for three months, ruining the latter half of the second year on campus. Despite such circumstances, my classmates were kind enough to lend me their notebooks; I was somehow able to clear the new year exams and become a junior without staying two years as a sophomore.

Incidentally, although I give up rugby soon after the accident, I returned to the rugby club from the middle of the third year.The last game as a senior was against the Keio (Faculty of Science and Technology) team. Coming from behind, our team finally won a victory with a try during overtime. The game took place nowhere else but on the rugby field on this Yagami campus of Keio! I cherish this memory even today.

What was your motive for undertaking research into images?

Following the serious injury I suffered during the rugby game, as a junior I began to feel it difficult to understand theoretical physics-related subjects. At that time I attended a "Principles of Measurement" lecture by Professor Shuji Hashimoto who would later become my teacher, when I was impressed with the depth of measurement. My interest suddenly shifted from science to engineering. I didn't think about joining the Hashimoto lab seriously. My intention was an easygoing one. Since the lab was so popular, I thought it might be easier for me to find employment with a company if I failed in the graduate school exam.

Fortunately, I passed the graduate school exam; at the graduate school I took up the study into facial image recognition and synthesis. For example, one of my studies concerned simulated images showing changes in facial appearances and teeth occlusion before and after orthodontic treatment.

I made a presentation of the results of this research at a meeting of the Japanese Academy of Facial Studies, which attracted the attention of a professor of Kyushu University Faculty of Dentistry and led to joint research. I was lucky to have the opportunities to experience, in the early stages of my career, such joint research projects and advising students of the image study group.

Later I obtained a doctoral degree and had served as a research assistant at Waseda University, then proceeded to Shibaura Institute of Technology (SIT – College of Information Science and Engineering) as an assistant professor in 2002 almost at the same time as I got married. In the first year at SIT, I took care of ten students, and a cumulative total of 80 students up to the end of the academic year 2007.

You came to Keio University in the 2008 academic year. What is your impression of Keio?

My impression of Keio students is that they are smarter than Waseda's, good or bad. A good thing about Keio is that senior students take good care of their juniors. Keio is also complete with systems that encourage academic pursuits. Three of our lab's doctoral students studied overseas taking advantage of these systems.

As an extremely busy researcher, what are you doing for relaxation?

Two of my children – an elementary school fourth-grader boy and a kindergarten middle-grader girl – are practicing judo. So I get rid of stress by joining them in judo practice once a week. I video all of judo matches of my small ones, editing the videos and analyzing tactics myself (*Laughter*). Sometime in the future, I'd like to take up research into image-based automatic analysis to identify judoists' center of gravity while they are practicing.

◎ **Some words from students . . .** ◎

● A hot-blooded person with a bit of severity, Dr. Aoki is a truly wonderful teacher who is always and sincerely considerate of us students. In particular, he always makes the best possible effort to prepare an ideal research environment for us. He was once a rugby player himself. He reminds us of the image of Mr. Takizawa, the hero of the "School Wars" TV drama series (Laughter). From Dr. Aoki, all of us are learning many things . . . the delight and severity of learning, among others.

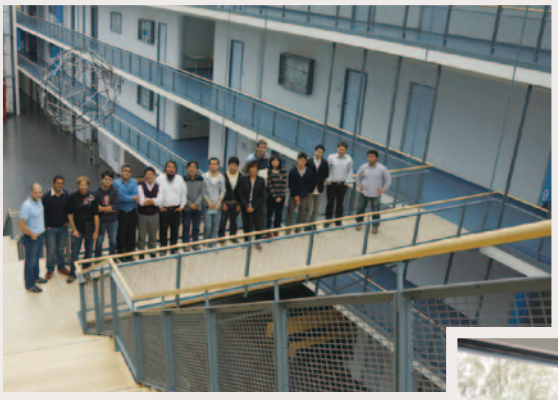
(Reporter & text writer : Madoka Tainaka)

For the full text of this interview
http://www.st.keio.ac.jp/kyurizukai

I'd like my students to address any challenge while always remaining conscious of what they are doing relative to the real world. Doing so will enable them to appreciate the true value and significance of their jobs.

Yoshimitsu Aoki

Born in Takasaki City, Gunma Prefecture, Mr. Aoki graduated from Waseda University Department of Applied Physics in 1996, then completed the doctoral course at Waseda University Graduate School of Science and Engineering (Physics and Applied Physics) in 2001. Doctor of Engineering. After serving as a research assistant at Waseda University Faculty of Science and Engineering, he became an assistant professor for Shibaura Institute of Technology Department of Information and Engineering, then assumed the current position as an associate professor at Department of Electronics and Electrical Engineering, Keio University Faculty of Science and Technology in 2008. In 2013, he concurrently became a board member of IDEAQUEST Inc. and continues to spearhead research aiming to put Keio-initiated image sensing technologies into practical use in the medical field. His specialties include perceptual information processing, intelligent robotics, media informatics/database, measurement engineering, and medical systems.



Active interaction with overseas labs

The Aoki lab encourages its students (mainly in the doctoral course) to study abroad and take part in joint research with overseas labs. This commemorative photo was taken with members of Prof. Nassir Navab's lab of Technical University of Munich (TUM).

I refresh myself with this!

Practicing judo with my son and daughter is the best time for me to refresh myself. Every time I receive instruction from the coach, I'm surprised by the depth of judo – the same experience I had during my high school days. I'd like my small ones to enjoy "intelligent judo" of their own.

Annual Aoki lab Alumini general meeting

Many OBs and OGs (including Aoki lab graduates of Shibaura Institute of Technology) come to our annual alumni general meeting to deepen friendly relationship with current members.

Aoki and his lab's ON and OFF time

Here I'd like to introduce some of Aoki lab's various activities, its past and present.

School festival during my high school days

As a member of a complete copy band of Seikima-II, I performed on stage as a drummer. I was also a busy student belonging to both the judo and cheer leading party. All these were possible because I took full advantage of a university-attached high school free of worry about entrance exams.

Presentation meeting for joint research results

Our presentation meeting for joint research results takes place in autumn every year. For this year (2013), we had participation from five labs: inviting two labs from the outside (from the University of Tokyo and Tokyo Denki University) in addition to three labs from Keio. This meeting is picking up year by year as an occasion for deepening interaction among students and for mutual stimulation.

A vital point of contact with the real world

We exhibit and demonstrate our practical systems at the annual KEIO TECHNO MALL. The whole of our lab considers this event as a vital point of contact and a venue for interaction with the real world.

私の本棚

My favorite books

Pattern Recognition

At the Aoki lab, recognition of various patterns from images is a major theme of research. Humans are able to respond flexibly to various situations by relating (as diverse patterns) enormous volumes of information to concepts and by accumulating them as knowledge. This book is ideal for learning basic theories about pattern recognition and machine learning – the technologies widely applied for various scenes of our modern life. As such, we make the most of this book at our lab.

Cognitive Psychology

This book is an easy-to-understand introduction to cognitive psychology, covering not only the past and present of this science, but even new fields yet to be developed. In particular, the book mentions hot topics such as cognitive evolution and brain, social cognition, culture and cognition, media informatics and cognition, and so on. In order to realize advanced sensing and artificial intelligence, I think it's necessary to find out new angles of approach while learning from the human cognitive mechanism. Answers are yet to be found, but I'm inclined to approach the goal from new angles by learning not only engineering, but cognitive psychology and related interdisciplinary areas as well.

Computer Vision – Algorithms and Application

Computer vision and pattern recognition are two of the fundamental fields of research we are handling at our lab. This book is rich in content, introducing from past achievements in computer vision to the latest algorithms, and even examples of their application. As such, this book is often referred to as "Bible" for this field of science. Some of our lab's doctoral-course students lent their hands in translating the book into Japanese.

Substances and Memory

This book is a masterpiece by the French philosopher H. L. Bergson who also has a great knowledge of science. As opposed to R. Descartes's dualism, in this book Bergson develops a new dualism by introducing the concept known as "Image" as an intermediate concept between body (objects) and mind (spirit) – the key, distinctive concepts of Descartes' dualism. All that we can obtain from images are the results of direct measurement of objects and phenomena only. By taking an indirect approach, I think we may be able to extract abstract information, such as consciousness, that lies behind physical measurement. As a source of new perspectives, this book provides me with valuable hints for my research.

Gibson – The Ecological Approach to Visual Perception

In this book, J. J. Gibson, the author, develops what is known as the direct perception theory that approaches visual perception from an ecological viewpoint. Instead of defining visual perception as a perceptual process by interaction between "the brain and eyes", Gibson says we should consider visual perception as the result of "how the eyes (the organ attached to the head) see" a particular object in a given environment as they move around in the environment. The content of this book is rather difficult, but it's a truly reliable reference for me to grasp and implicate human behavior in the environmental context.

DAI-KAO-TEN

Published by the Japanese Academy of Facial Studies and others, this pictorial book uses a wide variety of photos and illustrations to introduce facial studies from various fields of study and approaches. The academy is characterized as an interdisciplinary organization with membership of researchers from academic fields ranging from psychology, anthropology, medicine and dentistry to cosmetology. When I was a graduate student, I took part in this academy, approaching from the engineering field of facial image recognition and synthesis. These cross-cultural, joint research experiences in those days are proving to be a great asset for my lab management today.

The way industry-and-academia collaboration is conducted

Yoshimitsu Aoki

Needless to say, the end goal of engineering studies is to create new industrial and social value by applying new technologies resulting from research activities for the benefit of people's lives. Universities and businesses continue to pursue a variety of research activities toward this ultimate goal.

The foremost point differentiating university labs from industrial enterprises is that university labs use "research" – an ideal undertaking – as a means of educating students. As such, academic novelty and originality in approaches are required of universities' research activities. I assume what businesses eventually expect of universities in industry-and-academia collaboration are development of innovative technologies and new research approaches based on their unrestricted way of thinking. Nevertheless, the speed by which joint research projects can produce tangible results varies largely depending on the way collaboration is organized.

At my lab, we are developing a number of projects hand-in-hand with businesses as well as research organizations both inside and outside of our campus. Yet the way such collaboration is conducted varies widely. In typical cases of industry-and-academia collaboration, project progress is confirmed on a monthly basis. Recently we see an increasing number of cases, where we secure research spaces project by project, allowing students assigned to the specific project to get together daily and develop discussions with young researchers from the business concerned.

Such a situation may be difficult for students in a way, but it allows students to familiarize themselves with businesses' way of thinking and confirm each other's progress almost week by week. This setup can prevent the research policy from going off course, which leads to producing research results in a much shorter period of time. In some recent examples, the results of one to two years' collaboration have come very close to the stage of commercialization.

In the meantime, I notice a recent development in the attitude of businesses that come to us seeking advice on joint research. In the past, many businesses came to us seeking university-initiated technologies that could be commercialized in a relatively short period of time. But today, an increasing number of businesses seem to be more far-sighted; they want to establish a tie-up with us to identify and promote seeds of innovative technologies unique to our university no matter how long the projects may take.

Of course, the way industry-and-academia collaboration is conducted can vary widely according to specific stage of research. Knowing that, I spend each day in a positive way, trying to think out ways for win-win relationships in which each party will offer their strengths for mutual benefit.

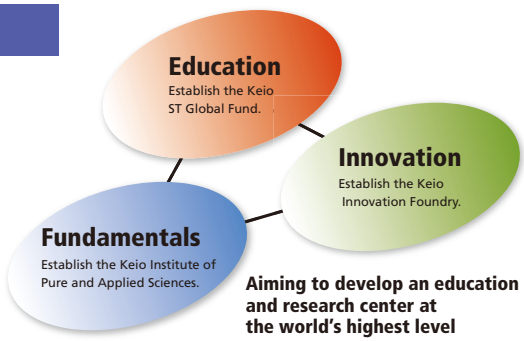
Science and Technology **Information**

Keio's Faculty of Science and Technology celebrates its 75th anniversary in 2014

The Fujiwara Institute of Technology (predecessor of Keio's Faculty of Science and Technology) was founded by industrialist and Keio alumnus Ginjiro Fujiwara in 1939 and later became Keio's Faculty of Science and Technology. As the faculty approaches the 75th anniversary since its founding, we are planning to carry out a number of commemorative projects to celebrate this milestone in our history.

The commemorative projects are comprised of three pillars: enriching educational programs which aim to educate world-class talent, including the establishment of the ST Global Fund; establishing the Keio Innovation Foundry as a research facility where postdoctoral researchers are trained to lead industry through cooperative partnerships between academia and private industry; and establishing the Keio Institute of Pure and Applied Sciences, which aims to generate unique, world-leading research. Both the Keio Innovation Foundry and the Keio Institute of Pure and Applied Sciences will commence research at the beginning of the new academic year.

Our endeavors to reform educational programs for global-minded human resources are already well underway. For example, in the current academic year, we held a Global Leadership Seminar targeting undergraduate first-year students on Hiyoshi Campus. Additionally, this year we decided to introduce a new quarter system for the undergraduate specialized education course on Yagami Campus to increase opportunities for students to take on new challenges like overseas internships. Moreover, our partner institutions for the double degree program in the master's course continue to grow, with the addition of three new partners—RWTH Aachen University, Universidad Politécnica de Madrid (UPM), and TELECOM Bretagne—for a current total of 14 partners worldwide.



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Editor's postscript

When we visited the Aoki lab for an interview, we found the students there playing a DVD of "School Wars." Curious about it, we asked one of them, who said, "Mr. Aoki loves 'School Wars' very much. He's really a passionate teacher." We felt that Mr. Aoki was loved and respected by his students. They say Mr. Aoki is willing to support his students, always encouraging them to study abroad to accumulate experience and expand their perspectives. As a sportsman with the experience of rugby and judo, his character seemed to be reflected in his lab's active atmosphere. But when it came to the interview, he spoke very gently.

This year falls on the 75th anniversary of Faculty of Science and Technology. We will further improve facilities and systems so that they merit the long history. We are looking forward to seeing the researchers and their lab students, who have been covered by this bulletin, leave new footprints in the future history of our faculty.

(Yuko Nakano)

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