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## Augmented Reality (AR)

### from Keio's Faculty of Science and Technology

Human-computer interaction based on spatial information

Maki Sugimoto

Assistant Professor
Department of Information and Computer Science

# Styles of communication being transformed by augmented reality

## What is AR that superposes virtual environment upon real environment?

**Recent years have seen application of Augmented Reality becoming increasingly popular along with the keyword "AR" in a wide range of fields such as smart phone applications, games, and advertising/sales promotional tools. Here, let's have a look at several concrete examples to overview the initiatives being developed by Assistant Professor Maki Sugimoto who pioneers the development of new styles of AR and pursues research into next-generation communication tools.**

### Spread of AR technology is accelerating in pace with its ever-expanding application to entertainment and advertisement.

Augmented Reality (AR) is the research field Dr. Sugimoto of the Department of Information and Computer Science is currently dedicated to. AR is a field deriving from Virtual Reality (VR) with which we are familiar in SF movies and games.

"While VR studies mainly aim to create sensory information that immerses users into a virtual environment built within the computer, AR aims to augment sensory information by superposing information from the computer upon that of our actual living environment (see Fig. 1 (Right)). In other words, by superposing a computer-created virtual environment upon the actual world in real time, AR allows us to access the virtual environment in a more natural way," as Dr. Sugimoto outlines his field of study.

A recent momentum that aroused interest in AR among the general public was the impact of the animation "Coil – A Circle of Children" televised on NHK (Japan Broadcasting Corporation) in 2007. The animation depicts scenes of children experiencing AR in their daily lives using a compact HMD (Head Mounted Display).

Meanwhile, "ARToolKit" software, developed by Professor Hirokazu Kato of Nara Institute of Science and Technology, is also worthy of special mention as having contributed to the spread of AR. It can make a virtual character or object appear on the screen after camera-scanning a pattern printed on a sheet of paper. Given its availability as an open source, many character animations produced by means of ARToolKit have been contributed to video-sharing websites, while video games and advertising/sales promotional tools based on similar technologies are also spreading lately.

"For example, there is a tool capable of drawing a computer graphics model of a vehicle's body on the screen if you hold the vehicle's promotional pamphlet over the camera, allowing you to confirm the vehicle's running state or internal structure. Competitive games combining a card game and CG are also rising in popularity. Thus, AR has now become a vital technology indispensable to advertising and entertainment."

**Fig.1 Human-computer interfaces taking physical presence and spatiality into account**

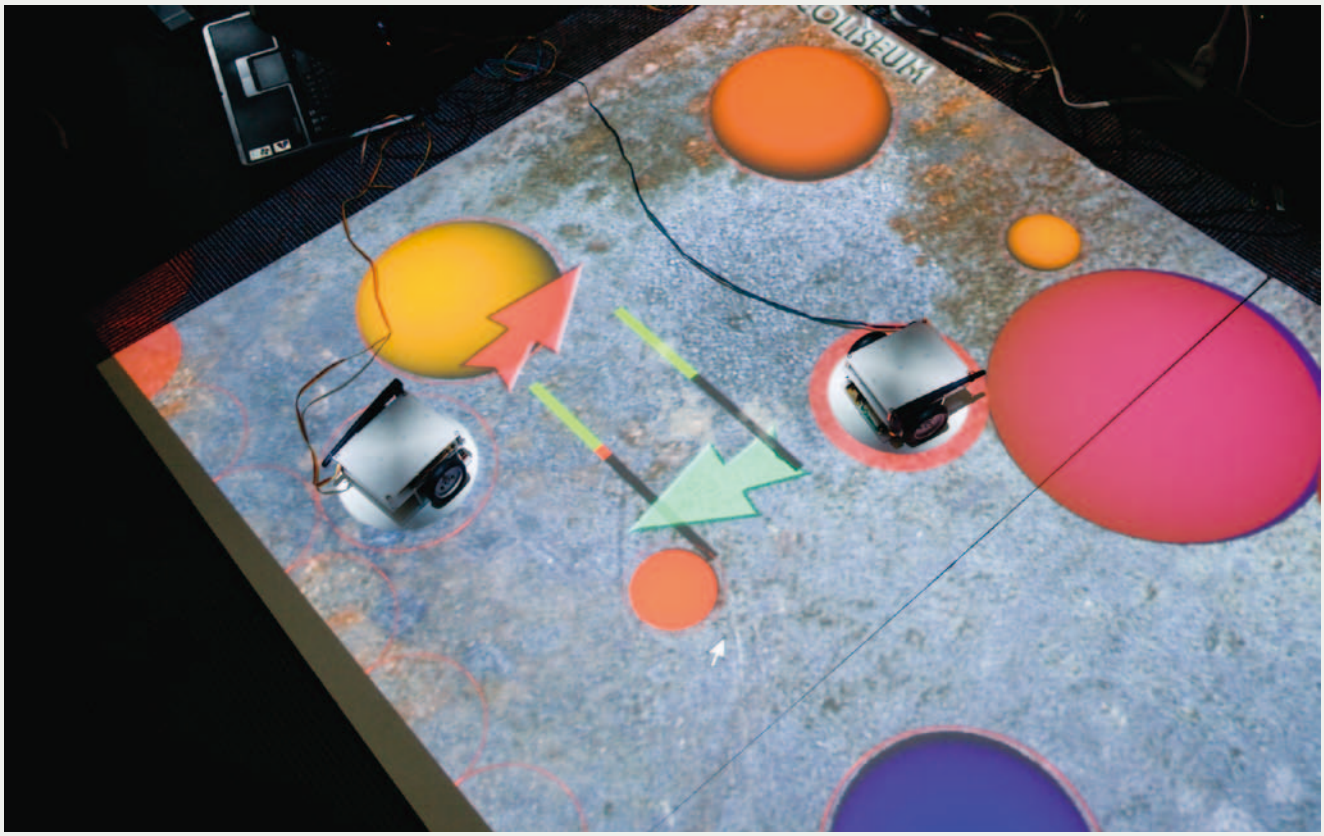
(Left) With this "Stickable Bear" interface, the bear-shaped robots of a size fitting in the palm of a hand support communication via gestures. The bear shape was created using a 3D printer.
(Right) This is an attempt to realize markerless tracking of location and/or attitude using a range image camera in a Spatial Augmented Reality environment. A texture projected by the projector follows a three-dimensional shape.

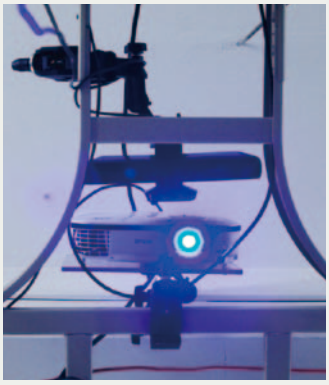
### Not only on a display screen but fusion in a real environment as well

You may talk about "AR" broadly, but its techniques vary widely. Currently most popular is a system known as "video see-through." Like the above-mentioned ARToolKit, the video see-through system realizes AR by superposing on the display the information created on the computer upon images taken by a camera. Meanwhile, the system known as "optical see-through" uses a transmissive display and is equipped with a half mirror and a see-through-type HMD. It is capable of superposing CG on real images that are optically visible. Furthermore, the system known as "spatial AR" can transform a real environment by projecting virtual images onto the real environment. The "Projection Mapping" event held in the newly renovated Tokyo Station Building in 2012 is a typical example of spatial AR.

"AR techniques are also very useful in work support. Application of AR to work support has already begun – for example, a patient's excision area can be clearly indicated by superposing a pre-photographed CT or MRI image onto his or her affected part at the time of surgical operation. Thanks to the recent spread of smart phones and personal digital assistants (PDA), the number of AR-based services easily available to general consumers is increasing. "Layar" combining location data and a camera is a fine example"

Dr. Sugimoto continues, "With the





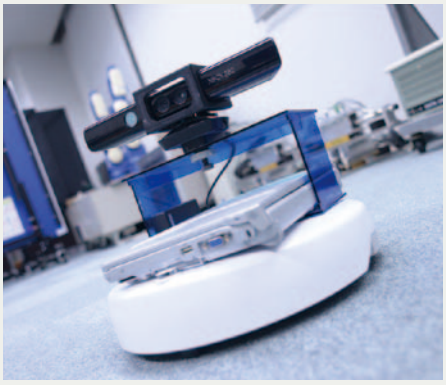


**Fig. 2 Robots acting in harmony with AR environment**

(Above) Based on the concept of Display-Based Computing, the entertainment environment "Augmented Coliseum" is capable of measuring and controlling by means of a projector and optical sensors mounted on vehicle-type robots.
(Below left) This is a projection system for building up a spatial AR environment. Collaboration with robots has been made easy by exerting ingenuity on projection patterns.
(Below right) This is a remote-controllable vehicle-type robot based on the video see-through AR technology. It is possible to control the robot while confirming future predictive images that have taken into account the interaction between the surrounding environment and the robot.

recent spread of AR, it is now perceived as a broader technology that can not only augment sensory information on the display screen but can also directly transform the real environment itself. This makes AR studies all the more interesting and worthwhile."

## Measuring and controlling robot movements using an optical ruler

Dr. Sugimoto is currently working on the development of a dynamic type of spatial AR, in which visual information is projected onto the real environment.

He adds, "By using devices such as projectors and robots, I'm trying to project information contained in the computer directly onto a real environment."

"For example, in the 'Augmented Coliseum' competitive shooting game using vehicle-type robots, robot movements are controlled by identifying accurate locations and attitudes of the robots mounted with optical sensors that can read fiducial images projected from the projector (see Fig. 2(Above)). By dynamically projecting a so-to-speak "optical ruler," the system realizes a highly accurate AR environment."

The greatest merit of this system is that it is possible to identify highly accurate locations of the robots only by using information read by the five robot-mounted sensors. Compared with common image sensors, the system allows computer computational complexity to be reduced significantly while also making it possible to move the robots in real time.

Dr. Sugimoto is also proceeding with a research project to achieve real-time synchronization, in an AR environment, of movements of a robot at hand with those of a robot in a remote location.

"Suppose you are doing a desk study to determine the arrangement of things inside a building. In this case, if you moved an object in front of you, a similar object in front of a person in a remote location would move in synchronization. This surely will enhance your sense of reality."

In this relation, he is also engaged in the development of a communication tool that allows an optical sensor mounted on a compact bear-shaped robot to read information on the computer screen and make various gestures in accordance with the information (see Fig. 1(Left)).

"What I want to realize by using augmented reality is flexible interface between humans and information. By presenting information with spatiality while setting much value on physical nature in the real environment, I would like to give concrete shape to abstracted information, thus contributing to smoother communication among people," concludes Dr. Sugimoto.

(Reporter & text writer : Madoka Tainaka)

# Passion for computers and virtual reality

**Dr. Sugimoto says that during his childhood he did not have a TV set at home. It may have been his counteraction to such a home environment that he became crazy about computers as a junior high school student. His devotion to computers continued to grow so much so that he came into a spotlight as a major player in inter-college virtual reality contests during his college days. His current hobby is the creation of CG design, indicating his endless enthusiasm for computers. In Dr. Sugimoto's lifestyle, virtually no gap can be seen between his likes and professional research work, with which his students seem to empathize. His lab is always full of students' vigor.**

### We heard that you are from Iida City, Nagano Prefecture. What was your childhood like back then?

Both of my parents graduated from universities of fine arts, and they were working in the same industrial design firm in Tokyo. One day, they were compelled to enjoy a self-sufficient life in the countryside and moved from Tokyo to Nagano. Thanks to their education policy of raising a child unrestrictedly in an environment of superb nature, I had lived a life without TV up to the age of elementary school upper grades. Indeed, as a small boy I spent everyday running about fields and hills.

Perhaps as retaliation to the life without TV, I came to take a special interest in computers when I was a junior high student. Toward the end of elementary school, I encountered computers for the first time in life when I visited the home of my cousin. There I found and touched an MSX, a computer for beginners. Since then, even before owning a computer of my own, I bought a computer magazine every month and was absorbed in reading them.

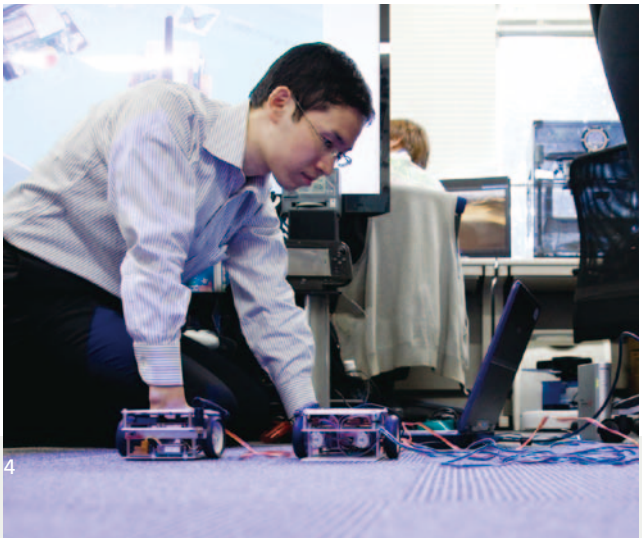
It was after I went to high school that I actually got a personal computer of my own. It was a high school admission congratulatory present from my father, who became unable to let my computer fever pass unnoticed.

After I obtained my own computer, I became even more fascinated by informatics so much so that a technical book on lossless compression became my favorite reading during my high school days. By the way, I still cherish the memorable computer that my father bought me.

**Fig.3 Hinode (Solar-B) satellite**

The "Hinode" or Solar-B is a solar observation satellite launched by the Japan Aerospace Exploration Agency (JAXA) in 2006. Boasting a full range of onboard equipment, such as a solar optical telescope, an X-ray telescope and an extreme-ultraviolet imaging spectrometer, Hinode is capable of highly accurate observation of magnetic fields, temperatures and plasma of the solar surface and the gaseous envelope outside the solar chromospheres (corona). The CG shown here is a work by Dr. Sugimoto.





### What made you decide to choose a researcher's career?

As an undergraduate freshman, I took part in the International Collegiate Virtual Reality Contest (IVRC), an event presided over by the then University of Tokyo Professor Susumu Tachi (now Special Research Professor of Keio University, and Professor Emeritus of the University of Tokyo). This turned out to be the first opportunity for me to think about a career as a researcher.

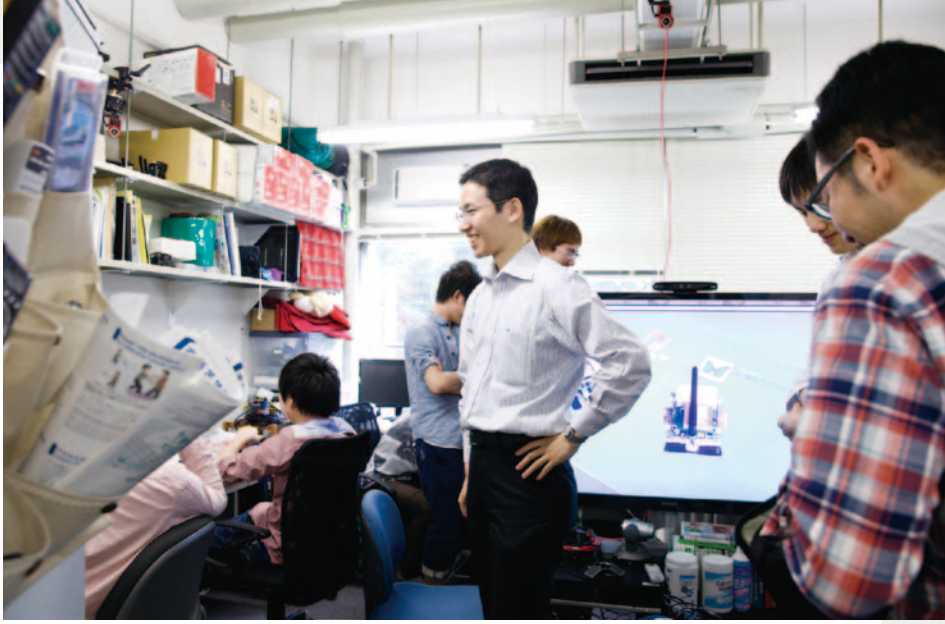
The seniors in the circle that I joined upon university admission were the contest winner for the preceding year, whom aroused my interest.

My first production as a freshman was a tele-existence system that creates a sense of self-projection to a target object placed in a water tank. Though it was the first ever challenge for me, we were honored with an encouragement award of The Virtual Reality Society of Japan. From the second year on, we also made entries with the help of many friends as well as a professor who became the supervisor of my graduation thesis. In the third year, our team created a system that allowed one to walk around freely inside a computer memory unit's folder structure expressed as a 3D environment. This system won both the encouragement award and technical award.

Through entries in this contest, I was blessed with opportunities to work with front-line researchers, such as Professor Taro Maeda and Professor Hideyuki Ando (both currently at Osaka University) who became colleagues after completion of my master's course, and Professor Masahiko Inami (now at Keio University) who was my mentor of my doctoral course. It was a truly valuable experience, awakening me to the excitement of studies.

### You are now involved in IVRC administration, aren't you?

I turned to the event's administrative side when I was a senior, and now I'm supporting it as an executive committee member.



I also had the experience of designing the IVRC webpage though I'm not responsible for it now. I undertook the webpage design because I enjoy CG design as a hobby and to get away from research work. During my student days, I even spent my living expenses worth several months to buy very expensive 3D CG software. Back in those days, it was a decision as desperate as making a leap in the dark. I am very envious of today's students because at educational institutions today, it is possible for students to take advantage of a variety of highly functional software programs for free.

The other day, I happened to find in NASA's website a CG model of the "Hinode" (Solar-B) satellite that I created for the National Astronomical Observatory of Japan when I was a doctoral student. I am very happy to see my own CG works being enjoyed and used by many people.

Recently, my lab introduced a "3D printer" (3D shaping equipment) as an application of CG design. It is capable of making fixtures for devices that we use for research on the spot by designing CG models. I'm extremely delighted that my hobby of CG design is actually useful in our studies.

Of course, not everything in my life, whether it is my research or pastime, revolves around a computer. Since three or four years ago, our team of researchers has been making entry in "Eco-Run" – an auto event in which participating light vehicles run on the Fuji Speedway racing course. At my home, I have a home theater of 130-inch LCD projector, with which I view SF movies and animations from time to time. Being so much attracted to such visual entertainment is perhaps retaliation to my childhood that I spent without TV (laughter).

**Currently how many students does your lab have?**

A total of ten – four undergraduate and six graduate students. They are all gentle, positive, and well brought up. Indeed, they are really worth teaching.

But it should be kept in mind that students could hardly learn what they are taught at classes if they remained passive. This is why I'd like my students to take up any hobby related to their interested fields and put it in practice as "their own challenge." Especially when it comes to the field of informatics, you are able to shape your own ideas readily with only a computer and sufficient enthusiasm. I sincerely hope that students will enjoy a meaningful student life by beginning with their interests.

◎ **Just a word from a student . . .** ◎

● Whenever we students approach Prof. Sugimoto for consultation, he responds to us with very kind advice, putting himself in our shoes. Our lab is always has a friendly atmosphere, so we can communicate very frankly with each other.

(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 take up any hobby related to their interested fields and put it in practice as "their own challenge."**

## Maki Sugimoto

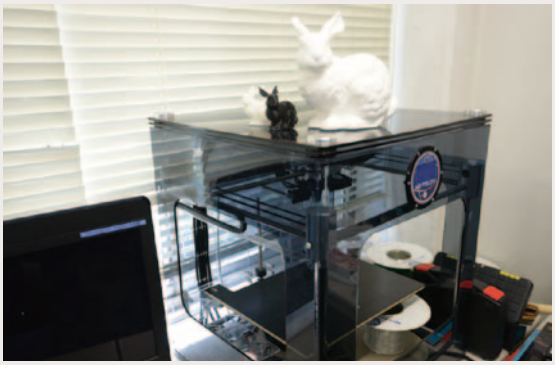
Dr. Sugimoto graduated from Iida High School in Nagano Prefecture, Japan. He received his Doctor of Philosophy in Engineering from The University of Electro-Communications. He was a visiting researcher of NTT Communication Science Laboratories, a research fellow of the Japan Society for the Promotion of Science, and a visiting scholar of MIT Computer Science and Artificial Intelligence Laboratory. He became a senior assistant professor in Graduate School of Media Design, Keio University in 2008. In 2011, he assumed the current position as an assistant professor in Department of Information and Computer Science, Faculty of Science and Technology, Keio University.

# Sugimoto lab and Mr. Sugimoto's ON and OFF hours

Sugimoto lab is a young one just started up in 2012. All members of the lab are eager to create an intimate and attractive research environment so that many highly motivated students gather in the lab.

### 3D printer

Our lab has introduced a 3D printer capable of freely shaping 3D shapes and a laser cutter capable of quickly cutting 2D shapes. These state-of-the-art pieces of equipment represent our motto: "Speed is Power."




### Overseas training

This photo is a shot taken at University of South Australia, our partner with whom we are conducting joint research into augmented reality environment measuring technology.

### Farewell party

Our farewell party for graduating students was held jointly with Professor Hideo Saito's lab. This shot was taken in front of the "Gin-tama" (Silver Ball) object, Hiyoshi Station's popular rendezvous spot. I'm looking forward to their success in the future.


### Sugimoto lab's winter camp

Our lab's winter study camp was held in the Mt. Zao area. Participants enjoyed skiing and snowboarding during the day while engaging in hot discussions for studies in the evening. Our watchword? – "Beware of muscle pains and sprains!"

### CG design

CG design is an interdisciplinary area spanning practical utility and pastime. I sometimes offer CG design service to support webpage design for an international coference for which I work as an executive committee member.

### Driving

When I have time to spare, I enjoy driving as a diversion. Joining Prof. Sugiura's (Graduate School of Media Design) driving team, I participate in endurance races (two times a year, in summer and winter) on the Fuji Speedway racing course. Safety First!

### My home theater

I have my own home theater for enjoying movies. At the end of each semester, I host a movie party inviting my students.

# 私の本棚

My favorite books


### Fundamentals of Virtual Reality

This book was supervised by Professor Tachi, the recognized authority of virtual reality studies. Though out of print currently, the book is a full compilation of practices that suggest how to design VR as well as intriguing knowledge based on such practices. Those who have become interested in this field are advised to read "The Study of Virtual Reality" – a book also supervised by Professor Tachi, which is easily available.

### Spatial Augmented Reality

This book is often referred to as the "original source book" for projection mapping technology. Of augmented reality, it focuses on projector-based spatial AR systems, comprehensively describing their concepts and mathematical principles. Professor Ramesh Rasker of MIT Media Lab, one of the authors of this book, is worthy of special mention as he is well known for his innovative research that constantly opens up new horizons inthis research field.

### Learning Game 3D Mathematics through Case Studies

VR and AR technologies have much to do with 3D spatiality-based game development technologies. This book provides systematic explanation of mathematical principles indispensable to thinking of factors interacting with three-dimensional space information, such as the handling of coordinate systems on the computer, geometric transformation by means of matrix operation, and crossing detection.

### Ready Made: How to Make (Almost) Everything

At our lab, I have my students design devices necessary for experiments on their own, instead of merely engaging in computer-based programming. By making the most of such leading-edge technologies as the rapid prototyping and physical computing technologies, I encourage them to value the DIY (Do-it-Yourself) approach as well. This book provides us with valuable stimuli for thinking about how to create various things on our own using easily available materials around us.

### The Laws of Simplicity

A friend presented this book to me as a memento when I was visiting at MIT. It is a work by Professor John Maeda of the lab the friend used to visit. When we have obtained a new technology, it is often the case that you can design ease of use by subtracting rather than unreasonably adding information. This book explains, in an easy-to-understand way, the "importance of simplicity" – a principle that should not be missed when we design methods of information presentation for research purposes.

### PATLABOR

This is a work by the manga artist Masami Yuki, in which the large robot "LABOR" is brought into the everyday world. It depicts the state of our modern society and teamwork between the hero and other characters. The story contains many points of engineering interest, such as: that the robot varies in performance according to the OS used, that researchers with the ability to develop highly advanced technologies are connected to each other through a university lab, and that the R&D team who have developed a superb mechanism is more valuable than the product itself . . . These aroused my interest in going on to university and majoring in science and technology.

## New horizons opened up by imagination

— Science and creativity —

Maki Sugimoto

Virtual reality studies are attempts to recompose our sensory information (including that of our five senses) and re-present it, allowing us to feel as if our bodies were in a world different from reality. The origin of "creation" of such virtual reality can be traced back to Lewis Carroll's tale (fiction) "Alice in Wonderland."

In 1965, Professor Ivan Sutherland, the pioneer of VR and AR, explained the VR concept in his thesis entitled "The Ultimate Display" that the ultimate form of presentation device in which a computer can control all sensory information could be "the Wonderland into which Alice walked." This remark indicates that the professor had an exceptionally superior imagination of finding a world of spatiality inside the computer back in those days when the computer was regarded as a pure "calculating machine."

Fiction can also lead to stimulating an interest in initiating a new research endeavor. Professor Masahiko Inami is well known for his study on transparentization "Optical Camouflage" based on the retro-reflective projection technology. He and his team explained this study in their 1998 thesis entitled "Study for the Reality Fusion (II)" while citing Masamune Shiro's (manga artist) "Ghost in the Shell" as a reference. It was because the "Thermo-optical Camouflage" that appeared in "Ghost in the Shell" motivated them.

Nurturing our imagination by reading a variety of fiction in this way can broaden our horizons and offer food for thought for exploring new possibilities while also serving as an impetus for converting such possibilities into reality. Science/technology and fiction are always complementary to each other. It may be safe to say that new fiction can be created based on science/technology while next-generation sciences and technologies can be inspired by fiction.

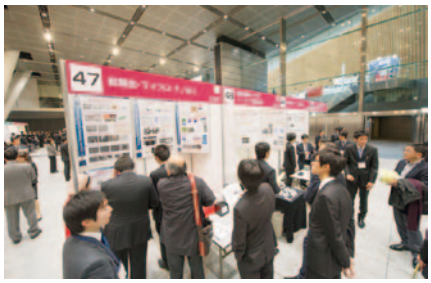
Creativity that can give shape to imagination is another vital factor indispensable to researchers. Researchers and research teams that have both imagination and creativity have the power to open up a new world.

I'd like all of you to enjoy a lot of exciting stories and nurture "imagination and creativity" – the powers to create worlds you have never seen before.

## Science and Technology **Information**

### 14th Annual Keio Science and Technology Exhibition

Date: December 13 (Fri.), 2013 10:00 ~ 18:00
Tokyo International Forum (Exhibition Hall 2, Basement 2)
Contents: Demonstration-oriented exhibit booths along with Technology Partnership Seminars and Round-table Sessions by researchers
Featured event:
A panel discussion in commemoration of the 75th anniversary of the Faculty of Science and Technology
Theme: "Emerging challenges in global tech leaders education"
Main panelists:
Mr. Koichiro Tsujino (Founder & CEO, ALEX Corp.)
Mr. Michimasa Naka (CEO, StormHarbour Japan Ltd.)
Mr. Ken Endo (Associate Researcher, Sony Computer Science Laboratories, Inc.)
Admission free. *No prior registration required.






**Editor's postscript**

When I first met Assistant Professor Sugimoto, my impression of Mr. Sugimoto was that of a student because of his young, gentle-looking face. As I began interviewing him, his eyes turned brighter and his look changed to that of a researcher and an educator as he talked about his field of study and sincerely said that he would like his students to maintain the spirit of inquiry.

When the time came for him to demonstrate the competitive game "Augmented Coliseum" for photographing, his lab students were cooperative enough to help the demonstration by suspending their research work for a while. When introducing a study of projecting images on a 3D object from a projector, it was not Mr. Sugimoto but the lab students that gave the demonstration and explanations.

Perhaps partly because of age proximity between the teacher and students, the Sugimoto lab was full of a friendly and yet lively atmosphere. (Yuko Nakano)

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