facebook
"keiokyuri"

Kyurizukai

新版 窮理図解

2019 March
no.
30

Bulletin of Keio University Faculty of Science and Technology
http://www.st.keio.ac.jp/kyurizukai

English versions are also available:
http://www.st.keio.ac.jp/kyurizukai/english/index.html

Field Robotics

from the Faculty of Science and Technology

Robots making their marks in extreme environments, including other planets and active volcanoes

Genya Ishigami
Associate Professor
Department of
Mechanical Engineering

The latest bulletin features Associate Professor Genya Ishigami, who develops robots exploring in space, volcanoes, and at the sites of natural disasters.

Development of robots for use in extreme environments through research in diverse domains

Including robots which will be of service for natural disasters, agriculture, and logistics chains based on research outcomes

"I want to make robots which help people," says our subject Ishigami-san, who is also developing robots to take on traditionally human tasks, with a particular emphasis on robots conducting surveys and other manual tasks, as well as carrying heavy loads, for use at locations such as the moon, Mars, and the sites of natural disasters, which cannot easily be accessed by humans.

The four basic fields of robot research

Technologies from various disciplines, such as mechanical engineering, electronic engineering, control engineering, and computer science, are encapsulated in a single robot. While most researchers specialize within either of these particular domains, Ishigami-san is engaged in research and development on the diverse aspects which relate to robots.

"I started out doing terramechanics, which is a critical concern when a mobile robot travels on rough terrain," says Ishigami-san. When robots move over the surface of the moon, the terrain surface is loose and non-uniform. A dynamic approach is required to investigate how a wheel would perform on the surface of the moon, scattered as it is with a mixture of sands and rocks.

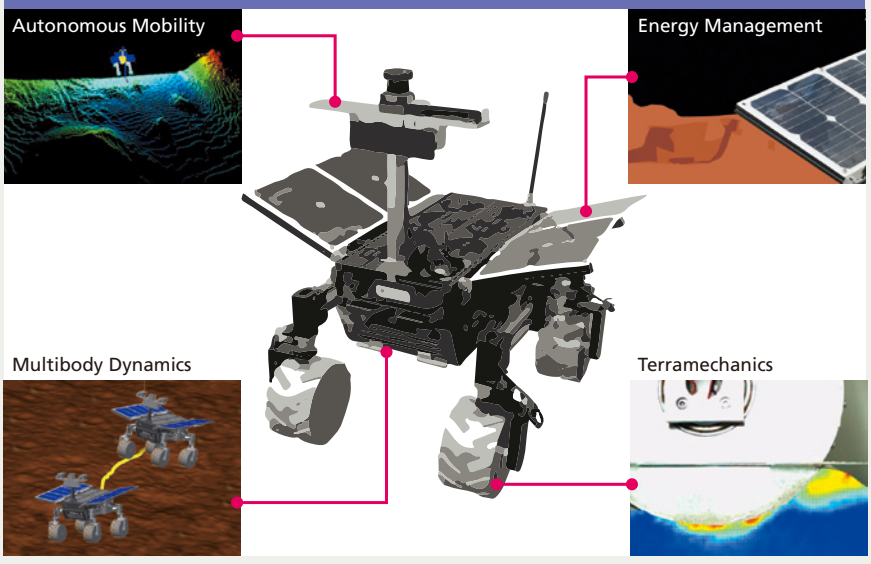
Having grasped the terrain, the robot dynamics came to attract his attention. He also tackled questions as to how the bodywork of a robot would dynamically move as it attempted to climb over particular obstacles, or whether it would in fact overturn, in the field of multibody dynamics using analyses and computer simulations. This is also used in simulations for probes touching down on the surface of planetary bodies.

Following the body, his interest would turn to robot intelligence. He moved on to the field of "autonomous mobility systems," hoping to find out how to: "Facilitate a robot in making its own decisions on how it should move." This kind of research leads in to autonomous driving, including questions of how to control the wheels of a vehicle and what would be the safest potential routes. Computer science deals with this research topic; however, his knowledge and experience of mechanics has served him well and enabled effective analyses and accurate interpretations of results.

This experience of diverse fields will bear fruit in the development of a "sensor wheel." A sensor wheel is essentially a vehicle wheel equipped with artificial intelligence, similar to sensible skin on the sole of foot. The wheel itself can detect the terrain stiffness, the extent to which it has sunk, as well as the degree of traction beneath the wheel. In addition, the wheel stores test data and improves its traction via machine learning. This has been heralded as an epoch-making outcome in the field of terramechanics.

Another critical issue is "energy management." Streamlining movement while limiting a robot's energy consumption are imperatives when operating in extreme environments such as on the surface of the moon. "We use a machine learning algorithm to derive an optimum protocol for power generation control in robots equipped with solar panels, and to plan a robot motion which takes into account of quantity of energy generation, energy consumption, and related factors." Ishigami-san's transdisciplinary research experience has been leveraged to realize locomotion which minimizes energy loss, an undertaking that also requires terramechanics know-how.

Fig. 1: Four basic research fields for robot technologies



Robots making their mark on Mars, the moon, and volcanoes

Ishigami-san is putting these four basic research areas to use in a variety of applied fields. He says that he is currently involved in three space-related projects. The first is a Mars exploration project led by the Japan Aerospace Exploration Agency (JAXA), which plans to take samples of the Martian surface and subsurface (underground) for a variety of proposed scientific surveys, including searching for traces of life. Ishigami-san has been participating in the capacity of system design and specification for a mobile robot equipped with a scientific probe.

The second project is the Martian Moons eXploration (MMX) project, also being led by JAXA, which aims to launch a space probe in the early part of the 2020s. Like Hayabusa, the project is an asteroid sample-return mission, which will bring back samples from the two

Martian satellites of Phobos and Deimos to earth. Ishigami-san tells us that his team is conducting a landing dynamic simulation of the probe.

The third project is for exploration of an underground cavity called a vertical hole, which has been discovered on the moon's surface. There is a large cavern resembling the caves, or *lave tube*, at the base of Mount Fuji directly beneath the moon's surface. There is expectation that this could be exploited as a shelter from solar radiation in future manned exploration on the moon. He also says they are in the process of exploring a miniature robot to be deployed into this vertical hole, and that they have meanwhile conducted a volcano monitoring experiment using a mobile robot on Mounts Mihara and Aso.

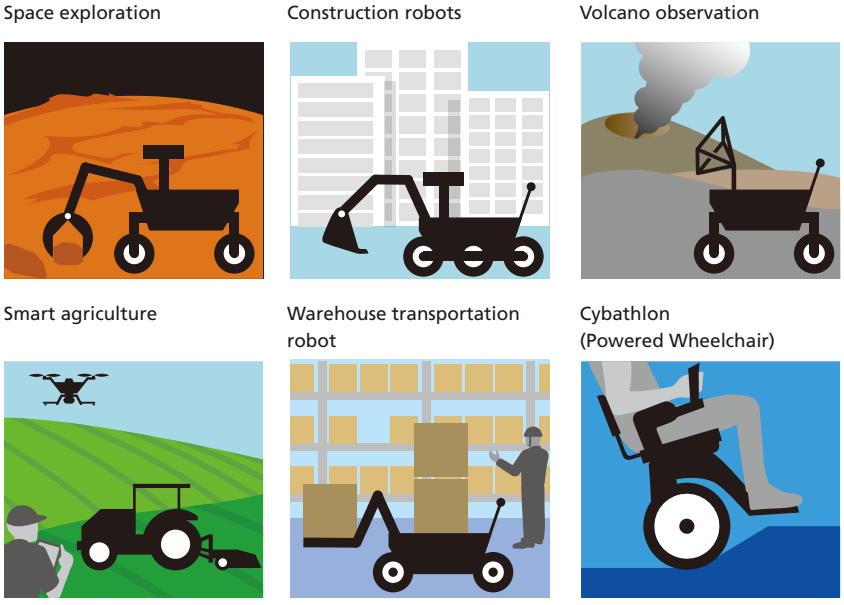
Ishigami's team are presently equipping robots with observational muography devices for surveying cavities inside volcanoes. Muography is a method to observe elementary cosmic particles called muons, which is now in the spotlight as a means to survey volcanoes, and has the potential to facilitate predictions on the size of phreatic eruptions.

Robots to contribute to load reduction at natural disaster sites and during transportation operations

Teleoperation technologies for robots come into their own at locations such as natural disasters sites. Tough Robotics Challenges (TRC) is a project which aims to realize tough robots for deployment at sites of natural disasters that involves in a part of the Cabinet Office's "Impulsing Paradigm Change through Disruptive Technologies Program (ImPACT)." Ishigami-san is responsible for dynamic simulations, including those for removal operations of large volumes of rubble piles at the sites of natural disasters using construction vehicles; lifting the roofs off houses which have collapsed due to earthquakes; and rescue operations for any persons trapped inside such buildings.

He is also working with robots to assist with the harvesting of farm produce and the spreading of pesticides using autonomous mobility systems. For example, robots can detect agricultural workers with a mounted camera and follow behind them at a fixed distance such that the robots transport harvested heavy crops instead of the workers. "I would like to be entrusted with [developing] technologies for stable locomotion over soft and uneven agricultural terrain," says Ishigami-san. It appears that the basic technologies which he has researched can be exploited in this context as well.

Fig. 2: Six applied research fields



All of the research in these six applied fields is supported by research in the four basic research domains.

He says that, "A similar approach could also be used in a distribution warehouse." In a warehouse in which a single operator transports several tons in a single day, the assistance of a robot in picking up and transporting cargo would allow for load reductions and the mitigation of personnel shortages. These kinds of robotization have occasionally been met by protests that "robots will take people's jobs." To this Ishigami-san replies, "Rather than robots completely taking over the work of people, this would ideally be a question of a set-up whereby robots help to realize the coordination and streamlining to allow people to do what people can do and robots to do what robots can do."

Participation in powered wheelchair race at international competition

The development of powered wheelchairs is research to actively assist people further. Ishigami-san mentions that one day he happened to be riding the same train as Professor Kohei Ito, Dean of the Faculty of Science and Technology. The original inducement was being asked by the professor, "Ishigami-san, wouldn't you like to compete in the Cybathlon?" The Powered Wheelchair Race is one event at the Cybathlon, an international competition which aims to put robotics to use for persons with disabilities.

The race involves battling it out against the clock over an obstacle course which includes six obstacles typically encountered by wheelchair users in everyday life. These include negotiating slalom and hills, opening doors using robot arms while seated, and mounting slanting pavements. Ishigami-san made a snap decision to take part and will appear in the Japan leg of the Powered Wheelchair Series set to be held in May 2019.

You cannot leave it at "research for research's sake"

According to Ishigami-san, "What researchers working on robots must keep in mind is that their research should never be for its own sake." Although emphasizing the importance of basic research, he says that it is necessary to keep a keen eye on how this research might actually be used on practical real situation, while his guidance to his lab students also encourages a continual awareness of the background to research.

What brought this home to him most strongly was the Great East Japan Earthquake. When the accident at the Fukushima No. 1 Nuclear Power Plant occurred, the first robot dispatched for exploration was a military robot made in the United States, despite the fact that it would have been possible to immediately dispatch a Japanese-made probe robot. While Japanese technology is actually superior to that of the United States, the many people involved with robots in Japan missed out on the chance to contribute immediately and ended up just watching impatiently from the sidelines.

Ishigami-san's underlying aspiration is to create robots which are useful to and help people at real-world sites.

(Interview and text writer : Yuko Hiratsuka)

I would like to share the excitement of the capsule retrieval campaign during the *Hayabusa* project with young people

Ishigami-san, whose career has included being a JAXA researcher. While he continues today to participate in exploration projects, including one intended for Mars and its satellites, he recounts that his memory of the excitement he tasted during the capsule retrieval campaign for the *Hayabusa* asteroid probe, which he experienced immediately after becoming a JAXA researcher, remains undiminished even today. This was an outstanding deed realized by the passion of the researchers. "I want the next generation to taste the delights and excitement of being a researcher," says Ishigami-san.

Tell me a little about your childhood.

As an elementary school student, I often spent it playing outside. At home, meanwhile, I would pass the time staring intently at the turbulence in the twin-tub washing machine or the waves created in the water as the bathtub emptied. I have fond memories of beating the sand to make the ground solid and using a spirit level to ensure the foundations were fully horizontal when I helped build a storage room with my father.

During junior and senior high school I busied myself with both basketball and my studies. However, in the spring of my third year of senior high school, I severed a ligament in my leg during a training match with university students. This was a real blow, as I had been intent on appearing in the final tournament that June.

You went on to join a space robot lab at university.

I had it in mind to study abroad at the University of California, Los Angeles (UCLA). At the time—the latter half of the 1990s—CG was in its ascendancy there, and I particularly liked movies when I was in senior high school. I put together a fairly detailed plan that also took in scholarships and then spoke to my parents. Unfortunately, as it turned out, there were too many difficulties on the funding end, and this had to be abandoned.

Then, just as I was contemplating university entrance exams, I learned that there was a space robotics lab at Tohoku University in my hometown of Sendai, and decided to set my sights on getting in there. I got into Tohoku University under a designated school recommendation, and succeeded in entering the laboratory of my choice of Professor Kazuya Yoshida as a third year undergraduate.

I was surprised to discover that they had the CG software 3ds Max at the lab. This was a genuine source of delight, as this is a sophisticated piece of software which is actually used by film production companies.

When were you finally set on taking the researcher route?

In April of the second year of my master's, Yoshida-sensei asked me: "Wouldn't you like to do a doctorate?" This proved the turning point, as I was reassured by Yoshida-sensei's faith in my ability. In the first year of my master's, a number of events also reinforced my own sense that I had indeed made substantial progress.

For example, when I did a short-stay study abroad program in Australia at the University of New South Wales during spring break, my research was received more favorably by the professors and students there than I would ever have imagined.

I was motivated by my interest in where it might lead me if I studied even harder for a Ph.D., which decided me on entering the doctorate program.

After getting your doctoral degree you made your way to Massachusetts Institute of Technology (MIT).

This was because MIT's Karl Iagnemma was producing consistently spectacular papers, and I had already aspired to working with him for some time.

It appears that Karl too was aware of my own existence, and he replied to my entreaties by saying: "As it stands, I reckon MIT can cover half your wages." At this point, I set about digging up a scholarship to cover the remaining half of my wages, and succeeded in getting funding from the Murata Overseas Scholarship Foundation. I remember being extremely nervous on finding out that Professor Kazuo Yoshida from Keio University was one of the people in charge for the final interview.

How was life as an MIT researcher?

That period was the skinniest I have ever been in my life (laughter). The first three months were distinctly challenging. The rent and taxes were higher than I had envisaged and I would eat just one bagel for lunch—in essence a subsistence-level existence. In addition, I made light of the need for English proficiency, but I was being naïve...

Nevertheless, while the laboratory as a whole was largely peopled by theoreticians, Karl valued my contribution as a researcher inclined towards practical work and experiments. By the time I got to my second year, I was involved in around four projects, including consulting for corporate entities.

The one that stays with me most was a project related to the United States Defense Advanced Research Projects Agency (DARPA). On one occasion there was an accident involving a bomb exploding as it was being disarmed by a remote-controlled robot in Afghanistan. I was able to participate in the

subsequently-convened DARPA academic conference, where the speech given there by a high ranking officer to the effect that "This robot saved the lives of three soldiers" was greeted by a standing ovation. This was the first time I had encountered a real-world situation in which research outcomes had directly intervened to save lives. I was deeply impressed by the hero's reception afforded to a robot designed to rescue people.

How did you find your work at JAXA after you got back to Japan?

I threw myself into my work at JAXA. I was allowed to present on what I might contribute to the Mars exploration mission at the second meeting in which I participated there. As a result, my membership of the team was approved; and I was also given the chance to present at a mission definition review several years later.

In June 2010, immediately after I assumed my post, I also had the privilege to join the capsule retrieval unit for the *Hayabusa* ("Peregrine Falcon") asteroid probe. The morning after we had successfully found the capsule on a vast desert in Australia, I was greatly moved by the passionate speech given by Professor Hitoshi Kuninaka who both headed up the retrieval campaign and was the developer of *Hayabusa's* ion engine. Having the opportunity to share in the emotion associated with the successful completion of a mission that had spanned some 30 years and generations of researchers at the same time sparked in me a burning desire to help the youngsters of the next generation have similar experiences.

This is partly what led me to turn my sights on Keio University. In fact, I was already being drawn into the gravitational orbit of Keio when I was at JAXA, with one of the researchers to whom I was most indebted in my work then, as today, being an adherent of Professor Kazuo Yoshida.

What do you perceive as the appeals of Keio University?

I feel that the ability of the faculty and staff members to unite and work towards a single goal is wonderful. Even if an undertaking has no particular precedent you would never hear "It can't be done." Instead people join you in looking for solutions saying something like "How about doing it this way?" or "Let's try it like this!"

I also find the relative lack of distance between faculty members and students appealing. Soon after I assumed my post I came across Yukichi Fukuzawa's phrase of *hangaku-hankyou*, or "learning while teaching, teaching while learning," and thought that this was a particularly germane way of describing this dynamic. While I may be in the position of teaching, I get a real sense that this also constitutes a position whereby I am taught and can learn from the students.

What is most important when it comes to research?

I often say to students "don't become passive or complacent." If you are sitting around waiting for someone's permission you will not do good research. As I said when I presented on the Mars exploration mission at JAXA, your work should also assume the attitude of showing off your own particular talents. I want my students to maintain a sense of spontaneity and dynamism in their work.

Another study I am currently tackling requires us to go about our work while keeping in mind "The significance and impact for society at large."

◎ Some words from students . . . ◎

● Ishigami-sensei has an extremely generous sense of humor. He is erudite and talented in many fields, meaning that whatever you choose to research he will offer concise and pointed advice. On the flipside, he plays softball with us and is a teacher with whom you can talk about almost anything (4th year undergraduate).

(Interview and text writer : Yuko Hiratsuka)

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

Do not assume a passive demeanor
The secret to research success is seizing opportunities.
To do this maintain spontaneity and dynamism.

Genya Ishigami

Associate Professor at the Department of Mechanical Engineering, Faculty of Science and Technology, Keio University. Ph.D. in Engineering. Specializes in field robotics, space exploration engineering, terramechanics, and autonomous mobility systems. Graduated from the Department of Mechanical and Aerospace Engineering, School of Engineering, Tohoku University in 2003. Completed doctorate majoring in Aerospace Engineering at the Graduate School of Engineering, Tohoku University in 2008. Research Associate at the Japan Aerospace Exploration Agency from 2010 following a Postdoctoral Associate at the Massachusetts Institute of Technology (MIT). Enters the Faculty of Science and Technology, Keio University in 2013 as an assistant professor, assuming current position in 2017. Born in Miyagi Prefecture.

Seminar camp

My students kindly plan various events each year, which have to date included caving, trekking, fishing, rafting, park golf, and *soba* noodle making.

Gifts

I decorate my laboratory with gifts from Lab members on their graduations. They have handcrafted the scale models of robots and stickers depicting my face.

Genya Ishigami's ON and OFF

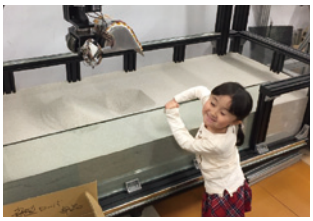
While I may look like someone who spends both their ON and OFF time in the outdoors, in fact I also love to be indoors.

Field experiments

Filed experiments are always tough and challenging, but I have come through many field experiments since my student days.

MIT/JAXA era

This five-year period broadened my horizons at a stroke by a wealth of experiences.



Family time

My arrival at Keio coincided with the arrival of my daughter, and recently it seems that she has become aware that "Daddy makes robots." Sometimes I even bring my children into the lab.

The Grand Circle

A drive equivalent to the length of Japan which, as the name suggests, gave me the chance to see glorious expanses of nature. Next time I'd like to bring my children.

Camp and coffee

I often accompany my elder sister's family on camping trips. The appeal of this lies in spending a relaxing time in the great outdoors without having to constantly watch the clock. Coffee enjoyed first thing in the morning during camping is also second-to-none.

私の本棚

My favorite books

A keystone text of terramechanics

Theory of Ground Vehicles

This is a textbook focusing on terramechanics, in particular vehicle-terrain interaction mechanics which is concerned with the dynamics of vehicles during off-road locomotion. Its wide-ranging content encompasses basic mathematical derivations to examples supposing actual sites as well as applied case studies and numerical analyses. This is an indispensable work first issued in 1978, with subsequent editions incorporating and building upon the trends and outcomes of research in recent years (the picture is of the 4th edition).

The monograph which led me to becoming a researcher

Mobile Robots in Rough Terrain

The author of this book, Karl Iagnemma, was my boss during my time at MIT. He published this book based on his doctoral dissertation in 2004. I read this in the second year of my master's studies. The clarity of the writing, the structure of the arguments, and broad scope of the research left a formidable impression on me. This got me thinking, "He is the one I want to work with." I would also characterize it as the monograph which led the way to my becoming a researcher. It is also a treasure trove as a reference book for specific examples of academic writing in English.

Jukuryo Danko

(Deliberate in council, decisive in action)

Saka no Ue no Kumo

(Clouds above the Slope)

This is a volume which has invited repeated re-readings, perhaps because I first encountered it in the latter half of my twenties when I was the same age as the protagonists; or perhaps because there is an intermingling of the Japan of then, which exerted all its efforts to challenge the world powers of the time, and the Japan of today, which is fighting hard just to keep pace with space development. I was moved by the unmediated strength of the image of the novel conveyed by the protagonist's own calligraphy *Jukuryo Danko* (Deliberate in council, decisive in action) which decorates his birthplace.

A field guide for spacecraft

Space Flight

This is a volume which I bought on a whim after finding it in a bookstore in downtown Boston. While many field guides directly equate space with astronomy, this particular volume methodically retraces the history of space flight from the dawn of the Space Age through to today, with an emphasis on spacecraft such as rockets and probes. This is an extremely rewarding read, and the meticulous precision of the illustrations means that I sometimes put it to use in the classroom.

The bible of lab management

Dokusō wa Hiramekanai

(Originality doesn't come from nowhere)

This is a wonderful book that will familiarize readers with the wisdom and approaches to problem solving of Professor Kanade, whose work enjoys renown across multiple fields, in particular image processing. It leaves you with the uncanny feeling that Professor Kanade is directly addressing you from beyond the book. This is a volume studded throughout with information and insights which will make any educator involved in laboratory management feel "yes, it is typical story" This makes it a relatable, enjoyable and occasionally exasperating read.

Unmistakably from a father to his son

Letters of a businessman to his son

This is a volume which my father presented to me with the words, "Here's something I was planning to pass on to you when you turned 30." It compiles letters which the author wrote to his son, and manages to maintain the feel of a work of philosophy even if it does contain somewhat embarrassing passages. Nevertheless, this is a volume that will make you reconsider your perceptions and coping strategies. The passage in which the author cites from Shakespeare in particular has become one of my mantras.

Reading the tide

Genya Ishigami

In William Shakespeare's "Julius Caesar" there is a passage which goes: "There is a tide in the affairs of men, which taken at the flood leads on to fortune; Omitted, all the voyage of their life is bound in shallows and in miseries." (Citation from a volume mentioned as one of "My Favorite Books.") Simply put, I think this means that you must discern the most fortuitous timing before taking action. The word "tide" in English contains the nuances of both prospects and favorable trends ("Tide" is of course also a strong-smelling brand of laundry detergent.) Just as the word "shiodoki" in Japanese, which is made up of the Chinese characters for "tide" and "time" also means "opportunity," the fact that the people of yore expressed the appropriate timing of life and its transitions in terms of the ebb and flow of the tide speaks to the intimate relationship which exists between human life and the sea.

As you learn in elementary school, the earth's tides are influenced by the gravitational pull by the moon, and these both nurture life and indicate the best times to catch fish via tide tables. In my case, if I get a bumper haul when I go clam digging at low tide I can pass this fortune on to my family. Meanwhile, it is no easy matter to discern the ebb and flow of the tides of the world at large. Especially as we find ourselves in an era in which the cycles of these tides are many times faster than those in Shakespearean times. The powerful tide of AI in particular, a notion which has been somewhat loosely interpreted in the past several years, is nowadays a constant presence. In addition, in the domain of internet cloud computing, huge volumes of content are proliferated and consumed, and there is a repeated ebbing and flowing of the tides as the development and culling of things proceeds at a fearsome pace. Where are these tides leading us, and are we currently in the midst of a high or a low tide? These can be thought of as complex undulations.

Universities make analyses and predictions on the tides of the times, and in a manner of speaking are the shipyards in which the boats sailing on these currents are built. It seems to me that most of students may often experience a number of dynamic confluences, from undergraduate, to master's student, through to doctoral candidate and finally working adult. During my student days, I scuba-dived, and experienced drift diving on several occasions. During this activity you enjoy diving while largely entrusting your person to the currents of the tide. However, in certain circumstances you are obliged to struggle against the current, which is where the skill comes in.

I have recently come to reflect on my tendency to get carried away on the currents of day-to-day affairs. I hope to continue my passage through life nurturing the kind of determination needed to ride the precursive currents which are brimming with energy, and swim against the tide or create new currents when needed, rather than continuing to drift away on the tides of quotidian life.

Science and Technology **Information**

Establishment of the Yagami AI and Advanced Programming Room

Keio University Faculty of Science and Technology have established the Yagami AI and Advanced Programming Room in Room 407 of Building 34 on Yagami Campus. Here, an environment is available for the common use of the very latest advanced AI machines by students wishing to engage with AI and conduct advanced programing so as to promote cutting-edge AI research and the utilization of programming implementation technologies. This environment allows students conducting research relating to AI and advanced programming to freely interact and discuss with their peers, while exchanging information and ideas that transcend university frameworks and affiliated laboratories. An AI beginner's course was also begun for third- and fourth-year undergraduates. An AI and advanced programming counsellor is on permanent standby, and visitors can avail of their advice at any time.

In addition, the "AI and Advanced Programming Consortium" will be inaugurated from April 1, 2019. The inclusion of corporate members in this consortium will facilitate interactions with employees from these companies, in addition to those with other Keio faculty, staff, and undergraduate students across faculties. We also plan various events alongside our corporate members, with an emphasis on AI contests, and also plan to host seminars by these members.

An "AI and Advanced Programming Room" was established simultaneously at Hiyoshi Campus (Room F11 of the Fujiyama Memorial Hall), and similar rooms are to be rolled out to the Shinanomachi, Shiba-kyoritsu, Shonan-Fujisawa and Mita Campuses aligned with the features of the various campuses.

Editor's postscript

I felt a powerful empathy with the warmth exuded by the film-like world Associate Professor Ishigami invokes of mankind and robots living a harmonious existence when asked to talk about the robot development in which he is involved. It is also persuasive to hear the students refer to him in endearing terms tinged with respect and familiarity as "Ishigami-san." This befits both his gentle demeanor and his passion and broad-ranging knowledge and experience in developing robots to contribute to humanity and society.

I felt that learning of the professor's impressions of his time as a researcher is more fate than coincidence, especially in light of the circumstances behind his upcoming appearance in the Japan edition of the Powered Wheelchair Series to be held this year. (Asami Fukumoto)

新版 窮理図解

New Kyurizukai
No. 30 March 2019

Editing: "New Kyurizukai" Editing Committee
Photographer: Keiichiro Muraguchi
Designers: Hiroaki Yasojima, Yukihiko Ishikawa (GRID)
Cooperation for editing: SciTech Communications, Inc.
Publisher: Kohei Itoh
Published by : Faculty of Science and Technology, Keio University
3-14-1, Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8522
For inquiries (on "New Kyurizukai" in general) :
kyurizukai@info.keio.ac.jp
For inquiries (on industry-academia collaboration) :
kll-liaison@adst.keio.ac.jp
Website version:
https://www.st.keio.ac.jp/education/kyurizukai/
Facebook: https://www.facebook.com/keiokyuri