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Model Base Control

from Keio's Faculty of Science and Technology

Model base control system designs useful for people and society.

Masaki Takahashi
Associate Professor
Department of
System Design Engineering

Introducing Researchers

Associate Professor Masaki Takahashi tackles the effective use of model base control technology to develop systems design that benefits people and society at large.

Making the Most of High-Precision Control Technology to Design Systems Useful for People and Society

Model base control technology meets the needs of people and society

Automobiles as a convenient means to transport people and cargo, high-rise condominiums providing ample residential space in the center of metropolitan areas . . . the development of technology has benefited people's lifestyles and prosperity of society in modern times. But when we look at such amenities brought by technological advances from a human viewpoint, there are still people who suffer from carsickness and high-rise buildings that shake due to earthquakes or strong winds, causing us discomfort. A new attempt is now being made to take a new look at the relationship between technology and humans from the perspective of "Safety and Comfort for Humans." In this issue, we listened to Associate Professor Masaki Takahashi who is contributing to the development of model base control systems to create products and systems useful for people and society.

Realizing a better relationship between people, society and machines

"Model Base Control" is a method to realize effective control by modeling a target system and developing an optimal control technology for the target. An advantage of this method is that it allows you to develop a desired control technology while conducting simulations. On the other hand, there are cases where the system developed cannot work as simulated if the model precision is poor or the simulated operating environment differs significantly from reality. This makes it important to develop highly accurate modeling as well as to design a control system that can properly respond to changes in the environment and modeling errors.

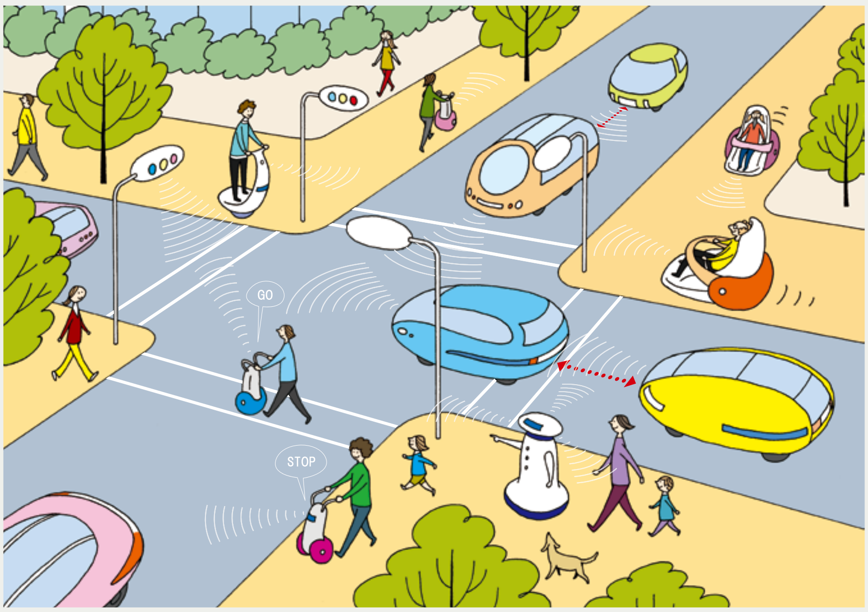
"Modeling including that of the operating environment is indispensable to perform highly precise model base control. Of various factors involved, the most difficult is to assume users. Modeling of users is difficult because we humans conduct ourselves based on our own judgment. But modeling including that of users is inevitable to create systems that can be practically used in actual society," remarks Associate Professor Takahashi.

As research themes, Dr. Takahashi has chosen robotics, automobiles and buildings – realms that have much to do with people and society. This is because by making use of model base control he aims to contribute to the development of products and systems useful for people and society.

Controlling robots' autonomic movement

An application of model base control can be found in robots for automated guidance and transport of expendables and other articles in hospitals.

Dr. Takahashi adds, "We aim to make such guidance/transport robots autonomic to act and move around inside a hospital. Therefore, we are developing a control technology with a focus on how robots should conduct themselves in human society. The key point here is how humans will react when they encounter a robot. Some may be surprised and leave the place, while other will be interested and come closer. We are currently making improvements to the robot so that it can predict and judge the behavior the person in front of it will take and respond to the person properly, taking the past behavioral history and the current situation into account. I feel that people's recognition of robots today is still at a low level, which is a major barrier to full introduction of robots to society. For



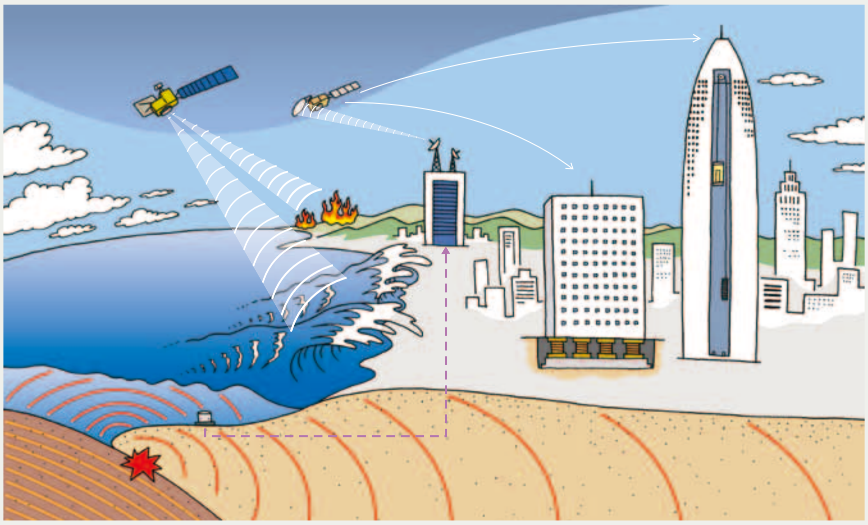
Safe and more comfortable society with control technology

Control technology finds its applications in virtually every aspect of our modern society – from daily lives to industry and to space development. If this technology advances further, it will become possible to use automobiles and guidance/transport robots, etc. more safely and comfortably as shown in this illustration.

robots to be widely accepted by society, therefore, it is important to provide people with more opportunities allowing them to see and better understand robots."

The key to achieving this goal lies in on-site experiments and observations. In other words, we need to visit hospitals and observe, as a robot's eyes would do, nurses carrying medical supplies and the like and how patients and visitors will look at them, as well as how patients on wheelchairs or crutches will act and move.

He continues, "We conduct experiments and observations together with many, such as representatives from robot manufacturers and students. Then all of us have a meeting to discuss the experiment and observation results. We extract characteristic elements from the behavior of nurses and people around them, which form the foundation for the development of component technologies needed. In fact, on-site studies are a rich source of discovery. For example, desk researchers tend to create advanced high-performance robots by introducing the latest in technology. However, the technology actually needed to transport goods in hospitals is not the technology needed to create fast-moving robots. On the other hand, if the robot design places too much emphasis on safety, the robot may cease moving, incapable of responding to constant changes occurring in the environment. This means that we need to develop technologies such as those enabling the robot to recognize obstacles peculiar to a place in question and evade them at a speed suitable for the place."



Control technologies active on various technological forefronts

Control technology can control quake-absorption of high-rise buildings, dealing with individual earthquakes based on information from emergency earthquake reports. The control technology for satellites and other spacecrafts can also be applied to terrestrial issues like shaking control of elevator ropes.

Protecting buildings from earthquakes and wind, while enhancing comfort

There are types of model base control that contribute to society in relation to social infrastructure. A typical example is the control technology for quake-absorbing base-isolated structures. Heretofore, architects assumed the magnitude of earthquakes beforehand and built structures that could withstand the assumed magnitude. Dr. Takahashi's approach is different. He is thinking of an active quake-absorbing control based on positive utilization of the latest seismic ground motion forecast/warning system.

"I'm now proposing a quake-absorbing control system based on the utilization of information from emergency earthquake reports. If the hypocenter location of an earthquake and its magnitude can be predicted in advance, the control system can enhance the quake-absorbing performance of buildings accordingly. Just as a strongly rocking swing can be controlled simply by changing the timing of its rocking, we can effectively control quaking and realize highly safe quake-absorption by controlling the quake-absorbing device in a way to alleviate the structure's shaking caused by seismic ground motion propagated from the hypocenter."

Dr. Takahashi's approach is based on a combination of knowledge obtained from preceding studies on the way the ground quakes (propagation routes of seismic ground motion and ground structures taken into consideration) and information available from emergency earthquake reports. This approach is attracting attention as a new method of quake-absorbing control as expansion and improvement of social infrastructure rapidly advance today.

Dr. Takahashi reveals his view saying, "This active shake control applies not only to earthquakes but also to shaking of buildings due to strong winds. I predict an ever-increasing need to control the shaking of buildings, which is interlocked with new forecast/warning systems."

Use of satellite-controlling know how to control elevator ropes

Control technologies are also being developed to control a variety of equipment operating in the space environment. One example is the attitude control technology for small-size satellites. In recent times, compact satellites are equipped with large-size, flexible and lightweight solar panels to meet their increasing power demand. If the satellite main body, heavily loaded with cameras and other equipment, changes its direction toward an observation target, that motion shakes the flexible solar panel, causing photo image distortion just as we experience with our digital camera shake.

Dr. Takahashi says, "Depending on orbit, it can take several days for a satellite to return to the position for photographing the same observation target point on the Earth. Meanwhile, there are increasing demands for photographing multiple observation points at one time – such as places suffering from serious environmental disruption and places of large-scale natural disasters. In such cases, the satellite needs to change its attitude promptly. Such attitude change involves the shaking of flexible structures like the solar panel. But it becomes possible to change the satellite attitude promptly without shaking if we apply a control technology."

The phenomenon, in which the whole of a flexible structure shakes, is not limited to artificial satellites. Similar phenomenon can be seen in elevator ropes, for example.

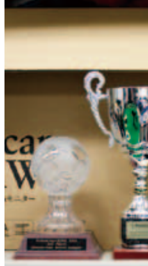
"Elevator ropes are becoming longer and longer as buildings rise higher and higher, causing the problem of shaking elevator ropes. The control technology enabling rapid change in attitude of satellites without shaking can be applied to elevator ropes on the ground surface – this is a merit of the model base control technology based on mathematics and dynamics."

Endorsed by a rich track record, "Model Base Control" technology is sure to enhance our quality of life and contribute to the betterment of society.

(Reporter & text writer: Kaoru Watanabe)

I'd like to interact with society through dynamics and control technology.

Using the model base control technology and by digging up latent needs of people, Mr. Masaki Takahashi pursues the creation of products and systems truly needed by people and society. In his students' ages, sports were the focus of his enthusiasm. He confesses that, though he was good at mathematics and physics, he was skeptical about why he was learning these subjects. But a lecture he received at the university class awakened his interest in dynamics and control technology, which brought him into a life of scientific research day and night. But his style of research pursuit has been inseparable from interaction with people and society. In fact, his sphere of activity extends far beyond his laboratory, with his eyes always directed toward the outside society.



What kind of life did you live as a student?

Recalling those student days, I was totally absorbed in soccer and skiing. I took up soccer as an elementary school boy. I was enthusiastic about this sport because eleven members playing their respective roles in a team play was great fun. As such a soccer-focused school boy, it was beyond imagination that I would choose a career as a researcher in the future. While I'm now specializing in control engineering and dynamics, for me as a high school student physics was merely a subject "a bit more favorite than liberal arts-oriented subjects."

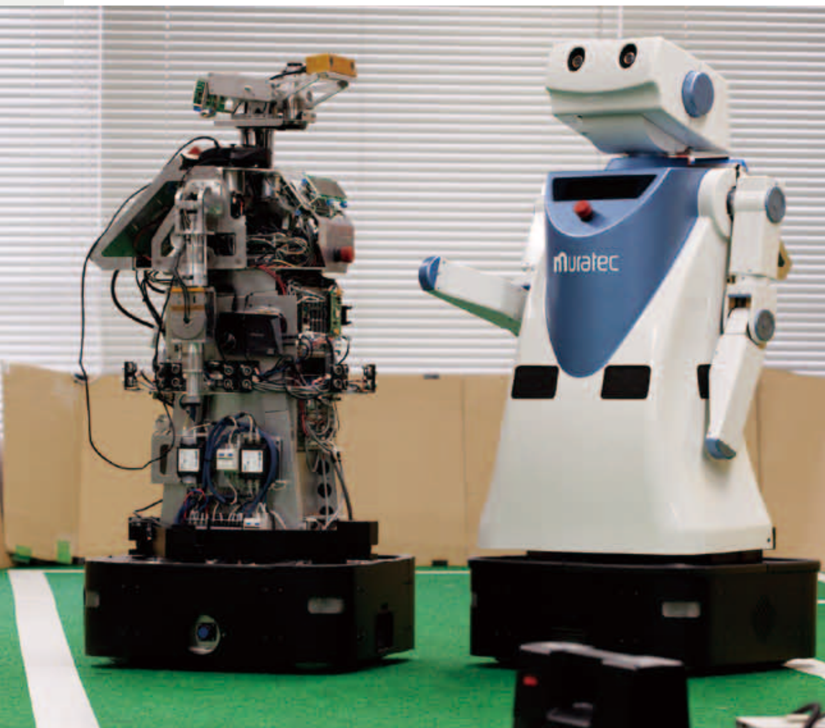
Then, about when did you become interested in control engineering and dynamics?

I took an interest in these studies only after I was admitted to university. During my high school days, I couldn't imagine that scientific formulas written in textbooks could be actually useful for society, nor could I recognize that they are necessary to understand and explain various phenomena in our lives. I should have noticed it much earlier.

You joined the System Design Engineering Department of Keio University's Faculty of Science and Engineering, right?

Yes. To tell you the truth, I was one of the first students who were admitted to the then newly established System Design Engineering Department. There was a description on the department's brochure: "To create systems geared to the forthcoming society, knowledge from both mechanical and electrical studies is required. As such, the department aims to foster talents capable of designing, analyzing and evaluating systems." Without any mental resistance, I could agree to the concept of designing an overall system by combining knowledge from different fields of study.

When I was a freshman, this newly born department was not equipped with everything. But we students enjoyed the privilege of being taught by marvelous teachers who lectured us with great enthusiasm and ingenuity, which more than made up for shortage of equipment. In particular, lectures on dynamics and control engineering were so impressive that they revolutionized my awareness. My supervisor, Professor Kazuo Yoshida, was responsible for these lectures. He was kind enough to explain, in an easy-



to-understand way, that mathematics and physics, which I had studied at high school, and the laws of dynamics I was then going to learn at Keio could be used as useful tools for society and were actually being applied to various business and industrial forefronts.

Mathematics and physics – the fields where I was merely interested in solving problems – actually have much to do with our daily lives . . . it was a surprising aspect of physics. This experience motivated me to know more about physics.

Professor Yoshida's remarks brought a drastic turnaround in your impressions about physics, right?

During his first classroom lecture, Prof. Yoshida showed us a video footage of the Tacoma Narrows Bridge in the State of Washington, U.S.A. This bridge collapsed soon after completion due to wind, strong but within the presumed velocity limit. This vivid visual record of the accident made the bridge famous. Many of you may still remember it. It was the very moment I became strongly aware of the role dynamics and control technology play.

The impressions I received at that time were so strong that, when the time came for me as a junior to decide which lab to choose from, I visited Prof. Yoshida's lab and, after observing what was going on, decided to study under Prof. Yoshida. When giving lectures, he was usually soft spoken and did his best to explain things in an easy-to-understand way. But when it comes to research activities, he was very serious, giving sharp and pinpoint criticism and advice as necessary. Now finding myself in a position to guide students, I would like to follow Prof. Yoshida's example. But it's difficult and I'm striving from day to day.

To my great regret, Prof. Yoshida passed away in 2008; I can no longer listen to his valuable views. What I can do now is to do my best to approach Prof. Yoshida's level by following his advice.

What else do you bear in mind as a university teacher?

I'm trying to arrange so that activities of my students will not be confined to the lab but interact more and more with the outside world. In my opinion, exchanges with other universities and interaction with foreign people will prove valuable not only for their research activity here, but also for their lives even after graduation. For example, my students' off-campus activities include participation in a space-related event held in Noshiro City in Akita Prefecture, and an event (ARLISS) in the Black Rock Desert, Nevada, U.S.A. that features the use of a rocket to launch a simulated satellite and recovering it. Another example is a student-initiated experiment class for flying PET bottle rockets as part of our Campus Festival.

The experiment class targeting elementary school children allows them to learn and experience the mechanism by which rockets can fly, as well as the phenomenon in which the distance of flight varies according to changing the angle of the rocket's trajectory. I believe experiencing things themselves will remain as lasting impressions. When these children grow up and learn physics at high school, they may be able to develop their interest in this study if they can relate the theory to their past experience, saying "Now I understand why my rocket could fly at that time!" I would also like my lab students to realize the difficulty of teaching things to others.

Do you have any person who remains particularly outstanding in your memory?

There is a famous robot specialist in an Italian university. An encounter with this researcher was really impressive. At that time I had just obtained a doctor's degree. But the moment he learned that my specialty was control engineering, he approached me saying, "I'd like to discuss with you since, as a specialist in information engineering, my knowledge of control engineering is limited." His attitude was very open, which made the discussion a very beneficial opportunity for information exchange. When you have thoroughly pursued your own specialty field, you inevitably find areas of study you need to know more about. At that time I realized that we need not feel ashamed of such lack of knowledge and that it is important for us to maintain our own specialist perspectives. I would like to convey this message to my students.

Challenging the creation of comfortable lifestyles with control engineering and dynamics

Masaki Takahashi

With control engineering and intelligent control engineering as his specialties, Mr. Takahashi uses model base control technology to address research themes relating to mechanical control, intelligent robotics and space engineering, among others. He obtained a doctor' s degree at Keio University Graduate School of Science and Technology in 2004. He became a postdoctoral research fellow at Keio University in 2004, a research associate at Keio' s Faculty of Science and Technology in 2005, an assistant professor in 2007, and the current position as an associate professor in 2009.

◎ Just a word from . . . ◎

● A student: Mr. Takahashi is a truly reliable teacher, patiently and attentively watching us at all times and giving appropriate advice casually but precisely when needed. What's more, he maintains a marvelous sense of balance as he well understands our part-time jobs and job-hunting activities.

(Reporter & text writer: Kaoru Watanabe)

For the full text of this interview, please refer to:

http://www.st.keio.ac.jp/kyurizukai

Takahashi Lab: Past Year in Review

Research work, extracurricular activities and sports events . . . A year at our lab is truly exciting!

April

When the freshperson-welcoming boarding camp is over, "Rinko" begins, discussing control theory and scientific papers. Research activities gain momentum as students' mood shifts from that of freshperson-welcoming events.

May

Our lab participates in the softball meet of the Faculty of Science and Technology. In 2010, our team advanced to the final stage consolation round. After the games were over, the lab members enjoyed Futsal to refreshingly perspire in preparation for the coming research activities.

June

When the freshperson-welcoming boarding camp is over, "Rinko" begins, discussing control theory and scientific papers. Research activities gain momentum as students' mood shifts from that of freshperson-welcoming events.

July

We warmly received foreign students (from Italy, U.S.A. and Spain) studying in Japan. Interaction with foreign students is a good opportunity for our students to experience foreign cultures face to face and improve their foreign language communication skills.

August

At our summer boarding camp, students not only present their research achievements, but they also have valuable experiences such as factory inspection tours as well as interaction with OBs.

September

As part of our extracurricular activities, our students developed a compact autonomous spacecraft , and participated in the space-related events in Noshiro in August and in the ARLISS held in Nevada' s Black Rock Desert in September (see page 5).

October

During our faculty' s campus festival (Yagami Festival), we featured a water rocket class – a volunteer activity by our lab students for space education targeting elementary school children in the neighborhood area.

November

Our students participated in various academic meetings (on control, robotics and space) held from July at various locations in Japan and overseas, where they read papers on their research achievements.

December

This is the season when students' research activities gain further momentum to mold their research results into shape. Before finally completing their graduation and master' s theses, students refresh themselves by skiing and snowboarding.

January

Master' s course first-graders take the lead in holding an "encouragement party" (cooking/serving rice and side dishes) for the last spurt so that all the lab members can successfully complete their graduation or master' s theses. It' s an annual event of Takahashi lab.

February

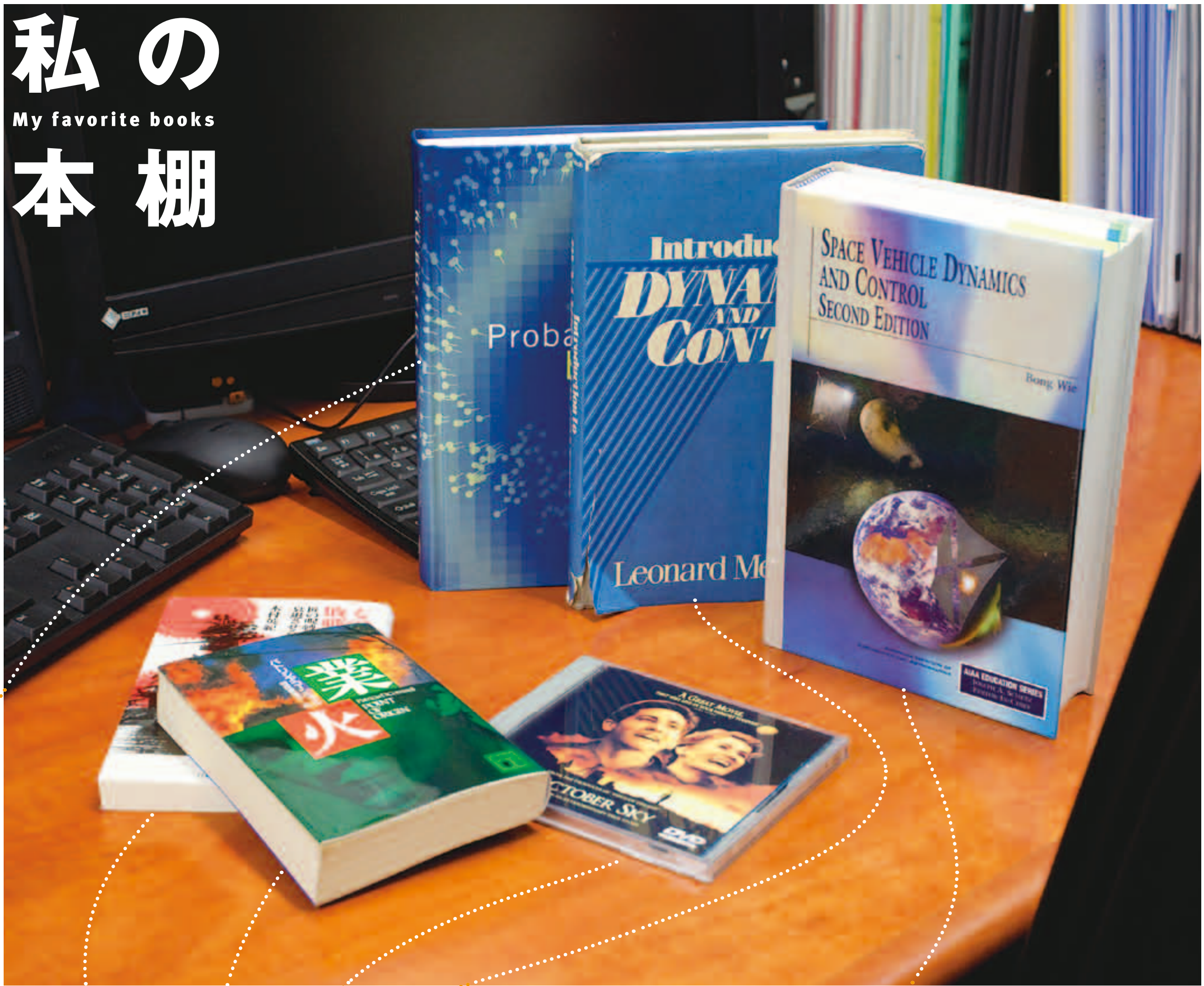
Students put their research achievements for the year into graduation or master' s theses and present them. The finale of this month is a drinking party, where the graduating students send passionate messages to their juniors.

March

This is the season of graduation and degree-granting ceremonies. Some advance to master' s or doctor' s courses, while others find employment with businesses – fledglings branching out into their respective courses in life, full of hope.

私の本棚

My favorite books



Probabilistic Robotics
-In English

When a robot moves around in an environment similar to the human living environment, it becomes necessary to deal with uncertainties and unpredictable phenomena that exist in the environment and/or systems. As a solution to this problem, there is a robot design method based on a probabilistic approach. This book explains mathematical backgrounds and main algorithms of probabilistic robotics by introducing specific examples of implementation and experiments. A translated Japanese version is also available. I found this book when I began developing behavioral algorithms for the MKR-003 transport robot for hospitals so that it could move around safely in an environment where humans are present.

Introduction to Dynamics and Control
-In English

This is a textbook on dynamics, vibration engineering and control theories. Prof. Kazuo Yoshida, my supervisor, introduced this book to me when I became a research associate. I still remember Prof. Yoshida saying, "While there are several styles of textbooks on dynamics, this textbook fits my style best." Now responsible for lecturing on dynamics to undergraduates myself, every year I strive to organize what to teach them and in what order, taking Prof. Yoshida's remark to heart.

Space Vehicle Dynamicsand Control
-In English

This is an academic book on spacecraft dynamics and control. Consisting of five sections – modeling, analysis and control of dynamic systems; orbital dynamics and control; structural dynamics and control; and dynamics and control of cutting-edge space vehicles – the book is comprehensive in content, covering fundamentals through applications. Since it contains numerous examples of numerical analysis and a comprehensive bibliography, it allows you to learn highly technical knowledge of space vehicle dynamics and control.

"Postmortem" Series (Patricia Cornwell)
-Translated in Japanese

"Postmortem" is a crime mystery series, in which legal medicine plays a major role and the latest scientific investigation is used to solve the cases. I would like you to read them, beginning with the first novel of the series in due order since the main characters are depicted in detail and their respective lives also develop as the series advances. It is intriguing to find the latest scientific investigation beginning to be used for what was formerly deemed unacceptable as evidence, thus enabling cases to be solved.

Defeat in Manufacturing War
-In Japanese

I recommend this book to students preparing for university entrance exams as well as university students. Authored by the highest authority in the field of control theory, this book explains the development of science and technology in Japan by tracing its history, shedding light on the essential problems underlying the situation facing us today. I hope readers will obtain clues on what they should learn as competition in the manufacturing world becomes increasingly intense on a global scale. Given we are in an era when virtually any piece of information is available relatively easily, it is important more than ever to exert yourself to acquire the insight into the essence of things.

October Sky (DVD)

This movie is based on the true story of Mr. Homer H. Hickam, a former NASA engineer. Impacted by the first Sputnik launch by the Soviet Union in 1957, as a high school boy Homer takes up the challenge of making a rocket. The movie depicts the process of Homer's growth through various experiences, such as friendship with his classmates, conflict and reconciliation with his strict father, and interaction with his teacher and mother who warmly support him. This story reminds me of my key turning point in life, when I could meet various people who supported and understood me. So moving that I went to the theater to view the movie three times! This movie is a truly memorable one.

The Beginning of "Control"

Associate Professor Takahashi's key research theme is "Model Base Control." "Control" means "to regulate machines, equipment or facilities so that they can move in a way as required by the purpose." While the history of control itself is very old, it was not until 1788 that what can be properly explained with today's concept of "control" was created.

James Watt is referred to as "Father of industrial revolution" because in 1776 he invented the "steam engine" – the first driving motor created by humankind. The motor is a device to supply energy to the machine. But unless it is designed to supply energy "when needed and in an amount required," the machine will fail to move as desired. In order to keep the steam engine output constant, Watt devised a regulator known as a "governor" and attached it to the valve on a steam-feeding pipe for the steam engine. The development of this "governor" contributed to the rapid spread of steam engines. Though not widely known, Watt is called the "Father of control engineering" because of this governor development.

In the mid-19th century, G. B. Airy of Cambridge University employed a "centrifugal governor" which represents the governor's operating principle, to maintain rotational accuracy of an astronomical telescope. In this process, he found an unstable motion of the centrifugal governor and analyzed it theoretically. This analysis is said to mark the beginning of feedback control.

J. C. Maxwell, famous for electromagnetism-related studies, wrote a paper entitled "On Governors" in 1868, discussing the stability of governors. He examined characteristics common with many governors and gave a quantitative account of these universal characteristics. In other words, he conducted analysis by making a "model" of governors. He also expressed the concept of stability in mathematical formulas. As such, Maxwell is credited for having achieved the first systematic study on stability of control.

If Watt's development of the "governor" gave birth to control engineering, then you could say that Maxwell's research results formed the very basis on which the control theory was built.

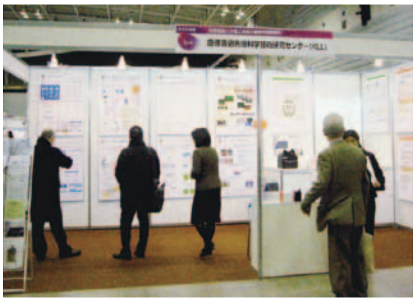
The concept of control thus came into being and subsequently went through the hands of many researchers for refinement. The results are robust control based on advanced mathematics, adaptive control, nonlinear control and so on, contributing to the development of technological forefronts such as robotics, space engineering and signal/image processing, among others.

Science and Technology **Information**

Keio Leading-edge Laboratory of Science and Technology (KLL) Participates in Technical Show Yokohama 2011 (32nd Industrial Technology Fair)

February 2 (Wed.) ~ 4 (Fri.), 2011 (10:00 ~ 17:00)
Pacifico Yokohama (Halls C & D)
http://www.tech-yokohama. jp/tech2011/

Keio Leading-edge Laboratory of Science and Technology (KLL) participates in the Technical Show Yokohama again this year. KLL's theme for this year is: "Pioneering the Next Technological Forefronts . . . From the Perspective of Fundamental Science and Technology." We introduce our fundamental science research activities that support today's society and industry. We welcome your visit.



A scene from Technical Show Yokohama 2010

The 10th KLL Seminar on Industry-Academia Collaboration "Fundamental Science & Technology Research Endeavors That Support Our Society and Industry"

February 25 (Fri.), 2011 15:00 ~ 18:00
2nd Floor, Kyosei-kan Hall (Multi-purpose Classroom 1) on the Keio University Hiyoshi Campus
Admission free; Prior applications required
http://www.kll.keio.ac.jp/

This seminar is organized and sponsored by KLL. In this seminar, we introduce four studies from mathematical science and physics under the theme "Fundamental Science and Technology That Support Next-generation Society and Industry." After the seminar is over, there will be a meeting for friendly interaction and opinion exchange.

Please apply for participation at the above URL.

A scene from 9th Industry-Academia Collaboration Seminar

Editor's postscript

About the robot appearing in the interview article (pages 4 ~ 5): It is an autonomous mobile guidance/transport robot named "MKR-003." "M" stands for Murata Machinery, Ltd., the manufacturer, "K" for Keio University, and "R" for a robot. The number "003" signifies that the robot is the third model. It's cute but has a "square" name. Asked "Why didn't you give it a more attractive name?", Dr. Takahashi replied, "This is better because it allows the hospital, the robot user, to give it whatever name they like. We were impressed by the fact that attentive ingenuities are incorporated so that the robot can adapt itself to the given environment, interacting with humans and being loved by users.

For the next academic year, we will also have a line-up of attractive researchers waiting to be introduced. Please look forward to the next issue. (Saori Taira)

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