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|---|---|
| Title | Title page |
| Sub Title | |
| Author | |
| Publisher | Faculty of Science and Technology, Keio University |
| Publication year | 2015 |
| Jtitle | New Kyurizukai No.20 (2015. 10) |
| JaLC DOI | |
| Abstract | |
| Notes | |
| Genre | |
| URL | https://koara.lib.keio.ac.jp/xoonips/modules/xoonips/detail.php?koara_id=KO50001003-00000020--001 |

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新版 窮理図解

2015 October
no.
20

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

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http://www.st.keio.ac.jp/kyurizukai/english/index.html

$$\lim_{k \to \infty} T^k(x) = x^* = T(x^*)$$



# Adaptive Algorithm

## from Keio's Faculty of Science and Technology

Pursuit of an ultimate filter
that extracts desired information from signals

Masahiro Yukawa

Associate Professor
Department of Electronics and Electrical Engineering

Associate Professor Masahiro Yukawa featured in this issue, whose field of research focuses on an ultimate adaptive filter capable of freely extracting desired information from signals.

# What is an adaptive filter that extracts and elucidates useful information from signals?

## Dedicated to creating an "ultimate filter" to unravel highly complex phenomena

**Our society is brimming with truly diverse signals (information), such as visual images, sounds, radio waves, brain waves and stock price fluctuations, to name a few. The primary role of signal processing is to convert these signals into numerical form and extract only a desired piece of information for identifying the characteristics of a given phenomenon or using it to make a projection. By taking a mathematical approach and making complex signals obtained from diverse phenomena in the universe easily usable, Associate Professor Masahiro Yukawa is intent on establishing a mathematical system useful for extracting needed information.**

### Signal processing – the backbone of electronics industry

"Suppose our modern world loses signal processing, we will suddenly find our life totally inconvenient and boring – no TVs, no mobile phones, no digital cameras and no airplanes flying in the sky. MRI, the medical equipment, is also a product of signal processing. Popular topics of our conversation of late, such as drones, androids and big data analysis, are also impossible without signal processing. In short, signal processing is something essential to our modern life just like air," mentions Dr. Yukawa.

For example, the microphone converts cellular phone sound into and the image sensor converts images captured by a digital camera into electrical signals, respectively. By replacing these electrical signals with numeric sequences, they come to be mathematically processed and become objects of the so-called signal processing.

"What I have actually focused my effort on is adaptive processing of acoustic and radio communication signals. One example is the echo canceler. In videoconference or cell-phone conversations, your voice may echo back to yourself belatedly via the other side's microphone, which is often annoying. The echo canceler is designed to cut the echoed voice only. Because your echoed voice is not necessary, signal processing performs subtraction and allows only the other side's voice to be delivered. Likewise, in the case of radio communication, adaptive signal processing deals with multiple communication data, which simultaneously arrive in the base station, separate and deliver them to individual users. What is indispensable to such signal processing is the "adaptive filter."

### The role of adaptive filter is to estimate a function from data

Just like a coffee filter, the adaptive filter extracts, through a mathematical operation called "filtering", an exactly needed piece of information.

"Speaking of sounds, the role of the adaptive filter is to estimate the function $f$ capable of extracting the required sound $x$ from the observed sounds $y$. Putting it another way, we simply have to seek the function $f$ because we need to estimate $x$ from $y$," explains Dr. Yukawa.

As the term "adaptive" suggests, however, we, operators, must work – flexibly adapting the filter function to the constantly changing environments. In other words, the adaptive filter's performance depends largely on our ability to express, in real time, a function made as closer as possible to the required information while minimizing computational complexity.

Here's a major problem: most of actual

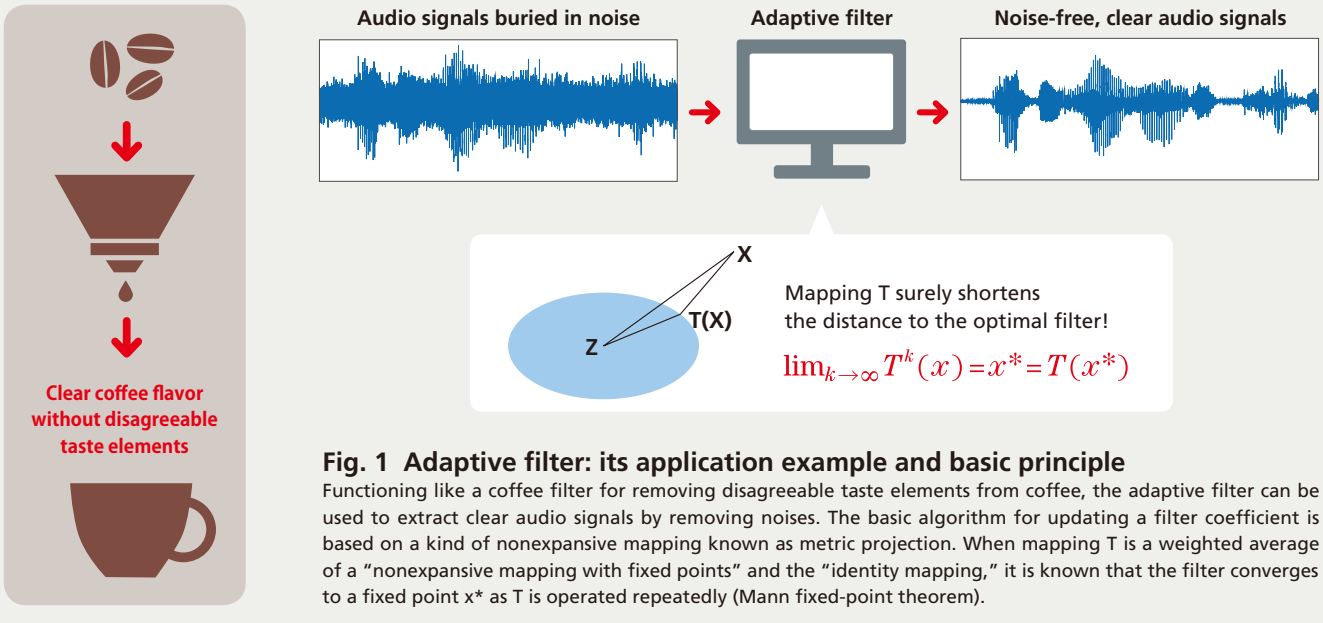



**Fig. 1 Adaptive filter: its application example and basic principle**

Functioning like a coffee filter for removing disagreeable taste elements from coffee, the adaptive filter can be used to extract clear audio signals by removing noises. The basic algorithm for updating a filter coefficient is based on a kind of nonexpansive mapping known as metric projection. When mapping T is a weighted average of a "nonexpansive mapping with fixed points" and the "identity mapping," it is known that the filter converges to a fixed point x* as T is operated repeatedly (Mann fixed-point theorem).

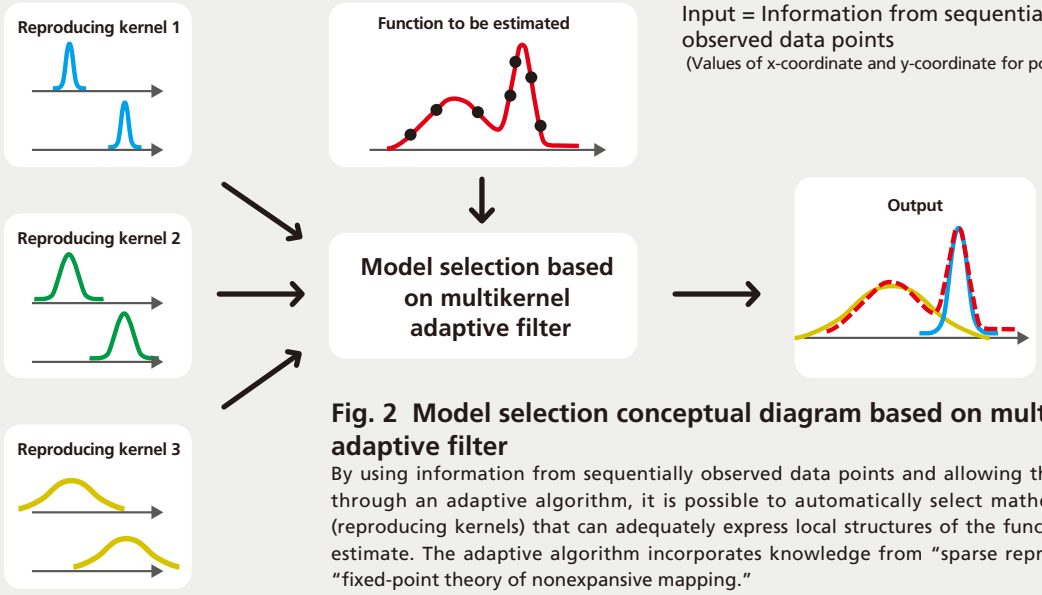



**Fig. 2 Model selection conceptual diagram based on multikernel adaptive filter**

By using information from sequentially observed data points and allowing the filter to learn through an adaptive algorithm, it is possible to automatically select mathematical models (reproducing kernels) that can adequately express local structures of the function you wish to estimate. The adaptive algorithm incorporates knowledge from "sparse representation" and "fixed-point theory of nonexpansive mapping."

phenomena are of nonlinearity, which is difficult in general to be handled mathematically. Nonlinearity means not being linear. In short, with these phenomena, input and output are not proportional to each other. Attempting to deal with nonlinear data causes the amount of computation to suddenly increase, making it difficult to extract the needed information speedily.

"Volterra filter and neural network are typical approaches to handling nonlinear data. But the former involves enormous volumes of computation while the latter has the drawback of ending up with a local minimum. To address these problems, I decided to adopt what is known as the "kernel adaptive filter" based on the kernel method.

The kernel method allows data to be mapped onto a feature space of higher dimensions (for example, from two dimensions to three dimensions), thereby converting a group of data into an easier-to-handle group. This technique is widely used for facial recognition and other pattern recognition as well as big data analysis. Formerly it was used in batch processing, a method to process batches of collected data all at once. In recent times, it is increasingly in use for online scenarios in which new data are collected and processed from moment to moment.

"I would omit explanation of reproducing kernel because it is too technical and difficult. But the benefit of reproducing kernel exists in that it can evaluate a function value as an "inner product." A simple example of an inner product is the sum of all products that have been obtained by multiplying two vector elements in series. The inner product makes it possible to express correlations between two vectors. Once these correlations can be expressed with an inner product, we can now use our knowledge of linear models to the fullest," Dr. Yukawa states emphatically.

In short, you can say that the greatest advantage of this method is that it allows us to use the easy-to-compute linear theory in dealing with usually difficult-to-handle nonlinear data.

## Extracting exactly needed information in real time

Dr. Yukawa has developed the "multikernel adaptive filter," based on the kernel adaptive filter and making the most of the latest developments in convex optimization.

"To put it in a general image, the filter I developed approximates a function's waveform by adding up bell-shaped curves known as Gaussian kernels. We prepare in advance a number of Gaussian kernels – wide and low curves, narrow and high curves, etc. – then arrange coefficients, which determine their heights, in matrices. Finally, we estimate the function by adding up a smaller number of peaks."

"The key point here is to include a mechanism designed to automatically identify peaks that fit the function you wish to estimate while nullifying coefficients for most of the other peaks. Sparse matrices refer to those matrices that contain many zeros. Neat arrangement of information (in sparse matrices) enables optimal model selection."

This allowed us to adjust Gaussian kernel widths to nonlinear function forms adaptively and automatically and respond freely to function forms even when they may change with a lapse of time. Highly accurate estimate is thus possible with a smaller number of peaks.

"By using this technique, for example, we can make highly accurate, real-time predictions of future power outputs in solar power generation on the basis of power output data of the past," he adds. The "fixed-point theory for nonexpansive mapping" is the mathematical foundation for Dr. Yukawa's study.

"A fixed point refers to a point that does not move even when mapping T is operated, that is, x such that Tx = x. Also, nonexpansivity refers to the characteristic which the operation of a mapping does not expand the distance between two points. Today, it is becoming increasingly known that solutions to problems – in various fields of science and engineering – can be expressed as fixed points of a mapping. Actually, the use of a nonexpansive mapping makes it easy to design fixed points, or algorithms to seek the solution of a problem. The multikernel adaptive filter estimates unknown functions by expressing ever-changing functions as fixed points of a mapping which is created using data that flow in from moment to moment," he remarks.

Dr. Yukawa expresses his desire to create an "ultimate filter" in the future — the ultimate filter capable of dealing with any complex phenomena. After 2015 set in, Dr. Yukawa is making a name for himself internationally as three of his papers were already accepted for publication in the journals of IEEE (The Institute of Electrical and Electronics Engineers, Inc.) and he was picked out as an Associate Editor for the world premium journal in the field of signal processing. He continues to focus on fundamental mathematical systems underlying the currently highlighted research themes such as distributed signal processing, big data analysis and deep learning while taking a side glance at them.

(Reporter & text writer : Madoka Tainaka)



# It's interesting to persistently pursue apparently minor things that are less popular among most other people.

**Over the years Dr. Yukawa has taken up and persistently pursued hobbies and sports, such as soroban (abacus, a traditional calculation tool), table tennis and dancesport, which appear to be minor (in Japan) yet are of great depth. This attitude overlaps with his mindset as a researcher who devotes himself to the theoretical side of studies rather than jumping at themes in fashion. Behind his way of life were valuable encounters with good friends and respected teachers, not to mention the support from his family.**



### What was your childhood like?

As far as I was told by my mother, I was a very talkative boy, who often reported to my nursery school teacher about everything that had happened at home the day before. To make the matter worse, I spoke out clearly and in an easy-to-understand way. Later my mother complained to me that she had felt pretty embarrassed (*Laughter*).

I was born in Minami-Ashigara City, Kanagawa Prefecture. Both my father and mother were public servants, father working for the Odawara City Office and mother for the Ministry of Finance's Printing Bureau. Both of my parents were good at math in their school days. Presumably having inherited their genes, they say I was good at mental calculation since my nursery school days.

Soon after entering the elementary school, I attended a soroban school. Thanks to a good teacher, I liked the art of soroban and continued to learn it up to the end of junior high school second year. I hold a first dan license in soroban and a third dan license in mental calculation. On the occasions of soroban competitions, I was always among the best; at an All Kanagawa Prefectural soroban competition when I was an elementary school sixth grader, I became the champion in the category of calculating figures read off aloud. Even today I still do two-digit addition and multiplication by mental calculation – not so well as in the past, though.

I used to teach arithmetic and mathematics to my friends. Looking back now, I may also have learned something by teaching them. I'm still grateful to my friends.

### Were you an indoor-oriented boy?

I don't think so. An expanse of rice fields could be found around my house, so rice and flower fields were ideal playgrounds for us children. Actually I was an active elementary school boy; the moment recess time began, I dashed out of the classroom into the schoolyard to enjoy ball playing with classmates. In my junior high school days, I served as captain of the table tennis club and even participated in the prefectural tournament. The more I exercised, the better I slept at night (Laughter).



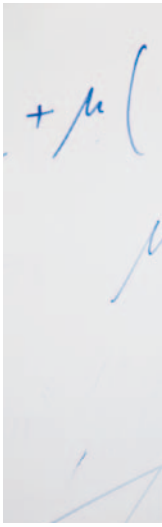
### Didn't your parents tell you to study hard?

No, they didn't. My parents never criticized me about my attitude about studies because I did at least what I should do – I did homework as assigned and listened carefully to classroom lessons. I'm grateful to my parents for basically allowing me to do whatever I liked.

Following entry to a local junior high school, I began to attend a small cram school in my neighborhood partly because of my elder sister's influence. Thanks to the cram school teacher's enthusiastic guidance, I became more and more interested in mathematics. In those days, however, I wanted to become a certified public accountant in the future, not a researcher.

As for senior high school, I chose Prefectural Atsugi High School, which was outside of my school district. It was my routine to make a 40-minute trip one way on the Odakyu Line train while reading the mathematics textbook on board. Presumably, this experience may have made my backbone as a researcher as I am today.

From halfway through the first year to the end of the second year, one of my schoolmates and I took up a part-time job at a co-op store near my high school – for a bit of real-world experience and earning pocket money. There I was assigned to the deli corner, so it became my special skill to neatly wrap food in cellophane. Once I demonstrated this skill and surprised my wife (*Laughter*).



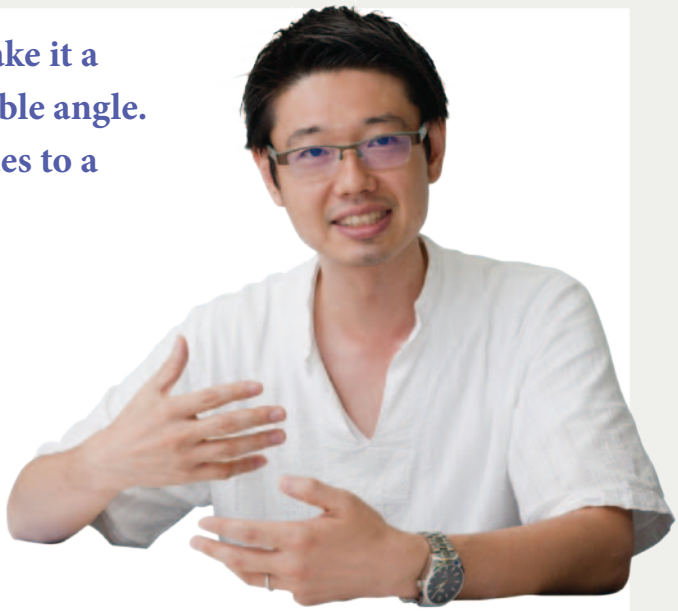
### You advanced to the 5th Academic Group of Tokyo Institute of Technology, didn't you?

I did so partly because of recommendation by a father of my friend and partly because of advice by a tutor at my prep school. By this time, I became inclined, vaguely though, to choose in the future a career based on IT-related or mathematical knowledge.

To be honest, however, I was not so serious about study while I was in the lower undergraduate grades. Although I knew I was interested in theory-oriented subjects, such as on Fourier transform and Laplace transform, I was still unable to narrow down my academic interest. Under such circumstances, as an undergraduate I focused on club activities and a part-time job at



**Whenever I face a difficult research task, I make it a rule to think it out patiently from every possible angle. This is necessary so as not to overlook any clues to a solution that I may encounter by chance.**

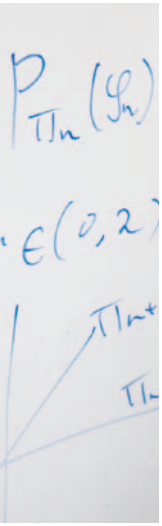


## Masahiro Yukawa

Dr. Yukawa received the B.E., M.E., and Ph.D. degrees from Tokyo Institute of Technology in 2002, 2004, and 2006, respectively. He is currently an Associate Professor at EEE Department of Keio University. He is pursuing a new horizon in the field of Signal Processing using mathematical tools, particularly Convex Optimization and Fixed-point Approximation. He has served as an Associate Editor of several journals including IEEE Transactions on Signal Processing. His academic carrier includes Postdoctoral Fellow at University of York, U.K. (JSPS Postdoctoral Research Fellow); Special Postdoctoral Researcher at RIKEN; Guest Researcher at Technische Universität München, Germany; and Associate Professor at EEE Department of Niigata University. He received the Young Scientists' Prize, the Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology in 2014, among many others.

a fast food restaurant.

Another pursuit I took up after entering the university was dancesport. While inspired by a TV program as the first opportunity, I can say that something minor, or something that not many people are doing, caught my interest. The dancesport club had only four or so male members for each undergraduate grade – really minor wasn't it (*Laughter*)? In this sense, it seems to have something in common with soroban and table tennis. Turning to my research side, signal processing is quite popular in the world, but I'm focusing on themes on which few people have an eye on.



**It's a surprise. Were you not shy when dancing with a female partner (*Laughter*)?**

In the beginning yes, but very soon I got accustomed to dancing with a female partner. To tell the truth, soon after marriage I invited my wife to enjoy ballroom dancing with me, but she gave up after only several times. Her excuse was that she got fed up with the way I instructed, which was too strict and specific … (Laughter). I didn't mean to be too strict with her, but it seems that the habits I had acquired through dancesport lingered, which urged me to specifically advise her on posture, shift in the center of gravity and so on. In everything, once I get started, I tend to forget myself, which, I admit, is my forte as well as my shortcoming.

It was when I became a senior and joined a lab specializing in signal processing and communication theory that I became hooked on the attraction of research work.

Studying in the master program, I came to have opportunities to present my research works at international conferences, which motivated me to study more and more – so immersed in study that my desire to live a researcher's career became immovable and I made up my mind to advance to the doctoral course.

Although it was already decided that the Institute of Physical and Chemical Research (RIKEN) would employ me as a Special Postdoctoral Researcher – a coveted post – following completion of the doctoral course, I was fortunately able to complete the course six months earlier. Taking advantage of the remaining six months, I visited the U.K. to study at University of York. After returning from the U.K., I worked at RIKEN for about three years from April 2007.

Then I worked for Niigata University (April 2010 ~ March 2013) before accepting a post at Keio University.

**Sounds like you have smoothly proceeded with your research career.**

So far, so good. I'm sure the fact that I have somehow been able to continue research work to date owes much to valuable encounters with good teachers and advisers at each turning point of my life. Above all, my special gratitude goes to Prof. Isao Yamada at Tokyo Institute of Technology and Dr. Shun-ichi Amari at RIKEN, not to mention the soroban instructor and the prep school tutor in my younger days.

By way of repaying my obligations to these teachers, I'm trying to teach and guide my own students as earnestly as possible. But I'm afraid my eagerness may sometimes be too much for them (Laughter). When dealing with my son, meanwhile, I'm trying not to be too particular about his studies just as my parents did for me.

**How do you take a breather from your busy research work?**

Ever since my childhood, I like eating; so each meal is the best breather for me. Next, my blissful time is when I listen to jazz or Latin music while enjoying sweets together with a cup of coffee that I've brewed for myself. My routine on the campus is to go to the cafeteria together with my students. I also enjoy a coffee break with them, which is enjoyable.

**What do you think are good points of Keio University?**

Keio has a well-developed public relations system effectively encouraging us younger researchers in research activities, for which I'm truly grateful. At Keio, even lower-grade students have easy access to professors – or an easy distance between students and professors, you might say. This is an enviable environment. Keio also offers a variety of student support systems, allowing them to become conscious of their future courses at an early stage. This is another strong point of Keio.

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

● Dr. Yukawa has a cool, objective eye to research, yet demonstrates extreme enthusiasm when striving to achieve research goals. His pet phrase is: "Let's make our lab No. 1 in the world!" Our lab is a pleasant place to be in, always brimming with conversations and laughter – exchanging ideas and developing discussions during lunch meetings or coffee breaks.

(Reporter & text writer : Madoka Tainaka)

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

# Masahiro Yukawa's ON and OFF time

I've been working on the border of mathematical sciences and engineering. Here are just some of the shots showing me in ON and OFF times.



## Studying abroad

While staying in Germany, I frequented a café, where I thought over ideas for my research work. You cannot speak of Munich without mentioning Oktoberfest!!! Enormous volumes of beer served in mass (1 liter mug) were consumed, which was an overwhelming sight. My host lab's favorite brewery was Augustiner-Bräu. Even a weak drinker like me could down my drink.



## Dance

In my student days, I was absorbed in practicing dancesport. I was really like a Latin American devoted to dancing rather than study. (In the photo, the one at the right end is me.) After ten years of practice, I could meet formerly hidden innermost muscles.



## International conference

International conferences are valuable opportunities for us to present the results of our latest studies. During banquet time, I usually exchange information and try to build new networks in a relaxing atmosphere. In a conference held in Santorini Island, Greece, I made a presentation in a cave-like place. This photo was taken outdoors; under the table were hungry cats waiting for food from above.



## Yukawa Lab

Upon transfer to Keio from Niigata, I hosted a home party inviting my students who followed me from Niigata University. Currently, I have eight Keio students in my lab. Once in a while, our lab members participate in Yamada Lab seminars (the lab I originally came from) of Tokyo Institute of Technology while also deepening friendship through joint activities such as hiking and a nabe hotpot party ("*Imoni-kai*").






## Joint research

So far I experienced joint research with Fraunhofer Heinrich Hertz Institute and Technische Universität München of Germany, KAIST of South Korea, RIKEN, Tokyo Institute of Technology and Niigata University. In the summer of 2014, I visited Prof. K. R. Müller (Technische Universität Berlin) to make arrangements for joint research.

## Intensive lectures in Europe

I gave intensive lectures at Technische Universität München in Germany (autumn, 2010) and Tampere University of Technology in Finland (summer, 2012), both targeting graduate students. The study of signal processing is thriving in Finland and Tampere University of Technology has a department of signal processing. During my lectures there, I encountered sharp questions, which was very stimulating. When the lectures were over, the audience presented a pleasant surprise for me – a thank-you paper coming with my likeness (tears!).





# 私の本棚

My favorite books




### Convex Analysis and Monotone Operator Theory in Hilbert Spaces

Coauthored by H. H. Bauschke and P. L Combettes who have led the field of convex analysis, this book is an indisputable masterpiece representing the modern convex analysis theories. The outstanding feature of this book is that the theory has been developed in general Hilbert spaces. Though its content targets specialists, it is self-contained and readers can follow theoretical demonstrations without referring to other books as long as they have undergraduate-level basic knowledge. I strongly recommend this book to those graduate students who aim to become world's leading researchers. In my graduate course (spring, 2015), I explained some topics relating to this book.

### Introduction to Kernel Method

The kernel method is a technique which is a focus of attention in the field of machine learning, which is being applied to a variety of nonlinear problems including pattern recognition. This book deals with wide-ranging topics from the basics of the kernel method to recent research trends. It helps you acquire a grounding in the theory of reproducing kernel, which is deeply related to complex analysis, as well as its applications. Knowledge about Lebesgue integral will help you understand it more deeply.

### Functional Analysis for Engineering

Taking many years, Prof. Isao Yamada (Tokyo Institute of Technology), a world leader in optimization and signal processing, elaborated this great book for engineering students. I still remember I, while studying in the master's course, devoted myself to "Short Course for Hilbert Spaces" – his lecture material which became the prototype of this book. If you go on reading it up to Chapter 7 in spite of anything you don't understand, you'll find yourself able to command an overview, from vector spaces to convex optimization. What's most important is that you have a full understanding of Hilbert spaces; in fact, a number of problems, in sciences and engineering, can be formularized using Hilbert spaces. Once you have become able to develop discussions in terms of Hilbert spaces, possibilities of application will be unlimited.

### 30 Lectures as Introduction to Analysis

A mastery of the concept of convergence of real number sequences will allow you to understand more advanced concepts, such as complex analysis and functional analysis. Inclusion of "Tea Time" pages make this book easily readable. I advise those, who are still uncertain of their ability in real analysis, to acquire as early as possible the knowledge and techniques offered by this book.

### Shinichi Hoshi

This book is a collection of short-short SF stories by Shinichi Hoshi. Even those who are not good at long novels can read this book with ease. It's ideal as reading for break time or before going to bed.

### Elementary Linear Algebra

This book is recommended to those who say "Linear algebra was too abstract to understand although I learned it as a first-year undergraduate student." Thorough explanation facilitates your understanding. It's especially advisable to have a full understanding of linear spaces, linear transformation, eigenvalues and eigenvectors. The classic "Linear Algebra and Its Applications" authored by Gilbert Strang is also recommended.

### The Best of All Possible Worlds: Mathematics and Destiny

This book for general readers was written by I. Ekeland who has contributed to a wide range of fields from convex analysis and variational problems to game theories to economics. The concept of "optimization" aiming to minimize (or maximize) a given objective function was created as humans' interest expanded from sciences for the explanation of physical phenomena to engineering. Today, the scope of application of optimization is not limited to engineering, but expands to include economics, management and financial engineering. Difficult challenges keep arising, such as those urging us to seek solutions to the question "Can we organize the best possible society through optimization?". In this book, the author reveals his unique view of the world as a researcher having a philosopher as his mother, which gives me food for thought about my own way of life as a researcher.

## Key elements required of research

Masahiro Yukawa

I think research must have "Sexiness" and "Elaborateness" as key elements. "Sexiness" can be translated as "attractiven-ess." In fact, we are excited by innovative research themes with an element of surprise. Developing a highly creative idea and doing something trail-blazing no one else would conceive – I think maintaining this mindset is very important. However, this alone is not enough. Once you have got a stimulating idea, you must verify whether it will be feasible or not. An important requirement here is "Elaborateness." Conducting experiments in an easygoing way and saying "Look at this result. It's a success, isn't it?" … It will bring you nowhere. Given today's highly competitive world, it's unlikely that researchers in any country will accept what you say.

When it comes to signal processing, verification is made by mathematical proofs and computer simulations. Speaking of myself, convex analysis (particularly fixed-point approximation of nonexpansive mapping) helps me a lot when developing rigorous discussions. So far I have addressed many, diverse research tasks. In all of these cases, convex analysis well demonstrated its worth.

Is the "ultimate filter" a sexy idea? I'll be happy if your answer is "It's ridiculous!" I was told that any idea not regarded as "ridiculous" at the outset would be hopeless after all. History gives a true account. In the summer of 2006 when I was a student in the doctoral course, I accompanied my supervisor to visit Prof. M.K. Tchobanou in Moscow, who used to teach together with Prof. V. Kotelnikov at Moscow Power Engineering Institute. It is said that in the era when analog communication was the only way, Prof. Kotelnikov's doctoral thesis on trail-blazing digital communication was considered "ridiculous" by the panel of examiners in those days. Even so, the thesis was accepted reluctantly because no errors were found in his mathematical demonstration. Once the true value of his study became known, however, it was classified as a government secret and had not been known to the world until 2001 when his work was translated into English. There's no doubt about digital communication having opened up a new era of information society, although C. Shannon, who popularized it, is credited with the arrival of information society.

In today's ever-progressing science and technology, it is often said that what's useful tomorrow will be of no use the day after. I take it as a lesson: no matter how hard you work on something right under your nose, it will be superseded in no time. In order to engage in long-standing studies, we must establish deeply rooted theories. Our ongoing bold challenge to seemingly "ridiculous" themes (researchers are convinced they are reachable) will bring us to the dawn of a new era, I believe.

In our lab there are students who are good at coming out with creative ideas and those who are good at precise discussions. But they are all talented. They seem to enjoy research work day after day while appreciating freshly brewed coffee. I expect them to complete their graduation studies – in sexy and elaborative ways. Incidentally, the coffee cup I'm holding as shown in the front cover photo is my favorite one. A cup of tasty coffee with good aroma, which I enjoy in the morning, gets me ready to start a new, productive day.

## Science and Technology **Information**

### Future-Oriented Technology ∞ Business Creation Forum ~ Thinking about Future Lifestyles ~

Date: October 23 (Fri.), 2015 15:00 ~ 17:45 (Sociable: 18:00 ~ 19:30)
Venue: Multi-purpose Room 1, Kyoseikan Bldg. 2nd floor, Hiyoshi Campus
* Prior registration via website is required (http://www.kll.keio.ac.jp/event/new.html).

[Programs]
❶ "New product development made possible by knowing the mind: toward a future world by online measurement of sensibility"
Yasue Mitsukura (Associate Prof., Department of System Design Engineering)
❷ "Biofied buildings: Living spaces for watching and comfort"
Akira Mita (Prof., Department of System Design Engineering)
❸ Session for opinion exchange between participants and researchers
❹ Sociable (fee: ¥2,000)




新版 窮理図解

**Editor's postscript**

What image will you have in mind when you hear the term "adaptive algorithms"? For most of you, I'm sure, it's far from a technology indispensable to our modern lifestyle. But the term "ultimate filters" somehow reminds me of something practical. It was with such vague images that I listened to Dr. Yukawa's explanation of his studies. Just as expected, the content of his explanation was a bit too difficult for me, a novice at this field, because it was full of theoretical matters (though admitting that Dr. Yukawa did his best to explain it in an easy-to-understand way).

When it comes to things difficult, we tend to think they are something of a different world. But once knowing that it's a technology which removes disagreeable tastes like a coffee filter, I was able to feel it as something familiar to our daily life. Seemingly having understood even some of it was precious fruit of our interview with Dr. Yukawa.

(Manami Matsubayashi)

New Kyurizukai
No. 20 October 2015

Editing: "New Kyurizukai" Editing Committee
Photographer: Keiichiro Muraguchi
Designers: Hiroaki Yasojima, Yukihiko Ishikawa (GRID)
Cooperation for editing: SciTech Communications, Inc.
Publisher: Tojiro Aoyama
Published by : Faculty of Science and Technology, Keio University
3-14-1, Hiyoshi, Kohoku-ku, Yokohama, Kanagawa 223-8522
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