Expanding Horizons : Frontier research at Iwate University

Vol.1

Expanding Horizons : Frontier research at Iwate University Vol.1

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Foreword for the publication of "Frontier Research at Iwate University"

Akira Iwabuchi
President, Iwate University

We are pleased to publish the English edition of "Frontier Research at Iwate University". The main purpose for this brochure is to disclose selected twenty-one frontier research made at each faculties in Iwate University during the second round of medium-term goals and plans from 2010 to 2015. The items shown here cover the wide range of academic fields from basic to practical, and related to the reconstruction from the disaster mentioned below. I expect that our frontier research attract many students all over the world and lead them to study at our university.

Established in 1949, Iwate University has been one of the best universities in Northern Japan. We offer wide range of courses at four faculties of Humanities and Social Sciences, Education, Science and Engineering and Agriculture. We also have two graduate schools of Education and Arts and Sciences for master's degree programs, and two for doctoral programs on Engineering and Agriculture. Around 5,500 undergraduate and graduate students are now studying with around 400 teaching staff. Iwate University is a middle size university between 86 national universities. We have excellent environment for study with clear four seasons in Morioka where Iwate University is located.

Great East Japan Earthquake and Tsunami Disaster brought strong damages on coastal areas in Tohoku region on March 11, 2011. After the disaster, we have concentrated to the reconstruction activities, because our motto is "Together with Iwate and its people". Since there was a strong demand toward universities to lead regional innovation for the reconstruction, we devoted ourselves to cooperate with regional organizations to develop new technologies, and educated students to be a leader in regional society for reconstruction.

While we produced this brochure in Japanese initially for high school students and citizens inside Japan, one of our missions is to create a "glocal" university, which means to take an active role in both local and global perspectives. I hope this English edition motivate international students to do research with us in the near future. We truly welcome you to Iwate University.

Prof. Tomoji Higuchi:
Humanities and Social Sciences - Japanese History

Rebuilding the Image of the Ancient History of Tohoku – From Aterui to Hiraizumi –

What kind of research?

Prof. Tomoji Higuchi (Faculty of Humanities and Social Sciences)

<Complete picture of the grand ancient history of Tohoku>

15 years ago, in 2002, various events were held to commemorate the 1200th anniversary of Aterui's death, and the Emishi leader Aterui（阿弖流為） that fought against the military of the Japanese government under the Ritsuryo codes from the late 8th to the early 9th century was catapulted into fame. Nine years after that, in 2011, the Great East Japan Earthquake and Tsunami and the nuclear disaster struck Japan. In the same year, the historical sites of Hiraizumi that were built by Fujiwara no Kiyohira（藤原清衡）, the first Oshu Fujiwara lord, in the early 12th century representing the Buddhist Pure Land were designated as World Heritage Sites in June. The Buddhist culture in Hiraizumi has been drawing attention from all over the world ever since.

My current research focuses on various events that took place in Tohoku over the long 400 plus year period from Aterui to Hiraizumi and attempts to paint a comprehensive picture of this grandeur and the dynamic history comprised of various pieces of evidence found throughout this history by carefully unraveling their causal relationship.

When Aterui was at war with the state, Tohoku was the land of the Emishi. While they were very antagonistic to the state, the state and local societies in Tohoku gradually started to cooperate in the political sphere after Aterui's death. During the 10th to 11th centuries, local ruling families like the Abe Family in the Kitakami Valley the Kiyohara family in the Yokote Valley increased their power under the command of aristocratic bureaucrats sent from the central government including the governors of Mutsu and Dewa provinces, the commander in chief of the defense of the north, and the provincial officer of Dewa. After the Abe and Kiyohara families lost power in Zenkunen-Kassen（前九年合戦, 1051-1062） and Gosannen-Kassen（後三年合戦, 1083-1087） in the late 11th century, Fujiwara no Kiyohira, who was a member of both the Abe and Kiyohara families, gained supremacy over the Genji（源氏）. By improving his cooperative relationship with the central government, he finally established a new administration based on the local society in Hiraizumi in the early 12th century. Over 80 years later in 1189, the Hiraizumi administration established by Kiyohira was destroyed after a fierce attack from the Kamakura shogunate forces led by Minamoto no Yoritomo（源頼朝）. Nevertheless, the cultural and ideological heritage of Hiraizumi that pursued a permanent peace based on Buddhist philosophy had a considerable impact on the later history of Japan.

What is it useful for?

<Significance of the historical study: What is the real "history of Japan">

History is not a practical science for acquiring concrete benefits. Although it would be difficult to explain what it could be useful for, I can say that historical events have a number of facts that teach us, people who live in the modern era, various lessons so that we can live a better life in the future. With regard to my above-mentioned research on the ancient history of Tohoku, understanding the position of Tohoku, and how it contributed to and had an impact on the history of the whole Japanese archipelago has remarkable modern significance to us living in Tohoku.

The "history of Japan" taught in school textbooks has not been relevant as the history of the entire Japanese archipelago. It was rather a local "history of Japan" centered around the location of the government. In contrast, a research methodology based on the "regional history" that I practice is quite important in building the framework for a real "history of Japan" that took place over the entire Japanese archipelago and will be compiled in the future.

Rebuilding the Image of the Ancient History of Tohoku

- From Aterui to Hiraizumi -

夷俘（いふ）と号すること莫（な）かるべし

Never call him “*ifu*”
(barbarian captive)

「阿弓流為」。それは律令国家軍を相手に長きにわたって抵抗を続け、九世紀初頭に世を去った人の名である。彼の名は史上に四たび、「阿弓流為」で一回、「大墓公」で一回見える。彼の個人名の正式な漢字表記が「阿弓流為」なのかは不明であるが、本書では従来一般的であった阿弓流為＝アテルイと呼ぶことにしたい。

今から一〇年あまり前の平成十四年（二〇〇二）はアテルイ（阿弓流為）没後一二〇〇年とで、とくに地元岩手県を中心にアテルイブームが巻き起こった。シンポジウムの開催や関連遺跡の市民発掘、アニメーション映画やミュージカルの上演などがそれを期に東北地方在住の人たちの間にも阿弓流為の名が一定程度浸透していったことを描き出した文芸作品に高橋克彦氏の『火怨―北の耀星アテルイ』（講談社、

“Aterui” may remind many of the head of Akuro-o (lord of the bad road) in the Homotsukan Museum of Kashima Jingu Shrine. However, this is now considered to be a created image of a bad devil that make people suffer and has nothing to do with Aterui.

Prof. Toshiaki Sasao:
Social Sciences - Environmental Policy / Environmental and Social Systems

Economic Analysis of the Disaster Waste Management in the Case of the Great East Japan Earthquake

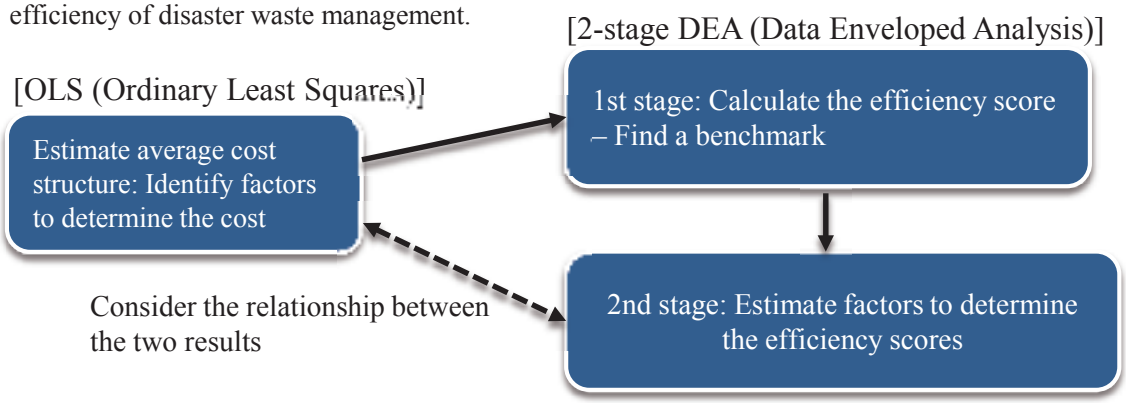
What kind of research?

<Analysis of the cost and efficiency of waste disposal associated with the Great East Japan Earthquake>

Prof. Toshiaki Sasao (Faculty of Humanities and Social Sciences)

The Great East Japan Earthquake has generated approximately 28 million tons of disaster waste and tsunami sediments in Iwate, Miyagi, and Fukushima prefectures. The generated debris (excluding tsunami sediments) in Iwate was equivalent to the municipal solid waste generated in the prefecture for 9 years. The disposal costs for removing the disaster waste and tsunami sediments amounted to1.15 trillion yen (9.5 billion dollars, including prefectures other than the above three). This amounts to roughly 37,000 yen per ton. These costs were covered mostly by national subsidies and the each prefecture's spending was kept to a minimum level. But, the national subsidies are financed national tax revenue including those from the local governments of the affected prefectures. The important challenge is to keep the cost low while the project remains safe and secure for the disaster-hit areas.

Most existing studies have analyzed the cost of municipal solid waste management and its efficiency, but there was no economic analysis targeting disaster waste either in Japan or outside. Thus, this project focused on disaster-hit municipalities in Iwate and Miyagi prefectures and performed economic analysis on the cost and efficiency of disaster waste management.



For more details, please see: Sasao, T (2016), Cost and efficiency of disaster waste disposal: A case study of the Great East Japan Earthquake, *Waste Management*, Vol.58, pp. 3-13

What is it useful for?

<Suggests cost-efficient disaster waste management>

This research confirmed the following points.
- The disposal of tsunami sediments and recycling the disaster waste can gain from economies of scale.
- The efficiency varies among municipalities.
- More temporary incinerators and secondary waste stocks improve cost efficiency.

Our research is expected to provide important insights on the cost and efficiency of the waste management when another large-scale disaster occurs in or outside Japan in the future.

The waste recycled as materials for reconstruction work

Analyze the regional issues in relation to waste management using economic methods

Economic Analysis of the Disaster Waste Management in the Case of the Great East Japan Earthquake

[2-stage DEA (Data Enveloped Analysis)]

[OLS (Ordinary Least Squares)]

Estimate average cost structure: Identify factors to determine the cost

1st stage: Calculate the efficiency score – Find a benchmark

Consider the relationship between the two results

2nd stage: Estimate factors to determine the efficiency scores

DEA (1st stage)

Input

Labor

Capital

Output

Amount of waste and tsunami sediments

Recycled amount of waste and tsunami sediments

Aim to minimize the inputs while keeping the outputs at constant levels

Collected disaster waste

Prof. Hitoaki Yoshida:
Education - Information Security

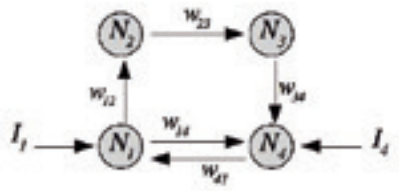
Highly Secure and Super High-Speed Pseudo-Random Number Generator for Information Safety and Security

What kind of research?

<Super high-speed and secure cryptographic technologies>

Our research builds a secure system by controlling the nature of chaos like long-term unpredictability and sensitivity to initial conditions. Normal ciphers can be decrypted if the key and algorithm are discovered. However, our research was still unable to decrypt it due to the hardware and compiler dependencies. In turn, if the system does not require such high level of security, the cipher can be made more common by reducing the dependencies. For the 901 different chaos neural networks (CNN), we successfully made 134,000,000 threads to work in parallel using the GPGPU. As a result of this, the speed of pseudorandom number generation reached 4.38 Tbps (4.38×10^{12} bit per second). The period was 10^{11052} and is regarded as a super-long period. It is a theoretical value based on an experimental value. We used the Chaos Neural Network (CNN) that we developed as a chaos generator. The basic unit is very simple as described on the right, which is composed of four conventional artificial neurons (artificial neural elements) that are used in the BP method and Hopfield network.

Prof. Hitoaki Yoshida
(Faculty of Education)



Basic unit of chaos neural network (CNN)

What is it useful for?

<For the protection of personal information and confidential information>

Ciphers can be easily made by combining pseudorandom numbers and XOR operations. If the speed of random numbers generation is 4.38 Tbps, information that runs through the internet backbone can be encrypted. In addition, GPGPU uses a low-cost GPU (graphics processing unit) unlike super computers and this suggests that our technologies could be operated by the standard smartphones in the near future. A GPU was originally for image processing for personal computers although it has evolved into a unit that is capable of performing super high-speed parallel computation. Our technologies manifest in the most advanced pseudo-random number generator that is one of the fastest in the world.

We have launched two products so far in collaboration with businesses. In fiscal 2004-2005, we launched a CF card reader/writer, AMI-410CF with encryption engine from Adtek System Science with the support of the Dream of Iwate, Iwate Strategic Research Promotion Project and held a press conference at the Iwate Prefectural Hall. The patent we obtained through this technology was licensed to businesses.

There is no perfect solution for protecting personal information and confidential corporate information on the internet. There are an increasing number of computer viruses, malware, and targeted attacks that use them, and it is no longer rare for large corporations to suffer hundreds of millions of data leaks. Our technologies are expected to cater to resolving such problems by helping in self-defense to survive this era.

Highly secure and super high-speed pseudo-random number generator for information safety and security

Normally, measured values are extracted and utilized to explain with equations and theories.

2398.081
Measured value

Equation/Theory

Our study extracted and used lower values that are normally discarded.

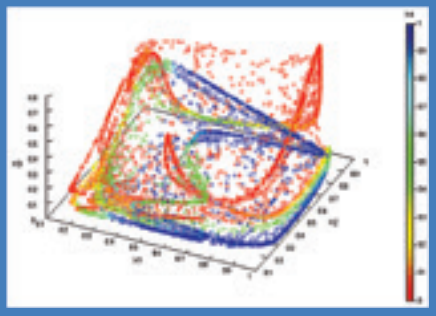
478500291881
Error? Noise?

47850029188
If the phenomena is chaotic, it could lead to good random numbers!

Observe/measure natural phenomena

2398.081478500291881

Measured value **Error? Noise?**



Strange attractor generated from the CNN

Actually, "pseudo-random numbers" are extracted from an "artificial neural network" that is modeled on a calculator.

Realized high speed with massively parallel computing
Security: long-term unpredictability, sensitivity to initial conditions, and super long period

Find out why good random numbers are obtained and what random numbers are in the first place.

Utilized for ciphers to protect personal and confidential information on the internet.

Speed of generation : 4.38×10^{12} bps, Period: 10^{11052}

Prof. Koichi Kawada:
Mathematics - Algebra

Research on Waring's Problem and the Waring-Goldbach Problem

What kind of research?

<Set the world record on determining the numbers that are the sum of fourth powers >

Prof. Koichi Kawada
(Faculty of Education)

If one can prove that "all the numbers greater than 10^{100} can be expressed as the sum of 7 cubes", then it is theoretically possible to completely identify the natural numbers that cannot be expressed so, by going over all the numbers up to 10^{100} simply. Waring's problem seeks, in this way, to completely determine the numbers that can/cannot be written as the sum of powers, such as cubes or fourth powers. To this end, we primarily endeavour to show that every number over a certain limit is the sum of a certain number of powers. Here, the less number of summands, the more difficult it becomes, so that researchers are keen on reducing the number of powers.
This type of research has a long history since it originated in 1770. As for the fourth powers, the first theorem was established in 1859 on the sum of 53 fourth powers. Since then, a great deal of elaboration has been made to reduce the number of fourth powers, and it reached down to 12 by 1989. Ten years later, in 1999, Kawada and Wooley (a professor at University of Michigan then, currently at University of Bristol) jointly achieved a theorem on the sum of 11 fourth powers, and the latter result remains the best in this direction as of 2016.
On this progress, the following identity played an important role:

$$x^4 + y^4 + (x + y)^4 = 2(x^2 + xy + y^2)^2$$

Making use of this identity, and with support from experts on computer programming, we further determined all the natural numbers that are not the sum of 16 fourth powers. While finiteness of such numbers had been already known in 1939, our research revealed the complete list of those 96 numbers for the first time.
A parallel problem, called the Waring-Goldbach problem, has also been investigated, where powers of integers are restricted to powers of prime numbers. In this direction, we obtained results on the sum of 14 fourth powers of primes, and on the sum of 21 fifth powers of primes in 2001. Both made world record back then, though the number of fourth powers was superseded by 13 in 2014. The result for fifth powers remains as the current record.

What is it useful for?

<Useful for nothing>

This type of research is done on purpose to explore itself, and probably it will never serve anything else. In fact, this research is not aimed at being useful for something.
For example, even if someone could succeed in sprinting 100m in 9.57 seconds, this feat itself would contribute no actual profit directly to our daily lives and society. Still sprinters work hard to attain better records, and those who are interested in it enjoy their new records with admiration. They may present no significance to those who are not interested. It might sound rather arrogant to compare my research with it, but I personally feel some similarity between them.

Research on Waring's Problem and the Waring-Goldbach Problem

$$x^2+y^2+(x+y)^2=2(x^2+xy+y^2).$$
$$x^4+y^4+(x+y)^4=2(x^2+xy+y^2)^2.$$

$$\mathbf{2016=3^3+4^3+5^3+6^3+7^3+8^3+9^3.}$$

Can every sufficiently large even integer be written as the sum of 8 cubes of primes?

Every integer larger than 13792 is the sum of 16 fourth powers.

Write $A(x)$ for the number of integers up to x that can be written as the sum of 5 fourth powers, then $A(x)>x(\log x)^{-1+o(1)}$ $(x\to\infty)$.

$$\int_0^1\Bigg(\sum_{m\le N^{1/4}}e^{2\pi im^4\alpha}\Bigg)^{11}e^{-2\pi iN\alpha}\,d\alpha\ >\ 0\quad ?$$

$$\mathfrak{M}=\bigcup_{q\le Q}\ \bigcup_{\substack{a=0\\(a,q)=1}}^{q}\left\{\alpha\in[0,1)\,;\left|\alpha-\frac{a}{q}\right|\le\frac{Q}{qN}\right\}.$$

$$\int_{\mathfrak{M}}f_4(\alpha)^{11}e(-N\alpha)\,d\alpha\sim\Gamma\Big(\frac{5}{4}\Big)^{11}\Gamma\Big(\frac{11}{4}\Big)^{-1}\mathfrak{S}_{4,11}(N)N^{\frac{7}{4}}.$$

Associate Prof. Chyon Hae Kim:
Science and Engineering - Intelligent Robotics

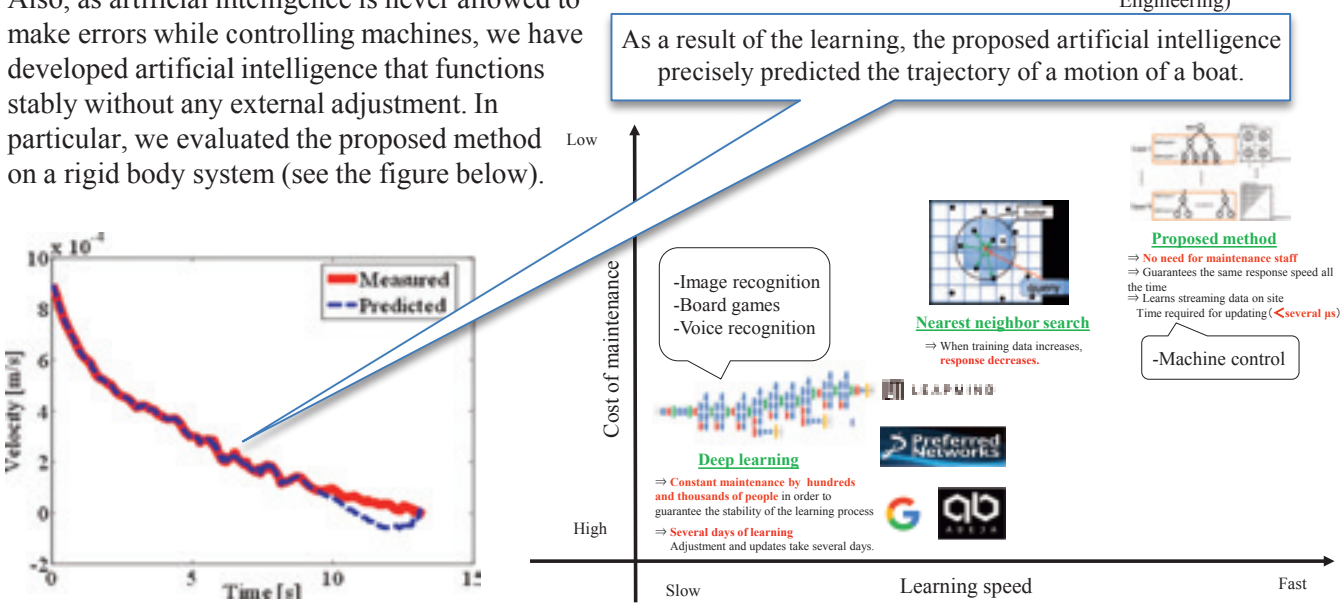
Research on Optimal Control through Rigid Body Dynamics Modeling

What kind of research?

<Improvement of mechanical control through learning (artificial intelligence)>

Controllers of machines like automobiles, air-conditioners, or microwaves are adjusted so that every one can use it easily, we often find them dissatisfying our preference (inflexible or inconvenient). We are developing artificial intelligence that is specialized for mechanical control. The method proposed here attained super highspeed learning at a rate of up to a few microseconds in order to introduce artificial intelligence to a "machine" that has very fast control cycles.
Also, as artificial intelligence is never allowed to make errors while controlling machines, we have developed artificial intelligence that functions stably without any external adjustment. In particular, we evaluated the proposed method on a rigid body system (see the figure below).

Associate Prof. Chyon Hae Kim (Faculty of Science and Engineering)



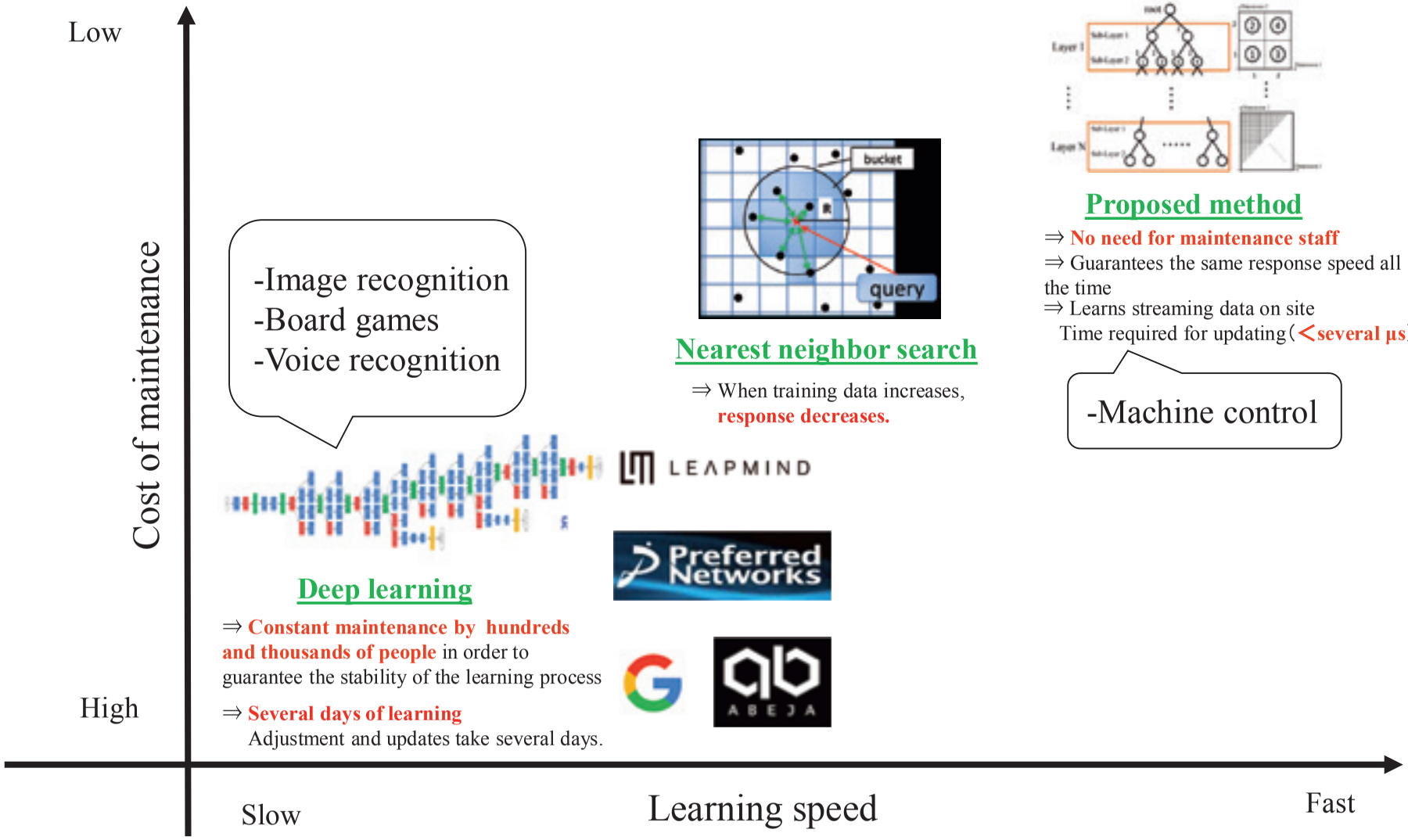
What is it useful for?

<Creates machines that are smart or can learn to be smart>

We can develop various smart machines by introducing optimizing methods while training the artificial intelligence models [1].

Machine automation: Ships that stay in the same spot by canceling out the impact of waves.
Machines that learn user's preference: Air-conditioners that adjust to the user's preference automatically without being controlled by a remote.
Auto-adjustment: Machines that modify movement patterns in response to aging deterioration.
Sensor adjustment: Online calibration of sensors including EMG sensors.

[1] **Chyon Hae Kim** and Shigeki Sugano: "Tree Based Trajectory Optimization based on Local Linearity of Continuous Non-linear Dynamics," IEEE Transaction on Automatic Control, Vol. 61, No. 9, pp. 2610-2617, (2016).


Low
Cost of maintenance
High
-Image recognition
-Board games
-Voice recognition
Deep learning
⇒ Constant maintenance by hundreds and thousands of people in order to guarantee the stability of the learning process
⇒ Several days of learning
Adjustment and updates take several days.
LEAPMIND
Preferred Networks
ABEJA
bucket
query
Nearest neighbor search
⇒ When training data increases, response decreases.
Proposed method
⇒ No need for maintenance staff
⇒ Guarantees the same response speed all the time
⇒ Learns streaming data on site
Time required for updating (＜several μs)
-Machine control
Slow
Learning speed
Fast

Prof. Masahito Yoshizawa:
Science and Engineering - Physical Properties II

Research on the New Superconductivity Mechanism in the Iron-Based Superconductor

What kind of research?

<Discovery of the key to finding a highly practical new superconductor>

Superconducting technology is expected to change our future life including power transfer from power plant to megacities of power consumption, maglev train, superconducting magnets creating high magnetic fields for MRI, and MEG and MCG for brain and heart diagnosis.

Prof. Masahito Yoshizawa
(Faculty of Science and Engineering)

Superconductivity is brought about by a pair of electrons carrying electric current. However, electrons have a negative electrical charge and repel with each other, preventing them from making pairs. To make a pair, something that puts the two electrons together is required just like the matchmaker for marriage or parents trying to reconcile children. The stronger the mediating power, the stronger the two electrons are combined and therefore the more stable the superconductor.

The iron-based superconductor discovered in 2008 becomes superconducting at a higher temperature and is expected to be adapted to various purposes. However, the mechanism (what mediates it) was unknown. Our research carefully focused on the hardness (elastic constants) of $Ba(Fe_{1-x}Co_x)_2As_2$, where a part of iron is replaced by cobalt. Our research found that this material shows a large softening towards low temperatures (Figure 1) and that the superconducting transition temperature increases as the elastic compliance (inverse of the elastic modulus C_{66}), a softness index for transforming the crystal structure from square to rhombus, goes up (Figure 2). According to research on quantum phase transitions, which is an achievement of the most advanced physics, the softening in the iron-based superconductor at lower temperatures is caused by the orbital fluctuations (wave function and its shape) of electrons. Thus, we proposed in 2012 a mechanism that the orbital fluctuations mediate electron pairing. This is the first candidate for the superconductor that originates from the orbital fluctuations and our research stimulated many theoretical and experimental research projects and now the electron orbital fluctuations are studied all over the world as a new superconducting mechanism.

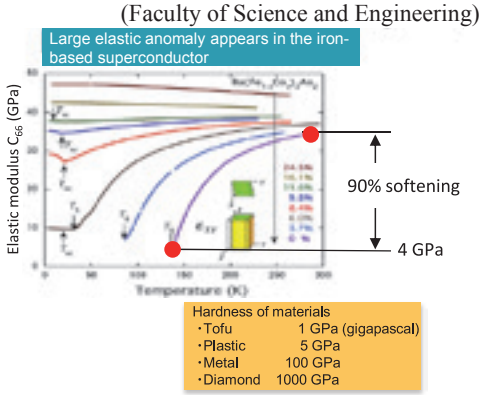


Figure 1. Temperature dependence of the elastic modulus C_{66} of iron-based superconductor $Ba(Fe_{1-x}Co_x)_2As_2$

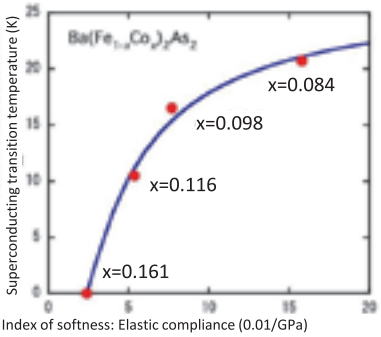


Figure 2. Correlation between the transition temperature and elastic compliance

What is it useful for?

Electron pairing mediated by the orbital is powerful and thus this mechanism of superconductivity is expected to bring high superconducting temperatures for practical use. Our research found that "the softer materials show superconductivity with higher transition temperature" and this is a key for finding new superconductors. We have looked for unknown properties of materials by measuring the hardness of the material in extreme conditions of low temperature, high pressure and, high magnetic fields, so far. During this process, we have developed super-technologies to measure the hardness of materials with 1/1,000,000 precision in as short as 20 microseconds. The discovery in the iron-based superconductor was also a result of such persistent research works. Material properties research is something like treasure hunting. We hope the discovery we've sought will help change the future in the long run.

Iwate University's major research achievement on physical properties

Research on the New Superconductivity Mechanism in Iron-Based Superconductors

Search | Yume-Navi Yoshizawa

Application of super-conductivity

Future pioneered by super-conductivity

Find materials with high superconducting transition temperature based on elastic anomaly

Pursuing superconductivity principles

Small | Large | Medium

Energy of mediation mechanism

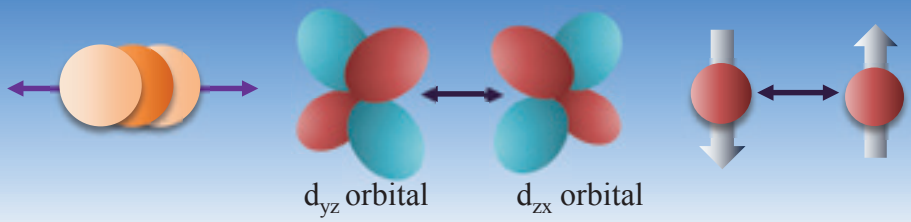
The mediation mechanism for discovering major elastic anomalies and orbital fluctuations in iron-based materials

Fundamental research

Medium | Large | Small

Size of elastic anomaly

Research on material properties is like treasure hunting for unknown properties of materials.



Ion vibration | Orbital fluctuations | Spin fluctuations

Look for big (with high energy) mediation mechanisms that combine two electrons tightly in order to find practical superconductivity.

Super-conductivity mechanism

How does superconductivity happen?

If the attraction force between electrons and the mediation mechanism is larger than the repulsion force, the two electrons are paired and superconductivity turns out.

Electrons (negative electricity) | Mediation mechanism | Electrons (negative electricity)

Attraction between electrons via mediation mechanism

Former Assistant Prof. Myung Seung-Taek and Prof. Hitoshi Yashiro:
Science and Engineering - Inorganic Industrial Materials

Synthesis of Titanium Oxide as an Active Material for High-performance Rechargeable Batteries

What kind of research?

<We develop electrode materials for non-aqueous rechargeable batteries>

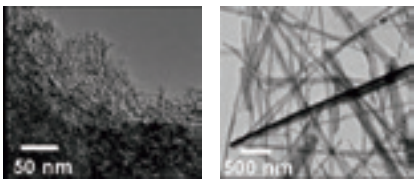
Lithium ion rechargeable batteries draw great attention as power sources for mobile devices and electric cars. There is an increasing demand for their performance and safety. The most important element that governs their performance is electrode material called "active material". Titanium oxide is an attractive resource and promising candidate for an active material.

We tried various syntheses to control the properties of titanium oxide including:

1) Shape Control of TiO_2 nanoparticles in various ways by fully examining conditions for hydrothermal synthesis
2) Synthesis of "Black Anatase," a highly electrically conductive black powder instead of the conventional white powder by hydrolysis/evaporation drying methods
3) Carbon Coating of TiO_2 nanoparticles.

Former Assistant Prof. Myung Seung-Taek (Prof. at Sejong Univ.)

Prof. Hitoshi Yashiro (Faculty of Science and Engineering)

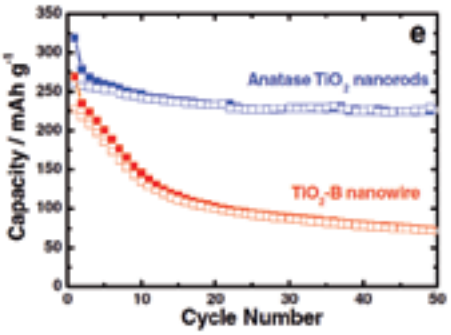


Left: TiO_2 nanorods
Right: TiO_2 nanowires

What is it useful for?

<To enhance the performance and safety of lithium ion batteries>

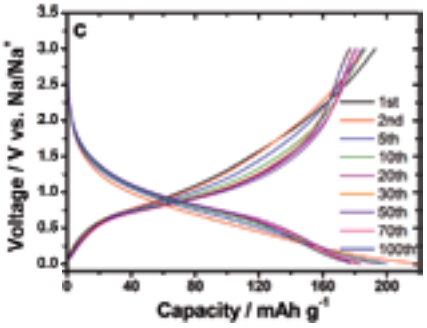
Titanium oxide discharges and charges around the 1.7 V vs.Li/Li+ range without generating metal lithium. Thus, it can be used as a safe negative electrode alternative to carbon material. Our research successfully synthesized titanium oxide nanoparticles and attained high electrochemical activity. While titanium oxide is normally a white powder with lower electrical conductivity, our research helped synthesize black (oxygen-deficient) titanium oxide and showed its high electrical conductivity and high rate performance.



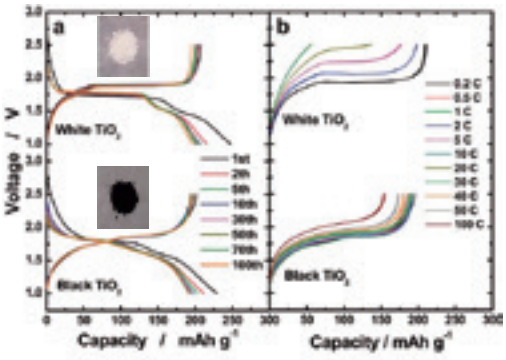
TiO_2 nanorods showed excellence in discharge/charge capacity (Li ion batteries)

<To Function as a sodium ion battery>

For the first time, the nanoparticle titanium oxide synthesized with this method was proven to be dischargeable and chargeable with sodium ions instead of lithium ions.



Carbon coated TiO_2 nanorods function as sodium ion batteries



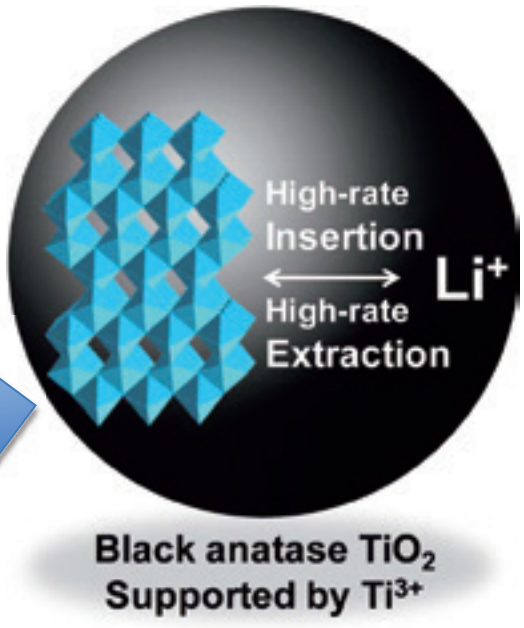
Black TiO_2 is highly electrically conductive and has high rate performance (Li ion batteries)

Hot material for battery use:

Titanium Oxide

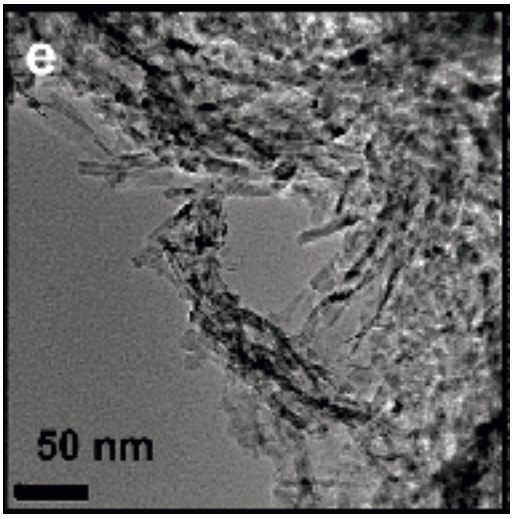
Anatase TiO_2

White powder to electrically conductive black powder

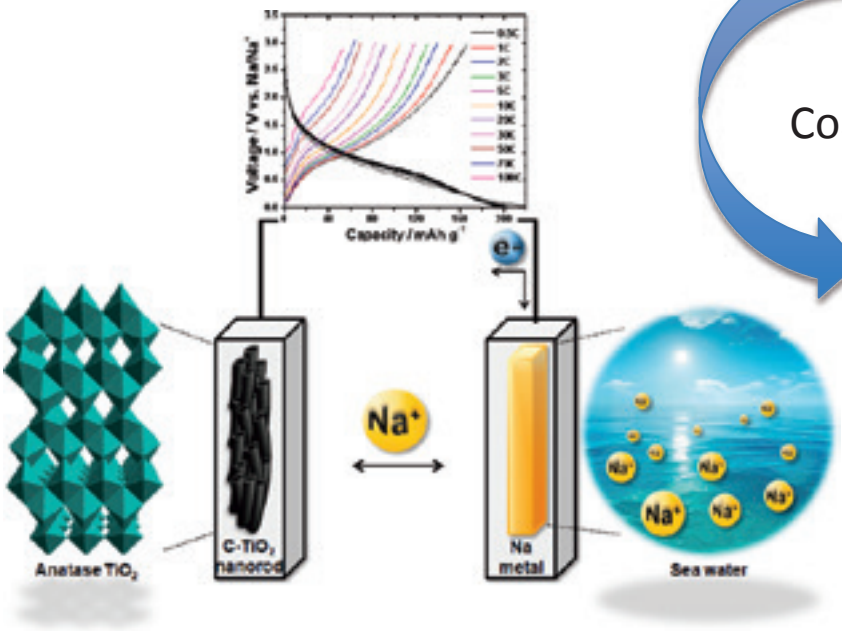


Black anatase TiO_2
Supported by Ti^{3+}

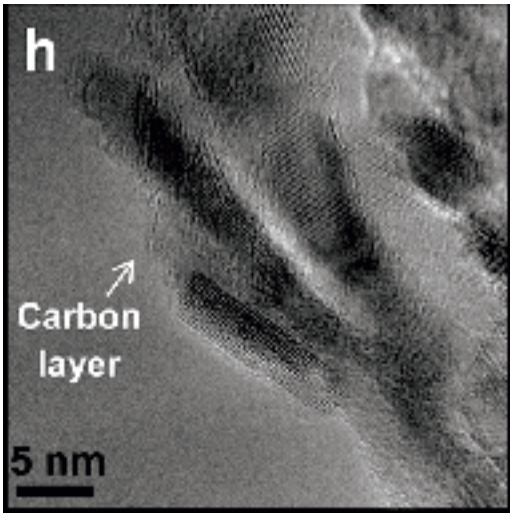
To nanorods



Coated with carbon



Applicable to sodium ion batteries



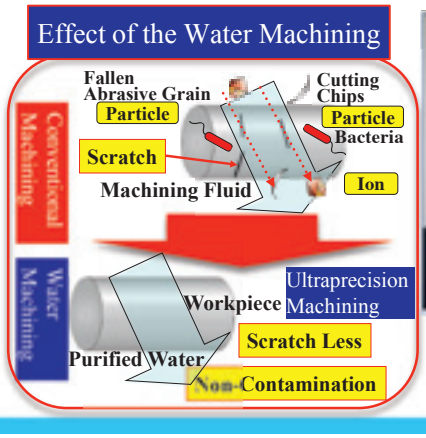
Assistant Prof. Naohiro Nishikawa:
Science and Engineering - Production Engineering/Machining

Research on the Water Machining (the Electric Rust Preventive Machining) System

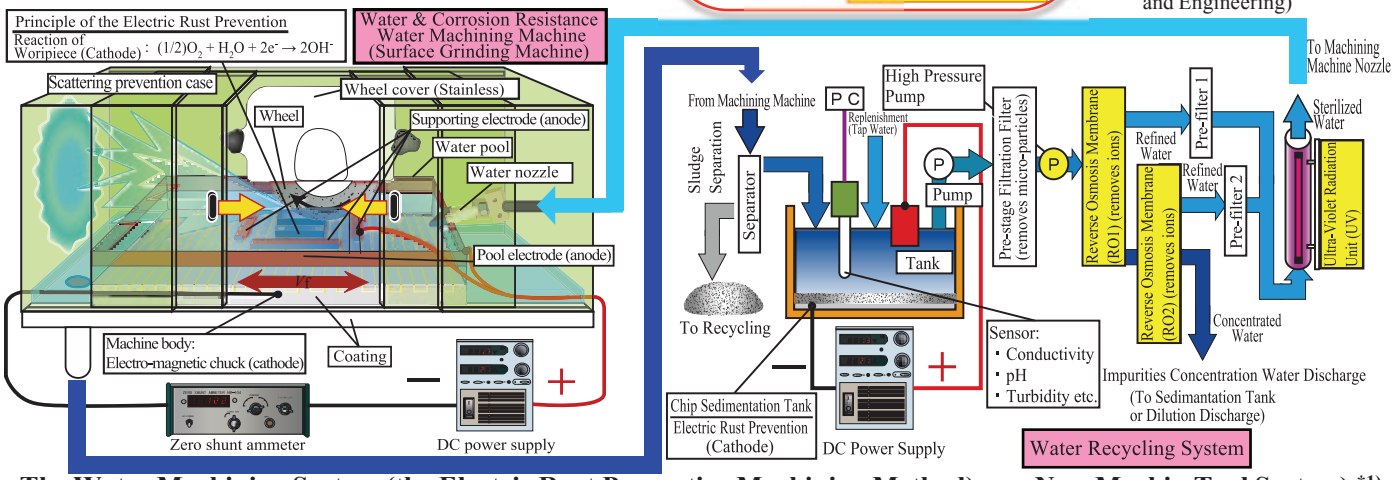
What kind of research?

<Successful technological development of machining (manufacturing) with water>

The **New Machining System Technologies** that utilize **Water as a Machining Fluid** (used for machining parts) in manufacturing (parts [workpieces] for automobiles, PCs, and robots etc.) has been developed. Machining with water (tap water etc.) was made possible by supplying weak current to workpieces and **Preventing Rust Electrochemically**.



Assistant Prof.
Naohiro Nishikawa
(Faculty of Science and Engineering)



The Water Machining System (the Electric Rust Preventive Machining Method) as a New Machin Tool System) *1)

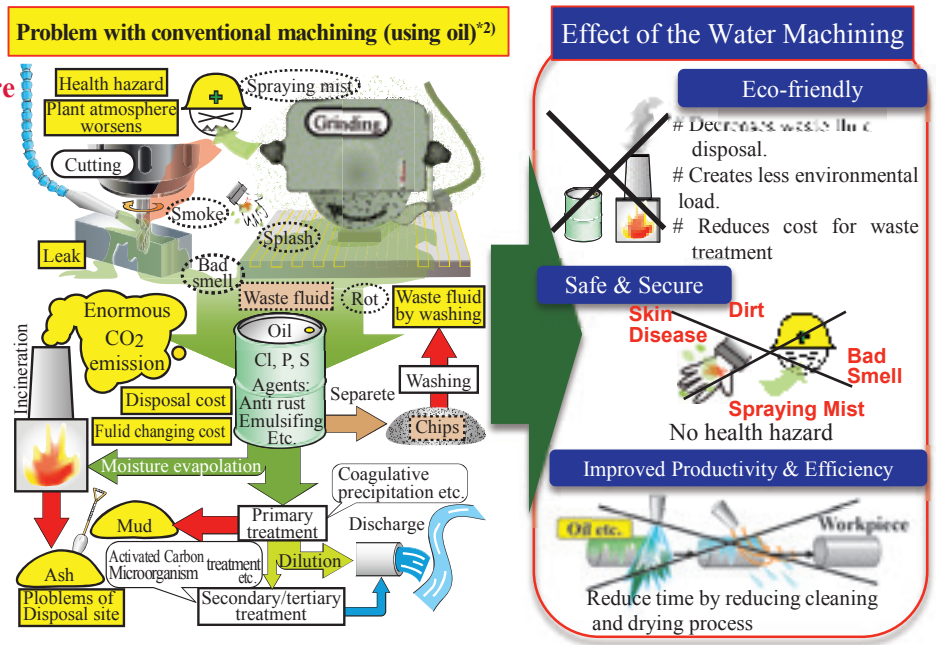
* 1) "Development of Electric Rust Preventive Machining Method System - Evaluation of Particle Removal for Water Recycle System -", Proceedings of ABTEC2013 (Tokyo, Japan)(Abrasive Technology Conference, The Japan Society for Abrasive Technology), D37, pp. 373-378 (2013)

What is it useful for?

<Cleaner production line and more ecofriendly ultra-precision and highly efficient machining>

Conventional machining uses oil etc. for the machining fluid and accompanies a large amount of waste liquid treatment (incineration, etc.) raising serious environmental and human concerns.

The Water Machining uses **abundant harmless water** and thus **oil stains are prevented and the production line is kept clean, safe, and comfortable** with **reduced effort for waste fluid treatment**. The Water machining is expected to make **ultra-precision machining** possible, **increase productivity**, and **contribute to the economy and environmental protection** by **saving resources and costs.**



*2) "Development of Electric Rust Prevention Machining Method in End Mill Cutting -Environmental Harmonic Machining Using Water in Cutting Machining-" Journal of Environmental Conservation Engineering, Vol.37, No.4, pp.274-281 (2008)

World's First & Unique Clean Ultra-Precision Manufacturing System Technologies for New Generation

Research on the Water Machining (the Electric Rust Preventive Machining) System

Award winning research: The Young Scientists' Prize, The Commendation for Science and Technology by the Minister of Education, Culture, Sports, Science and Technology, Japan, 2014; JSME Young Engineers Award; JSPE Young Engineer Award; JSAT Encouragement Award and Kumagai Award and so on.

Water Machining System: Cleaner and safer manufacturing with water

Water-proof & corrosion-proof machining machine*3)
(Prevent rust from water with electric rust prevention etc.)

Water recycle system*4)
(Ultra-purification of water with reverse osmosis membrane, UV, etc.)

Eco-Friendly & Human-Friendly

Developed demonstrator of water machining machine (surface grinder)*3)

Purified Water

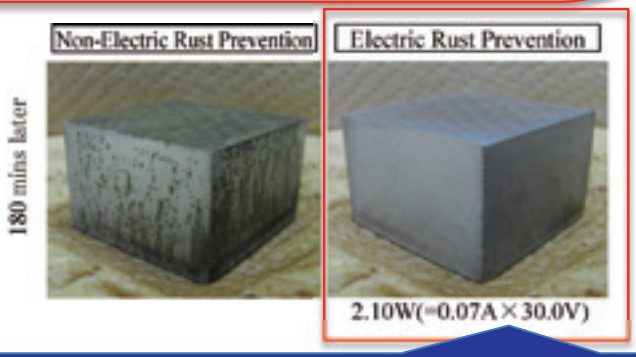
Used Water

Water Recycle System*4)

Reducing Waste Fluid, Highly Efficient, Ultra-Precise

No more "Dangerous, Dirty, Hard, Smelly, Dark" work without oil in Factory

Situation of Water Machining*5)
(Surface grinding, on-site prototype machine)



Effect of Electric Rust Preventive Machining Method*6, 7)
(Preventing rust on iron during machining in water by supplying a weak electric current)

*3) "Practical Use Development of Electric Rust Preventive Machining Method -Examination of the Practical Use Machine-", Japan Society of Mechanical Engineers (JSME) annual meeting Proceeding of Mechanical Engineering Congress, 2013 Japan (MECJ-13) DVD-ROM, No.13-1, S131023, p.1-5 (2013)

*4) "(Special feature article, State-of-the-art to support the production processing of the next generation) Development and prospect of environmental harmonic machining technology -Water machining and machining water supply system that removed bad influence for environment-", Machine and Tool, Japan Industrial Publishing Co.,LTD., Vol.4, No.1, p.18-25 (2014)

*5) "Episodes of JSAT Encouragement Award, "Proposal and Development Investigation of a Series of the Electric Rust Preventive Machining Method System with Water and Corrosion Proof Machining Machine and Ultra High Precision Machining Water Purification Recycling Filtration System and so on for the Purpose of Using Water as a Machining Fluid"", Journal of the Japan Society for Abrasive Technology, Vol.57, No.1, p.25-26 (2013)

*6) "Proposal and Development Investigation of a Series of the Electric Rust Preventive Machining Method System with Water and Corrosion Proof Machining Machine and Ultra High Precision Machining Water Purification Recycling Filtration System and so on for the Purpose of Using Water as a Machining Fluid", Proceedings of ABTEC2012(Kyoto, Japan)(Abrasive Technology Conference, The Japan Society for Abrasive Technology), [Winner Paper of Encouragement Award], p.1-4 (2012)

*7) "Development of Electric Rust Preventive Machining Method -Evaluation of Influence on Rust Prevention with Water of Different Regions-", Journal of the Japan Society for Abrasive Technology, Vol.55, No.11, pp.656-661 (2011)

Prof. Koichi Takaki:
Science and Engineering - Electrical Engineering, Power Conversion, Electric Equipment

Iwate University 岩手大学

Research for the Application of High Voltage Plasma to Agricultural, Fishery, and Food Processing Fields

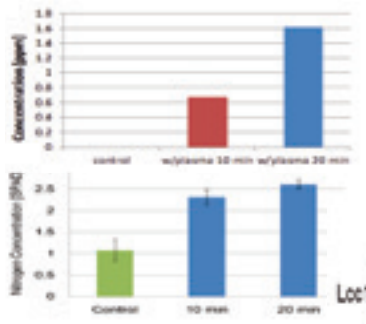
What kind of research?

<Increases agricultural/fishery productivity using high voltage plasma>

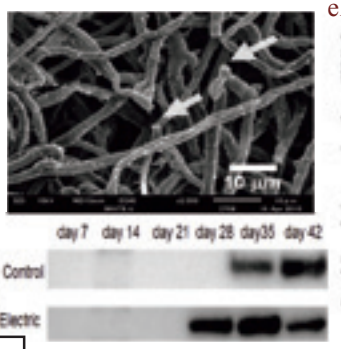
Thunder (lightning) is called “Inazuma” (稲妻), which means the good partner of rice plant growth. Thunder has long been considered essential for the vegetation of rice and other plants. Thunder is actually high voltage plasma. We developed a compact high-voltage plasma generation system that is easy to use in order to elucidate the mechanism of the high-voltage plasma contribution on vegetation and control of an environment suitable for the plant growth. With this system, high voltage plasma can be utilized to control cultivation and fruition, maintaining the freshness of agricultural and fishery products, and extracting functional components in food even without the professional knowledge of high voltage electricity or plasma.

Prof. Koichi Takaki
(Faculty of Science and Engineering)

● Nitrogen fixation and biostimulation with high voltage plasma

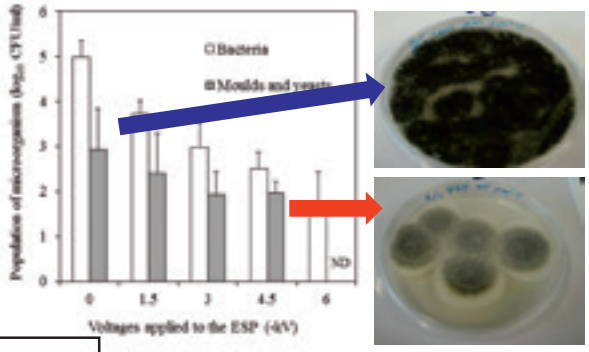


Nitrogen fixation in the cultivation water and nitrate ions taken in by plants controlled by plasma



Applying electric field to cut shiitake mushroom hyphae and followed activation of enzymes

● Capturing and deactivating bacteria using the static electricity in the storage

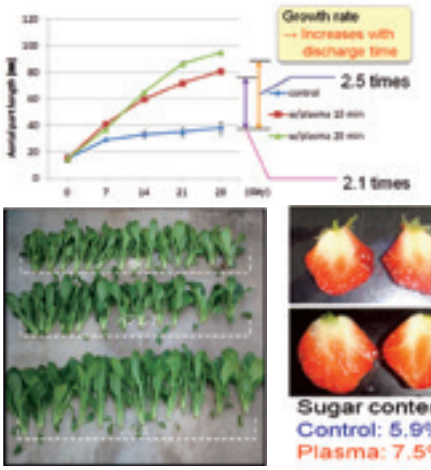


Changes in the viable bacteria and basidiomycetes numbers by applying high voltage to wire electrodes (log-scale)

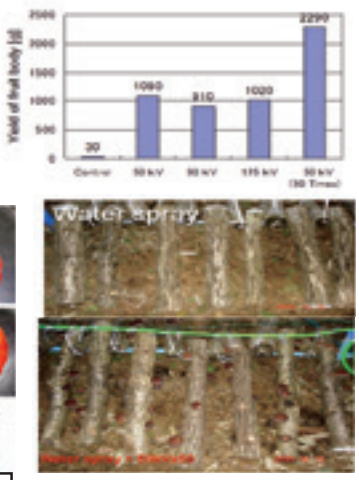
What is it useful fort?

<Stable harvest, shorter cultivation, maintenance of the freshness of the harvested products>

● Nitrogen fixation and biostimulation with high voltage plasma

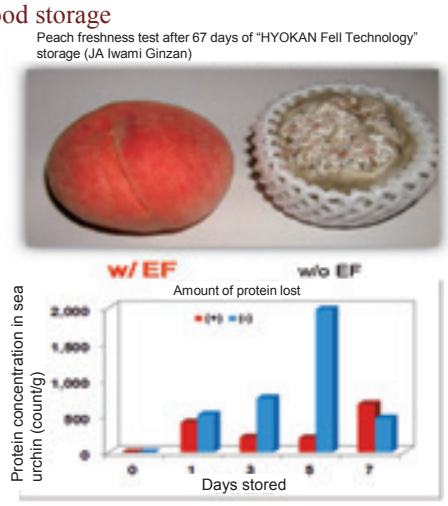


Growth enhancement of Komatsuna plant and increment of sugar contetnt of strawberry by plasma irradiation



Enhancement in shiitake harvest by applying high voltage to bed logs

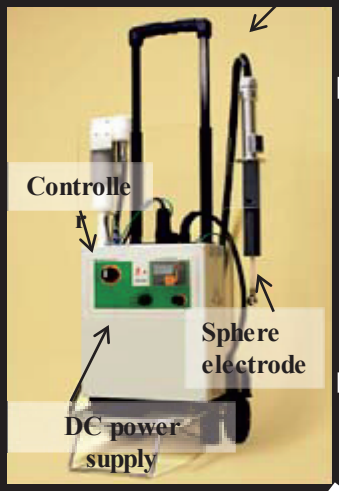
● Eliminating and inactivating bacteria using electrostatic effect in the food storage



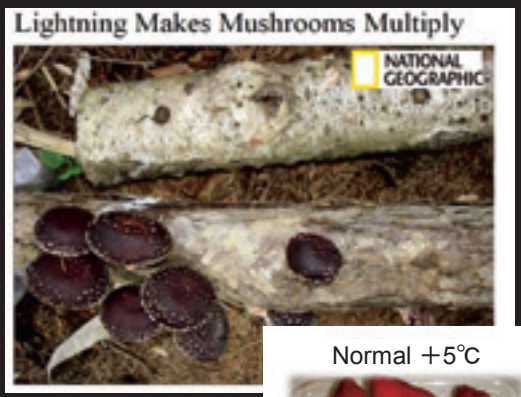
Maintains the freshness of peaches and reduces drop loss in sea urchin by applying an electric field in food storage

New agricultural and engineering interdisciplinary research takes off at Iwate University to spread to the whole world

Research for the Application of High Voltage Plasma to Agricultural, Fishery, and Food Processing Fields

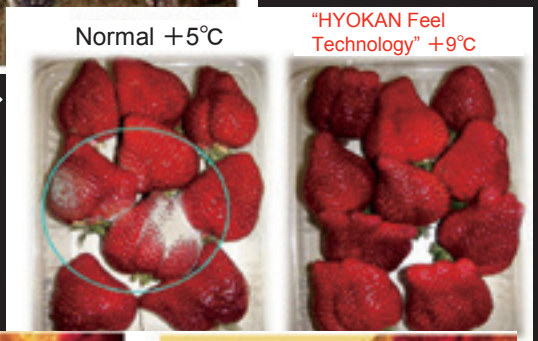


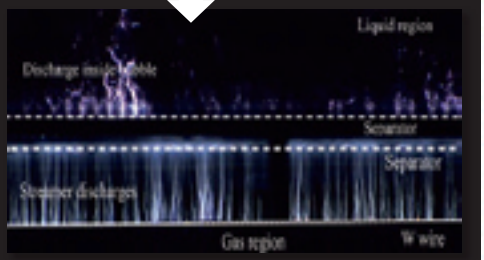
Easy to handle high voltage power supply



High voltage electricity stimulates multiplication of mushrooms (Top: No voltage applied. Bottom: 50,000 volts applied)

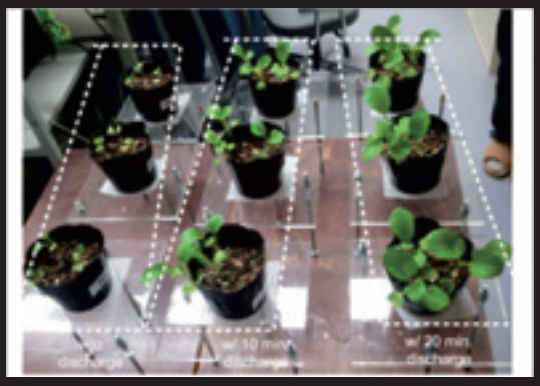
Maintains freshness of agricultural and fishery products with high voltage (Left: w/o electrostatics . Right: w/ electrostatics).



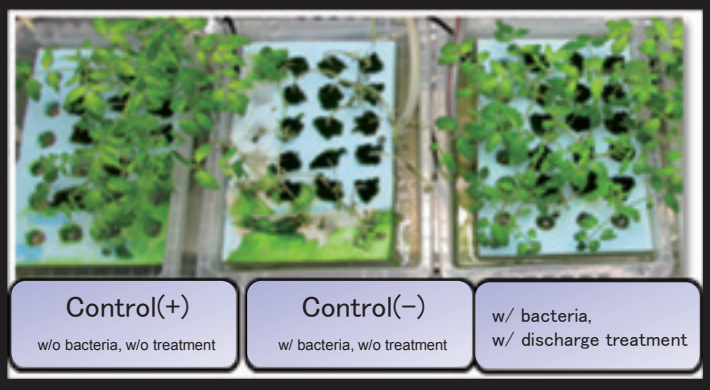


Plasma generation by a high voltage power supply

Electrolytic extraction of useful components (polyphenol) from crops (Left: w/o pulse electric field applied. Right: w/ pulse electric field applied.)



Enhancement of the komatsuna growth with plasma irradiation to cultivation water (Left: No plasma irradiation, Middle: 10 mins. plasma, Right: 20 mins. plasma)



Inactivation of ralstonia solanacearum in culture for tomato seedlings with plasma (Left: Culture without bacteria. Middle: Culture with bacteria. Right: Culture treated with plasma after the bacteria is mixed in.)

Prof. Naoki Honma:
Science and Engineering - Antenna Engineering

Research on the Microwave Biosensor using Multiantenna

What kind of research?

Prof. Naoki Honma
(Faculty of Science
and Engineering)

<Highly sensitive detection of the human position and status using microwave signals>

The microwave sensors to detect the human position and vital-sign have been studied for long time. However, they have had a problem in sensitivity especially for observing vital-sign unless the distance is extremely short or significantly wide frequency band is used. Thus, our research focuses on a method using multiple antennas called MIMO (Multiple-Input Multiple-Output). MIMO is a new technology, which can enhance the data-rate of wireless communications by increasing the number of antennas even when the available frequency resources are limited. MIMO technology in sensing enables to detect a person's position accurately even at a distance over 10 m. Our research also found that multiple persons' locations can be detected at the same time. Furthermore, the respiration and heartbeat can be observed by increasing the sensitivity using multiple-antennas.

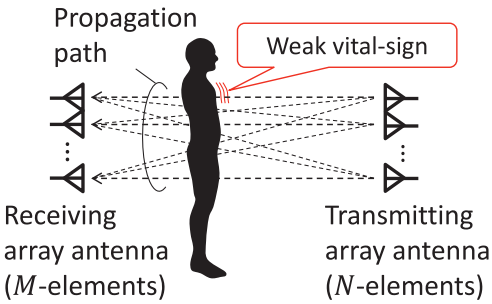


Fig. 1. Concept of bio-sensing using MIMO

Figure 1 is a conceptual sketch of a biosensor that uses microwaves. The human body affects the propagation channel between multiple transmitting and receiving antennas, and the channel fluctuates corresponding to the biological activity , which is called a vital sign. The microwave sensor that we propose detects vital signs related to the small movement of human body due to the breathing and heartbeat. Figure 2 shows an example of the temporal change in the signal observed by the microwave sensor. While slight fluctuations are observed due to environmental noise even without a person, the signal is mostly stable. On the other hand, in the case with a person present in the area, the signal shows fluctuations even when the subject remains stationary. This shows that the microwave sensor can easily detect a person's presence. However, this is not enough to detect respiration or heartbeat. Vital sign components need to be separated from the unnecessary body movements. Our research uses beamforming technique using multiple antennas, where these different components are successfully separated. In particular, heart rate can be estimated within 5% error.

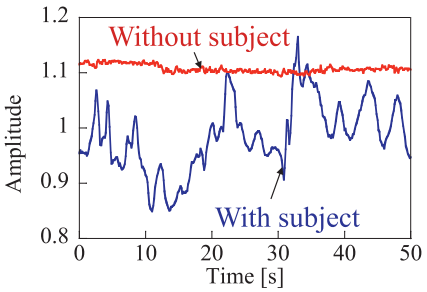


Fig.2 Temporal transition of received signal

Our method also successfully estimates the positions of multiple persons. Figure 3 shows the principle of positioning a target. The target is positioned at the angle at θ_R, θ_T from the transmitting and receiving array antennas, respectively. The directions of departure and arrival, θ_R and θ_T, are estimated from the signal phase difference among the antenna elements in the array antennas at both transmitter and receiver sides.

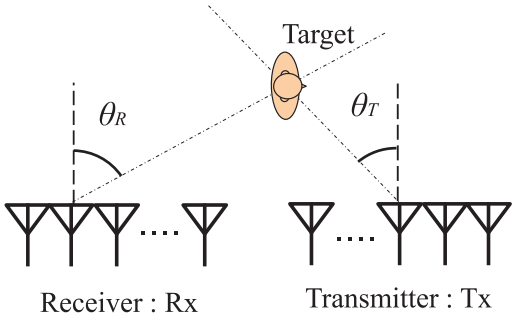
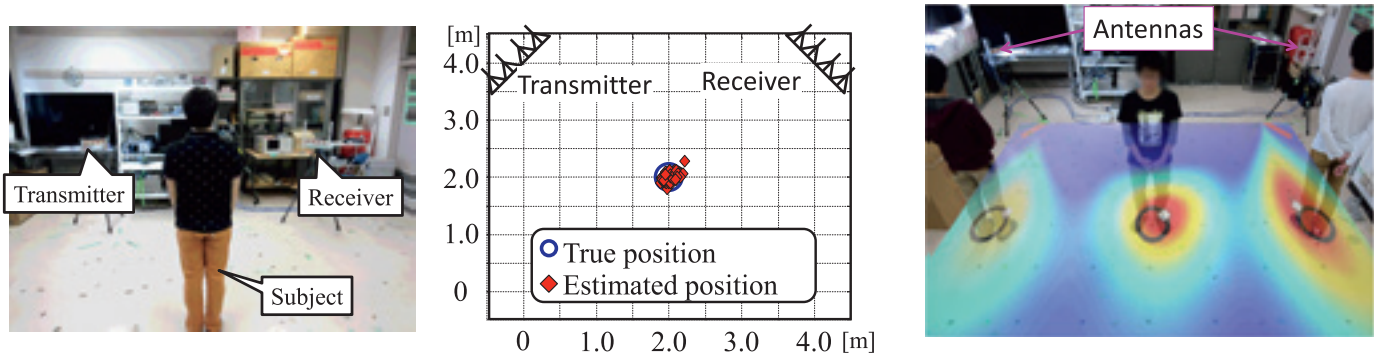


Fig.3 Positioning target using MIMO radar

This allows calculation of the target location by triangulation technique. In addition, the radio waves normally undergo multiple reflections during its propagation in indoor environment. In this case, the wave is not only reflect off the person but also the wall or furniture, and this prevents the detection of reflected waves via the person. The radar used in our research allows the analysis of the signal coming from the person by using the Doppler-shifted components due to respiration and heartbeat. Thus, the position of the person can be identified by observing vital signs.
Figure 4 shows the experimental result of the human body localization. A transmitting array antenna and a receiving array antenna are arranged in an indoor environment, where both the transmitting and receiving array antennas have four elements. The operation frequency was 2.4GHz band, which is almost same band of wireless LAN. Figure 4 (a) shows the experiment with one subject who is standing still in the center of the room. Figure 4 (b) is the result of the experiment. ○ indicates the actual position of the person and ◇ indicates the position of the person that was estimated with the waves. The average accuracy of the position was 10 cm, which shows the position can be estimated at a sufficiently accurate level. Figure 4 (c) is a overlaid image of detection results for three-target case. This shows that the positions of the multiple subjects are successfully detected.
Moreover, our latest challenge includes the identification of the posture and behavior of the person as well as biometrics. We believe the sensing humans using radio waves offers an unconscious and stress-free monitoring, which will bring a significant change in our life.



(a) Overview (b) Single subject (c) Three subjects

Fig.4 Experiment of localizing human target using MIMO arrays

What can we do with it?

<Changing our life with invisible radio waves>

In Japan, the population is aging, and the birthrate is falling. We are now in a super aging society. By 2025, the elderly population living alone is expected to exceed 7 million and elderly care and lonely death are serious social problems. There are various technologies to monitor them in order to address this problem. Microwave radars are one of the powerful solution for it. Unlike the systems using camera, the microwave radar causes fewer privacy violation. It is also a better option than infra-red as it is less likely to be affected by walls or other obstacles. Also, vital signs can be observed all the time without any contact, that will save the elderly from unexpected accidents and significantly alleviates the care-giver's concerns.

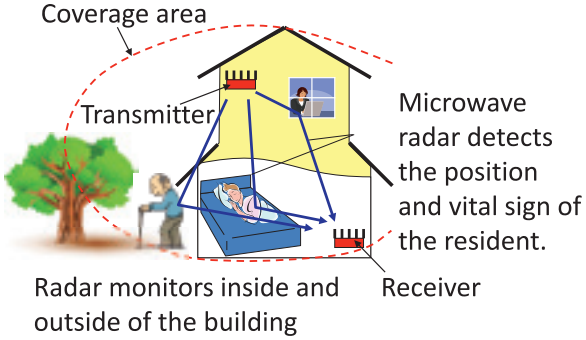


Fig.5 Monitoring system using microwave

Prof. Tatsuya Takeguchi:
Science and Engineering - Catalyst/Resource Chemical Process

Development of the Catalyst for Highly Efficient Fuel Cells toward the Era of Hydrogen

What kind of research?

<Successful development of a high performance nano-particle catalyst for fuel cells>

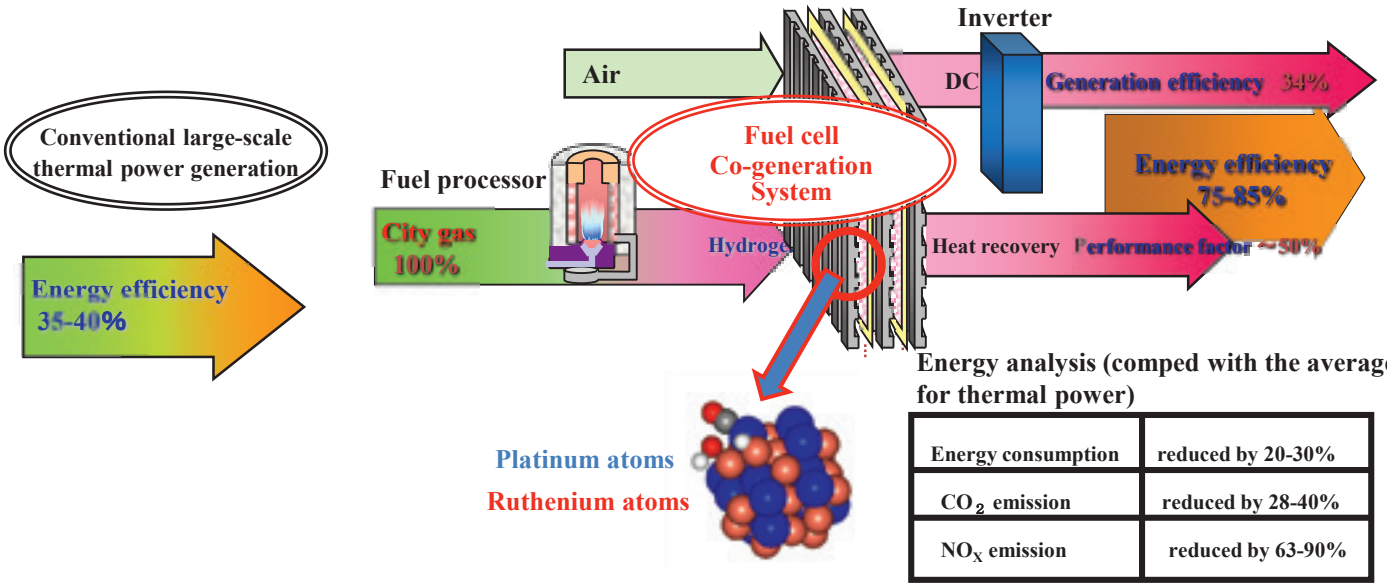
A highly efficient nano-particle platinum-ruthenium alloy catalyst is successfully synthesized in our research. On our developed method, atoms were completely mixed with each other and the number of Pt-Ru bonding reached the theoretical maximum. For a catalyst that can be utilized for ENE-FARM, or residential polymer electrolyte fuel cell (PEFC), the alloy catalyst (that attained the maximum entropy) shows the highest possible resistance to CO poisoning among the currently available highly active catalysts. An alloy catalyst is capable of generating power highly efficiently, enhances efficient use of platinum that has a limited resource reserve, and contributes to the effective use of the platinum resources.

Prof. Tatsuya Takeguchi (Faculty of Science and Engineering)

What is it useful for?

<Reduction in CO_2 emission>

ENE-FARM uses city gas as raw fuel to produce reformed gas containing hydrogen through steam reforming. However, when CO is produced and the reformed gas containing CO is supplied as it is to PEFC in ENE-FARM for operation, the Pt catalyst for the anode is poisoned by CO absorption to bring the operation to a halt. Thus, CO needs to be oxidized and removed, and the extra equipment for that purpose leads to the expensive operational nature of the ENE-FARM. Lowering costs and introducing user-friendly technologies are required in order to ensure its wider adoption.
The high performance nano-particles catalyst that we developed helps lower costs involved in the ENE-FARM and realizes a wider adoption of it, and achieves energy-saving operation. It will create a co-generation system with 34% power generation efficiency and 85% total efficiency leading to a reduction of CO_2 emissions by over 30%. It is also an eco-friendly environmental technology by significantly reducing NO_x emission.

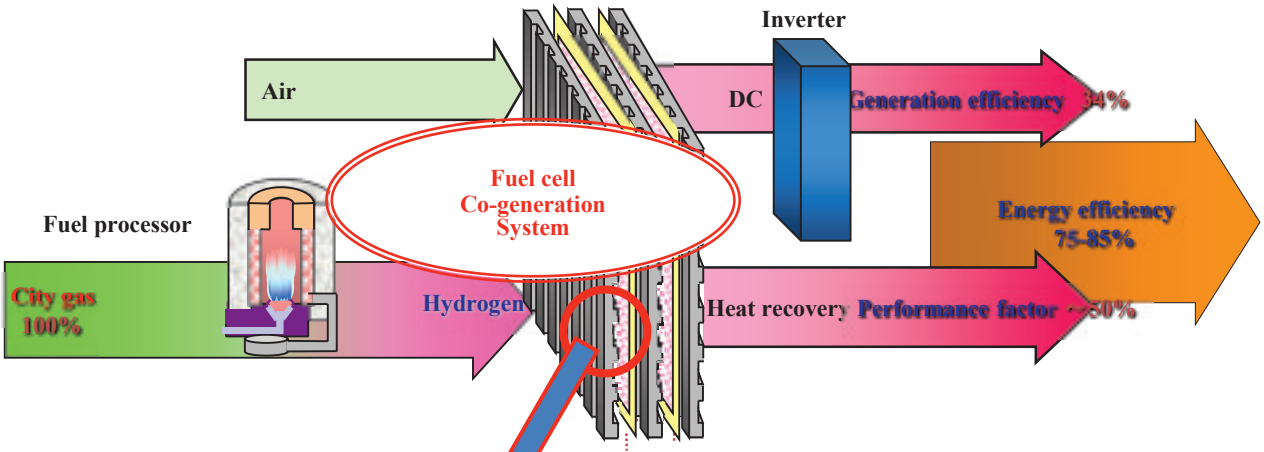


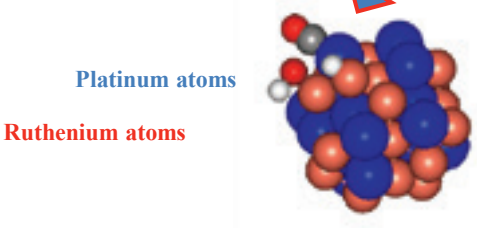
Energy analysis (comped with the average for thermal power)

Energy consumption	reduced by 20-30%
CO_2 emission	reduced by 28-40%
NO_X emission	reduced by 63-90%

High performance fuel cell catalyst that is planned for mass production in Iwate

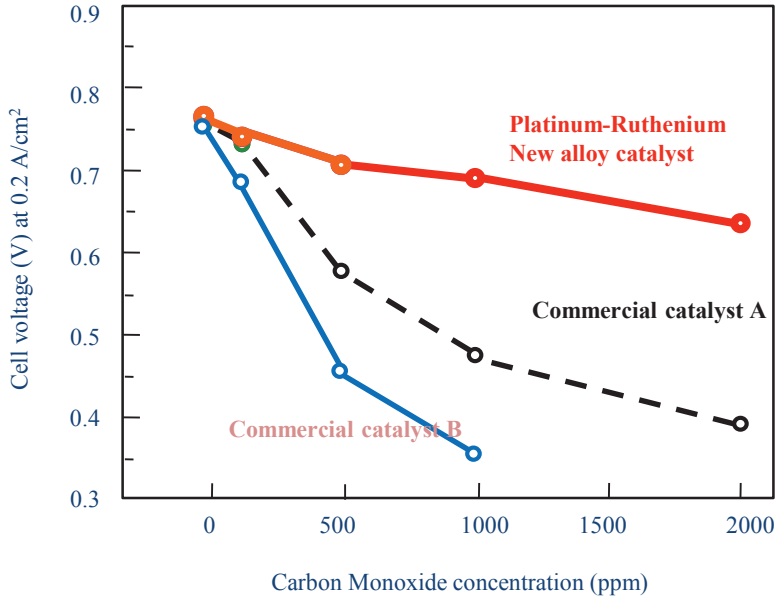
Completely mixed nano-particle platinum-ruthenium alloy catalyst





Energy analysis (compared with the average for thermal power)

Energy consumption	reduced by 20-30%
CO_2 emission	reduced by 28-40%
NO_X emission	reduced by 63-90%



Prof. Hiroshi Tomita:
Science and Engineering - Ophthalmology

Vision Restoration of Blind Rats by Transducing Modified Volvox Channelrhodopsin-1 Genes

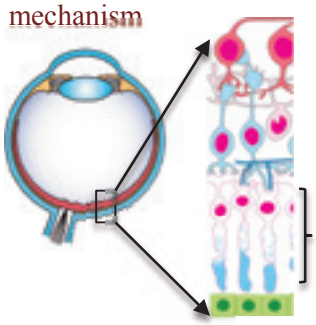
What kind of research?

<Developed a photosensitive ion channel protein that responds to optical wavelengths>

Generally speaking, over 80% of external information is obtained through vision. So, when people loses their vision, their lives changes drastically. We successfully invented a photoressensitive protein (mVChR1) by modifying a photosensitive ion channel gene possessed by the green algae, volvox. Also, by transducing a gene carried by the adeno-associated virus (AAV-mVChR1) to the retinal cells of blind rats, we developed a gene therapy technology to restore their vision.

Prof. Hiroshi Tomita
(Faculty of Science and Engineering)

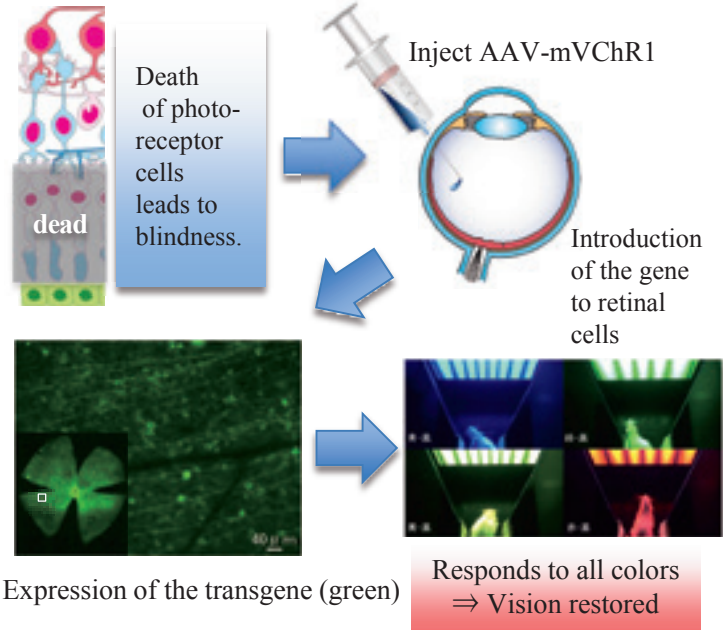
● Structure of the retina and the photoreceptive mechanism



Cells that change information into electric signals (Retinal ganglion cells)
Analyzing cells

Photoreceptor cells

Visual information from outside is projected onto the retina after its focus is adjusted through the cornea on the surface of the eyes and the lens. The retina has cells to receive light from outside, cells to analyze the light information, and cells that change it to an electric signal (retinal ganglion cells). The information is fianally sent to the brain through the optic nerve as an electric signal to create an image.



What is it useful for?

<Vision restoration for blind people>

Currently there is no treatment for the restoration of vision once it is lost. Treatments like “retinal prosthesis” that places implants on the eye or transplants of photoreceptor cells made from iPS cells are currently under discussion and in the research phase. Both of these treatments require complex surgical procedures such as placing implants or transplanting cells, and thus a high level of technology is necessary. On the other hand, our method is very simple as it only involves the injection of a virus solution into the eyes.
The development is underway at a pharmaceutical company with a view to apply it to humans several years in the future.

"Vision Restoration Technologies" (Faculty of Science and Engineering: Hiroshi Tomita)

Theme/background: Method of Vision Restoration with Gene Therapy

▲ Once vision is lost, there is no treatment to restore it.
▲ Blind people's Quality of Life (repeated accidents such as falling from the platform at the station have become a social problem)
▲ Increased medical costs (including the burden of caring for them) and social loss due to a the reduced laborforce (as much as 8.8 trillion yen according to the Japan Ophthalmologists Association 2009)

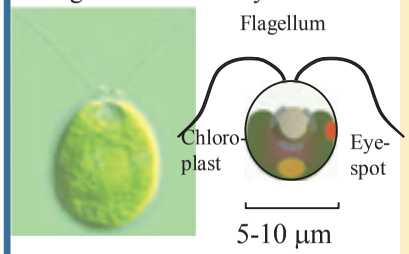
Requires a treatment that restores vision on a fundamental level.

Iwate University seeds, "Application of Optogenetics to Vision Restoration" as a key to treatment!

What is vision restoration using optogenetics?

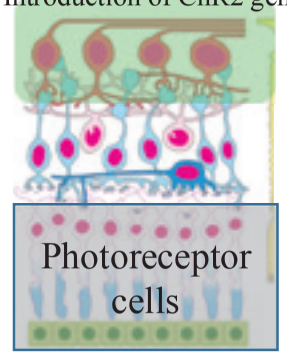
Utilization of photoactivated genes from green algae

Single-celled Chlamydomonas



○ Channelrhodopsins-2 (ChR2) isolated from Chlamydomonas allows positive ions to pass through cells along with photoreception. By allowing this to be expressed in nerve cells, the process from photoreception to a neural pulse sequence was enabled⇒ Vision restoration

Introduction of ChR2 genes



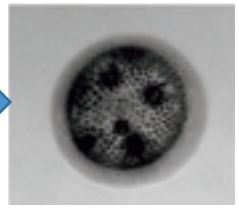
The world's first treatment that utilized genes derived from a heterogeneous organism and restores vision enough to visually recognize the full range of visible light from a state of blindness

Introduce ChR2 genes to the remaining cells of retina that lost vision due to retinal cells

Significance of this technology

- **It is highly effective as seen in the improvement of resolution compared to other existing technologies (retinal prosthesis) and the time required for surgery is shorter (one injection leads to recovery of vision).**
- **Iwate University is the only group (vision restoration treatment using optogenetics)**
- **Treatment of pigmentary degeneration of the retina is licensed out and is in preparation for clinical trial at a company**
- **Potential application to treatments of various other conditions in addition to blindness**

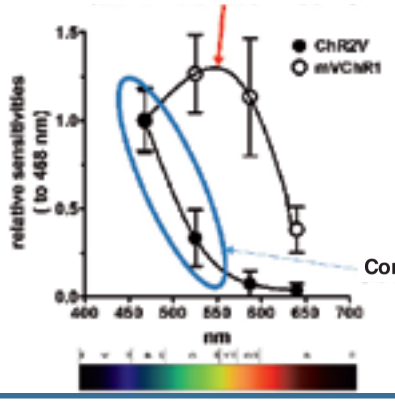
Successfully developed the protein (mVChR1) that is susceptible to multiple wavelengths



Modified Volvox Channelrhodopsin-1 Gene (VChR1)

Responds to wider wavelengths compared to ChR2

The gene we developed (has wide-ranging wavelength characteristics)



Can create vision enough to see the full range of visible light with a single gene.

Associate Prof. Kyu Yoshimori:
Science and Engineering - Optics/Photon Science

Digital Holographic Spectrometry

What kind of research?

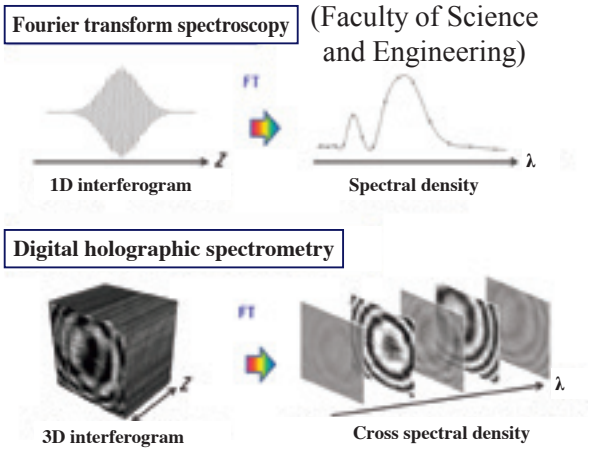
Associate Prof.
Kyu Yoshimori
(Faculty of Science
and Engineering)

<3D images and a continuous spectrum are obtained at the same time like a camera shot>

It is a technology that measures 3D images of a set of spectral components by interferometric measurement of light waves from polychromatic objects illuminated by natural light and applying signal processing. In order to realize this passive 3D imaging that doesn't require special light sources for measured objeds, we came up with the two-wavefront folding interferometer and successfully confirmed its principle and obtained spectral 3D images.

<Principle of digital holographic spectrometry>

The principle of digital holographic spectrometry is a fusion of the Fourier transform spectroscopy and incoherent holography. The observable measured by the Fourier transform spectroscopy is a 1D interferogram of incident light along the optic axis of the Michelson Interferometer. By applying the Fourier transform to this, a series of spectral density data of an object can be found. Let's think about a situation where this 1D interferogram is replaced with a 3D volume interferogram on which the wave front information and spectrum information of the light propagated from the object is recorded such as the volume-type Lippmann hologram. Here, application of the Fourier transform to the thickness of the volume interferogram will render complex incoherent hologram related to the numerous wavenumber components of the light propagated from the object all at once.

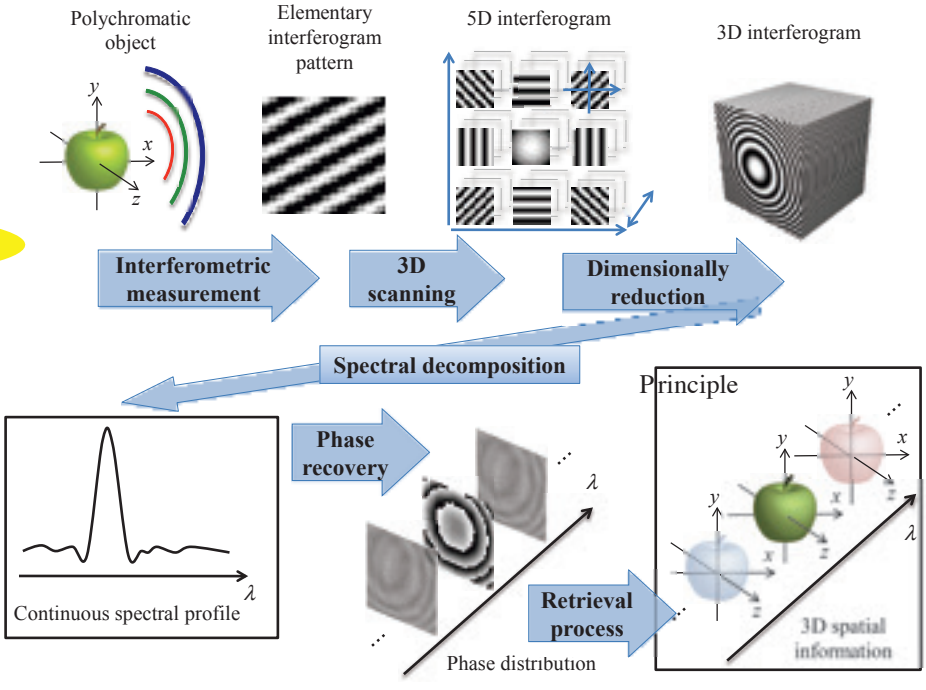


Principle of digital holographic spectrometry

These complex holograms will help reconstruct a number of 3D spectral images and continuous spectrum data related to polychromatic objects.

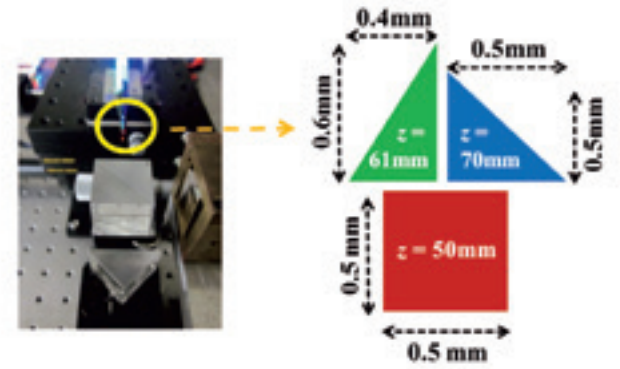
What is it useful for?

-3D spectral camera without lens
-3D fluorescence spectral imaging of body tissue labeled with several fluorescent proteins when combined with a microscope
-Unlabeled 3D live imaging of biological proteins based on their spectral signature

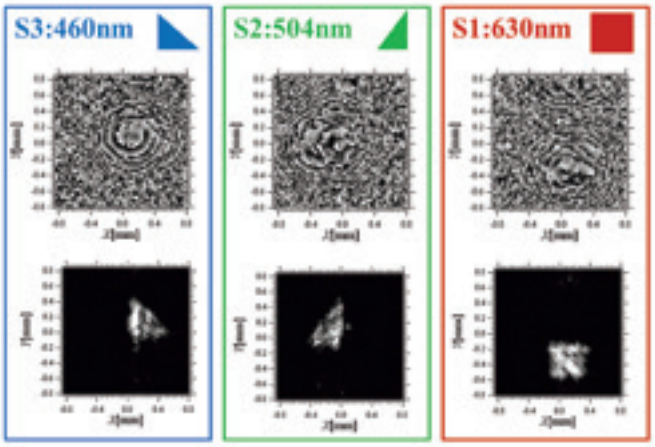


The process of measurement and signal processing

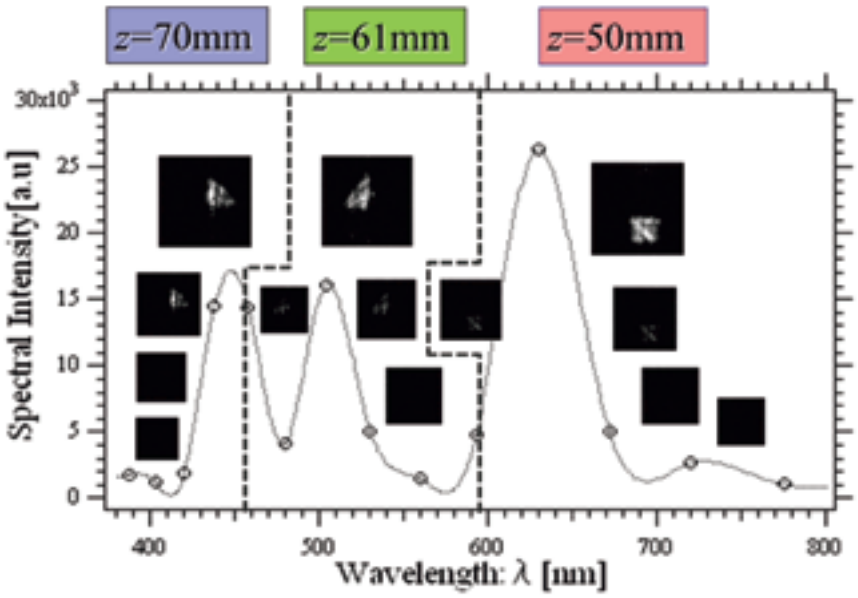
The world's first 3D spectral imaging technology launched at Iwate University



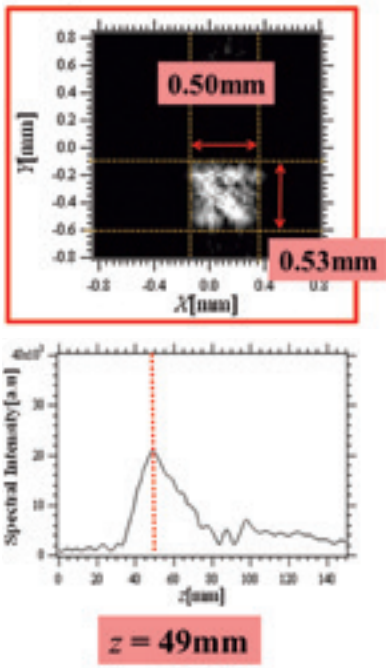
Measurement experiment of a 3D polychromatic object



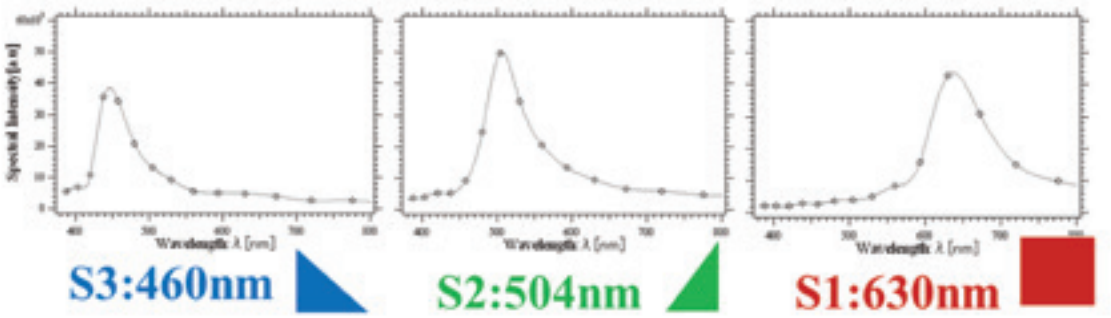
Hologram of the polychromatic object and the reconstructed in-focus image



Continuous spectrum of a polychromatic object and multiple spectral in-focus images



3D imaging characteristics



Continuous spectrum of the surface of an object can be obtained independently

Associate Prof. Yukio Kawamura / Prof. Matsuo Uemura:
Agriculture - Plant Molecular Physiology

Elucidating Mechanism of Receiving and Responding to Signals in Plants in Cold Environments

What kind of research?

<Elucidation of mechanisms of plant survival under low-temperature and freezing conditions>

[Background]

In natural environments, plants are exposed to various stress factors, covering a wide range of conditions such as temperature, humidity, light, soil composition, and water conditions. These factors influence plant performance continuosly. Although these stress factors have been constantly threatening the life of plants, the plants also have developed a mechanism to sense and communicate, as well as respond and adapt to these factors throughout the long history of their evolution. Among such stress factors, our laboratory has paid particular attention to low temperature.

Prof. Matsuo Uemura (Faculty of Agriculture)

Associate Prof. Yukio Kawamura (Faculty of Agriculture)

[Research content]

How do wintering plants recognize the cold season (mechanism of cold acclimation)?

Plants recognize the changes in air temperature and length of the day when fall arrives and prepare themselves for the cold season. We are trying to find out how plants sense the low temperatures and light, and how such information is transduced to their cells.

How do wintering plants develop tolerance to freezing conditions (mechanism of freezing tolerance)?

We know that the main target of freeze-induced damage is the plasma membrane. Thus, we focused on the plasma membrane to study the changes in the membrane compositions under cold conditions from a physiological perspective, and understand how freezing tolerance increases from a view point of the involvement of the plasma membrane by directly observing it in cold temperatures.

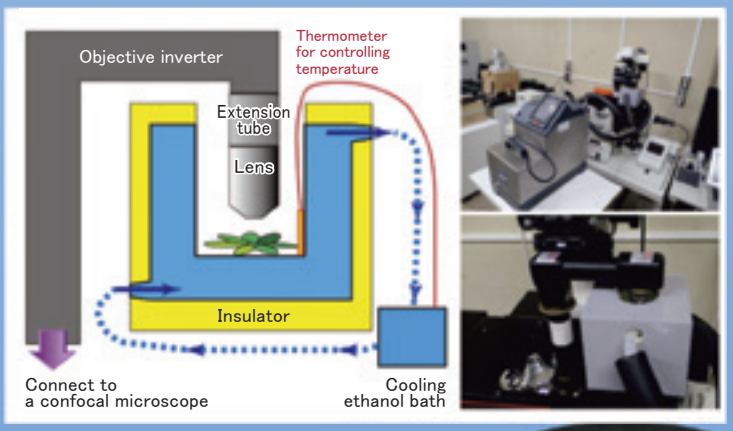
Plants in cold regions can overwinter freezing temperatures

What is it useful for?

There are various wintering herbaceous plants, including winter rye and wheat that are important for agriculture. On the other hand, in the global warming era, the freezing tolerance does not fully increase in the fall and an unexpected cold spell could seriously damage plants with low temperature and frost. In addition, the same risk can be expected during early spring when their tolerance to low temperature weakens (deacclimation process). For these reasons, our research to elucidate the mechanism of cold-acclimation and deacclimation will provide the basic data for its application and the foundation for stable supply of agricultural products.

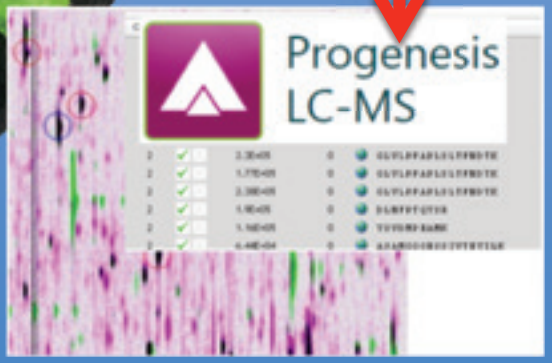
An imaging system which allows us to observe living cells under low-temperature and freezing conditions has been developed in Iwate University

High spatiotemporal resolution analysis of low-temperature and freezing tolerance mechanism in the process of cold acclimation and deacclimation



A new imaging system that allows us to observe intact plant under low-temperature and freezing conditions

Identification and quantitative analysis of micro amounts of protein



Proteome of temperature stimuli responding variant

Realtime expression analysis in an environment with controlled temperature and light

Development of the low temperature stimuli/response map with high spatiotemporal resolution as a foundation of basic and applied studies

Associate Prof. Rahman Abidur:
Agriculture - Plant Molecular Physiology

Molecular and cellular mechanisms of plant growth and development under temperature stress

What kind of research?

<Developing crops resistant to temperature stress>

Associate Prof. Rahman Abidur
(Faculty of Agriculture)

In the present world there is a huge imbalance between population growth and food production. By 2050, world population will increase by 34% to 9.1 billion, whereas potential cultivable land area will increase only 5% (FAO; www. fao.org). In addition, crops susceptibility to various abiotic stresses, such as temperature stress, make it a difficult task to maintaining the crop production. For instance, low temperature stress caused financial damage totaling 158 billion yen in fiscal year 2009 (Rahman, 2012). Global warming also causes serious damage to the crop productivity. The combined annual loss rendered by high temperature is $5 billion (Lobell and Field, 2007).

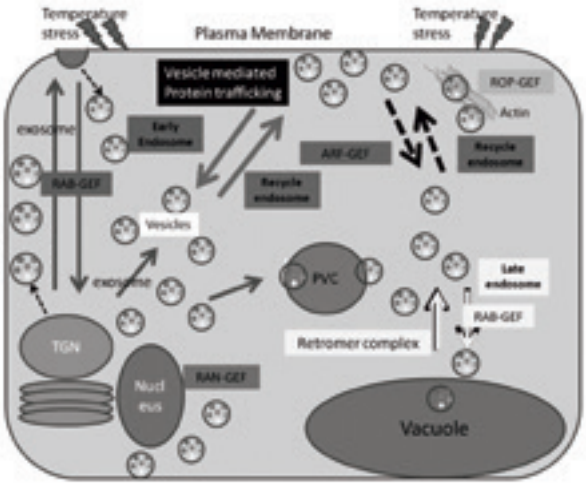
Because of the current climatic changes, temperature stress will have a huge impact in future crop production. Our research aims to produce new breeds of crops that can tolerate temperature stress by understanding the molecular mechanism of temperature stress regulation pathway in plant.

Genetic screening of model plants under temperature stress → Discovery of the genes regulating temperature response → Manipulating the expression of discovered genes in crop species → Developing crop cultivar tolerant to temperature stress

Why it is useful?

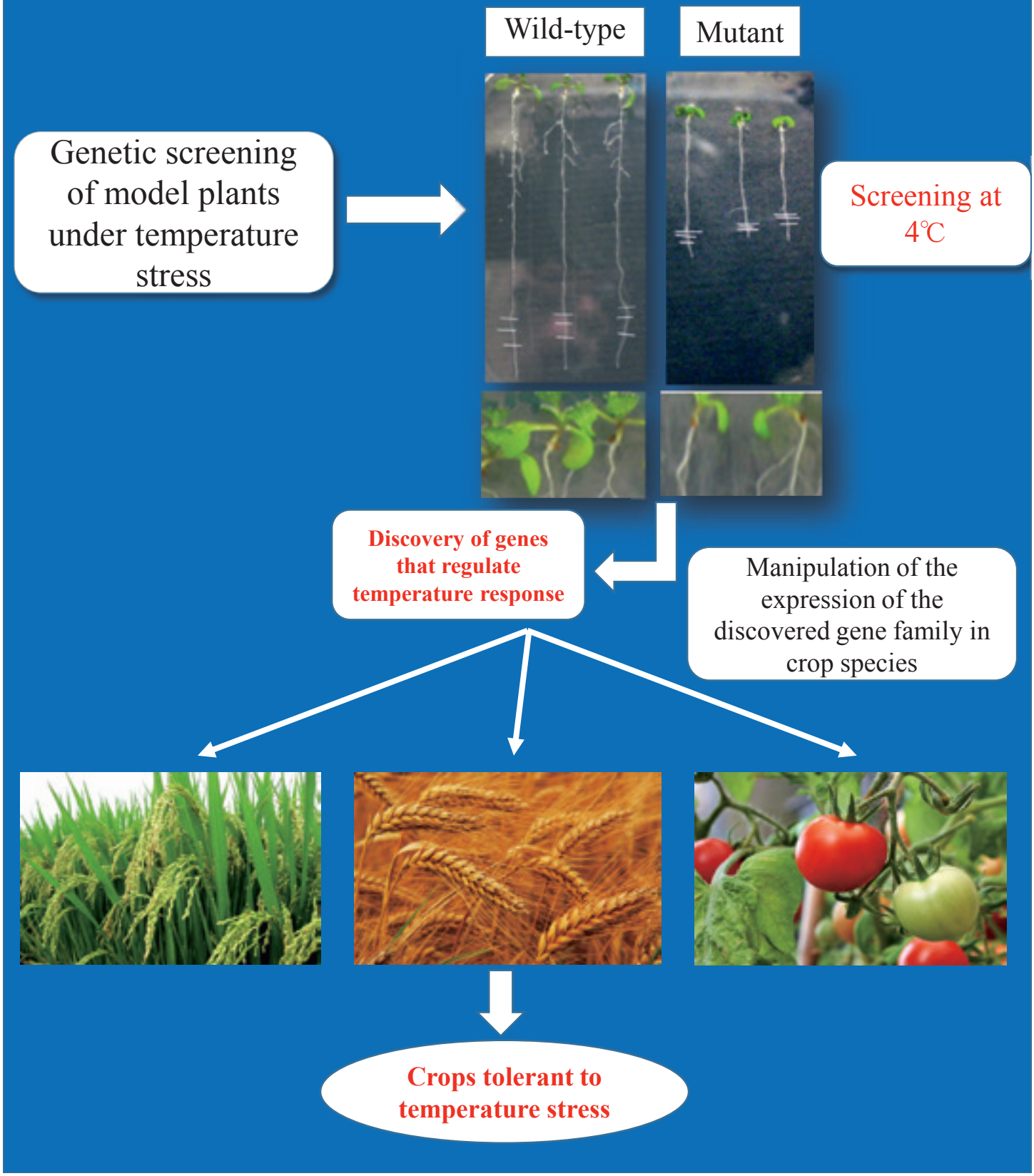
<Stabilize food security by increasing crop production>

Any stress response results from a complex interaction of genes that eventually controls the expression of the number of proteins. Understanding this basic mechanism is crucial for improving the specific response to stress, and temperature stress is no exception.
Our recent research results using Arabidopsis as a model plant revealed that the temperature stress response is closely linked to the intracellular protein trafficking. This protein trafficking plays an essential role in cell viability and plant development. We also identified a gene family, guanine exchange factor (GEF) as a master regulator of temperature response. GEFs are the upstream regulators of several small GTPases and ARF family proteins that are essential for vesicular transport.



This protein family is highly conserved in all living species ranging from humans to plants. Currently, we are trying to elucidate the role of this gene family in regulating the temperature stress in crop species. The next step will be to manipulate the expression of this gene family in crop species in order to increase resistance to high and low temperature stresses. World food production is now threatened by climate change and other global problems. Temperature stress limits the crop productivity all over the world and threatens the food security. Successful development of new temperature stress tolerant crop species will be an important contribution to win this battle and is expected to help maintaining stable food production in the future.

Molecular and cellular mechanisms of plant growth and development under temperature stress



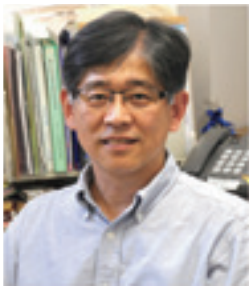
Prof. Nobuyuki Yoshikawa:
Agriculture - Horticulture

Development of Technologies for promoting the Flowering of Fruit Trees using a Virus Vector

What kind of research?

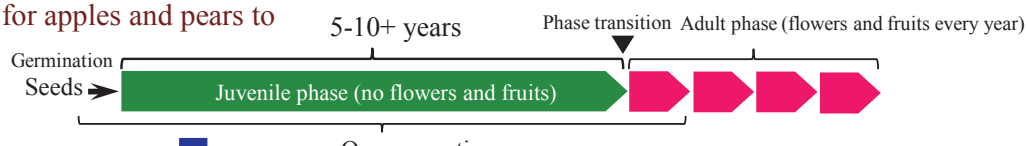
<Successfully developed a technology to reduce one generation of apples/pears to one year>

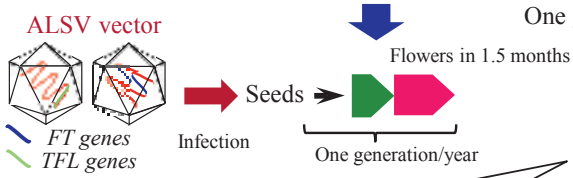
As the Japanese proverb, "the peach and the chestnut fruit in three years and the persimmon fruits in eight years" suggests, it takes several years for seeds to germinate, flower and produce fruits. Thus, it usually takes over ten years to several decades to improve the cultivos of fruit trees. By combining a harmless virus isolated from apples (Apple latent spherical virus, ALSV) and florigen (*FT*) genes that facilitates the flowering of plants, we developed a technology to reduce the time required for the flowering of apple seedlings down to 1-2 months after germination.



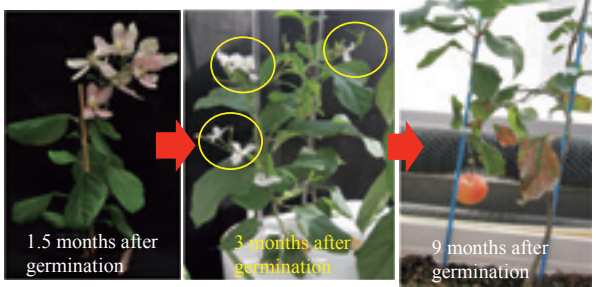
Prof. Nobuyuki Yoshikawa
(Faculty of Agriculture)

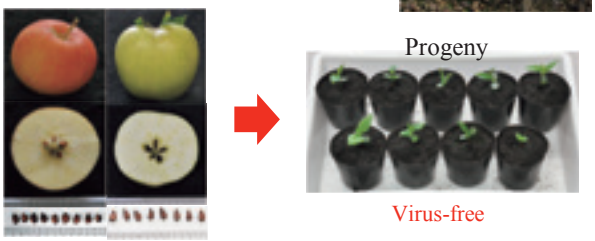
● Period required for apples and pears to flower





When apple seeds are infected with the ALSV vector [designed to express *FT* genes and suppress *TFL* that delays flowering] right after germination, they develop flowers after 1.5 months and consecutively flower after that. Once they are pollenated, they produce seeds. The 5-10+ year cycle from germination to flowering is reduced to less than a year. Progeny seedlings originating from the seeds are free of ALSV.

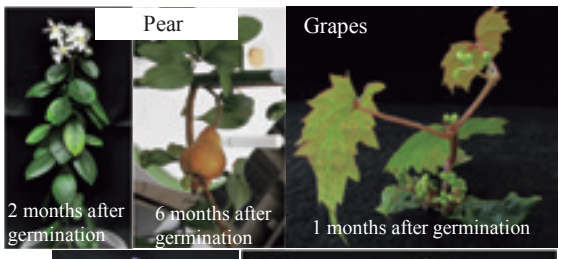




What is it useful for?

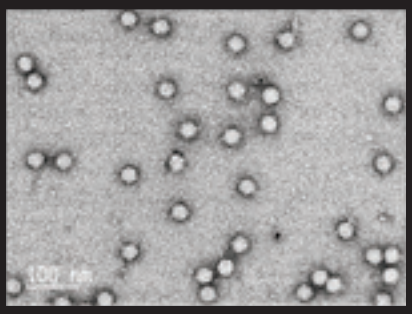
<Significantly reduce the time required for growing new cultivos of fruit trees and flowering plants>

With the progression of global warming, fruit trees face serious high temperature injuries such as poor coloring. Growing new breeds is necessary to respond to this problem. New breeds of fruit trees and flowering plants are developed by crossing different breeds and selecting better types but it takes ten years to several decades to create one. The primary reason for this is the period required for flowering and producing fruits. By introducing the ALSV vector technology, the period can be reduced to less than a year for one generation of fruit trees including apple, pear, grape, or orange trees and to 2-4 months for gentian to flower while it normally takes 2-3 years. Now we can expect the faster development of new cultivos of agricultural products using this technology.



The world's first new plant breeding technology
launched at Iwate University

Technology for Facilitating the Flowering of Fruit Trees Using a Virus Vector



ALSV vector

Early-flowering phenotype of an apple
Seeding at 1.5 months after germination

A young apple seedling produced fruits 11 months after germination

Prof. Kenichi Nishiyama:
Agriculture - Applied Biochemistry

Research on the Structure and Functions of a "Glycolipozye," MPIase as a Catalyst for Membrane Protein Integration in Escherichia Coli

What kind of research?

<Studying the mechanism in which membrane protein is integrated into biological membrane>

Prof. Kenichi Nishiyama
(Faculty of Agriculture)

- The mechanism in which membrane protein is integrated into membrane is conserved in all organisms (Figure 1). We find out how the mechanism works using Escherichia coli, the most frequently used model organism in microbiology.
- We successfully demonstrated the reaction of membrane protein integration in vitro.
- We discovered that membrane protein integration requires a glycolipid called MPIase (Membrane Protein Integrase) that we named and reached a conclusion on its structure (Figure 2).

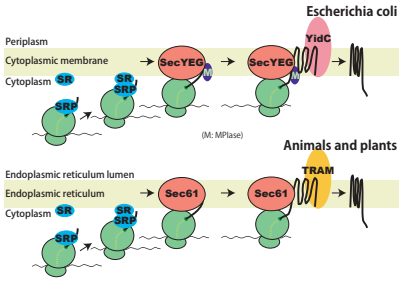


Figure 1. Mechanism of membrane protein integration conserved in all organisms

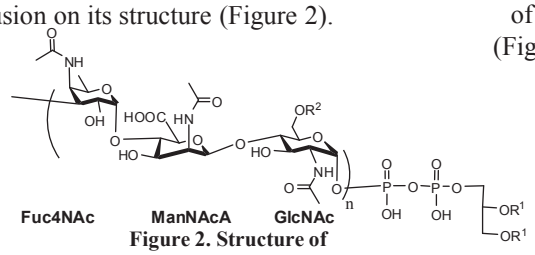


Figure 2. Structure of MPIase

- We found out that MPIase changes the dimeric structure of the protein conducting channel SecYEG significantly (Figure 3).

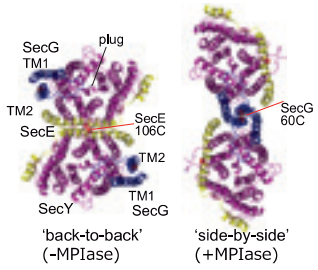


Figure 3. Change in dimeric structure of SecYEG by MPIase

- We identified a part of the biosynthetic enzyme of MPIase. This is a gene conserved in all organisms.
- As MPIase is a catalyst for membrane protein integration, we proposed a concept of Glycolipozyme for the first time in the world.

What is it useful for?

<Can elucidate the specific mechanism of membrane protein integration>

Membrane protein integration is one of the most important life phenomena that is universal to all organisms. Even if it cannot be applied in a visible way, the mechanism will create a wide potetial of applications once it is clear. The concept of glycolipozyme is also innovative as it would change the conventional approach to glycolipid.

<Can be applied to the development of cold-tolerant plants>

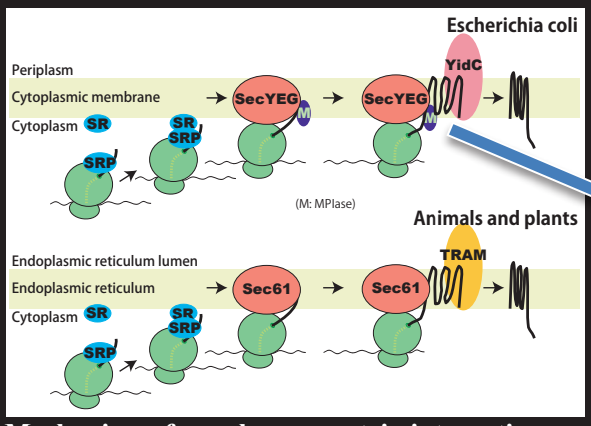
Membrane protein integration is slowed down at low temperatures by nature because the fluidity of biological membrane is significantly reduced under such conditions. On ther other hand, the expression level of MPIase increases significantly at low temperatures. This means that MPIase suppresses part of the inhibition of membrane integration at low temperatures. Some experiments showed that MPIase-like activity was detected in higher animals or plants. Also, part of the biosynthetic genes of MPIase are conserved in all organisms. Thus, modifying an MPIase homologue in plants will allow the development of cold-tolerant plants.

<Can be utilized for synthesis, purification, and function analysis of membrane protein>

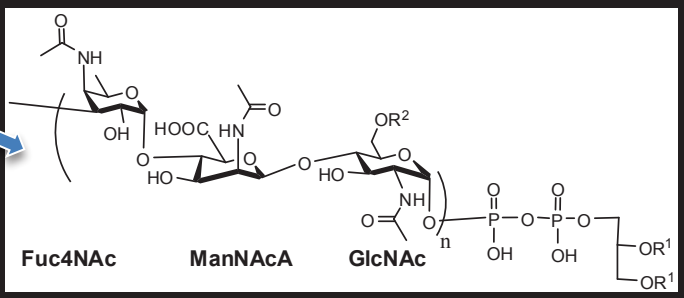
Genome projects revealed the existence of membrane proteins with many unknown functions, which are now drawing attention as the target of drug development. On the other hand, membrane protein is very hard to handle due to its highly hydrophobic nature. Once the mechanism of membrane protein integration is clear, it will help build a mass production system of membrane protein and also allows for the synthesis of membrane protein in vitro.

The first discovery in the world created at Iwate University.

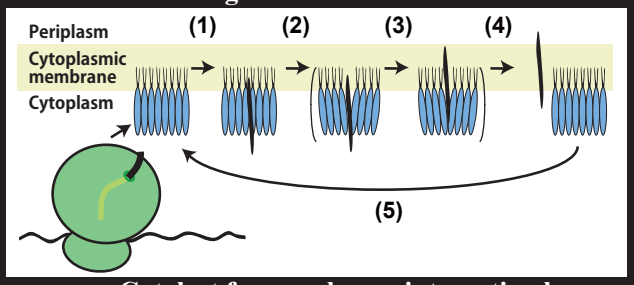
Discovery of a Glycolipozyme, MPIase (*M*embrane *P*rotein *I*nteg*rase*)



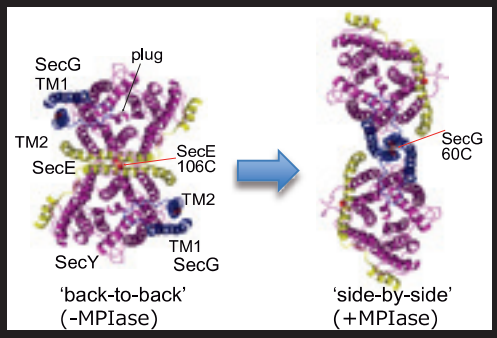
Mechanism of membrane protein integration conserved in all organisms



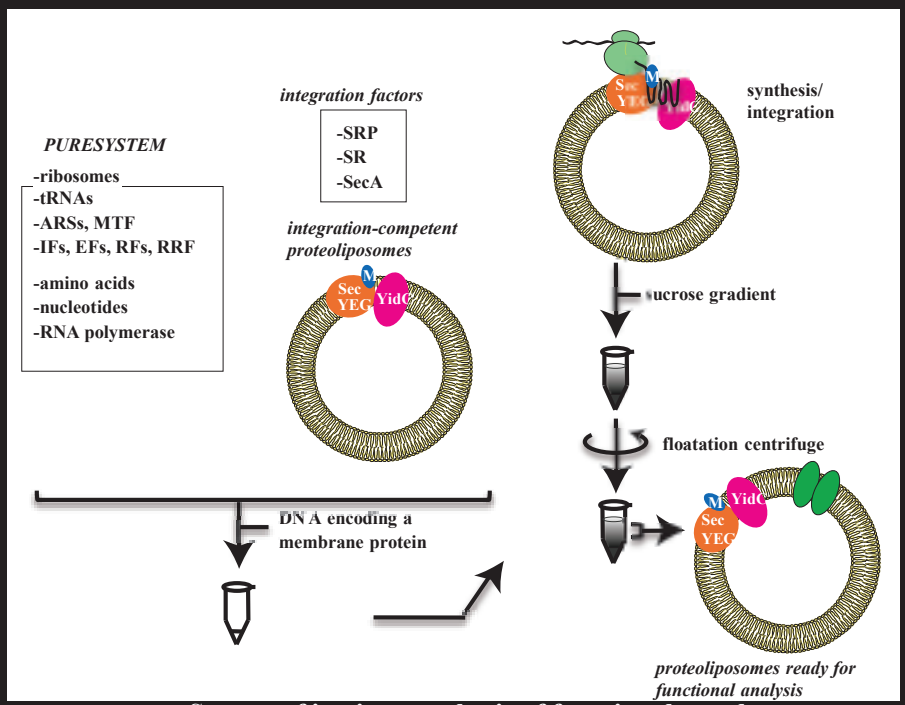
Structure of MPIase



Catalyst for membrane integration by MPIase



Change in dimeric structure of SecYEG by MPIase



System of in vitro synthesis of functional membrane protein

Prof. Ken Sawai:
Agriculture - Animal Production Science

Research on Gene Expression in Bovine Embryos Derived from Somatic Cell Nuclear Transfer and Its Regulatory Mechanism

What kind of research?

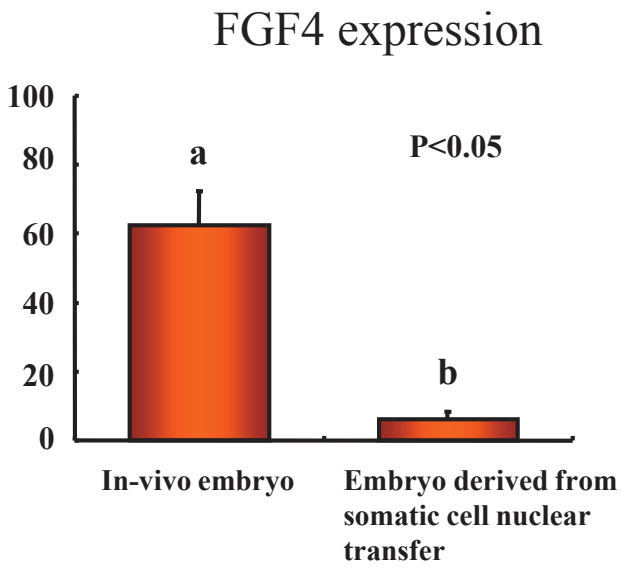
Prof. Ken Sawai
(Faculty of Agriculture)

<A part of the cause for anomalies in bovine embryos derived from somatic cell nuclear transfer was elucidated>

Since the birth of Dolly, the sheep cloned from an somatic cell in 1996, cloned animals have been created using somatic cell nuclear transfer in many animal species. Further research has been done on creating clones from somatic cell nuclear transfer in order to increase the number of improved varieties or test fertile bulls.

Bovine embryos derived from somatic cell nuclear transfer exhibit anomalies that seem to be caused by the gene expression regulatory mechanism (epigenetics) including lower fertility and frequent miscarriage. We identified anomalies in the expression of the transcriptional factor such as OCT-4 and the growth factor such as FGF4 that play an important role in the embryo development in bovine embryos derived from somatic cell nuclear transfer and found out that the anomalies are attributed to hypermethylation and deacetylation of that bovine embryo.

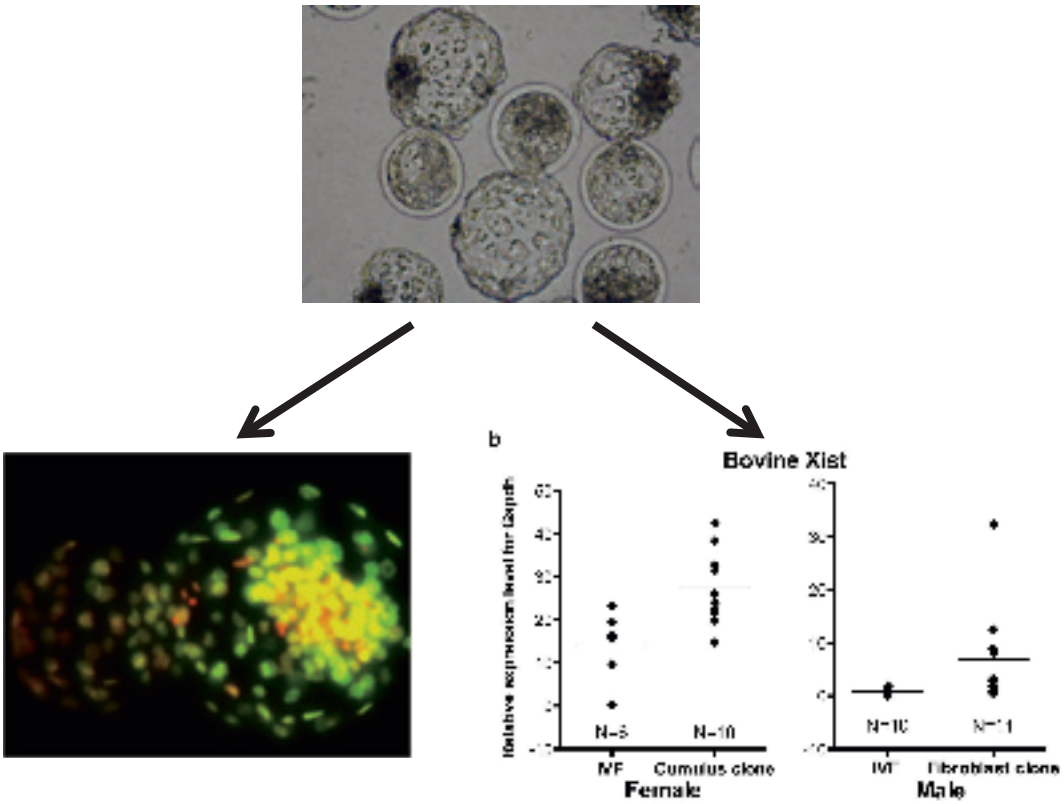
We also found that bovine embryos derived from somatic cell nuclear transfer show anomalies in the expression of Xist that regulates inactivation of X chromosomes as in the case of mouse embryos derived from somatic cell nuclear transfer, and that suppression of the expression of Xist genes with RNA interference increases the rate of development to the blastocyst stage significantly.



What is it useful for?

Elucidating the cause of anomalies in bovine embryos derived from somatic cell nuclear transfer will improve cloning technology with somatic cell nuclear transfer. This will allow the efficient development of calves derived from somatic cell nuclear transfer and be useful for the creation of next generation fertile males such as carcass evaluation with calves derived from somatic cell nuclear transfer.

Research on Gene Expression in Bovine Embryos Derived from Somatic Cell Nuclear Transfer and its Regulatory Mechanism



Epigenetics analysis of bovine embryos derived from somatic cell nuclear transfer and its artificial regulation

Effective production of calves derived from somatic cell nuclear transfer

Prof. Keiji Okada:
Agriculture - Veterinary Medicine

Research and Studies on the Impact of Repeated Exposure to Low-Dose Radiation on the Biological Body of Cows Affected by the Fukushima Nuclear Accident

What kind of research?

<The world's first impact assessment on repeated exposure to low-dose radiation in a large mammal>

In the aftermath of the Fukushima nuclear disaster, the area within 20km of the site was designated as a hazard area and entry was restricted. Surviving domestic animals received no veterinary care and it was recommended without any legal ground that they be put down. It is practically impossible to perform a study of the impact of radiation on large mammals. Thus, cows kept by farmers who would not allow them to be put down were valued and studying such cows is a privilege that is only available within Japan, where the disaster occurred.

The research team, made up of veterinary and animal husbandry researchers from Iwate University and Kitasato University was established first and later the members increased to their present level of about 30 including ten Iwate, six Kitasato, and some other university researchers and clinical veterinarians. They manage three stock farms with a total of about 150 cows for research and study.

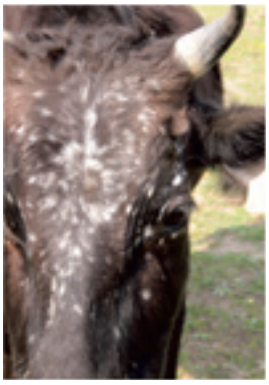
Their primary topics are as follows:

- Distribution and changes in radiation in the rangeland soil, vegetation, and air
- Change in cows' radiation dose
- Understanding the health conditions of cows (thyroid function, leukemia, genetic damage, immune function, etc.)

The government would not recognize the significance of this research as "the initial dose was unknown" and they are struggling to secure fodder that costs over 10 million yen per year. Public organizations still haven't done any research on the cows left in the former hazard area.

Prof. Keiji Okada
(Faculty of Agriculture)

Checkpoint at the entry of the hazard area



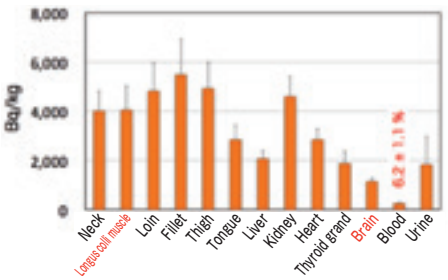
Unexplained white spots
By Jun Sasaki

What is it useful for?

There has been no report of impact assessments of low-dose radiation in large mammals and there is broad uncertainty. The air dose at a farm provided for experiments was at a level that exceeds 30μSv/h as of August 2012 and the cows were contaminated with over 10,000Bq. Other farms had more cows with lower doses than those in the adjoining prefecture though they were put down.

If our research can shed light on the reality and process of exposure, we could extrapolate this knowledge to other areas. We will also be able to prevent unnecessary killing in the future in case of nuclear disaster as nuclear power plants are resuming operations. Our research is underway and will take more time for the results to be published. Thus, I would like to introduce some results that have already been published.

We are updating information on our website and Facebook page, so you are welcome to check that out if you are interested.
http://liffn.jp https://www.facebook.com/liffn.jp

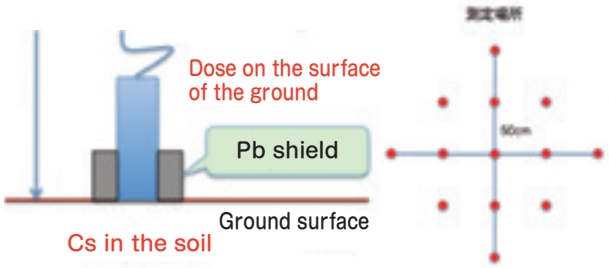


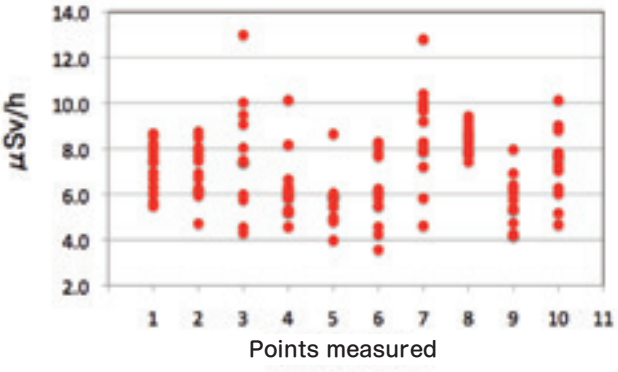
Cesium was often detected in muscles.

Local variation of soil contamination with radioactive cesium at a farm in Fukushima

Itaru Sato[1,*], Masahiro Natsuhori[2], Jun Sasaki[1], Hiroshi Satoh[1], Takahisa Murata[3], Tatsuro Nakamura[3], Kumiko Otani[4] and Keiji Okada[1]

Japanese Journal of Veterinary Research 64(1): 95–99, 2016

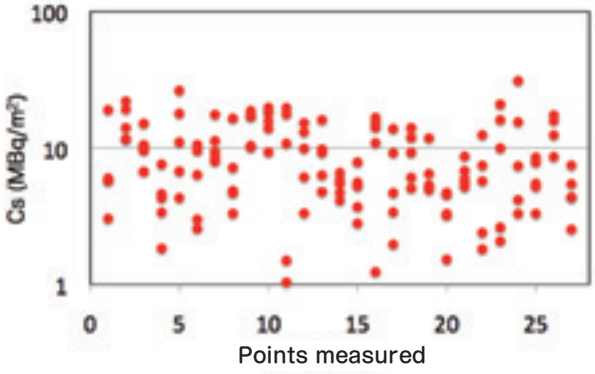




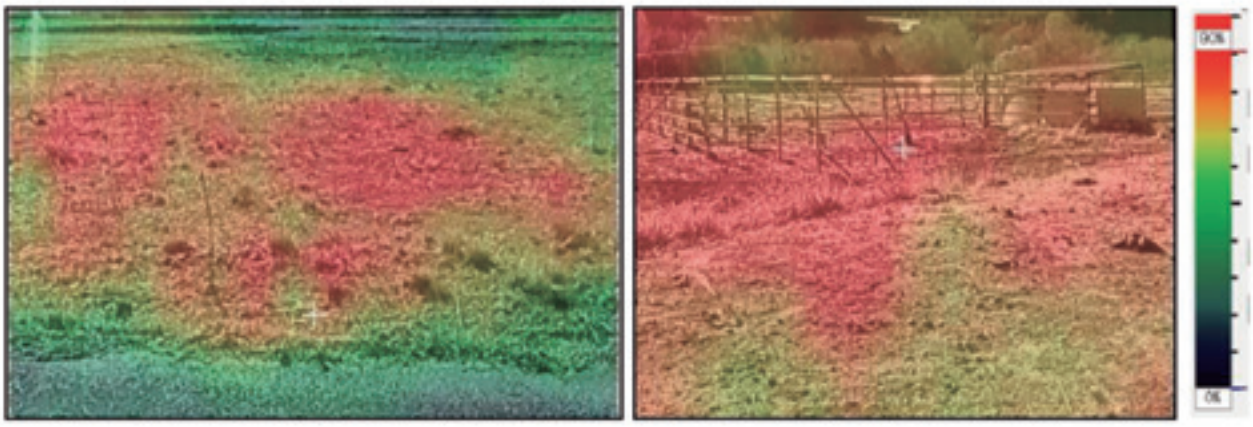
We researched the contamination level on the surface of the ground and in the soil in a high-dose rangeland 10km away from the Fukushima Daiichi Nuclear Power Plant.

Figure (above): The dose at the surface of the ground was measured at 13 points with 50cm intervals at 10 different locations. The coefficient of the variable was up to 30%.

Figure (right): The dose in the surface soil at 5 points in one spot was measured and data was collected from 27 locations. The coefficient of the variable was up to 94%.



Images (bottom): When the dose at the surface of the ground was visualized with a gamma camera, the contamination was uneven. (Red for highly concentrated contamination and blue for less concentrated contamination)



Prof. Ken Sahara:
Agriculture - Entomology

Gene Mapping and the Evolution of Lepidoptera Chromosomes

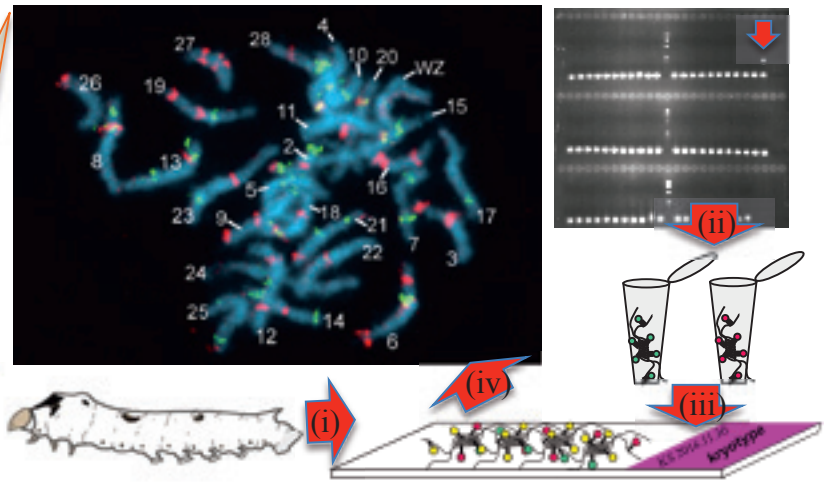
What kind of research?

<Lepidoptera Chromosomes are Now Identifiable with Visualized Genes>

Insects are the most diverged organism on the earth. Insects represent over 60% of all living species. Lepidoptera (moths and butterflies) is the second largest order in insects after Coleoptera (beetles), which includes many pests. Among moths and butterflies, the silkworms being used for silk production since ancient times have been one of the most studied lepidopteran species. Chromosome identification of Lepidoptera was very difficult task until our success in the silkworms. We accomplished the chromosome identification for the first time by coloring silkworm gene sequences with fluorescent dyes.

Prof. Ken Sahara
(Faculty of Agriculture)

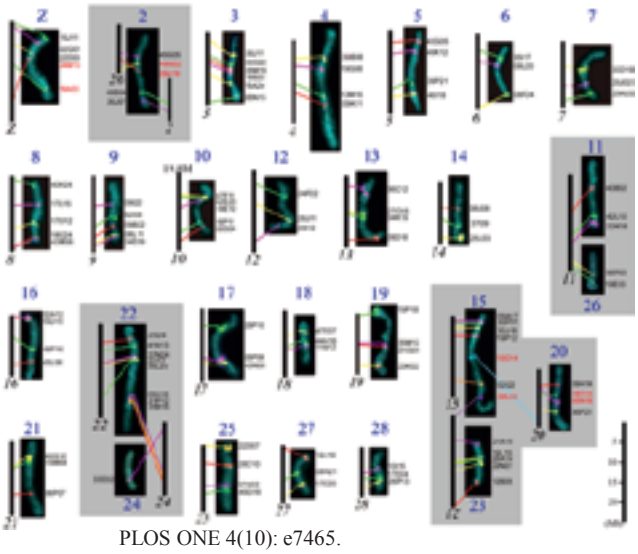
(i) Prepare the chromosome specimens from silkworm gonads
(ii) Identify clones carrying target genes from a genome library
(iii) Label the clones with fluorescent dyes in a tube (probes) and incubate them together with the chromosomes
(iv) The probe signals on the chromosomes can be detected through a fluorescent microscope and identify the chromosome number like in the image on the right.



What is it useful for?

<Useful for evolutionary research in lepidopteran chromosomes and the selection of target genes for pesticide developments>

There are a number of moth and butterfly families and they appear in various environments. They are living for example in the water, snowy mountains, and even crossing the ocean. The problems are caused by the ones that live in rice paddies, fields, orchards, and forests. How can they be pests in agriculture while there are so many none pest insects? If we know the evolutionary mechanism, pest control and prevention will become more effective. We are exploring how chromosomes that carry genetic information have evolved in the lepidopteran order. So far, we have found that gene orders on the chromosome of pests are very similar to those of the useful silkworms. By utilizing the silkworms that are easy to breed and have been studied enough, we can search for the vulnerable genes that pests have.



PLOS ONE 4(10): e7465.
doi:10.1371/journal.pone.0007465

Research for understanding pests based on their chromosomes is underway at Iwate University

Gene Mapping and the Evolution of Lepidoptera Chromosomes

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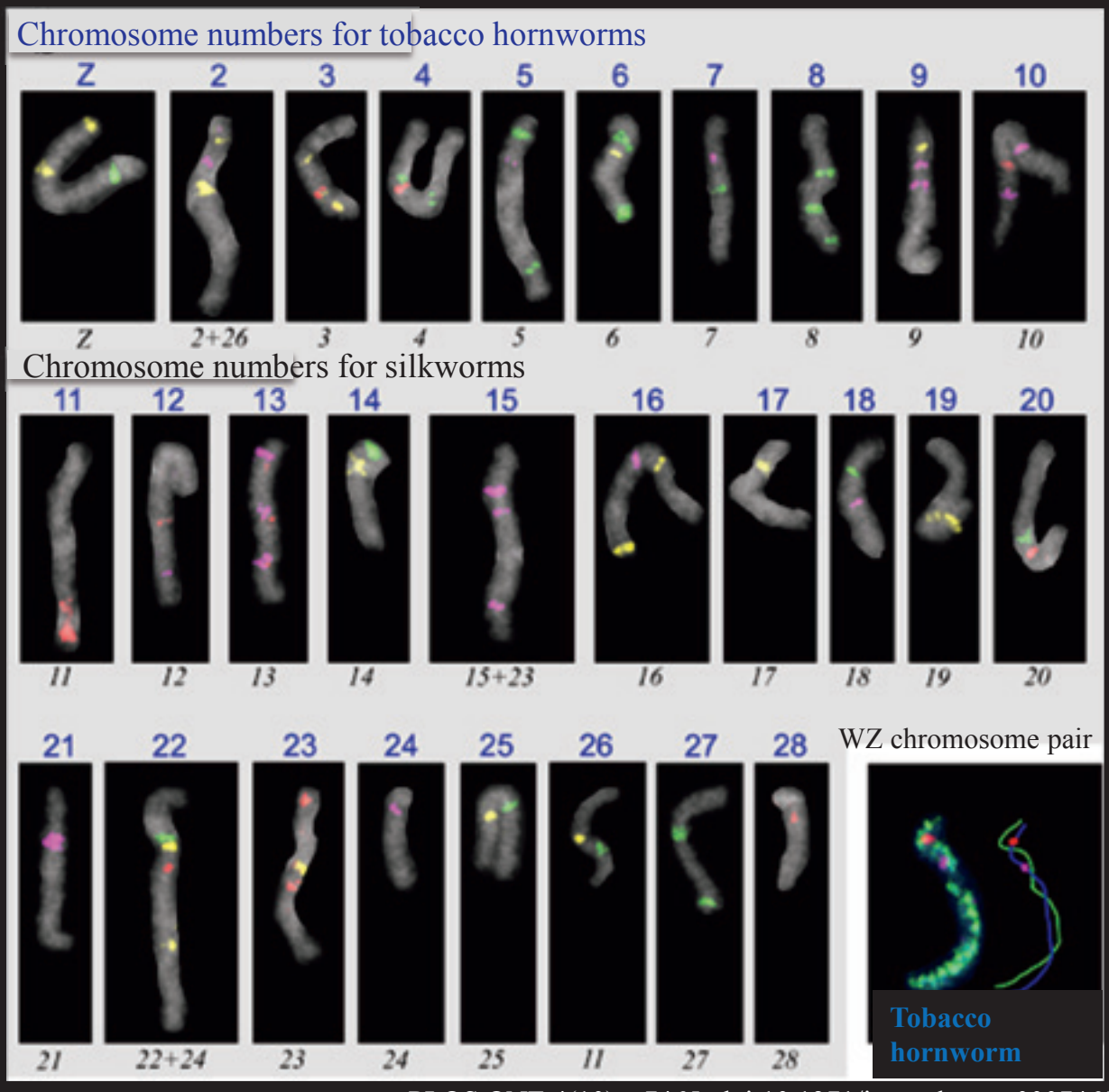


PLOS ONE 4(10): e7465. doi:10.1371/journal.pone.0007465

Prof. Kikukatsu Ito:
Agriculture - Applied Molecular Cell Biology

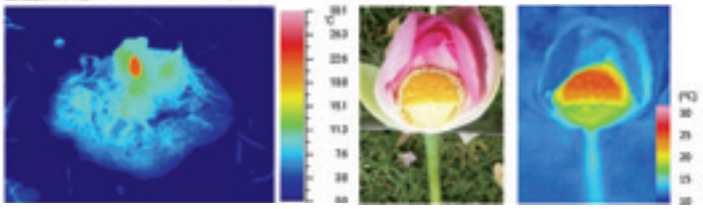
Thermoregulation in Heat-Producing Plants

Plants That Warm Themselves

<Warm-Blooded Plants>

The flowers of certain plants are able to regulate their temperature during blooming by modulating the rate of cellular respiration to remain much warmer than the surroundings. For instance, spadices of skunk cabbage can be maintained at 23°C despite changes in environmental temperatures below freezing. Thermoregulation in animals involves a complex nerve system. Plants, however, have no brain, no muscle, no blood and no nervous systems. Then, how do homeothermic plants regulate their temperatures with incredible accuracy and precision?

Prof. Kikukatsu Ito
(Faculty of Agriculture)



Skunk Cabbage

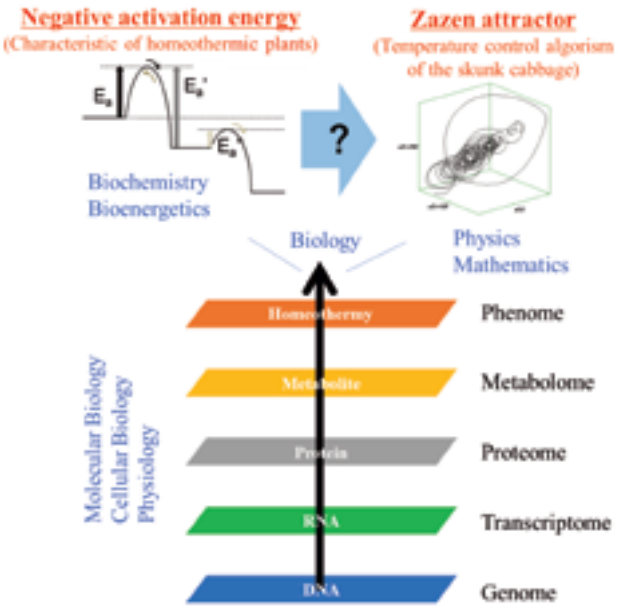
Sacred Lotus

What's New?

In modern life science, most research are conducted in each layer of omics space composed of genome, transcriptome, phenome, metabolome and phenome. However, the mechanism that governs the entire omics space remains unknown. **This research is unique in the way that it explores to identify the mechanism of controlling omics space using homeothermic plants like skunk cabbage**.

So far, we have found that homeothermy of skunk cabbage has a deterministic control mechanism characterized by the Zazen attractor, and is regulated by thermodynamically negative activation energy. However, the mechanism in which the negative activation energy creates the Zazen attractor remains unknown and requires further studies based on interdisciplinary research.

The achievements of this research lead to an understanding of the mechanisms that establish, maintain, and collapse homeostasis, which is one of the characteristics of living organisms.

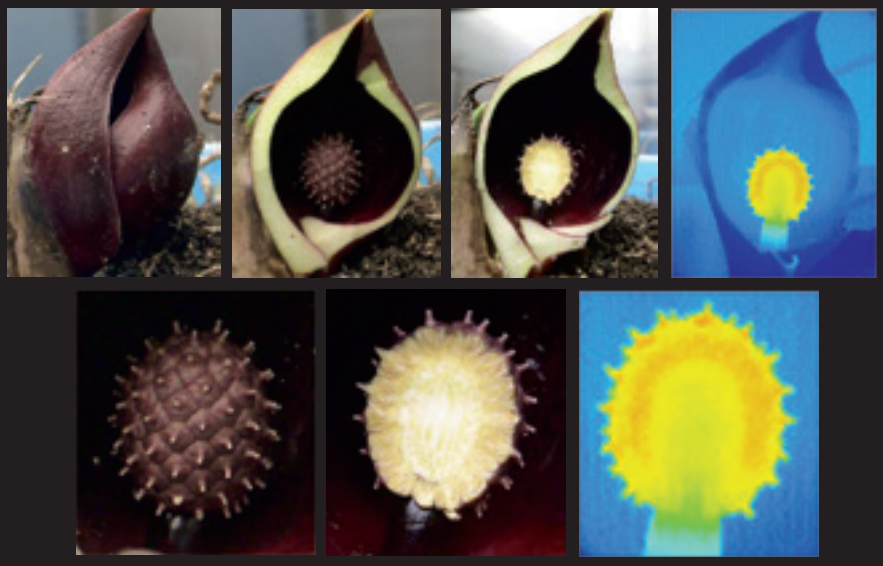


Mechanism for controlling the homeothermy in plants
(vertical arrow)

Application:

The world's first practical temperature controller made by mimicking a living organism

(Collaborative research between the Faculty of Agriculture, the Faculty of Science and Engineering, and CHINO Corporation)



Thermogenesis in the skunk cabbage

Temperature controller modeled after the skunk cabbage

http://www.chinocorporation.com/temperature/temperature-controllers.html

The all new Japanese temperature control technology was developed based on the analysis of the temperature control algorithm of skunk cabbage. Z control (temperature controller modeled after skunk cabbage) has excellent temperature controlling functions and shows great energy-saving effect depending on how it's used.

This technology is introduced at industrial sites in and outside Japan and made achievements as the world's first temperature controller that operates based on biological principle.

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Frontier research at Iwate University
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