The JST-Mirai Program Lecture Notes Series:

Introducing Innovative R&D for the future Vol. 02

Japan Science and Technology Agency

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JST-Mirai Program

Preface

Due to the COVID-19 pandemic it is harder for us to meet face-to-face and stay in contact. JST Connect was launched in 2020 as a webinar series to keep the communication channel open between JST (Japan Science and Technology Agency) and representatives of the global STI community. By sharing information about JST's various activities we can create new connections and stimulate cooperation.

Following the first webinar on the JST-Mirai Program at JST Connect held in January 2021*, the second webinar on the program took place in June 2021. This booklet is a collection of presentations at the second webinar on three more of the research projects and the overview of the new mission areas of the program. The three projects are "small-start type" in the "full-scale" research phase after passing stage-gate evaluation.

Stage-gate evaluation is one of the unique features of the JST-Mirai Program. It is not an easy gate to pass, and many of the projects in the feasibility study phase unfortunately end at this point. The projects introduced in this booklet are the best of the best. At the stage-gate evaluation, a project leader must convince the board that the project can produce social and economic value by overcoming clear and challenging scientific and technological hurdles. The chances of success may not be high but if the project leader can show confidence then the gate will open. In other words we encourage high-risk, high-return challenges.

Of course, Japan is not alone in its aim to invest in basic research and generate new social and economic values, and we are actively welcoming overseas partners to make international collaborations happen. We hope this booklet, together with the first volume, will be a good starting point for such collaborations.

*Lecture notes of the first webinar is available online at the JST-Mirai Program website (https://www.jst.go.jp/mirai/en/evaluation/index.html).

Contents

Acknowledgement

We would like to thank the Department of International Affairs of JST for providing us the opportunity to introduce these research projects in the JST Connect webinar series.

Presentation 1

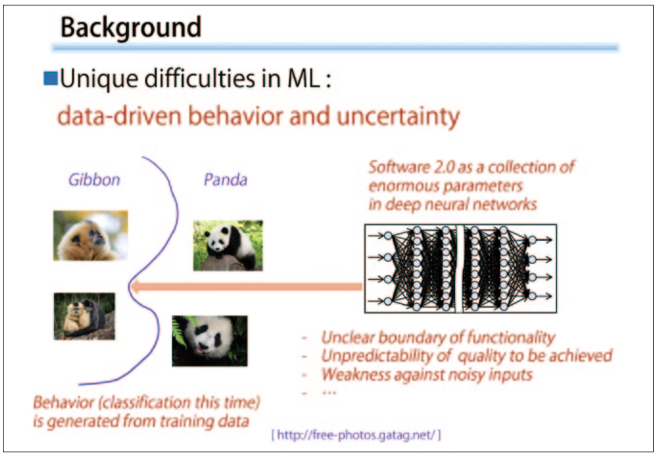
Engineerable AI Techniques for Practical Applications of High-Quality Machine Learning-based Systems

ISHIKAWA Fuyuki
Associate Professor, National Institute of Informatics

I am Fuyuki Ishikawa from the National Institute of Informatics. Today, I will talk about our project called "Engineerable AI" Techniques. AI is difficult to engineer. Of course, there have been really great advancements in AI techniques. When we think about our AI products today, we did it with best-effort techniques but it is really difficult for us to have a clear, sound disciplines for AI systems. This is the point of our project.

As a background, I think all of you know that there is very active investigations for industrial applications of AI systems. Here, artificial intelligence systems are supported by machine learning techniques. We give a lot of datasets to make AI systems learn what to do. But if we think about social or industrial applications, we need to think of some sort of quality assurance or dependability.

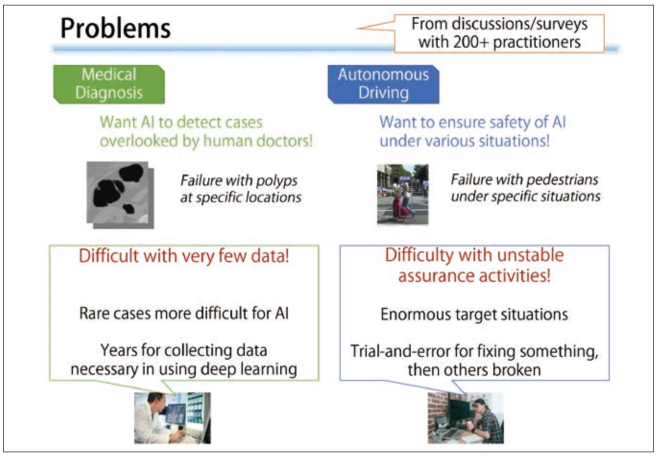
When AI research was done in the laboratory, getting higher accuracy was the major concern, so we had benchmark datasets and the objective was achieving higher accuracy. Let us say, 90% correct answers were given based on the benchmark datasets. But this is not sufficient for industrial and social applications because now we are talking about using AI systems in autonomous driving, medical systems, some factory systems, and so on. There are many safety-critical and quality-sensitive application domains, and of course there are additional customers, from the automotive domain, doctors and so on.



AI is built by machine learning. The behavior is driven by data, and it is a cause for high uncertainty. Here is one very, very simple example. You have images of gibbons and pandas, and you want to let your AI distinguish one from the other. But we cannot explain concrete rules on how to distinguish these two kinds of animals.

Then, we give a lot of training data to the AI system. We often use deep neural networks. There are a lot of neurons, and each neuron has some parameters, and so in total we have an enormous number, thousands or millions, of parameters in it. Then, from the training data, this neural network learns how to distinguish a gibbon from a panda, so actually how to make this boundary line shown on the slide.

Now we built the AI system but we do not know what the boundary actually is. Here we have high uncertainties, but the situation is quite different when we speak of a product or quality assurance.

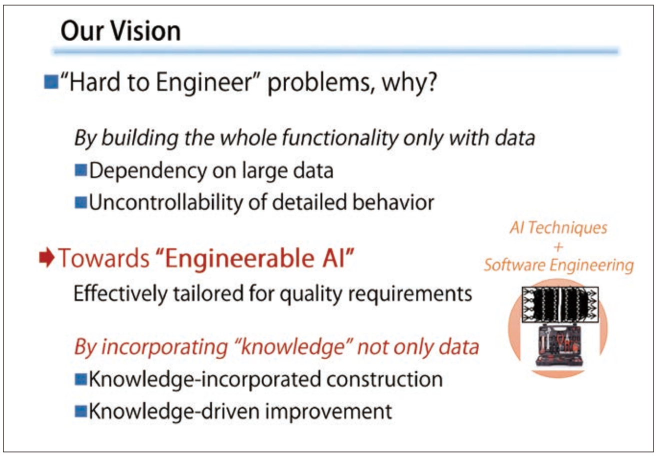


It is really a problem if we think of safety-critical or quality-sensitive systems. Here are two examples.

In medical diagnosis systems, of course we already have high-performance AI systems for some applications. But, for example, we want our AI to detect cases overlooked by human doctors as it is important. A majority of the cases can be discovered by human doctors, so we want our AI to find some rare or difficult cases. But such cases are also difficult, actually more difficult for AI because in such atypical cases, we only have very, very limited number of available datasets. Rare cases are more difficult for AI, so we cannot ask AI to cover what were overlooked by human doctors. Of course, we can collect the data but it would take several years, which makes it really difficult.

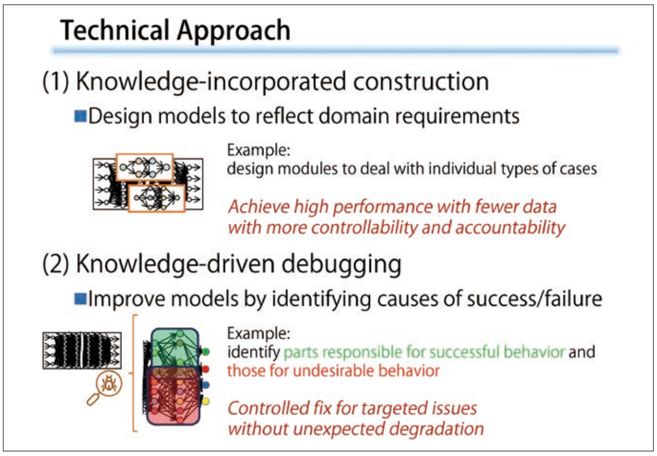
If we look at autonomous driving, of course we want to ensure safety of the driving systems under various situations. But the difficulty is that the AI systems are very unstable. We give data, and then something is generated. In driving systems, we need to ensure safety in many, many situations like: "How about this situation? How about in that situation?" We need to talk about a lot of situations such as when at intersections or in mountain areas.

AI may have some weaknesses in specific situations, and of course we want to improve or fix them. But when we can only give some additional training data, then AI may change completely. What happens is that, okay, suppose there is some weaknesses in a certain situation. We go to fix it and we add some data about that specific situation. As a result, in other situations, the AI may get other additional weaknesses. This could happen. It is really hard because we need to have trials and errors to fix something, but it is often the case that we get some other parts broken at the same time. It is really critical for autonomous driving systems for which we need to ensure safety for many, many situations.



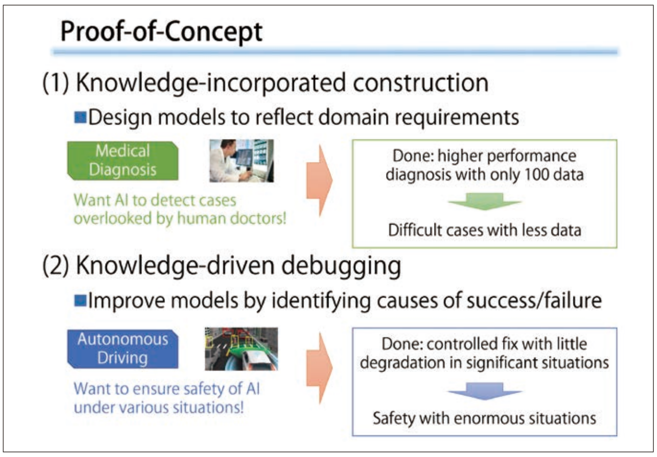
This is our vision. Compared to traditional software programs, it is hard to engineer. The reason for this problem in the previous examples is actually because an AI depends on very large datasets and we cannot control so much about the detailed behavior. We can only give a dataset and the behavior is somehow derived by the system.

Our project envisions the new term "engineerable AI", which can be effectively tailored for your requirements. Each system has its own set of users and so each system should be tailored accordingly. We aim to enable engineerable AI by investigating some set of techniques. The key idea is clear. Okay, the problem was that it is difficult if we only rely on the data. Now, the answer is, simply and truthfully speaking, we can give knowledge to the system. We can do that when we build a new system or when we fix the existing systems. That is our project.

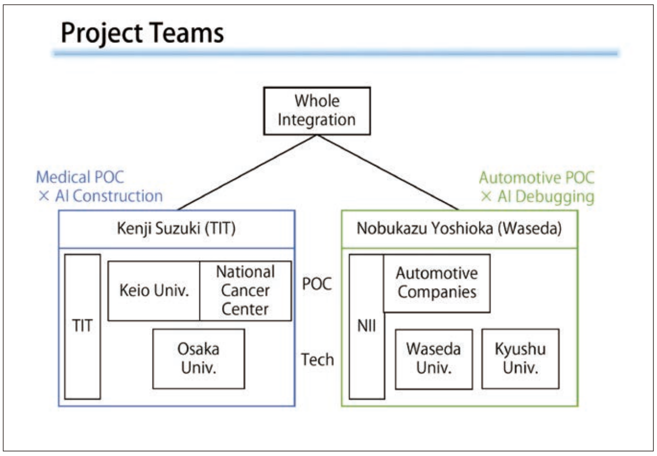


I am not going into so much detail about the use of our techniques but the first point is that we build or provide the techniques to build our AI by providing some knowledge and not only data. For example, we may know what rare cases or the types of diseases are when we build the medical AI systems. Not only providing data, but we can also reflect our knowledge into the design of AI. Then, the AI can use the knowledge in addition to what can be obtained from the data. We need less data because the knowledge can cover it. That is one point.

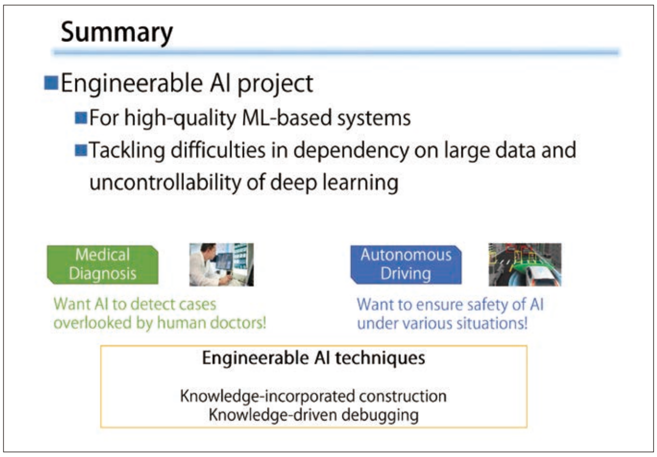
Of course, we have a lot of existing AI systems and we also do debugging or fix the existing AI systems. I used the word "debugging," which is a term from the software engineering community. We should understand what is the cause of the failures that are currently happening. Then, we can focus on fixing only that part. Training of AI may change the results completely, but we want to have it fixed with a specific focus. We try to identify which part of the neurons, for example, is responsible for the failures, and which part of the neurons is responsible for the successes. We can avoid touching the successful part and only fix the failing part. In this way, we can control the expected performance of the AI, and we can avoid a lot of trials and errors: “fixing here, this is broken; fixing another one here, now that is broken” – we can avoid those kind of iterations.



These are techniques and steps of the application. We are working on the two domains, as I already mentioned, medical area and autonomous driving. For the medical area, we want AI to detect the cases that are atypical and overlooked by human doctors. We have already built some AI prototypes, only with 100 data but it has higher performance than existing AI, and now we are trying to build more high-performance AI with less data. For the autonomous driving, we have already done controlled fixing, without breaking something when we try to fix the perception AI for driving systems. Now we are moving to discuss the whole safety of the large and complex autonomous driving systems.



We have some research teams in this project, combining the researchers of AI techniques and researchers for software engineering, reliability engineering researchers. Of course, we have specialists for the medical systems and specialists for automotive systems. The important point is that our challenge is to unify this heterogeneous expertise into one project.



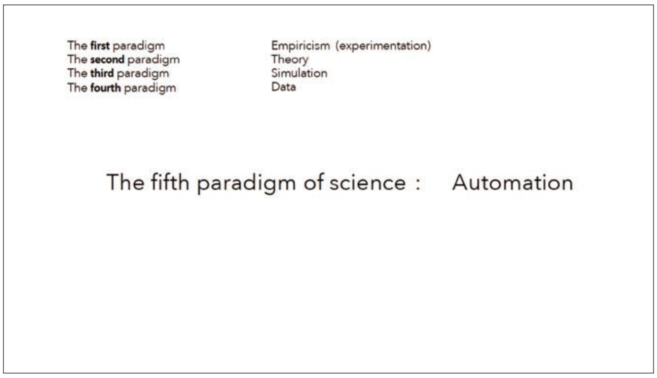
That is our project "Engineerable AI". We are aiming at making reliable AI products by resolving the current difficulties of AI systems that need a lot of data and are highly uncontrollable.

That is all from me. Thank you for your attention.

Presentation 2

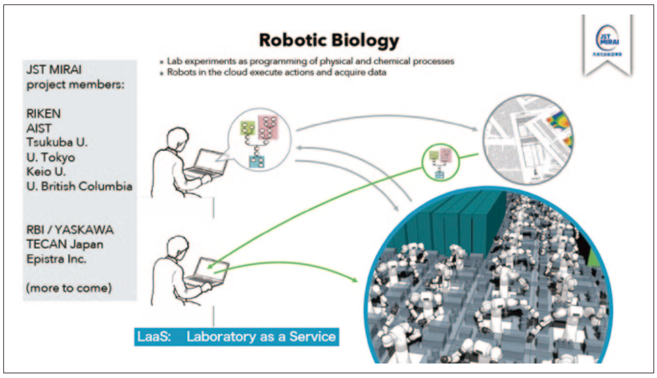
Accelerating Life Sciences by Robotic Biology

TAKAHASHI Koichi
Team Leader, RIKEN



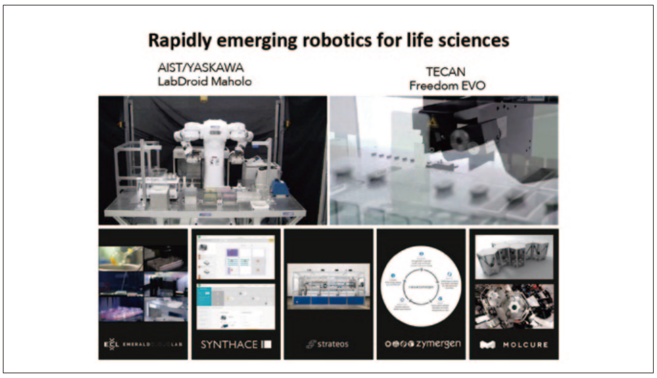
I am going to talk about a project that we are doing as a part of the JST-Mirai Program. Our project is a bit different from many others; what we are working on is about the methodology of doing research and not about specific research targets. The history of science has seen some major paradigm shifts from experimentation to theory, theory to simulation, and simulation to data. We believe that the next paradigm will be automation. By automation we would be able to integrate those approaches – experimentation, theory, simulation and data – into one cycle.

As a foundation of this paradigm shift, we are designing and constructing a robotic biology facility in Kobe City, Japan.

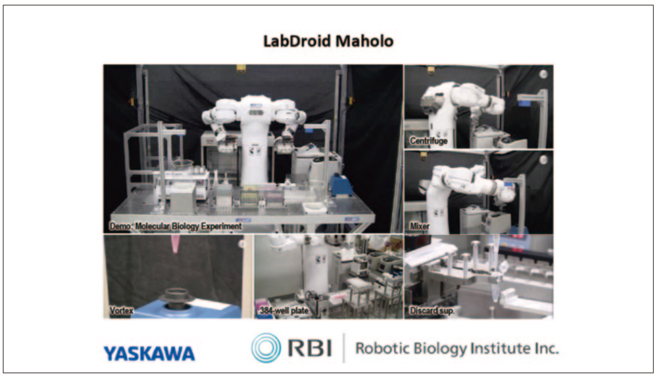


Our concept of robotic biology is like this. We would like to change laboratory experiments, redefine laboratory experiments as programming of physical and chemical processes. If a scientist can describe experimental protocols in the form of computer programs, then he or she can transfer this over the internet to robots in the cloud and get the resulting data. This data and the experimental protocols can simultaneously be shared all over the world, over the internet. Then, a third person could download and reproduce the same results or even improve the experimental protocols to obtain better performance and accuracy from the experiments.

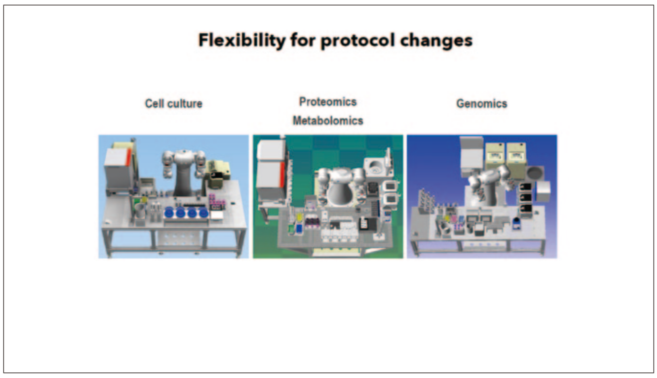
Our project consists of members from six academic institutions, RIKEN, AIST, Tsukuba University, the University of Tokyo, Keio University and the University of British Columbia, and some corporate members. We are actively looking for more members to join us, so we can expand the project. We would like to make this more international.



The reason why we started this project was because we were inspired by the rapid emergence of robotics for life sciences. AIST and Yaskawa Electric developed this experimental robot called "LabDroid Maholo." I was involved in this development as a Chief Information Officer (CIO). This is a humanoid robot, and it is quite versatile. We also have a partnership with TECAN, from Switzerland. They have built pretty good liquid handling machines, another type of experimental robotics. In the United States, there are companies such as Emerald, Strateos, Zymergen all in Silicon Valley. Synthace is another startup company in London, and there is Molcure in Tokyo. Actually, I am a Scientific Adviser of Molcure. The robotics is getting ready.

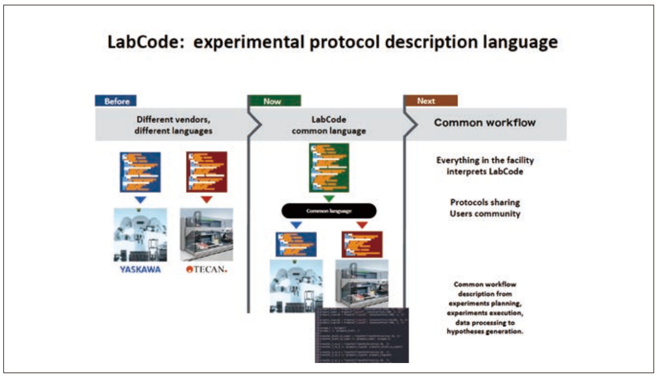


Our main weapon is LabDroid Maholo. This is a humanoid. It can use exactly the same equipment and labware as human laboratory technicians. It can do centrifuge, for example. It can use a mixer, a vortex, or liquid handling, so it is quite versatile.

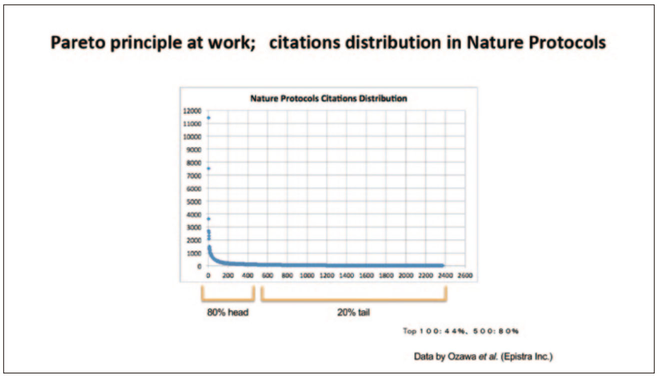


By changing what is on the stage, the robot can execute a wide range of different protocols, like from cell culture, proteomics, metabolomics, and genomics.

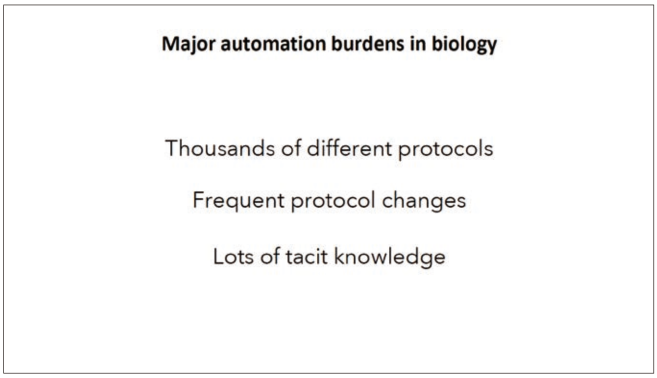
Some years ago, we wrote a paper on the formation of a consortium on robotic biology. This is what we had before starting this project. What do we do in this project now?



A key component in this project is the Protocol Description Language, what we call "LabCode." Before, it has been the norm for users of robots to write different programs in different languages for different types of robots. But we developed a common language. You just write a transcript in this common language once and compile it into the vendor-specific languages, so that robots can work together.

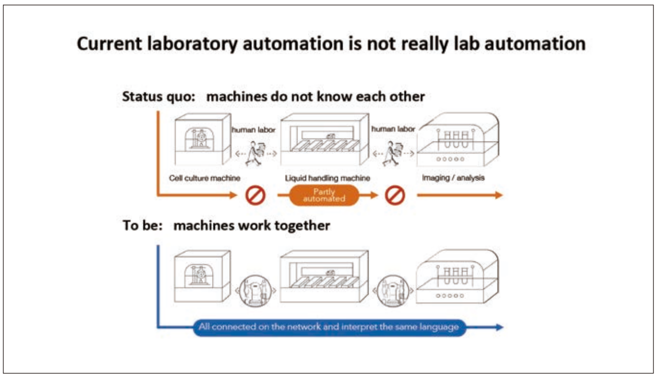


Why did we start this? We did citations distribution analysis of all papers ever published on Nature Protocols journal, and we found this beautiful power-law distribution, meaning that it is long-tail.



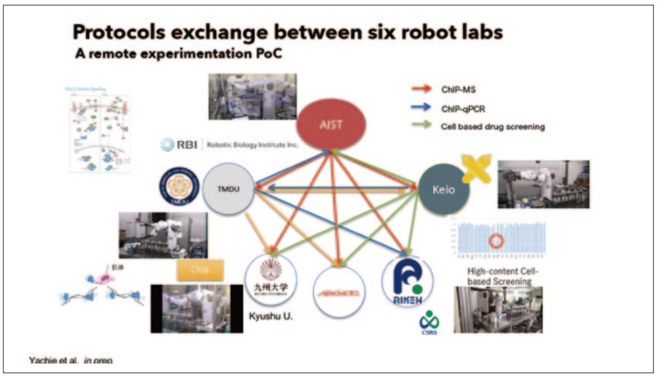
What is the implication?

The implication is that we have to handle hundreds or maybe thousands of different protocols to automate the life science research. Also, because it is science research, the protocols frequently change; almost every day, we have to change what we do in the lab. This is a quite different situation from some previous applications of robotics, like car factories or semiconductor manufacturing. In those manufacturing industries, a robot does just a single task. But in the laboratory, a robot has to do many different things and they have to change the protocols very frequently. Also, there are lots of tacit knowledge in the lab which determine success or failure of experiments.

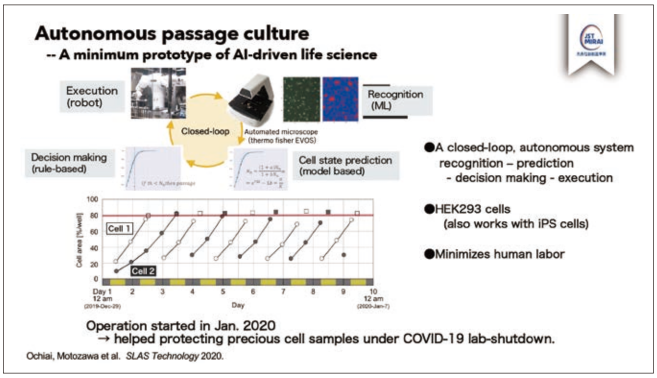


Of course, there are already some automations in the laboratories. Like, we have a cell culture machine, liquid-handling machine, imaging machine or DNA sequencer. However, they are disconnected humans have to go between these machines. We would like to make this happen: We would like the machines to talk in the same language and work together.

This is a POC we did some years ago. We picked a genome editing experimental protocol actually used at the University of Tokyo, and described this with LabCode. The compiler automatically analyzed the structure of this protocol in the form of a graph. Each subtask is assigned to different robots or even human operators. Because this was a POC, not everything was automated at this point. But from the viewpoint of the machines, there was no difference between humans doing some experimental procedures and robots doing experimental procedures, so we established some foundation for the automated workflow planning for robotic laboratory.

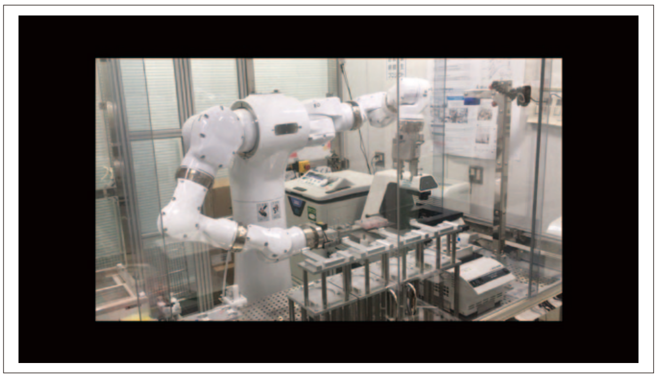


Here is another POC we did. We placed the same robots on six different sites around Japan such as the Keio University, the Kyushu University, RIKEN, Ajinomoto, and the AIST. The robots exchanged the experimental protocols in the form of computer program over the internet. Usually, at biological laboratories, it is quite difficult to set up new experiments. It often takes weeks or, in some cases, months. But because we had the formal description of the protocols, and we had the same robotic software, all experiments succeeded from day one.

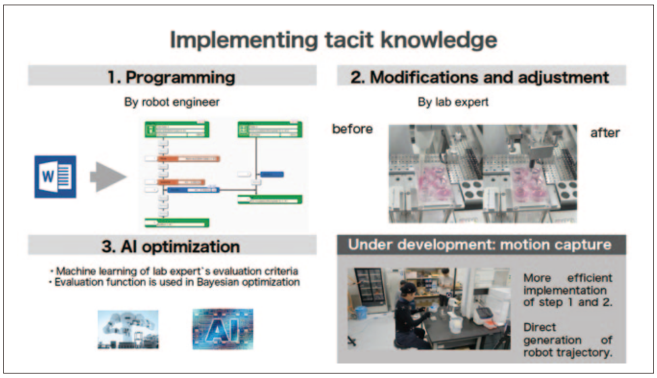


We also created this robotic machine for autonomous passage culture. We implemented the passage culture protocol in a robot that was combined with an automated microscope. The AI recognizes the state of the cells from this image. Then, the AI can make a prediction of how the cells will grow in time. Then, based on this prediction, the machine makes some decisions on when and what type of experimental procedures has to be done next by the robot.

This is an autonomous closed-loop system that combines recognition, prediction, decision-making, and execution. We think that this is a minimum prototype of AI-driven life science. Actually, this system started operation in January 2020, and helped in protecting precious cell samples under the COVID-19 lab-shutdown situations when none of us could enter the laboratory. This was published on SLAS Technology journal.

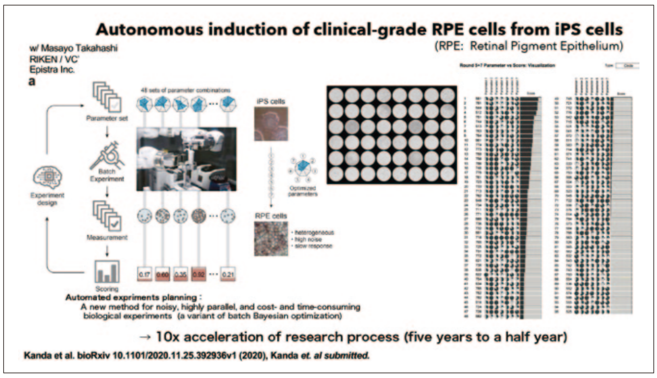


This is an image of the experiment. The robot is trying to put the plate where the cells are growing, to this automated microscope. Then, the AI can obtain the data from this microscope and make some decisions to determine what has to be done by this robot next.

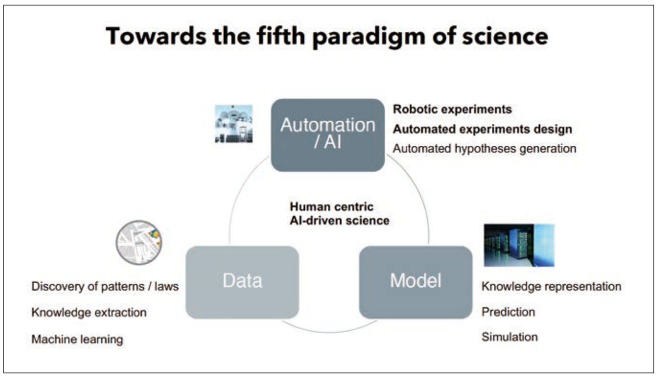


In this type of experimental protocols, there is a lot of tacit knowledge that determines the success or failure of the experiments. We had to invent a way to transfer the human tacit knowledge to machines. We do this in basically three steps.

First, we program the robots from what is explicitly described in the experimental protocol. This will be the template for further optimization. Then, the lab expert sees the actual movement of the robots. For example, the first implementation by our robot engineer had some bubbles around the cells. But cells basically do not like bubbles. The lab expert instructed this robot engineer to use a different type of pipetting operations so that there would be no bubbles. Then, we used AI to optimize the conditions.



By using this kind of tacit knowledge transfer, we succeeded in making autonomous induction of clinical-grade eye cells, retinal cells from iPS cells. The best part is that our collaborator had required 5 years to develop just this viable protocol. By using a combination of the robot and the new automated experiments planning AI, the machine could find the same or even better cell induction conditions in less than half a year. There were at least 10x acceleration in the research processes.



We talked about the automation of the experiments. What's beyond is to use this automated experimental robotics to embody "AI scientists". The key idea is to combine a data-driven approach and a model-driven approach. Without proper representation knowledge, it is impossible for humans to explain or understand what AIs are doing and to work together with them.

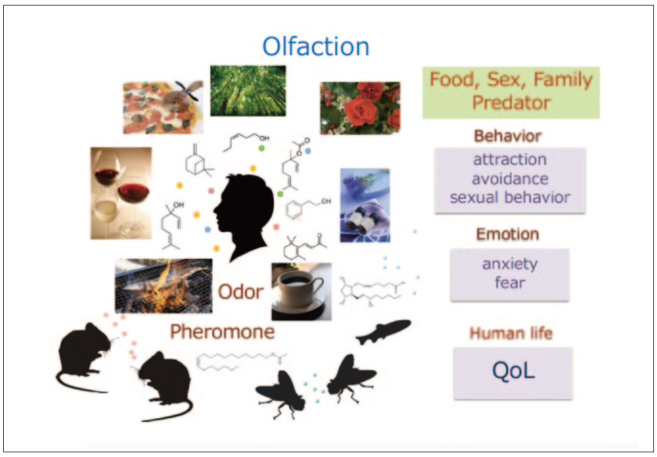
Lastly, to put things into a bit of international context, we had a joint workshop on "AI Scientist Grand Challenge," between the U.S., the UK, and Japan. Actually, this was the last overseas trip for me before the COVID-19 turmoil. The Chair from Japan was Hiroaki Kitano. We had workgroups from biology, geosciences and materials science. We published a whitepaper from this workshop. We look forward to working with scientists from all countries towards this grand challenge.

Thank you very much.

Presentation 3

Providing Humane Services by Expanding the Function of Flavor and Fragrance

TOUHARA Kazushige
Professor, The University of Tokyo

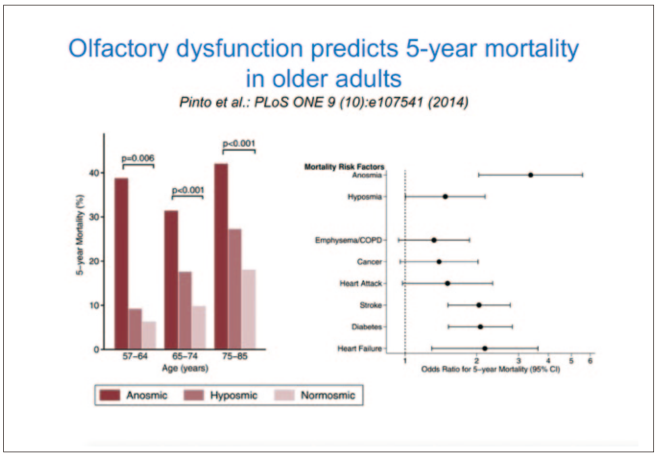


Today, I am going to talk about the research studies we are performing under the support of JST-Mirai Program. The title of the project is "Providing 'Humane' Services by Expanding the Function of Flavor and Fragrance."

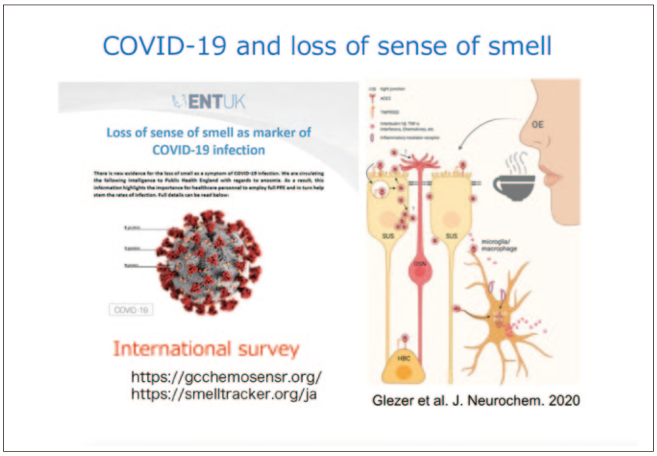
The meaning of humane is to show kindness and sympathy to others. We always think of this concept. This is the concept or consideration we have when we think how to use the flavor and fragrance in our societies.

In the external world, we are surrounded by many odors and pheromones. It is considered that there are about 0.5 million odor compounds in the external world. Most of them are small and volatile chemicals, and in many animals, these odors and pheromones convey the information about food, sex, family, or predators. These compounds, odor and pheromones, induce various behaviors such as attraction, avoidance, mating, and also induce a change in emotions, such as anxiety or fear.

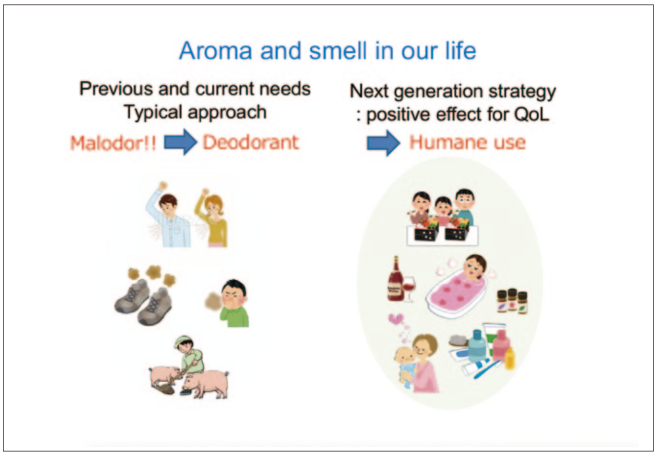
In human lives and societies, it is a little bit different. We use our olfactory system for the quality of life; for example, when eating or drinking, and also in daily life. The odor and pheromones are very important for survival for many animals, but in the human societies, it is a little bit different. It is thought that the olfactory system, or olfaction, is the least necessary sense among the five senses. When you do a survey, people think "Okay, among the five senses, olfaction is the first sense that can be eliminated or removed."



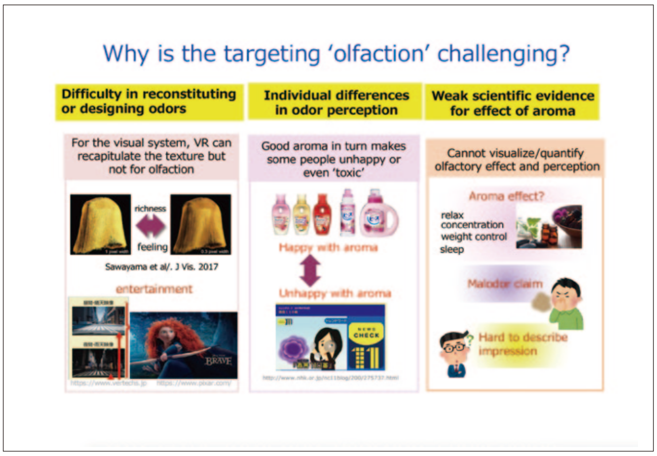
But actually, there is a little surprising report from the group in Chicago, in the United States. This paper showed that olfactory dysfunction predicts a 5-year mortality in older adults. This means that when they examined what kinds of disease or dysfunction they could find 5 years before the death, they found that there was a much higher probability to suffer from olfactory anosmia compared to other diseases like cancer, stroke or diabetes. This surprising result suggests that the loss of olfaction may be related to some kind of deficit or defect in health. This suggests that normal olfaction is a kind of indicator or evaluator of our health.



Indeed, as you know that due to the COVID-19 infections, we experience the loss of sense of smell because the virus infects the sustainable cells that support the olfactory neurons in the olfactory epithelium in the nasal cavity. And due to the infection, we experience a deficit of the lack of smell. This, again, suggests that having a normal sense of smell is a good thing, and when you lose the sense it suggests that something wrong is happening in our body. The olfactory system is actually more important than people have thought.



But the typical approach towards aroma and smell is, "Okay, there is a malodor, so we should remove it with a deodorant." This is a typical approach in our societies. But in our Mirai project, we take the next-generation strategy, which is to take advantage of the positive effect of aroma for the quality of life, and we call this a "humane use." This is an approach or a purpose we pursue in our Mirai project.

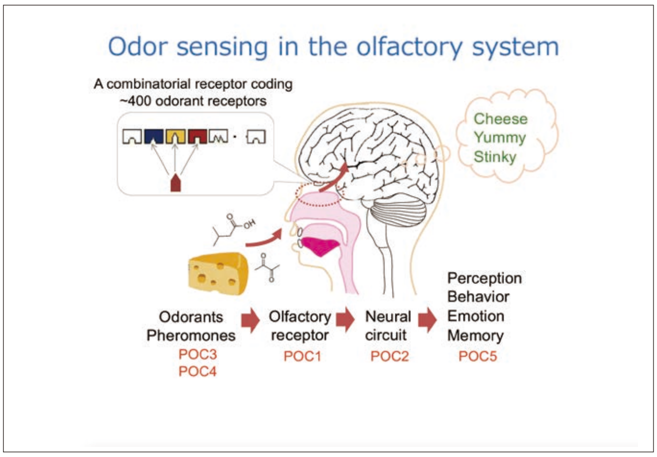


But to do that, there are various obstacles or difficulties. Why is targeting olfaction a challenge? What are the difficulties? The first point is that there is a difficulty in reconstituting or designing odors. The odors are chemical compounds. It is not like a visual or auditory system where there are physical stimuli. Also, as I said, there are about 0.5 million chemical odors in the external world, and also they are all mixtures. It is really difficult to reconstitute or design odors. It is not like a visual system where virtual reality can recapitulate the texture. This is the first point that makes our approach challenging.

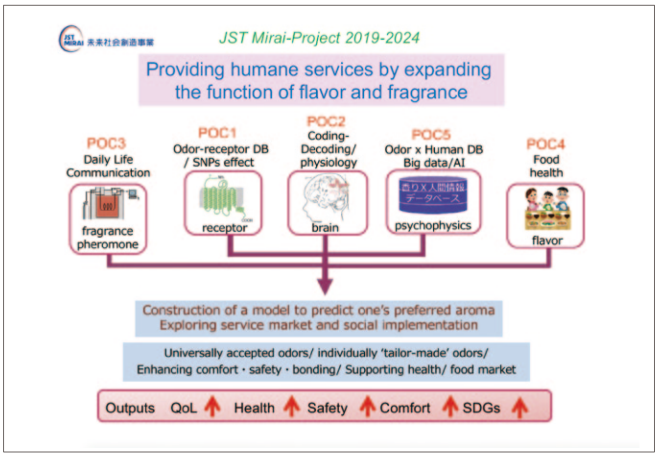
The second point is that there are big individual differences in odor perceptions. Good aroma in turn makes some people unhappy or even feel "toxic." This individual difference is known to be due to the differences in the genomic levels, for example the receptor gene, and also due to experiences. The odor preferences are very affected by experiences. This is the second difficulty in using odor in the society.

The third point is that we only have weak scientific evidence so far. We know that there are good effects in aroma therapy. But the mechanism for the aroma effect is still unclear, I would say. Also, we cannot visualize or quantify the olfactory effect nor perception. This weak scientific evidence on the effects of aroma really makes it difficult for us to use the odor and aroma in the society.

These three points have to be overcome to achieve the humane use of aroma in the societies.



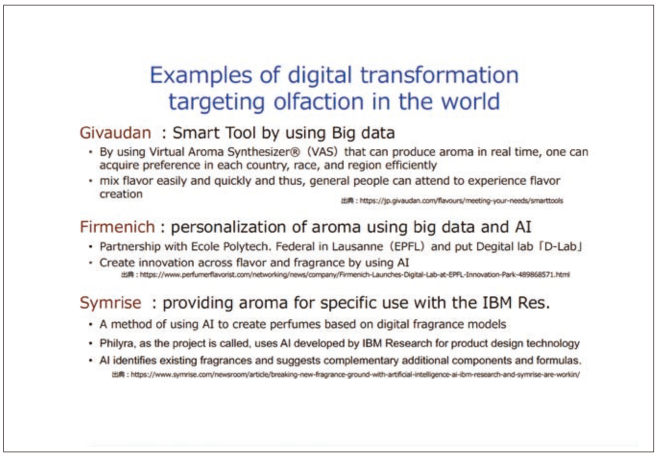
Let me introduce the mechanism of odor sensing in the olfactory system and then introduce our POCs of our project. The odor and the pheromone molecules enter the nasal cavity and activate the receptors, which consist of 400 receptors in the humans. The odor information is coded by the combination of activated receptors among the 400 odorant receptors. We call it the "Combinatorial Receptor Coding Scheme." Each odor activates a unique set of odorant receptors. Then that information is sent to the brain, and finally, we perceive the odor like "Okay, this is cheese." It also affects the behavior: "Okay, this is kind of stinky and should be avoided." Also, it uplifts emotions, such as “yummy” or “this looks delicious”. Also, that affects the memory because the odor and memory are really closely linked.



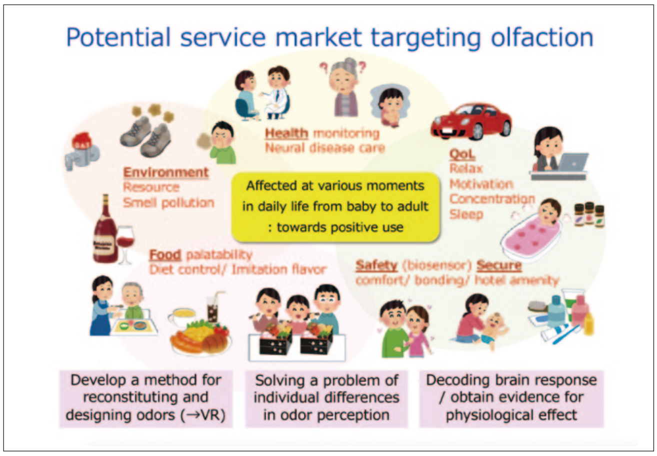
We set up five POCs at these levels and in detail; here are the details. For POC-1, we try to construct an odor-receptor database, especially considering the SNP, single-nucleotide polymorphism effect. For POC-2, we try to make a model for the encoding or decoding of the olfactory signals in the brain, and also get evidence for the physiological effect of odor compound. For POC-5, we construct the odor and human database, and analyzed the big data. This is done in collaboration with NTT DATA and this is the psychophysics approach.

We also focus on molecules, fragrances and flavors. Flavor is related to food and health, food industry, so we are collaborating with the Ajinomoto Company. For daily-use products, we are collaborating with the Kao Company, making fragrances and toiletry goods.

Then, we try to construct a model to predict one's preferred aroma and explore the service market and social implementations. In detail, we can design the universally-accepted odors, or in turn, individually "tailor-made" odors. We can also design odors for enhancing comfort, safety, bonding, for supporting health, or for food market. Actually, the final output is an increase in QoL, health safety, comfort, and also SDGs, related to the SMGs.



If you look at the worldwide level, here are some examples of DX targeting olfaction in the world. For example, Givaudan and Firmenich: These are big pharma companies in several countries, and they use big data and AI to analyze and personalize. Symrise also uses the AI in collaboration with IBM. But there is no approach combining multi-levels of the olfactory system from chemistry, receptor biology, brain response, and psychophysics, which is the kind of approach we have in our Mirai project, so we think that our project is unique.



What is the potential service market targeting olfaction?

This can happen in many places. For example, in clinical health we can use odor signals for health monitoring, and we can also use aroma to improve the neural disease. For the environment, we can save the resources and we can also solve the problems of smell pollution. For food, of course there is a possible market related to the palatability and diet control. We can use odor molecules to control diet, or we can create imitation flavors efficiently. For safety and security, we can provide more comfort and bonding in an environment; for example, to strengthen bonding between a mother and her baby, or to improve the hotel environment. Also, in daily life, we can use odor for relaxation, motivation, concentration and sleep.

The good thing about the olfactory system is that we are affected by odors at various moments unconsciously from babies to adults. For the humane use, we take the advantages of the effects of the odor molecules. But to do that, again, we need to develop a method for reconstituting and designing odors, and for solving the problem of individual differences in odor perception at a genomic level and by taking experiences into account. We also should develop a method to decode odor responses, and obtain evidence for the physiological effect of aroma.

This is the detail of our Mirai project and its intended output toward potential service in the market.

Thank you very much.

Q&A

MC

We now have some time for questions.
Maybe let me circle back through to the first presentation that we had by Dr. Ishikawa.
In your presentation, you had the examples of two specific fields, medical and autonomous driving fields. You mentioned this kind of knowledge-feeding can be used in other fields as well. Are there other types of fields that you immediately think of where we can use this technology in?

Dr. Ishikawa

Thank you for the question.
For example, our technique is more suited for systems that require high quality or safety. Again, if the average quality performance matters, then we may use the current AI. But in some systems, the failures are not so much acceptable, or specific kinds of failures are not acceptable. For such kind of systems, our technique is more suitable.
For example, you can imagine the manufacturing domain. We want to detect a specific type of abnormal products which may break a machine. As another example, let us think of the financial domain. For example, AI application in investment may be okay with high average performance rather than taking care of each failure. But if we think of selecting customers, for example, in the case of rejecting the credit card payment, then the decision should be very carefully explainable. For that kind of system, our techniques also should be useful.

MC

Okay, interesting. For example, in investment applications, insurance applications, in those kinds of fields, it is also applicable? When AI is going to get into those fields, it is a bit scary. I would be very happy to know that it is a fail-proof system. Have you done any kind of specifics in those other fields as well, at the time being?

Dr. Ishikawa

Not yet but we are receiving a lot of requests from the industry. But in Japan, I would say, manufacturing and automotive are highly interested, at least around me. I think we are working on the most important fields.

MC

Okay. Thank you very much.
Perhaps, I can now move on to Dr. Takahashi, for a question about your presentation. This kind of robotic laboratories, all science, extremely cool. When will they be made available do you think?

Dr. Takahashi

Okay. Our project actually started this January. We are in the process of designing and starting construction of the sites and facility. We are going to finish this construction maybe sometime next year.
Then, we will do some POC experiments to see if our concept is possible, like get external protocols over the internet, do the experiments and get this data back to the users, and share the data with all the people. This is going to take maybe 2-3 years. That is our schedule.

MC

That is still a little bit of time that it takes.

Dr. Takahashi

Yes.

MC

I am wondering as well because you had a nice picture about the international conference that you participated in, right before the COVID pandemic struck. It seems like an obvious kind of field as well where you could develop more international cooperation. Within the schedule, as it would take a while before this robotic laboratory can be available, what is your timeframe to develop further things?

Dr. Takahashi

Okay. While we are constructing the robotic laboratory, we are working on a software, especially on the common language for the protocol description and how we interpret and process those languages so that we can distribute the subtasks to different types of robots and equipment. We are working on that.

There are lots of technical issues and research topics in this specific field, in terms of information technology. Our project is a combination of engineering robotics, information technology, and biological sciences. It is quite multidisciplinary, and so there are lots of things to be done.

MC

Specifically, in all these kinds of specific tasks that are necessary, and, of course, you would need partners in order to solve all these kinds of specific elements. I just received a question here from one of the participants, "What are you looking for specifically in partners, and what are the particular topics that could be covered here?"

Dr. Takahashi

Actually, we have nice engineers and scientists in our project already. But we would like to see more collaborations in terms of basically two things in technological foundations. Especially in terms of robotics, we are using the humanoid-type robot and liquid-handling machines. But there is a lot more different types of experimental robotics out there. We will actually see those different types of robots connected by using our software. Then, we get more expertise and more data so we can strengthen our technology more. Also, we would like to see some collaborations in terms of the industrial IoT, the technology that German companies are very good at. That is for the technical foundations.

Also, we would like to see some collaborations in terms of applications of biological experiments. We are now working on the cell culture and basically, we are handling the higher cell organisms. But there are lots of useful applications using, for example, bacteria, such as biomaterials production or genome editing. Synthetic biology would also be a nice application.

MC

Thank you very much.

But perhaps, let me move to Professor Touhara about this also very interesting presentation. I have learned a lot about smell, I must say, with your presentation and I did not know it was that complicated. It seems like a lot of things still need to be clarified, in the mechanism of olfaction, of like the sense of smell. What are the most important issues that are still on the table?

Prof. Touhara

Okay. There are many things that should be solved in the basic olfactory research. As I showed you in the slides, starting from the odor to the perceptions, the question at the first step in olfaction is that why the very high sensitivity of olfactory perception cannot be explained by the sensitivity of the olfactory receptors. The second question is that why we cannot predict the odor quality from the chemical structure of the odor. That is also something that needs to be solved. Further, we do not know how the activation pattern of olfactory receptors is correlated with the odor quality. Lastly, we cannot decode the odor responses in the brain, and also, the mechanism underlying the physiological effect of odor, which is often called an aroma effect related to aroma therapy, is unclear. There are many things that we have to solve before we think of application. Actually, by using a mouse as a model system – it is very advanced – we know much about the olfactory system in mice. But in human beings, the understanding is behind because the approach of the research is limited, that is, we have to use a noninvasive way. That is the kind of the things that we have to really tackle.

MC

Okay, thank you. We have another question for you, specifically regarding vision disability. Can this technology be used for disabled people, for example, vision disability?

Prof. Touhara

This is an interesting question that I have never thought about. It has been known that when we lose one of the senses, the other remaining senses become really sensitive. People with visual disability have a little bit higher sensitivity in the olfaction. For example, they can recognize individuals by body odor, who is who. I think it is really difficult to imagine how we can apply the technology because the olfactory information is very important and also that affects a lot for the people with visual disability. I think it is nice to design the kind of odor or aroma that helps them to become happy or mentally stable. I do not know, but definitely that is something we can think of.

MC

These kind of disabled people as a kind of a target, is that kind of a service that could also be interesting to develop, do you think?

Prof. Touhara

I do not know. We have to think how to tackle this problem. We need to go to the next level, which is a cross-modality interaction in the five senses. That is the next step. For our project, we are focusing on olfaction at this moment, so we can do something about people with olfactory disability. But to tackle the problems related to the other senses, I think we will probably have to go to the next step. That is a huge project, I think.

MC

I see. Thank you very much.

There just came a question, specifically for you about what is the situation actually of international cooperation in the field of olfaction?

Prof. Touhara

Actually, as I had introduced in my presentation, the fragrances and flavors market is much bigger in other countries than that in Japan. But the point is, each country has a unique food culture, which affects the odor preference. It will be really nice that the approach we are taking, which is to construct a human database with odor preference information, can be done in other countries, like what we do in Japan.

We very much welcome collaboration but at the same time the problem with olfaction is very specific to each country, because, as I said, each country has a unique food culture, and each person has a different odor preference. But we are really welcome to find collaborations in the future.

MC

Okay. Thank you. Actually, to follow-up on that, every country has specific smells. Are there any kind of smells that you are specifically interested in? I think, of course, many countries have different smells, so there must be smells that really stand out perhaps, for you in other countries.

Prof. Touhara

Well, each country has each country's smell. You can sense it when you get off the airplane actually. That is due to the different plants, the different food, and different culture.

MC

I am just perhaps thinking about there might be other countries that have a completely complementary type of smell pallet to Japan. In order to create this kind of a database, perhaps a certain country would be really interesting to add this kind of data, to your database.

Prof. Touhara

I have never thought about it. Well, several countries have cultures of fermented food, and that might be a really interesting target. For example, in Asian countries, each has really stinky smell of fermented food, and each country's people really love that kind of fermented food. Even in Japan, we have that culture. That might be the kind of interesting target too.

MC

Thank you very much.

Ishikawa-sensei, if it is all right with you, I would like to ask you another question.

Actually, this kind of AI for medical usage and autonomous driving – these two fields are really all around us. I wonder if you might enlighten us on a couple of development options in these fields.

For example, I think right now, we have these kinds of automated driving cars but the application is still limited. To what extent do you think that your type of technology can make the application in society quicker? Would you have any comments on that?

Dr. Ishikawa

Sure. Our project actually aims at making autonomous driving in the society earlier. Our technique especially aims at safety for the Level 4 where the car needs to handle many, many situations, and especially applications to city roads. Now there is a Level 3 driving system but it is limited to the highways. But the situations the car needs to handle is quite different from highways to city roads. That is actually an explosion of different situations. Our project aims at tackling that difficulty and then make a value of our style by solving it ultimately.

MC

Thank you.
If I may, moving towards the medical field as well, I heard myself that at the moment, already AI is being used in order to make diagnosis. To what extent are these technologies already being used in our current society, to your knowledge? Or when do you expect that these kind of AI technologies for diagnosis are really going to become mainstream?

Dr. Ishikawa

Actually, maybe the current AI systems will come to the society possibly early because it is quite different from the autonomous driving. In autonomous driving, it is really hard to expect the human user to work with AI because we need to quickly react to the situation, but currently in the medical field, it is felt that human doctors and AI systems can together to make some diagnosis system. That said, we may not have more applications like automated doctors, but we may expect the use of the medical diagnosis by AI. For example, eye diagnosis has a good performance in AI, so I think we can have complete applications in near future. Actually, there are already accepted commercial products.

MC

Okay. Thank you very much.
If I may now I'd like to move again back to Dr. Takahashi, for another question. I see there are a couple of more questions to you regarding specifically international cooperation. You have already covered it before. If there is still anything you would like to add, please do not hesitate. But before that, I was wondering this kind of robots and laboratory that you have presented, in the lab, is there a need for them to be humanoid-type?

Dr. Takahashi

The short answer is, no, there is no need to be a humanoid. But there are some good things about using humanoid robots. There are basically two things. One thing is that, as I mentioned in the presentation, we can use the same equipment and labware exactly as the human operators are using, without modification. We can set up new experiments much more quickly and at a low cost. The second reason is tacit knowledge. If the robot is humanoid, it is much more easier for human experts to see if it is doing it right or wrong, or what kind of improvement has to be implemented, so it is much more easier to transfer the technology from humans to robots. That is the reason we are using humanoid robots.

MC

That makes a lot of sense actually to do it that way.

Dr. Takahashi

I talk a lot about the humanoid robots because we use that in our small-scale projects. But the basic idea is to combine different types of robots and also humans to make laboratory operations much easier and more efficient.

MC

Okay. Thank you very much.
Is there anything else you would like to add about the current status of international cooperation at this time?

Dr. Takahashi

Because it is science, there is no distinction between domestic and international collaborations!

MC

Those are very true words. Thank you very much.

Dr. Takahashi

Can I ask a question to Ishikawa-sensei?
Your presentation was very nice and I liked it. What is the relationship between engineerable AI and explainable AI?

Dr. Ishikawa

That is a very good question. As you know, explainable AI has been a very, very large trend now in the world, maybe almost for 5 years. But most of the famous technologies explained why the AI made certain output by, for example, showing a specific part of the image. But that needs many intuitive explanations and some people may become biased with that. Moreover, it does not have a steady reliability with that. Our target is engineering. Explanation can be scientific or mathematical and we want to have assurances. That is the difference and for us explaining is just a bonus statement. We want to speak or we want to construct. We should have actionable AI techniques. That is the engineerable AI.

Dr. Takahashi

Thank you. How do you quantify reliability or the accuracy? How do you talk about those things in terms of a quantifiable measure?

Dr. Ishikawa

That is very difficult. Of course, in order to have quantifiable reliability, that is a part of our project. We are having some commitment with the automotive companies and the medical companies. But in what sense can they have confidence of their product when AI products are evaluated by accuracy of large datasets and 80% correct answers?
For example, for the automotive systems, we want to think of risks. In situations where the pedestrians are at the same part of the road, the accuracy must be more than 80%, I would say. Our technique and our project aim that we propose and also ensure AIs can satisfy such groups, with very granular performance there. That is one point, but your question may suggest a more socially-acceptable notion of dependability. That is, of course, our future challenges.

Dr. Takahashi

Thank you.

MC

Thank you very much.
Another question we have received is that in terms of the environment for researchers, like all of you three, who cross boundaries of academia and industry or boundaries of academic departments, what do you consider currently the biggest challenge or difficulty, remaining to further accelerate very high risk, and high impact R&D? Perhaps, I can start with Ishikawa-san.

Dr. Ishikawa

That is a really difficult question. As a software engineering researcher, in the software engineering reality, the challenge is that the companies are not satisfied with the daily development. There are still a lot of bugs in the current systems. They may not need very advanced techniques and they rather need solutions for their daily activities. But academic researchers tend to relate to the interesting and advanced techniques. There may be some mismatches here. But for AI systems, actually, companies are also, for example, looking for the state-of-the-art. I think that our project can take a good match there and have a good integration of academia and industry collaboration.

MC

Thank you.
Takahashi-san, would you have something to add?

Dr. Takahashi

There are actually some boundaries between research fields and also between basic research and applications. In terms of the boundaries between research fields, I do not see that as a big difficulty. I am always curious about what other people are doing, in even philosophy and literature, interaction between science and other fields. It is not a big problem for me, personally.

But a bigger problem remains in crossing boundaries between basic research and applications. I am actually involved in some startup companies while I am running a laboratory in RIKEN, a national institute. There are lots of problems to be solved between these different types of entities. Startup companies are becoming main players in innovation, recently.

MC

Thank you very much.

Perhaps, Touhara-san, would you have some comments?

Prof. Touhara

I think there may be some overlap with the previous comments but the first point is that on the academic side, it is really difficult to find the persons to do the risky projects because people like students or post docs have to write papers, so they do not want to do a really risky project that takes like 10 years. The second point is that the risky and high-impact project takes about 10 years or even more, not like 3 or 5 years. We have very few grants in the academic side that support 10 years. Also, a company cannot wait 10 years. They can wait a year or two, or 3 years at the longest. That is a big problem. Also, the stance is different. On the academic side, we want to know the truth and we want to do the science. But companies want to make something where they can earn money. The aims are different. I think those three points are something we have to overcome or consider in accelerating the high-risk, high-impact research.

MC

Thank you very much. Those are all very true points and I think with this we can conclude the Q&A session.

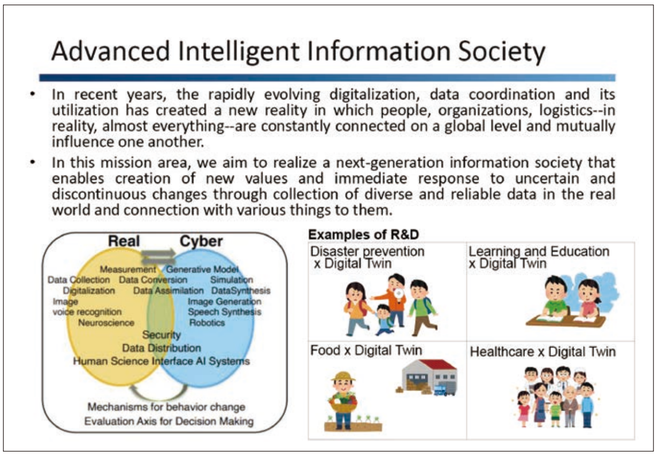
Let us now, I would say, give you a round of applause.

Overview of the New Mission Areas

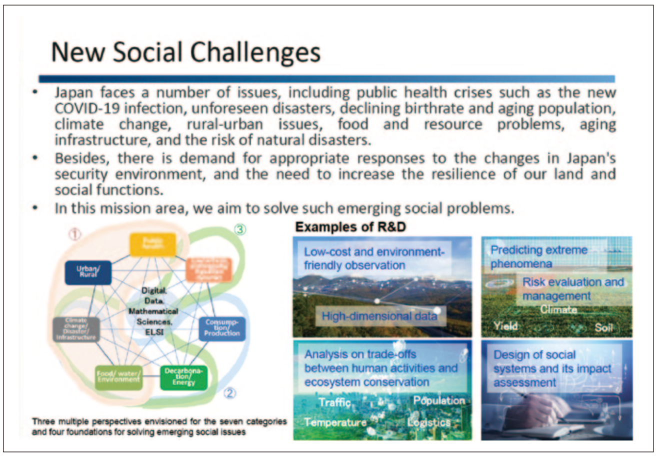
OGASAKA Yasushi
Director, Department of R&D for Future Creation,
Japan Science and Technology Agency

I would like to thank all the participants for joining today's JST Connect Webinar on the latest results from the JST-Mirai Program. Now, I would like to share some news from the program, which is a launch of the new mission areas.

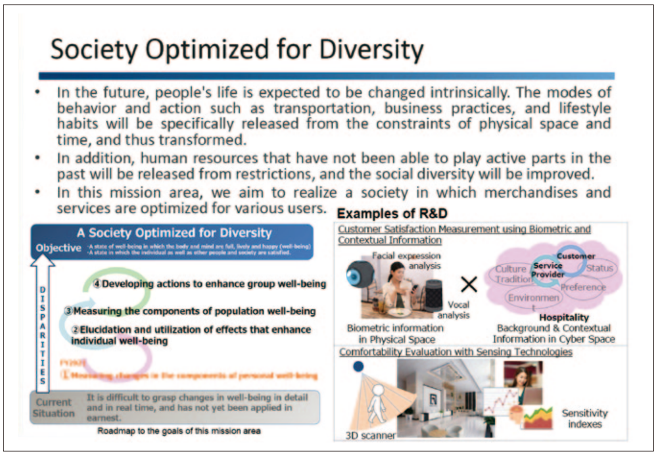
I would like to take this opportunity to share this news. As you might know, the call for proposal of the JST-Mirai Program is all thematic, and the call for proposals is issued under the priority themes, set every year for the call. Now, those themes are set under the concept defined as the mission areas. In fact, the projects presented today are all launched under one of those mission areas. Now, we have five mission areas so far. This April, we launched three new mission areas, as shown in the slide, with the names of the mission areas and the R&D supervisors for each of those. I would like to introduce these new mission areas with the following slides, very briefly. You can visit our website for detailed information.



The first one called the "Advanced Intelligent Information Society," aims to produce various services that you never see today that will only be possible by utilizing cutting-edge digital technologies such as artificial intelligence and the digital twin. For instance, the digital twin technology has already been adopted in the industry, as you might know, but mostly in the manufacturing industry. But there are high hopes or expectations to expand the application of this technology to other sectors. We expect many new ideas will be proposed, something like in the disaster prevention areas or learning education, food, healthcare, such and such.



Moving on to the next one called "New Social Challenges." Now, this area aims to tackle various social issues such as the Sustainable Development Goals but with new approaches, under the recognition that each pieces of issues are not isolated to each other but closely connected to each other. The project in this mission area is expected to focus on multiple social issues, related to each other, and to cover not only intervention but also monitoring and measurement of consequences of intervention, and to serve as a feedback loop between them. We believe such approach is necessary to implement the technology to society and solve the global issues such as SDGs.



The third one called the "Society Optimized for Diversity" will pursue so-called human wellbeing using the scientific methods. The wellbeing is actually a complicated concept and can never be treated by single displaying or a single approach. This call for proposal focuses on measuring individuals' wellbeing scientifically. This is quite challenging, and the R&D supervisors strongly recommends applicants to form R&D teams with diversity and multidisciplinarity. Also, the R&D proposal needs to consider diversity in inclusion in this research design. You might well know that the New Horizon Europe Program mandates applicants to consider the diversity in inclusion in its team formation and as well as the R&D design. This is an emerging use of component that we need to consider to carry out R&D. We do hope this approach will create new solutions to increase human well-being, both at an individual level, all the way up to the society level at large.

This is the introduction of the new mission areas and we hope to announce new projects this fall.

Once again, thank you for your kind attention, and thank you for attending today's webinar.

Contacts&Website

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