Exploring the future relationship of humans and machines

Machine capable of understanding distinctive characteristics of individuals.
Facing the exciting challenge of creating a new human-machine interaction.

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By drawing on its core technologies of "Sensing & Control + Think," OMRON has been committed to probing into the relationship between humans and machines. As such, various R&D projects are underway toward the goal of achieving a harmonious interaction between them. Professor Tomohiro Shibata of the Graduate School of Life Science and Systems Engineering at Kyushu Institute of Technology is engaged in research for nursing-care assistant robots by adopting robotics and brain science. Masaki Suwa of OMRON´s Technology and Intellectual Property HQ has been focusing on vision sensing since he joined the company. Dr. Shibata talks with Dr. Suwa to provide insights into the technological breakthroughs that are essential for harmonious human-machine interaction.

The key is differentiating between individual capabilities, which are not visible through Big Data alone

Shibata: The areas of my specialization are intelligent robotics and brain science (with a focus on computational neuroscience). By drawing on these technologies and the expertise in these fields, my research focuses on the theme of understanding humans and society as a system that can learn and adapt. With that understanding, we can create a system that can assist them. Above all, my study is characterized by a dual approach. One is a physical approach that involves considering a person and society as machines that can execute information processing tasks. Based on this, I am conducting essential and in-depth modeling of these systems. The other part of my approach is an engineering focus that involves modeling in a degree that is sufficient to predict output from the person/society or enable a system to provide assistance. I think that if the assistive system I have developed earns sustainable acceptance from society, it will become solid evidence of our success in modeling at a level sufficient for providing robotic assistance. As such, I set up the Smart Life Care Society Creation Unit at the Kyushu Institute of Technology in order to conduct R&D for the assistive system while verifying its feasibility in the medical and care-giving settings.

Keys to the assistive system are environmental adaptation and individual adaptation. Human cognitive and physical abilities have characteristics that differ greatly from person to person, and they change over time and by social circumstances. Thus, assistive systems are required to have autonomous capabilities to adapt to each individual, which has plenty of room for further research. By adopting the reinforcement learning theory, I am promoting research into robots capable of adapting to individual differences, including a robot that teaches physical exercise, and a lifestyle assistant robot. This theory is a highly developed version of the learning theory in animal behavior and brain science that has become a standard theory for autonomous learning in robots.

Suwa: OMRON, in its mainstay business field of factory automation, comprehensively handles everything from sensors to robots. In view of the progress in the relationship between humans and machines as well as related technologies, we expect that human operators and machines will continue to work together on the manufacturing floor for the next 20 or 30 years. In other words, it will still be in the distant future when all the manufacturing operations are fully automated. OMRON´s founder Kazuma Tateishi established a corporate philosophy, "To

the machine the work of the machine, to man the thrill of further creation." His thoughts behind this philosophy resonated deeply with me. As I mentioned earlier in relation to factory automation, this can also mean that tasks that only humans can do will continue to remain no matter how advanced machines become. I´m constantly thinking about how we can have machines support people in solving social issues. I felt that several key phrases that Dr. Shibata mentioned earlier, such as sustainable acceptance, environmental adaptation, and personal adaptation, are also aligned with the direction that OMRON is heading for.

Personal adaption is an especially important theme for us. Potential users of factory automation systems that we focus on are those who are inexperienced in operating a machine. We are devising ways to incorporate the knowledge of experts into machines for the sake of such inexperienced users. When exporting Japan´s manufacturing expertise overseas, we understand the difficulty of directly transplanting the knowledge we have developed in Japan to overseas due to cultural and language barriers and other obstructions.

Today, automotive trends are more and more oriented toward autonomous driving as a means to prevent accidents and traffic congestion. Even so, we think it will be a long time until we have a society in which fully autonomous driving will be enabled. So the necessity for a driver interacting with a car in some way or another will be with us for at least 20 more years. With this in mind, we now concentrate on the development of technology to realize a level of driving automation that makes driving more secure, more comfortable, and more enjoyable for the driver. Take the example of supporting an elderly driver with cognitive impairment. The conditions of elderly drivers are diverse and vary greatly from person to person. There is also a partial tradeoff between safety and comfort, so the challenge we face is how we can combine these two qualities without compromise. But the degree of non-compromised combination of safety and comfort largely depends on the individuality of drivers. Thus, thinking in terms of "averaging" will no longer be applicable for today´s social structure.

Shibata: In science, for example, it has been common to write something like "Study with mice using averages over them has led to a conclusion," which ignores the unique characteristics of the individual mouse. But recently, the factor of individual differences among mice has sometimes been pointed out. Even mice from the same family can cause a difference in experimental performance depending on the environment they were raised in. Scientists began to recognize the importance of keeping a record of meta-information indicating the way a particular mouse was raised, experiments done in the past using that mouse, etc. Professor Noriko Osumi of the Graduate School of Medicine at Tohoku University launched a new academic field to focus on "Integrative Research toward Elucidation of Generative Brain System for Individuality," funded by MEXT. This field stresses the importance of scientifically understanding diverse forms of individuality and making effective use of this knowledge to contribute to society. I'm also serving as a leader of one of her project teams.

Dr. Masaki Suwa

Suwa: I understand that we must again give in-depth thought to the use of averages. You say that keeping a record of meta-information is very important and that's a very interesting point. In the world of sensing, approaches using Big Data and Cloud have worked out effectively, leading to progress in verifications. By contrast, the importance of adding such information as the environment in which the sensing took place, etc. has not been fully confirmed. In manufacturing, we are actually aiming to raise the level of quality control by taking information, such as process conditions under which the product was produced, and adding it to the sensor-monitored product data. I wonder how we can use meta-information that is difficult to quantify, such as degree of proficiency or skill. One thing that may provide clues is to return to the "small data and edge" approach during the course of pursuing improvement in data quality.

Shibata: My research on using a reinforcement learning agent to accelerate human learning of a physical exercise, which earned the Best Paper Award from the Japanese Neural Network Society in 2015, was a study about a robot that assists a person in learning darts, which achieved individual adaptation. The reason that we used darts as the target exercise is that it involves one of the simplest movements in terms of the throwing action. Scientific research should start with something that is as simple as possible. While engaged in this research, we found there is not much difference in their throwing motions in detail among skilled players. By contrast, the playing styles of unskilled players vary considerably. I used to envy people doing research on professional athletes, because it seems easier to apply mathematical engineering to professionals. I also thought it was a lot more "cool" than what I was doing. (laughs)

"Small data and edge" is exactly what is needed for the subject of assisting unskilled players in improving their skills. We first tried to identify what makes the biggest difference in movements, by viewing exercises between skilled and unskilled players. We also tried to identify the feature value that best describes the poor performance of unskilled players. We then sought to determine which of a robot's motions are optimized for assisting novice players.

Suwa: From what you said, I can see the importance of extracting the relevant feature value and breaking it down. The clothing assistance robot in your research also expresses a key factor for smoothly providing assistance in a low-dimensional space, which impressed me very much. I'm curious about which feature explains the poorness of my own play. (laughs)

Dr. Tomohiro Shibata

Shibata: We identified differences between skilled and unskilled players statistically based on measured data by using motion capture. This helped us design the method of robotic assistance. To improve a dart score in a short period of time, we used a trial-and-error-based model-free "reinforcement learning" approach to gradually decrease the robot's assistance as the subject of our experiment becomes better at playing darts (individual adaptation based on AAN: Assist-As-Needed). I think we should focus more on model-based reinforcement learning because the use of a model can reduce the number of trials. In the case of factory automation, the perceptions that skilled workers have about unskilled workers through many years of experience, such as "Beginners are poor in such and such areas," may be useful for determining the target feature value and for designing the model, which can be a theme of our future research.

Suwa: That´s an area that is still not addressable by means of current AI technology. If the research advances in the direction you mentioned, do you think it will be possible to apply what we have developed for manufacturing to other areas involving human-to-human interactions, such as in medical settings or a care-giving environment?

Shibata: Well, that has already been taking place in the education sector. For instance, a leading private correspondence tutoring school now sends a workbook suitable for each student´s capability instead of sending the same one to all students. This is one example of a model-based approach. So far, I´m not aware of any cases of using this approach in the medical or care-giving sector. But, because quick cultivation of caregivers and medical professionals is in high demand, we should further generalize the latest skill improvement assistance technology so as to expand uses into the medical and care-giving sectors.

Harmonization of robotics and brain science for enhancing human creativity

Suwa: Based on our belief that machines must autonomously acquire what humans perceive through the five senses, OMRON has embarked on research in this area. Dr. Shibata, can any approach in brain science, your field of specialization, be applied to engineering as well?

Shibata: I don´t think that detecting what is perceived with the five senses has developed far enough in the field of brain science. As for vision, technology has advanced quite a bit. So it has become possible to a certain degree to see what a subject is seeing at present, or even guess what kind of dream the subject is having by combining an fMRI system and machine learning. Neuroeconomics, which uses brain imaging technology to study the science of decision-making, has also advanced remarkably. It is becoming possible to understand the human process of decision-making and behavior selection in terms of the function of the entire brain, including various cortexes in addition to the basal ganglia system in the deep brain.

Suwa: There are two important aspects of our research. One is delving into the brain mechanism, while the other is the question of whether a certain type of information reaches the basal ganglia, which plays an important role in forming goal-oriented behavior. For the second one in particular, it is essential to extract information in a form closest to the actual form when working with a sensor, and that is the technological area we should be addressing.

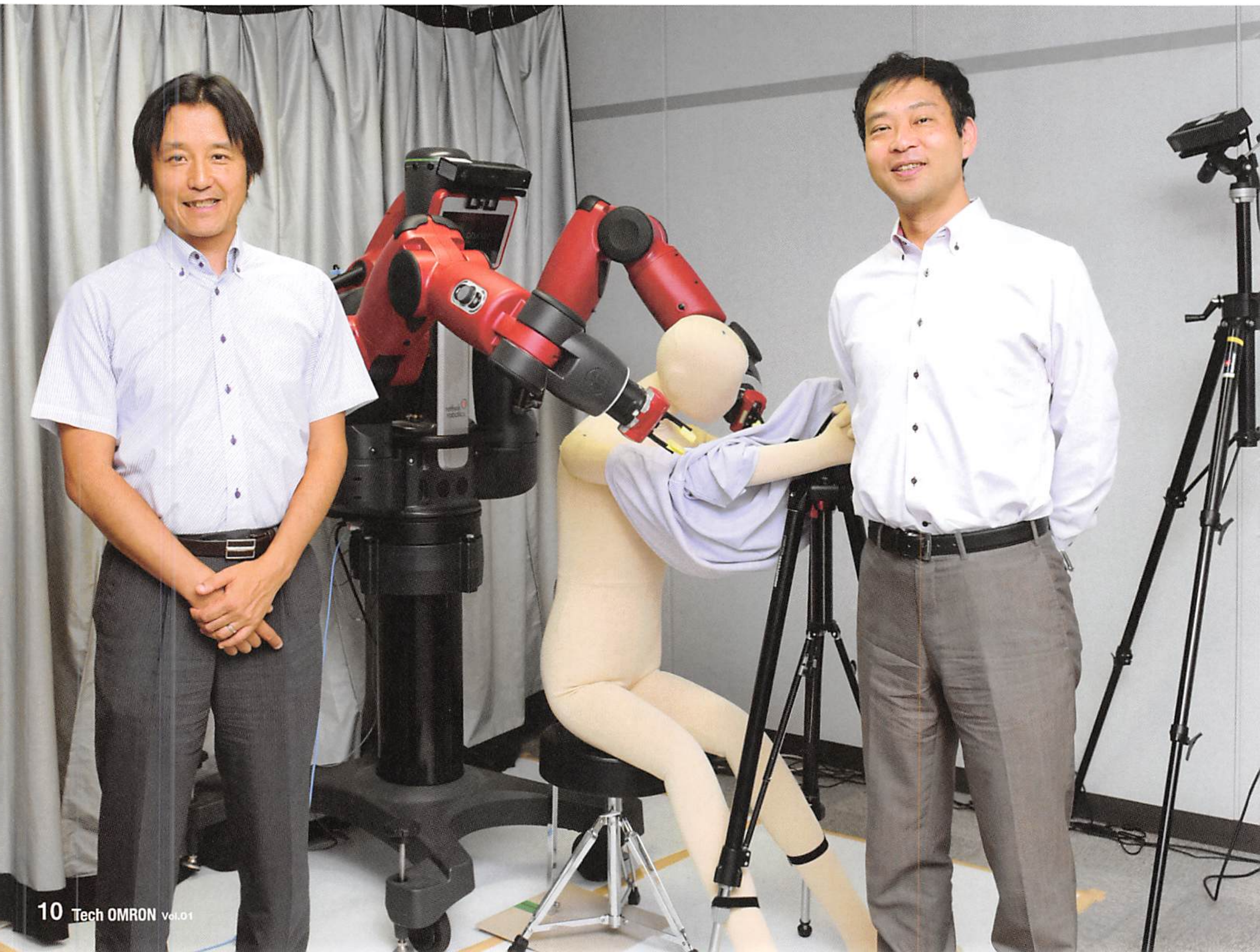
Shibata: In reality, it is impossible to directly see the deep brain area, but it has become possible to easily monitor the activity of the prefrontal cortex at a shallower part of the brain, using a commercial wearable brain imaging device that employs near-infrared spectroscopy. The MRI that records the brain of a human subject lying down on a bed can deliver activity information even from the deep brain with high resolution. By contrast, a wearable unit can monitor only a specific part of the brain with low spatial resolution. But its advantage is its ability to monitor brain activity in a real-life environment. For example, just by monitoring the prefrontal cortex alone, we will be able to detect various types of information, including attention and concentration, reward, and emotion. As such, we should be able to construct an assistive system while gathering evidence on-site by means of brain activity data, instead of relying solely on previously acquired knowledge.

But the currently available technology cannot recognize human thought. So it is important to develop technology that calculates human thoughts through communication with a robot as a practical method. I think the AAN theory I mentioned earlier is useful for communication as well. For example, with a car navigation system, we sometimes feel like turning it off if its guidance is too persistent. If a driver turns off the navigation system before it can interact with the driver to warn of inattentiveness, the machine is no help in avoiding an accident.

Suwa: I′m the type who turns it off immediately. (laughs) There is no doubt that we should delve into what is recognizable through sensing. But to be more practical, we should also use model-based or model-free (trial-and-error) interaction and verification. On the production floor, there are both skilled and unskilled workers who find learning bothersome, so optimized tuning is needed in many cases. Each factory has its unique characteristics and know-how of its own for raising productivity, so the necessary information varies from factory to factory.

Shibata: I guess so. That′s true especially for the manufacturing floor.

Suwa: I think modeling must be two-faceted: one for understanding humans and the other for determining what a machine should do. Listening to what Dr. Shibata said,



I learned anew the need for letting machines understand that humans have individual characteristics so they are different from one another. Moreover, I realized the importance of continuously refining our sensing and control technologies to identify optimal interactions, based on the assumption that it is impossible for humans to 100% understand one another.

Shibata: Another difficult challenge in reinforcement learning is how to determine a reward function, or a goal. There are two methods: one is that a person arbitrarily determines it based on his/her knowledge. The other is estimating a human reward function based on the human behavioral data acquired during his/her learning. Note that a reward function cannot be determined uniquely. Ultimately speaking, what makes a person motivated or happy differs from person to person, so individual adaption technology is necessary. In the end, it comes down to philosophy. A company like OMRON with deeply instilled corporate principles is wonderful.

Suwa: Our mission is: "To improve lives and contribute to a better society," and the OMRON Principles centered on this mission are at the heart of our technology developments. In our daily work we always refer to these principles and relate them to our work. By putting these principles into action and confirming that what is stated is correct, we are always focusing on developing technologies that can help solve social issues. Talking with Dr. Shibata, I was very inspired and motivated to generate new ideas regarding human-machine interactions and the tasks machines should perform. Thank you very much, Dr. Shibata.

Dr. Tomohiro Shibata
Graduated from the University of Tokyo in 1991, and received a Ph.D. from the Graduate School of Engineering at the University of Tokyo in 1996. After working as an associate professor at Nara Institute of Science and Technology, he became a professor at Kyushu Institute of Technology on January 1, 2014. He is a member of the working group for the national strategic special zone in Kitakyushu focusing on nursing-care robots. He is an executive board member of the Robotics Society Japan, and an executive board member of the Japanese Neural Network Society.

Dr. Masaki Suwa
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Field of specialization: Vision sensing. He has engaged in R&D for signal processing and machine learning algorithms, as well as 3D imaging theory and algorithms.

Dr. Shibata and Dr. Suwa discussing the robot's learning method and motions to assist in everyday activities, in front of the robotic arms assisting in dressing. This is one of the main research projects being conducted at the Smart Life Care Society Creation Unit headed by Dr. Shibata. This research is aimed at giving smart nursing care by making maximum use of ICT/IoT and robotics.