“Welfare Engineering at the Core
Searching for New Potentials in Science and Industry

Interviewer: Hayato Kuroki, Special Assistant

—— First, could you tell us about how this laboratory was established?

My field is called Rehabilitation Engineering, and it's been thirty-odd years since I started. In the beginning, I was part of a medical engineering lab where we were applying the technologies of electronics engineering to medical devices such as artificial hearts and CT scans. That's how I got into the field. At the time, Hokkaido University was the only place with a medical engineering field, and I joined their Medical Electronics Research lab as a Master's student. For the next two years, I had the extremely rare experience of being able to take courses in medical subjects like physiology and anatomy while pursuing my own themes.

——You were involved in a wide variety of areas, weren't you!

About half of the people in our lab were medical doctors, and since the field of medicine is so diverse, that their background also varied-radiology, internal medicine, surgery, and so on. The other half of the people weren't just from electronics, but also mechanical engineering and materials engineering. People from all different fields were doing research in one lab, trying to figure out how to put technology to work for the sake of medicine.

——Has your work always been tied to medicine?

Back then, everybody was doing cardiac research, which is one reason that I was working on measuring strain on the heart during exercise. But I realized that when it comes to doing research like that, you have to enter a medical school if you want to follow through to the end. Besides, the values of medicine and engineering are always going to be different, aren't they? It comes down to wanting to help people on the one hand, and wanting to bring something to fruition as an industry on the other. That's the fundamental difference. So what occurred to me, in the end, was rehabilitation engineering. I thought that there must be a way to use engineering to help people who had suffered impairment or loss of function. Or, with the power of engineering, if someone were missing a hand, we could build an artificial hand and make it seem just like their own-that's the kind of field I was aspiring to.

——In that sense, we could say that you have your roots in engineering.

My roots are in engineering, but I share the values of the medical field, in that I want my work to be useful for people. My research is what they call interdisciplinary. Nobody was doing this 35 years ago. Maybe it was because there were always a lot of composers and musicians in my house, but the first thing I looked into was whether there was a field called rehabilitation engineering where they did research on sound, my old friend. I was hoping to revive the pleasure of music for people who couldn't sing because they had lost their hearing.

——Specifically, what kind of research did you do?.

The first thing I worked on was a device called a tactical vocoder, which lets the hearing-impaired "hear" voices with their fingers just like the blind read Braille. With Braille, it's possible to read ten characters per second-fast readers, anyway. When people speak, they use about five characters per second. Since you can read ten characters per second with Braille, we took five-character speech and converted it into a stimulus that can be felt with the sense of touch, just like

Braille.We were sure that people would be able to understand if they could read well with their fingers, so we developed a device that would let them "hear" voices with their fingers. This research took a really long time, but it was featured in the NHK (Japan Broadcasting Corporation) documentary "Hearing A-I-U-E-O With Fingers" and became quite well-known.

——Is that the research you did as a Master's student?

I dealt with it in my Master's thesis, but it took about five years to actually complete. That research provided the opportunity for me to establish myself in this field, but at the same time it made me realize how terribly difficult rehabilitation engineering could be. In other words, when you're hearing with your fingers, it's a question of whether your brain can properly process the stimuli as words. The information picked up by your fingertips travels to the brain, then it's converted into speech and understood as language. If the information doesn't pass through that way, then you can't understand it. Even if vibrations from the fingertips get transmitted, it's up to the brain whether they're heard as words. On the other hand, it's also possible for the brain to change so that it can accept words like that. Nobody knew anything about the mechanism by which such a change might occur.

Socially as well, it's hard to introduce new technology in a field of education like this. Cost was a major problem, and the selling price ended up at ¥740,000 [about $7000]. In the end, it was too expensive to sell. I thought, "That's the way it's going to be with this field," and I was thinking about quitting. What encouraged me to keep at it, though, was when the members of support groups for the hearing impaired told me that if possible, they would really like me to develop a device that could convert speech into text. They said, "We might not be able to understand with our fingers, but if you've come this far, surely you can turn speech into letters." So I decided to try my hand at building a machine that could convert spoken words into letters. That was the device that's called a "speech typewriter." What a tough task-I had to manage everything with the microcomputers of the day, just 32 kilobytes! I ordered a CPU from America and built my own computer, and I used a language called Assembler to make a device that could convert voice into text. At a speed of about 0.2 seconds, it had about 96 percent accuracy. The only thing was, it broke words into syllables: for example, it would turn the Japanese word ohayo into o-ha-yo. At the time, Japanese word processors had just come out, and in connection with that it became possible to convert syllables into Kanji (Chinese characters) so we made a product out of it. It cost ¥1.5 million [about $13,000]!

Before putting it on the market, some students who made the device started up their own venture company. That was about 25 years ago. This was at a time when the industry-academia collaboration was completely unheard of, and it was strictly forbidden to do any research for one's own profit in academic institutions. Under those conditions, they developed the product secretly in the lab and started up a joint-stock corporation while they were Master's students. That's the company that became today's "B.U.G. Inc., *1,"the pioneers of venture business.

——The results of their academic work became a product, and then they created a company to sell it?

In that company, they started out by devoting themselves completely to creating assistive devices for the hearing impaired, but the selling price wound up at ¥1.5 million. However, they were surprised when Dai Nippon Printing unexpectedly showed an interest in the machine. At the time, the number of workers who could quickly lay type was dwindling, and they figured that if they could get somewhere around 90 percent accuracy even with novices just reading out the original documents and converting them into text, then it would come in handy around New Year's or the end of the fiscal year. They used the machine for seven years. That's when we realized that there was a way to make a business out of this: of course, the hearing impaired could still use the machine, but we could expand the range of applications as well. A device designed under the strict conditions required to allow the hearing impaired to use it can be expanded more broadly into the field that we call today "universal design." We figured that we could drop the price once the device had come into wider use, and as a result, we would be able to deliver the devices to the hearing impaired who really are in need.

—— In what ways are you furthering the research on speech recognition at RCAST?

On the technology side, we're making full use of both the Internet and speech recognition devices. Personally, having worked many years in the field on research to promote the well-being of disabled people, I think that we shouldn't leave everything up to machines, but rather have people use machines to help people. It might seem like common sense, but I think that in this field, this is the fundamental way in which machines should be used. We should let machines do what machines are capable of doing, but let humans do the things that machines can't do and that humans are particularly skilled at. I'd also been thinking for a long time about industrial applications, but after coming to RCAST I received funding and got support from TBI" (Technology Business Incubation),*2", and suddenly my ideas started taking shape.

Speech recognition devices are extremely difficult to develop because they deal with problems that can't be solved without the kind of high-level processing that the brain performs. Today's speech recognition devices are always highly error-prone, and when you get a different person with a different voice, the machines can't cope. It's impossible to get over this huge wall with today's technology. Therefore, since we have achieved about 95 percent accuracy as long as there's a designated speaker, we've got to use the system that way. If we take something that someone said and have it repeated by a person whom the machine recognizes, then we get 95 percent accuracy. In this way, no matter who's speaking, the accuracy rate remains high. There are several problems that we have to resolve if we're going to develop this into a bigger business. One of them is the language barrier. For example, when someone speaks in English, how could we have that come out in Japanese? If we could achieve that, surely it would meet a serious need. Of course, we will anyway need people who are capable of simultaneous interpretation.

Using networks over the Internet, regardless of where the speaker or the person who converts their speech to text might be, it's possible to send information and have it sent back as text. No matter where a meeting is being held, even if the interpreter's not present at the meeting, you can transmit the voices to the interpreter and have the translated information sent back. The audience, the speaker, the interpreter, the person who converts speech to text-it doesn't matter where anybody is! You can use interpreters at venues where there aren't any interpreting facilities, and if you add up the cost of things like travel, this system will be much cheaper. Once this service gets established, even people in their homes will be able to work. For example, a visually impaired person will be able to listen to speech and convert it into text. I think this will make it possible to provide employment opportunities for disabled people who find it difficult to get out of their homes. In my lab, this is the project that we're currently tackling with the most enthusiasm. Our work is very highly regarded at RCAST, and we've received generous funding. We're now in the middle of setting prices, with plans to make a business out of this in 2005.

Actually, we put this service into practice at the International Film Festival held in Yubari, Hokkaido, in March 2004. They needed to translate four languages into Japanese, so first we sent the voices down to an interpreting center in Tokyo. From there, they went to the staff in Sapporo, who converted the information into text, then the textual information was returned to Yubari, where it was displayed on a screen. This had a huge impact. Now, a convention planning company, an interpreting company, and B.U.G., the company started up by my students, have formed a partnership to think of ways to popularize this technology in the future.

“Mynahs, Parakeets, and Bats
Practicing Science by Solving Familiar Problems

——You're making progress in a variety of ways, aren't you? Providing barrier-free linguistic services for so-called able-bodied people as well as the hearing impaired, linking that to the creation of new employment opportunities, and so on.

Since it became a business along those lines, we had achieved one of the functions of engineering, but the science was still lacking. In other words, if we ran into a snag, we would have nowhere to turn. It wouldn't really be engineering without that scientific foundation, so we decided to tackle a variety of scientific problems. Thinking that working on simple, familiar problems would lead to the fundamentals, the first thing that we worked on was mynah birds. We wanted to find out why mynah voices resemble human voices so much. So we bought some mynahs, analyzed their mimicry and dissected their throats, and we realized that the waveform of their voices is totally different from humans. Even so, to the human ear it sounds just like they're speaking. Gradually, we learned that the human brain processes their voices just like human voices, even though the waveforms are different.

From there, we thought that we might be able to create a "voice" like the mynahs', even if it sounded somewhat unnatural, so we developed a pitch controlled artificial larynx. We made it for people who've lost their voices after having laryngeal cancer removed. It's essentially the same concept as the mynah, so the waveform is quite different, but it produces a sound that sounds just like a voice to the human ear. That way, even without vocal cords, you can send sound out of the device and move your mouth to turn it into a voice. When research is founded on solving familiar problems, these are the kinds of results that emerge.

After that, we worked on parakeets. I had just happened to hear from a TV company about a genius parakeet that could do things like recite the Heart Sutra. They wanted me to look into it, so I went all the way to Fukuoka. After doing some research, I found that parakeets and mynahs were totally different. That's when another big puzzle appeared. Mynahs and parakeets both have voices that resemble those of humans, but their vocalization is completely different. Moreover, they can make plosive sounds-"pa," "ba," "ma"-with their mouths open. It's impossible for humans to make those sounds without closing their mouths. I just couldn't understand how they could produce those consonants. I hypothesized that they were making the sounds directly from somewhere in their throats, but even though I dissected their throats, I couldn't figure it out.

About 15 years went by, then one day I had a big surprise while watching the ventriloquist Ikkokudo on TV. He was saying "pa," "ba," and "ma" without closing his mouth. I thought that this might help me solve the problem, and since I was at Hokkaido University back then, I went to go see one of his shows at a hot springs resort near Sapporo. I went backstage afterwards and told him, "This is incredible! You might tear down what's been considered common sense for all these years." I said, "I could never figure out how mynahs and parakeets can say ʻpa,' ʻma,' and ʻba' with their mouths open, but you can do it!" If we could solve this problem, it would be useful in a number of ways. For example, patients with cleft lip and palate can't close their mouths, and they can't say ʻpa,' ʻma,' and ʻba' because they don't know how to vocalize them. When I told him that, Ikkokudo said, "If it would be of help, then please study me." It turned out that he didn't know how he was making those sounds himself. So I asked him to let me do some research on him, and a few days later, I attached sensors to him and recorded his voice and image. After analyzing his voice, I solved the problem.

In October 2004, the 3rd International Ventriloquism Festival was held in Tokyo, where professional ventriloquists from all over the world gathered. I was asked to make a speech there. They work hard on "pa," "ba," and "ma" too, don't they? Since I understood the mechanism behind it, I gave a demonstration with videos and so on in front of an audience of about 200. They were so delighted at hearing that what they work on just for entertainment might actually help others. I've studied ventriloquism quite extensively, and I learned some incredible things. Actually, it's not that I discovered this mechanism, but rather that others knew about it through experience. There's a part in the book written by world-famous ventriloquist Valentine Vox that deals with how to make "pa," "ba," and "ma" sounds. It was exactly the same as the hypothesis that I had come up with.

——Which was?

If you want to say "pa," first say "ta" with your mouth open, then reposition your mouth to make the "a" sound in "pa." The changes your mouth undergoes are different between the "a" in "ta" and the "a" in "pa." So if you just imitate that change that takes place at the end of the sound, even if it starts out as a "ta," it sounds like "pa" to the human ear.

——If you don't mind my changing the subject, how did you come to be involved in Professor Hirose's Sensory Information and Communication Project?

Ever since I arrived at RCAST, I've been working in collaboration with Professor Fukushima who specializes in the barrier-free studies, but I'm also participating in Professor Hirose's Sensory Information and Communication Project. It all started with bats. I knew what it was like working with mynahs, but we wondered if it would be possible to analyze how bats can find prey in the dark by detecting the reflected ultrasonic waves that they emit, and to create a device equipped with the same mechanism.

Normally, students at schools for the blind use canes, but obstacles that come close to their heads, like tree branches and eaves, are quite frightening. We wanted to make a device that would alert them to such things, and the first thing that came to mind was bats. After conducting various studies, we managed to create a device that generates ultrasound waves like bats and converts the reflected sounds into the sounds audible to human ears. We took that device to the blind students, but they had no use for it. They told us, "We don't need anything to do something like that." Actually, they go by "feel". So then we thought, "What in the world is 'feel'?" and we studied it for five years. "Feel," or perception of obstacles, is all about sound, subtle changes in the sound field. We can't hear it with our ears, but it's comprehensible through the brain's compensatory functions. After the loss of sight, the sense of hearing begins to play a more active role in spatial recognition that had not previously been required. People can tell what's on the other side of a wall and, depending on the person, some can even tell the texture of clothes people in front of them are wearing. Some can perceive a 6-cm disk that's about 4 meters in front of them. If you use this mechanism well, it's possible to artificially create a sense of "feel" and project imaginary obstacles. If you line up a bunch of speakers and control them with a computer, you can feel the presence of obstacles that aren't really there. This ends up tying into research on virtual reality, in which they're trying to make people recognize imaginary objects. Unlike the normal VR method of inserting one image into another, we insert sounds into a sound field and make imaginary obstacles out of them. Since I was doing research like that, I ended up working together with Professor Hirose.

The results of this research will lead to new technologies, such as allowing robots to walk around obstacles in the same way that seeing impaired people avoid them. Figuring out what the "feel" is is a scientific endeavor. Also, if we can present our hypotheses as cognitive physiology about how the brain's functions change when the sense of sight is lost, that would contribute to science as well. With this research as a foundation, we'll also be able to make a lot of progress in the field of engineering. I've been told that rehabilitation engineering would never make any money, that it would never amount to a real academic discipline, and that it wasn't even engineering. But at RCAST, there's the view that, to the contrary, rehabilitation engineering is about removing barriers and that it's going to be the future of industry. I've been here for two and a half years, but the speed at which my research progresses has totally changed.

“Tactile Support for High-Speed Aural Comprehension, Artificial Muscles Made with Metal Hydride Alloy

——In addition to that, are you currently involved in any new collaboration with companies or other labs?

I've revived "TouchVoice," the device for "hearing" with one's fingers, which transmits the vibrations from speech with little pins. That's another collaboration with a company. In 2cv004, a blind man from IBM took his doctorate at RCAST, did research on converting online textual information into speech by well using compensatory functions. The speed at which you read aloud comfortably is actually quite high. But if you read too quickly, you can end up losing track of what's most important in the text as a whole. When a headline or a word has turned red, that's quite important information too. So I thought, what if we transmit that information with a tactile supplement device for the hearing impaired? While you're listening to the voice at high speed, "TouchVoice" sends a little tactile stimulus whenever there's something important, and it makes you stop and say, "Hey, what was that?" You can also feel it when lines and fonts have changed. This way, the reading speed becomes about 2.5 times faster.

——How about your involvement in the medical field?

Due in part to my having worked in a medical lab, I've always had strong ties to the field of medicine. I went to Stanford University for a year to study artificial inner ears, and I thought about a lot of things during that time. Things like differences between Japan and the US, differences between medicine and welfare, etc. I think that this field of rehabilitation engineering is going to gradually overlap with medical engineering.

For 20 years, I've been working on artificial muscles for people with decreased muscle strength of limbs. When you cool or heat an alloy called metal hydride alloy, it releases or absorbs hydrogen 1000 times the volume of the alloy. If you can make that hydrogen go into a container, the container expands and shrinks, generating incredible energy. With 100 grams of this alloy, you can lift a person who weighs 100 kilograms. I've been making progress on research along these lines, such as developing assistive devices using this alloy, and attaching such devices to arms in order to loosen up joints.

This ties into robotics as well. Actuators using hydrogen are extremely resilient, so we can use them to make robots that won't cause damage if they bump into things. Ultimately, everything that I've been working on up until now will be brought together in robots. Attaching eyes to robots so they can detect obstacles, adding ears so they can comprehend speech, or enabling them to speak and feel, on and on. What I have in mind, for the long run, is for my work to come to fruition in the shape of a robot that can help human beings.

——The potential for developing your work for industry as well as for the disabled has become more of a reality, hasn't it?

Since there wasn't much of a demand before, up until now it just wasn't possible to make a large industry out of my work. There were also fundamental systemic problems, among others, so I've been collaborating with barrier-free labs and getting them to suggest the necessary social systems. I've also worked with researchers specialize in intellectual property to think about how patents and laws should be set. At RCAST, these things are all possible. We take our ideas that will easily take root in society to the legislature, and then with the social systems that the legislature creates, we can make an environment in which it's easier for venture companies to be born. If this succeeds as an industry in Japan, then in the future it will become an export industry. There's potential for it to become one of Japan's key industries.

I've been working in rehabilitation engineering for over 30 years, and I've gathered my thoughts about the field, including suggestions about how it should change in the future, in my book Fukushi kogaku no chosen [The Challenge of Rehabilitation Engineering, on sale 12/20/2004, Chuko Shinsho]. The first half features a lot of stories about my failures. The second half is mainly about how I finally started to believe that rehabilitation engineering could become true engineering after coming to RCAST.

“Overcoming the Barrier of Time Playing 100-Year-Old Voices from Wax Cylinders

——Your most unique project is probably your research on wax cylinder playback, wouldn't you say?

There was a time when the field of rehabilitation engineering was so difficult that I was thinking about quitting. I think it was around seven or eight years after I had become an associate professor. While I was looking around for my next theme, I got wind of some news that 73 wax cylinders used to record the music and voices of Ainu from the Kuril Islands had been discovered unexpectedly in Poland. The recordings were over 100 years old. The Polish man who made them had taken a wax cylinder recording device invented by Edison to the Kuril Islands, and there he recorded about 100 voices. After that, though, he committed suicide in Paris, and no one knew what had become of the recorded media. Many years later, someone just found them one day under the roof of the inn where he had been living. At the time, well, there were some political issues involved, but the Japanese Foreign Ministry and the Polish government negotiated, and a special JAL jet transported the cylinders to Japan. I worked on playing back the sounds from the cylinders for six months, but then I ended up going to America to work in the artificial innerear laboratory. So I was in the US when the NHK documentary "Yukar: 80 Years of Silence-The Secret Story of the Kuril Ainu Wax Records" was televised in the "NHK Special" series, I could not watch it.

The documentary is very interesting to watch even now, though. Back then, I spent a lot of time looking for Ainu who had come to Hokkaido from the Kurils, and I finally found three. I asked them to listen to the playbacks, and they would tell me, "Oh, that means such-and-such." I wrote down everything they taught me. At the time, they were all in their mid-80s, and they all passed away a few years later. So if I hadn't done that study back then, the mystery never would have been solved.

——That's research that you probably couldn't have done anywhere else but in Hokkaido, don't you think?

Since I was born out in the provinces, I always wanted to do things that weren't possible in big cities. Now I'm at Tokyo University, but that feeling hasn't changed. Everybody thinks about what can only be done in their particular places, don't they? For example, I think that we could create a new industry if we introduced IT into farming and fishery. No one bothers to think about such things in Tokyo. So nobody would ever imagine that there could be something to learn from the Ainu language. In that sense, I'd always like to concentrate on things that can only be done in the countryside. For example, if we're talking about Hokkaido, if we create original technology to solve problems related to snow, the cold, and open spaces, then maybe we could send that technology, as an export industry, to other northern regions that suffer from the same problems. Just like we're using regional "handicaps" as springboards for the development of new industries within Japan, I think it would be great if we could take Japan's current position in the world and turn it into a springboard for creating new industries, demonstrating Japan's unique strengths.

Recent Publications

Fukushi kogaku no chosen [The Challenge of Rehabilitation Engineering]. Tokyo: Chuko Shinsho, 2004.
Jinko genjitsukan no hyoka [Evaluating Artificial Perceptions of Reality]. The author and editor, Tokyo: Baifukan, 2000. Oto no fukushi kogaku [Rehabilitation Engineering with Sound]. Tokyo: Korona, 1997.
Onsei taipuraita no sekkei [Design for a Speech Typewriter]. Tokyo: CQ Shuppan, 1984.

Curriculum Vitae

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