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Tatsuo Arai

An interview conducted by
Peter Asaro

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Q: Okay, so we're rolling. I'm just going to ask you to tell us your name, introduce yourself, tell us where you were born and went to school.

Tatsuo Arai: Okay. I'm Tatsuo Arai. I'm a professor of Osaka University. Actually I have been involved in robotics research and development almost for 37 years after I graduated master's at the University of Tokyo. And at first I joined National Institute for Mechanical Engineer Laboratory. It was in the northeast of Tokyo, 70 kilometers from Tokyo. I worked there for 20 years and there I was involved in the research robotics. Twenty years. So I have been involved in many developments including a manipulator control, mobile robot, micro robot mechanisms, a special mechanism called a parallel mechanism. And in 1997, I moved to Osaka University to get a position for professor. And there I have spent almost 17 years. And I'm teaching robotics and also doing research on robots, of course. And currently I have two major topics. One is a mobile robot called Limb-Mechanism here. It has six limbs. And our major concept is we can use these limbs as a manipulator and of course leg. And our objective is to obtain the compact mobile robots capable of doing manipulation. And we have applied these robots in a little complicated environments. For example, of course rough terrain or ladder climbing or even walking on the ceiling if the ceiling has some grid. So it can the – hook down his body from the ceiling and moving. And another project is micro manipulation. This is a micro hand which has two fingers and each finger is driven by a parallel mechanism here. We have here two sorts of parallel mechanism and one finger. So maybe you can see three plates. And we have one parallel mechanism and another parallel mechanism here. And one finger comes from the middle plate through the whole of the top plate. And another finger comes from the top plate. And if you move this parallel mechanism you can just move this finger. And this works for supporting some small object, holding or releasing like this motion. Okay? And once you grasp the micro object, and we want to move the robot, you know. So in that case we only move this part of the mechanism. This mechanism drives two fingers at the same time so you can obtain some global motion. So we apply this micro hand to hold say this micro object, say a few micrometers to 100 micrometers size. And currently we are applying this micro hand to the assembly of the cell, you know. So we try to pick up cell one by one and precisely place the cells and assemble, well some sort of 3D, three dimensional cellular systems that means a tissue, okay? And so our challenge is to make a tissue by assembly in vitro. That means the outside of the body. Currently we have a big project, a national project which is supported by the Ministry of Education. And we spend approximately $2 million USD a year on this five year project. Of course we have a consortium including nine major research teams from different universities. Osaka University and Nagoya University, the University of Tokyo, Chiba University, Tohoku University and Women's Medical University in Tokyo. That's our current major projects.

Q: If you could go back a little bit and tell me when did you decide that you were going to become an engineer?

Tatsuo Arai: <laughs> Well that's a very sensitive question. Actually in my younger age, I mean in elementary school, I liked to make something. Even also I liked to disassemble something. And so maybe I played and built crafts or some small gadget or a machine. And so, and also I was good at math, physics, chemistry. So I decided to go to engineering school for that simple reason.

Q: Did you decide that you wanted mechanical or electrical or anything?

Tatsuo Arai: Well I studied at the Department of Applied Mathematics and Instrumentation Physics in the University of Tokyo as an undergraduate and master's. And so it's a little different from the mechanical engineering. But I was interested in mechanics or in mechanical things.

Q: And where did you do your Ph.D.?

Tatsuo Arai: Well actually I graduated master's and I spent 10 years at the mechanical engineering laboratory. And after that I submitted my Ph.D. thesis to the University of Tokyo and I got the Ph.D. in 1986.

Q: What was the thesis?

Tatsuo Arai: It's about a walking robot. All kinds of mobile manipulation including a bilateral motor operation.

Q: What was the company that you were working at for 10 years? Or the lab?

Tatsuo Arai: No, no, no. It's the National Institute.

Q: National Institute.

Tatsuo Arai: Yeah. It's affiliated to the Ministry of Economy and Trade and Industry. Yeah. So it's not a company.

Q: What was the first robotics project that you worked on?

Tatsuo Arai: Well it's care robot. I mean when I joined the laboratory, as they started the new project on patient care robot which could hold up the patient from bed and carry them inside in the hospital. And so I mainly worked on the mobile robot which has an omnidirectional wheel. Because you know in the hospital and the bedroom it is very narrow, so we need a very dexterous mobile motion. So that's my first topic in robotics. And I developed the sensors which can locate the mobile robot in a room. It utilized the ultrasonics. We had three different frequencies of ultrasonics. And we had three transmitters in the corner. And the robot has a receiver, three different receivers, and each receiver can detect the source of the sonic, ultrasonic. And so we could know the three different stations. And based on this information we can locate the mobile robot, including its direction. That's my first.

Q: And after you did your Ph.D. you stayed at the laboratory?

Tatsuo Arai: Ah, yes. After getting the Ph.D. I spent 10 years more. But 1986-1987, were lucky to me. I have a chance to stay at MIT in Boston for one year. And I stayed with Professor Tom Sheridan's robot. He already retired but he at that time he was very famous in the area of man-machine. At that time they called it a man-machine interface, so currently human-robot interaction or communication. So because at that time I worked on the teleoperation so I wanted to study more of his robot. But I changed my mind to completely different topics. Because at that time I saw a very interesting mechanism, it's a parallel mechanism. They developed the special arm which was used undersea. And they built a machine with six cables, you know, the top plate and they have six cables. And the moving six cables, they control the end plate. Of course it has some rope in the center which has compressive motion. Because you know the wire can only produce the, you know, tension so we need to make some compression to keep the end plate stable. So first I saw that mechanism. I was very interested in that mechanism so it's a part of mechanics. So then after I have been involved in the research and development of parallel mechanism and when I returned back to Japan, so I started the project to make – to build an excavation machine. Because excavation you need a big force, and also we needed to move the end, the dexterously. And I applied the parallel mechanism. So we built a big machine. So that's my – so first parallel mechanism.

Q: What were the challenges of designing parallel mechanisms?

Tatsuo Arai: Well you know, do you know strut platform? It's you know a very simple mechanism, you know. We have two plates and we have six pistons between two plates. And if you control the ceiling disk so you can get these six degrees of freedom. And so if you look at the mechanism carefully, the mechanism can produce the force, much force, in this direction because the piston on the ceiling does the direction. But in the horizontal axis we cannot expect big force. So my first challenge is to get isotropic force out of it. And I analyzed the statics and also I applied the singular vertical position to the Jacobian matrix and compared the forces

produced in every direction and to arrange the sitting position to get the isotropic arm force out of it. So that's my major work of that time.

Q: What work have you done subsequent to that?

Tatsuo Arai: Pardon me?

Q: What other projects did you do after that?

Tatsuo Arai: After that, well you know, at that time I was working on the mainly big machines. But sometimes when we developed the big machines, in the beginning of experiment it is very dangerous. So we cannot expect how it moves, you know? So sometimes I was scared, you know. It suddenly moved towards me. So and if I could work on the, you know, small machines, so I have no danger, you know, <laughs> guarding against the robots.

Q: Do you have experience of robots doing things they shouldn't do?

Tatsuo Arai: Yeah. <laughs> Yeah. So as my next idea is to make a micro hand. It's micro, this micro hand, you know. So as I mentioned, it's also the application of parallel mechanism. Because the parallel mechanism has nice features compared with the conventional serial mechanism, for example the, uh, it can produce this big force. And also we can expect a nice, good precision, accuracy and stiffness or high speed. And I was interested in the application parallel mechanism to the micro hand. Because we can expect a nice, good accuracy or precision. So that's my next work. And so I started the research almost 20 years ago. So now I have been working on it for 20 years or more.

Q: So when did you start working at the mobile robotics? So what got you interested in the mobile robotics?

Tatsuo Arai: Mobile robot?

Q: The walking.

Tatsuo Arai: Walking robot, yes. Well because my first work was a mobile robot, omnidirectional mobile robot. But it's a weak robot. So it doesn't – It can walk only on a flat plane. But sometimes we need to move on the rough terrain or even, well, climb up the wall. So I challenge to make a compact small leg machine. But I also wanted – I was also interested in

making a manipulation task. So we got a concept integrative locomotion to manipulation mechanism. So we called it Limb mechanism. So this is a prototype.

Q: So you mentioned some people you've met earlier at MIT. Were there other people that you worked with while you were at MIT?

Tatsuo Arai: MIT. Yes, of course. So they are working on mainly a man-machine system including teleoperation or bilateral control. And also they are working on the optimization or control theory. I'm not sure, what do you say in English? Maybe – system engineering or something like that.

Q: Are there any names of people that you were working with?

Tatsuo Arai: Youcef-Toumi. He's working on a teleoperation. And right, sorry. Forgot the name. Sorry. Actually they are not active in the robotics field now. They went to different fields.

Q: And then were there other people that you collaborated with after that who are still working in robotics?

Tatsuo Arai: In the United States?

Q: In Japan. Anywhere.

Tatsuo Arai: In Japan?

Q: Yes. Other collaborators.

Tatsuo Arai: Collaborators. Professor Fukuda, Toshio Fukuda. He's my best colleague. And because he and I joined Mechanical Engineering Laboratory at the same time. And we spent several years at the laboratory. And so since then we have nice relationship and collaboration with him. And actually he is involved in the other project, the bio project. And also Professor Makoto Kaneko in Osaka University. Also other good collaborator, Dr. Tamio Tanikawa in AIST. Dr. Kazuhito Yokoi also at AIST. Yeah, of course more. <laughs>

Q: Any of the other people that were influential early in your career?

Tatsuo Arai: The people influential to me? Well of course Professor Fukuda is a very nice guy. Yeah. You know, he is very energetic and aggressive and very talkative every time. And he suggests me many things. And sometimes he gives me a harsh word. <laughs> But it's – he's very kind, you know. Yeah, he's a nice guy. And of course Professor Makoto Kaneko. He was also, he worked at the Mechanical Engineering Laboratory and we spent several years. So he's also involved in our project.

Q: And in terms of the history of the Mechanical Engineering Laboratory, how much has robotics been a feature of that laboratory and when did they get involved in robotics?

Tatsuo Arai: The Mechanical Engineering Laboratory?

Q: Yeah. How is robotics situated there?

Tatsuo Arai: I say there used to be in Mechanical Engineering Laboratory. Now it's AIST because the government de-organized, you know, the National Institute.

Q: When was that?

Tatsuo Arai: Ten years ago or more. Maybe 2000. So before that the Mechanical Engineering Laboratory has 300 researchers. And we had, well how many? Forty or…fifty robotics researchers and engineers and I was one of them. And yeah, I studied many things there, you know, about robotics. Because the Mechanical Engineering Laboratory is one of the founders of the Japanese robotics, you know, intelligent robotics.

Q: And who sort of pioneered that work? Who are some of the early people involved in robotics that were around?

Tatsuo Arai: Yes, how many. Now they are too old, senior. But well, so many people. For example, Professor Nakano. He was the professor at Toho University but he retired. And also Professor Susumu Tachi. He is very famous in the teleexistence or telepresence. He is now in a professor of Keio University. And so there are yeah, as a main people, the founders of robotics. It's almost, you know, 37 years ago, so many years ago.

Q: So since you've been teaching at the University, do you train many Ph.D. students?

Tatsuo Arai: Yes.

Q: And have they gone on to teach in robotics or work in industry?

Tatsuo Arai: Yeah. Actually, I've given a course, two courses about robotics. One is for undergraduates, so very basic including kinematics or statics or dynamics, so robots, you know. Mechanical arms. In the master course I give, another course, which is more advanced including the current topics. And yeah. During my 17 years at Osaka University I had 12 or 13 Ph.D. students. And so but you know, the curious thing is you know I have just two Japanese Ph.D.'s. One problem with the Japanese university, the current Japanese university, so in the Engineering School the master's students do not want to go Ph.D. They prefer working for the company. So I'm not sure, but they are interested in getting money <laughs> rather than Ph.D. degree. So unfortunately to me, I have just two master's students going to Ph.D. And other students came from overseas. Southeast Asia, Middle East, Turkey, Arabic countries, or Mexico. So I've mainly educated foreign people. <laughs>

Q: And are they going back to teach?

Tatsuo Arai: Yes. Yes. They got a nice job in their home countries.

Q: So what are some of the big challenges in terms of the kind of 3D tissue construction?

Tatsuo Arai: Yes, okay. One of the challenges, you know, in the conventional sense we cannot create thick tissue because outside the body, in vitro, because they need oxygen and nutrition. So we need to introduce vascular blood inside. So we need to include vascular system in the artificial tissue. So that's a big challenge for how we create that tube-like tissues which we can flow the blood inside. And then we can increase the thickness and the size of the tissue in vitro. So that's the major challenge. And of course we need to position the every specific cell one by one at the exact place. So that's another challenge. And also we need to speed up the assembly. So we need a quick manipulation or we need to apply some microthreadic techniques. So inside the micro chamber so we can cultivate the artificial tissues or even assemble the cells to get the good size of tissue. So that's our challenges.

Q: And more generally for robotics, what do you see as some of the big challenges over the next 5 to 10 years in terms of the engineering of robotics and the development of new systems?

Tatsuo Arai: In a general –

Q: The really hard problems in robotics that you see in the next 5 or 10 years. If you solved them, robotics would make a big step forward.

Tatsuo Arai: I would possibly be interested in the application, especially in the service robotics. I mean to provide the services to the humans or society. And in that sense we need the robot safety. In my idea, I believe there are two types of safety. One is a physical safety. It's a conventional meaning, safety, you know? The robot does not harm the person, the people. And another safety is psychological or mental safety. For example, if you get the robot, suddenly he approaches to you, maybe sometimes you are scared or you're surprised. So in that sense we need to carefully design the robot motion as well as robot motion or robot behavior as well as robot appearance our outlook, you know, outlook design. So in that sense I have been working the psychological evaluation of the humanoid robot and with collaboration, collaborating with a psychologist. Actually in our groups we have a psychologist and currently she is working on the, you know, psychosocial evaluation to connect the many subjects. Once we have done the big survey and the evaluation, collecting people and the number of people is almost over 3000. And we show the robot emotions, robot appearance and they gave us their impressions for scores of some items.

Q: Did you see any surprising results?

Tatsuo Arai: Well, yes, in the academic sense. Their impression, the ordinary people's impression towards the robot is a little different from the impression towards the human. Maybe it's natural. But we extract a variation index and also we develop the variation scale based on this survey. And maybe it's helpful to design the nice robot which cannot give me some scales on this on, you know, about feeling to the human user.

Q: So one of the questions we like to wrap up with is what's your advice to young people who are interested in robotics as a career?

Tatsuo Arai: Oh. Well, you know, I'm not sure it fits to the U.S. or European people, but in Japan or Japanese writes mechanism, or you know, action robot. And in my experience any way we make action machine, first try and of course we need to consider <laughs> more before designing a building. But finally you need to make the action machine and realize your idea in the form of action robot.

Q: So just start building?

Tatsuo Arai: <laughs>

Q: Great. Is there anything we didn't cover that you would like to talk about? Any other things you did in your career that we've missed?

Tatsuo Arai: No. That's good. Yeah, that's it.

Q: Thank you very much.

Tatsuo Arai: Yeah, thank you.