Flagstaff AZ
1:28:08
m4v

Rudiger Dillmann:

An interview conducted by
Selma Šabanović
with
Matthew R. Francisco

August 30 2011

Q: So could we start with you telling us your name and where you were born, and when?

Rudiger Dillmann: Yes, my name is Rudiger Dillmann. I'm a professor at KIT, Karlsruhe, Germany. And I am German. I was born in Mannheim, Germany, in 1949.

Q: And when you were young, where did you go to school?

Rudiger Dillmann: Yes, of course one was primary school in my city, and then I went to a technology and natural science oriented high school, also in Mannheim. And at that time, I guess it would have been the early days of the first computers. At that time cybernetics was in favor, so I was very – and high school confirmed it, with cybernetics. And this was something I was really excited and decided to further in this direction. On the other side, my city is an industrial city with a lot of manufacturing industry, chemical industry, mechanical industry, and then I decided also to go more to technical areas, maybe related to automation and electrical engineering. Informatics was at that time not yet existing, so the first ideas on computers – there have been some pioneers. Zuse was at that time – I had opportunity to meet him on high school, and then there have been also pioneers in the fields, like Steinbuch. He was one of the founders of informatics in Germany; Bauer in Munich, where there are two schools. One is more theory oriented and Karlsruhe was more technically oriented. And so the idea to build computers, we have one of the first computers built in Germany. So I applied, naturally, for different places and Karlsruhe sent the first response, and then I went to this place.

Q: What were the other places you considered?

Rudiger Dillmann: Yes, at the time I applied to Munich and then Darmstadt, and also to Aachen. These are the large universities. Karlsruhe was very close to my city so I was not very happy as a student to be at a distance of 100 kilometers to my house of my parents, but then when I got the acceptance – and in parallel I had also some semesters in Heidelberg on medicine, and this did influence my career.

Q: And you mentioned that early on you came into contact with ideas in cybernetics. How did you come across works in cybernetics?

Rudiger Dillmann: Yes, it was some of my teachers in mathematics and in physics, and yes, also in religion. This was very strange. We did discuss very often on the future, what is good for working for in the life and what is a good education, what is important to understand of society. And then I got from different side this information that cybernetics is important for understanding the society, understanding technical systems. And I'm not sure if a teacher did understand very much, but they get us from journals papers, and then we discussed what is good for. And so I decided to go in this direction. So I started electrical engineering. And of course we had the classical areas – mathematical education, physics. And after that, learning the basics. There was a possibility to specialize and I went into control theory, systems theory and bio-cybernetics. And there I did study bio-cybernetics also about four semesters, which means two years.

Q: And was this in undergraduate still?

Rudiger Dillmann: No, this was – yes, it was undergraduate. So we had at that time the system of the Diplom. So I have no bachelor, no master. I have the Diplom. And so mathematics, physics was in the undergraduate level, and then towards the Diplom we had the possibility to specialize. And there I had of course control theory, bio-cybernetics, some medical courses. And on the other side I did work to have a better student budget as assistant student in bio-cybernetic institute and later in the control engineering institute. And so it was a possibility to learn more, to see what the professors are really developing, what's happening in the institutes. If you only go to lectures you don't see the background and also what they are planning, what are the new ideas. And I started early, I think in the second year, to work there, and this was mainly development software. At that time there was not so much software. It was electronics, building boards, control boards, building systems. One of the first systems was electrical stimulation system. This was electrodes to generate pulses patterns, and then you could influence the muscles. And what we did study there was mainly to move the fingers. My director at that time was one of the pioneers in electrical stimulation and so this did also influence my further development to study humans and this interaction. And the second one was to build controllers for electromechanical systems, the first robots in electrical control department. And in parallel, I developed my own robots, starting a small company.

Q: About what year was that?

Rudiger Dillmann: This was in, let's say in one of the last semesters. I did study 13 semesters, and I started to do that intense after 5 years being at the university. And so there was a need – University of Heidelberg wanted to have some robots for – high-precision robots for studies on synapses, to study neurons, and it was necessary to have very precise needles to hit the synapses and to – not only one, you need one influencing the ion concentration; you need reference electrodes; you need measuring. So we developed multi-droid systems, three or four axis, or eight axis, with pulse motors. And at that time we had – we have been very accurate I think in absolute accuracy was micron, and then relatively 200 nanometers. This was really the top development. And we did sell a lot of them.

Q: Was this in the mid '70s or –?

Rudiger Dillmann: Yes, this was at – I started on '69, we started. So it was after mid '70s. And so I continued a certain time, I think four or five years, and then when I went to a PhD program I had to stop it, because I had no time. So I did sell the company.

Q: What was your company called?

Rudiger Dillmann: Scientific Precision Instruments.

Q: And did you have partners in the company?

Rudiger Dillmann: The company still exists, and they are building 'til today high precision positioning devices for microscopes, for calibrating the lens in microscopes. Fresnel lenses. They do some work for bracelets industry, to grasp very small diamonds. And then to produce that, this gets also used for artificial fertilization to grasp sperm with <inaudible>, and then to combine that with eggs and to have these artificial fertilization. Yes, I do – I'm consulting the company.

Q: You mentioned also that while you were still in the – you're doing your diploma degree, your undergraduate degree, you worked in a laboratory. Whose lab were you working in?

Rudiger Dillmann: Yes, this was Institute of Biomedical Engineering and Institute of Bio-Cybernetics. And there I did work two years, or two and a half years, also developing there some instruments for this artificial stimulation. And these have been instruments which became products, mainly for people who are spending long time in hospital in bed. So if they do nothing, the muscles disappear. And if you have artificial stimulation, you can stimulate people in bed and save the muscle system. And this was an application – my professor at that time, he had his own company and the results he converted into products at that time.

Q: Who was your professor?

Rudiger Dillmann: This was Professor Fausius [ph?]. He had a medical degree and his main interest was this artificial stimulation of muscles. And I think he's one of the pioneers. He is now about 88, 90 years. Still playing tennis and he's active on conference. Sometimes he's coming to my lab.

Q: And were there people who were also working on robotics? Because you mentioned you started developing robots.

Rudiger Dillmann: Yes, robotics was at that time very in early stage. We didn't say this was a robot, this was a positioning device or this was an electrode manipulator. The word robot came after my PhD degree. Where the first systems appeared, it was the first system named robot was PUMA. I think we got one of the first Puma robots in Europe. <inaudible> the number was number seven of all Pumas. So my professor at that time, he was an American and he came for four or five years before to Europe to Karlsruhe. So he brought a lot of ideas from automation and from robot applications in the U.S. to Karlsruhe. So his chair was related to real-time computers, and so I grow up with building the first micro processor based controls, starting with 4-bit, with 8-bit, with 16-bit, mainly learning to program on machine level, and then developing the first languages on medium level, then Pascal language. And the experiment we had was a Puma 500, and then we developed a new language called Pascal for Robots, Pascal, and this was a Pascal-like language with libraries to program robots.

But the application of these systems was more industrial, so the dream of my director at that time was to have the unmanned factory, and this was an idea he brought from U.S. companies, and this was his vision. And at that time, we had manufacturing planning, scheduling, assembly planning, implementing mobile robots. We build one of the first autonomous mobile – two robots – for manufacturing. But I can say later how this did look like. My PhD thesis was outside this institute. The idea came from the bio-cybernetic institutes to build the pulse systems. And so the topic of my PhD thesis was pulse frequency controlled systems and one pulse frequency control system of the muscles to have models to stimulate the arm, and then to have a defined motion. And in simulation, this did work very well, studying how to stimulate the systems, what is the response. And so the idea, we didn't call that artificial neural nets, but it was something like that, with spikes and with frequency trains. But we have been limited at that time because of limited computing power. And second application was a pulse frequency modulated systems. It was a Viking satellite. The first I think two of the Viking satellites have been lost on the missions.

One of the reason was that they had so-called limit-cycles. One jet did give an impulse. Then it did rotate, and you need – on the other side is the second. You had these so-called limit-cycles, and the fuel was empty after – very quickly. So they couldn't control the machine. And I did study that also with my pulses, how to stabilize this with pulse frequency based methods. In simulation, it was well. If NASA did apply it, I don't know. I didn't follow that. But this was the control to use pulse systems, and on the other side I had a lot of experience with this first robots we did build with stepper motors for the electrodes, and then we did use also pulsed motors. And the performance we did reach at that time was really very high, and astonishing <inaudible> and all these things we could manage at that time. This was also one reason that I got the position at university, from my director that said, "Okay, I give you more opportunities. You can build robots for me," and then I said – I had a choice to continue the company or not. To sell the company, one reason was that the institutes we did sell our systems. They did learn how to use microprocessors, and then they developed themselves. So after some time we had strong competition and I had decided to spend all the time in the company or to go to development and research, and then I got the offer to go to the institute. And there, this was 1976, about that. The first Puma came, and then I was in robotics, and the first years have been mainly manufacturing, assemblies, and industrial application. And the program we had at that time, the Puma was more or less a closed system, and it was really difficult to open the system to modify the controls to do something new.

So on the user interface we could do a lot of nice things. But as a researcher, we are interested in to go deeper, and this was a decision then to start to build our own robots. And then also programming systems, and this decision I continued 'til today in my lab, that most of the systems – of the advanced systems – we are building completely ourselves. If you don't know them and if you don't know the technology, this is a strong limitation, and we must have also the rights, property rights, to sell it to industry. And so building robots was also – yes, at that time, the first conference is on robots started, it was ISIR, International Symposium on – no, it was ISIR, International Symposium on Industrial Robots. And then there was one conference on ICAR, International Conference on Advanced Research. And there was a possibility; we sent papers, they have been accepted. And so the first conference, international conference, was in Tokyo. So I had opportunity to meet the pioneers in Japan. It was Kato, it was Hasegawa, it was Miura. It was also Professor Inoue. He was a young professor at that time. And then discussing with them.

They had this biologic-inspired system and this did influence our development very strongly. At that time there was the – what was it? – was the world exhibition the expo in Tsukuba, and they presented piano, the keyboard-playing robot with the first humanoid arms. And this was really impressive. The second influence was we had with IARP, International Advanced Robotics Program. This was a program, a government program, decided by NATO countries. They said at that time robotics is important and then they had six member states – I think it's also United States, Great Britain, France, Germany, Canada and Japan – to cooperate, and we had missions. And one mission was to visit other countries, to meet researchers to discuss. And at that time, the U.S. mission started at MIT, then going to Carnegie Mellon, the National Bureau of Standards, to Martin Marietta in Denver, going to San Diego to NOC, the Naval Operation Center, Stanford, Berkeley. And so this was very impressive to meet the pioneers there and to see the systems, and this did influence also. So we came back with a lot of ideas, what we can do. And so my agenda has been influenced at that time very early with meeting these people.

Q: So just to ask for a factoid, who was the American professor that you worked with, you mentioned, during your PhD?

Rudiger Dillmann: This is Professor Ulrich Rembold. He originally is a German, and he studied at Stuttgart University, made there his PhD. And so in the early '50s he wanted to practice for two months in the U.S., but then he did stay there 20 years, and came back as a professor of 20 years. And he had also already a lot of colleagues in France and a network. And some of these people – I had also the opportunity the meet the people. Dick Volz, a former president of – IEEE-RAS was one of his network. So I met very early George Lee, Dick Volz. But this was the network of my – Rembold was not my PhD. He was my boss at the institute. My PhD director was a professor in control theory, outside the institute. So the PhD is – I separated my PhD from the job. This has advantages because you are independent from your boss. And so I had a very short PhD period of two and a half years, and this is – usually they have five years in Germany. So by separating this, I had a lot of flak, of course. I finished PhD very quickly.

Q: Who was your PhD director?

Rudiger Dillmann: This is a Professor Föllingir, F-Ö-L-L-I-N-G-I-R and Professor Frank, Paul Frank. He was – I think he was a certain time in Seattle developing pulse frequency method for missiles and satellites. And so he was the only one interested in these pulse systems. And so I decided to go to him, and at that time I had a half-day job at the real-time processing institute with Rembold, and half-day and the night I did write my PhD thesis, sleeping four hours. It was hard, working half here and then doing the thesis, but then it was big fun, and it was passion. It did accelerate it.

Q: And so you mentioned also – oh, before I go there, do you know where Ulrich Rembold was in the U.S.?

Rudiger Dillmann: He was in Michigan, and I think it was Whirlpool. He spent a long time measuring fridge and washing machines. And so he started to automate measuring the fridge. One was to automate assembly of fridges in manufacturing and the other one to have sensors to detect how the temperature and the parameters of the machines are going, how to tune the fridge. So he did know everything about that. And so my first projects I did work for in the institute where I was hired was also to automate signal processing to monitor and to help quality control for fridges. I did build also some machines for manufacturing. One was machine for building resistors. This was a cylindrical body with ceramics, and then they put carbon on that, and then it was – we had to mill the surface and there was a resistor bridge, and then you could mill 'til you got the value of the desired resistor. And then we started with the simple automation then later we used the laser to pulse – to do it more precise with lasers. And so this was the first machines I had to build, which have been converted to industry.

And then when we got Puma, I got the robot development program. I was responsible to learn how to program the systems, to build first program language. We started of course with ALGO like language. Then there was Fortran-type language, and then we decided to go to

Pascal at that time. Then we developed that, build the compilers, and connected it to the machine. And at that time, the early European program started. It was of course planning the program, then we did meet in Brussels with other colleagues with industrials to discuss how the program is looking like. I was a young researcher at that time so we had high-flying ideas. But there have been people like Jean-Claude Latombe, who is a professor at Stanford. He was our competitor. He developed also programming language called LM, <inaudible> Manipulator. And so we have been in competition, but the European network did start. So I had contact with Georges Giralt, who is one of the pioneers of robotics. Maybe he is the one pioneer. And then in Italy it was professor Somalvico. Somalvico is the research father of Maria Gini. And so there are a lot of people who are now in the world famous people came originally from these European sources. I am not sure if Paulo Dario, I do not know where he – maybe he was also from this school of Somalvico. It was Politecnico di Milan, and the other one was Karlsruhe and Grenoble. And so between them we had the first European network.

Then the first program, it was called ESPRIT, has been started. And at that time, I guess the first robotics European projects had been started. The first one was in the area of computer integrated manufacturing, CIM. At that time, this means to model the object, to run the task, to study assemblies, to make the layout for the no idea, to program that to have automatic planning systems, programming systems. And then we have done a lot of basic systems, we made them running. Part of that, there have been companies like Renault-Automation being involved. There have been companies like KUKA being involved in the early days and then, of course, some end users. And this was until 1984-1985 where I was strongly involved in industrial robots, but I wanted to have more flexible systems. I did hate programming. So, the idea was to have programming by demonstration, to have sensor cameras and to show the robot what to do, how to do, and how to make it better and what to look for. And this is a vision which is still now one of my main interests – to make machines learning from humans; so, to observe, to understand, to trace the signals, motion is a time history, and then to segment it, to parameterize that to make a symbolic representation, going into semantics. And if you have semantics/symbolic representation, you can go up and down and this is one of my main interests. It's closely related to machine learning and this is the red line, which was developed let's say in '85-'90 going into this area.

Of course, I decided to make a professor career. In Germany, it's still usual and important to have a habilitation. Habilitation is more than Ph.D., plus, plus. It's a research program; so, where you make an analysis of one field and then to have a roadmap, let's say, for the next 10 or 15 years, but it must be very well defined. And so, the habilitation was machine learning, learning robots. This was mainly one of the first thesis books at that time. In the '80s there was artificial intelligence area and there have been, of course, the pioneers in this field. One is Tom Mitchell, Jamie Carbonell from Carnegie; Michalski is one of the first A.I. people and they came in and said, "Cybernetics? Forget it. We go to A.I." This was for me completely new, so I decided to go into A.I. and then to compare that with my experience with cybernetics.

And then, most of my work was to evaluate existing approaches. Most of the approaches are still valid and so, you can take advantages/disadvantages of the methods.

And so, today, I am sure that it's possible that robots can learn, but I think the robot need a human to learn better, to have the human in the loop as a teacher. Robot learning everything itself; some people say that this is possible. I'm not sure if this true. Maybe I'm wrong, but I think if a robot interacts in human environment, the human is the best teacher and then to study how to understand motion, grasping, what is intention; then to convert the signals, the time history, to the symbolic level; then to have symbolic level planners or symbolic learning levels. So, we had following that different approaches and then going back from the symbolic level to the signal, to the motors. Obviously, this is necessary. And then what I think is the robot must be able to explain why it's doing this and why it's deciding to do that. So, if a robot can explain why it is doing something and explain that, this is better for the human. So, the dependability is higher and that's one vision I have, that one is to learn from observation maybe or to advise. So, it's possible that the robot which learned already something can give this to another robot so that the robots exchange or that they are interwebbed. This is also possible, but all the time, the human is in the loop and must be in the loop. So, this is the vision.

Q: This habilitation, did that start right after your –?

Rudiger Dillmann: This was an overview and from cybernetics to symbolic, deductive methods to inductive methods to hybrid methods, learning from analogy and I discussed what is useful for robotics, what is not, what has a potential and then to give this survey. Of course, we had some simulation. Let's say 50% at that time from the A.I. work came from MIT and Carnegie Mellon from the U.S., but then we had also very early works in Europe, also in East Germany on cybernetics. It's very good mathematical descriptions. Most of it, we forgot that, but these things are of very high value. A lot of the things are reinvented, but I said all the time it's very important to read books, to read all books. Unfortunately, most of the books are not in the Web. So, people don't know that.

Okay, this was the habilitation, and after habilitation then you're allowed to teach and then you can apply for professor position. And at that time, I became an associate professor. The area was related to robotics and then I started parallel to the industrial part more biologically motivated systems. So, one was a walking machine, a six-legged walking machine that we tested some theories from biocybernetics, also neural nets. We worked closely together with researchers for biology, Holk Cruse. He is one of the pioneers studying the normal processes of insects and stick insects. Stick insects have the advantage, they move slowly. So, you can observe them. You can make experiments. And so, the first robot we had was a stick insect-like robot. This was 60 centimeters, 15 kilogram, a lot of motors, six legs. Each leg has three motors.

So, we do learn how to integrate and to run a system with high degrees of freedom. At that time, we had signal processes for each joint. So, we could build a type of spine. We had a lot of fun with this research, making them walking. Then, we got also a first project on walking machines and started from this project a national network with biologists, with people from sports signs or motion signs; then other institutes. There was Professor Pfeiffer at Munich. They had also a six-legged machine. And, we have been also inspired by Ken Waldron with his six-legged diesel motor, hand controlled six-legged walking machine and then, of course, Professor Miura. I met this person at the visit in Japan, at the Expo and Miura was such an open person, so open minded it was fantastic. So, he encourage us to go in and then, this was one reason to go into walking machines. This was relatively large machines. The first one was built by wood because we no money for other materials. So, the second one, when we got some money for the project, we built it with carbon, carbon fibers and later, when we got real money, we did build a lightweight metal and materials. I continue to work until today and actually, we are planning the sixth generation of walking machines.

Q: When did you start your associate professorship?

Rudiger Dillmann: The professorship was – oh, that's a good question, '86.

Q: Okay and your habilitation then was written about 1985?

Rudiger Dillmann: Yes.

Q: So, just after you had come from this trip of going to Japan.

Rudiger Dillmann: Yes, '80 was the Ph.D. finished and then '85, it was finished. In '86, I had examination, the exam and I had to show that I'm able to run all programs to make research planning, to be capable of teaching, writing a book. This was the thesis. At that time, habilitation was really hard. I personally try to continue this tradition. Today, it's very easy to become research professor or research assistant professor. If you have a good Ph.D., a lot of professors – but, I think people must also be finding a certain time maybe going to industry and then going back to academia. I myself, I was more or less all the time in academia, running a company between and doing this type of work, to show how to make programs, how to have a roadmap, to discuss the roadmap on an international level, meeting and compare with colleagues in other countries. It's one of the reasons going to IEEE, to meet the people. I met a lot of people via IEEE RAS. I did know them by books and papers and so, they were pioneers and then I had a possibility to meet them and this was very encouraging. And so, I think a professor has to go through, we must learn to fight – if you have a vision and we have passion, we must have energy to reach the goal and to go forward. And on the other side, I must convince the students to follow, to make them excited. And so, I say we have to approach a samurai for these type of people, learning to fight. If everything is easy, the value is not very high.

Q: When you went to this visit just kind of at the end of your Ph.D. and before your habilitation and you went to the U.S. and different places in Japan and Europe, what are some of the different things that you saw? You said you were inspired by some of the things you saw. What were some of those?

Rudiger Dillmann: Yes, of course, it's very different cultures in research. So, in Europe or mainly in Germany, of course, we are very systematic. It's the German type of engineering. I did learn to go towards visionary systems; for example, building systems for the moon or the Mars Rover, the early systems we have seen in Pasadena at Caltech, at JPL. That his is possible. Also, thinking in very advanced systems and that it's possible to go step-wise. In the U.S. and there are different application parts: Manufacturing, of course. Military has a strong role, entertainment. We have been also at SARCOS at that time in Utah, Salt Lake City, seeing the humanoid components, the Hollywood movie robots. So, thinking of advanced systems and where we say, "Oh, this is difficult. It's possible to reach it," this idea I see it, learn in the United States and I practiced part of that also in Europe. I continue to do that.

In Japan, this was quite different world, to see this Keyport, playing robot and these walking machines. No one could say for what is this used for. And then, to have systems to develop technology and to look also, to have systems, they say, robots for the society and one was in Keyport, playing the humanoid robot. This is a different way of thinking, but in Japanese, they go out very systematic into the field. They have, of course, also five-ten year plans and the technology developed is also discussed with industry. So, it's not blue sky research, what Japan is doing. They develop technology and early products. Sony is one example with the entertainment robot. Honda, no one knows for what the humanoid robot will be applied, but they show leadership, a lot of servo control methods you find in cars and in other products. The study of cognitive systems, you find also part of that in cars, learning methods. There are other car manufacturers in Japan going in. Maybe they make a break now because of the economic situation and after the disaster. So, to see in Japan the developing machines close to humans; also the cybernetic approach was also fascinating. I did find some common interests. And so, since the first visit, nearly every year or two years in Japan meeting the colleagues and so I have long contact and I think to have over decades contact to the people is very important. You see the development of them, what they are doing. They can give also feedback to our research and try, of course, to bring younger researchers in to build their own network or to continue the network. So, it's to them what to do.

So, the projects we started after I got the professor position always have been made European projects. At the beginning, I said already manufacturing. Then we continued with the service robots, robot systems closer to humans. We had the first projects on learning. Skill-MART was one to study a learning method. It was a continuation of my habilitation or part of that, working together with A.I. people and with engineers, computer scientists. Then, we had European project integrated. After the SP program there came the Framework program, Framework 1, 2 and 3. These are periods of five years and there they have topics emphasizing basic research and cognitive systems, then to convert the research closer to make use or to build systems and in the next step to have innovation towards industry. This is the mission. And of course, there, we have a lot of projects on studying grasping, studying dexterous manipulation, studying <inaudible> neuron. This was basic modules for cognitive systems. That is going on actually.

Actually, there's one project called Experience we started in January. It's the question how to gain experience for robots from the robot itself, from humans; so, from robot-to-robot and there we're studying so-called generative processes, which allows as a robot learns in terms of programming by demonstration and the robot should learn in a generative process to react to new situations and this needs the capability of predicting, to have some ground rules, but then to use this generative processes to enable the system to do something new. Completely new, I'm not sure, but maybe situation, which is different, which adapts. This we started with the project. What I'm wondering and I'm excited also is that the linguistic approach is very important, to have a body of language maybe for cooking and then if you have this linguistic body then we can build systems for robots learning to cook and to interact with humans, or if you want to have a robot for the supermarket, we must describe a language body of what happens in the supermarket. And then if this is once defined, you can build systems to act in the supermarket, doing logistics, helping customers, or if you have a system on the moon, you must also decide whatever robots do on the moon and maybe we don't know very much what happens there. A human must stay in the loop. So, it is most important to have these linguistic people inside.

Also the trips planner people to take the idea – so, to take the idea of trips and to extend that to open system with uncertainties, with noisy environments and to push them forward in this direction. The main project for me, this was at – I started in 2001. It was a very large project on humanoid robots at Collaborative Research Center. This is usually located on one campus and this was related to humanoid robots. That's a project for 11 years. Next year, we are the end of the project and the topic for this center is to build interactive learning humanoid robots. There, we got the budget. Let's say we have had an 11 or 12-year period. You write a program for four years, then you evaluate it. If good, you can continue the next four years. And then, about ten institutes are involved and actually, they pay us for the researchers, for the students, 80 students and we have some money for hardware and for equipment. This was, for us, a very important project; also for Europe and what we built was a human-like system, AMA1, AMA2, AMA3.

AMA1 is already in a museum in Munich and the background is maybe we learned – I mentioned these six-legged walking machines. We had to study lightweight materials for these machines and with this knowledge, how to build lightweight walking machines, we went into the humanoid robots and built the first, very primitive humanoid arm. This was finished 1999 and then we built the next generation. Actually, we are assembling generation four. This is a full humanoid robot with feet, legs, hip and body; actually, I think 72 motors. And so, we are not interested in walking. I think the Japanese can do that much better. We are more interested in body balancing. So, if the robot is doing something with their hands, you can use also the legs to support or if I push the robot that it must balance to be more safe. If you cannot guarantee, no one will install a humanoid robot in the supermarket. If this machine with 60-80 kilogram is falling on a child, a catastrophe.

Q: So, why humanoid?

Rudiger Dillmann: Humanoid is, of course, itself it's fascinating to build human-like systems. So, more important is pose to understand better human, to study human and to build machines using the knowledge and showing that it works. Second, if you interact with a machine looking like a human, you can evaluate. Is the robot imitating, is the robot understanding, is it doing it properly? That's the reason we have five finger hands, we have two eyes and we have neck and head. The acceptance is from our point of view higher. On the other side of the stage, if there is a robot looking like a human, people expect that robot is capable to act like a human and this is wrong, of course, because they are not very intelligent. Being provocative, a robot is pieces of metals and silicium until you put it together and this is not human. But, it should behave like a human. It should interact and what is important is to have this cooperation and the feedback of humans and this is the key if we want to have technology at home. Maybe it's humanoid or not. Humanoid, this interaction is very important.

Dependability is very important and if the machine is not – if the human don't know exactly what the machine can or where humans over estimate a capability and then they throw it out. If there is a machine, they know exactly what it do and if it's useful then I think there's a good chance to have the technology. I call that, that's the hidden robot because the example – today no one is looking to cars because cars are part of our daily life. Even children don't look to the car. We are using that and if a robot is at home, everyone – this is something very special and everyone is proud if the robot is able to grasp a cup but most of them cannot do not than grasping a cup. Sorry; 20 years research on cups, this is a scandal I think. So, we learned a lot, but I cannot say it again. I mean ask a robot, "What are you doing?" "Studying grasping a cup" - 20 years. So, it's more important to have other things like loading the fridge, loading the dishwasher, manipulating textiles. I hate irony to have machines like that, but if they do the job and if they are not looking like a monster, if they are smart, sexy or how you say to that then people will buy it and use. But, if you have problems and if you have to call, to check the Internet everyday and say, "It does not work" – so, the hidden robot, these are machines, intelligent machines doing the job, adapting to the human environment maybe firstly in a very small defined area, then they work. It can also be a box or a vacuum cleaner, but if it does the job then you don't care any more. You start, the machine works and you do something else and if there's a humanoid and you say, "Serve the tea," and it's doing that then it's a hidden robot.

So, there is someone doing that. This is important. On the side, everyone discuss elderly care and if you speak with elder people, okay, I'm also elder people, but we have also other aged people, high age people, handicap people, they don't like that because robots look like monsters. They are slow. They can only grasp a cup and nothing more. It's clumsy, falling down from the bed to pick it up and to give it. These are things. And so, we must be very careful with elderly care. This is for roboticists something they have to learn that elderly care is something you need a global solution, working together with architects, having smart networks in the house. Privacy is very important and the technology shouldn't limit the human. If a robot has limited capabilities and the old people have to adapt to that they have more limitations than benefit. And the other side is, of course, aging is a very individual thing. So the handicaps are different. And so if you have a good environment with robot technology, with sensor-nets which may be humanoids or black box or other devices, which allow the people to have their independence. What is important is to be able to communicate, to have social contact through the outside, maybe from medical side. There is a link so that the people can accept help from a medical people. Or even if service people come and help them in the morning bring food, looking in the evening, this will be the market of the future. And then during the day having these machines. I think this is something. But this is a solution where we need designer, architects, even city planners to have obstacle free cities, obstacle free houses. And what is good for elderly and handicap is good for robots. This is something, a message we are fighting for.

There is also plan in Europe on the flagship project to have real technologies having in mind a better technology sentient, very sensitive and adaptive technologies to develop that. It's a large program maybe ten or twenty years from now. And to go in this direction that's very important. And on the other side, robots this may be also something this has to do with lifestyle. If you see the iPad technology that's wow, no one did expect that iPhone, iPad, maybe TV is next and communications. My TV is with the outside. These are some driving motors also for robot technology. We have to observe that and to adopt the technology into machines. And people like that. No one did expect that the iPad is so successful. We can hope that maybe in robotics we have also if you design the right system and if this is sexy and people like to use it and it's something of lifestyle then we are on the right way. Unfortunately, engineers are not familiar with lifestyle. So this means we have to speak also with designers, people, societal people. I personally prefer architects. Most of the architects don't know the potential in the market for – people fear the society with elderly people. But the future is different. We have a lot of immigrants from Asia, from Africa. We expect in Europe from Arabia a lot of people following the latest developments. So we need an environment which is multicultural, which relies on technology where we have infrastructure logistics in cities, open logistics. And here robotics is very important part. So this humanoid robot program will continue.

There is now a new professor coming from my lab. He applied. We have a new professor position. Humanoid robot this will continue. And now what institute is not able to do all of the work. So we started now or I started the initiative with some colleagues to concentrate areas important for robots like vision, speech understanding, interaction, bio signal processing. Now, we have a new institute called Institute for Anthropomatics. Anthropomatics is the science of human and robots. It's human and then in the word matics we have metrics. To have metrics of the body, of the actuators, of kinematics, of the dynamics, but also metrics for the sense, the sixth sense or seven sense or eight. Robots can have more than a human. And then on the other side to have automation to build systems. And now, there is an institute with eight professors. We are enlarging this institute and this is related to we say science for humans and there is medical robotics and applications, rehabilitation. Humanoid robot in human centered environment and also bio signal processing too. There we see a market, there is a need, and industry is very positive to that and the community also. That's the institute.

And then at KIT there is, of course, other roboticist groups for manufacturing, for micro robots, for medical robots, for tele-presence system, for disaster management systems, heavy machines. We work closely with the French together. They built the Caterpillar, the heavy machines. We are responsible for building some sensors which survive under radiation let's say half-an-hour, twenty minutes, half-an-hour. And with them we have built now a large center with about 22 institutes. So that the university can offer a portfolio, a wide portfolio on experience on robotics for industry, for society, for research for different purpose. And so that's our mission. The purpose is to build a center in Europe participating, of course, in the flagship initiative. Or to have centers in Europe, let's say ten centers where resources people experience are existing. And, of course, we are partners too worldwide. So in the U.S. people are also now there are some centers, I think also eight, about eight in the West Coast, Midwest, the North. And to cooperate with them our idea is to have some idea of global teaching with the Internet students study different. There are these Facebooks. And yes, when they learn usually I did learn maybe with some friends, we had books and then we did learn and check and to study.

Today, they go to the Web and there's a team of students who is the best, he explains to the other one and they exchange information. And they study quite different. And the question is what is the consequence for teaching in a global sense? There are actually courses. There is this <inaudible> AI course with AI courses which are transmitted worldwide. So you can participate. You can ask and interact. And some of our colleagues are teaching in Arabia or in Singapore. So to look what is global teaching. We believe that the students meet their professor at the local institute, but global teaching they have the people to participate in the best courses of the world. And the other one is global research. And there we are looking also for possibilities to organize global research, to have a network with universities having a similar structure. And we call that interact. And there is a network between beginning. We started with Carnegie Melon, Karlsruhe. The initiator was a professor having appointment here and appointment there. Then we added ATR in Japan, Nara Graduate School, Waseda. USC is a member and Italian Institute of Technologies. We exchange students. We have common Ph.D.'s. And we do that in an organized manner with research topics. The exchange of students we did all ready since – everybody university is doing that. And that's one area.

And the other one is engagement in societies, like IEEE. But starting maybe in my country there is from a computer science, one society called Gesellschaft für Informatik, Society for Informatics. There is a small robotics group. Then we have the German Electrical Engineers. There is a robotics groups. They are more related to national programs, but we have all of the industry inside. And there we have networks more to do national leads. And, of course, it's open for everyone. But we discuss things, which are of local matter. Then we have a European network. It's EURON. I'm one of the starters of EURON. Henrik Christensen was the speaker. And then about more then 300 institutions member of EURON. It's an academic network. And then we <inaudible> Europe which is the industry part of the network. So they are developing roadmaps and then we give it, of course, to the official politicians, hoping they will follow our ideas and suggestions and dreams.

And then the other one is IEEE. I joined IEEE first when I became professor. The ruling in Germany is you need someone who writes a suggestion, a letter of recommendation. Then at that time it could become an IEEE member. And then I participated in the network also for having some responsibilities. I was two terms AdCom member. And so that's – I think this network is also important. And you meet also the people there in the working groups, in the technical committees. This event here is quite different. In IEEE it's more the society, you have the international society and everyone is busy having committee meeting and you have not so much time for science to meet people. But here ISRR is – IFRR is quite different. Here it's a small group but everyone is representing one field, himself, of course, or herself and then people have experienced people. So we are looking for a future field for emerging work. And inviting also young rising stars. And also good Ph.D. students to present new ideas. And we have time. We have five days. It's quiet and the benefit for me is much more than to go to the big events. They have lots of different functions. The big events are for the students, for the researchers, for industries, or the whole community. It's a market.

Q: I was curious. You talked about a lot of different projects that are sometimes within Germany, sometimes with different partners in Europe and you also mentioned partners all over the world. So how is some of this organized and funded particularly in Europe? How did the different institutes in Europe start actually cooperating together and planning resources for these large…

Rudiger Dillmann: So I have basically from my university here basic fund in terms of personnel. This is for the whole working lifetime. It's a secretary and a number of researchers. And then I have a space. And with this I can work. We have relatively large space in our laboratory. And then with this basis we can do our research. And then starting to write proposals with other labs. So the other university expects, if I give you let's say five people and a certain amount of dollars, then you have to propose why you are doing that. And usually you have to duplicate that to multiply with four or with five and to set something up. This is the basic idea in the university in Germany. In comparison with U.S. professors we have very large groups. I'm responsible for, including my lab and the innovation lab, it's 40 people. Most of them – there are some post docs helping me to organize research. But all of them want to have a Ph.D. at the end. So I must look then for money when it's to go to the national agency, Deutsche Forschungs Gemeinschaft, to apply there are possibilities of small projects you can apply at any time. It's like NSF. NSF is not launching programs. You can apply and the chance is not very high but a very a good proposal. And that's the same in Germany.

But we have also the possibility to have networks, when network is this network on dynamic walking I mentioned. Here, eight, seven, universities involved with related projects, two-legged walking, four-legged walking, six-legged walking, human walking, machine walking, neural controls. And they are coordinated slightly coordinated. Then we have the large project. I said the collaborative research centers which is in one location. If the university is too small it's allowed at two universities. I have a collaborative research center because you need a critical mass in robotics. And the rule is not only one faculty must be also interdisciplinary. Robotics this is obvious with mechanical engineers, electrical engineers, computer scientists working together. And there is a research plan necessary. And from this collaborative research center we have a lot of seeds going to Europe.

And then going also to European projects. They have a lifetime of five years, four years, five years. The rule is a minimum of two countries or three countries. You must find the partners. You must show there's a common interest. You must show excellence. And then it's evaluated but it's program oriented. So there are calls and these are the European programs challenge one, challenge two and framework one, two, three. And then you can apply and it's also necessary to have a coordinator and the roles who is doing the management, who is distributing the money, what is the measure of success? And then the milestones. I think everyone also the U.S. everywhere in the world and they do these break tests. And on the other side, we participate in the discussion on the programs, where to go, what is necessary. We tried to sell our visions and our ideas to Structure Net [ph?] and to sell it to the politicians. And, of course, industry. This is the way we are working. In Europe, the network it's very good. I think the U.S. and Japan and in the leading countries is the same. No one is isolated and doing research for itself. They are all integrated. And that's what is important is to avoid redundancy. So if you go worldwide people do the same and invent the wheel again. So this international cooperation is very important. And very important is that the senior people meet the younger people and they discuss and then the younger people they must have their own ideas to run it.

So evaluating the European projects I think there is visible progress. The first product we have are the students, of course. They leave university and go to industry with the knowledge. So the implementation of success is maybe longer but this is a human capital in this case. So what we produce are international people being able to work on European level or on worldwide level. And then, of course, the research being done which is partly going via spin-offs to the market, partly via <inaudible> companies to the market. And, of course, a large networks is, of course, also some friction. Inside Europe we have different languages. So everyone is speaking English, not in its mother language. Exchange different cultures play a role. But it all there is an added value to have the network and also the research resets. And, of course, there are discussions, it's better to keep the whole money, one institution, one person or not. But this discussion is everywhere in the world. People say give me money and you get more. But the cost for this fertilization is a good one. And for Europe I think it's very important.

And also the possibility to cooperate with institutions outside. There are possibilities to have Asian or Japanese corporations, U.S. corporations. I think also some of our reports are in the United States. The iCub actually one or two iCubs are in the U.S. And so to have – this is the kind of global research which is necessary. And if you look to the challenges and the problems worldwide we have no choice. That's my opinion. Fukushima is one example. It's not only a Japanese problem, it's a global problem. My country decided to go out but this is not the solution. We have about 20 old nuclear power plants. Our industry wants to sell nuclear technology. But we have a lot of chemistry in our country. If there is a chemical disaster no one knows how to react. We have one of the biggest chemical factories BASF Hoechst. In Swiss they have the pharma industry and there's always a potential for a disaster is not only nuclear. There are a lot of others. And these are challenges, which have to be done in terms of global research. No country is able to produce and develop the technology on its own, the robot technology. What I don't know is what happens in India, and in China. This is a rapidly growing IEEE. I don't know how far they are integrated. We have students from China and from India. But I concentrate on Europe and to some labs in the U.S. and Japan; that's enough.

Q: One thing I was curious about, we didn't talk a lot about your research that has more to do with medical robotics. Could you tell us a little bit about that just so we don't miss that.

Rudiger Dillmann: Yeah. So the first one we're more or less my company were building robots to measure processes on synapses. Then this <inaudible> robot and we had also collaborative research centers starting 1996. And this was related to computers for the surgery. I mentioned all ready that Heidelberg is a medical center and the German Cancer Center. And they have no engineering department in Heidelberg. So we say the doctors are in Heidelberg and the engineers are in Karlsruhe. And so we started yes it was in the late '90s with idea to have processes from computer integrated manufacturing in medicine and surgery. It's also product design, preparing the product for manufacturing, preparing manufacturing, doing manufacturing and risk quality control and the processes. And the idea was to map that to surgery starting with the diagnosis and generating a therapy plan and to have a process chain but also the tools. And at the time this was imaging, this was diagnosis, robot technology what is doing the robot, what is the surgeon. How to plan surgery and what is with exceptions. And at that time we started from computer science, computer supported surgery project.

Then we had two locations, one in Heidelberg and one in Karlsruhe. And this developed basic technologies also with robots with European robots from Staubli. Staubli is – they did follow Unimation. There was one robot between was it Irish company or and England company. Then it went to Staubli in Switzerland. So we had the first robots for surgery. And my interest was more to look for soft tissues because at the time they started cutting bones, having these cranial facial surgery and which where you have to bulge, you have to repair that or if this is too long you cut it and then this is for aesthetics. There a lot of children that the eyes are too wide or like that and then you can – this was the first type of surgery we have done. This was to have a diagnosis to make a plan, how to cut and how to assemble. Sorry when I say it but these orthopedic people it's assembly. And this was mainly measuring, cutting, changing the geometry and looking for functionality. And then we had very exciting surgeons in Heidelberg doing – making experiments and some robots have really applied to that. And this was eight years the project. And now we are close to start a new one.

This is related to soft tissues. Everything below we say abdominal area, this is very difficult to detect. Also it's the liver, it's the stomach. And it's elastic. And most of the surgery is endoscopic so that's one area we are interested in or to have the other if there is an arrhythmia you need customized stents. You must position them first to measure then to design it. Today, you get the standard stent for arrhythmia and people hope that it really works. But it can be customized and you can also be detected and it's a lot of robot methodology inside. And what we have in mind now is in March we have the review, the first study review was positive, very positive. Now, we hope that we get an allowance in the contract after the next review is to have something like cognition supported surgery. And what we have in mind is, of course, continuing this process chain. I think this is standard. I think in Maryland you have very strong teams. In Pittsburgh you have teams that's intuitive, that's a market leader on this invasive surgery. And completion means in this time more to not build expert systems as we have done that in '98 and '99 in the medical field. It's more to gain and to collect experience of teams of surgeons starting from the radiologist to the diagnoser, to the surgeon. And to have experience from the team.

For example, if you ask a surgeon, do you remember your surgery number 917? You say no. Of course you can have his notices. But what is interesting is that we have something like cases; like a case-based, experience-based database or knowledge-based. And the question is how to take that. The reason why we are doing that is that in surgery I think there are 40 percent- in the abdominal surgery area 40 to 50 percent is standard. Even young surgeons for starters can do that. But the other 50 percent, even very experienced surgeons don't know exactly what to do. And it's very tricky. But in the end they are successful, I think. And if we ask them, "What you have done; why you have done that?" they cannot say. And I think humans have very often something like intuition; or a lot of people decide "from the stomach" we say.

This is something you cannot measure, you cannot analyze. But it's something like experience. This is what we are looking for. And the chances to reduce in some areas the mortality. It's mainly cancer, with 2 percent or 3 percent. And this is a good argument to do this type of research. And then of course standard is imaging; not only visualization, it's so to have semantics. Very often you have small structures, and the radiologist is not able to see them, to have interpretation of these images. The vision is something like speaking medical images. So that we have, "Tell me what you see". or vice-versa; so that the radiologist and the diagnoser can have a dialog with that.

And the other one is developing the knowledge base: Have I done similar things? What was the result? How I did treat that? Other options. And it's something like an online thesaurus so that the medical people have, when they're starting to consult the thesaurus, which can image the information. But it's more personal information. Worldwide you have a medical database. You can have a certain cancer – breast cancer or others – and you go to there, you get 10,000 of data. The question is what to do with that? And so the problem – this is the idea. And the other one is the robot technology. This, minimally invasive, is to have stereo endoscopes or flight-of-time sensors which can reconstruct precisely decubitus [ph?]. There are no landmarks. It's smoky; very slight. There's ________________; everything. And if the surgeon has exactly a representation, he can map with the model, with the medical images. And this is some area where we have interest and where we are engaged in this field, so that you can very precisely manipulate. And again your skill acquisition and programming by demonstration is also there. That we observe surgeons, how they do. And then we represent it internally in the computer. We can use that to train surgeons.

If it's possible to do it automatic, I'm not so sure. Because responsibility is all the time not with the robotics, to the surgeon. But to facilitate the surgery, this is our goal; and to shorten the period of the surgery. So instead of six hours, maybe three hours. Oh this is the medical part. And of course there are companies in our region – in Baden-Württemberg is 70 percent of the medical instrumentation industry; mainly family-based companies of SMA. Secret [ph?] stars; and some of them are leading in the world. And so we have also in the innovation part a corporation, for example – that's not me, that's a colleague – having laser cutting robots. It's important in the prep of brain surgery to cut the bones very precisely; and after you can reposition that wherein it's healing very quickly. And so there are some well certified areas where industry is interested in. Also sections for liver. It was a very risky operation five or ten years ago. Today the problem is to localize the tumor; to compute how to make the section, how to go into the liver. This is not easy, and there's a lot of our technology with high-precision instruments necessary. The same is with the blood vessels. And so my group is focusing on two small areas. We are too small; we cannot do everything.

Q: There's a final educational question. But I was just going to ask you: How do feel has your initial experience with cybernetics and interest in cybernetics had an impact on the kind of work that you've done? Or is it something that you just kind of left after awhile? <Inaudible>

Rudiger Dillmann: No, no. It's different, it's different. We are coming back to cybernetics. At that time we tried – we did see the living beings; these systems which have control everybody. This is not classical control. This is cybernetic systems, with a high potential on adaptation. And this is more or less a red line to see living beings, not as a finite machine. It's very complicated cybernetic systems. It can be disturbed. It has a lot of mechanism to balance and to survive. And to continue these principles. The question is what is the role of the brain; what is the role of the nervous system? And to understand the controls or the cybernetic system of human – I think one human is enough. There's also cybernetics of multiple humans. And from that to learn and to find principles which can be modeled maybe on a technical basis. And we must decide if this, from the point of view of engineer is useful or not.

But to see humans not as a machine but in a cybernetic system is something which continues. And a long time this was – the AI people said, "We are better. This is old-fashioned model." But now it's coming back there. It's an authentic [ph?] source of cybernetic systems. And the – well a lot of colleagues agree to this. So it's part of education. In terms of teaching, we have of course the classical robot courses. I have three courses, basic courses. It's introduction into robots for beginners; then programming in centers; then building and learning, machine learning, one and two. And so I give not personally all courses. But so by a legal point of view, I'm responsible for that. But I think also younger post-docs should learn to teach – so as part of the courses they are doing – and to grow, of course, and to get experience. And then we have some courses. These are these courses "beyond the horizon"; partly as informal seminar, partly of a course, or interdisciplinary courses where we invite leading researchers to speak in front of the students, and to discuss, who have an idea where we are traveling to.

Q: And if you were going to give advice to young people who are interested in robotics –

Rudiger Dillmann: Yes, that's my main job, to identify- to make young people excited – maybe they have passion or they have no passion; but somewhere they have to start – and to make them excited; to give them possibilities in the lab; to give them, of course, the basic education. And on the other side, to give them the opportunity to global learning, to go to outside. And it's also one reason to be active in the network, to identify or to have friendship with some labs to bring students. So I'm not a traveling agency. But we check if the students have the potential. We train them; for example, if they go to Japan, they have to learn the basics, Japanese language. And then of course we prepare them too. If they want to do something in imaging, they are pre-trained more or less. So that if they come to you, they can immediately start with the work. If you got a student starting from scratch, and he stays three months with you, it's without any value. Because if they understand the task, then he is starting to think, to go back; and this makes no sense.

So the job is to encourage people to say that it's an interesting area, and that they have the possibility also to have a career, a business career or a professional career. And also to have females too. It's natural in the medical field, 50 percent are females; very good engaged females in the field. And in the classical robotics you find not very much females; so it's maybe 10 percent or 5 percent. And to encourage also young women to go into the field. And of course, Medicine is – it's natural maybe. Then we have foreign students. In the basic courses, it's 30 percent; from East Europe, partly Latin America. And then for graduate courses there are of course foreign students with grants. They have grants of three years, four years. And they are all over the world. So actually it's five people in my lab; Korea, from Mexico, from East Europe.

Q: Great. So those are the questions that we had. But if there's anything you wanted to add that we missed that you wanted to have in the video, you can let us know.

Rudiger Dillmann: Yes. Of course the question is if I ever will have a look at the video.

Q: Yeah, yeah, we'll send it to you.

Rudiger Dillmann: But if this is not too much –

Q: But if you have something to add at all, let us know.

Rudiger Dillmann: Just to add is –

Q: We're going to edit it into chunks anyway.

Rudiger Dillmann: Of course what is important maybe is – what I observed is that unfortunately the community's vision, in the AI community and the robot's community, is – it's a little bit separated. I think progress could be in any case stronger if we have links between the communities. So if we speak with our problems to vision researchers, they say, "Of course this is interesting." But they are not engaged to apply robotics. Also in neuroresearch is they want to have robots to verify their theories on neuro control and on brain. But they are absolutely not interested in controlling a robot arm or a humanoid robot arm with neuro principles. So they see robotics as just to verify their theories. And this is one problem actually to be solved, to build the bridge. Even in education, this is difficult to build a bridge, because we have now this broad

– the wide spectrum. Of course in the anthropometric – we have a program on anthropometrics – there is some vision people. But they have only a small view of vision. Bio-signals; and to bring that together, I think this is a challenge which is necessary.

This means to integrate and to cross-fertilize the systems. We tried it here on the- discussed this on the senior level very often. And I think progress could be faster if this bridge could be built. But we have a different language. I have sometimes the feeling we are living on different planets; and to find a common language this is very difficult. With speech, it's important the robot should be able to understand speech. It should be able to tell something about himself. If I give a robot an example, and the robot don't understand the example, it's useful that the robot says, "I cannot see this. I cannot see this. Repeat; demonstrate again." And then we need this speech representation. And the other side, with psychologists and brain researchers, we need also a platform to understand more how the human brain is working, and to have some – a stronger exchange and synergies. So Europe tries to do that at the moment with this challenge too. There is cognitive research, research on cognitive systems. There are roboticists inside. And on the other side, microelectronics and the nanoelectronic field is also developing very quickly – remember the iPhone and the iPad? – and to adapt this technology for building the systems.

Q: Well yes, those are very good. Thank you.

Rudiger Dillmann: Maybe something which is important in the end is I like also to work with designers. Humanoid robots have of course a higher acceptance if you have a nice design. Too, this is maybe one of the key issues, besides megatronics and all this stuff. And also to decide if going more human-like, android-like systems. Or I prefer more humanoid machines or robots that people see this is a machine; never to have a machine which looks like a human, because expectations are extremely high in this case. And so we work together with designers being on the market. Also to get more information on lifestyle and design, to get here. So but to work with artists at the end, is also one part which makes the field very interesting.

Q: And so you've had a lot of chance to work with artists and –

Rudiger Dillmann: Yes. In Karlsruhe we have a center on art and media, and a designer school. And we import courses on computer graphics, on CAD, and on robotics to this school. I'm hoping that some of them have interest to have designs. We have designed female robots, male robots, a family of robots. And a lot of funny ideas. And they have to play with that. And we'll see. One is to make the machines working, doing what we want. But the other side is to have the appearance and the design; which is also one of the key factors.

Q: There's the whole field of HRI, which is kind of still trying to interface better with robotics <inaudible>.

Rudiger Dillmann: Yes, this is part of anthropometrics. But the _________________ of social robots we are not active. Personally I'm not convinced if a robot can act socially. What is a definition of what is social? And maybe I don't understand it, what this is. But I'm critical, also feeling a machine – I cannot imagine that a machine has a feeling. A machine can act; that you have the impression if it's smiling. And but in itself, I don't believe that this is also mentally; and the robot is a piece of metal and a lot of _______________ and some sensors put together. What is important is to react hybrid teams, how a robot or a machine and humans act together – this may be in case of disasters important – so that you share: This is better for the human; this is better for the machine. And to build systems where – I say hybrid systems where the capabilities of humans can be used. And things where the human is not being capable to do, or what a machine can be better, to have a system where you share and where you distribute that. And how to design such systems; how they learn. And I think there will be a lot of scenarios – it's surveillance. The American program has security, military. We have supermarkets. We can go to the factory; there are also teams of machines and humans. And you have lot size manufacturing sequences. You cannot schedule. It's grasped, this the machine, this is this. We made systems which can dynamically distribute and that you say, "You are doing this; you are doing this." A machine is doing this; and then you rely that the machines do that.

And this is something new; a new field which is also upcoming. But I cannot say very much on that. But cybernetics is inside. If you have hybrid teams, you need an idea how they organize themselves. It must be adaptive; so that you say, "Hey, can you do that better than me?" And, "Okay, you do that plus." And this changes the system itself. And but I cannot say at the moment very much on that. We have a program under preparation, a collaborative research thing. And it's another colleague. And we must wait to realize that. We have also NGENDA [ph?] of course in Europe, the next European projects; discussing with potential partners, having new ideas. But this is also important to ensure the growth and the continuation of the laboratory. And unfortunately this is a lot of management, administration. And actually the key between teaching, administration and research is one shot [ph?], one shot, one shot. But administration is sometimes –

Q: It expands.

Rudiger Dillmann: Yes.

Q: Well thank you very much. That was really, really great, really helpful.

Rudiger Dillmann: Oh I hope you have all the information you wanted to happen.

Q: Yes. Definitely. That's great.