Zurich, Switzerland
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Roland Siegwart

An interview conducted by
Peter Asaro

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Peter Asaro: **...**where you grew up and went to school?

Roland Siegwart: Yes. So, I was born in Switzerland, towards the Swiss Mountains in 1959. I went over there in school, it's rather in the countryside and had a very good time for playing around but also in school.

Peter Asaro: Did you have any interest early on in robotics or mechanics or anything?

Roland Siegwart: I had a lot of interest in building stuff. I had also the chance in primary school to have a teacher which was building crazy stuff and he introduced us also to, for example, build a bridge out of a couple of papers which can withstand a lot of load or building the highest tower out of one hundred matches and this actually made me very excited about designing, building stuff, and I think there it was the moment where I felt that I could probably become an engineer.

Peter Asaro: Is that what you studied when you got to school?

Roland Siegwart: Pardon?

Peter Asaro: When you got to university, you went into engineering straight away?

Roland Siegwart: So, actually the decision of what to do after my high school was not so easy. I wanted either to go for medical doctorate for emergency surgery or to engineering, and at the end I ended up in engineering but I still have the – because medical doctor, surgeon, has also a lot to do with doing something with your hands, to build something or to fix something and from my point of view it has some similarities.

Peter Asaro: And did you do electrical or mechanical engineering?

Roland Siegwart: I was doing mechanical engineering because it sounded to me a little bit more really concrete and more hands on, and I think it was a good choice.

Peter Asaro: And where did you end up going to graduate school?

Roland Siegwart: So, I ended up at ETH. So, this is the best technical university in Switzerland. It's the most obvious choice and I think it was a good choice and I did then also

continue with a Ph.D. where I started to move a little bit away from pure mechanical engineering. I did a Ph.D. not in robotics directly but in mechatronics, combining rotor dynamics with magnetic bearings which are controlling the levitation of a rotor without contact, and this was also a moment where I first got in real contact with robotics. So, next door in the same lab we started and I was a little bit involved in building a robot which was able to play ping pong. It was more than twenty or twenty-five years ago, this time it was still very difficult because we didn't have the appropriate hardware or computer power or vision system but we came up with a solution where there was a robot playing ping pong against a human and actually it was, we needed very good ping pong player against the robot, not because the robot was good but we had to be very precisely in moving the balls back. But it was amazing, it was at this time, I think, the fastest robot in the world because ping pong playing needs really very fast robotics. So, robotics has also a lot to do with dynamics, modeling, control and this was very fascinating for me.

Peter Asaro: And what year was that?

Roland Siegwart: This was around '88, '89.

Peter Asaro: And did it ever go up against serious human ping pong players?

Roland Siegwart: There was at this time a competition, robot against robot, and of course it was somewhat funny because I think that the most exchange it was probably three times because most robots were not ready. Our robot was pretty good but it was more or less a project where we could learn a lot on modeling, building robots, and also controlling robots.

Peter Asaro: And who was the advisor on that project?

Roland Siegwart: This was Professor Gerhard Schweitzer, he was actually the first person which was getting involved in robotics at ETH and which did really serious work in this. He was one of the early pioneers in Europe doing robotics from ping pong playing robots for force controlled robotics, it was mainly on manipulators and then also for some first step to service robotics, so cleaning tables with a robot, for example.

Peter Asaro: And what was the next robot you worked on after that, the ping pong…?

Roland Siegwart: So, after my Ph.D., which was not mainly in robotic but on this magnetic levitation...

Peter Asaro: And was he also your advisor on that?

Roland Siegwart: Yes, he was my advisor. So, we were in a group, which mechatronics and robotics work very close and so it was a lab working on modeling control and actuation on fast and dynamic systems. Then I had the chance to go to Stanford for one year as a postdoc and I got involved in some visionary ideas about very small robots, micro/nanorobotics. It was the idea to have systems which can manipulate very small parts, and I was also involved there in tactile manipulation and in the third point which then made me, after coming back, also to start a new thing was that I learned there that robotics is an excellent tool for education and I think I'm still extremely convinced that for education it's really perfect for getting young people excited for different topics. It's very interdisciplinary, it's very tough, very difficult, you have to model, you have to learn about actuation, control, sensing, and so on. And when I came back from United States I immediately started a new course which was about building robots, hands on education which was pretty successful, which allowed students really to apply their knowledge, to go beyond what they did in pure mechanical engineering, for example, and to learn how to integrate sensors and actuators and control.

Peter Asaro: And what kinds of components or platforms were they building at that time?

Roland Siegwart: So, it was at the end a competition, this course, and we had always about probably five, six to ten teams and they were tasks like playing football or building fully autonomously out of wooden blocks, a tower, and this was probably the most impressive what I had with the students. They build really with a small robot, a tower which was nearly 1.5 meters high, fully autonomously. So, it was also a lot about design, so there was the appropriate design and then all the sensing and control integration.

Peter Asaro: And who did you work with while you were at Stanford?

Roland Siegwart: So, it was mainly with Larry Leifer and Mark Cutkosky and some people which other Ph.D. students which worked on this nanorobotics, and it was a very stimulating environment. So, actually I have the chance that Larry Leifer is now starting a one-year visiting professorship at ETH. He was involved in robotics but also a lot in design, how can you design, how can you stimulate a good design and innovation and we are continuing on this.

Peter Asaro: What year was it that you were at Stanford?

Roland Siegwart: At '90, '89 to '90.

Peter Asaro: Great, and did you encounter other of the robotics groups that were working there in manipulation or did you...

Roland Siegwart: Yes, of course. One other person I was a little bit in contact at Stanford was Oussama Khatib which is since then a very good friend of mine, which is a very visionary in a different kind of modeling control of manipulation and now also whole humanoid robot, which I think was very important in this field, but there were other people which I was not directly interacting with like Bernie Roth which was one of the really pioneers in robotics at Stanford, and some people from the AeroAstro Institute which did a lot for space manipulation and so on.

Peter Asaro: So, outside of Gerhard Schweitzer's group, was there a lot of other robotics going on in Switzerland at the end of the 1980s?

Roland Siegwart: So, at the end of 1980s there was some mobile robotics starting in electrical engineering and then later on this was also moving over more to mechanical engineering aside to the mobile robotics. Also, Schweitzer did a very interesting and very visionary design of a robot and implementation for delivering post parcels that do the different office building. This was, at this time, I think a very tough challenge and we learned a lot and it was a nice robot which was doing more or less the job at the end. And it was also same time we started to also think about where should robots be at various – probably the most challenging in the environment where humans have not directly access. So, in early 1990 there was a bigger project at ETH, a so-called Poly-Project on nanorobotics with the vision to have very small robots which can handle objects in the size of a couple micrometers with a nanometer position, which was in more or less also the time where tunneling microscopy started to become very popular and so it fitted well together that in this environment where you can actually see single atoms, you probably would like to also manipulate very small parts.

Peter Asaro: And who was doing that work or running that lab at the time?

Roland Siegwart: So, Schweitzer was still the head of the robotics lab. I was, from the robotics side, the leader of this nanorobotics project and then I have people from computer vision were involved and where people from mechanics were very involved in this, and from computer vision side it was Olaf Kubler, who was not really a roboticist but very close and using his knowledge, innovation for this and he was later on then the president of ETH Zurich.

Peter Asaro: And so they brought you back as a professor after you were at Stanford?

Roland Siegwart: So, I was there as a post, sort of a senior scientist and then I had the chance in '96 to be appointed as a professor in Lausanne at EPFL.

Peter Asaro: Ah, okay.

Roland Siegwart: But I had since a while a department of micro engineering which had a lot of robotics involved, so I had the chance there to interact and start work with Jean-Daniel Nicoud, with Professor Burckhardt which was another pioneer in Switzerland in robotics. He did a lot of early work in searchable robotics and there was a lot of stimulating elements which came in, from Nicoud more the bio-inspired and behavior-based robotics, and they had also a very good team in design. So, there was Clavel, which is the inventor of the parallel robots, the Delta robot, which was a very fast manipulator which today is now built and sold by ABB as an industrial robot for specific applications where you have to move very fast.

Peter Asaro: Okay. And how long were you at EPFL?

Roland Siegwart: I was there for ten years, so I had then a call to move back to Zurich in 2006 and during the period at EPFL we had a couple of very interesting projects which also moved out to interact with neuroscientists, with people more from biology. One project we had there is a very small robot in the size of a sugar cube which interacted with cockroaches. So, the idea was to study...

<brief interruption>

Roland Siegwart: So, we had this fascinating project about very small robots, size of a sugar cube which should then interact with cockroaches and the idea was, from the biological side, to study how the collective behavior can be influenced. So, the robots were imitating cockroaches, and there were some indications even in that science paper showing that you could influence robots to behave of cockroaches so that they, for example, select another place to stay because the robots smelled like a cockroach and they were attracting the other cockroaches.

Peter Asaro: As someone who was both at ETH and EPFL, do you get a sense of the different sort of tradition of robotics that goes on in each or the spirit of research in different...

Roland Siegwart: I think there is a difference that in Lausanne there was one person really was strongly influencing and bringing new ideas in was Jean-Daniel Nicoud, and this may brought up this tradition to have this mobile inspired robotics where people also study more in detail what nature is doing and trying to imitate this on robots. This is probably a difference, I think in the spirit and how we work is pretty similar and I think both places are great places for robotics.

Peter Asaro: But ETH is mainly more traditional engineering?

Roland Siegwart: Yes, ETH is probably more traditional engineering and I think we are probably covering a broader field. We are covering from mobile robotics, microrobotics, up to rehabilitation robotics and walking machines and so on, where Lausanne has a strong focus on bio-inspired robotics, behavior-based robotics and new ways how to generate intelligence for robotics.

Peter Asaro: And so while you were at EPFL did you still focus mainly on small scale and microrobotics or did you do some large scale robotics as well?

Roland Siegwart: I did, on one side focus on the small scale, I think at this time we had the smallest and the most performed very small robots, they were called Alice robots where typically – they won also the competition in Japan in the maze, running through the maze fully autonomously. But we did also quite a lot in the larger scale and in 2002 we actually had the chance to organize IROS, which is one of the biggest conference in robotics, in Lausanne and in the same year we had an exhibition in Switzerland which is the Expo 2002, which is a national exhibition and we were invited to have a part on robotics and for this we built tour guide robots which showed the people around, which explained what robotics does today and the robot themselves which were tour guides but were also a part of the exhibition. And I think it was the biggest installation, probably, of things ever of number and time of robots, we had eleven robots working twelve hours a day for five months and interacting with roughly about seven hundred thousand people, and it was very interesting experience for us also to learn how people approach robots. So, we learned for example that if a robot can speak, we had a very good speech synthesis in different languages, the people which are interacting with the robots, they assume that the robot can also understand them. So, people had the tendency to start to speak to robots and then they had to learn that the robot can speak but not understand.

Peter Asaro: Interesting. So, what were some of the big challenges of building small robots?

Roland Siegwart: I think what we also focus on, I think it's very interesting to see that there are some scalings law in mechanics, in computing, in sensing, and we try to see how the scaling changes, and of course also in nature you see obvious changes in the scaling law. If you compare the body shape of an elephant with an ant, you can see that the structural loading through the mass is very favorable with changing when you get small. So, small robots you can throw out of the window and they will survive, if you have a big robot it will not survive. This is the same in nature, and so you can do new things. On the other side we, of course, which is probably also evident but that if you get smaller even a small particle is all of a sudden becoming an obstacle and this was actually what motivated us then to start going into flying robot because the smaller you get the more difficult is it to go on rough terrain, for example, or even on flat ground with a little bit of, for a small robot it's immediately a hill. And so we started to combine the small robots with flying robots and we started to work on quadrotor helicopters and I'm still

convinced in a very tiny space where the space is very complex, for example, a destroyed building, probably the best way to go through it is flying. Even if it has other challenges where you need all this power even if you wanted to stand still in the air, you have very limited calculation power, you cannot carry too much of sensors around, but on the other side you have much more mobility and this is again, in nature. If you see the smaller you get, that the animals get, the more probably they are flying. So, you have flies, but you never see elephants fly, you can also see in birds, the biggest birds that don't fly anymore. So, it's really interesting to realize this and we did, and also some flying stuff which I think is probably the first and only up to now with a rather small airplane with two meter wingspan. We did a continuous flight, so we flew twenty-four hours and we had full charge batteries, so in a sunny day you could continue for days and also there we did a lot of study, how does the structural size influence more or less the probability that you can fly in continuous mode? And so it's interesting also to see that flying is, from a structural way, much easier with small units because the structural loading is much less an issue which is shown in nature, but on the other side of course is the smaller you get the more problem you have with high dynamics, you have to control faster. On the other side, you have less calculation power available, so it's also a very challenging part.

Peter Asaro: Interesting. So, what was the first flying robot, the quadrotor or...?

Roland Siegwart: It was a quadrotor, actually it was, even, the first one which was not a really fully autonomous flying, was the Alice robot which was the sugar cube robot which was equipped with two small propeller and which allowed us to make small jumps. So, for example, fly from the ground to on the table and then you will continue. This was more or less touching a little bit, it was nothing very serious but it was a starting point which was a lot of fun to...

Peter Asaro: Apart from the general laws of scaling and body types, did you take a lot of biological inspiration in the specific design choices of some of these robots?

Roland Siegwart: I think we are always trying to get inspired by biology but in principle, I think, as an engineer you should get inspired by whatever you see and I think you have to move around and I think one important thing is bio-inspiration is very good, but all the inspirations, also speaking with colleagues and I think this is extremely important to speak and to interact with other people because this gives you inspiration. Imitation is another issue and I am personally not so in favor that I don't think that too strong imitation is good because biology is not a basic ingredient for building something. So, molecules and cells are extremely different than computer chips and so you cannot directly copy something on a computer chip and this, I think, is important to consider. You can get inspiration but then you have to bring it to this new way of mature, you have to build it and so this makes a big difference.

Peter Asaro: And did you look to animal perception or neural models at any point for control system ideas?

Roland Siegwart: We had a couple of European projects where we had neuroscientists involved from, mainly from all over Europe and we learned a lot from them. I think they learned also from us. So, what we did in one of the European project we showed that the base approach for actually learning and dealing with uncertain information can also actually model more or less the brain, the structure and the concept of the brain. So, at the end there is one way that you have the neural networks but on the other side also the brain is doing some sort of statistical calculation, which was very exciting but we learned also that the goals are quite different. So, neuroscientists have other principle goals and other approach how to understand and to do science.

Peter Asaro: And how did they lure you back to ETH?

Roland Siegwart: So, I had one moment the chance to have, because they had a person who passed away too early and they had an open lab and they asked me to move back to ETH. I think it was a chance to restart a change. I think it's always good if after ten years you start a new field or you start at a new place and I think it was very interesting. I was moving actually also with a lot of my Ph.D. students, so it was not a big loss that I had to build up again. I could more or less directly continue, but I was in Lausanne in this microengineering department which is mainly students which are in between mechanical, electrical and computer science here, then I was in the mechanical engineering department which of course has then an implication that you have people which were known less for probably computer science but more about mechanics, and which motivated me then also to start much more now on walking robot. Walking robot, I think it has a lot to do with modeling, dynamic modeling, control, and it was very interesting and so we are now moving fast-forward on the walking robot which is a new field which I'm very excited about.

Peter Asaro: And you're focusing on biped, quadruped?

Roland Siegwart: We are focusing on the moment on quadruped. We are focusing on the type of locomotion but then also on the actuator. So, in order to do, what the final goal is that we can run with electric actuators and for doing so you cannot, you need elastic elements in the actuator which can store the energy during the step on the ground, and so we have now a concept which I think is very permissible and hopefully pretty soon we can really show for the first time in the world that you can really run with a robot and with electrical actuators and which is something pretty close to what nature does. All the muscles have elastic elements and there, for example, we are getting a lot of inspiration from nature, but of course we are doing it quite differently. So, we are not trying to imitate muscles, we are convinced that today electrical motors are extremely efficient and the best you can get from technology, and we found ways how to imitate what

nature does but in a quite different way, still having elastic elements and having an actuator but quite different implementation.

Peter Asaro: Why is it so important to have that elastic element in that walking machine?

Roland Siegwart: So, if you don't have elastic element you have an impact with the ground once the foot – and this is a lot of energy which will be lost. So, in principal, if you have no elastic element you lose at each contact with the ground, all the energy. You need an elastic element, of course you could probably also recover part of this in the motor but the motor is not fast and dynamic enough, so it's better to store this energy during the step in a spring and get it directly back, because otherwise you will end up with a motor which is probably about ten times bigger because you're really losing all the energy and with a perfect system which has elastic elements in theory, you can gain probably ninety percent of the energy which you otherwise lost. And if you have the big actuators, at one point you're getting too heavy and you will never run, so I think the only way to even think about running with motors and with an artificial system is that you have to have this elastic element in it.

Peter Asaro: And did you develop a lot of your ideas in relation to the work of Marc Raibert or are they...

Roland Siegwart: Of course, this is one of the main source of inspiration. I think it's still the stronger in this field and there is a lot of inspiration coming from there. Of course, also a lot of modeling is not actually new but it's a lot about the design. I think we came up with very innovative designs which allowed to have an optimal way to control walking so that you, mainly during the stance phase, you are trying to get best out of recovering the energy and getting off again, and during the flight phase you have to have the best situation to move the legs where you need to move it so that it has a best contact in next point.

Peter Asaro: And what kind of strategies and techniques did you use to achieve that?

Roland Siegwart: So, it's more or less the similar elements which Marc Raibert started off and now we are, of course, then optimizing the control, so you have to switch actually controller. During the flight phase you control more or less the movement and during the stance phase you have to try to optimally get the best kickoff after this in moment, and then there is always the question, "What type of case is best?" And we did quite some investigation actually on what is the best gait for which speed on the model, on simulation, and you can also see in nature, so depending on the speed a horse is either walking, trotting or galloping and you can exactly see the same with models that, depending on the speed, there is different gait which are most optimal and this is actually also what we try to now bring on the real system.

Peter Asaro: Great. So, we were talking about ISIS, that's the Intelligent Systems lab, is that part of your...

Roland Siegwart: IRI...

Peter Asaro: IRIS.

Roland Siegwart: Yes, IRIS.

Peter Asaro: IRIS.

Roland Siegwart: Yes.

Peter Asaro: Okay. So, is that the name of your lab or is that...?

Roland Siegwart: So, we have actually at ETH a structure, we have departments and then the next lower level is typically an institute and so we have an Institute of Robotics and Intelligent Systems where we have currently have five professors involved, Brad Nelson with micro/nanorobotics, then Robert Riener with rehabilitation robotics, Roger Gassert in search robotics and the similar stuff and Fumiya Iida also on the walking and especially new design on locomotion, and I think we have a really strong team. We have also some other people from computer vision which contribute to this field and since two years we have now, a little bit more than two years, a specialized master program in robotics systems and control which attracts a lot of students and which even further boosts this field.

Peter Asaro: How old is IRIS? How long has that been around?

Roland Siegwart: So, IRIS was, actually there was Gerhard Schweitzer which was really the main pioneer in robotics at ETH but also in Europe he was among the very first working on this, and then when he was retired Brad Nelson came in and then IRIS started with one professor and since then there have been a lot of new people coming in. So, I was then coming in in 2006, shortly after Robert Riener and then our two young colleagues a couple years ago, and we had also the chance to have people from computer science which are more and more getting involved in robotics being now at ETH, like Marc Pollefeys, Luc Van Gool, and then we have Raffaello D'Andrea, who is a controls person but who is doing a lot of robotics with flying robots also. So, we have really a strong team meanwhile, and it's extremely exciting to be here.

Peter Asaro: Yeah, as I walked down the hall I couldn't believe how many lab stations there are and how many students are working on robots here. So, in terms of the master's in robotics are you aware of any other master's programs in robotics in Europe or, it seems like a pretty uncommon, to actually have a degree in robotics.

Roland Siegwart: Yeah, there are a couple other places in Europe which have master's programs there but also some kind of master's program, interesting we had some very interesting discussion at the beginning. We have seen that we have these people from perception, computer vision, and we have people on the control and people in robotics, which we share a lot of ideas and we interact a lot and we said we should do something together because have also more or less the same type of students which are interested in our work. And so we came up with we should have a special master for this and interestingly the number of robotics people were very in favor to have robotics as first, robotics and then system and control, which covers more or less field because robotics is somewhat an attractive field and it turned out very well. So, it attracts people, it's actually not too much disciplinary so we can attract people from computer science, even from physics and math, and from electrical engineering and mechanical engineering, which is I think very nice and robotics is exciting but we are not only doing robotics. So, there are some people in our master program which are much more on pure control, even some working on actuator or motor control or pure computer vision, but most of them are interested at this interdisciplinary element that you have a system which uses sensors, actuators, and some sort of an intelligence in between to control systems in real world settings.

Peter Asaro: So, Brad Nelson has done a lot of microrobotics now, do you still also do microrobotics or are you mostly –?

Roland Siegwart: No, we don't do much of microrobotics anymore. So, we were never actually in this very small scale as he does it, so he is really a pioneer in this field where you have very small devices. It also changes the whole concept, so he has small robots which then of course now have not integrated actuators, which are activated from outside, and there is a very high potential for medical robotics and then other fields in this. We are still trying to push limits. We had recently a project which was recently finished on very small helicopters with fully integrated control and navigation tools. So, again to see the big limits, but this is still in a size of centimeters and not micro or millimeters.

Peter Asaro: And so now you're also finding yourself in administration. How did that happen?

Roland Siegwart: Yes, so sometimes it happens by <laughs> accident, I think. It's also very challenging and very interesting job. I think that robotics helps quite a lot because robotics is very interdisciplinary. I had to do, view my research with neuroscientists, with biologists, with chemists, and so you can probably easier understand a little bit different disciplines and I'm

actually surprised myself to see that a lot of robotics people are ending up in somewhat else of similar jobs or – in Australia now Hugh Durrant-Whyte is also now head of one of the biggest research institution in Australia which is, they're not on robotics but on a lot of different fields.

Peter Asaro: Yeah. Pradeep Khosla is dean of engineering at CMU. So, as a roboticist that's sort of in charge of research for the university – vice president of research, is that right? What role do you see robotics having in research at this university and within Switzerland into the future?

Roland Siegwart: So, I typically claim that we are really one of the top addresses in the world in robotics. I think we have really a large spectrum of very good people in this field and what we need for robotics. And robotics is, on one side, on research a lot of different topics where you can follow on. Sometimes it's, even moving a little bit away from robotics but I think the most interesting part on robotics, probably even more, the education part. I think robotics is a perfect environment and field for educating brilliant young engineers because it touches on so many elements, it deals with very tough mathematical problem, theoretical problem but also with real world situations. You have to deal with sensors which are not perfect, you have to deal with models which, in reality the real system will not follow the model anymore and even if robotics industry is not huge today, but if you see where our people end up, they end up in a lot of fields where this system thinking, this integration of all these elements is of importance. I see a lot of my former students ending up in car industry because cars are getting more and more close to robotics devices with automatic parking, with a lot of sensors, actuators. Google is hiring a lot of people from robotics. On one side they have also some project in robotics but they also, I think they can benefit from people which know how navigation systems should be done in the future, how you can probably more faster build maps, and so on. And so robotics, I think, is perfect for motivating and developing young people and so it's a very strong added value for a university to have a strong program in robotics.

Peter Asaro: Who are some of your students and where have they gone to work after they left your lab?

Roland Siegwart: So, it's actually funny. I had once a visiting student from the United States and he went through the, this was still at EPFL, he went through the list of alumni and he said, "Did you realize that most of your alumni are ending up in spinoff companies?" And that was the point I realized, of course there are some still in academia but I would guess more than fifty percent are in spinoff companies. A big part in our own spinoff company, [inaudible] and of course this reflects little bit, with the robotics, it's still a little bit far ahead from real product but they are so excited about the system so they are starting their own spinoff companies. So, we have a company in Lausanne which is doing a service in robotics, mobile robotics, and there are some people that did something which is not directly robotics but related to robotics. We have a

spinoff company which is doing inspection robotics together with Alstom, inspecting big machinery.

Peter Asaro: What is the names of those spinoff companies?

Roland Siegwart: One is Bluebotics in Lausanne, one is in Zurich, it's Alstom Inspection Robotics which is a main focus on inspecting big power plants, for example, where there are very interesting applications because imagine if you have to service a power plant which is producing typically energy, and if it's down for one day you are losing an income of up to a couple millions per day. So, if you have robots which allow you to be faster in inspection, for example, you don't have to open the whole machine, you can bring robots in, you can gain those money. I think this is the field where it's probably the most promising to enter with robotics technology because it's worthwile. If you think about this dream of having personal robots at your home, this is on one side extremely complex, on the other side there is a lot of pressure on the price. So, people will not be able to afford a one hundred thousand dollar robot in their home, so there is still a long way to go. But there is fields, I call this typically the industrial service robotics, where robotics can really do only today a good job.

Peter Asaro: What were some of the other spinoffs?

Roland Siegwart: So, there is one, it's called Shockfish which is not directly robotics but they have developed some devices which allow you to get along and get better in contact with other people at conferences and other events. So, it's some sort of a conference navigator system, which is not too far from robotics. It's exactly this type of technology where roboticists are very good in working on.

Peter Asaro: Okay, and who are some of the other people you've collaborated with over the years?

Roland Siegwart: So, we have quite a large number of collaborators in Europe, especially because Europe has since a long time now, these bigger projects where you collaborate with other universities. So, I think with all the people which are known in Europe like Rudigger Dillman, Raja Chatila, Paolo Dario, or Bruno Siciliano, with all these people we had a lot of exchange, then more currently we have with Paul Newman and Wolfram Burgard. These are all people which I think they are very influential in robotics and it's really great to have these tools also in Europe to work together with them, to submit projects and to get funding for a strong collaboration. International collaboration it's, from a funding side, a little bit more difficult but we have a lot of exchange. With CMU we had, especially in Lausanne, every year more or less one or two students exchange. We had, with MIT, we are collaborating a lot with Stanford of

course, which is always a very inspiring place. And with Australia also because they are, the center in Sydney, the Field and Service Robotics Center there is one of the very advanced environments for mobile robotics and we have a lot of students there and they have some people in our lab as well.

Peter Asaro: Alright. So, where is most of the funding coming from for robotics right now, especially in Switzerland?

Roland Siegwart: In Switzerland we have interestingly or nicely a very strong program, a government assistance in robotics which was starting out with this Framework 7 a couple years ago, and this allowed really to have a lot of interesting project and a lot of interesting collaboration. This is, in my lab for example, the biggest funding source for doing robotics. We are typically involved in about four to five or six of these Euro projects in parallel, on flying robots, on search and rescue robotics, for example at the moment. Then since last fall we have a so-called National Centre of Competence in Robotics in Switzerland, which brings mainly EPFL and ETH Zurich together which it does not cover all aspects in robotics but we have some important aspects on locomotion and we have some important aspects on rehabilitation robotics or medical robotics, and also manipulation. So, this is a way to boost in the next, hopefully up to twelve years, robotics and collaboration in Switzerland and we had a very good start and it brings this communities in Switzerland even closer together and it gets also some industry involved.

Peter Asaro: So, even though Switzerland isn't part of the European Union, they're still very much involved in EU research?

Roland Siegwart: Yes, from a research point of view, we are fully part so we can lead European projects. We are all very successful in European funding and of course Switzerland has contracted, we pay our part of the funding to Brussels and then we can also benefit exactly the same as the other European countries.

Peter Asaro: So, what do you see as the big technical problems and applications sort of facing robotics and where is robotics heading in the next five to ten years?

Roland Siegwart: Of course, I think the biggest challenge is still intelligence. I think we are still extremely far from having robots which can understand the world. I will say that you can today do a lot with computer vision, you can train robots so that they can recognize faces again. You can train robots to recognize people but if the situation is drastically different but – where humans would still be able to, for example a person in a wheelchair, if you didn't train your system, the system will not realize that this is still a person. A human has no doubt, you can

always recognize. It's also as simple as a chair, if you train a system, and you can train it with one-armed chairs, if you have done a special design of chair, the system will not work anymore. So, there is a lot of issues which I think we are not so clear how we can solve this. It's also that today we can navigate with robots very reliably with lasers because you have distance information, but we are still very poor in pure visual navigation and this is actually a topic we are strongly pursuing for the future. Also, for example, car navigation, vehicle navigation only with vision only because humans can do it, so obviously there must be solutions but today an artificial system have a lot of problem, we don't have the depth information and actually what we do is actually we understand depths because we understand the world. So, you have a feel of what a door size is and automatically if you see a door you can estimate a depth because you know a typical size of a door and this, I think, we are still far from knowing how to handle this. Especially also with limited calculation power which is given typically without, and then with robots because you have to move the computer with the robots, so you cannot have infinite calculation power.

Peter Asaro: So, you think that things like active vision are gonna be helpful in solving some of those problems of how to...

Roland Siegwart: Of course, the type of approach is which, hopefully help, but I think it's much more. I typically say that it's about understanding an object is an object not because it has a certain appearance, which is today what computer vision is doing, but because it has a certain function. A chair is not a chair because it looks like a certain appearance, because chairs can be extremely different, but a chair is a chair because you can sit on it. A mug is a mug because you can drink something out of it. And I think we have to describe or the robot has to learn how to describe the environment based on the functionalities because then you start to understand, because once you want to interact with the environment, you have to also understand what can you do, can you move something around? Can this be used for something? And this is actually, if you think back on how the intelligence of humans evolved, I think typically you say animals or humans, you start to become intelligent if you come up with new ideas how to use something for a certain function. Once you've started to use tools, this shows that there is intelligence involved and you can only use tools if you have an idea about the function and about the interaction of elements, and so on. And there I think we are still in the very early stage in the research.

Peter Asaro: And apart from this, what you described as industrial service robots, what do you think the big application areas are in the near-term future for robotics?

Roland Siegwart: I typically claim that robotics has a lot of outreach in other fields, which at one point probably will not be considered robotics anymore, but parking aids for cars, safety system in cars, this is very much inspired by robotics. There is a lot of other fields, even handheld devices or devices at home, machines or the appliances, they get more and more

elements which I think a lot of them are also coming out of from robotics because it's systems engineering, it's perception, action, intelligence, and so this brings us back to this point of education. People educated in robotics are typically very good in coming up with innovative solutions of other systems which have some sort of an intelligence, which have some sort of simple decisions to make and I think we should probably not too much concentrate and say, "We want to have tomorrow a service robot which can do everything at home," but for us how can we now use this knowledge to do a better machine? Which is probably at the end only a toaster, but it does probably something better than the current toaster and I think there's plenty of potential to do something in this direction.

Peter Asaro: And in terms of education, for young people who are interested in pursuing a career in robotics, what would you advise them to do?

Roland Siegwart: I think I would advise them to try to work on these real systems and to try to really get a grip also on not their core field, but their related fields. So, I think also in the industry people which probably started in mechanical engineering or electrical engineering and they start to evolve then, during the master program, during the Ph.D., in another field. So, they are very understanding the whole systems and they are extremely valuable for designing new systems, to come up with new ideas and robotics is probably one of the top fields offering this, that you can learn in all the different fields and you can roll from mechanical engineering to a systems engineer which really also knows about what is a sensor, how can you filter a sensor, how can you, something about artificial intelligence and I think this is very important for industry also.

Peter Asaro: And as a teacher and advisor, what was Gerhard Schweitzer like to work with as a student?

Roland Siegwart: I had a very great pleasure to work with him and I think he really was my mentor which helped me to end up where I am today. He was very open-minded, he was very good in really feeling where the new elements come on. He was actually coming from really mechanical engineering, he was doing a lot of dynamics and rotor dynamics when he was a student himself in the Ph.D., but then he realized that at one point this mechanics is not a closed system anymore. We have now all of a sudden sensors, actuators and a control and you can do much more than only having a mechanical system or a rotor, we can actually actively control a rotor. If you control it, you can probably reach higher speeds, and then of course robotics was the next step. So, you can have a simple machine but you can have also a machine which uses sensor to do much more than only moving around, but then also to really, to adapt to an environment and so he really was, I think, very instrumental in the whole Europe on this mechatronics idea which was the first step and then it evolved for us to have even a stronger focus on robotics.

Peter Asaro: Was there anybody else that influenced you as a mentor in that way or was he your primary mentor?

Roland Siegwart: So, he is the primary mentor but of course then later on I had the chance to be in contact with a lot of people. So, as I mentioned, it was when I started in Lausanne there was this new aspect on different type of approach for control which came in. Also, a strong element of Reymond Clavel, who was the inventor of Delta robot which brought more this very mechanical part in, he was and still is an excellent designer of mechanical systems which is also important. So, I think to have a very good system you have to understand and to take the best of all of them and bring them in the best way together. And then I had the chance to meet in a lot of meetings with all these people from all over the world and I think this is, I can fully not, I could, an endless list of people which inspired me in different ways, some more probably for to do with science, some more on specific aspects, on mathematics, on neuroscience, and so on.

Peter Asaro: Okay. So, that pretty much does it for my questions. If there's anything you'd like to add or any stories we missed that you need to tell?

Roland Siegwart: <laughs> Of course, probably in general, a little bit back to education, of course the nicest thing about university job I think as a professor is that you are always in contact with young people, and I have also the feeling of robotics attracts even especially gifted but also very fun and inspiring people and if you ask before about who was a mentor and inspired me, I think probably in the last fifteen years the main inspiration were my students. It makes such a lot of fun with working together with them and see how they develop. You give them some guidance but very fast, in a lot of fields, they are better than you. They come up with new ideas and I think this is extremely nice and this makes me happy every day to do the job, working with young people and see how they – I have the feeling that today they are more intelligent than we were at this time because they are learning probably earlier, they are much more multidisciplinarial. So, that mechanical engineering student, they are not only good in mechanics but they can also even do about interface and they do control and it's amazing how they develop.

Peter Asaro: Are there any particular students that stand out or projects that they've done that stand out in your mind?

Roland Siegwart: I have a lot of students and it's probably very difficult to really, if I start to name somebody I would put names forever, but it's interesting that it's not only Ph.D. students, it's also the master students and even bachelor students which are sometimes bringing a lot of elements back. So, we have this so-called focus project in the third year with our students, this is the last year of the bachelor program where they can select some focus and most students can select probably energy and mechanical engineering or biomedical, but one selection is also that

they have less courses and more project work, so they work for one year on a project and we had outstanding results in this. There are typically teams of six to eight students and they are so dedicated. At one point you have nearly to speed them down a little bit because they are working twenty-four hours a day about a project and they really, even as an undergrad student, they can do wonderful things and go far beyond what you would expect from this, they're still students and young students.

Peter Asaro: Okay. Anything else you'd like to add?

Roland Siegwart: Difficult to say, there might be hundreds of...

Peter Asaro: <laughs>

Roland Siegwart: ...elements to add.

Peter Asaro: What would you say was the first robotics conference that you attended?

Roland Siegwart: So, I was actually not so early getting involved. So, as I mentioned I was mainly in mechatronics, I was probably in '92 or '91, it was first real robotics conference I attended but then I was moving very fast, especially when I started in Lausanne because in the phase between '90 to '96 I was also, half of my job was with a spinoff company which I was involved, and this was also very interesting because then you get a little bit feeling what it means then to go from a invention to an innovation and I think I'm still profitable from them to understand also that it's not so easy if you have a new idea, it's still a long way to go for going forward. Then of course there is a lot of robotics conferences, there is on one side the very big conferences like ICRA and IROS where I think the nice thing about there is that you can really meet the whole community, it's more or less the meeting, if you want to meet again with your colleagues you meet there. I feel like that I have two families, one is the local family, my family with my parents and brothers and sisters and my – but there is also this robotics family and it's amazing how nicely this works so you meet two or three times a year but you are immediately catching up what you did discuss before, we have a lot of very informal and good interactions. On the other side, apart from this big conference we have the smaller topical conference and I think this is also extremely interesting because then you are probably less than one hundred people. Everybody is focused on the same topic, you have everybody there for really discussing and so next week there will be that dynamic working workshop which is a very small workshop but all the people which have to say something on this, they will be there and there's a lot of very strong interaction and this, I think, drives research forward.

Peter Asaro: What was the spinoff company that you worked on?

Roland Siegwart: This was a company working on electric magnetic bearings, this was the topic I did in my Ph.D. and which then continued. This is, for example, used in turbomolecular pumps, so to have high speed rotation without contact. So, the whole rotor is in the air hold by active magnets, so it's also not too far from robotics in the sense that you have a sensor, you have some sort of a control and intelligence in between, you have to know a model of the whole system and you have actuators which are some coils to have the whole thing in place.

Peter Asaro: What are the challenges of taking technology from the lab to a product?

Roland Siegwart: I think you have to be dedicated and you have to be willing to go a long way. I always claim, there are a couple of exceptions, but I claim that it takes from the moment where you have a very new thing and where I think this has a potential that you really have success, some success on the market, ten years. Some very often even more. And you have to be willing to go this way because you are suffering sometimes, it's a lot of fun but sometimes it's also very hard. If the sellers are not so high, you're getting always running for money and this is a difficult but a very rewarding way, but if you want products on the market you have to do this and this is also the motivation variables of supporting for having spinoff because robotics is still a very young field in a way. Very often research is done, you show once that it might work, you have a nice video that shows it works, very often it's you probably had to do five videos until it worked as that you can show what it does. To go from this to something reliable on the market where you can hand over this into a client, it's a long way and I think the young people are probably willing to do this and probably the most adapted because they are at the state of the art and they can bring this over and it's the way, I think, how robotics can really become a real, much more appear in real products.

Peter Asaro: And in terms of intellectual property and patenting, how does the university encourage professors to take their research into startups?

Roland Siegwart: So, in a way, we have a concept, we are a governmental university and I'm responsible also for the technology transfer. I will say that our goal is not to make money out of patents, our goal is to bring it as fast as possible to use and to best for our society. Which means that we still have to do patents because then this allows the companies to follow on but we are very open, so if you have spinoff companies we try to support them best so that they get this product for reasonable price or very often we have other deals that in the first couple of years they don't have to pay any royalties because they have not enough money. So, that really they can go forward and I think this is important. On the other side it's also my conviction that typically you have not to convince a professor themself, you have to convince the young people to go for it because the professors will, at least in Europe typically, not all of them change to go in a startup. It's more often United States, but professor of ETH typically they stay as a professor of ETH but their students, they are keen to do something and the professors can

support them on their way forward. It starts by somebody having them at the university, so we are supporting, allowing our startup companies stay in the lab for the first two years and then we have also the other places where we can support them. There's a lot of other ways to support them, so it's very important I think for, in the beginning, that you have a strong connection still with the research people, you have access to other young people so to bring the whole thing forward.

Peter Asaro: And what are some of the successful startups that have come out of ETH in recent years, especially in robotics –?

Roland Siegwart: Yeah, in robotics of course there is probably nothing where you can say it's huge a success until now, but it's also not a field like Facebook and Google, this can evolve much faster. Robotics will take much longer but we have for example, Alstom Inspection Robotics was founded 2006. They have, in all, a good start, they are having their first applications of robots in inspection. Yeah, so these inspection robotics companies, these actually are a special concept also of a company, it's called Alstom Inspection Robotics. Alstom is one of the biggest company in power production and also trade, and so on. It's a French company with a big part in Switzerland also, and this is a new concept we are trying to promote even more in the future that we have from the beginning a strong contact with potential users of the technology. Alstom is not building, that is not their main interest to build inspection robotics but they have to inspect their machineries, and because we have a strong link with them, they're involved in the company financially. It allows us to be much faster because they bring the market knowledge in and they have also good connection to the market, and so I think this is important that you have the right partnership with probably bigger companies which are not exactly in the same field but which can largely profit from your field, and on the other side you can profit from them to bring them the market knowledge and to bring them probably to contact customers and also financially can support you if you need to expand.

Peter Asaro: And do they have, like in the States they have these research parks that sort of evolve around universities, is there a similar concept in –?

Roland Siegwart: Yes, we have a so-called technopark and actually even different places, one is in downtown Zurich, unfortunately not on campus which would be even nicer, but Zurich we have a university which is in downtown and downtown you cannot expand so easily. So, this is about two kilometers away from the main campus here in Zurich but it's still close enough where you have these startup companies.

Peter Asaro: And is there also collaboration with University of Zurich in robotics?

Roland Siegwart: Yes, of course there is Rolf Pfeifer which is at the University of Zurich, and he's a very inspiring person taking a lot of inspiration also from biology and doing a lot of crazy stuff which I think is really inspiring and to learn from, and in this context we have collaboration. We have probably even more strong collaboration in the field of medical robotics because ETH has no medical school, but we have the chance to have the University Hospital next door so it's fifty meters away, and this allows us together with University of Zurich which has the medical school to be really extremely close to real environments for rehabilitation robotics, for example, or surgical robotics, and this is also a field which we will strengthen in the future. We will have a new department starting next year which is health science and technology, and interestingly there is two professors of robotics in there and there will probably even be more. All the health varieties, then there will more or less be in between engineering department and this new department of health science and technology, which is a perfect environment for boosting this field because you are challenged then by the real users and the real environment.

Peter Asaro: Alright. I don't have any more questions.

Roland Siegwart: Okay.

Peter Asaro: That's good.

Roland Siegwart: Thanks.