Lausanne, Switzerland
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Francesco Mondada

An interview conducted by
Peter Asaro
with
Francesco Mondada

[Interview Date]

Q: And where you were born and grew up and where did you go to school?

Francesco Mondada: Okay. I'm born in the Italian part of Switzerland, so that my mother tongue is, it is Italian. And I've grown up there for, you know, until university, and then I came here to Lausanne for the university. And directly I – so basically people from the Italian part, normally they go to Zürich. They don't come here to Lausanne. Zürich it's closer. German, in any case, you need to learn it. So basically people normally don't come here to Lausanne. But I wanted to do what we call here microtechnique, which is a kind of system engineering, which was not existing in Zürich. So I came here to make this system engineering studies at EPFL.

Q: And when was that that you first came here?

Francesco Mondada: '86.

Q: '86. And so the microtechnique, was that within the mechanical engineering or…

Francesco Mondada: Well, at that time, when I came, yes. It was an institute of mechanical engineering. So it was a precision mechanics, basically. But already with a flavor of system engineering, with mechatronics, so electronics and computer science. It was very strongly centered around robotics. And during my studies it became a department, so it became independent from mechanics and it became the department of microtechnique.

Q: And who were the faculty that were working in the…

Francesco Mondada: So the creator of this was Professor Burckhardt. And one of the key player was Professor Clavel, which was, and still, active in parallel robotics.

Q: When did you know you wanted to get into robotics?

Francesco Mondada: So basically I already made some robots before coming to Lausanne. So there was already a big interest at that time. So before coming to the university. And then I found my, really very well, my place within this department. Nicoud was a different tier of the department, so basically Nicoud was making the bridge between the microtechnique and computer science, and taking care. So basically the core microtechnique was more mechanics, and the Nicoud was doing the bridge with electronics and computer science. So I found my ideal place in Nicoud's labs and doing – so we a background of mechanics coming from microtechnique, but with the link to computer science electronics that was inside the lab of Nicoud.

Q: What were the robots you built before you came to Lausanne?

Francesco Mondada: So I just built a robotic arm, controlled by –

<off-topic conversation>

Q: So robotic arm.

Francesco Mondada: No. Basically a robotic arm that was controlled by Commodore… It was the Plus/4. It was a very specific model at that time. Because I started doing… So in my family, my father was a teacher in mechanics. In mechanical practice. And do you want – so how –

<off-topic conversation>

Francesco Mondada: So basically my interest came from the fact that, okay, my father was totally into mechanics. We had a workshop under our home. Okay. So I had my – how you call this? Turning machine. So okay. I have my small equipment to do mechanical parts, et cetera. And in the same period I won a contest, so a standard… So this type of win, you know, you fill in something with a product and then you win something, and I won a computer, a big, a Commodore V... I don't know the name in English. It's a VIC-20. So V-I-C 20.

Q: Yeah, VIC-20.

Francesco Mondada: Yeah.

Q: What's that? <laughs>

Francesco Mondada: That was the first.

<laughter>

Francesco Mondada: And then based on this, then I start programming a little bit and interfacing something, and then interfacing some electronics. And then putting motors and then controlling devices, so…

Q: So how old were you when that started?

<laughter>

Francesco Mondada: I don't remember.

Q: Yeah?

Francesco Mondada: We should recover when was the period of the –

Q: The VIC-20. Yeah.

Francesco Mondada: Of the VIC-20 invented.

Q: Okay. We'll look it up. Okay. So when you got here even as an undergrad, what was the first sort of robotics projects you started working on?

Francesco Mondada: So basically when I entered here, so it was just standard studies. And then the first project I made was with Nicoud, the first full robot I made here was a six-legged, six-legged robot, with only five motors. So it was a challenge to make, to control six legs with only five motors. This was the type of challenges Nicoud likes a lot, so I'm doing something with as few material as possible. And so the robot never worked, so just in the air. <laughs> Because there was many, many design mistakes. And then I came back to Nicoud's lab to do the final project, so the diploma project at the end of the studies. And I made a juggling robot. So a robot that was juggling on a plane with a camera and looking to a ball and then juggling with three balls on a plane.

Q: So just on an inclined plane.

Francesco Mondada: An inclined plane, yes.

Q: Yeah.

Francesco Mondada: Not on the air, no.

Q: Ah. Ah.

Francesco Mondada: So it was a little bit slower.

Q: <laughs>

Francesco Mondada: Because basically we had a HC11 microcontroller. I don't know. It was one megahertz at that time, doing all the vision.

<laughter>

Francesco Mondada: So it was taking 25 frame per second and extracting the ball coordinates.

Q: That's pretty good. What kind of camera was it, you know?

Francesco Mondada: It was an analog camera and then the analog signal was taken by the HC11 with a AD converter and… <laughs>

Q: It worked. <laughs> <Inaudible>.

Francesco Mondada: And it worked. And it was already a multiprocessor system based on a communication between several process, so there was a 86,000 controlling everything and then the two or three microcontrollers controlling the, getting the image, taking the, extracting, the information and then controlling the motors. And then to be fast enough, because we were thinking of sending back a ball, so two ball per second, something of this. So we had to control the motor in an accurate way. And then we had the parallel structure, lightweight [ph?] structure, Clavel was developing at that time too, to catch the ball and juggling.

Q: And that was your undergraduate diploma or your master's?

Francesco Mondada: Yeah.

Q: Okay.

Francesco Mondada: So it was the –

Q: Master's.

Francesco Mondada: We didn't have any master and bachelor at that time it was. But it's the equivalent of the master now.

Q: Okay. Okay. And then what did you decide to do for your Ph.D. work?

Francesco Mondada: Ha. At that time I was not interested at all in doing a Ph.D., so basically I started by doing something in Nicoud's lab as a normal assistant. And then after three years we decided to turn what was done into a Ph.D., so starting doing a Ph.D. But basically my first intention was not to do a Ph.D. then. So I did some post-graduate courses on neural networks, on databases, et cetera. So try to get little bit more into some specific computer science topics. And then at one point I was enough into robotics and spent enough time and with enough result to start thinking, "Okay. We could do a Ph.D. out of this." And then so… And then at that time it was easier to do a Ph.D. We had more time than now. And it was easy also to start a Ph.D. later on, et cetera. So it was much more flexible now. So then I decided to do the Ph.D. and then totally I spent six years in Nicoud's lab before doing, before ending the Ph.D. And then I spent still some years after the Ph.D. as a post-doc. To run some project in Nicoud's labs.

Q: And what was the Ph.D. thesis?

Francesco Mondada: It was on the application of basically neural networks on mobile robotics. So the idea was to find out – it was not only based on neural networks, but it was, there were several bio-inspired approaches to mobile robotics. And yeah. So the core was the design of the Khepera robot and on the Khepera robot, I have been able to make the link with neural networks with some collective experiments, et cetera, and showing some bio-inspired approaches to robotics, running on a real robots. Where it was, at that time, it was not simple to get a robot. Most labs had NOMAD robots, or the big device, and we were the first having a robot on a table able to run complex algorithm, and be able to display some interesting behaviors. And doing experiments on a table with a Khepera robot was just speeding up incredibly the process, so we were able to run experiment very quickly. The setup was quickly done. We were able to quickly program it because we could program in any language we wanted to on the computer and then control the robot with serial port or these type of things, or bring some part of the algorithm on the robot. So it was very flexible and very simple to use. So we were able to run experiment very, very quickly and I was able to make the bridge with several people, so… Dario Floreano, for instance, Paul Verschure and Rolf Pfeifer. So people who were looking for quite a lot of ideas about algorithm and were looking for a robot, where to put it. And I was in the opposite case. <laughs> I was good in doing the robots, the mechanics, the electronics and the software. And I was looking for algorithm, so we found very, very good matches at that time. And it was the beginning of the Khepera story, basically.

Q: So yeah. Tell me the Khepera story.

Francesco Mondada: <laughs>

Q: From the beginning, I guess.

Francesco Mondada: So basically the Khepera was developed together with Edo Franzi and André Guignard to solve the problem of having a robot to do the research, because when I started in Nicoud's lab there was a project on bio-inspired artificial intelligence on robotics. But we had no robots to run it. And it was quite clear that most of the algorithm we have made would run better on a mobile robot. So we wanted to have a mobile robot to do our experiments. And here we are, we are in the world of watches and small things. So it was clear that we wanted to have a small robot to run our algorithm. So we decided to build up a robot that was small but powerful. So putting one of the one 32-bit processor in a small robot, five, six centimeters in diameter, putting batteries and motors and sensoring it. Having it modular to put extra module on it. And this was at the beginning just a solution for our own problem. So was never planned as a product or something that we would distribute outside. And then when we had this, I started moving around, showing this around the world in conferences, et cetera. And then we saw that people were interested in having the same, because at that time, you had either roboticists that were able to have their own robot. They had their own technician <laughs> and they had the budget to do it. Or you had computer scientists and people having ideas on the algorithm. But no possibilities to just have a robot run their experiments. So you have many people doing evolutionary algorithm, but in simulation or neural networks with simulation, et cetera. So the Khepera was a very good middle pile between the complexity of the robotics on one side, and the cost of the robots on one side and the simulation on the other side. So the Khepera was a kind of model of the real robot still in reality, but simple enough to be controlled by people able only to do computer science, I guess it was. So I heard some criticism that Khepera was merely a simulated robot, so it was not a real robot. It was closer to the simulation than to the real world. No. Khepera wasn't the real world. So you could have the real problem of sensor, noise, of real-time. So you had the real world, real problem of the robot, but on a table near your computer, you could move the robot just with your hands. Like, you could catch the robot and move it in another position or put it again in a new position. And this was just totally different than people working with the NOMAD robot, for instance. So you could not take a NOMAD <laughs> and replace it. It was heavy, it was costly, et cetera, so… And by chance, <laughs> Khepera was really answering to a problem of, or by chance, because we answered to our problem, we showed that we were answering also the problem of many other people. And so people started to ask, "Could we have a Khepera also?" And then we started building some, building more. <laughs> At one point we built, we were doing, only this in, you know, free time, and we decided to build up a company and then K-Team started. And we started to sell Kheperas all around. So building up the company and going up, et cetera, so…

Q: So when was that? And how much did the first models cost?

Francesco Mondada: So K-Team was created in '95. The Khepera was – the first Khepera prototypes were '92, '93. And K-Team started in '95. But basically K-Team started with a full set of orders. So K-Team was not created as a company like spin-off now, where you create, where you look for a capital and then you start building up your company and your business model, et cetera. So K-Team was born to just satisfy <laughs> the orders that we had. So we created K-Team already with full list of order of robots. So K-Team was created just to, just to satisfy, the request of them.

Q: And how many requests was it, would you estimate?

Francesco Mondada: So we were already in the order of the hundreds, at that time. And the Khepera was not cheap, because it was not planned to be produced, to be mass produced. It was really designed to be made piece by piece. And so it was really… So we started basically producing a prototype in larger quantities, but with the same techniques as a prototype, so…

Q: How much was the first one that you sold?

Francesco Mondada: So from the beginning we had the price of 3,000 Swiss Francs, which if you think now, it's huge. But at that time the price of a robot was much larger. And so we, in fact, before starting K-Team, we looked a little bit around to find somebody who could sell it. Because we were not interesting ourself to build up the company at the beginning. So our goal was, "Okay. We are doing research. We will look for a company producing it and selling it." But everybody found the idea very ridiculous. So <laughs> we had, several companies told us, "Are you crazy selling small robot, 3,000 Swiss Francs, where robots, normal robots cost 50,000? And selling robot 3,000? It's a business cannot work. Can't." So it's too… "The price is too small and you cannot. You cannot follow people or support people at that price." And so that company gave this field back to us. Then collapsed and <laughs> K-Team survived. Because in the meantime nobody were able, were ready to pay large amounts for big robots and then we started to have smaller robots, lower prices, et cetera, and then K-Team was the right model at that time.

Q: Where did the name Khepera come from?

Francesco Mondada: So this is an area of Nicoud.

<laughter>

Francesco Mondada: Because basically because of the size and the shape, et cetera, this was called within the lab between us, khefar, which is a cockroach, basically. And Nicoud was not happy about this. Not happy at all. He said, "Nah, that's a bad name. We cannot call like this." And then he found an Egyptian god, was the head of a cockroach, but it's a god. And the name is Kheper. So this is the origin of the name Khepera, is an elegant way to <laughs> cover the cockroach…

<laughter>

Francesco Mondada: That was born in our lab.

Q: Great. That's very bio-inspired.

Francesco Mondada: Yeah, very bio-inspired, yes.

<laughter>

Q: Great. Okay. Let's go back a bit. So you did some collaborations like Rolf Pfeifer and others. What kind of collaborations were they? What kind of projects did you work on with them and some of the other people you collaborated with early on?

Francesco Mondada: Yeah. At that time, it was Paul Verschure in Rolf Pfeifer's lab, was developing a model was called DAC, to make learning using neural networks on robots. And in Nicoud's lab there was an activity on neural networks, and we were, in any case, interesting in putting neural networks on robots. But at that time in Nicoud's lab, the neural networks was really focused on data processing and not to be applied on mobile robots. And Paul Verschure had a nice model to do learning on robots. So basically we made some experiments porting his learning algorithm on a real mobile robot. On the Khepera, using a little bit of vision, so linear cameras, and doing some learning of some patterns to do obstacle, so visual obstacle avoidance. So this was one of the collaboration. Another collaboration was with Dario Floreano, on artificial evolution. He had a lot of brilliant ideas on artificial evolution, to use it to shape neural networks for robotics. And so also in that <phone rings> case we…

Q: You were talking about some work you did with Dario on artificial evolution.

Francesco Mondada: Yeah. So Dario, again, was a typical situation where he had a lot of ideas, brilliant ideas on artificial evolution, how to put this on robots, et cetera. And we are the robots. And …

<laughter>

Francesco Mondada: And it was also filling a gap that we had in the sense that he was also shaping neural networks for robotics. So the collaboration was very, very natural in a sense that he was bringing all the bio-inspired ideas into robotics and we were bringing the robotics technology and all the support, et cetera. So these were the fantastic years of collaboration with many people. We had other collaboration with Claude Touzet, with several other people around the world who had, who were thinking about, a new way of shaping neural networks or using neural networks or using bio-inspired algorithm, but missing the opportunity of having a robot. And some collaboration went in that way, in very direct ways, in the sense that we built up together something, or as soon as we started distributing the robot people started to put their algorithm themself on the robots and do experiments. So indeed we, now, we have a huge literature on people having done experiments on Khepera robots.

Q: And did you use an open-source kind of model for the software on that or…

Francesco Mondada: Not at all.

Q: No. Hmm.

Francesco Mondada: At that time it was not. It was not a trend.

Q: I see.

Francesco Mondada: No. And all the software within the Khepera. So we distributed the interface pinning so people were able to build up extensions that basically we never distributed the core software of, within the Khepera. At that time, it was not so important and I think that our work, for the same customers, were people interested in controlling robot but not touching the lower level of the robot. So the interface was open. Everything was documented but the firmware of the robot was interest – most of the people doing bio-inspired robotic in that time. So we never went to that – to in that direction. Now I would do it totally different way, of course and in indeed the last robot we developed, the E-puck for instance of the – or the Thymio robot that we are developing now for the kids – that these are totally open source. Today is, I think, is very different. But at that time, no, it was not open source.

Q: And then the Koala followed?

Francesco Mondada: Yeah, the Koala was an attempt to give the possibility to the Khepera user to move up to larger robots because basically – okay, Khepera user could start touching the real world but then the next logical step would be to enter into application and you cannot enter into an application with a Khepera robot. So the idea was to have a larger robot where people could basically and in a compatible way move up to a larger scale. But okay, the Koala robot was not so successful as the Khepera. So the Khepera was really answering our need and the Koala was not so successful.

Q: How many Kheperass do you think you sold altogether?

Francesco Mondada: At one point, I left K-Team so I don't have the complete number but I think that we equipped something like 1,000 labs. So we sold several thousands. Now how many thousand at the end really – so K-Team continued to sell Khepera until some years ago. Basically, they still got requests for Kheperas. I don't know how many years ago but a few years ago. So the lifespan of Khepera was just huge, incredibly huge, because of the reference aspect. So people started to just by Khepera because Khepera is a reference. There are plenty of articles doing experiments in Kheperas, so. We buy a Khepera because then we can reproduce these experiments, et cetera, et cetera. So I don't know. I don't know the final numbers. I don't have the real numbers but several thousands. I don't know how many thousand.

Q: I think it's important that it became this kind of reference point for replication of experiments. Do you see that there's a robot now that serves that function in the way that Khepera did, that's replaced it?

Francesco Mondada: So Khepera was a reference robot within a specific group, so people doing bio-inspired robotics. So it was not at all a reference for people doing robotics. So for people doing robotics, this was a toy. Okay? And we sold it especially in Europe and Japan but nearly – very, very few at the beginning in the U.S. So basically we had big problem to sell Kheperas in the U.S. So people interesting into bio-inspired approaches at that time were basically Japan and Europe and not U.S. at all. So for U.S. – for the upper grants a Khepera was not <laughs> interesting at all. And so it was not a generic reference. It was a reference within a specific group. So basically, you can find now similar situation like I don't know, the board – Arduino board within the people doing art and technology. Yeah, so that – this is a reference board or you can have some – perhaps not at the level of the platforms now there is no real – a reference platform used by all the community. It's more – there are some reference for some libraries and so you have some libraries which are reference libraries or reference operating systems, et cetera. So – but I don't see a platform today doing – playing the same role – an hardware platform. Perhaps a little bit more in the software level there are references now but at the hardware level is a little bit different now. There is more choice <laughs>. You can buy much more and for lower price. You have several producers and...

Q: And just to get a sense of the scale and the success of the K-team, it's still an operating company. How many people are employed there?

Francesco Mondada: So basically, the K-team went up to 10 people, I would say, and then they had some big project on the robotics, outside the field of research and education. So they made, for instance, the camel jockey for Qatar. And now the Khepera is not reference anymore and so they are selling a third version of Khepera that is not so successful as the Khepera itself. So now, the size of the company is very small. I think there are a couple of people.

Q: Have you ever been involved in any other startups or things of that...

Francesco Mondada: I've been involved in other startup making a software. So for making a software SysQuake. And now I created a non-profit organization so <laughs> things are changing <laughs>. At that time, the model K-Team company closed firmware was, I think, the right model and now the model for me is non-profit organization and open software, strong social involvement et cetera. So perhaps this – I've also – is a bit changed <laughs> so...

Q: <laughs>

Francesco Mondada: ...in my way of thinking. But I think that – so, for instance, now we are distributing. So after the Khepera, we – a nice success was the E-puck robot, which is an education robot. It has also been sold in several thousand copies and this – the model was open source. I think the position of the EPFL was a little bit – was very different. At the time of K-Team, EPFL gave a license to K-Team and got money back. Okay? And finally, I'm a little bit sorry that the name Khepera was more associated to K-Team than in EPFL. And I think that, as a EPFL, we missed something at that point. Yeah, it's better to get the image or the money <laughs>.

Q: <laughs>

Francesco Mondada: And I think that at the beginning, <clears throat> the choice of the license and the company and the closed software, et cetera – okay, was a good model at that time but, okay, now I prefer to say, “Okay, we give everything for free. We make an open license people can produce. So the E-puck – anybody can produce the E-puck and sell it. But the name of a EPFL stay linked to the device so people know that, okay, E-puck is linked with EPFL and not to a company – not to a specific company. So I think that at that time, a good model was the Handy Board from MIT. So they managed to do this in a nice way. So, really, having the design made at MIT, nice license and then a large distribution that is made by company who can really do a nice distribution and have a cheap product that can be available to anybody. So with the E-puck we started doing this and went fare, well. So we have – there are two companies outside producing it and it has been nicely distributed. And now we are – so the next step is that I build up, with some colleagues, a non-profit organization and we try to produce this within a non-profit organization. So try to reduce the margin and even push a little bit more the open concept. Not only to open software, not only to open hardware but really distribute the order itself to a lower possible cost and change a little bit the business model to a less commercial model but a more sharing of the knowledge model. So a model based on – okay, distributing robot without guarantee so people can get everything. They can get the schematics. They can get the plans. They can get the software. They can get the sources of everything. And they can get the hardware at the lower possible cost. Then they don’t get through – we try to avoid the commercial support and try to push it more to the sharing of know-how than the relationship between company and customers, so.

Q: What’s the non-profit called?

Francesco Mondada: Mobsya.

Q: How do you spell that <laughs>?

Francesco Mondada: <laughs>

Q: Is this the robot? Oh, <clears throat>.

Francesco Mondada: So it’s a mix between mobile system and...

Q: And this is the platform here.

Francesco Mondada: And this a platform that we are distributing to kids. So here the – but this is still another goal. It’s not the same goal as the E-puck of – or the Khepera. So the Khepera was a research robot and it was used a lot in education. The E-puck was mainly an education robot that we developed here for our recourses and then we started distribute it and people started using for research <laughs>. And this is a robot that we really want to have for kids. So the goal is to have a very cheap robot that can be programmed, that does several sensorings, et cetera. And here, the goal is to distribute it to kids – to have kids starting playing with robots, start programming robots but easily. So not – so we want to remove some barriers, for instance, the price. A programmer robot now is not cheap. If you want to have a programmer robot at home, you have to spend some hundreds francs and we want to stay below the hundred francs with a robot that is modular enough, programmable and very intuitive in the programming interface and in the way of interacting with it. So to reach that goal, it was not possible to follow. So we didn't want to follow a commercial model. So if you start be – having open software, open hardware, give all the schematics, et cetera, why not say, "Okay, then we are – open also the level of the price or the level of the model." So we can say how much it cost to everybody, how much more or can – how much margin we do to live, to have people having a salary, to distribute this and then reduce all the other expenses like a guarantee and support, et cetera, by having a community that is able to answer to the question and share their competencies among the community. We are trying. We'll see <laughs>.

Q: So it's under $100 francs?

Francesco Mondada: Yes, it's under $100 francs, yes, and it can be programmable. So it can be programmed. It has proximity sensor all around, so in the front, in the back. We have a proximity sensor on the ground so to follow lines, to detect the edge of a table. And then, inside, we have a accelerometer, so three-axis accelerometer. We have a microphone, remote control receiver, and then we have some capacity touch sensor. We have a SD card to record sound and then we have a USB to recharge it and to program it. Two wheels, the penhole and the speaker, and that's it.

Q: A trailer hitch.

Francesco Mondada: Hm?

Q: A trailer hitch.

Francesco Mondada: Yeah, yeah <laughs>.

Q: <laughs> That's great.

Francesco Mondada: And then we can connect Lego parts. So we can build up structures using Lego, which are – so at the beginning, we had another robot where we didn't had the Lego connectivity but basically people were able to build up so – people were able to build up these type of robots and so, using the – so this was the robotic base and then they were able to build up something. But then you don't want to dismantle this. Okay? You don't want to do. If you want to do another one, then to a – "What do I do?" So basically this robot was always finishing shelter and kids were not using it anymore. So the idea was to – and then we – several – we made a study where several parents told us, "Okay, if you use Lego, then people are more – much more used to dismantle and rebuild something, et cetera." And, in fact, it changes completely way of constructing something on the robot. As soon as you have – you can even – even doing this. So you can build a robot but then we have the Lego bricks here so that we can – you can just remove the part and then build something else and build this house and reusing the robot again and again and reprogramming and reprogramming and reprogramming it, et cetera.

Q: Okay, so what are some other projects you've been working on?

Francesco Mondada: So?

Q: Okay, let's go back to, say, the '90s. So in addition to the Khepera, were you working on other projects during that period?

Francesco Mondada: No, basically the Khepera was my <laughs> project during long time. I've been working a little bit on a project, on a remote tele-operation in that time, after the end of my Ph.D. So I finish my Ph.D. in '97, but at that time, I was already 50 percent within K-Team and 50 percent at the EPFL. So I spent less time on research and more in running the company. And in '99 – so 2000 I went fully to the company – one year – and I discovered that I was not made to be a CEO of a company. I was too much a researcher and I had – so I went into K-Team with a motivation for researcher and it was incompatible. So after one year I left the company fully and came back to a EPFL to do research. And then, at that time, I've realize, I worked on mechatronic design of robot. It was my main activity. So design of robot for industrial application and then we started doing <clears throat> larger project on collective robotics. So collective robotics was already part of my Ph.D. <clears throat> but from a bio-inspired perspectives we used Khepera to do collective experiments. And then, when I came back here, it was a nice opportunity to enter into the Swarmanoid project – the Swarm-bots project and then the Swarmanoid that were both project on swarm robotics, based on self-assembling. And because of the self-assembling, there was a key issue on mechatronic design of robots, for a collective, within a bio-inspired framework. So it was a natural continuation of what I was doing. So we designed it with Andre Guignard the S-bot. Within the team, we had also Michael Bonani, who joined the team and then continued on the Swarmanoid project. And so, basically, we built up a technology of robot that required high complexity. So the idea was – the Khepera for me was small enough. I was not interested in going smaller but I was interested in going in more complexity. So, instead of building smaller and smaller robots but with a same complexity, I decided to go into more complex robots. So I have robot that are able to self-assemble, robot that are able to do complex task. For instance, now we are able to do SLAM with the robot robot the size of the Khepera III, for instance, which is a – so something like– so the S-bot was this one, so the first robot that we built after I came back from K-Team. So a robot that is able to self-assemble with other robots. But here, we had already Linux inside, Wi-Fi and everything. So a lot of actuators and sensors. And then we – so this was the –a step up in complexity, building a – so using the technology, coming from cellular phone PDAs and embedding a Linux into a small robot like this. And then I'm continuing in that direction, so having complex robot that are able to do complex task into this type of science. So this is the science I keep now and we are getting into – the robot here is covered but here, inside, we have a tracked robot with a display that can display several patterns to do interaction with animals. So for instance, here we do a robot/animal interaction with chicks. So we use social behaviors. We exploit the social behavior of chicks to introduce robots into the social community and we exploit the social links to influence the behavior of the animals. And these are the type of experiments. So instead of focusing on the technology and going down in science, I prefer to explore the technology and the increasing complexity to solve more challenging tasks, always in connection with other fields, like biology. So again – here again, we are doing interaction with animals using collective – in collective groups. So we are using, also, several robots but, in any case, several animals and we interact with them using social behaviors that are studied within the animal behavior. So we are really reusing – pr – it's not bio-inspired but we take <laughs>, again, the intelligence of the animal. We reproduce some aspect within the robots to be able to communicate between the animal and the robot.

Q: What are the big challenges of collective robotics with swarm robots like the outstanding problems and what are some strategies you've been using to address those?

Francesco Mondada: So we have always been approaching swarm robotics or collective robotics from the mechatronic point of view. So one of the interesting challenges has been self-assembling. Self-assembling is – seems – is a way to physically cooperate and is very interesting because there are interesting feature from the mechanical point of view that can appear and then it can be very constructive. If you use one of those robots to pull an object, you will generate a very weak force. The robot is not very stable. If you put two of them self-assembled, then the robot are not able to pull twice, but much more than twice the force. So you can, because the system is another system from a mechanic point of view – from mechanical point of view, the system become more stable and has different properties. So by self-assembling, you build up a structure that have different properties and you can gain on several properties in a very, very incredible way. So I think that – I still miss the real comparison with nature because I'm strongly convinced that ants, which are self-assembling into structure – they exploit this type of feature. We still – I think that we still don't thin – don't know enough about self-assembling and the impact of the mechanical – of the changes in the mechanical structure to really understand the potential of self-assembling in swarm robotics. ‘Cause I think that there is really something at that point and this is the field were I’m interesting to work and where we can bring something from the mechatronic point of view and use this for the, say, culture of building robot that we have here to bring something into robotics. So this is one aspect. So the fact to be able to self-assemble and to exploit self-assembling to build new structure and change the properties of the robotics system. Then the other challenge that I like very much is the challenge of interacting with animals. And there the resultant challenge of having a robot which is able to enter into the community and become a member of the community. So we started doing this with cockroaches. Okay, cockroaches are not too difficult animals, and you can lure them with some smell and some behaviors. As soon as you have chicks then it changes little bit. You have vertebrates which have a good vision system. They can hear very well, etcetera, so that the challenge become more complex and you enter also in a field where you can start having application in farming or in controlling some species of birds – birds in air. Birds, for instance, are this type of application of controlling animal species or animal communities with technology and robotics technology.

Q: You didn't go for the geese that do the imprinting?

Francesco Mondada: So we are doing imprinting on robots. But we are starting the level of imprinting – how long the imprinting remain stable, and how we can reinforce imprinting by having a reaction. So basically, you can imprint the chicken on anything, but there are very few studies on imprinting something which has a reaction. And can - so if you imprint a chicken in a robot then you can have and robot that react to chick, okay? And then you can build up relationship between both which is not the same as if you just imprint the chicken on a static shape. That doesn't do anything else but being there. So you can even imprint on everything, but when you start reacting and building a loop then things start to be very very interesting, and then you can reinforce some behaviors. You can create – you can of course having a chick following a stupid shape. But the imprinting – so we have started the imprinting level – the imprinting level of changing colors for instance. We can have several robotics that can change themselves colors and then see if the chicks follow one or the other. You can have groups that follow one robot and then the other. First robot with this color, and then the same robot with another color would be followed by other chicks. So you can build up a set of behaviors and a set of construction that are very, very interesting.

Q: Have you been collaborating with biologists and things like that?

Francesco Mondada: Yeah. Yeah. Yeah.

Q: Who are some of those people?

Francesco Mondada: I've been always collaborating with people in my life <laughs>. So on the Khepera with biologist or psychologists or people doing neural networks, etcetera. And now I still always interested in cooperating with people, and I'm bringing the mechatronic component and they bring their – the other component. So in that case we're working with Jean-Louis Deneubourg in Brussels. And they are running the experiments, and we are providing all the robotics know-how and we are – we built up a kind of methodology of collaborating together where they give us some kind of specifications, and we can answer by building the robotic devices that follow the specifications. And then we iterate until we get the results we want.

Q: The other side, who have been some of your students or supervised Ph.D.'s, and what kind of work have they been doing?

Francesco Mondada: So somebody who is the director of some of the robotics there, and they're always doing a lot of mechatronics is Michael Bonani. So he has been the first students I had working on the S-bot, and he's a guy who's building up – who's still building up robots. He's now involved into the non-profit organization that I created, and we are pushing together some nice concept of a robotics design for education. The other – so he's very from the mechatronic point of views for mechanics and electronics, and from the computer science point of view somebody who gave a huge contribution and was putting together some architecture that were very interesting is Stéphane Magnenat. These are of course the two main students now. I have some new students who are working on education and on other – on other ideas. But I would say from the mechatronic – the mechatronic guy who came out from this – from this study is for sure Michael Bonani, and the computer scientist – so the geek was – behind many, many development is Stéphane Magnenat.

Q: I'm just going to change the tape real quick, and I've just got a few more questions.

Francesco Mondada: From the animal robot interaction perhaps the person who is now working on this, and is very good in that field, is Alexey Gribovskiy. So this other – the three doctors now that are –

Q: So they all defended their –

Francesco Mondada: Yeah.

Q: – dissertation – the EPFL – it seems like a lot of the good people that do interesting work stay here and keep doing interesting work, which is not always the case.

Francesco Mondada: So basically when I came – when I came people doing really robotics were basically <inaudible> and Burghard. So I came in '86, and the – so this robotic activity has been developed a lot. So the troop of <inaudible> became huge, and they made a lot of nice contribution in industrial robotics. But when I came, mobile robotics was considered as a joke basically for people who want to play around – no real application – nothing to do in that field. And this is the field which developed – they developed a lot. Mainly onto the first – so the first who pushed a lot in that direction was Nicoud, and the group – so basically Nicoud the Khepera – plenty of development were done at that time around mobile robotics. And then Dario Floreano came. So basically Dario Floreano came in Nicoud's lab, Aude Billard came in Nicoud's lab, <inaudible> came in Nicoud's lab. So the lab of Nicoud was really a core in developing bio-inspired and mobile robotics – both. And then this effort was continued by Roland Siegwart. Who came to – so to say replace Nicoud when he retired, and Siegwart developed not only – not only he supported the people that were growing up here like Dario Floreano and Aude Billard, etcetera, from the bio-inspired part, but he developed a lot of the classical robotic part with SLAM, with vision, etcetera, etcetera. And then he left – so not everybody stays here. So he left for Zürich which was his home institution. So it's not – it was not a real leaving from – because the EPFL was not good. But Zürich was a nice opportunity for him at that time. And then the EPFL focalized a little bit more on bio-inspired robotics. So the classical part left to Zürich. I think now in Zürich they are strong, so they have a strong board in everything which has to do with SLAM and also larger robot. And he we are like a bit more specialized in smaller robot – bio-inspired robots, education – robots for education. And so there is a little bit of sharing the field between Zürich ETH and EPFL in Lausanne. Now we have a big common project which is the NCCR. I don't know if you heard about this. It's a national pool of competences, and this is a common project which is – which is very nice because as soon as you do – okay, if you want to have money for research here you can get European grants, but then basically you have to look for European partners not people in Zurich – and not people at EPFL. So we cannot build up team within the EPFL or within Switzerland. If you do Swiss level project then – okay, you can build up a group of one, two labs, but you cannot build up a larger group. And this instance here is really an opportunity to build up a stronger community in Switzerland where people really cooperate and put together their competences to build up something interesting. So at that level I think – again, NCCR is a nice opportunity for Switzerland to build up something. And within the NCCR I'm in charge of one of the five project which is a robot for daily life, and I'm trying to approach this from – again a mechatronic perspective, of course. But in cooperation with people that would bring the other perspectives, and this is very nice. And this is something that we missed for a long time. So I'm very happy that we can now join our forces in Switzerland and build up a career and project at the Swiss level. Not only for the application of robotics, but also for the education. So we are doing quite nice actions on the educational part, both for our students – that this is something we made already with the E-puck on the EPFL level, but now we have a robotic festival that we have every year. That attracted this year between 10 and 15,000 people who attended the festival. And we are starting interesting – with the large public with robotic issues, and this is for me very important because I think that there are many, many, many misunderstanding on robotics in the large public. If you look to the press what type of image of robots they came. It is in my opinion totally wrong – this image of science fiction. It's completely out of our imagination etcetera. Another tool – I work with engineers that are doing machines with standard problems and standard components. So we're not using another technology than the technology that people have in their cellular phones so. People have a cellular phone in their pocket and don't have any idea what is inside, and they imagine robotics as a magic field of – I don't know. So basically we try to bring people a little bit close to robotics – and to the true robotics not the true robotics that they can see in the newspapers or in the media. But the real robotics that come out from research that is useful in daily life etcetera.

Q: What do you see as the big applications coming out of robotics in daily life for the next decade or so?

Francesco Mondada: So I think robotics will come not in the way that we see it in the newspaper. Now I think that we have already many application – more than what we think. So when we – okay, we have, of course, the vacuum cleaner. The classical robots that you see on the market, but we have plenty of other robots that we don't call robots like the metros that are becoming more and more and automatized, or the cars that start parking themselves. So we don't have cars driving themselves. This seems to be always the dream, but very difficult to bring into a real product, but cars starting parking themself this is something that is starting to be into products. Even our cellular phone start to have actuators and sensors and start behaving in an angular way. So I think that robotics is coming slowly from the back doors. Not in the form of humanoid – helping people etcetera, but more in the form of everyday object that are becoming more intelligence – more active, and perhaps a bit more cooperative with us. And this is the way we are also trying to also follow into our NCCR. Starting – evaluating how can we design new form of objects that could be in our daily life. Form of robotics that are not the form of robotics that we see as a humanoid or the standard cylindrical robot that is moving around in the room. I think that the robots would have another form. They'll be real object that become robotic objects like chairs and stuff to help our – in collaborating with us or other object in our daily life that can be robotized. Therefore, we call them robjects – so robotic objects. And I believe this is a more realistic way of introducing robotics in our daily life. But already now we have – I don't know how you call a car which is parking itself. It's still a car. It start to be a robot. It's a hybrid, or a robotic car. I don't know, but I think car will do more and more themself. They started doing some small things, and they do more and more. And there are other object that start to be active more and more. So I think we already – many robots around us that we don't call robots that are entering our daily life slowly but surely.

Q: My battery is about to die so – definitional difference between mechatronics and robotics, or how would you define a robot?

Francesco Mondada: No. I don't want to enter into this [laughter]. I prefer to use my time to more interesting topics. No. I do this type of – I like to play a little bit with this type of things when we have visitors. So I ask what is a robot, you know. Is a car which is parking itself a robot or not? Is a kitchen robot – you know those machines that are able to do several things they're sometimes called robots, okay. Is that a robot? Humanoid is a robot, okay, but a metro running itself is robot or not. An airplane in auto pilot mode is a robot, or is not a robot? So it's probably closer to a robot than many other things that we call robots. So I don't think that there is a clear definition, and I don't want to [laughter] spend time in finding the right way to do a definition. There are plenty of remote control devices that are called robots that are not robots, or that perhaps less robot than an airplane, or less robot than a washing machine.

Q: So some automatic control essentially?

Francesco Mondada: So some autonomy – or some – yeah. Some ability to take decisions in respect to a given complexity – but in another sense the industrial robot is not able to take many decisions is just perhaps flexible enough. So there is a mix between flexibility and autonomy, number of sensors, number of actuators. When I – I got some – Burgard was making some definition. He defined the robots with the number of degree of freedom. I think he said – yeah, a robot need at least three flexible or programmable degree of freedoms – or two even, but mobile robot are two programmable degree of freedom. So and then you take a plotter and – and a very old plotter it does two degree of freedom. I don't know. It's difficult to define.

Q: What would you say are the biggest challenges technically facing robotics? What are going to be the hard problems to solve?

Francesco Mondada: I think that the question of the intelligence is probably the hardest problem. In a sense that the – we're able now to do humanoids that are impressive in terms of mobility, etcetera. But we are not still able to let – to have them moving around in a free way. We start to be able to have robot navigating around, but soon as you have a little bit of complexity around them everything collapses. So we have still nice work to do in term of understanding intelligence, and build up something which is intelligent enough to deal with the complexity of the real world. And I think that we still underestimate a lot – this aspect of the complexity of the real world. It's something that – when I hear some colleagues saying, yes, in 20 years we will have a robot which has the intelligence of a human or – ah, come one. If in 20 years we have the intelligence of an ant then I would be happy [laughter]. No. I think that we underestimate in a clear way this one. We are progressing very well in – at the level of the management of energy at the level of possessing power. We are compensating a little bit the missing counts of intelligence with computational power. So we have huge computational power available, and then we can in some sense compensate the fact that we miss the real concept when we put enough computational power, but that's it. From the mechanical point of view we start having a very interesting solution, but we are not able to control them in the right way. So when you see as it's moving around, and you're just impressed. And then we are – when you see how they control it, and what type of control you have – you have on board of it – then you are totally disappointed. So I think that we still missed the – we have some bricks of intelligence – some small bricks that solves some problems. So we can do some demonstration of intelligence in some specific fields now within a given framework which is very well defined, but as soon as you go outside the standard room then [laughter] you still have a huge amount of problems.

Q: Which is smarter a cockroach or a Khepera?

Francesco Mondada: Sorry?

Q: Who's smarter a cockroach or a Khepera?

Francesco Mondada: [Laughter] I'll chance myself. It's trivial – even an ant or – I don't know if we can compare the Khepera with a – I don't know – a bacteria or... [laughter]

Q: Virus?

Francesco Mondada: **Y**eah.

Q: So you've taken quite an interest in education for youth for science and robotics. So for young people interested in pursuing a career in robotics what do you recommend, and what's your advice to them?

Francesco Mondada: In term of career steps or general approach?

Q: Both.

Francesco Mondada: Now I think that people should be curious – curiosity is the first element. And I'm a little bit disappointed by the missing curiosity in the young people now. They use a cellular phone they have no clue about how it works. Why the screen rearrange itself when you turn it. They don't care. They just use technology as it is, and they don't care what's behind. And that's something that worries me. So I think that the first step that a good engineer should have is the curiosity to understand what's behind. This is something that we try to push forward with the festival. Try to tell people, look, it's not magic. There is something behind your – there is something within your cellular phone that makes your cellular phone do this and this. And when you touch a cellular phone there is something to detect your touch and do something. And there is a program behind, and this program is not magic. So there is a set of logical rules. There are bits and bytes and – I think people should – I would like people to try to be a little bit more curious about this, and maybe a little more critical about this. So people are just now taking all this as magic, and the use it and they don't care. And then they are surprised that their profile that they placed in a web server somewhere then appears somewhere else, and their information is used to do whatever. So people don't understand what's behind – or don't want to understand what's behind, and this is one side too bad, and the other side is even critical if you want have a society where people built up the society and decide about the society. People don't understand what technologies about. In a technological society like ours it's bad. So we just waiting that companies do technology for us, and then we use it. And we don't push anything forward. We don't criticize anything. We just waited to – Apple or Microsoft or anybody else deciding our place, what to do, and how to use technology, etcetera. I think it's too bad. So robotics now we are in the entry phase. So I think that there is a huge opportunity to create something new also for younger generations, but they have to be curious. They have to understand what's behind. They have to study a lot. There are a lot of knowledge that is accumulated behind all this technology and, you know, people have to study a lot of things before having an overview. And I – okay, I love a lot at the system view. I'm a system engineer, and I love to have this overview of the system and not be a specialist in a given field. So I think that people should look a little bit more from a system point of view. And then perhaps once they have this system view they can specialize into a more specific field. But getting an overview I think it's a good point – it's a good starting point. So get an overview and then go into electronics or go into computer science but get an overview. Otherwise, people are computer scientists who program incredible things, but they don't have an idea how the processor works.