About Rachid Alami

Rachid Alami was born in Morocco in 1954. At the age of 20, he moved to France where he attended the Academy of Toulouse for his undergraduate and doctoral education. Alami graduated with a degree in computer engineering from the ENSEEIHT at the University of Toulouse in 1978 and a Ph.D. in robotics from the Paul Sabatier University in 1983. He has contributed to several international research projects, and his work has focused primarily on robot-robot and human-robot collaboration. Alami is currently the director of Robotics and A.I. research at the Laboratory for Analysis and Architecture of Systems (LAAS) of the CNRS, the French National Research Center at the University of Toulouse.

In this interview, Alami discusses his original experiences with robotics under George Giralt at LAAS, the development of his interest in robot collaboration, and finally his work on human-robot interaction. Alami also provides insight into the challenges of robotics and the future of the industry.

About the Interview

RACHID ALAMI: An Interview Conducted by Selma Šabanović and Matthew R. Francisco, IEEE History Center, 31 August 2011

Interview # 661 for Indiana University and the IEEE History Center, The Institute of Electrical and Electronics Engineers, Inc.

Copyright Statement

Interview

INTERVIEW: Rachid Alami

INTERVIEWER: Selma Šabanović and Matthew Francisco

DATE: 31 August 2011

PLACE: Flagstaff, AZ

Early Life and Education

Q:

So the way that these usually go is we start with your name and where you're from and we go through your schooling, which universities you went to, what kind of projects you worked on, who you worked with.

Alami:

Yes.

Q:

And then end up with the different institutions you were involved with, and then end up with where you think robotics is going in the future basically.

Alami:

Wow. [laughs]

Q:

So we want your life story in short. Let's start with your name and where you were born and when.

Alami:

Okay, so my name, I'm Rachid Alami. I was born in Morocco in '54, 1954 and I studied in Morocco first until I was 20. So this is the first part [laughs], and then I went to France to Toulouse to attend engineering school. So I have chosen engineering school in computer engineering. And then I spent three years and became an engineer.

Q:

And that was undergraduate?

Alami:

Yeah, it's the equivalent of undergraduate. Even in France at the end of engineering school you have the equivalence of a master's. So then you can enter PhD program, in our system. But I did not do this after engineering school. I decided to be engineer so I went back to Morocco and worked as an engineer for two years as a computer engineer [inaudible].

Q:

Oh so your degree was in computer engineering.

Alami:

Computer engineering, yeah.

Q:

How did you decide to go into computer engineering?

Alami:

[laughs] Okay, to be completely frank [laughs] in fact you know in this system of engineering schools in France after the bachelor that you have two years to prepare for exams and then you have to choose which engineering school you want. And I didn't want to specialize so I didn't want to do civil engineering or chemistry or be a draft engineer. I wanted to stay as general as possible and that's why – and I was essentially doing mathematics – I chose from an engineering point of view what was closer to mathematics [laughs] which was computer engineering, particularly at that time. At that time computers were still something that people did not know that much so I have chosen the less specified and something more generic than a specific field. That's why I had chosen this.

Q:

What about engineering in general? Before even computers?

Alami:

Ah, yes. So basically in Moroccan-France system you can enter engineering school to do science also afterwards, okay? It's simply a kind of good way to do it because it's very selective, and because it's selective it's good [laughs] somehow. Somehow it is. This is how the system is built, and that's true that when I became engineer I found out that I wanted to know more, to do more. That's why I came back to research, or I entered research.

Q:

Where did you work in Morocco as an engineer?

Alami:

Oh in Morocco it was two steps. First when I came back to Morocco with my diploma I decided to teach computer engineering so I went to engineering schools in Morocco to apply for a position as a research assistant for a professor. Assistant professor somehow to be a professor afterwards, so I entered first in engineering school as a teacher. And I found that it didn't have enough computers because at the time computers were mainframes. It was very expensive to have a computer and most engineering schools didn't have a computer. The students programmed on boards, on cards, and then went to a place where but they didn't have the computer themselves. So I didn't like it and I went to an administration department where they had computers, and it was so I left the university and went to the Ministry of Equipment and Dams, the Ministry who manages the dams etcetera, and who had the biggest computers in Morocco. I went there [laughs] to have the computers so almost two years I worked on the computers of this department. And there I developed computer models for dams, etcetera.

Q:

And that was just before the '80s?

Alami:

That was –

Q:

[inaudible] [laughs]

Alami:

Yeah [laughs]. That was between '78 and '80.

Q:

Okay.

Alami:

I was an engineer in '78 and during '78 and '80 I was an engineer. And in '80 I decided to know more, to go deeper and already I had some experience in research there because I had even as an engineer in Morocco you had interns from the University of Rabat and we worked on things and read articles etcetera, etcetera.

Q:

What kind of work projects were you?

Alami:

It was essentially computer models of flows, flows to study floods in Morocco and so it was essentially to accumulate data from, to study influence, to try to estimate how would a flood develop in addition to the rain data. Tried to build models of this so I liked it too, it was quite interesting at that time. So it was entering the research with this issue of building models and putting the models in the computer and running the models, running the programs, okay? That will already simulate things so that was the beginning.

First Meeting George Giralt

Q:

And so when you went back to Toulouse for your Ph.D. Is that where you went?

Alami:

Yes.

Q:

What was that like there? What was the department like? Who was there? What was the research like?

Alami:

Okay, okay. If you want the stories I will tell you. [laughs]

Q:

Yeah, stories.

Alami:

You like the stories.

Q:

Uh-huh.

Alami:

You like the stories, okay. So I have to come back. I have to come back a little. When I came to Toulouse the first time so in '75 we had an engineering school at ENSEEIHT in Toulouse. We had an excellent teacher, excellent professor who was a researcher in A.I. at that moment, '75. It was really the beginning of A.I. And he was also professor at this engineering school and he was doing something very good. He was doing a kind of introduction to all what is informatics from the chip, from the – at the time from the electronics and the assembly language and the thing that is now very far to A.I. Going through all the disciplines, all the domains in computer engineering and computer science. And I was impressed by this professor and by the fact that A.I. at that time already was a challenge for computer engineering. So when I came back after being an engineer, I came back to do research in A.I. [laughs]. Okay, so I came back in '80, eight-zero, to try to find a lab and I went to Toulouse because I knew Toulouse and I had friends there.

Q:

And who was this professor?

Alami:

I went to and found him and came back. He was Henry Farreny. He has retired now I think, yes he retired. And he has worked and written books and afterwards so I went to him and asked him if he had some Ph.D. program. Well he had a Ph.D. program but he has no place for me, and he told me, “Well there was a place, there was a very good place because I know you are enthusiastic. There's a really good place where you have to try it's LAAS.” I'd never been to LAAS before so I went to LAAS which is on the campus which was another lab. It was a lab of automatics and systems so informatics was not trivial to see there so I went there. I went there and tried to find this George Giralt that I didn't know. And the story started like this. And by chance he was starting a program and looking for a computer engineer, someone to develop programs in a new language at that time. And so I said, well I'll do it.

Automation and Advanced Robotics (ARA)

Q:

So what kinds of projects was George Giralt working on at the time?

Alami:

Ah yes. Now we are in the '80s. At that time George Giralt was starting the first national program of robotics in France. George Giralt was a very…became incrementally at the time… he started already to be a central person in robotics in France and elsewhere also, and he at that time he had – he took time to prepare it but around when this program was ready to start – and it was a national program and of course – LAAS was one of the main points of it, not the only one but one of the main points at that time. They were buying computers new kinds of computers for that time which were mini computers because mini computers, 32 bits computers and at that time that was the first time where the users had real time computers that touch themselves. They were not blocked behind the fence where [laughs] these mainframes that were behind the fence and you have just give the cards. They were buying the first computer that you the students were touching, were plugged into the robots etcetera, so I lived this adventure of having our own computer [laughs] and it was quite big. We called it a mini computer at the time and it began like this and there were things missing, this computer. We had to build languages, programs etcetera and there was one – so this program – sorry, I should do it like this. George Giralt built a program and he was the coordinator of this program called ARA. ARA in French is Automatic Robotique Automation, which is in English Automation and Advanced Robotics. At the time already they were making a difference between robotics and advanced robotics. You know because it was a challenge of doing advanced robotic. Already thinking about the intelligent robot, the autonomous robot; that was a dream of George's from the beginning. And so I am one of the "sons of ARA" I should say. We say this in France we are a number that we know and at that time, and we are a number in France and elsewhere now, one of the sons of ARA because this program started that time and you obtained finance for ourselves at that time.

Q:

Who was involved in ARA?

Alami:

It was all over France, you know in the different centers there was Toulouse, there were also people from Paris, people from Grenoble, essentially Grenoble/Paris at that time and already Montpelier were big centers. That's where the big centers that started Robotics as that came also Sophia Antipolis which is in South of France, these were the centers where we were starting Robotics, and Toulouse was one of the big centers because we had one of the computers. We had the computers, we had the computer and we were an integration place so people were coming from other places to integrate their software, their ideas in our system. So we had the computer. We had the manipulator, two manipulators, etcetera.

Q:

And so what were some of the types of questions that were part of this advanced robotics?

Alami:

Yeah, so ARA was built and it was organized into different aspects, so one was the essentially what they called advanced teleoperation. We're not doing this, people of Paris essentially are doing this, advanced teleoperations so it is operating a distance robot which was far and at that time the applications were essentially for nuclear plants, for example to operate a remote robot which is still very necessary today. So that was one of the applications of this advanced teleoperation. The other aspect was more at that time and even everywhere in the world robotics was quite linked to manufacturing so there was one – another theme was advanced manufacturing essentially. The third one was what we call advanced autonomous robotics which was the autonomous robot that you have to develop tools to control it and to program it offline. At the time it was essentially offline programming so the intelligence was essentially offline, not online. And so there were – these were the main points and it was organized in workshops. We had two or three workshops per year, so we also had challenges. For example, for the advanced robotics we had as a challenge to assemble an electrical contactor which was quite complex to find assemblies of who can do automatic. That was basically the challenge, essentially assembly robotics auto for doing assembly.

Q:

And how was this funded?

Alami:

It was funded by the French government through its different agencies, CNRS, Ministry at the time of research and education, essentially. There were also industry partners involved that essentially gave equipment or provided these challenges of the electrical contactors to assemble, etcetera, also subsystems.

Robots, Artifical Intelligence, and the LISP Language

Q:

And so what kinds of questions or projects did you start working on?

Alami:

Oh myself. So myself, I started at the time which was I was hired to do the intelligent part of the robot and in order to do the intelligent part of the robot at that time, in order to develop systems in A.I. I should say, planners or expert systems like we said, rule-based system at that time, it was necessary to have one language that was the language of A.I. Which was Lisp and in the computer that we had if you should remember at that time when you – when we were buying a computer we didn't have a standard operating language, operating system. Each computer has its own operating system so you had to learn the operating system and the assembly language of that computer. And because of this, this computer didn't have a Lisp interpreter so I was hired first to build a Lisp interpreter in order to run my A.I. programs in it. So I first built the Lisp language, a Lisp interpreter which was used by the community so I already had a number of users in ARA, a number of students were using my system and I was so I was obliged to deliver and maintain the system for four years. I had done it with pleasure. So I built a Lisp interpreter and then I began to build my own system inside. I remember, my own system was essentially a programming and control system of what we call at that time a flexible assembly cell. What we call the flexible assembly cell was a system composed of sensors which were not onboard the robot but near the robot, for example you have a camera, and also a number of other devices like a conveyor belt. A number of object deliveries, subsystems etcetera. And this the assembly cell that we have built there at last, we had two robots and between them a conveyor belt and a number of systems to deliver cameras, etcetera, and simple sensors also like contact sensor and things like that. So that was the idea. The idea was to build the cell. We called it flexible. Why flexible? Because the idea was to develop programs that would allow you to parameterize as much as possible programming of this cell because at that time essentially robot programming was by moving the robot and learning trajectories and simply re-executing trajectories. And we wanted to have programs that are more general that run the system. For example the flexibility came from the fact that we wanted this flexible assembly cell to assemble the contactors, part of it, something. We have chosen this simple spots of these contactors to assemble and the challenge was to program this assembly with two robots, two manipulators and conveyor belts etcetera and the challenge was that the objects would arrive in this order, a known order and the robot system will have to identify the objects to localize them, to take them to assemble them to store momentarily to use buffers to store the objects that are coming online, to build the assembly and when the object is assembled to put it again on the conveyor and it goes. That was an amazing idea and so we worked on this on how to – I worked on this programming office, this aspect of program directories, programming grasp programming. Essentially they wrote the high-level system. A system that they called NNS, No Name System. And this system was the system that was running the flexible assembly cell and to sufficiently generate to allow people to program in it different assemblies. It was not one assembly. Yes, one assembly program within it you can program inside the system different assemblies. That was in a flexible way. That was a challenge.

Q:

And the robots themselves that were part – so you seemed to have a manipulator, grasping and stuff like that.

Alami:

Yes.

Q:

What were the different components and also did you make them in-house or did you purchase?

Alami:

Oh yes, we purchased the computers but the robots, we purchased the robots sorry, right. And of course there was all this activity of finding the good robots, purchasing them, writing the control programs of these robots, and there were two robots. The two robots were French robots. One was a small company called SCEMI, and at that time it was difficult to have – to buy easily what you want. You had to go through market and there were various limitations for market etcetera. And also at the time they wanted to push, of course, the French industries so we – one of the two of us was SCEMI. It's a small company. It's a small company building this kind of – it was quite beautiful robots. At the time the equivalent of – already at that time I knew very well my colleagues in America, in Japan etc. at the time, essentially the American had Puma robots. We had our Semi which was equivalent somehow. And there were several Semi in the ARA programs so we were able also to share software and ideas and hints, etcetera. And the other robot was built by Renault. It was a big robot, Renault Automation which is one subsidiary of robot. We were building the robots for in-house use. In Renault. So they are the two robots so we bought them, but we had to program the controls of these robots. It was not delivered with it so it was not at this level to program might be by other researchers doing this low-level control. I was doing essentially the high-level control of the A.I. part. [laughs] The A.I. part where other people were doing – but from that moment I had to link between A.I. and the control programs. That was essentially my contribution is to plug from A.I. to the control of the robot which I still am doing now [laughs], still working at this issue of making the robot really use planners so that my work was essentially this. And for the rest there were cameras with vision system etcetera. At the time it was black and white vision, it was 2D vision, very simplified, based on contours only so you localized the object only on 2D, etcetera.

Q:

Who were some people that you worked with closely?

Alami:

At that time? People who were involved in the ARA program. You have George Giralt, I mentioned him. I'm trying to mention people that still exist. One who was a little more senior than us, already senior at that time compared to us even if he was young, was Jean-Claude Latombe who is now in Stanford. So he was one of the partners of ARA who was responsible for the Grenoble part of it because it was in Grenoble. And in terms of students I can mention Vincent Hayward, who was in Paris at that time. He is one of the ARA boys [laughs] one of the ARA boys. And then he went to McGill. Now he is back in Paris but he – his main career was first in U. Penn. and then McGill, so Vincent Hayward. Also Emanuel Mazer who is still a researcher. Who is now a researcher in robotics in A.I. in Grenoble. Who else I can mention? I can mention Etienne Dombre, also who was in Montpelier who is a senior researcher in Montpelier today. Others, I can find others. Yeah this is basically I'm looking to people who were not from my lab but other labs. So as you see there were people from some different places and so all these people are good friends of me today.

Q:

So what was your thesis project for your Ph.D.?

Alami:

What do you mean? Essentially it's developing this NNS, No Name System, which is a high-level control, programming and control. It was programming and control system, both sides high-level control for flexible assembly cell. That was basically the main result which was quite advanced at that time. I presented here and there in different conferences, here in the U.S. etcetera, and at that time it was one of the main issues, the main challenges in robotics to build this. And at that time we started to think about motion planning for example. So we started to look at this. We were very interested by people who were doing this and beginning to do this essentially here in the U.S. Thomas Lozano-Perez, for example, at M.I.T. so there was him and there were us. That's why we had a lot of contact. It was one of the guys who influenced us at that moment. It was very interesting at that time. Other people that were of high interest for us and also collaborating at that time it was a small – we knew almost everybody. Lou Paul also at U. Penn. at that time.

Q:

And did they also come visit you?

Alami:

Oh yes, yeah. George Giralt was—they were friends essentially of George Giralt, and we had a lot of contact already at that time, already in the beginning of '80s and from '80 to '85, '84. Eighty-four it was the first ICRA I attended the first ICRA and presented NNS, the first ICRA which was in Atlanta in '84.

Q:

And then so you also had exchanges kind of student exchanges or people went –

Alami:

Yes well at the time they were not – the exchanges came afterwards. At that time we had contacts and we read papers etcetera, and we contributed to conferences. It was quite intensive in terms of contacts and reading papers and going and visit. At that time I made visit of main labs in the U.S. already.

Q:

What were the labs you visited?

Alami:

At that time it was in '85, '84, '85, '86. Oh it was essentially M.I.T., C.M.U., Stanford, U. Penn. Yes I think basically these, S.R.I. also, Berkeley.

Q:

And this was when you were already a professor at –

Alami:

Me?

Q:

Uh-hum.

Alami:

No, I in '84 I applied, see I'm not a professor. I'm full time researcher in CNRS and so CNRS provided this possibility to have positions so I applied to enter to CNRS, so this is French system so CNRS is an agency. There is national competition to enter so you don't enter at Toulouse level. You enter at national level so it's national competition. It is quite difficult to enter CNRS until now. Today also it's very competitive to enter the CNRS so I entered CNRS. At that time I don't want to stay that much. I will stay only five years or three years and I will see. And I stayed. [laughs] So in '84 I entered CNRS. I did my Ph.D. in '83, end of '83 and applied and entered CNRS in '84.

Q:

And were you then working on a different project?

Alami:

We continued this ARA program for one or two years until '86 and then other projects came and I worked also with another colleague who entered CNRS two or three years before me who was Raja Chatila a year or so. I was working on the flexible assembly cell and Chatila was working on Hilare on the robot and incrementally we mixed both in the sense that we made everything to go towards autonomy and not offline programming or assembly cell but more autonomous issues.

Challenges of Autonomy in Robotics

Q:

And what were some of the challenges in taking the systems more and more toward autonomy?

Alami:

It was a dream of the beginning. We wanted that dream. The omnipotent smart, clever [laughs] robot from the beginning so whenever it was possible we moved towards that direction. Okay we are still going that direction. I think that basically these people I know at least Raja, George, myself, etcetera when we stayed there, our dream was this one. That dream the big dream of the robot that is autonomous that is omnipotent that is able to do everything to learn etcetera, the full dream of the robot. And all the projects were for us only steps towards this dream so.

Q:

I'll come at it from a different way. What problems did you run into?

Alami:

Oh.

Q:

Or so when did the dream get tripped up?

Alami:

Oh so we had a number of dreams. We found out it was difficult. [laughs] Yeah, we found out it was quite difficult, okay? Yeah.

Q:

Not a five-year plan.

Alami:

No. [laughs] No and so we entered interesting questions of what is real navigation, what is really assembly, what is contact. What does it mean to program at a high level so at that time the main challenges was what we call the task-level programming going from a factor 11 programming to – I'm using the vocabulary of that time, okay? We are no more using this vocabulary today. But that time we were thinking about using task level programming so programming in the sense that you program the assembly without even mentioning the robot. Describing what would happen and the dream was to infer the program for a specific robot that would achieve the task. That was the idea of the task level, you describe the task. And again to come to Lozano-Perez, the issue motion planning and then at the still now so that was a big challenge which is still here of genericity and description at the highest level that you can possibly at a symbolic level of a task. And work on inferring all what you should be doing. Of course we got through difficult – for example we found out that navigation which was assumed to be simple was not that simple at all. And so we found out, to give you an idea of what happened in our lab not only in our lab, but however in our lab. In our lab we found out concretely that you had motion planning that is in the configuration space but if you have a system that is not holonomous, like the robot that we have Hilare was unfortunately not holonomous so it created a complimentary problem to us to solve and perhaps it's because of this that my colleagues worked on this non-homonymous issue because it had a robot that was like that. Also issues of uncertainty in building models SLAM problem so we found out concretely that there was a need to solve this problem at the SLAM, so we contributed, not myself but my colleagues to the SLAM issue. I contributed more on the issue of task-level programming: how to program at a high-level, how to decompose the system into subcomponents, how to decompose a task into different motions so at that time we are speaking about what we called grasp synthesis, local motion around the object, the gross motion when you are far from the object, this aspect. And so that was a challenge to find out what were the components, what were the, sorry, the sub-problems, to find solutions for the sub-problems essentially developing plan is motion plan or grasp planner or local motion planner. And at that time we had also the ambition of completeness so we were trying to develop essentially ethical systems that will solve the problem completely and incrementally appeared this aspect of randomized search and systems that were not complete by construction but complete only well at, in time I should say basically. So the challenges came like this we were decomposing the problem and building the different components. And the other big challenge that we stared at that time was the grounding problem, the link between the geometric and numeric data, the signals and the symbols. Tried to build and we found out it was difficult, difficult to do it in a generic way and even if you build a generic system you have a guy that says "Oh, this place, this symbolic place is [laughs] X23Y44" etcetera, etcetera directly by yourself a symbol to a number which was wrong. You should assemble a symbol to a property to satisfy a property or an attribute and have a system that will compute this. So we went through this I think essential issues of robotics basically and we are still there.

Application to Space Exploration

Q:

So when did you go from the more kind of manufacturing or oriented applications to some of these other applications?

Alami:

Oh, okay. Myself, I in fact it happened for me, for me around '86, '87 essentially because even though I was very pleased with this issue we were in an environment where the application was essentially industrial and so it was essentially oriented towards solving problems offline, so it was not after solving a number of issues essentially based on CAD etcetera, it was no more interesting for the assembly line but still the problem of assembly today is important and not solved okay but autonomous assembly you had papers and this conference of autonomous assembly. But at that time assembly was looked only as an engineer process. And autonomy was oriented towards navigation mobility. And so the challenge for autonomy was more in this field. Even though at that time I was – I didn't understand this very well because I thought autonomy was also in the assembly. But well things go like this. I went to essentially mobile so I worked in other projects which were essentially projects to develop robots for rescue basically, recue applications and space applications so the second challenge was the Mars Rover French initiative, so we worked on this.

Q:

What was the name of that project?

Alami:

Yeah, it was in France it was RIISP, Robotic- R-I-I-S-P. And this also was a project that was built by George, George Giralt. He built a new project in the middle when ARA finished he built a new program which was a challenge of the autonomous robot and one application of the autonomous robot was because it was necessary absolutely necessary it was the planetary robot and so we convinced the French agency the CNES, George essentially a member of the – to build a program with this so we had a national program. It was basically a number of labs working with CNES to think about this complete mission and we spent years thinking about all the components that are necessary to build programs and operate a robot on Mars. So we had to program this and we looked to all these aspects. This program stayed only on Earth [laughs] in the sense that we have built robots. We have around exploration on Earth. Even in CNES, they have built a model of Mars and a model of the moon and soil and we played there essentially with this program has never gone until really implementation but so everything – so when the Mars Rover project appears in the U.S. and it went there etcetera we were understanding everything because we have thought about this also and we knew the different parts of it. For example this issue link to the fact that you have low bandwidth and you have long delay that will go from five to twenty minutes between Mars and Earth so you cannot program – you cannot teleoperate the robot – impossible, the robot should be autonomous. Even if it is so you have to program once every day somehow. All these issues we studied at that time. This was between I think '86, '87, I don't remember, '92 or something like that, '90, '91, '92.

Q:

Did the NASA folks make any contact with you?

Alami:

We had contact of course. We had contact also we knew what was happening here and there. There were conferences etcetera but of course we are a research lab so we are not building the final project. The idea was – after this first project there was another project that was more applied with industrial partners that were assumed to build a second prototype, you know, it's similar to what happens here. It was not yet a flying prototype but a real prototype of the system. But the thing didn't go because after that, you know, the main choices in Europe made that the Mars Rover never happened, the program, I mean the real program never happened. So the CNES maintain it as the CNES was responsible as a French agency of preliminary study so they have done the study, this preliminary study and they were ready to do a second step but it didn't happen completely for a number of reasons, essentially money. It's very expensive, very, very expensive. Of course it could have been done only at the European level or international level, it didn't happen.

Q:

And this was just a French program?

Alami:

It was yes, at the beginning it was a French program, then it was the second step after this French program to which I contributed. I contributed also the second level a little, a little was the European program. It was European program but not a Space program. Not yet the Space Program. It was Europe program oriented towards the technology of the robot. Not really the flying system. So I think we were quite aware of the global problem from the robotics point of view, for the other point of view it was different. So we were running VxWorks, we're still running today on some robots. Yesterday when we were – two days ago when we're in the NASA, they were running still VxWorks on some of the robots. It's a real-time operating system.

Q:

I was curious about the public discourse in the '80s about space. I mean, because the U.S. – we had the shuttles and everything and there's kind of NASA and everything. So was there – I guess what kind of discussion was happening about a French space program? What was kind of the catalyst for this project?

Alami:

Oh, I think this program of the French Mars rover or the European Mars rover was at the level of specialist. It didn't reach really the public. But in Europe it was quite easy because we thought out autonomy and not sending people there already. So it was accepted and justified to build and to think about the autonomous robot that you'd have to operate from far and which has autonomy from the beginning. So it was quite natural and quite well accepted. So we didn't have really – so we presented – public was not really concerned, because it didn't reach that level.

Q:

So in comparison – I mean, NASA has this whole focus on human – or used to have a focus on human flight, and now that that's kind of gone – so in France there was never such a [inaudible].

Alami:

No, there are human –

Q:

Space station?

Alami:

Yes, on the shuttles and space station, but we're not thinking about human on Mars. But for us as researchers it was also – contextual autonomy was necessary, and I wanted autonomy. We're happy. We're happy to study this issue. But also we are trying to take into account – that was interesting – also the reality, the context of the application. For example, at that time, still now, you have limited power, limited computer resources on the planet. You have to limit your computation and [inaudible] this issue, issue of, again, the bandwidth, issue of the delay – all this taken into account. We're thinking about also the – you know they have the – in fact the mission was completely built so it was also about this satellite that was there to maintain communication between the robot and the Earth with different rendezvous of possible communication between the robot and the satellite, and then Earth.

Q:

So here still there's not that much – unless it's maybe about tele-operation – discussion of where the human fits into –

Alami:

Yeah, there is no – here the human was – my first contact with here, the human was at Earth, and we are thinking about what the human should do operate robot at a distance and to program it, and that way. So we worked with – it was essentially issue of interfaces and what program will you send. So we work with people from ergonomics, etcetera. So it was not yet; this came far after that. It was not yet the robot and human who share space and task. This came afterwards.

Other Applications

Q:

So what were some later – what other things did you do?

Alami:

So that was the French. Then, another program – in fact, they corresponded to the – and here, the essential work that we have done, and there I began to, we worked intensively with the Raja Chatila, and other colleagues, and this project was responsible of part of it. It was responsible of another one, we worked together. So our main result, there was thinking about the architecture, control architecture of a system: what should be onboard, what should off-board, what should be online, what should be real-time, which could be used – we thought anytime algorithm, things that could run offline, etcetera. So essentially our contributions, us, was linked to robot architecture and planning. At that time we started another project which I didn't contribute that much – so Raja will tell you more about it – which was SKIDS project, which was – it's there that they worked on SLAM, essentially. They didn't work on this aspect. So I worked essentially on control – on intelligent control, I should say; on control architectures. And then came another project which was another European – so we have several projects on this. And so we went from space to rescue robotics – same problem, same idea – robot moving in rough terrain. So environment it has to discover while moving in it. It doesn't know it beforehand so you cannot program anything really in detail because robot will discover. So that was basically the idea. We had a number of projects on this, national or international projects. And then we had another project which was a little different, which we came again to Earth, which was linked to multi-robot aspects. And this project was called MARTHA. It started in '92, and there I was really responsible of the main part of – the main contribution of LAAS in it. In MARTHA, the problem was how to operate – the MARTHA project is essentially thinking about robots for logistics. You have a number of robots to transport, for example, containers in harbor from one place to another, or also for freight essentially, applications in railway stations also you might have this, and harbors, in airports also. You have to transport small containers at airports. And it was a very interesting project where we had essentially two contexts of application: the airport and the harbor. And the idea was to think about how to operate a number – you cannot have one robot doing this. You might have 2, 10, 20, 50 – 50 robots doing this in a big environment. And the issue was how to do it in a way that you do not program everything, that you have flexibility, etcetera, etcetera. So it's there we started to seriously – I started seriously to work on multi-robot cooperation, how to make the robots cooperate, and if you make them cooperate this allows you to give high-level mission to all of them and they will arrange by themselves what to do. So that was the basic idea. So we started in this project which was quite – a number of constraints. You had industrial partners, you have real users for the robot even though you try to make some – fundamental research. So we started issues of task location, who will do what at which moment; of coordination, coordination at level of directory, how to make them move without colliding and synchronize, and immediately if you think about motion planning it's combinatorial. There is a combinatory explosion for this issue because if you have 50 robots, you have 150 degrees of freedom, etcetera, so you have to do something. So we studied this issue – these issues, I should say – and also we have some quite interesting results on this and how finally you could have robots essentially [inaudible] and we found it quite interesting, and it worked quite well. It's this notion of what we call plan-merging. The idea is that the robot, through communication, merges itself in what the other robots are doing. And this is done by deliberation. So the robots, essentially through communication, exchange their plans. They exchange their plans and they deliberate to synchronize themselves. And so I introduced and we worked about this issue what we called plan-merging.

Q:

Kind of a robot democracy.

Alami:

Yeah, somehow. [laughs] Somehow. Somehow. Yes, in the sense that – the idea is that in order to send – to acquire the information on the robot and to send everything to a central station that will have a global view. At the time we were far more limited than what we have today. You really had to do things onboard because you cannot – it was through '96 and still we had the best – we didn't have Internet, not yet, really. And we were using 9600-volt maximum, which was quite limited. But however, so yes, it's kind of a democracy. So the robots, by negotiation, decide what to do at this level, and we tried also to compose at different levels. So they negotiate what to do. It's essentially a transport task. "I will go there and get the object because I'm not far from it," or "I will move not far from this so I can take this task with me at the task location." The second level is coordination, and coordination we had through plan-merging mechanism, which is somehow an inspiration from traffic. When you do traffic, you merge your car in the traffic. So there are rules for merging. You have rules. If you don't respect rules, you will create problems to the others and to yourself. There are rules, and using these rules – and so if all contribute and you have a certain structure in the environment, if you have rules and structure you can do quite efficient plan-merging. And quite efficient, and it can resist even to errors. The robot can re-plan, to renegotiate their plans, etcetera – abandon, do something else and come back. That was possible.

Q:

What were some of the competing frameworks or some work by other people on this multi-robot, not cooperation, but navigation cooperation at the time?

Alami:

Essentially – here again we find the same people. [laughs] We find the same. We had also new collaborators and new friends from – at that time also what was important, starting from '87 even, '87 and incrementally, there was this European project beginning to be launched and constructed. So we had to find European partners to work with, and it was a challenge to – we knew incrementally each other and we found people who were sharing the same challenges with us, etcetera. So we found interesting people to work with, essentially in motion planning. At that time motion planning community was created in Europe and also in – essentially in the U.S. and Europe, and there was contribution here. So you find the same people that you have in motion planning here. Again, Latombe. Lozano-Perez was there, and others. At that time you had a number of – the number of people who worked with Jean-Claude Latombe became then – do their own research, like Lydia Kavraki, for example, and others. And in Europe there were also people doing motion planning that lived in France and Grenoble. Again, and in Netherlands, for example, [inaudible] and others. And in Italy also, began to work with our Italian friends also at that time.

So that was a second step, I should say. And the idea was to link multi-robot cooperation and motion planning. Why? Because essentially the task was linked to motion task. And then there were also contributions in CMU, working a lot in robots, mono- and multi-robot things. Going from – number of names I don't remember. I should have prepared a little. Reid Simmons, for example, in CMU was working on this issue. Also people from MIT like, at that time, Lynne Parker, who is now in Tennessee working on this issue of distribution of tasks between robots using different architectures, who are discussing different architectures. Also people in Japan; for example – people working on multi-robot issues – Hajime Asama in Japan, for example, at that time. This is for multi-robot aspect. We are still working now on multi-robot, but in other aspects. So it's no more for logistics. It's more for, I should say, military or rescue applications. And also in the future – also, we are starting a new project now of assembly in the air with using rovers. Well, using UAVs.

Q:

Is this for – what is the [inaudible]?

Alami:

So this is very interesting. It's very interesting. The application is essentially building or maintaining structures that are high in altitude, in mountains or in buildings. Building or maintaining or changing an equipment or repairing an antenna, for example, things like that. And today you use people who climb there, and we would like to do it with flying. Flying assembly. Flying arms and grippers, etcetera.

Work with Service Robots

Q:

How did you get interested in personal and service robots?

Alami:

Oh, yeah. So that was another step, again, of the – I think I came to it because it was also an idea came in to discussion between us with Georges Giralt and the others, thinking about new challenges for robotics. And in fact we organized – I think it was the first – it was the first workshop. We called it at that time – I should have prepared a little – I think it was a workshop that was called the first Workshop on Human-Friendly Robotics. And it was a CNRS NSF workshop. It was organized between – co-organized by CNRS, which is my institution, and NSF. And the two people who have organized were John Canny, from Berkeley, and myself. So we organized this first workshop in Toulouse, in LAAS, and it was in '99. So it was the first workshop on human-friendly robotics, thinking on what does it mean. [laughs] What does it mean? What could we do about it? So it's there that our adventure started. And incrementally we thought about this number of issues. Then I tried to build – starting from this, we had a number of discussions. We have done some kind of thinking and we're mapping and defining challenges. And based on these challenges, we organized a second workshop at that time in California. First in Toulouse, then in California. Again, I think it was linked – in Toulouse it was independent. The second one I think it was an IROS project workshop. IROS workshop. And then I applied for a French national project that we called HR+, Human-Robot Plus. The idea is that the human and robot will do plus than human or robot. That was the idea of the HR+ project.

Q:

How did you come to the idea – to the question of what is human friendly?

Alami:

Well, because of our experience, we know how the robot is stupid, how the robot is difficult. [laughs] We know what is a robot very well, and we know that there was a difference between our dream and the thing that we have in front of us every day. In fact, sometimes I – well, I like to do jokes about this. I say that the robots are far more autonomous than we think because they never do what we want. We just want them to do what we want. [laughs] We don't want them to be autonomous. We just want them to do what we want – no autonomy. They never do.

Q:

You've succeeded already.

Alami:

Yeah, exactly. And then you think about this, because I say if you give to robot a task and you don't give the robot a deadline, it could take an infinite time to do it. It starts by doing nothing.

Q:

I think positively next time something doesn't happen.

Alami:

I am doing what you said because I have infinite deadline, okay? [inaudible] So we came through this – so we came to this like this, and then we tried of course – when the ideas come, they appear everywhere. You think you have the idea alone and it's everywhere. Then you have of course to go deeper. But the shallow idea, basic shallow idea, goes very fast everywhere. So we can't say we have started human-friendly robots. We think, but I'm sure it's not true. I mean, it's something that happens here and there. However, we organized workshop and we sat down and worked together and thought together and produced – so it was interesting in the sense that we went deeper than simply this shallow issue. We tried to understand what that means. So we go to issue of safety, through issues of reliability. If you put human and robot together you have to think about certifying your system. You cannot leave it like this. All these issues, and of course utility. The robot should be useful to do something, etcetera. And then you add something which is complementary, is that this robot is designed to be used by naïve users, not by engineers. So you have to do something. This user will not program in – they will not speak in C or in C++ to the robot with a keyboard, even though it doesn't work. So you have to think about all this issue. And it came really like this. And then we found out incrementally that a number of things that we thought had been almost done have to be revised because you have to take into account the human. For example, motion planning. In motion planning for a number of time, we are doing motion – first, we are very happy when you had one solution we found the best. Ugly. Ugly path. It's okay when you see it on paper, less – it's still ugly but you accept it when you see it in simulation. When you see it really executing on the real robot, it's awful, because it's a path in the configuration space, not in the Cartesian space. This is the first thing. This is first, second it's not – and then we thought about optimization. Optimization was essentially linked to minimum time. And so people were working about optimizing, which means finding the shortest path in the configuration space. And this is not good, because the shortest space in the configuration space doesn't provide your directory that is understandable by human or acceptable. If I do this to give you an object, you will not understand. All this, okay?

Q:

I would think you're very good at [inaudible]?

Alami:

Because I'm – perhaps I'm very optimal in some space, but not in – [laughs]. And so we began to think about this, about what are the criteria of a good plan, a plan that would be – that first would achieve a task, then would be legible – a behavior should be legible [inaudible], and acceptable. And so I presented this today. My work today is – I summarized in one point, in one word. I work in order to make the robot not incongruous. This means that we are trying to think what to do in order to make the robot do the pertinent task at the right moment, in the right place, etcetera. And this is not easy. Not easy. It means that you have to understand what is the task, understand what is your partner, to understand how the partner behaves. If the human really wants the robot to give the object or not, because human changes their mind, they have an urgent thing that happened that makes people do something else – and all this would be taken into account. Again, you have serious question of safety. Serious. And so then based on this we started to work seriously on different aspects, and this we have done through European projects with partners. We had several projects. One we just finished three years, which was called PHRIENDS. It was essentially focused on physical robot interaction. Now we are starting new project on this issue. The coworker, basically. The coworker, this is a robot that will work – you have the assistant, or the robot who will assist the elderly people, etcetera, which is a real challenge, which is I think very interesting, and perhaps useful. [laughs] This is modest. But at least interesting. And you have the coworker which is also interesting, and perhaps useful. And the coworker is a robot who will work this time with a professional. But even though it's professional, it will not have a keyboard, will not have time, etcetera, so the robot has to be flexible and to adapt and to be reactive, to be proactive, [inaudible] to intervene, to be responsive to the human, to be in a way always ready to leave the place [inaudible] the human has priority in doing things, etcetera. And for this you need good perception. You need intelligence. You need physical safety, of course, but all these issues that we – and it's also – and in fact I think it's also an initial link to the notion of interaction. And I think you can find it. I think you will find it. A number of people, of researchers, who are still doing – I'm still doing – multi-robot cooperation are also interested in this decisional aspect of human-robot interaction. It's the interaction that is important. The interaction. The notion of interaction, which is independent of the task. You have to manage it as an entity, as a concept. In both situations you have between robots and between human and robots, and in the future you will have – I'm convinced of this – you will have teams of robots and humans. The robot will have to cooperate with the other robots and with humans. All this will be mixed together so the two concepts should also merge. The same robot should be able to interact with human, interact with the other robots. It will have these two abilities. And we hope that part of these two interactions are based on the same concepts also. Not all, at least part of it.

Q:

Do some people come to mind – I mean, Reid Simmons, I guess, is one.

Alami:

Reid Simmons, again, is one contributor to this. Today, human-robot interaction, you have full community working on different aspects. When you think about Reid Simmons – and I agree, it's [inaudible] decisional aspect and a control architecture aspect. Yes, you're right. There are a number of people in CMU working. They have excellent results on multi-robot cooperation, task location, etcetera. They have worked on this a lot. They have a number of results. In Europe also there are different places when we have worked on this, from Zaragoza to other places in France. And yes, we have also contributed – we have colleagues – for example, I am working a lot with colleagues in TUM, in Munich, Michael Beetz, who is very interested in this issue also of the autonomy and autonomy in collaboration. And this is based I think essentially on the issue of, yes, robot intelligence. It's one of the cognitive robot, somehow. It's the cognitive robot basically, and one of the aspects of cognition that is key for me is interacting with human, working together. It's not – because some people think a human-robot interaction, they see it independently of something to do. We are trying to transform it into something that is linked to a task to perform. Human-robot has – there is a task to do. There are other people thinking about human-robot interaction for other issues that are also very interesting, which is support or, for example, very interesting work, which I'm not doing, which is, for example, using robots to interact with autistic children, etcetera. Very interesting also. It's a different field, but however this is also interesting because it opens our mind also, because we have to think about human, what models of the human. So more and more in robotics today you have it. You have people – not only in robotics, in neuroscience, etcetera, who are studying humans – or using robotics to study humans – a presentation of Nakamura the other day, which was very interesting for this.

Q:

[inaudible]

Alami:

Yeah, for the muscular aspect, etcetera – really using robotics to study humans, to understand the human. And I am doing the other way, but both are not independent. Working with people who study humans and contributing a little to it, to serve the human. We need models. We need to understand the human to serve the human and to work with him, and for this you also need models. And of course this happened independent – he mentioned it, for example: if you understand the human, you will recognize a human who is tired, for example, and then the robot will not interact in the same way with a person which is tired and with the person which is not. It will recognize a human that has difficulty to move or not, or a really dynamic guy, etcetera. It will not do the same. And so we are preparing from the other side a robot that, depending on this, will not put the same costs to the task it has to do. If the guy is strong, etcetera, it will not try to assist him, to give an object to him, etcetera. Also it will be far more efficient to share the load if necessary sometimes instead of putting all the load on the robot, etcetera, all these issue.

The COGNIRON Project at Toulouse

Q:

So this notion of cognitive robotics – in Europe people talk about it a lot and there's a whole – the COGNIRON project, which you're part of. Were you around and hearing where this notion of cognitive robotics came from?

Alami:

The COGNIRON project was a project that we were coordinator in Toulouse. It was a FET program. Well, this is jargon of Europeans. FET is Future Emerging Technology. It's basically projects that you do not have direct applications. They are to do fundamental issues. The COGNIRON project was very interesting because it allowed us to open our mind and to have some time and some resources to think globally about this. And we built this project – it was quite interesting because we were able to look at the different parts, the different aspects of the problem – from user study, to learning, to dialog, to motion, to control architecture, to decision, etcetera. And we had [inaudible] partners with us on all these aspects, for example – people from KTH. Heinrich [Christensen] was there at that time, before coming to Atlanta – was part of this project. We had people from Germany, Professor Dillman and his team also on this project. We had people from Amsterdam. We had people from – in COGNIRON – we had from Switzerland, from EPFL, Roland Siegwart and Aude Billard. And also people from U.K., Kerstin Dautenhahn. And having all these people on board, we were able to have a look at these different issues and incrementally try to build this figure of what would be, this cognitive robot in this field, the companion – the companion robot. So I think COGNIRON can – and after that, other projects went in this direction. And so yes, there is a community in Europe thinking about these different aspects of human-robot cooperation. In COGNIRON, we had also people from IPA Stuttgart, working with us, Martin Haegele and the others.

The Challenges of Human-Robot Interaction

Q:

So after COGNIRON, what are some of the challenges that you see in this kind of intelligent robotic-human environment?

Alami:

Of course, it has not solved the problem. It just opened, and looked a little in it, but I think in an interesting way. We are moving towards different issues, moving more from this. So I think for us in COGNIRON we put a number of issues linked which we have to understand what is this interaction at the [inaudible] level, which we are essentially doing today. So we'll essentially continue to investigate the different aspects. Also in an interdisciplinary approach. We perform psychology, developmental psychology, sociology also. We are also interested – and this will I think open a little more the issue – is in the future we think about this robot will be – it’s not the future; it's today – this cognitive robot will not be isolated. It will be in an ambient system. It will have to interact with a number of other robots and other devices that exist – cameras, smartphones, tablets, or [inaudible], and human who might be perhaps equipped with a number of devices. So all these issues should be – we are just beginning to look at this issue. But I think we are, all of us, in this challenge because we are beginning to have robots who have two arms [inaudible] of the humans who can do work with human, and so I think we continue towards that direction. And at the fundamental level, and also we try to find reasonable and acceptable application contexts. I think one of the contexts is elderly people assistance. Even though we don't think they will – of course the robot will not replace the nurse or the parents or the children. It will simply give more dignity to these people. They will be able to take objects that are far, to be assisted. And having this, they will not have to wait a long time for a simple thing. "Give me this," if they cannot reach. And this happens in home, this happens in institutions. And so there is room for this. Also of course for assisting handicapped people. It is certainly very, very important also. Very, very important for these kind of applications.

Advice for Young Researchers

Q:

I was curious about what kind of mentoring you do with younger researchers in the lab and everything like that. What's your experience doing that?

Alami:

My experience – I like to work with students and PhDs because – basically because it's with them that we build the concrete challenges: "Let's do this." "You are in charge of this." And we are trying to do these two issues. You have kind of a challenge in each one. But also we are adding something, and this is perhaps different from what is done in different places, because we have also this perhaps stupid ambition to build a complete system. [chuckles] And so we need several persons working together, and we need to build systems that will go beyond one phase, because so often I say it's not able to finish [inaudible] have this issue also. So I like to struggle with this problem of giving challenges to students, to PhDs, essentially. So sometimes it works very well, sometimes it works less, of course. It depends if people [inaudible] it depends on a number of issues. But from time to time we have good success. We find things. We make things more concrete. We find out interesting – small problems, for example, we – to give just an example, I presented yesterday. We found out that you take one task, and it's huge problem, just the handover problem. Just the handover problem. If you take it completely, you really want to have a generic robot that does handover, you are there for years of working and issues, etcetera. In fact, by doing this, if you want to do it in a generic way, you will also solve other problems. You will also solve other – you will solve a number of [inaudible] not only the handover. There are a number of tasks that you have to do in face to face, in approaching, in sharing space, in moving towards the guy. You have to move and to retrieve. You have to wait. You have to interact. You have signals at different levels when you do this, etcetera. And so essentially we played that kind of games with the students, kind of challenges.

Q:

If you had advice to give to young people who are interested in robotics, what would it be? How to start.

Alami:

They have to share the dream, first. [laughs] Yes. They have to share the dream, really, and also they have to pay attention to not to be too disappointed, because robots are far, far, far from being able really to do things. So somebody's disappointed because they say, "Oh, I thought this problem is solved [inaudible] in order to add this." And it's not that case. So they have to share the dream. They have to be quite ambitious and to persist in their direction. And also be modest. It's because it's difficult. And the last thing, which is I think important, but I think it's true for everything: to think about how things could be done in a generic way, in a way that will be reused, that will – you draw lessons – you draw lessons from what you are doing [inaudible]. I think when a PhD finishes with a lesson that you draw, you are happy. But they have to share the dream. [laughs]

Q:

Is there anything else you want to include? These are mostly all our questions, but if there's anything else you wanted to add, please let us know.

Alami:

No. I was very frank, so [inaudible]. No. No, I don't think so. I don't think I have some very specific issue to say. I really think there is a lot to do in robotics. It is far to being – and what is good – what is also interesting, I think it's – I like robotics because it's a field that allows you to open your minds, to see things from different aspects. So [inaudible] to say this, but when I see my other colleagues in my lab working on other issues which are very different – networks or [inaudible], it's boring – [laughs]. Robotics is not boring. Robot [inaudible].

Q:

We're going to put that as the first thing [inaudible].

Alami:

What's this? It's a boring thing, or the microelectronics, something like that. Or control. It's small dream. It's not the big dream, you know? You get it?

Q:

Yeah, we get it.

Alami:

[inaudible] The clever – smart, clever, omnipotent robot is –

Q:

Build another human.

Alami:

Yeah, to play with.