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Jean-Paul Laumond

An interview conducted by
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with
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Q: So if we can start with your name, and where you were born and when?

Jean-Paul Laumond: Okay I'm Jean-Paul Laumond. I born in '53 in countryside North from Toulouse in France, in a small village in France.

Q: And where did you go to school?

Jean-Paul Laumond: I have been to school in Brive which is the main city of the area in that countryside, and after that I entered the university in Toulouse, first by following special training in French which is what we call the “classe préparatoire” for the engineering school. But in fact after two years I moved to university to in the mathematics department and I got a diploma to be a teacher in mathematics.

Q: What did you study while you were in university and how did you decide on that particular direction?

Jean-Paul Laumond: <clears throat> At the very beginning, I was not very convinced by the choice I made to enter into engineering, because engineering is to go towards the industry world while I was more interested by the academic position. And at that time I didn't know that engineering could be a possibility to enter the university or to make then. Then for me it was just pure abstraction or like literature, and then this is why and of course I was very enthusiastic with mathematics, and this is why I chosen to enter in the university in the department of mathematics.

Q: So after the university you did one year of teaching or longer?

Jean-Paul Laumond: No, no, no, no. Not one year, five years, five years. And in fact this has been with the French system you know the position of the national level and then my first position where in the very north of France, and I enjoyed teaching. I enjoyed the relationship with the kids, with the girls, you know there were 17 and 18 something like that. And I was very, quite young. I was only 24. Then the relationship was quite interesting. But the problem is that teaching mathematics is kind of repetitions and I very often summarize my wish to escape teaching by saying that with the profession of teacher there are two aspects: one which is knowledge transmission and one which is education. And I was not very interested by the aspect of pure education, to be involved in the life of the student. Not the student but the kids and the girls. And then I start thinking about how to make the conversion to go towards the academia. It was a kind of nostalgic. And it took four years to do that, to make that transition. First I enter in contact with some friends, chosen at that time to enter in engineering and I've seen that they were working in academia and I was very surprised, and then I remember a critical discussion with a friend of mine and explaining what are you doing and “I'm involved in artificial intelligence and robotics.” Wow, artificial intelligence and robotics but I never heard about that world. “What is that?” What is that? I just pure training in mathematics and I – then he tried to – it was in '77 or something like that.

This was the very, very beginning in France of robotics and okay and then I remember he advised me to enter in contact with Georges Giralt who was the chair of the Robotics department in Toulouse at last in Toulouse. And it was the very, very beginning and it just started that group. And then there has been very good contact with him because what were my position. First of all he accept to welcome me and I call him and I say what I can say? I didn't know about him. Then I just say "Okay, I am a teacher in mathematics. I am interested by doing other things by using mathematics to do something else and then is it possible to meet you?" You know we – after several years you should understand that listening so famous researcher saying "Yes, you are welcome" it was completely fantastic! Why? I'm welcome. And then this is I think one of the fundamental qualities of Georges Giralt and the UNT to take. And then the first rendezvous has been a failure, a complete failure. Because of course I was a little bit intimidated and then I tried to explain something a little bit confused. I am a teacher in mathematics. And I would like to use mathematics to do academia things and then his main advice has been “Okay try to be graduate in the Mathematics department and get a Ph.D. in mathematics, this is natural. Then I have some contact at the university then call these guys.”

And after that finishing this first rendezvous I was completely disappointed because I knew at that time the situation of the mathematics department and in Toulouse and I was not so enthusiastic to do that. Then this was a failure. And then after thinking but just a few minutes does that mean – I call back Georges Giralt two hours after the first meeting saying "I'm sorry, Mr. Giralt. I cannot express. I would like second rendezvous.” You may imagine, this was in some sense this was very impertinent. <laughs> And then he say okay yes, okay. And then the second one, he understood that I was a little bit lost and then the second one he said okay the only possibility then we are working in robotics, robotics is such and such. Of course they may be very useful to get some students in mathematics but you have no graduation in robotics and so on. Then I propose to you to structure a little bit your future. But first you try to get the graduation in computer science and since you are teaching because I was teaching at that time and full time and then that you can go to the lab on Wednesday afternoon and on Saturday, then Sunday you are welcome as well but and then but since the charge is quite heavy okay it's possible to organize this first year within two years. Okay then the first one for the theoretical issue, the formal homework and examination and the second year for the training phase where there are some projects to realize. Let us fix that and there will be the following possibility. Either you fail in getting the graduation and then we will stop the relationship. Either you will succeed, and in that case there are two other options. Perhaps you don't care about Computer Science, Robotics, and so on, and we will stop that, and if you enjoy that part, then we will see at that time. And this is exactly what has been done and after two years I succeeded in getting graduation in computer science and graduating in computer science for me it was completely an abstraction. I didn't know what it was. I have some anecdotes about that which is – which is incredible.

Just to tell you what is the level of training, of mathematics in France. My advisor was a friend now was belonging for this training first was Marie Garab (sp?) and then belonging to the group of George Giralt and a good friend of mine now asked me to work on some algorithms. Oh come on, what is algorithm? Okay I remember that okay we made that in mathematics to compute the biggest integer which is the common divisor of two numbers. Okay I know a little bit but in general I don't know what is an algorithm. And he gave me for the study the study of some work by Hopcroft and Tarjan. I remembered it was an algorithm to decompose graphs into simple or big connected components. And this is very abstract. I don't want for you to explain what is this but and then at that time the algorithm were presented in the some informal language called algol. And that means that you explain the algorithm in the paper and there were "I", letter "I", double dot, you know, equal, "I" plus one. Then we see the affectation of "I" becomes okay then this is algor. "I" duh duh duh, okay, no double dot, what is this sign? Then I remove that sign in my mind. Then "I" equal "I" plus one. But come on, it's impossible. I promised you that this was my level, okay? And I tried of course, I don't want to say that I don't understand and okay now after several years, oh what was the original problem? The problem is that the training in mathematics in France was at that time very, very abstract. We study the structure of the mathematical structure of the mathematical object but without constructive view. The question is to prove the existence of an object, understand? The existence for the mathematical object but you don't care how to build the object.

Building the object is a problem of engineering, oh come on, it's not very interesting from the mathematical point of view. The critical point is to prove that these objects exist. Building the object and that means that the dynamic character of the mathematics that building something is completely abstract but this is computer science. That means that variable that takes value at a time "T" and then another value at time "T" plus one. I don't understand what does it means? You see the point. Then I had to learn a lot. And the cherry on the cake is that several years after that I realized that the paper I was working on by Hopcroft and Tarjan was one of the most sophisticated algorithms which has been ever published in the Graph Theory. But means that my advisor put the level very, very high to understand that. Okay and this is that by that way I enter into the domain of computer science and from the mathematical background and to all of that. And then after that my talent of programming in programming was has been always, always very bad. I stopped programming in '84, something like that. And then I was enthusiastic with a language which were at that time APL. You heard about that very abstract, very completely in opposition of the current language, the modern one with the object level and so on and the competition was to make the program, as short as possible. Okay you know we thought it impossible for somebody else than you than to understand what the program was doing.

And then after that I enter into the PHD, where the subject was to use the graph theory to better understand the environment which is captured by mobile robot and the idea was how to provide mobile robot with the capacity to understand its environment by using graph decompositions. Then it seems that I was at that time welcomed in the robotics community. First paper was about that and so on and this is that.

Q: Where was it published your first paper?

Jean-Paul Laumond: Ah, it was very interesting. It was at IJCAI '83 in Karlsruhe. And to continue about anecdote I never learned English at school. I just learned German, Latin, or Greek. Then I am completely autodidact with English and then you may consider that with my accent and voice with my capacity to speak in English that this is clearly that I am completely autodidact and my first presentation at IJCAI was totally phonetic. <laughs> I learned – I remember the very beginning the first sentence "I am presenting to aspect of learning for mobile robot navigating in a given environment." <laughs> This was the first sentence that everything has been – it was phonetic. And each guide and it was I did not realize I was the single author of the paper and my advisor was very, very good for that. He was encourage me to he made the correction of the paper but he was considering that he was not sufficiently involved to be a coder. Again this is not at that moment that you realize this is years after that okay, my first paper I was single author in a very selective conference IJCAI. You don't realize that. You say okay, it should be normal. No but in fact it was not so bad.

Q: And so when you started working in the lab what kind of robots were there? What kind of projects were there?

Jean-Paul Laumond: It was the beginning of the project HILARE the mobile robot promoted by Georges Giralt. At that time my colleague Raja Chatila was working on the navigation system of HILARE using ultrasonic sensor and so on. But for me I was far from the physical robot. It was at the level of artificial intelligence, of the abstraction of the concepts, then I was not touching the sensor and so on. Again, remember I am not an engineer. If I touch the robot it will be a catastrophe and but speaking this has been a real problem for me. I was considering myself as not allowed to be involved in such engineering part. I was observing and of course part of my thesis of some piece of software have been done at that time in collaboration with Raja Chatila ,who were much more involved than me on the real robot. And this another aspect of the situation in Toulouse at that time. George Giralt knew about creating a true group. And this is definitely very, very important. A true group, what does it mean? That means that how to make a researcher working together. Then of course when you are at the level of the Ph.D. it seems to be natural. You have a mentor and then everybody is working under the supervision of the mentor.

But in fact the management of George Giralt were much deeper in the sense that after that along our careers we maintained this capacity to work together. It's not simple. It's not simple at all, but George Giralt succeed in creating a critical mass to conduce very ambitious projects where you need to combine a competence in perception, in vision, in signal processing, in decision making, in control. It's not possible for a single guy to get that and robotics is all of that. And I think this has been a very, very good point at that time to create a synergy allowing several researchers working together. In that sense the organization is completely under opposition at the opposite with the American system for instance where there is or Japanese system where there is one professor and then the student. And your former colleague okay? And then has to create his own team, one professor and then his former students and then it's very difficult to work together. While with the French system of the national lab like this which is not exactly the university lab, it was possible to have a critical mass and today the number of researchers in robotics at last is 80. But 80 within an organization of only three groups. That means that there are perhaps 25 or something like that, 20 or 25 senior researchers with tenure, with permanent position. But only three groups. I think this is very, very important.

Q: And so after this first paper and kind of your initial work, what were some of the other projects you worked on while you were doing your Ph.D.?

Jean-Paul Laumond: The paper was in '83 I got my Ph.D. in '84 and at some stage I had some proposition to enter the university in Paris in the department of pure Computer Science. That means graph theory because in my Ph.D. committee there were professors in theoretical computer science who were very interested by my work and encouraged me to go to Paris. And this was the only offer. And I declined the offer, why? Because at that time I understood that entering the university that means teaching at the university would be exactly the same job as teaching in for kids and girls and I didn't want to enter again in that system. And then there were the possibility in France to apply to a CNRS position in the National Center for Scientific Research that allows researchers to do only research. And then I applied for a position. It has been not easy but I applied and I entered the CNRS in '85. Then you remember the date I born and that means 32 years old. It's not so young, eh? And but keep in mind there were five years of teaching and in fact I never regret that period of teaching. Why? Because I remain a teacher, but I remain a teacher with complete freedom, complete freedom; I just teach in some institutions what I want. If the people don't care about me, okay but I teach my topic of research and not the undergraduate course and not everything like that with the administration of the university. Just this is a module and then I definitely enjoy teaching that.

Q: And so at CNRS what kinds of things did you do and who was there when you went there?

Jean-Paul Laumond: Okay then I enter CNRS in '85 and then I got a Ph.D. in '84 to do what? And then this is the first question of the researcher. You have to pay the freedom, okay, then you have to define by yourself your own topic. Of course you are discussing with your mentor, with the colleagues and so on. And then this is the time where I will say computer science, math, robotics in the following sense. I was interested by geometry and this was the I remember as an anecdote which is very interesting, in Karlsruhe conference IJCAI '83, I gave a talk just after or before I don't remember another talk which were given by Rodney Brooks and Tomas Lozano-Perez on the motion planning problem by using cell decomposition at that time. There were other geometry ideas in the like this. And then with my background in mathematics I was studying by myself some element of computational geometry and how to solve a geometry problem with a computer. Where the model was quite abstract and sophisticated and I started a little bit working with that and the first connection has been theoretical paper. We sought an interest for robotics which has been to prove that it was possible to draw a planar graph than a graph classical data structure; it's a planar if it's possible to draw that graph by putting the nodes on the plane in such a way that there is no edges crossing outside the – the node. Okay.

Then there were theorem by Fáry mathematician, I don't remember when but it was in the '40s or '50s I don't remember exactly, that proved that it is possible to draw such a graph just by using not curves but straight line segments. It is possible. But nobody provide the algorithm. Okay just the existence yes, it is possible to do. And then I provide one of the very first algorithms. Unfortunately just three weeks after Japanese computer scientist who did exactly the same work <laughs> and published just before me. That means that the algorithm that I propose I remember it was to the *Journal of Algorithms* which is quite a selective journal in computer science. And then the reviews say okay then it's the review after I don't remember, three months or six months something like that. The algorithm is very nice. But this is exactly the same algorithm as the algorithm by Shiba and Noguzuki, I think. Shiba, I'm pretty sure, I don't remember the second name, which has been published but the date was after my submission. You know it was not possible for me to accept that. But the algorithm was completely current then I never published that algorithm in a journal. But okay.

I mentioned anecdote because this is the first link between graph theory and geometry. And then I discovered that a structure of Voronoi diagram or visibility graph everything. There were another Ph.D. student finishing the Ph.D. Laurent Gouzelle and also Thierry Siméon they were studying deeply the concept of the configuration space promoted by Tomas Lozano-Perez and then we were working together and trying to do that. And then a key idea appears at some stage. It was in '85. I'm correct? Yeah, it was in '85 when Georges Giralt enters my office and tell me "Jean-Paul, okay I understand everything you are doing in configuration space and how to translate the physical problem in to an abstract problem. How to move bodies, how to transform that problem to how to move points in the configuration space, the configuration space approach. Okay, I perfectly understand what is this." Tell me "Okay come with me. Give a look at HILARE." Yeah, and then what is the dimension of the configuration space? XY and Theta and the configuration space is three. He told me "But there is something I don't understand. HILARE moves like this but it cannot move like this. Now because you told me that the existence of motion is characterized by the existence of the passing connected components but if your algorithm provide motion like this, it cannot be executed by the robot. HILARE has wheels. This is not a manipulator with all the degrees of freedom which are controlled by a given motor." Okay then this was the very, very beginning of a very enthusiastic topic the non-holonomic motion planning which has been truly the starting point of my career.

And I will be always jealous against Georges Giralt because he asked the question. And the right one with the intuition that these questions were very, very deep. And I just solve in some sense at some stages the problem but the intuition to say "Okay Jean-Paul, there is a difficulty here." The intuition comes from in and this is why this is truly a mentor. Because the problem was very, very deep and very exciting and in what sense? Because the solution of that problem comes from the combination between computer science and control theory. And for that there are some concepts to make the connection which are purely abstract and mathematic. There were definitely the need to use sophisticated mathematic tools, and then my first conference was in Amsterdam on that. I solved the problem in Amsterdam in '86. This has been the first paper showing that it was possible to reduce the problem of the decidability that means the existence of a trajectory for mobile robot to the classical piano mover problem. The piano mover problem was the seminal problem of the motion planning. That means that it's possible to in some sense to kill the constraints of holding without sliding by an approximate scheme where you first solve the problem for the mobile robot as if it was a piano and then after that you approximate the path by a sequence of feasible one. That means that you solve the problem like this and then after that you approximate the path like this and this is the parking this is the parking task. The first algorithm was not so efficient of course, but there were formal proof that it was possible to do that.

Then Amsterdam IAS symposium intelligent autonomous symposium one of the very first promoted by Groen, I think professor Groen, from the Netherlands, the symposium already exist and is running and there are a lot of anecdote because at that time I had questions after my talk in the room there were persons that had questions, yes. "I think that your theorem is wrong." Oh come on in public, I just proved that. Okay please could you develop? "Okay if you are considering these example such examples then that case your algorithm will never converge." Of course you are right. Of course you are right. But the hypothesis I was completely destabilized, huh? You may imagine. You are proving something and then something in the room say okay in a public manner your theorem is wrong. <laughs> Okay in fact he was a mathematician and the hypothesis under which my theorem were wrong is a hypothesis where you should consider an infinite number of obstacles was the size of the obstacles converged to zero again so all like this. Okay then but this is not the real world. This is not the real world. If you are considering the true world, that means that the number of a chair here is finite and the length of the trajectory is finite, and then okay and they say okay in that case you are right. <laughs> You know there are a lot of anecdote like this but that makes you very enjoying you know because there are a lot of stress and some people tell you okay your theorem is wrong. Okay and then after that I continue and after that I think this paper had some success in the sense that I have been for the first time invited to give, to present an invited paper in some conference in Jerusalem, in Jerusalem it was very fantastic for me to travel in Jerusalem and discover that magic city.

Okay, there are a lot of anecdotes. And then this has been my first lesson for researcher. You have to take care to what you announce and then you are completely free to give a talk any topic you want but mainly related to your presentation in Amsterdam and then in Amsterdam I proved that it was possible to park a car. Just a car parking problem. I said oh, what would happen if we add a trailer, mobile articulated system? I put some question and paper like this okay and okay it will be yeah, okay then. In my presentation in a few months I will prove that the results about the carlike problem can be extended to the mobile robot with one trailer and then we will present the proof of that system at the time. And then I send that. But I didn't make the proof. And then the proof is not so simple. And then it was let's say I don't remember exactly the timing but let us assume that the conference is supposed to be in December. Then we have to send the paper in September, the final paper to be printed in the proceeding. Then in September, then I had the abstract in the February before. Okay then at some stage, perhaps in July I say okay I have to make that proper way okay and then I start working on it. I don't succeed in proving the theorem. Come on. And then September arrives. No. I made the proof in November after the edition of the proceedings. And then I was not very comfortable because I gave my talk with the printed copies of the paper but outside from the proceedings, then that means that this paper exists, but nobody except the audience get that paper.

And this has been a very good lesson. Never announce a result before you are sure to have proven that. And then at that stage I made some critical meeting there with new people and mainly there were very active collaboration thanks to Georges Giralt between LAAS Toulouse and Berkeley, the University of Berkeley and I met some nice guys like Shankar Sastry. And then we had my very first discussion with him to see that we have to continue in that direction of the non-holonomic motion planning. This is a very, very rich topic, and I started promoting that area at the European level then applying for project where the main – the key ideas was together not only roboticians to work on that but roboticians, computer scientists, control theorists, and pure mathematics, not applied mathematicians but pure mathematicians. You know that I made this strong distinction between applied mathematics which is very well known topic, very well numerical optimization, numerical analysis, and so on. Okay then it could be mechanics. It could be probability. No, no, the pure mathematics in terms of topology, the study of the structure and so on. And this has been three years between '92 and '95. Very, very exciting years of where we made a lot of new results and we create very synergetic relationship and I made all my friends at this moment which has been truly very, very important for me but also for the production of the new results.

That means that the key idea to make different people working together, keeping their own competencies. And the question is not to transform a pure mathematician into a robotician. It's not possible and the converse is also true, but making them working together we provide a lot, a lot of very exciting results, training very enthusiastic students who are no permanent researcher or very huge position at that time. There were connections with Richard Murray, for instance, a former student of Shankar Sastry. There were Paul Jacobs who is the president of Qualcomm at that moment. Then there were you know a lot of people that we met, Hector Sussman, a scientist from Rutgers University and then the core group in Europe was the group of Alessandro De Luca in Roma, Mark Overmars and Alessandro De Luca from the control theory part. Mark Overmars computer scientist in Utrecht. Jean-Daniel Boissonat a French specialist in combinatorial geometry. And Jean-Jacques Risler a mathematician at Ecole Normale Superieure in Paris and myself. And then this kernel has provided a lot of results.

I remember the first workshop I organized at the time in some countryside close to Toulouse. This was the very first workshop of Lydia Kavaraki for instance, you know? There were also Oussama Khatib of course. There were you know this was the standards. And during all this period there were parenthesis which has been very critical for me for several viewpoints which has been the summer '90 where Jean-Claude Latombe invite me spending some time in Stanford. And I spend three or four months here. And then I just provide one result but I learn a lot that this was the controllability of the multi-body trailer system. That means that the proof I made for the carlike system but and then for the carlike with one trailer can be extended to an arbitrary number of trailers. Nobody cares about that. This is a purely mathematical results and we sought in the effective application but very, very nice results from a mathematical point of view and we learn a lot about the structure of the non-holonomic system. And during that period then I'm just reporting enthusiastic manner because it was very, very exciting period. Then something which may appear as very abstract and we provide new results but in fact we kept in mind the robotics application and the true robot.

And then I succeed in convincing myself to build a trailer, an effective one to attach to HILARE. And thanks for an engineer at that time, he passed away too early, he made the trailer for me because I don't know how to make a trailer and then to attach that to a robot. And then we had an effective experimental platform to test the abstract algorithm and then we succeed in making the first, very first experiment of the mobile robot parking itself by pulling or pushing a trailer. And this is very, very spectacular and it remains today very, very spectacular. And everything, the solution we have developed, use are based on the mathematics we have developed. And this has been very good lesson again with the feedback after several years that don't reduce robotics only to technological development or to engineering or just to apply mathematics to that. Take the time to think about your system and then to see the true problem which are don't avoid them. Try to capture and then after that, if you cannot do more, if you can solve the a question, then ask perhaps some other method numerical optimization or something like that to solve the problem for you but before that spend some time to think about the way to solving, I will summarize that by saying to solving the analytical way before using the numerical method. And this has been – this remains for me very, very important. Okay and we have to convince young students which are attracted by mathematics, by pure mathematics that robotics may offer a very, very nice room for enjoying the development of their favorite tools in mathematics.

Q: How did people from both more pure mathematics and also more kind of applied robotics react to this approach?

Jean-Paul Laumond: You mean the people from mathematics?

Q: Right so from one side there's kind of robotics and how they thought about having this more analytical approach prior to application and things like that and then also from pure mathematics, how did people respond to –?

Jean-Paul Laumond: Okay I will tell you. Now this is an interesting question. From their perspective, from the perspective of pure mathematicians, how would they react? I can give you a perfect example. This is it was in '87 I think. There were a huge congress has been organized, national one in France at Ecole Polytechnique which were called mathematic avenirs. That means the translation will be there is a joke in mathematic avenirs means the future of mathematics okay? But also mathematics to-go. What will be the mathematics? And then there were several symposiums, huge symposiums and then some mathematicians invite me <inaudible> invite me to speak about the robotic problem, piano mover problem and the non-holonomic system and so on. But what has been very interesting is that the congress was organized with several topics and probability and then there were applied mathematics, and then but I was invited in the session of pure mathematics. And I was introduced by the chairman by saying "This is a perfect example of not applied mathematics, but a perfect example of the application of pure mathematics." You know the distinction? That means that the mathematicians were very, very excited by the idea that the very abstract concept which are developed in <inaudible> geometry, in very sophisticated mathematics are have application effective application in robotics.

And then you see that this is truly a critical point with this perspective. Very often you know we put walls between the discipline and then there are pure mathematics applied mathematics, okay applied mathematics is for engineering. It's obvious, this is the mathematics for engineering and then we are the specialists. But the pure mathematician don't care. No, no, no, in fact the reality is much more complex than that one and that means that as an engineer in robotics we need some tools which are not developed in applied mathematics. That comes from pure mathematics. This is why we have to take care about the walls and to push them at the maximum and then to maintain, but not to become a mathematician. I am not a mathematician. I define myself as a robotician. I'm not at all a mathematician but I may work with some mathematicians. And the key point is the human relationship. You should make friends or people who would become friends. That means that to have mutual respect about the problems you are addressing because you may some people say oh, you are robotitians, only robotitians, okay. Your problem is very easy, it's not very interesting. Okay. But after that you are very, very nice people who are respecting you and to the discussion and this relationship has been very, very good.

Q: And when you were working with Latombe in Stanford University what else was going on there at the time and how was working with Latombe?

Jean-Paul Laumond: It was a fantastic experience because I was working more than Jean-Claude Latombe at that time and you know working more than Jean-Claude Latombe it's almost impossible. <laughs> I mean it's, no there were not competition between us in that sense, but for me it has been very completely crazy period. I was sleeping only three or four hours a night, completely immersed in the <inaudible> theorem and Lie algebra coefficient and then the theory of the distribution, spending time in the Stanford Library, discussing with Jean-Claude Latombe and his students about the emerging probabilistic approach to motion planning discussing with the student about that. No it was a fantastic period where we worked with Jean-Claude a lot. It was perfect condition for me and you know this is what I say several times from the beginning of this interview. What you are doing at some stage in that period takes a value months and even years after. You don't realize what you are doing at that time, okay? And everything I learned during that period has been a fantastic period with me but truly I never worked again so intensively. At the very end I know that I wanted to prove that the multi-body trailer was controllable and then I remember I finished the report, the Stanford report which is existing now still. At some stage at perhaps 4:00 in the morning I would like to finish it before Jean-Claude arrive to see "What do you think about that?" But it was very, very, very nice. And of course this has been completely reconnaissant, I don't know the word in English. I thank Jean-Claude for having given me the possibility to spend such a time in Stanford, yes.

Q: And did you work closely with any of his other students? You mentioned discussing with one student.

Jean-Paul Laumond: Yeah, I remember Yoshihito Koga at that time he was using the – he was developing the seminal idea by Jerome Barraquand and Jean-Claude which are the very first probabilistic approach combining gradient descent and random walk. When you finish in some trap. And again, for me this was a strange feeling because we spent years and years to solve the piano mover problem by using sophisticated tools based on algebraic geometry developed by all the teams at the Courant Institute in New York, Micha Sharir, Jacob Schwartz, and providing sophisticated proofs of the decidability of the piano mover based on the decidability of elementary algebra proved by mathematician Tarski in the '50s and very, very sophisticated tools. And then of course completely un-useful due to the complexity of the problem. And then you arrive here and then you have a young student showing a system with eight degrees of freedom which are eight bars like this, articulated bars. Where you see that in few seconds is solving the problem to go to the final position. Come on, come on, how are you doing that? And gradient descent, random walk but random walk you don't control anything, you don't know. No, but it works. Come on.

And then this was the very, very beginning of the probabilistic approach and that means that we have to revise everything and forget about the completeness of the algorithm. Forget about that introducing new concepts, try to – and then the challenge is to understand in some sense okay before saying that I was a little bit disappointed in the sense that okay then these guys are solving problems which are out of the scope of the current method. Okay then I tell – I was discussing with the student and then I tell him okay, with your system which is articulated like this, I put the starting configuration in such a way there is okay you see I put it in that shape. That means that the solution to find the solution to the problem should be something like that. You have to make several turns and then to go back here. That means that if you start by being attracted directly like this, you cannot. You know you have to go back. Then that means I create very, very deep trap and I was pretty sure that any random motion will never escape that. And after one night of CPU the day after I took, I didn't succeed in solving the problem. Ah, come on. I'm very, very happy with that because there is no miracle, there is no miracle you did. But the key point is that I had to think about counter examples. That means that in general it works well. And in order to make the algorithm failing I have to think to come to counterexample. That means that in general it works. Then you know this is still the current status of the probabilistic motion planning.

Then we try to understand that and I remember when I went back to Toulouse I ask a student of Florent Lamiraux who is a very well-known researcher in my group in Toulouse to address that problem. The question is not to provide a new algorithm but it's the question is to understand why this algorithm works so well and we spend one year of full time research on that problem. We publish one paper. I don't remember when we do it, '92 something like that which is the explanation of a very, very simple case a small toy example where we understand a little bit what happens, but impossible to generalize that. And then impossible at that time. How to – this is another lesson, how to stop a line of research? Because this has been exactly the case. Then Florent Lamiraux provide that results giving the estimation of the number of loop, gradient descent, random walk, gradient descent, random walk in one specific example you say okay the average number of loops should be six and it was not ten. It was not 100. It is six. It's not four, it's not – it's the constant six. And then we may understand that according to the time then it's very efficient, six. And the question was to compute the effective experience, the mean of the <inaudible>. And six is nice, okay. Then let us try to generalize and with these results it's no more robotics. It's no more – we have to take some advice to mathematicians. I don't know a physicist and mainly a nuclear physicist.

And there is a lab in Toulouse at the university where we enter in contact with those people saying okay we are robotitians and it could be interesting to for us to give a seminar because we are using some tools which are we think to statistical physics. Okay, welcome, you know this is getting out and the ambiance is very nice and then we give the seminar here explaining what we are doing and in front of us we have the researcher from statistical physics and the people who were oh, the robotitians are interested by that kind of problems. Oh yeah, yeah. You perfectly explain. We understand very well your problem but what is your ambition? To understand why the algorithm runs so well. Okay yeah, if you want that ambition forget about robotics and come with us. We are working on that type of problem for several years and we are still working on that, but forget robotics. It's too much complicated and then you will do a pure statistical physics. And then after the seminar the Feron Miro had a discussion with him okay perhaps it could be good to change the subject of the Ph.D. And then this is what we did at that time. We resign and we the ambition that it was a deadlock and you know as an advisor you have the responsibility to advise the student and to take care not entering in a trap where you will provide nothing for his own career and so on. Then okay we stop here. And that means that this problem remains in my mind okay but I consider it's very, very difficult.

And the main contribution today has been done by Jean-Claude Latombe and his school with David Hsu with some concept of expansiveness of the space is to be explored. And the results are very, very deep. We understand that the conversions of the algorithm is quite fast but there remain for me that is from miracle. To summarize my opinion, my view on that very often I say that if this algorithm was appearing in the '60s, let's say in the '60s the success will never been the same because the time of computation the famous constant, the average thing of computation due to the power of the computer that had been much less. And then there is I think that the clear view of Jean-Claude Latombe and <inaudible> at the very beginning has been to see that the technology were mature enough to allow some new algorithms using the probability etcetera to solve some problems which were out of the possible scope of the pure mathematics and so on. That means that in some sense the solution may appear in some sense and with double quote as a technological solution which is not a bad point for that time. This is the new contribution of engineering to the development of a new algorithm. And but it remains the idea of why this they work so well, why these crazy ideas in some sense work so well. Okay then in fact I have been convinced why because after that in that period in 2000 and with my colleagues Thierry Siméon, we were developing our own algorithm probabilistic motion planning. Okay then we were of course using the same idea then we start making the platform and then after that we decide to create a company to promote that kind of technology and start a company where Kineo CAM – Kineo Computer Aided Motion, and that means that the companies are still alive. We have no more <inaudible>. I managed the company during two years and then after that I go back went back to my lab. But the company is selling that kind of algorithm. And very often in a very provocative way I say that we are selling a technology that we don't understood, we don't understand why it works so well but the customer doesn't care.

The customer doesn't care about the philosophical attitude, the thing oh yeah, but why it works so well? No they are not interested by they are going. They want just to have their problem solved and this is applied in virtual prototyping, virtual prototyping to check if it's possible to disassemble some part like this. The customer happy, then this is the key point for a startup. Don't care about the conversions and the expensiveness of the spaces and etcetera, etcetera. They don't care about that. And Kineo is very happy that they don't care about that. They just provide the technology that allows them to solve the problem, which were not solved for them. That means just to give you an idea that today when you are working in the digital mock up for instance in the automotive industry when you are designing a motor, an engine and then when you want to check if a given part of the motor has been well-designed and to access to be maintained, just to be maintained. Then you have the problem of piano mover and how to remove that part. Then today there are years ago they were using physical mock up and you design and then you build the system and then you check and then there is a loop to adapt. Of course the digital mockup and virtual prototyping give a lot of money saving in some sense that to perform the same task in the virtual world. Okay this is just a mockup but you need an operator that move the pieces using sophisticated interface to make the reasoning in 3D and so on. And then I have seen the people working on that. They are very expert to see if it's possible to extract a given seat from the car habitat the main part of the car.

Q: Chassis?

Jean-Paul Laumond: Yeah the chassis from the chassis, thank you. And then it's moving that checking, oh it become red. That means that there is a collision and so on. Okay to do that task for let's say for a seat of a car the operator in some case, this was the case of the car maker Renault in France, it takes two days where you say the trajectory and then you try because the engine is very, very tight and the guy has to check where is the collision and then two days. By using that technology it is done within ten minutes. This is very simple. Ten minutes, two days, this is money. They don't care if this is not probabilistic complete. They don’t care about that but the problem is solved, and of course, the problem cannot be solved as we know from a theoretical point of view it's not possible to say that. But in that case if there is no solution we have some formal models that show that even the guy will never find a solution because the narrow passage is very, very, very narrow and very challenging. And then this is completely effective. This is a technological solution and this is another point which is very interesting. This is not exactly robotics. This is the output of the robotics research towards <inaudible> which hare virtual prototyping and this has been a very nice period that one, and completely different. Before starting – before thinking about creating a startup you have to take care. Give me a call. And I will give you some advice because the life truly changes, okay?

Q: And when was your startup? What time were you working?

Jean-Paul Laumond: It was in – I managed the startup in 2001 and 2002. Then I have been after that scientific advisor from 2003 to 2007 and now I no more connection except that we remain friends, but no more interest with the company.

Q: After before the 2000s in the '90s you also had one or two large European projects on motion planning?

Jean-Paule Laumond: Yeah, yeah. After the very first one I mentioned with pure mathematicians I promote another one which were more effective in terms of application and I participated in two other ones. I just mentioned the seminal one because it was truly my baby in one sense. The other one also but it was less important, not in terms of results but in terms of investment and key new ideas it was less important.

Q: And who were some of the people that you worked with there?

Jean-Paule Laumond: What?

Q: Who were some of the people that you worked with on those projects?

Jean-Paule Laumond: On the second one?

Q: Uh-hum.

Jean-Paule Laumond: It was okay then their idea was to be much more effective. That means that we revised the initial consortium to have practitioner and then at that time then this was the idea to apply that not directly to robotics but to virtual prototyping and then there were already and it was in '96 something like that, yes, should be '96. Then their idea was to better understand the structure of the market in virtual prototyping and who are the actors, who are the customer, and then we identified EDF, the electricity company in France, then involving the nuclear power plant. They wanted to have automatic system to make robot programming in the nuclear power plant, how to make obstacle avoidance to operate the robot in very confined space in the nuclear power plant. Then there are effective problems. What tools they are using in terms of virtual prototyping, then this is a question of software development. What are the platforms and what are the provider of that platforms? And the provider at that times were a subsidiary of Intergraph CAD Center where the company providing the system to model the digital mockup of the nuclear power plant. Then we work altogether to be effective. At the very end it was possible to plan some trajectory and so on. But of course with Kineo, then after that there were basis how to go forward and know more in developing the new European project but to be much more effective for our self with respect to the platform, the software platform we have developed at last and this is the beginning of Kineo Cam.

But the question is again, what are the customer beyond the avion industry and the maintenance of the power plant and so on. And the more mature market was definitely the automotive industry and where the provider of mainly the Dassault Systèmes with CATIA platform and Unigraphics and the company which were the closer to our community at that time were a company from Israel, Technomatics. And Technomatics now is part of Unigraphics and now Siemens you know them. But there are very few providers and then a lot of customers. Then, okay two words about the strategy of Kineo. The question is not to address directly the customer. Why? Because if you are a small startup then in that case you need to have a huge department for marketing for you know a lot of people traveling everywhere convincing everybody. Now the idea was to the final target was clearly the Dassault Systèmes with CATIA and Unigraphics with Technomatics or Siemens now. And but it takes then to summarize and to be charicatural only two customers, the provider, you can concentrate the effort only on software development and on the technological part of the company.

But it's very easy to analyze as I'm doing at that time to convince the huge company like Dassault Systèmes or Technomatics to diffuse and to get the technology you are developing is not so easy. And that means that the strategy has been to work very closely with some final customer where we prove that there is another value and to impose that customer to make the situation where the customer ask the provider to integrate the solution in their offer in terms of the software development. And this is the current strategy of Kineo, which is quite successful to say I think quite successful because they are in good shape. With that strategy which were at the very beginning my strategy the strategy we discuss from the very beginning you don't need to have a huge marketing department. Kineo Cam remains a small company with only 15 people or 20 people, between 15 and 20 I don't know exactly but more than 60 percent I think of the people are engineers, developers and engineers that are developing the technology. And on the market I think there are no concurrence at all and almost all the <inaudible> automotive industry are using that technology with rather success.

Q: And your current research group also has some of this combination from what I understood motion planning and also the virtual kind of virtual agents or virtual actors I think you were saying, and then human motion analysis or studies of human motion.

Jean-Paul Laumond: Okay.

Q: So how <laughs>.

Jean-Paul Laumond: Okay.

Q: Is that something that came out of your work with the company?

Jean-Paul Laumond: Yeah. Okay then now if we summarize at the time you can see that the interviews follows a historical perspective, okay. But in my mind in my mind I have the movie then we are in 2003 okay, we are in 2003. I told you that in 2003 I resigned as the chairman and CEO of the company and then I went back to the lab. Okay a new page is opened, new pages of the book new sequence of the interview. <laughs> New sequence of the movie. Okay but you know this is very important, what next? And this is always the question for the researcher. What next? And then you are right. We at some stage in the virtual prototyping domain and so on, then there are only mechanical parts and there are very sophisticated simulation of robot. Where is the human? Where is the human? And at that time there were some actors on that and mainly the most performing I think were in Canada in Montreal people coming from computer graphics and there were also the people coming from robotics who was created Jack which is the name of mannequin so yeah, I don't remember his name. He's a guy very close to the robotics community, very good one that makes various schematics and so on to animate characters. And all this technology was very interesting for the provider, the Dassault Systèmes or Unigraphics and so on. They were interested on that. But of course if you give a look at that time it was less than 10 years ago and even today if you give a look to the current status of the animation of the mannequin in virtual in digital mockup the result is not so nice and there are a lot of research to do to improve that.

And what we should understand is that a digital mockup for industry, this is not Pixar or Walt Disney. And this is completely different while there are some connections. There are truly some connections again the technology which has been integrate within CATIA or the CATIA product which are the we see system product which is for instance <inaudible> are based on a technology that was developed at the very beginning by people working in computer graphics. Okay but then I had that idea in mind, why not developing motion planning technology for anthropomorphic motion? Okay then the pages was white completely white and I start this line of research. Then I ask a student working with me okay you know what is the human body? The human body is a robot manipulator. A little bit complicated because the shape is a tree. You have two legs, okay but it is just a mechanical problem and then you have just to solve the question. I think we may apply all the robots technology to animate a character and I was right. It was okay. And then the student finished his training period with success. Then the mannequin were avoiding the obstacles, were working but how it were working? It were working like this, making motion like this, completely unrealistic. That means we solved the problem of course, but the motion were not natural at all. Then the collision checking, probabilistic method etcetera, etcetera. Everything were working very, very well but the results were very bad in terms of realism of the motion. Then okay oh come on, it's not possible to say that. Okay then how do the people in the video games in Pixar and Walt Disney are doing? Because the people in virtual prototyping and so on are not so, not better than we have provide, then how do Pixar is doing? And of course I discovered for me it was completely new. I discovered the topic of motion capture and motion imitation and you put the sensors and you put the markers on the bodies and then you try to imitate. Okay.

Come on, to imitate, that means that you record motion and then you replay the motion but how to adapt the motion to a given environment, this is the question of the autonomy of the planning. No, it seems that the question is challenging then how people are doing in computer graphics that they are using motion graphs and they are making blendings of the sequence and it's possible to fuse that. But okay then this is computer science solutions in some sense. I would like to have a better understanding in terms of control. And then I start research with Ph.D. Julien Pettré. And with Julien Pettré, I ask him to okay, you record some motion for instance from a database which at that time which were available at Carnegie Mellon, then providing recording motion of walking people and you try to transform that into a control system. And then he did a good work because he succeed and it was possible to control a virtual artifact, a human artifact just by using a joy stick. Then giving two input, just two input, the linear velocity, angular velocity and then all the degrees of freedom, the 30 degrees of freedom of the mannequin were animated in a very, very credible way. It was very, very impressive, yeah the results was very good. And then to tell you the story for me it was completely normal. I asked him to do that. He did that. This was just with double cut signal processing using Fourier transform and then combining the coordinates of the main components of the Fourier transform based on the structuration using the Delaunay triangulation of the databases of all the motion captures okay then okay then I asked you to do that. You did that.

Okay then let us continue. Now we want to provide truly motion planning. We may start studying the motion planning for the actual artifact. Okay and this is what he did but at some and then the first paper has been on it was in symposium on computer animation in San Diego in 2003. Then we provide the system that avoid the obstacles in a realistic way and so on. Then for us, Symposium on Computer Animation. There is no robotics at all. You see that we change a little bit the focus. This is the area where that kind of technology is the better understood. But at some stage I have some remarks from some colleagues saying “Oh, your mannequin is working quite well. How you do that?” Oh we just make that that that etcetera. Okay but it's not so bad. It's very nice. Oh yeah, it's not normal and in fact I didn't succeed in evaluating at that time the work the student did. For me it was completely normal but in fact I was unable to evaluate the quality of the work and the people told me "No, no, it's very nice." And then the locomotion controller has been published after these results. And in fact I was not aware about the deepness of that techniques based on signal processing and some numerical method to make the mixture. In fact it was much more clever than the evolution I made by myself. And why? Because this is not the same area, this is not the same topic. We have another view and then we enter a little bit this domain of computer animation. Then from that perspective a lot of possibilities were open and mainly two main areas which has been developed in parallel. One has been discussion with neuroscientist to better understand human locomotion.

And then I met some very important people in that area in the connection between robotics and neuroscience and cognitive science, then main leader Professor Alain Berthoz and we worked together and on trying to better understand the general laws which are at the basis of the generation of the locomotive trajectories. And then the discussion has been very, very exciting, very nice because they were a mutual synergy between the way the neuroscientists were approaching the problem and the tools we may provide coming from robotics and you know that the seminal discussion with the Professor Alain Berthoz was the deep discussion about the relationship between the position of a body in space and it's orientation. It seems to be very naïve, very simple but this relationship is very, very critical. It means that when some people is walking, is traveling, when it leaves some tracks in the snow or in the sand if you want, you have the track of the guy. The traces are left in the snow understand? But there are traces of the position, not the orientation. But you have no ambiguity to decide where what was the orientation of the body. Why? Because the orientation of the body were in the tangent direction of the body. Then this is the characteristic of nonholonomic system. That means that we walk as a mobile robot rolls. Okay? There is a connection. Of course we may walk like this. Then this is another story and we are shooting that. And then this has been the seminal discussion.

That means that there is a coupling, a differential coupling between the body position and the body orientation, and at that time all the experiment in no science to better understand was consisting in drawing trajectory on the floor to be followed by the subject. But by asking somebody to follow a given trajectory your first variable which is the body orientation. Then that means that at the cumulative level this valuable is no more free. Okay then how to address the problem, I don't know. And then we start the discussion like this and we put together a new protocols for studying the human locomotion and for studying the intentional motion with goal-driven locomotion and then we start really fruitful research where the neuroscientist knows are publishing in robotics conference and professor Alain Berthoz is an invited speaker tomorrow in that conference. And where I have two papers I'm very proud in *Journal of Neuroscience*. And this is very exciting topic. Then this is one line. And then there is a line has been the opportunity in France to reactivate collaboration with a Japanese lab and we have been very lucky because we the CNRS, my institution in France, got a copy of the HRP2 Robot and then from 2005 to 2008 I have been with my colleague Eiichi Yoshida co-director of French and Japanese lab. Then Eiichi Yoshida spend five years in France working together where there were exactly the equivalent in Japan where Abderrahmane Kheddar and Kazuhito Yokoi were directing the Japanese part of the lab. And working on the same robotics platform has been a very, very huge success because it's been possible to exchange the expertise, the students. The students were traveling a lot and then fantastic period and this period continues of course except that the recent tsunami in March has been catastrophe of course for the Japan but also all the French researchers have been asked to go back to France and then we have to reactivate the work but I'm optimistic with that.

And then today my own topic is around anthropomorphic motion. Then that means motion for the digital actors, human motion, better understanding of the human motion and the humanoid motion. That means that it makes an occurrence where I create in that perspective a new group in at LAAS called Geppetto. Geppetto the father of Pinocchio of course, that which is made not by new people but just by reorganizing the people interested in focusing their research on human robotics. As an example for instance my colleague Florent Lamiraux then who has been my former student who made the very first experiment of nonholomic motion planning for mobile robot with a trailer, now is fully involved in motion planning for humanoid robots where the challenge here is to take into account the dynamics and the balance and so. Then this is the end of the story but of course the story is continuing. It is continuing in that direction of the anthropomorphic motion and the future perspective on anthropomorphic action the perspective of research and developing.

Q: What are some of the different types of issues that you're dealing with anthropomorphic motion compared to your previous focus on mobile robots and – or are they different?

Jean-Paul Laumond: How they are different?

Q: Uh-hum.

Jean-Paul Laumond: Then let us speak just humanoid robot and mobile robot. I think that the main challenge for a humanoid robot is to maintain the balance. The question of the balance for mobile robot is not so critical. It has mainly four wheels and there is no <inaudible>. Humanoid robot is by definition unstable and then that means that there is truly a challenge how to with respect to the technology in motion planning which address mainly the problem of the obstacle avoidance then this is the main goal. In a singularly way how to take into account the kinematic constraints then the close kinematic chain for instance or the non-autonomic constraints of the moving car, but there are I like to summarize by saying that the collision checking is the level zero of the geometry then kinematic constraints are the level one in terms there are the first derivative of the motion and then there are constraints at this level. This is typically nonholomic motion planning and dynamics, this is the second level of the geometry you have to consider the acceleration because the force and the gravity are expressed with the second derivative of the mechanics and to make sure there is two levels in my mind. You can do reasonably motion planning and control for mobile robot with the two first levels. While for humanoid robots you are definitely involved with the second derivative of the motion. And then this is truly challenging and then for instance the workshop on Friday I will present the last results which has been provided in the Geppetto group about some extension of the notion of controllability to provide well-grounded algorithm that allows effective motion for the humanoid robot to avoid obstacles with the guarantee that you maintain the balance of the robot.

Q: And how did you get involved with the Japanese with the AIST and the HRP2 group to begin?

Jean-Paul Laumond: Oh yeah, may I take a pause?

Q: Oh we should have brought some stuff.

Jean-Paul Laumond: Okay the question is how has been the starting point of the collaboration with the Japanese team? This is the IOS congress of Sendai in 2004. Then in that sense this anecdote will prove that this congress was very, very fruitful. Okay then you remember that I told you Julien Patin my former student was presenting a paper in the symposium of computer animation showing some virtual character avoiding the obstacle and so on. Okay of course we continue doing that and with more sophisticated system and then for instance considering <inaudible> virtual character to manipulate the object, okay. And in the digital mockup or collaborating with mobile manipulator to collaborate to transport to given load and so on. And then there were a little bit more robotics in terms of application. The algorithms were roughly the same, but the way to present that, it was possible to present that also in the robotics community then we submitted a paper on it. IOS, it has been accepted, and then strangely the paper appeared in the session humanoid. There were no humanoid robot at all, but you know how to organize the session.

Okay I was a little bit disappointed to be in that session with people speaking about the very first pattern generator for humanoid robots and so on. And then my mind I say okay in that audience nobody is interested by the computer science approach to motion planning for digital mockup. In fact I was completely wrong. After my presentation two guys came to me and it was Eiichi Yoshida and Kazuhito Yokoi that told me "Okay we have seen your work. Do you think that it could be applicable on true humanoid robot?" And then we start thinking about that "But you know your system is too sophisticated. How do you consider the balance?" "Oh we know how to do that. HRP2 robot is very nice robot. We have very reliable and robust stabilizer and we know how to control thing and then okay then, if you want we may try to – we make computer directory and then you try to execute on the robot." Okay, why not? And then we start like this and in fact this has been a success. And of course there were also some strategical action at the level of the institution AIST and CNRS promoting a joint lab. The structure were existing. I use the word "reactivate" the lab. The lab was existing but this has been a new direction of research which has been promote with great success. And the very first experiment on HRP2 for us has been a HRP2 on you see the robot HRP2 manipulating a barbell and very then the problem is truly a 3D problem because you have to coordinate the motion of all the limbs, the arms to avoid. The legs to walk and so on and so on. And this has been the starting point.

Q: You are getting close to two hours so you may want to wrap up. That was a movie. <laughs> We have one question. We have a part of the website that's kind of for education purposes so we ask everybody this so if you had advice for young people who are interested in robotics what would that be?

Jean-Paul Laumond: Do mathematics. It's not too short? And no, no, of course it's possible to develop but I think that in the interviews I gave some element to do that. Okay?

Q: Thank you so much.