Oral History of Hans Berliner

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Q: Who has graciously agreed to do an oral history for the Computer History Museum. Thank you very much, Hans.

Hans Berliner: Oh, you're most welcome.

Q: O.k. I think where I'd like to start is maybe a little further back than you might expect. I'd like to know if you could share with us a little bit about your family background. The environment that you grew up in. Your mother and father, what they did. Your brothers and sisters.

Hans Berliner: O.k.

Q: Where you were born. That sort of thing.

Hans Berliner: O.k. I was born in Berlin in 1929, and we immigrated to the United States, very fortunately, in 1937, to Washington, D.C. As far as the family goes, my great uncle, who was my grandfather's brother, was involved in telephone work at the turn of the previous century. And he actually owned the patent on the carbon receiver for the telephone. And they started a telephone company in Hanover, Germany, based upon his telephone experience. And he, later on, when Edison had patented the cylinder for recording, he'd had enough experience with sound recording that he said, "that's pretty stupid". And he decided to do the recording on a disc, and he successfully defended his patent in the Supreme Court, and so the patent on the phono disc belongs to Emile Berliner, who was my grand uncle.

Q: Oh, wonderful.

Hans Berliner: And, of course, that was very beneficial to his family. Now, me, I felt very uprooted leaving Germany at the age of eight.

Q: Well, could you tell me just a little bit about your father and mother.

Hans Berliner: O.k. My father had a master's degree in electrical engineering. My mother had essentially no education beyond high school. And that's about it. I would not say I came from an intellectual background at home. I think they were more just interested in surviving. But I was always very interested. And somehow I think one of the most formative things in my life, probably the most formative thing, was before I was three, my grandmother got me a chalkboard which had the letters and numbers around the edges, and I started making words and doing sums. And from that point on, it was a piece of cake, you know. I just wanted to know everything about everything. And that was a wonderful experience.

Q: Oh, that's so wonderful.

Hans Berliner: Yeah. I thought that was very good. That made it a lot easier to get into new things that I liked, and so forth.

Q: Did you have any brothers or sisters?

Hans Berliner: I have a brother who is an engineer, and he lives in Denver. And that's it, I guess.

Q: O.k. When you were growing up, what are your earliest memories of thinking about what you might want to do when you grew up?

Hans Berliner: Oh, when I was 11 and 12, I read every book in the adult section of the library about astronomy. And I had a feeling that I knew a very great deal about astronomy. However, what's a 12-year-old kid going to do with a phenomenal knowledge of astronomy? There was no school that could handle you. There was no special place to go. And so here I was, and I even was at the point where there were some theories about the formation of the solar system that were patently wrong. And I knew that, because they violated certain physical things that I knew about. But then, into this vacuum…. Ok. School was a piece of cake. School was always very easy. And then into this vacuum comes chess, which was a place where a kid could all of a sudden compete in the adult world. So from that point on, I was hooked on chess.

Q: So you discovered chess.

Hans Berliner: Yeah.

Q: At 11 or 12.

Hans Berliner: Thirteen.

Q: Thirteen.

Hans Berliner: Yeah. And, you know, I progressed fairly rapidly.

Q: Who taught you? Who introduced you to chess?

Hans Berliner: I was at a summer camp and it was raining, and there was nothing to do, so people were playing chess. So I asked what the rules were. And they taught me the rules, and before the end of the day I was beating one of the other kids. So chess seemed a natural, you know. In a way, I sometimes thought maybe that was not the best path to go, but that was the one that presented itself.

Q: That you start [ph?]?

Hans Berliner: Yeah. That's right. And so it worked. Yeah.

Q: Alright. Good. So as you're progressing, tell me a little bit about your high school background. What was.… You went to high school in Washington?

Hans Berliner: In Washington, D.C. And it was very easy, and I didn't work very hard, and nobody said anything about if you work hard and get all A's you'll get a scholarship. And so I never got a scholarship. But, you know. And then I went to George Washington University and at some point I got bored with that.

Q: Now, when you went to George Washington, what were you...

Hans Berliner: Well, I was majoring…

Q: What were you initially a major in, yes.

Hans Berliner: in physics, you know. I wanted to be a top notch physicist, but I didn't… I had no idea that you needed to have a PhD and all sorts of things like that. But I was very good. I was one of the top physics students, but I got very bored with it, and started majoring in bridge, and not going to class, and before long… I'm sure you've heard this from other people, maybe such as Greenblatt.

Q: Yes. Absolutely.

Hans Berliner: And then all of a sudden Uncle Sam beckoned and said you'll lose your deferment, come into the Army. And I did that.

Q: Now what year would this be?

Hans Berliner: This was in ’51. Beginning of ’51 I went into the military. Then I came back and had this complete fiasco to face up to. In fact I didn’t want to go back to school, but some very solid person in my life said you’ve got to go get a degree, otherwise you don’t have a chance in life.

Q: Could you share who that was?

Hans Berliner: Yeah. It was a fellow named Isador Turover [1892-1978] who, in the early 1900’s, was one of the top U. S. chess players. He settled in the Washington area and had a very successful lumber business. In fact, he made it possible for me to go to college because there was no money for college, and he gave me a summer job so I could earn money for college, since I didn’t have a scholarship.

Q: And you met him through chess.

Hans Berliner: Through chess, yeah.

Q: Oh, very good.

Hans Berliner: So that worked. Yeah. And so then I came out of the Army. Couldn’t finish in physics because my quality point grade average was much too low.

Q: Yes. It had been “bridged”, so to speak.

Hans Berliner: Yes. Very good. [laughs] Yes. So I got a degree in psychology and then I was very fortunate to get a decent job in the government where knowledge of physical science and psychology merged into a position of some kind.

Q: Oh, tell me a little about that.

Hans Berliner: Well, it was something called Human Engineering, which I will disavow at this point. But that was something that they decided needed to be done. And they needed people that had this kind of knowledge. So I had a job like that. And eventually -- I pursued this for awhile -- and eventually I.

Q: Where were you working?

Hans Berliner: At the Naval Research Laboratory in Washington, D.C.

Q: O.k.

Hans Berliner: And then later on I worked in Denver for Martin Company, and then for General Electric in Philadelphia, and then for IBM back in Washington.

Q: Oh, no, no. Now, you're going too fast.

Hans Berliner: Too fast? All right.

Q: I want to hear a little- I want to hear- take it a little slower, all right?

Hans Berliner: There really wasn't much significant

Q: I understand. But it is.… It's part of the fabric of your background.

Hans Berliner: Alright. O.k.

Q: It's important to get the things that aren't significant but part… add up eventually.

Hans Berliner: O.k. In 1954 I started at Naval Research Lab, after having graduated. And there was a person there that I guess I met over lunch who was involved in… Naval Research was building their own computer. There were no computers around at that time.

Q: Yes.

Hans Berliner: And maybe, you know, here and there, there was a very.. special one.

Q: Very few

Hans Berliner: So they were building their own computer and he was manufacturing, the code for instructions, or what. And he was teaching me that, and he said maybe we can write a chess program. We talked about it. We even did a few things, but it never got off the ground. But that was my first brush with computers. And then-

Q: So you did- Yeah, he had some access to a computer.

Hans Berliner: Yeah. And, you know, and conceivably if either one of us knew what we were doing, we might even have gotten the program. But I had read the articles by Shannon, and Newell and Simon, and these various people, which had just happened, I guess, at the time, really.

Q: Yeah, very contemporary

Hans Berliner: They were in *Scientific American*. And it sounded very interesting, but of course I didn't have the foggiest notion how to implement it. And then- o.k.

Q: Now, you were playing chess- you were always playing chess.

Hans Berliner: Yeah. I was, by this time, in 1952, actually… well somewhere in the 1950's I became a master.

Q: Oh, really.

Hans Berliner: Yeah. Oh, yeah. In '50, I think, '49 or '50 I became a master. And then I played on the U. S. Olympic Team in 1952, and then in that period of time, through '55, '56, '57, I was one of the top ten players in the country. And I played regularly in the U.S. Invitational Championship, and I even… the year Bobby Fisher won it for the first time, I finished fifth, and I drew with Bobby. So, you know, I was a good chess player.

Q: Yeah. What was your rating at this time?

Hans Berliner: Oh, Senior Master, I guess, 24 something, 2420, 30, 40, somewhere in there.

Q: Yeah. O.k.

Hans Berliner: Yeah. So that was good enough to be somewhere around 10th in the country.

Q: So, of course, then, since you're still very active in chess, now I understand when you're talking to somebody who has a computer, and they have a research lab, the subject, of course, comes up.

Hans Berliner: Well, chess- being good at chess is sort of like being good at pool. It's the sign of a misspent childhood, and you don't brag about it. But chess has got a reasonable amount of respectability.

Q: Yes.

Hans Berliner: I find it an interesting research subject. While we're on this subject, I have been world champion of chess by correspondence, by mail. And that was in 1955 through '59, in there, I won that tournament, and it was the largest margin of victory of all time.

Q: Wow.

Hans Berliner: And then I just stopped. And then I went to school at Carnegie Mellon after that because I wanted to do something different.

Q: O.k. So now you're at the Navy- So let's flow back to the Naval Research Lab.

Hans Berliner: O.k.

Q: And you're working there. And so what? What's happening?

Hans Berliner: O.k. It wasn't all that interesting, the work.

Q: You weren't that interested in it.

Hans Berliner: No. Well, you know, I was happy to have a job. This was at a time…

Q: Exactly.

Hans Berliner: …when it was good to have job that paid you a living wage. I got married, you know, so I had a lot of responsibility.

Q: Now when did you meet your wife?

Hans Berliner: I met my wife at the Olympics in Helsinki, Finland, in 1952, and we got married in '54.

Q: Oh.

Hans Berliner: She came over here.

Q: Now, did she have any interest in chess?

Hans Berliner: No. No.

Q: You did not meet her in a chess venue

Hans Berliner: No, she was just somebody who lived in Helsinki, that's all, and we met.

Q: And you were young, and abroad.

Hans Berliner: Yes, yes.

Q: You met.

Hans Berliner: Yes. O.k.

Q: That's wonderful.

Hans Berliner: And so let's see. So from the Naval Research Lab… Probably I shouldn't say these things, and you shouldn't put them in there anyway. But the government has strange ways of operating, you know. Something is "in" and something else is "out". Well.

Q: Of course.

Hans Berliner: Something called Human Factors was "in". They knew about Navy pilots who pulled the wrong lever and instead of putting the landing gear down, they ejected themselves. And they said, oh, this should never happen. We should have engineering talent that looks in to make sure things like that don't happen. So I was involved with that. And it got carried way, way, way beyond any reasonable thing. And so I was working like that at Martin Company in Denver.

Q: Oh, did you get hired by Martin, or were you still with…

Hans Berliner: Yeah,based… No, based on… I changed jobs, in the same specialty, based on my years of experience and the fact that they had a government contract that needed a person to fill the slot.

Q: Ah. So of course you knew that.

Hans Berliner: Yeah.

Q: And because you're in the government, and so.

Hans Berliner: Yeah. Well, no, actually they approached me.

Q: They approached you.

Hans Berliner: Yeah.

Q: O.k.

Hans Berliner: But the point is this was not something that I considered to be anything to…

Q: A real accomplishment.

Hans Berliner: Accomplishment.

Q: Anything to brag about.

Hans Berliner: Not even a small accomplishment. alright.

Q: O.k.

Hans Berliner: So then I went to General Electric in Philadelphia for a year.

Q: Now, how did you- how did that happen? Just tell me the story.

Hans Berliner: A friend of mine who knew me said we'd like to have you there. So I went. Always is a raise in pay, you know, you got to change where you're living and all that, which was fine, I guess.

Q: So you moved your wife to

Hans Berliner: Philadelphia.

Q: Now was this out in Valley Forge?

Hans Berliner: Yeah. This was the missile and space vehicle… one of the finest places I've ever operated. They had more talented people there than any place, and maybe even better than Carnegie Mellon. Unbelievable collection. But they never got a contract and eventually the thing went down hill. But it was really a wonderful experience to work there, because everybody was so smart and so knowledgeable, you know.

Q: Yes.

Hans Berliner: And then from then.

Q: So what were you working on there? You got hired.

Hans Berliner: Same thing- human factor stuff.

Q: Human factors, but now in.

Hans Berliner: Now for missile and space vehicle. They were trying to get contracts for things like Dinosaur and some of the orbital spacecraft, and things like that.

Q: I see. O.k.

Hans Berliner: And as far as I could tell, not engineering nothing, but they seemed to be doing very wonderful work, but they never got a contract.

Q: Alright.

Hans Berliner: So then some friends of mine, who I knew at Naval Research, had meanwhile started up with IBM in Bethesda, Maryland, and they said we'd like to have you. So I went there. And that's where I really first made contact with a real computer. They had a- what was it called? 504 or something. It was an accounting machine.

Q: Yes, all right.

Hans Berliner: But maybe- I don't know. I don't remember any more. And eventually I got to the point where I- I was doing my work again. We had a contract to do various kinds of things for the Pentagon.

Q: Analyzing human. Still analyzing human factors.

Hans Berliner: No. Well, and also, you know, all sorts of strange things, you know. Computer applications, personnel records, and all sorts of crazy things.

Q: Yeah.

Hans Berliner: But there was plenty of time for doing other things. And I started thinking seriously about computer chess. And I think- let's see, this was about '61, '62. And I… Again, the journals and things were full of stories of people doing chess on a computer. So I thought, why not me too? And I'm not quite sure when this happened. Maybe Greenblatt had already had some of his successes. I'm not quite sure about that. Probably he did. And so then I decided- I'd never written a program in my life, so I had to learn programming, and I had to get all the help I could.

Q: O.k.

Hans Berliner: And I wrote a program which actually played chess. And I did it in the way Greenblatt said it ought to be done. It wasn't anywhere's near as good a Greenblatt's program and I wasn't really a very good programmer obviously, since that was the first time I had written a program.

Q: Yeah, exactly.

Hans Berliner: But it played.

Q: But what machine did it run on, do you remember?

Hans Berliner: It ran on this IBM- whatever it was.

Q: One of their big, scientific machines?

Hans Berliner: No. It was written in PL/1, and it ran on a commercial machine.

Q: O.k.

Hans Berliner: And this program played in the first U.S. Computer Chess Championship back in 1970. And it finished around the middle of the field.

Q: That's pretty good for the first program you ever wrote.

Hans Berliner: I mean, yeah, there were people that were worse. That's right. That's always a consolation. And so anyway, yeah. So it played. Let's see, I've got to get the timeline right here. Now this was in 1970. Now in 1970 I had already left IBM. I left IBM in 1969, and went to Carnegie Mellon as a doctoral student.

Q: O.k.

Hans Berliner: And, of course, their attraction with Newell and Simon was they would like to find somebody to push their ideas further forward, and that was me. And so I had this program which, in retrospect, was pretty woesome.

Q: I would love if you could remember what machine it ran on. That's just- it'll put a little detail.

Hans Berliner: It ended with a 4,

Q: 704? Not 704…

Hans Berliner: Yeah. I think it was probably a 704. Then they added, when they went to.

Q: Or 709.

Hans Berliner: It wasn't 709.

Q: Oh, there's a commercial machine.

Hans Berliner: Yeah.

Q: That's a 7- yes.

Hans Berliner: Yeah. Then they made a 7070

Q: It was a 705. And then that's the business machine.

Hans Berliner: Yeah.

Q: And then when they went to transistorize, they went to a 7-

Hans Berliner: It was, yeah, a 7074.

Q: Yes.

Hans Berliner: Yeah.

Q: It had to be- it probably ended in 05.

Hans Berliner: Yeah, could be.

Q: You mentioned 5.

Hans Berliner: Well.

Q: But that's a character-based machine.

Hans Berliner: Yeah.

Q: As opposed to a binary machine.

Hans Berliner: It was woesome. Then later on when it played in New York in that tournament, I was running on a machine, I believe, at NYU, and we had to change my PL/1 code a little bit so we could run on their 70- I think it was a 7070. I'm not sure what it was. Well, maybe a 90 something.

Q: Maybe a 7090, yes.

Hans Berliner: Yeah, 7090, something like that. But it was a much faster machine which made some difference, but not enough to make a really big difference.

Q: So this was another- yes, alright.

Hans Berliner: This was this program that I had been writing in the late.

Q: Yeah. And this was another competition.

Hans Berliner: Yeah. This was the first- this was organized by Monty Newborn, and somebody else in New York.

Q: As a computer-.

Hans Berliner: As a part of the ACM. The ACM was having a convention there. So this was part of one of the side events. And I still remember all the good New York players came and laughed, 'cause they understood just how badly the programs were playing, you know.

Q: Right. But it was computer against computer.

Hans Berliner: It was computer against computer, and it was sort of- and this was… O.k. Now I'm getting way ahead of the timeline for other things, but in the meantime when in '65 Greenblatt had produced his MacHack VI, and it had played in some Massachusetts tournament and beaten some people who called themselves tournament chess players.

Q: Yeah.

Hans Berliner: And that got everybody's attention, you know.

Q: Yes.

Hans Berliner: And that was probably also part of the motivation for Newborn to organize this tournament. But in 1970, when nobody had heard of any… People had heard of me because I was a good player, but they didn't know if the program was any good or not. And I knew it wasn't any good. But in this tournament emerged the Northwestern University people, David Slate and Larry Atkin, who basically dominated the field for ten years from that point on with their continuous innovation. First of all, they used- now we're getting into technical things.

Q: That's o.k. Absolutely, I want to hear this.

Hans Berliner: In fact, let me, at this point…

Q: Let's take a pause in your personal history.

Hans Berliner: Alright.

Q: And you can now do your timeline.

Hans Berliner: The technical things. Yeah. O.k. I want to go back like to day one.

Q: Go back anywhere you want to.

Hans Berliner: Day one in the history of computer chess. Back in the '40s, when the only thing I knew of that had happened is that there was a Dutch- actually there was a Russian psychologist who had- who's name I don't remember. But he had done some experiments on master chess players, and ordinary chess players, and shown them boards for a very short period of time, like two seconds, and then asked them to reconstruct the board. And the master chess players were able to reconstruct 90% accuracy in the position, with two seconds time. And the average players didn't do more than 50%. So the question was, how was this? Could this be because the master chess players have much better memory? And so he did the coup d'etat, the second part of the experiment. He showed both sets of players random positions that couldn't possibly have occurred in game, just dropped the pieces on the board. And in that, the

ordinary players did just as well as the master players. So that proved beyond any doubt that what the master players saw was some structure in the position, and they saw that structure and remembered the structure, which was called the chunk, and that made it possible to identify not just a single piece, but a group of pieces that were somehow engaged in some activity that was understandable to the master.

Q: Yes.

Hans Berliner: And that allowed this to happen. Now, other than that, that was later on replicated in 1938, by a Dutch psychologist, and that was about it. Nobody had ever written anything about, I mean, people talked about- they interviewed top players and they said, oh, in this position, this is like so and such's game, and I'm going to make this move and that move because of some reason. And if you understood that, you had to be a very good player, because it's <inaudible> tough.

Q: Ok..

Hans Berliner: They weren't talking to a machine. They weren't talking to an average person. And then in 1946, I believe, appeared Von Neumann and Morgenstern's The Theory of Games and Economic Behavior, which for the first time talked about game trees, and that games were played between max and min, where max tried to get the maximum possible score, and min tried to get the minimum, and there was a system called Minimaxing, by Von Neumann, which allowed you to start in a position right down the tree of possible moves, give each terminal node in the tree a value and then back it up to the point where you could tell what would be the best move for the player to move at the root. Now that was significant progress. That was real science. For the first time we had a mathematical, scientific way of doing games.

Q: Yes.

Hans Berliner: And then based on that, Turing, I believe, who was involved during the war in the Whirlwind Project to break the.

Q: It was actually the Enigma Project.

Hans Berliner: Oh.

Q: Yes.

Hans Berliner: Well Whirlwind was his name? Wasn't Whirlwind the name?

Q: Well, Whirlwind was in MIT.

Hans Berliner: Oh, was it?

Q: Yes.

Hans Berliner: Oh, I'm sorry.

Q: That's o.k.

Hans Berliner: My goodness.

Q: Yeah, yeah. And, yes.

Hans Berliner: O.k.

Q: And they built- they were at… they were decoding...

Hans Berliner: Bletchling House, or something.

Q: At Bletchley- yes, at Bletchley Park.

Hans Berliner: yeah.

Q: And they built Bombes and then they built- oh, now I can't remember. They built a very high speed electronic machine.

Hans Berliner: That could try all possibilities.

Q: Try all possibilities, yes.

Hans Berliner: And break that code. Break the code, yeah.

Q: Yeah, exactly. And Turing.

Hans Berliner: O.k. And then, I think at some time after that, Turing decided he could do computer chess and he had a computer in mind, even though it hadn't been built. And he was going to do this simulation. And he wrote about that. Now from a chess point of view, it was poor. It was interesting just to see somebody was trying. And then not long thereafter, Newell and Simon at Rand Corporation talked about a chess program and this and that and the other, about how to select moves and so forth. And the one thing about that, which was truly important, was they pointed out that once you have refuted a move -- in other words you can show that there's a better move somewhere in the tree than this move -- you could immediately stop processing it because you didn't need to refute it more than once. All you needed was one refutation.

Q: Yeah, right.

Hans Berliner: Now Von Neumann, as brilliant as he was, never pointed that out. And these were the only people, and although I've talked to a number of people who said that's so obvious, but they never wrote it down, so it doesn't count to say it was obvious.

Q: Yeah, sure.

Hans Berliner: And when Minsky—no what am I talking about… when McCarthy saw this paper, he said, oh, that's an algorithm and he made it into the "alpha beta" algorithm without which we wouldn't be here today either. And the thing was that, the reason it was called alpha beta was because in the diagram in Newell and Simon's paper, they labeled one branch alpha, and another one beta, and so McCarthy said, o.k., this is the alpha-beta algorithm, and it's a recursive algorithm, and it works beautifully and at its peak efficiency, it saves you the square root of the effort. So if you're doing a tree of a million nodes, you can do it as if it only had a thousand. And that progressively grows, you know, and it just makes all the difference in the world.

Q: Exactly.

Hans Berliner: It sounds like you're running out of tape. Is that? No?

Q: No, I'm doing fine.

Hans Berliner: O.k.

Q: I will watch the tape.

Hans Berliner: Alright. So that was one of the- so that was in some ways it was not very different than the other efforts that I'm going to talk about, but in this way it was very, very different, because without that observation, very likely we wouldn't be here. Now maybe we would. Then there was another effort by Stan Ulam and et al, at the Los Alamos Weapons Lab. They did chess on a six by six which, again, I really don't consider to be… other than intellectual exercise, it didn't contribute anything to the progress of computer chess. And then there was a better effort.

Q: And that was the one on their Maniac.

Hans Berliner: Maniac.

Q: Computer.

Hans Berliner: Right. That's right.

Q: Yes. Yes.

Hans Berliner: And then there was- at IBM now they had considerable computing power, and there was a fellow named Bernstein there who worked at IBM Research in Yorktown Heights, I believe. And he recruited people like Arthur Bisguier, who was one of the top players in the country. And they tried to build a good evaluation function, but again, as we were yet to learn from Greenblatt's efforts, it wasn't so much how good the evaluation was, but how deep your search could go, and the efficiency of the search, and the tricks you could employ to make it go deep, that were really important. So that was- those were the early efforts. And I sort of- I tend to be a little dour in my appraisal of things and hopefully of myself, also. But I felt, at that point, we had reached the talking stage where the intellectual said, "Oh, isn't this wonderful? We can do this, and we can do that" And nobody did anything. Now, as you pointed out, though, McCarthy did manage to get Kotok to write this program, but I must say I saw the games of Kotok, and I didn't think that was much better than what these other people had done. Now, maybe it was, but it wasn't enough to get my attention.

Q: Yeah.

Hans Berliner: And, you know, I was still thinking, yeah, these are wonderful.

Q: It at least covered the whole board.

Hans Berliner: Yeah, that's right. Well, it did a lot of things but, you know, could it beat even a lowly human being at chess? And the answer was, no.

Q: No. He said, it was- it plays- it does well against total neophytes.

Hans Berliner: Yeah. Well, but that's, you know, I mean at some point that's praiseworthy, but after awhile, you got to do better, you know.

Q: Of course.

Hans Berliner: And so now here, and there's Greenblatt, like you were saying earlier. He saw the Kotok program. He said, my God, you know, a child could do better than that.

Q: I know. He was reading the code.

Hans Berliner: Yeah.

Q: And that's how he figured it out.

Hans Berliner: Yeah. Yeah, so Greenblatt is a genius, there's no question about that. He is very brilliant.

Q: Right.

Hans Berliner: And so he wrote this program and it played in some Massachusetts State Championships, and won some games. And that got everybody's attention. Now all of a sudden, it was out of the laboratory into the real world.

Q: Out of the computer science world into the real world.

Hans Berliner: Yeah. Into the real world. And everybody said, what is Greenblatt doing? Well, he knew about alpha-beta. He didn't know about hash tables apparently, or at least if he did, it wasn't a major part of his activity. And that was in '65 or '66, and things, again, language more or less, for another five years…, I had gotten interested and I decided- I was at IBM at that time, and I thought here's a wonderful opportunity. And I used to go- I would spend, you know, maybe three or four evenings a week and 12, 14, 15 hours on the weekend...

Q: Oh, my goodness.

Hans Berliner: …standing in line there, putting my deck, and in those days we had cards, you know, deck- having it processed, waiting for it to come out, making some changes, and doing it again. And that's the way- there were no terminals. There were no- no nothing, you know.

Q: Yeah.

Hans Berliner: And so I would give it problems and see what it did, and see how it did it, you know. And most of the time I was debugging it, it wasn't even working right. So that was that program.

Q: And as you said, you did it in PL/1.

Hans Berliner: In PL/1.

Q: Yeah.

Hans Berliner: It was called Patsock [ph?], and it played in the first computer championship. But see all these things really, until the first computer championship, I don't think I- I never even wrote about this program because I didn't think it was scientifically worthwhile. I hadn't done anything that not- somebody else hadn't done. And I hadn't reached the level of achievement that other people hadn't done, so to me that was not something to write about. Now, then this first tournament really made a big difference. All of a sudden there were these people and it was very clear the Northwestern program was far and away the best program. Just looking at the games, and the results, and everything, it was better. And then everybody wanted to know what they had done. And what they had done is- now here's a good place to talk about the fact that the game tree is really not a tree.

Q: O.k.

Hans Berliner: Because what happens is that if you can think of a move A, and another move B, and then a response to both these moves, is a move C by the other guy. And then where A-C happens, comes B, and then you have A-C-B, and over here you have B-C-A. And you get back to the same position. In three ply, you can get back to the same position. That doesn't happen all the time, but now it can happen. It can happen. And there certainly are lots of exceptions, but it happens an awful lot of the time. And so the point was, if you had already evaluated this A-C-B, then why go ahead and evaluate the B-C-A, since it's the same position, right?

Q: Yes.

Hans Berliner: So all you needed was a table to store that information reliably, identify the position, how deep you have searched it, and what the result was. And then you could use that information to save huge amounts of work. And the Northwestern people did that.

Q: Ah..

Hans Berliner: They were the first people, I think, to really do that effectively.

Q: O.k.

Hans Berliner: And on top of that, let's see, what else did they do?

Q: And they used hashing to save these positions?

Hans Berliner: That's right.

Q: Because that would of course be an elegant way to do it.

Hans Berliner: Yeah. And they, you know, they also had a very good- they had a CDC machine, a 64 bit machine, which was ideal for chess, you know. They had a lot of good things, but that was not nearly enough to account for their success. Their success came from the fact that they did experiments, and they improved things until they got it right. So they had hash tables. Can I look at my crib sheet? I've gotten myself.

Q: Absolutely.

Hans Berliner: O.k. The other thing they did which really, in retrospect, was not that significant, but I think it was significant at the time, they had something called bit-boards, and this is where the CDC 64 bit machines came in handy. So there are 64 bits in a word, and there are 64 squares on the chess board. So what you could do, is you could perform logical operations on the chess board. Like you could say, this set of squares is occupied by white pieces. So certain bits in the 64-bit word were turned on to indicate that a white piece was there. And the same thing for black. And lots of other things, for bishops, and king- you know, everything you might want to know can be encoded in the bit-board. So you didn't have to search down a list to find things. There it was. All you did- you had this word and then they all- the

machine all had this operation, find first one. So it would scan from the left and find the first bit that's set, and that was a member of the set that you were trying to identify. Now that helped them a lot, and allowed them to do some clever things, which hadn't been done up to that time. And, of course, poor Greenblatt couldn't do this, because he was on a PDP-6, I believe.

Q: Which is a 36-bit machine.

Hans Berliner: Yeah. Was it? Yeah. O.k.

Q: It was.

Hans Berliner: It was certainly.

Q: It was 36-bit machine.

Hans Berliner: O.k. That's a funny number, but o.k. Anyway, it certainly- yeah. He would have to do everything twice in order to do that. So in any case… So he had a disadvantage there. So here they- and also they had a very, very robust program. Now robustness is something that I sort of learned at Carnegie Mellon as a PhD student. One thing Alan Newell always said to me, robust, robust, robust. The program has to be robust. You can't just poke a finger at it and have it fall down, you know.

Q: Yes.

Hans Berliner: So the Northwestern program was incredibly robust. It played under all sorts of conditions, always did well. Always did. Every once in a while it lost a game, but that was very rare. And it seems to me at this- o.k. And then- o.k. Here: another small sidetracking.

Q: O.k.

Hans Berliner: From the very beginning, people wondered: how many moves are there in the average chess position? That clearly makes a difference if you're thinking of doing something with a computer. And there was a guy named Slater, a British person. British somehow seem to be involved in lots of interesting things. So he counted… ,looked at thousands of positions, and counted the average number of moves in a middle game. The number of moves gets smaller at the beginning and at the end.

Q: Yeah.

Hans Berliner: But the average middle game, and he came up with the number 35, which everybody accepted. So when people like Shannon and Turing talked about chess machines, they said, well, there's 35 moves at the first level, and 35 at the next level. That's a thousand possibilities.

Q: And he just kept multiplying out the positions

Hans Berliner: Yeah. By the time you get to 4, it's a million, and then after that it's a billion. And nobody talked alpha-beta. And, of course, alpha-beta, if you can really order the moves in such a way that they get fed into the buzz saw in the right order, you can save the square root. So at the point where you would have a million possibilities, you could do it as if there were a thousand, and nobody talked about that for quite awhile. Now, I think Kotok probably did that. He implemented McCarthy's…

Q: Alpha-beta.

Hans Berliner: Alpha-beta. Right. O.k. So- let's see. I lost where I was now.

Q: Were you talking about other things that the Northwestern people had done.

Hans Berliner: Yeah, ok, very good. Thank you. O.k. So the point was everybody said, oh. At first they said, oh, it could never be done because there's a thousand possibilities just looking one move deep for each person. Then they said, oh, alpha-beta. Oh, boy. We can- instead of a thousand, we'll do the square root of a thousand, whatever that is. And that's going to save a huge amount of effort. Now what the Northwestern people discovered is that the Hash table adds, besides identifying position... Well, o.k. It identified positions that had been previously seen, so that meant that along some perimeter, lets say, at depth 4, you find lots of positions you've already seen before, and you don't need to evaluate them. So you save a lot of effort. And it turns out that instead of the square root of 35, which everybody always used to use as six, the real number is closer to three. It's maybe 3.1, or 3.2, which means that the collisions due to the fact that it wasn't a tree, but it was a graph, were highly significant, and the total effort required to go from depth N to depth N+1, was probably a factor of 3. Now that made a big difference. All of a sudden you were in a realm where you could say, oh, man, only… And we know the computer, the speeding up at a what is it? A factor of two every year and a half, or something like that. Whatever it is. So you could say, oh, you just wait a couple of years and you can go one ply deeper and, you know, and you keep going like that.

Hans Berliner: And here we are in 1970 and the Northwestern people have just made a big splash and everybody realized that they were very, very good and that they were not the kind to rest on their laurels, they kept finding things to improve. Now I was at Carnegie-Mellon where I had been admitted at the age of 40, not because of any academic credentials but because I knew how to do chess and I'd already written a computer program and they had hopes that I could push this state of the art doing computer chess, which I

tried to do. But my program was not in the style of these modern programs, it was a program based on conceptual things and it was a very-- a lot of effort was devoted to structure; in other words every position had a lot of structure and there were programs that delineated the structure. And probably… There was one thing in this dissertation that I'm proud of and that was something that I called 'the causality facility' and-- this is a dead end though I have to say that ahead of time, it was a dead end but it was a nice one -- and the idea was that when, lets say, a human being makes a certain move and then a rook comes down to the back rank and says 'checkmate' the human being says 'oh I gotta do something about that, I can't make a move over here and he's gonna give me checkmate.' And I was once having a conversation with Minsky and he said you know 'how do humans do this and why don't machines do this?' So I started thinking about that and when I did my dissertation I had descriptions -- as I said I had a lot of structure -- and I dragged descriptions back as one backed up from some terminal node and you backed the value not only do you back the value up, you're backing up a description and the description said which pieces moved where and- and some other information. So in other words at some point you would arrive at the point where you say 'oh, this last move must have been a mistake because I got checkmated' and then you look at this description and see what the opponent did and say 'oh probably I will lose again the same way unless I do something about that description' which meant you either had to capture the piece that's doing the moving or you had to block it or guard the square on which it landed or something like that. And that's what my program was able to do, and it did some very nice clever things where something was being threatened and it figured out the only way to block it without trying everything, by just reasoning about what the characteristics of a move would have to be in order to prevent this, so it was doing-- it was good PhD work but it didn't fit into the main scheme <laughing>. Well I think as a knowledge exercise it was good. Okay so there I was with…

Q: …you got there in 19…

Hans Berliner: …69 and I got-- I actually finished my dissertation in 73, I believe, yeah but I still had some other things to do; they let me go ahead and do my dissertation and then I had some other things to finish and I got my degree, I guess, either 74 or 75, I'm not sure at this point, but…

Q: What were the other things you had to do?

Hans Berliner: Well they had- they had these qualifying examinations in various subjects such as the mathematics of computer science which I really wasn't too well equipped to handle <laugh>.

Q: You had no background, you had no computer science _____ under your belt at all.

Hans Berliner: …yeah, well no I mean I was in the PhD program so I was taking these courses but you know…

Q: But you <overtalking>

Hans Berliner: But my brain was 40 years old and…

Q: And you didn't have this background…

Hans Berliner: Yeah that's right, that's right I mean… Recursive function theory and- and all that stuff. Now I can think about it and I say 'yeah I think if I knew what I know now and I was 40 years old I think I could tackle it but at that time it was just a blithering… very, very tough, yeah. But anyway, I think somehow everything came together, and I got my doctorate. But what had happened in the meantime, this was now five or six years later, the bruteforce programs had made a tremendous amount of progress, and it was absolutely clear that this approach of mine was never going to get close. And the reason was that one needed a tremendous amount of knowledge. The knowledge I had given it was very rudimentary, it said 'okay here's something tactical that happened and here are the actors in this drama and we have to do something to change these actors in a certain way so it won't happen again.' But that was in a case where you got mated or you lost the piece or something, but we're talking -- at top level chess we're talking about very small differences, like 'my pieces are better placed than yours'. Well, how bad is that and what do you need to correct that? Well,you'd have to dredge back you know zillions of items of data and that just wasn't going to work and besides there was another thing that-- and this is important too in the scheme of things. Newell and Simon believed that chess was a logical activity, which is true to a certain degree, in the sense that you can say "well if I could get my bishop over here and then I would have a very good position", that's logic and then you'd try to create a plan to make that happen. However there is another aspect to top level chess which is not at all logical, and in fact you find this in all animal behavior. You find it as low as the worm that knows that a wet and warm place is better than a dry and cold one, so he is where he is and he wiggles toward wet and warm instead of toward dry and cold. And this is called intuition, if you will, and human beings, chess players, have intuition too; they look-- you can get the 20 top players in the world and show them some positions and they will agree fairly well which ones are better than others, and they're all materially equal and a Class A player will look at them and say 'they all look the same to me' but the top player sees some things and he has this…

Q: If you give me the starting board I take that one…

Hans Berliner: Absolutely. So they knew that, and I didn't … and that could not be done with logic; you can't say 'oh I prefer this position because this bishop's here and that king is over there and that doesn't control this and blah blah blah and so forth and so on.'

Q: Yeah you can't write a universal function.

Hans Berliner: That's right, you would be spending until the end of the universe trying to write such a thing, and even then you wouldn't get it. So how do human beings get it? Human beings get it by practice; they look at a position and they say 'oh this position has worked out better than…' or they segregate a position into what Simon always called chunks and so there were like seven chunks and the seven chunks said something about the position: the pawn chunk, the king safety chunk, the mobility, the attack on the square and so forth. And all these things came together to decide how good the position was. And a top level player -- as indicated by this thing I said earlier about this Russian experiment -- in two seconds he could see most of that; he could look at the position and see what was defending what, and what the king's safety was, blah blah blah blah. And that allowed him to look at a position that was brand new and decide how good it was, among other things. So I said 'I will never be able to do this by logical reasoning'. And then I started to work on backgammon, which I thought was a lot simpler. And in backgammon there were like 60 possible moves at any point, plus the fact that -- and there was a roll of the dice, so on the next turn you could have, I think what is it, 21 different outcomes in the rolls of the dice. You had to anticipate all that. So searching ahead was completely useless in backgammon -- almost essentially useless -- so you had to use judgment. I wanted a domain where you could use judgment, so I found it in backgammon. And I tried doing backgammon with rules, ala Newell and Simon, and the program was not robust. It would get-- it would play beautifully up to a point and then all of a sudden something would happen – boomp. And I did an analysis of what the boomp was and it was that there were different classes of positions. You know here's a position in which white is ahead in the race and they're about to disengage and blah blah blah blah blah. And there were rules for dealing with position of Class A and there were rules for dealing with positions of Class B but when it was near the boundary these rules frequently miscarried. And so in other words here you were in Class A and it's very clearly you should do this and then you landed in Class B and said 'how could you have done this to me'. So you needed something that could smooth the path and that's where I came up with this method of membership classes – fuzzy set theory theory – borrowed from fuzzy set theory. The point was that if you were in Class A but heading toward Class B you made an estimate and it turned out it didn't even have to be a superlative estimate, just fairly good. You could say 'I'm 80 percent in Class A and I'm heading for Class B and I'm going to say I'm 20 percent in Class B'. So you use the evaluation from Class A for 80 percent of the value and 20 percent of the other one. And boy overnight these precipices that had felt…disappeared, and it went smoothly. And by some very fortuitous set of circumstances some entrepreneur wanted to back this thing and managed to arrange a match between the winner of the world backgammon championships in 1979 and my program. And sure enough, it played and it won! Now it wasn't nearly as good a player as he was, but the dice have something to do with the outcome, and it was lucky. But it played well. You know it was certainly-- it could've played in the tournament. It would have not gotten to the final, but it was good. But not that good. But the point was that I had shown that this business of trying to do chess with logic may be okay, but beneath that is a huge swamp of understanding which is based-- you look at the position and you have to understand something about the position which is not logical -- which is just experiential --and then you could say 'oh okay this is a position of Class QFD, and now in this kind of position I should go ahead and attack the king, so now I can try to work out some plan for attacking the king.' But if you listen to a grandmaster protocol -- which is what they say into the microphone when somebody asks them about a position -- he doesn't say anything about Class QFD, he just says 'oh well in this position I gotta go and attack the king.' How does he know this? How did he know that? And without that information you cannot make a chess program which reasons. And to make a program like that, you would have to feed such

incredible amounts of information into the program, it would take till the end of the universe. So you're basically-- I'm basically saying you'd have to have a learning device. The only way-- just like humans -- the only way you learn to become a top chess player is you've gotta expose it to some sort of neural net learning or something like that, and you've got to learn the things that are necessary to tell a good position from a less good position. And then you can try doing logic on top of that. But in 1975 there was just no way, no way, you could even come close to that.

Q: There was not enough processing power even if…

Hans Berliner: Oh that's right.

Q: …you could figure out how to put the rules in.

Hans Berliner: And you're weren't enough programmers and even if…

Q: …and you'd never get through it…

Hans Berliner: And even if you did, there would be conflicts. Some program over here would have said 'oh this is worth 3.2' and somebody else over here would've said 'it's only 1.9' and then all these things would have to be consolidated. So that's why you need neural nets to sort of smooth things out. Well, okay, this is around 1979. And then… let's see what happened then... I was working on a number of things and I guess I was-- did I start another… Oh I'd finished my PhD and I think I started another program but it wasn't good, it wasn't. It was built more along the lines of Greenblatt's, but it wasn't good. And I wasn't gonna take it out on the road, because there was no point in it, you know.

Q: All you had to do; you're a great chess player; you just have to play your own programs to see how good it is…

Hans Berliner: Yeah and -- I can tell where it's gonna finish and I don't want to see that; it's not something that you want to brag about. So I had that, and I was working on some other things including this backgammon thing. And then in 1983 I-- in the meantime I also had some students who did various things. And in 1983 when the world was beginning to-- the hardware world was changing quite a bit and there was all this VLSI structure and one of my students had this idea.--In a chess machine, oh I- I got ahead of myself a little bit so let me back up. Somewhere along there -- I'm not sure, it was just right around 1980, I think Ken Thompson of Bell Labs-- have you talked to him at all?

Q: Yes we have interviewed him also. I didn't do that interview.

Hans Berliner: It's very important, okay. He's a very key person you know. So he took the algorithm of Slate and Atkin, and programmed it on a machine with… The big effort in a chess program is the amount of time it takes to generate the legal moves, so he transferred that to a machine. It was hardwired in hardware, could be done very, very quickly and you've basically saved like 90 percent of the effort that you would otherwise expect. So he built the first successful chess machine. Greenblatt had tried and he had a somewhat different design, they didn't know all the things that Slate and Atkin knew at that time and it wasn't successful. But Thompson built a successful chess…

Q: The Greenblatt machine was not successful? Did it play?

Hans Berliner: He wrote about it, but he never played it. I mean I guess he had also the idea of hooking it up as a move generator, and I think they tried that but it was not… I think he had this idea that he wanted to have a top level thing that was in charge of things. And there would be this machine that would generate moves very quickly and then it would be some functions say 'oh this is a good one' and then they would search down below that and see how good it was and then they'd come back and try something else. And it was a hop around instead of a brute force scanning all parts, it was a hop around and it wasn't successful - same kind of problems I had. And so Thompson built the full width search machine and it won the ACM tournament several times, I believe, and it was successful. It got to be an expert on the human scale. At that time I was involved in what came to be known as the 'Fredkin Competition' -- Ed Fredkin from MIT had donated a hundred thousand dollars for this competition -- first program to beat the human world champion -- and it was quite obvious it was going to take many years for that to happen. So I had this idea: why don't we have some interim competitions? We'll invite the strongest programs and some comparable player and we'll play at some place where the audience can look at it. So we did that. And actually…

Q: Tell me about that.

Hans Berliner: Okay, is there any-- now my memory is not a hundred percent all in this -- but I think the two programs that were the best at that time were Slate and Atkins Chess 4 point whatever, and Thompson's Belle. And we had them play on various occasions and as I recall Chess 4.X, which was more knowledge orientated and more human–like, did much, much better even though it was less highly rated than Belle. Belle was sort of a brute force cruncher - it could do well against the other machines 'cause it would find mistakes they made, but in playing against humans, the humans would take it down the garden path and it didn't do well. At one point we actually had a four by four tournament in Pittsburgh; I'm not sure what year that was, I could look it up…

Q: Approximately when would you say?

Hans Berliner: 79.. Yeah it was before I really got involved. We had a four by four tournament where we took the four strongest programs and four Pittsburgh players that seemed to be appropriate and played them -- all the machines played all the humans. And it was fairly close, and again I think the Northwester program was by far the best of the programs. And I think the humans squeaked out to a -- you know, they got more points but,again, I would have to look that up to be absolutely sure. So how did I get on all this?

Q: You had been working on the fact that it's really hard to use logic, or even to figure out a rule-based scheme…

Hans Berliner: It was basically…

Q: …that could be used with computers in, we're talking, nineteen eightish.

Hans Berliner: It was becoming apparent that that was not going to happen anywhere in the near future. No matter how much resources you threw at it, it wasn't going to happen. Into that situation I had some students that did work on various games…

Q: What were you teaching at this time?

Hans Berliner: Computer Science. I was teaching artificial intelligence and computer science and…

Q: And was Newell still there?

Hans Berliner: Oh yeah…

Q: So after you got your PhD -- you left that out that you were actually…

Hans Berliner: I worked under Newell, yeah…

Q: …and then you actually…

Hans Berliner: I was a member of the Artificial Intelligence staff at Carnegie Mellon University and I taught part of the graduate courses. I taught searching which I thought I knew better than anybody else there. There's a lot to searching, not only the Alpha Bata algorithm, there we a lot of little tricks about how to-- how ordering things and- and there were… Logic played an interesting role in searching that you-- Alpha Bata is really just a logical device that says once I've shown that this move refutes move A I don't need to

refute it any further. It's refuted; move on. And there were lots of other things of that nature, and other problem solving things where you could do things like that. And I had a game -- actually this is sort of interesting. Way back as a little kid in Germany there was a game that I think I knew as "Patience" or something. It's a card game played with a four by thirteen raster of cards that were laid out four deep and thirteen across. And there were certain rules for moving-- you took up all the Aces which left four blanks and then you moved the cards around and then presumably you eventually got to the point where there were no legal moves and you were allowed to deal the cards again and see if you could finish in three. Well this was an infantile creation, but there was a real game there. And once computers… You know, humans are just awful at certain kinds of things. Once computers got involved it turned out that—well, I knew I couldn't play four by thirteen because that was too much, but I started playing four by six, and four by seven, four by eight with computers. And computers could solve the four by six game, lets say, almost all the time it would win; but no human being could. It was a combinatorial thing, seeing sequences that no human being could…

Q: Could think through… simulate them in their brain to get down to the bottom on all these trees and figure it out.

Hans Berliner: Yeah and see what was successful and what wasn't and frequently it was very convoluted -- you'd see what the program was doing and say 'how can that possibly be good' but it saw some way to get through some narrow somewhere and did it. So I was doing this and I had the feeling that one of these days I was going to do the four by thirteen, but in the meantime it was very interesting because there were lots of cute little ideas for how you do this efficiently - hash tables and other things. And then I had a student who got interested in this and he started doing that and we got it to the point where we could actually say that, like, 83 percent of all the four by ten games are solvable and the other 17 percent are not. That was a statement based purely on statistical examination with an algorithm that would 99 percent of the time terminate. So you could say 'okay even if we're off by one percent the other one percent, I know where it is'. So we were doing this for as far out as we could. And he was very good, he was a great programmer and he had some good ideas of his own and so we published a number of papers on that. So there were a number of things like that where we were starting to understand efficient search and I taught those things too. So then in 80… one of my students in this time had this idea that-- and now I'm back to the point of the move generators, the idea that since most of the time is spent on move generations, that's what Ken Thompson contributed, it would be good to have a machine. And he had this idea that after all there are 64 squares, and a knight moves the same no matter what square it's on; it's only the edges of the board that make a difference. And he thought about an idea of a chip which was a general chip, but you had to initialize it to tell it where it was on the board so it would know how far from the edge it is and would know how far a bishop could move in this direction and the other direction and so on. But that initialization should easy and I had a student… Now the student who thought of this idea and he had a friend who was looking… See at Carnegie Mellon there are some truly wonderful things there about education, in the sense that nothing is carved in stone. The powers that be understand when somebody has something they may contribute which may be a little bit off the beaten path but still quite acceptable. So anyway, one of the things we always did, that we asked our students to do, was to do a project. A project was something where you did something interesting -- it was not a dissertation but you showed that

you could do research and you presumably found something that people would like to know. It wasn't as momentous as a dissertation, but it was good. So anyway there was this idea for these chips so this Carl Ebeling thought he would do this as a project. This was the day when ARPA was just getting their VLSI effort ready, and again it was one of these things -- you submitted a design and then maybe a month later you'd get back a chip or two to test and then you'd find the mistakes and fix them and go back. So it was a long process.

Q: But still, yes, you could… Chips were accessible to

Hans Berliner: That's right and they-- to the university that's right….

Q: …the university -- custom chips.

Hans Berliner: Yep and they… And he did this. So here all of a sudden we had this set of chips that could do move generation and very fast; a microsecond-- no, yeah –a microsecond for a move generation. You could have 64 of them together and in a microsecond you'd know all the legal moves. And you could order them in some way by some preordained… So we ultimately had a machine that had-- I think had a six microsecond cycle. In that period of time it could look at all the moves, pick one to do something with and do some bookkeeping and so forth blah blah blah and six microseconds later it would be finished processing that position. So that meant that we could do -- what is that? -- a hundred…

Q: Well that's a lot, that's all I know.

Hans Berliner: What is it? Is it a hundred and-- a hundred and sixty thousand positions per second. That's a lot. In those days nobody was doing more than maybe thirty or forty so…

Q: Now is the valuation -- has to be combined in because…

Hans Berliner: Yeah evaluation…

Q: …otherwise you're stuck without knowing what to do for the next.

Hans Berliner: No, no evaluation-- was not done except for terminal nodes but it didn't matter because everything was done in parallel. So the evaluation was being done… as soon as the position got set up, the evaluation began. We didn't always use it but there it was. So the Carl Eberling designed this machine and I helped them a lot with the chess knowledge and things like that, and we had some other students. In fact this was a truly… Other than my winning the world correspondence chess championship this was

certainly the best time of my life because once we started doing this and the word got around and we started playing in tournaments, we had offers of volunteer labor like you wouldn't believe. Everybody wanted to do something: 'can we do something to help?'

Q: 'Can we be involved in this?' This is clearly a really fun project.

Hans Berliner: Yes, it was wonderful. And every week it got better. Every week the machine played better than it did the week before; now that's incredible, that's truly amazing. And we went from the point where nobody knew we existed. Ken Thompson was kind enough to offer to play Belle against us, and I think there were two draws but we had the better of both of them. But we learned a lot as we were going along. Then I think in March we played in our first tournament which had masters in it, and did fairly good. And it played in three tournaments in that spring and summer.

Q: What year is this?

Hans Berliner: I should know this -- just a second -- it was 84. I'm sorry 85. 85. In 83 the project started; till the end of 84 the machine was taking shape; in the spring of 85 it started playing in tournaments.

Q: Now you were saying that this machine was just all, you know, that a lot of it was scrounged parts.

Hans Berliner: Yeah well okay I'll tell you what <overtalking> I went to the department head and I said 'this looks very, very good; we could use some parts.' And he says 'well I can't give you anything but maybe we can give you a hardware allowance'. So I think we got about five or ten thousand dollars-- not even ten thousand, we got maybe five thousand dollars for hardware. And we used to buy these-- god can you believe this? -- we bought these 32K memory chips, they cost twenty or thirty dollars each at that time. And we needed a lot of those; we needed them all over the place. And then Carl, he had to do-- there was a lot of wiring you know. There was a board which had all these chips on it, and they all had to be wired. He had wiring diagrams that were generated automatically by some machine but somebody still had to route the wire -- there was a program that guided you but you still had to route the wire, and we had volunteers for doing that. And all of a sudden the thing took shape; this was all happening in the winter of 84 and then in the spring it made it's first move, so to speak, and I said 'wow' you know it was really good.

Q: So you played it a little bit?

Hans Berliner: Well I just saw what it-- I gave it some things to do and I saw its tree and so forth and it was amazing. And it went to depth 8 -- at that time nobody was going to more than 6, maybe 7 -- so it went a whole ply deeper plus. And also, I thought it was smarter, so this was going to be very, very good. And we were learning all the time about how to do things even better. So we played in this tournament and I

think we finished like third, but there were several masters in it and I think we either drew or beat one of the masters or maybe two of them. Then we played in another tournament, again with masters in it, and maybe tied for first or something. And then the third tournament we won outright including beating two masters. So this was the first time that masters had been beaten, you know -- nobody had beaten any masters before - oh maybe -- no I don't think so, no program had ever beaten a master before. So we were.. this was a real big jump. And the only thing about it-- well there were several things, but you know it was basically the same old Slate Atkin model and-- but we'd used a lot of the things that Ken Thompson had written <overtalking>… speed, that speed and we also… One of the things that happened early on, the program would make certain very stupid mistakes. Like one of the favorite things it seemed to want to do is to get a bishop trapped. A bishop would-- I'm- I'm going to have to go to chess -- and at a place like B3 or G3 would be a place where a bishop might find itself, and then a pawn might be advanced to F4 attacking the bishop and it couldn't go anywhere and it was locked in and they wouldn't see this coming. Or even if it wasn't going to be lost it could be locked in in such a way it could never get out. So I decided this was something that required patterns. So we built pattern recognizers -- designed and built -- and Carl figured out how to get them in without slowing the machine down at all. So it had these pattern recognizers which sat like gargoyles on the edge of the thing watching the positions go by and each time they-- there were like, I think, there were like seven or eight pattern recognizers, each one of which could detect at least one pattern and many of them could detect three or four. And then they would make known what they found and that could either be used or not be used depending upon what we had decided the evaluation function should look into. That was done at the beginning; before the search began we decided what kind of position is this, which pattern recognizes should we invoke? It was possible the program-- that actually took a few seconds at the beginning which, you know, which would be real anathema nowadays -- but we actually spent two or three seconds getting everything ready and because it was a three minute search so it didn't matter that much. And so it would do that. All these things really worked together, and all of a sudden -- at a point where nobody had ever had anything more than a low expert program -- all of a sudden we had a master program in the, like, 2270s, which is well into the master category and we were beating other masters. And tthen we kept going, improving this until eventually that program reached a rating in the twenty four hundreds, 2430 or 40, somewhere like that, so senior masters. We took the state of the art from expert through master to senior masters. So now…

Q: Tell me a little bit more about this program. By this time you've got a database of openings that you go through – you have an opening book that you go through…

Hans Berliner: Yeah I- I had to make an opening book for it, which by today's standards was really poor because nowadays they have a machine involved, but I tried to get High Tech-- High Tech was the name of this program in case that hadn't been mentioned -- but I tried to get High Tech involved and it seemed to me there were too many nuances that it just didn't understand. So I knew its style of play and what it could do and what it couldn't do, so I programmed a book for it and frequently it found improvements on what I wanted to do, so that was very gratifying.

Q: Oh that's really good.

Hans Berliner: Yeah, that's excellent yeah. That's like discovering a new theorem in mathematics or something like that -- it would say, well… And sometimes I would just program in what the book move was, and it found a better move than what the book move was, so that was exciting, you know. That- that was exciting yeah.

Q: I read about, in one book I was reading, about how at least some of the earlier machines they go through their opening book but then sometimes the opening book would leave them off at a place in the middle of a continuation that – they just went this deep and…

Hans Berliner: …then all hell broke loose…

Q: …all hell would break loose.

Hans Berliner: Yeah that- that's the way things were back in the early 70s and maybe even in the middle-- the Slate and Atkin people were very good about that…

Q: Oh they figured that out…

Hans Berliner: That's right, that's right they tried everything and I don't think it ever happened. I mean the worst thing that can ever happen if you're a designer of a computer program and it's playing in a tournament and it makes this move from A to B, and then the opponent moves, and then it moves back from B to A because it didn't understand why it went to B in the first place and it didn't like it so it's coming back to safety you know. That really tells you you did something wrong you know so <laugh>. So I don't think we ever had that. But there were other things that we dealt with that were difficult. Like sometimes it would get a position that it liked so well that it was unwilling to make an investment. It was winning, but in order to actually win the game you had to make an investment; like you had to invest the pawn, or make your position worse in some way, and it was quite content just to move back and forth because it had this wonderful position. So we had to put in something that says 'it is a rule in chess that if you go 50 moves without a pawn being-- without any piece being exchanged or pawn being moved, the game's a draw'. So you had to let it know that so that after a while it decided to get a little bit more active and that worked too But that was again something you had to learn the hard way. I don't think it ever came up before the 80s that programs were that good and that is really made a difference.

Q: What about the other end: the end games. How were you dealing with those at that time?

Hans Berliner: I was amazed how well it played the end game, utterly amazed. Now there were-- the kinds of things we're talking-- if we're talking about the databases it certainly couldn't do that and nobody was building those databases at the time. But I had programmed in -- lets see; there were patterns-- see

that's where the pattern recognizers were very good, they-- it knew which king and pawn versus king endgames were wins and which ones were draws. -There was a pattern recognized with that and as soon as you got down to the end game that pattern recognizer got invoked and as soon as… if it ever got a chance, some… It could be a queen ahead but if it saw an opportunity to get into a king and pawn vs. king that it knew was a win, it would head for that because it was a known win. It was higher than anything else, okay. So those kind of things really…

Q: So you used the pattern recognizer; normal evaluation might be clueless.

Hans Berliner: Yeah that's right; it wouldn't know whether it is is a win or a draw.

Q: Wouldn't know what to do.

Hans Berliner: And also these pattern recognizer also were very good with bishops. It could tell whether a bishop was hemmed in by its own pawns, which made it inferior. And it was very, very good at telling bishops -- the quality of bishops versus knight was very- very-- it was better than any program. In fact nowadays that's not an issue any more because everybody looks so far ahead that these issues get resolved. But if you're only looking eight ply deep it helps to know whether the bishop you've got left at this point is a good one or a bad one.

Q: Right, that really seriously matters about the evaluation.

Hans Berliner: That's right and so these pattern recognizers were very, very good at that. So that was-- I thought that was very good. And eventually the students graduated and the team dissolved, so to speak. And I ran it… I did a few things. I wrote some programs for some special things in the evaluation function, but that only made small differences, you know.

Q: Yeah.

Hans Berliner: And the technology was moving ahead; this was starting in 85, and by 88 it was-- it actually had won the Pennsylvania State Championship in 80. Three consecutive years: 85, 6 and 7, I think, or 6, 7 and 8 -- one of those.

Q: All right.

Hans Berliner: Something that I'd never been able to do in one try as a human being. So <laugh> it's not a completely given activity; it took some ability.

Q: Yes okay yeah there's some pretty strong players in…

Hans Berliner: Yeah there were masters in it, and things like that.

Q: Yeah okay.

Hans Berliner: So lets see, now lets continue in terms of what happened next from the.. [change tape]

Hans Berliner: [gap]…and how Ken Thompson basically started things off in a certain direction by building a machine, which turned out to, within a short period of time from the time he'd done it, to be the best chess playing device in the world. And then we sort of did a copycat, and we had a student that wanted to do something innovative and then HiTech came along and pushed that along a lot more. And then later on there was another machine built by Hsu based on, I think, a better design of chips and things like that. And that played still faster, maybe not as smart, but faster, which was really more important, and they did very well at the…

Q: Meaning that you could get deeper.

Hans Berliner: Deeper and yeah.

Q: In deeper play, yeah.

Hans Berliner: And in the ACM tournaments, where all you've got to do is to look one ply deeper, and if the guy makes a mistake that… He can go down to a certain point and everything looks fine. If you go one step further and the roof falls in, well if you can always look one deeper than him, sooner or later you're going to get to one of those places where the roof falls in.

Q: You're going to get him. <laughs>

Hans Berliner: That's right, so that's how computers beat other computers, but whether that's good for beating humans is another matter.

Q: Right.

Hans Berliner: And I don't think that Deep Thought ever played against humans, or if they did it wasn't anything that got anybody's attention.

Q: Well, that was not their objective.

Hans Berliner: Yeah, well, whatever their objective was, but.

Q: Okay.

Hans Berliner: But Hitech had basically gotten a rating of 2440, and that was there., That was there for everybody to see, and so forth.

Q: Yeah.

Hans Berliner: Tut I think now, with all the advantages of the 20/20 hindsight, we're getting these microprocessors which are just incredibly fast and getting faster all the time, and there are programs that know how to take advantage of them, and while these programs maybe don't get quite the number of nodes per second that one does with a machine, they are easily modifiable and every one of these projects has workers, and they find some terrible thing that this program did, it can be fixed fairly easily.

Q: Yes.

Hans Berliner: Whereas with a machine, you're never sure -- can it be fixed, and can you fix it in such a way that it doesn't mess up something else., With Hitech we had that problem all the time. Now the only resource… we had a built-in evaluation function. The only resource we had were the pattern recognizer, but you can't make pattern recognizers for everything, you know, there is a certain limited amount of things you can do with pattern recognizers, and we did a lot with bishops, and pawn structure, and king safety. We had pattern recognizers for all sorts of things, and they really helped the program play better. But the point is, that if you can do almost as well with a microprocessor and as well a program that's been developed over 20 years, let's say, it works better. And there have been.

Q: Just because you can evolve it.

Hans Berliner: Yeah, it's more flexible.

Q: It's more flexible.

Hans Berliner: You can micro-evolve it.

Q: Yeah, exactly.

Hans Berliner: Yeah. And if you look at the records of these microprocessors, I think one of them drew a match with Kramnik, who is the sort of the official world champion human, and that program has also played several others including maybe Kasparov.

Q: And which program is this?

Hans Berliner: Fritz, Fritz.

Q: Yes, okay.

Hans Berliner: Fritz drew with Kramnik, in London somewhere, and there have also been several other matches, and there's not been a single case where a human has beaten one of those machines. Not a single case.

Q: My goodness.

Hans Berliner: So they are as good…, and those programs are there available to be studied by whoever wants to study them in preparation, whereas with the Deep Blue situation, there was no program available, there was nobody to watch what was going on in that closed room or anything else. So there's quite a bit of unanswered questions with respect to them, and these programs are available to be purchased, and all you've got to do is to invest a few hundred dollars in a fast processor. And I guess the most expensive thing is probably the memory, if you've really got to get gigabytes of memory.

Q: Yeah.

Hans Berliner: You get gigabytes of memory. See, that's because of the hash table and what I was telling you before. In fact the thing -- that factor 3 that I mentioned.., You know, initially they said "Oh, factor 35", then he's "Oh, no, the square root is a factor of 6" then said 3. But the 3 is part of an exponential shrinkage, that the deeper you go, the more pronounced this effect becomes. So if you go to depth 8, maybe it's 3, by the time you get to depth 12, maybe it's 2.

Q: Okay.

Hans Berliner: So in other words this invagination of the tree encountering examples of positions already seen keeps increasing. And so having a large hash table allows you to remember almost everything that's happened before and saves you an incredible amount of work.

Q: Okay.

Hans Berliner: You know, you're going to depth 16 and you get to depth 6 and say "I've seen this position already, goodbye, I don't need to do the last 10 plies".

Q: Right, forget alpha beta.

Hans Berliner: Well, no, well. <laughs>

Q: No, you then apply that too.

Hans Berliner: Yeah, yeah, but you have a value there and that value.

Q: You have a value and so you can, that's all you need.

Hans Berliner: Yeah, yeah. So, you know, so the point is that these things have basically changed the priorities of what it takes to be a good chess playing device.

Q: Okay.

Hans Berliner: And the big thing is a huge memory, and a relatively fast processor, and a flexible program, and with that… You know, I have no doubt… Well, let me… This is something good to say. I hope you retain this, okay.

Q: Oh, we retain everything, don't worry.

Hans Berliner: Okay. I think that if there was a proper incentive to both human and machine person to have a match for, let's say, the any-entity earth's championship of chess, I think you will find that it would be very, very close. And that probably maybe two years after its inception, machines would win regularly. I think it's that close. And what's usually been happening is that grand masters will play these machines because they get a pot of money for doing it.

Q: Yes.

Hans Berliner: And but… You know, Kasparov was sort of brave. He was world champion at the time he did this, and then he did this very foolish thing in the sixth game. But in any case,, when I ran this Fredkin competition, we tried to balance it in such a way that nobody would be tempted to just get the money, let's say, and not worry about the outcome of the match.

Q: Okay.

Hans Berliner: And I think that certain matches have been arranged where the difference between first and second prize was so small, “let's just take the money and run”, you know, that kind of thing. But what it should be… There should be something that if somebody is a real human world champion, then… The humans are never going to agree to a match for the.. You'd have to create a new title, you'd have to create a new title like the Planetary XYZ Champion, open to anything, alright.

Q: Yeah, right, because they're not going to risk their title if they're world champion.

Hans Berliner: Yeah, well, that's right, and not… You know, there's too many things that go with it. Although let's say Kasparov didn't seem to realize what he was risking. Somehow I talked to him and he just didn't seem to know or care or whatever.

Q: Yup.

Hans Berliner: But… So the point is, what we would like to do, is to say, like, say, have three years of this and at the end of that period of time say "Oh yes, the issue is settled and let's move on to greener pastures" that kind of thing. But at this point there are still all sorts of innuendos; somebody says “this is better, that's better”, and most of the people that are saying that are not really qualified to look at a game of chess and decide what's happening in the game, you know.

Q: Yes.

Hans Berliner: So anyway. So my thesis is that chess machines have run their course. We learned a lot, but I think that a general purpose microprocessor with a huge amount of memory and a good program is better. It's as simple as that.

Q: And will continue to get better.

Hans Berliner: Well that's right. Everything is in its favor, right?

Q: Right.

Hans Berliner: The two programs that I'm aware of -- there may be others -- are Fritz and a program called Shredder, which is done by the same people. It's called, what is it, Chessbase, Chessbase I think peddles those things.

Q: Okay.

Hans Berliner: So they have both of those. I have both of them on my machine, but my machine is, you know, is a real weakling from the <laughs> speed point of view. But I..

Q: So can you beat them on your machine?

Hans Berliner: No, not if I can't see what they're doing, you know. If I only get a move from them, no way, no.

Q: Yeah, okay.

Hans Berliner: But I have some friends that have machines that are, let's say, several hundred times faster than this. If there's something that I really want to know about I'll call them up. I've been so under the weather -- both I've been ill and then these hurricanes -- but maybe toward the end of the year I'm going to buy one of those and have my own to do analysis with. Then you feel a lot better about anything you write about chess; that you really feel it's been proven.

Q: Yeah, exactly, exactly.

Hans Berliner: It's been in the cauldron and been proven.

Q: Wow, alright.

Hans Berliner: So I think that was what I have on my sheet here.

Q:. Do you know anything about the authors of either of those two programs? Have you ever met them or is that sort of too recent.

Hans Berliner: Well, okay, I know Frederick… what's his last name… I've met him a number of times. He's the entrepreneur behind Chessbase. And of course they do a lot of other things. They specialize in databases and all sorts of things.

Q: Yup.

Hans Berliner:,I may have talked to some of the programmers. The thing of that is, they're mostly very lacking in chess knowledge and very, very good at getting the most out of these micros, so somebody tells them what needs to be done, they do it. See, one thing that's wonderful about that kind of an approach… It's like all science, you do something, you test it and it works or it doesn't. Or you can improve it in some way, you make the supposed improvements, see if it really improves it. Like when you go to the optometrist and he puts a lens in front of your eyes, is it better this way or that way. And they did that -- from Greenblatt on they've done this. They've tried different things and the things that were best won out and made it to, sort of, the next generation. And so I really don't know the programmers. I know the people that had Shredder, who are a couple of German people that I once talked to but I'm sorry I can't remember their name, and they were eventually bought out by Chessbase. But their advertisement… you know, I can give you some places where you see advertisements for them and it's easy enough to get them and I'm sure all I've got to do is get in touch with Frederick and he will be happy to send you all the copies you want of these things. But I say, it's not a big deal, it's like between 50 and 75 dollars.

Q: And so it's fundamentally… in your view it's… at this stage it's just very good programmers.

Hans Berliner: Yeah. Well, you know.

Q: And they aren't inventing new things, they're just doing clever programming.

Hans Berliner: No, and… Well, so, it's fundamental, they're doing things right, you know, whatever that means, and the databases… they're openings are fantastic. I mean like my programs are three or four years old so they don't have all the latest innovations, but they have almost everything up to that point. You really have a hard time… Like in the days when I was doing this, there were zillions of holes where if you only knew what was in the computer's database, you could beat it regularly because it's something you didn't know. Nowadays those places are very few and far between, so they really have stuffed the opening book full of good information and stuff.

Q: Yeah, full of really good stuff.

Hans Berliner: Yeah, and then this problem you brought up earlier: when you emerge from the book, they don't fall apart, they go smoothly into the middle game. Yeah, from the opening.

Q: Okay, yeah.

Hans Berliner: So it's really good. And as far as this thing about that event where Deep Blue beat Kasparov. If you looked at the two previous matches -- there were previous matches in two previous years -- the play of Deep Blue on defense was unbelievable. It could defend positions that a human being would give up on, say absolutely, because it looked at everything and it knew what it meant to keep its head above water. But as soon as it…

Q: So it could evaluate… it looked at everything and had a good evaluation function _____.

Hans Berliner: Well, good enough to know what losing meant, you know.

Q: No, no from a defensive point of view.

Hans Berliner: Right, so in other words, it didn't know what… it didn't know how to get an advantage necessarily but it did know how to keep its head above water.

Q: Right.

Hans Berliner: And so, you know, time and again it would save a position that everybody thought was lost. Now.. but when it came… when it had the better of the position, it frequently went off the deep end. It didn't have the slightest idea how to proceed. Now the big change in that last match was that they had hired two grand masters and they said they were going to make a big effort on evaluation and try to get it to play better in superior positions, and it did. The only question that remains unresolved was: did the grand masters keep their hands off the machine during the game or didn't they. And that's a question that many people have asked, not just me.

Q: So they should… Maybe the grand masters should have been sitting in the audience during the game?

Hans Berliner: Yes, yes, that's right, or they should've been…

Q: That would've been a wonderful way to…

Hans Berliner: …or some observer should've been in there or something like that, you know. And this is something, this is a question which is still being discussed today. That was, I don't know how many years ago.

Q: Oh yeah.

Hans Berliner: But the point is with these micros, all you've got to do is to just purchase it, install it and bring your grand master or world champion and it's all there to be seen.

Q: Yeah, exactly.

Hans Berliner: So there's no hocus pocus, and these do have very, very good evaluation functions, and I'm very interested in evaluation functions, having written a few myself.

Q: Exactly.

Hans Berliner: I watch it, take a position which is potentially… well let's say equal, slightly maybe better for it, and you say, "well, you know, it can never beat me from here because I know all the things it can try to do and I can block them all". And five moves later I'm lost. So it knows… Not only does it know the obvious ways to make progress, but it looks deep enough to find some way that even a grand master may not think about in terms of making progress. So that's why there's really no future for humans against computers.

Q: Against computer chess.

Hans Berliner: It's absolutely not the case. It's just the case where … One thing I'd just like to say, in terms of all the forefathers and their dreams, I think that was all very laudable. In fact, I don't see how any other thesis could've been put forward. The idea was we have this human being and we know a little bit about psychological studies about how he plays chess and that's the thing to do. We know something about the deep structure of a human being and what he does to play chess, and nobody in their… In those days they were still bantering this number of 35 moves per ply, that it's going to increase by a factor of 35.

Q: And there was no hope of doing anything else.

Hans Berliner: Every child knew that that can't be done, you know. But then things kept changing, and so these ideas were good in terms of getting people interested. And then as time went on you got more and more… This to me is the beauty of the whole thing. These people, Greenblatt, Slate and Atkin, Ken

Thompson with Belle (although that turned out to be a dead end) and I think by that time… I don't think anybody uses pattern recognizers so that's not on the mainstream either, and that's all it takes. And, in fact I had this, you know, Carl Eberling, a wonderful person, and he worked very, very hard to build this machine. I mean, he did five times as much effort as the average person does on a dissertation. So he really.. And he got, at that time we were really knocking heads in 1985, and he got his degree, and he got -- MIT awards a prize for the best dissertation every year, and he got the second prize. There were three, I think, three awards and an honorable -- first, second, third and honorable mention -- and he got the second prize. And oh, long time after that, we were trying to discuss, in the light of maybe another seven or eight years of experience, what really did Hitech have that made it good. And you… Because I thought, "oh, it's got to be that wonderful knowledge that I put in there, the pattern recognizers and things like that" and it was certainly true that it went about a ply deeper than any of its competitors, but then again, after awhile, we didn't play against machines anymore, we only played against humans, and so that extra ply would only be useful in the sense as it helped to uncover the secrets of the position. But the more I started thinking about it, I think the size of the memory was probably as important, if not more important, than anything else, because it allowed us to go deeper, even though we were going fast as it was, but we had a larger memory than Belle.did, and this was, you know, these 20 dollar chips we had to buy, and they were part of the main memory for the hash table. And anyway, I think now what one sees now, if you… In fact, this friend of mine has invested -- I forget whether it's three gigabytes or two -- but he's got gigabytes of memory for the hash table and I have, I don't know, 300K or something like that, you know.

Q: Yeah, yeah, exactly.

Hans Berliner: And an incredible difference. The same program… yes it does run a little bit faster, but the speed doesn't in any way account for the difference in the playing strength. The difference in the playing strength is that it knows everything, almost everything it's done before. It never needs to repeat anything which logically doesn't need to be repeated, whereas these other program they don't know that they've been there before, they do it all over again and there's a lot of wasted effort. So it all boils down to the fact that a hash table, a large memory and a reasonable evaluation function, and a fairly good processor. That's it. That's the story of computer chess. <laughs>

Q: Really, yeah. <laughs>

Hans Berliner: It is, yeah. I mean, that's the fundamental story.

Q: Okay.

Hans Berliner: Which, in some ways some humanist might find that a little disappointing. I don't. I think that's the nature of progress. I think we're understanding what it takes to win in this world.

Q: And we may discover in, you know, in the next 10 or 20 years that in fact the brain has a massively parallel…

Hans Berliner: Oh yeah.

Q: …you know, computational system of its own.

Hans Berliner: I've been doing experiments on myself about parallelism and it's very.

Q: Really?

Hans Berliner: Yeah, it's very interesting. If you, you can.. If you don't suppress the parallelism, you will be thinking about all sorts of things, and if you really… That's one thing about chess for instance, you really have to concentrate. You better not think about what's going to happen tomorrow or the weekend or anything like.

Q: Or what you're having for dinner or anything.

Hans Berliner: That's right, just think about chess, and that's really what's important, you know.

Q: Okay.

Hans Berliner: And, let's see… I was going to say some other thing about this. Oh well. Yeah, I don't remember.

Q: It'll come back to you.

Hans Berliner: Yeah.

Q: What I'd like to do now is to just roll back a little bit in your personal story. We left off on your personal story where the, you know, you were teaching…, You'd finished your PhD, you were teaching a course in searching, at the graduate level, and you'd gotten these graduate students that were really interested in building what turned in Hitech.

Hans Berliner: Yeah, yeah.

Q: Start there and…you know, that's still '85. That's a long way back.

Hans Berliner: It is, but I retired in '98 and the students all fled the coop, you know, by the time we got to '89, I don't know if they're… I was involved in doing lots of other things that produced interesting papers, but they didn't have anything to do with chess.

Q: Well maybe you could just outline a few of those. I'm interested in the diversity of things you looked at.

Hans Berliner: Well, okay. There was this one thing that we called Super Puzz that was this four by 13 solitaire game, and there are some papers in the AI conferences. When I moved here, I had to leave my office and a huge part of my library behind, and those things didn't make it, but they're there in the archives of things and I thought that Super Puzz was an interesting project, because it…

Q: How do you spell that?

Hans Berliner: S-u-p-e-r P-u-z-z.

Q: ZZ, I thought I needed to get a spelling of that.

Hans Berliner: Right, and so that can be found in the AAAI -- I don't know whether you've encountered them, they have… there's a society, American Association of Artificial Intelligence.

Q: Yeah, I know of them.

Hans Berliner: In their meetings back in the '80s, early '90s...

Q: So you did some work in there?

Hans Berliner: Yeah, and we did other things. You know, I tried to get involved in neural net learning, not very successfully. I had a student that worked on that, and I still believe… Right now neural net learning is at an impasse, and all I can say is it's waiting for somebody with a bright idea to break that impasse, and it would be fun to try, let's put it that way.

Q: Yes, okay.

Hans Berliner: But of course I think the people in computer science are probably as bright as anywhere on the planet. If there's any brighter people, I don't know where they are. I don't think in nuclear physics and astronomy they're any brighter than they are in computer science. So if they're not doing it, who knows, it may be very, very, very difficult. And maybe not. You know, sometimes all it takes is the notion that nothing can go faster than the speed of light, and then everything else falls into place.

Q: Did you ever think about or consider analyzing a game like Go that is intensely more complicated than chess?

Hans Berliner: Yeah, well, there are people I know that are working on Go or have worked on Go and I've consulted with them and I feel what they're doing is very competent. I don't have much knowledge with respect to Go and clearly it's a pattern-based kind of thing and the search does play a role, but it's very selective. You can't look at everything, and there's really no need to look at everything, but… And the people I've talked to seem like they were doing it well, and I know there was a, like a million dollar prize that was being done in Taiwan for the first program to do something like beat the world champions. They've withdrawn that prize now, so things are getting close, I guess.

Q: <laughs>

Hans Berliner: But you see, that'll be a somewhat different enterprise than chess. I'm sure memory will have a role and a good evaluation, right . The thing, you know… One of the interesting questions which I guess we hadn't talked about at all is quiescence. Now the first person that I think mentioned quiescence.. well I think, maybe Turing did, I'm not sure, but certainly Shannon spent a great deal of time talking about quiescence. Now quiescence, for those who are not good chess players or computer science, is the fact that if you arbitrarily decide to evaluate a position -- let's say you've gone down eight or 10 or whatever ply and you reach this position -- and you arbitrarily decide to evaluate it. What could go wrong with that? Well, it may be that he just captured your queen, so he's a queen ahead and you're about to capture his queen back, but we're not going to allow that in, because we're slicing it right here. So the notion of quiescence was to follow out captures until they die out, and then that would be a more accurate...

Q: Point at which to do an evaluation.

Hans Berliner: Well yeah. The evaluation at the end of the quiescence is much, much better. However, that doesn't include moves such as rook to C8 mate, you know, that's not a capture, it's a mate, you know, how do you find mates? And that's something that has plagued chess programs from the early days on. But nowadays with them going so deep -- going 17 and 20, 25 ply, who knows -- it becomes less and less of a problem because somehow those lines, I don't know, there's enough other things wrong with moves that are picked up by other things, and the people who do these experiments say quiescence is no longer a very big problem. They do a very modified form of quiescence, maybe only capturing queens or

something, I don't know what they do, but something like that. Now in Go, I have no idea. I believe that Go is really the kind of problem that Newell and Simon had in mind when they proposed some of their ideas, because Go is a question of territories. There's a number, maybe seven, eight, nine, 10, who knows how many territories, each one of which either is in dispute or belongs to one side or the other, and there are life and death threats. If somebody plays near that territory in a certain way, that means something that needs to be answered. Otherwise, the territory changes hands or something like that. Now those things are all well-known, and so one can think of a territory and analyzing it as if that was a separate game in itself. The only trouble is when these territories begin to approach one another, then you get these funny interactions, and that, I think that is, well, that's that last I knew of a really difficult problem that they had to solve there.

Q: Yeah, but that's… Okay, alright.

Hans Berliner: So, as far, you know, I'm not sure… I understand why games have a role in trying to understand the way the universe ticks, I certainly believe in that. But chess, I think the bottom line is it's an inferior game, you know. <laughs> It's not a game that can challenge the intellect of an excellent computer. And what the goal probably will be for awhile, and… Somebody was just telling me, I never saw this, but somebody was telling me there's a game that's like chess but no computer can play it, but that's all I heard and I never saw an example of anything like that, but maybe there are things like that. I guess the bottom line is that all these things… Okay, this is something I really do want to say. There's this thing called evolution and evolution favors the successful critters, and like one of the people that writes about this, like Gould or somebody like that, will say you cannot evolve a propeller driven airplane into a jet. It would have to give up its propellers in some way and have some interim… , It would sort of have to develop jet propulsion along with its propellers, which would be a lose, because it would take an awful lot of energy to develop all that while it already has a reliable form of locomotion. And so that's an evolution that probably would never happen. And in the same way, human beings' brains evolve to solve the problems that were necessary for survival, like knowing where food is and knowing how to preserve it so it doesn't rot on you, and fighting successfully, and getting along with your fellow man, and all these kinds of things that our brain does very well. But now adding numbers and searching trees is not among those things. And all we're saying is, even though human beings somehow have managed to cope with these problems in a very ingenious way by all sorts of things that psychologists fill their books about -- pattern recognition and logical things -- but the bottom line is that a machine that gets the essence of all these things and goes like a bat out of hell is better. And that is the story of computer chess. That is the story. And it's a very interesting and wonderful story because it probably is just the first of other stories to come like this.

Q: Okay.

Hans Berliner: I'm quite convinced that airplane designers will design airplanes that will be like nothing we've ever seen in nature or anybody thought of. And that'll happen just by the sheer ability of trial and

error and testing: try something, test it and then you find out that “oh yeah, we can do it this way”, and it's different and it turns out to be better, you know -- oh every once in awhile it turns out to be better.

Q: Yeah, every once in awhile.

Hans Berliner: And that's, you know.

Q: And we call those breakthroughs.

Hans Berliner: Right, and it's good stuff, you know, it's really great. It's a wonderful feeling both for the human race and also personally.

Q: Okay, good. What would you say… Let me just try to ask some random questions.

Hans Berliner: Sure.

Q:, When you think about the moments in the history of Hitech playing, are there any particular games or particular moments that you still remember? That means, they really, you said, "Oh."

Hans Berliner: Okay, we somehow were very lucky to have a match arranged with somebody named Arnold Denker, who was a grand master, and he came to New York to play a four game match with Hitech and we beat him 3 1/2 to a half. Now that's absolute devastation, you know.

Q: Yes.

Hans Berliner: And it outplayed him in every game, in every single game. , It completely beat him. But the highest on my list is this period at the beginning of 1985 when …, when you put together a chess machine, there's all these parts, and you see the part is working the way you want and then sooner or later the moment of truth comes where you put them all together and see what it does. And from the very beginning, I could see that it had the potential -- maybe not every single time -- it had the potential to play better than any device that existed, and we had this wonderful group of people for whom I really give… Carl Eberling, very charming person, who everybody loved him, and it was easy. You just had to say, "oh, would you?" and people came to run to do things for us. So we had all these people and there was a set of tournaments that were easily accessible, and we played, like, one tournament every three weeks. And in those three weeks I used to work easily hundred-hour weeks, and so did many of my cohorts. And we would have Monday morning meetings in which we discussed how things were going, what was wrong, if there had been a tournament over the weekend, you know, what had they discovered, and maybe we

played some games against somebody or something. And there was always an agenda of things that needed to be done, progress report and things moved at an incredible rate. I just don't believe… if we could've known, we probably should've had some documentation. I don't think people would believe the rate at which we progressed. Like when we first started, I think we maybe had like -- again, I don't know to what extent people are familiar with the chess rating system, but an expert is a 2000 player, up to 2200 that's master -- so I think at the very beginning we were right around 2000, maybe a few points below, maybe a few points above. But in a period of a month and a half, we were playing master level chess. So that's a 200 point increase, which showed you what a… at that point there was so much flexibility and we were putting an awful lot of work in and a lot of good ideas too. There were a lot of bright people contributing good ideas. So we advanced like 200 points in less than two months. And from that point on it slowed down a lot, but it kept on going. It's sort of interesting when Hitech played in its first ACM championship, which was in Denver in 1985. They asked all the participants to project an expected order of finish for the 10 programs or so that were there. And then they read off -- nobody had their name on this list -- and they read off what different things, well there was a program called Cray Blitz, which in my opinion was a relatively poor program. It took advantage of a very fast machine, but the quality of its play… whenever we had it invited, it always did badly against humans. Anyway, that was winning all these tournaments and everybody had them at the top of their list except we; we had Hitech, and.

Q: You had your own. <laughs>

Hans Berliner: Well, not only that but, you know, it turns out Hitech had played in three tournaments and its rating was like 2270 or something like that, which was way better than any other program that had ever existed, not to speak of the ones that were in the tournament. It was the best program.

Q: Right.

Hans Berliner: But these people didn't know about it and Monty Newborn said "Hitech, where did that come from?".

Q: He didn't even know… you just appeared.

Hans Berliner: Yeah, well no, but it was there. I mean we'd been written about in Time and Newsweek and we'd exchanged information with a number of the other people there. Some were interested in this exchange and some were not, you know. But there it was. We were the highest rated program, we won every game…, so.. But anyway, those were exciting times; those were very exciting times.

Q: Those are, that's great.

Hans Berliner: Yeah, yeah, I mean, you were right in the middle.

Q: That's a great story though.

Hans Berliner: Yeah, it's just like -- I'm sure everybody knows this book, the Soul of the Machine, is what…

Q: Soul of a New Machine, yes I know that.

Hans Berliner: Yeah. That kind of thing. You know, it's that kind of thing. Where you have something and you know it's good and you're pushing it and then it comes to fruition. And it's very good, yeah.

Q: And it works.

Hans Berliner: Yeah, yeah.

Q: Hitech ran… What processor was in behind Hitech, computer?

Hans Berliner: It was a standalone machine.

Q: It was a standalone? Was there any computer involved?

Hans Berliner: Okay, we, let's see… Carl is the right person to answer, but let me see what I can do.

Q: Well, I know Ken Thompson had his machine, but he had a PDP-11 behind it that sort of controlled it…

Hans Berliner: Yeah, that's right,. Okay, what did we do?

Q: …was referee.

Hans Berliner: Okay, we, I guess we ran it on one of our PDP-10s. Let me just make sure about this. Yeah, we always… when, like when we went to Europe, we always had to have a data link, and always had to log on, yeah. And Hitech… I guess Hitech, see I… boy, that shows you how far, how long ago this has all been… but I think Hitech ran on a PDP-10 but it… you know, once you invoked the Hitech, the

control… No, okay, all, like the book files and stuff was, I think was on the PDP-10, so whenever you went… whenever a move had been completed and there was a… waiting for a response, it went to the top level and I think that was on the PDP-10.

Q: Okay.

Hans Berliner: And it did things like analyze a position, and decide which pattern recognizers ought to be invoked, and things of that nature.

Q: Yeah, the things that were better… that you don't want to have hardwired…

Hans Berliner: No, no. No way in the world, yeah. So those were done there and then as soon as we got a move, we entered it at the console and then the control would pass to the main processor. And there were these various things that it did… I'm sure you've heard the term iteration, you know, fifth iteration, sixth, seventh, eighth. And each time you'd check and see: have we satisfied the condition for termination, which was a artificial condition that we had invoked to…. The idea is that if you keep coming up with the same move, then that's probably the right move, but if it changes then maybe there's some things that you ought to… One iteration being: you look at every single move, but you look to one depth deeper, and then if you still found the same thing that you did the last three times you did that, you'd say "well, I suppose that's it." That doesn't mean it's the right move, doesn't mean on the next one you wouldn't find some terribly informative...

Q: But it improves your confidence.

Hans Berliner: Absolutely, very much so, very much so.

Q: Okay. Alright, I think we need to stop.

Hans Berliner: Okay.

Q: <change tapes> We're recording. All right, well that's good. I was curious a little bit about the technical set up of how it worked. So you would take the HighTech physical box with you … when you put… now how did…

Hans Berliner: No, no, no. We -

Q: …how did you play a tournament in New York City for instance?

Hans Berliner: We took a laptop.

Q: Okay.

Hans Berliner: And dialed up to Carnegie Mellon University.

Q: Ah, I understand.

Hans Berliner: And there we were.

Q: Okay, yeah. You just did it remotely.

Hans Berliner: Now, I think in the early days, before laptops, we may have carried a -

Q: A terminal?

Hans Berliner: - terminal, which was awful. Yeah, I remember in Philadelphia we played in a World Open, and I remember carrying a terminal around, yeah.

Q: Yeah, I'm sure you probably did

Hans Berliner: - That was, like, '87 or '86, '87 in there.

Q: All right, that sounds right, because laptops were…, took a while.

Hans Berliner: Well, in that time we were getting all this great press and we were… I don't think we ever beat an active grand master. But we certainly drew with a lot of them. And probably had them on the ropes and could have beaten them if they had a little bit more understanding or something. But… So that was still pretty good, you know. It came from out of nowhere.

Q: Oh, that was.

Hans Berliner: It was worth going to do that.

Q: Yeah. Tell me the – you don't have to comment on this if you don't want to -- but there's been – there has been – there has been some sort of conten… speculation about your relationship with, you know, your fellow – sorry, I guess Ph.D, or I don't know whether he was just a Ph.D student, I think he was, at Carnegie who did Deep Thought.

Hans Berliner: Yeah.

Q: Yeah. What -

Hans Berliner: I won't say on the record anything. If you want to turn the camera off I'll tell you everything you want to know.

Q: Oh. All right. <camera stopped> All right, good.

Hans Berliner: Ok, Alpha Beta. Alpha Beta as I said earlier -

Q: - and multiple processors...

Hans Berliner: Yeah. Well Alpha Beta made incredible things possible because instead of looking at a million nodes you do the same work as if you were only looking at a thousand, so that produces an exponential speed, up which is truly wonderful. And the nature of the exponential effect is that something that's going to happen and some part of the tree which may or may not have been looked at, but that's preserved in a table, and when the uni-processor -- the single processor -- is ready to look at that part of the tree, he looks in the table and sees there's something interesting, which can help him to avoid the work completely or partially. Now. It's been a dream of a lot of people -- I must say, I don't understand where they're coming from -- to believe that if you can do all this wonderful stuff with one processor, you should be able to do better with two or more. Now many people have tried this, and it turns out that the second processor actually improves things by maybe 60%. So in other words, out of the second processor you're getting about 60% of its value if it were all by itself. But from the third processor on, it drops very rapidly, maybe to 25 and then down to 5 or even less for the rest of the thing. And that is, its not worthwhile going through all the shenanigans to get a 5%. If you're getting like a 1% or even less out of your 20th processor, that just isn't worth it. Well, there are people who sort of thought there must be some way of doing it. And they produce some sort of an algorithm, and if you do this, and this, and this. And very few people in the formal area knew – know -- about Alpha Beta and how it works, and so forth. And. I mean… I must say that if a student came to me and said I want to parallelize Alpha Beta I would say: you're wasting your time, it can't be done. Not in a general way. Yes, you can get a little bit out of your next processor and

maybe a little bit out of the next one, but it dies out very quickly. But anyway, there was this thesis published at Carnegie Mellon that said we have a linear speed up of Alpha Beta, and we intend to use it. And as far as I know it was never used. And further, I know there was at least one proof -- but I believe I heard about two -- that it couldn't be done. In other words, in computer science you have this wonderful way of proving that things can't be done.

Q: Yes.

Hans Berliner: And so somebody actually proved that the communication problem between processors, if they were going to share this information that was vital, would completely overwhelm the processes so that they couldn't even contribute anything; not to speak of anything useful.

Q: Okay.

Hans Berliner:. So I haven't seen the proofs, and I'm really not a mathematician, but the idea that it couldn't work seems intuitively obvious to me. So that's about all. So the point is, that while Alpha Beta is wonderful, parallel Alpha Beta may work up to two processors but not more than that really.

Q: And nobody has…

Hans Berliner: No. And as far as I know, nobody's even trying. Now, like you can get – you can buy the processor Fritz -- and there's something called Deep Fritz, and Deep Fritz runs on two processors. So meaning that they somehow have some information sharing among the two processors, which does produce some benefit. But as soon as you got to start sharing among three or more processors, everything goes to straight to hell, you know.

Q: Now did Cray Blitz – I know it ran initial – early on, on a Cray…

Hans Berliner: Yeah.

Q: And then ran on a four-way Cray. I don't know… Did you know, happen to know anything about - how they made use of the fact they had more processors? More processor power…

Hans Berliner: I think they divided – I think what they did is they divided the tree. They said, okay, you work on the first… Well that's sort of the way the parallel thing would have to work anyway. So, you know, I'll… First processor one works, you know. You have some results from the previous iteration. So the first, the best alternative goes to the first processor. The second best goes, and so forth and so on.

And then when you get finished, then you go to the next one that hasn't been taken yet. Now, that sort of is the essence of all these things, and it doesn't work. There's too much overhead.

Q: Yeah, okay.

Hans Berliner: Way too much overhead. Now I really don't know… I really don't feel qualified to speak about what they did. This is just based on some presentation I heard and what I remember.

Q: And then… All right, good.

Hans Berliner: But I think parallel Alpha Beta is dead. It's just something that doesn't work. As simple as that.

Q: And it's unnecessary.

Hans Berliner: Well it would be nice. Well suppose you could get a speed up of 50 – even if you don't get a full benefit. But even – if some linear speed up... Suppose you could reliably add 15% for each processor you add, and you wouldn't… you know, every six processors you're doubling your speed. And so – well you know -

Q: Yeah, that's – yeah.

Hans Berliner: It would be a hairy -

Q: It's expensive but - it's a hairy thing to do.

Hans Berliner: - hardware thing to do. But nevertheless, there would be some who would undertake it if it was really a reliable thing to do. But it isn't; yeah, so.

Q: Have you ever thought about whether, as computers continue to improve, computers competing against each other will achieve even higher chess scores -

Hans Berliner: It's quite possible.

Q: - than our current…

Hans Berliner: It's quite possible.

Q: You know might hit 3,000 or something like that?

Hans Berliner: Oh yeah.

Q: Someday.

Hans Berliner: I think you know -

Q: That people just can't ever get to it.

Hans Berliner: There are several parts to this question. Like one of the things… Like all the top grand masters, they spend almost all their time… they figure there's very little about their game that can still be improved. They're excellent in the end game, they're excellent in the middle game, they may try to think a little faster or get less distracted or something like that. Or learn to think a little faster or something. But the main thing they spend their time on is openings. Everybody wants to find an opening innovation that you can use and beat somebody because he can't find the right more, or hopefully, even where there is no right move.

Q: Yes.

Hans Berliner: Now I… In this world championship that I won by correspondence, I found a move in a position that was well known, that had never been tried, and it upset the whole apple cart.

Q: It flummoxed all your competitors. Yes.

Hans Berliner: No, well just one, but it upset the apple cart and thousands of games have been played with this variation since that time. And it's… The move that I played is still good. It seems to at least draw for black, which is always good, and maybe even win, you know. Anyway it's a good move. Everybody's looking for that kind of thing, and it's very hard to find it and employ it, but that's something to do. Now, I do believe that computers will have a role in this. If we really let them loose on the opening book, and let them figure out a move that it wants to play based on a 25 ply search -

Q: Yes.

Hans Berliner: - it's going to find some things that no human has found. And, because you need a human there to say this is real and this is not, but… so it'll be pushed forward that way. Now with defense… I don't think I've ever seen a computer game that did something that I considered truly original on attack. They all did things… Maybe they saw the way clear to the attack that maybe a non-world champion might have hesitated about. But I think the top players would have played those moves, especially given a reasonable amount of time. But on defense it looks at everything and if there is a path through a series of haystacks or whatever, it finds it. So it's already –computers have already shown… in fact, I think Kasparov despaired… in that last match he had like two positions that he would have won against any human on the planet, but he didn't win them against the computer. The computer found a way to -

Q: To defend.

Hans Berliner: - to save it. Yeah.

Q: Wow.

Hans Berliner: So that gives you pause to think. You're playing our best chess. You think you've got a winning position and this machine pulls it out. And that's why I say it's really not going to be any competition down the road. It's just too one-sided. The machine can do several things very reliably that human beings just … especially, you know, when they get tired after several hours, there's no chance. So as far – I think the – if there's going to be progress in chess – well you know, I mean… Right now it's possible to look to a depth of, let's say, 22 or 23 in about a half an hour. And – now again, I'm not – I shouldn't say that. It's not – it depends – some different programs count their depth a slightly different way.

Q: Right.

Hans Berliner: And that may not be very reliable. But very, very deep. Much deeper than any human being would hope to be able to look in that period of time. And so, half an hour – how many times do we have to divide that in half before we get in the realm of three minutes, which is how much you're allowed per move? So it's – I think the safest thing to say is it's going to be very, very hard for humans to find mistakes in games of the best computer. Not very far away, a year or two away, maybe even less.

Q: Yeah. Are there still computer champion – computer -?

Hans Berliner: Well they have these tournaments I guess.

Q: They do still have tournaments?

Hans Berliner: Yeah. I really don't follow it. Because there's always been funny things happening at those tournaments. You know there's… The thing I was talking about, you look one ply deeper than all your opponents, and it's like somebody who has a better pair of glasses. You're walking in someplace where there's all these cracks in the earth and this guy can see a little bit further so he didn't step on that crack and the guy before him did, so that decides the game.

Q: Yeah. That's not very interesting

Hans Berliner: And that's not very interesting chess. That would not add anything to the theory of chess. That's just the theory of errors or something like that. But as far making real pronouncements -

Q: Well it will be – maybe heuristics, not chess knowledge, will come back when the computers can go 25 or 35 plys -

Hans Berliner: Yeah, that's right.

Q: - and everyone can, and they won't be that one goes one ply further because it probably doesn't matter too much.

Hans Berliner: Yeah, at that point.

Q: - at 25 or 30 that one could go to 31 and one could go to 30. The chances of finding something different when it's so far away are…

Hans Berliner: Well that is… Well that actually… Something I didn't mention at all and should have, is these databases of simple end games that Ken Thompson started doing. I don't whether – you said you didn't do the interview, so maybe - he must have – hopefully he touched on it.

Q: Yeah I've actually heard something about that, that he does – did do it.

Hans Berliner: There was a time… There are certain things where there were pronouncements made by humans that everybody accepted as gospel. Including that in the most difficult position a king and a rook could mate a lone king in at most so many moves, and he showed it was one less than that. But that isn't terribly important. It just shows you that how that something was about to crack, you know.

Q: Yes.

Hans Berliner: So now… Then he did… He found that two bishops will beat a knight almost all the time. Meaning -- unless there was some special position, we had some special characteristic -- in the general position, two bishops could beat a knight. Now, we always knew that was a big advantage but nobody ever jumped to saying it was a forced win. But it is. Then there was a situation of queen against two bishops was pronounced by Reuben Fine to be a draw, because obviously the two bishops can control both colors and can keep the enemy king away from our king. Not so. There are maneuvers -- and they are very, very difficult, incredibly difficult -- where, in fact, in the general case, a queen beats two bishops. And I have watched Belle play Arthur Bisquir I believe, one of the formerly top players. Bisguir would take the queen against two bishops, he couldn't win. Then he'd turn it around and he'd take the two bishops against the queen and he'd lose. So the machine – this was working from a database though.

Q: Yes, yes… and had analyzed…

Hans Berliner: Yeah. And the database would beat him every time. And analyze to completion, yes.

Q: Well -

Hans Berliner: And then there was another one that was very important. It was always considered that winning with a queen against the rook, with no pawns, was a piece of cake. And Ken Thompson discovered that there was a defense on the sixth rank with a rook, where you had to really play very ingeniously. And I watched that database draw against me and against several other masters who couldn't figure it out at the table. Then you go home and you analyze it and you can figure out what needed to be done. But it's not – was not -- in any book. Now it is. But this was 25 years ago maybe.

Q: Right.

Hans Berliner: Some time ago. So these are the places… , This is sort of like… One of my favorite subjects has always been chemical synthesis. A machine could go through… give it a 100 atoms of various kinds, and certain simple rules for combining them, it could make up compounds at a dizzying rate. And then maybe say, okay, of all the compounds I made up, these 100 look the most likely to me. and then have a chemist… As far as I… Maybe they're doing this. I wouldn't be surprised if it's being done somewhere in chemical labs where nobody know about it. But I proposed this a long time ago at Carnegie Mellon University and the Chemistry Department didn't want to hear anything about it. So I'm sure that that's something you can do. And sometimes people know – they know the chemical composition of a compound but they don't know the structure. So you can put in all the constituents and see what kind of structure. So this is very much like the computer chess problem. These are things – design problems

where the question is: what is the best design? And that can be done by sheer iteration with a little bit of knowledge to guide the thing.

Q: Very interesting. I never – yeah. And a somewhat analogous problem, yeah.

Hans Berliner: Oh yeah.

Q: Fascinating, okay. Well, are there any other things you particularly would like to cover or mention?

Hans Berliner: I don't really think so. I don't consider my career in chess to be part of this. And so we've already covered on a number of things and I think that's quite enough, if not too much already. I think the one thing that I sort of feel: the end-all is the beauty of these various people who each contributed intellectually to the whole thing, until finally, maybe the profit motive in these micros, produced a machine that anybody can buy that can play world championship level chess.

Q: Yeah that is like a remarkable isn't it?

Hans Berliner: It's like a slide rule which can read out to 10,000 digits or something like that.

Q: Yeah.

Hans Berliner: It's just unbelievable. And so in a sense that's a wonderful comment on technology and the people involved in it, that something like that could happen. And that's something that we can all be very happy about I think.

Q: All right; very good.

Hans Berliner: Okay.

Q: Well thank you very much Hans for -

Hans Berliner: You're most welcome I enjoyed it.

Q: - for doing this. We really appreciate you taking the time to do this, this is wonderful.

Hans Berliner: Well my pleasure.

Q: Very good.

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