An interview with
HEINZ ZEMANEK

Conducted by Philip Davis
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Technical University of Vienna

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This is an interview conducted on Saturday, June 11, 2005, with Professor Heinz Zemanek of the Technical University in Vienna. The interviewer is Phil Davis.

DAVIS

I am just a few years younger than you are and I know how World War II influenced my education and later career. I wonder if you could say a few words about the same thing for you, how the war influenced your later life.

ZEMANEK

I had hundreds of protecting angels, and they looked also that I could also profit from the war. The first positive event was I got permission to go to my French friends in the year '39, just before the war broke out. Had I been in Vienna they would have picked me for the very first attempts to get the people together since I was not here when I came they said it's okay, you were away with our permission, you can continue to study. And that made it possible that I went into the one year of the history of this university where they had tri-mesters instead of semesters and so I could make all the second part of my studies in one year. On Wednesday, in early October 1940, I finished my last laboratory exercise here and on Friday I had my belongings in a little package and went to the barracks to become a telecommunications soldier.

DAVIS

You studied electrical engineering as a student?

ZEMANEK

Telecommunications, right. So I went to the barracks and again I was lucky because that was the period where I was neither sent neither to Poland nor to France or Russia, I was sent to Greece. At the beginning, I was with troops in Romania, and I was in Bulgaria, but most of my military

service I did in Salonika. In Salonika, I became a teacher in the telecommunications school of the German Army. My rank was not even Obergefreiter at the time; I was a normal soldier.

DAVIS

Priváte?

ZEMANEK

Private, you would say, yes. I had in my description, "typical Viennese" therefore I was not able to become Unteroffizier, and the guy who wrote that did not realize how thankful I was for that description. Anyway, that was a very fine time not only to learn the practical side, and some theoretical aspects. You said you were not interested in formulas.

DAVIS

No, not formulas but theories, and so on.

ZEMANEK

Even counting has certain funny aspects.

DAVIS

Counting?

ZEMANEK

Have you ever realized that the second decimal of counting contains only one number with a two at the beginning, namely, eleven to twenty, and that has a practical side, if you have to plug in telephone customers where number one has those with zero, number two has those with one, number three has those with two, so there is a shift, and to be careful with counting is something

you can use all your life. In particular if you use routines and you number them you never are sure did they start with zero or one. Is zero a number or not?

DAVIS

I have been writing something about how counting is impossible, and I'm thinking about the elections in the United States where to count large numbers is really a problem.

ZEMANEK

It is really a problem. On the other end, on the primitive end, you also get away without counting because you never count how many legs a cow has.

DAVIS

You don't have to count –

ZEMANEK

You look, you see.

DAVIS

That's right.

ZEMANEK

And looking is better than counting.

DAVIS

You can look accurately only up to about six or seven, and so forth, and then? –

ZEMANEK

Well, my limit is five.

A children's game, how many pigeons are on your roof, you know.

DAVIS

Yeah. Anyway, continue with your story.

ZEMANEK

That meant that I could make preparations for completing my studies, and indeed that's a complicated story, set of stories, how I managed to get out of the Army and to be called into radar development of the Germany Air Force.

DAVIS

What year was that roughly?

ZEMANEK

That I can you tell precisely, again in October, but this time '43.

Much too late of course, which I knew very well, and I knew it better the more I saw what was going on. But for me it was ideal. I made all my examinations, and I started my diploma work. For that purpose I had to be moved around. I was for a short time in Berlin, and then in Ulm, in southern Germany. I had a relatively short connection with the Technical University of Stuttgart. There, under the supervision of Professor [Richard] Feldtkeller, a famous name at the time, I produced my diploma work. But I submitted it to the University of Vienna because I did not trust the German universities at that stage of the war.

DAVIS

Was Feldtkeller very influential in your career?

ZEMANEK

Not in my career –

DAVIS

No I meant, excuse me, in your studies.

ZEMANEK

At the time, he was the expert on filters; he was the German "filter man". But the filter people in Germany made the mistake of not moving to modern mathematics, but that's another story.

DAVIS

That's very interesting. When you said modern mathematics what aspect did they not go into?

ZEMANEK

They had one guy, in Berlin, [most likely a reference to Wilhelm Cauer][1],[2]], who made up a formula by means of the Chebyshev approximation where the results tells you the structure of the circle. While these people stayed with the old method, the low-pass filter is a coil, the condenser in the core, etc.

DAVIS

Chebyshev approximation gives you equal - up and down.

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[1] W. Cauer, Siebshaltungen, VDI-Verlag, Berlin, 1931

[2] E. Cauer, W. Mathis, and R. Pauli, The Life and Work of Wilhelm Cauer (1900-1945), Proceedings of MTNS, Perpignan, France, June 19-23, 2000.

ZEMANEK

And it gives you a complex formula, and the formula tells you how to design the filter. In other words, you could produce the filter automatically. They had no computers at the time, but, if they had, they could have produced filters and even ship them fully automatically, which you cannot do by the trial and error method using Feldtkeller's approximation. This approach was used after the war. The whole of German circuit theory did not go fast enough.

DAVIS

I think the expression in English is hit or miss, just trial and error. Trial and error, was this Feldtkeller's approach?

ZEMANEK

That was. You had corresponding American people who did the same. Of course, you had German mathematics, but the connection to practical design was not strong enough.

DAVIS

What was the title of your thesis?

ZEMANEK

"Production of a Micro-second" is the short version. And how did I do it? I took a sine wave over-amplified it, so that I got a square wave, differentiated it, and then I had pulses.

DAVIS

Since you were originally in telecommunications and ultimately moved into computers, when did this change occur, and why did it occur in your career?

ZEMANEK

When I returned from Germany. I did so a little later because I had information that the Russians had taken away, from Vienna to Moscow, people, not absolutely with their free will, who knew much less than I knew. I said I will not return to Vienna until these people are back, and that was February 1946.

DAVIS

These people were essentially kidnapped by the Russians, or compelled to go to Moscow?

ZEMANEK

To work in Russia -

Do you know what is "beite Deutsche"?

DAVIS

No.

Were there any particular people at that time that influenced you to go into computers?

ZEMANEK

No.

DAVIS

This was on your own?

ZEMANEK

You see, we were a set of assistant professors at that time and the situation was such that the war had interrupted general development. America had not been hindered in development. So the German literature explained a number of things that had not happened over here. So we had a large spectrum of things to try out and to recover what was lost. The computer finally won out, and this could not necessarily be seen at the beginning.

DAVIS

When I think of the individuals and personalities in America that were in the early stages of computer development, of course, I think if Vannevar Bush, and then I think of Howard Aiken and [John] Mauchly and John Von Neumann, and so on. Can you think of some more names of the American computer people that I missed? Was Sam Alexander one of them, would you say?

ZEMANEK

He was important for the development of computers in The National Bureau of Standards –

DAVIS

That's true, that's where I was.

ZEMANEK

He was one of a large spectrum [of individuals]. The point where I first came in, very naturally, was with Aiken, because he organized meetings, and I managed to be invited and to get the money to come. That's another complicated story; I had no money at that time.

DAVIS

That interests me as a matter of fact because, although I didn't know Aiken, I was a graduate student in the building next to his computation laboratory. There were a lot of stories. What was his personality?

ZEMANEK

Aiken?

DAVIS

Yes, Aiken.

ZEMANEK

First, he went his own particular way. Secondly, he was much more of an architect than a builder. In other words, he did not care in which technology to proceed, but he cared to proceed. And that explains why he built three computers with relays [Harvard Mark I, II, III].

DAVIS

These were relay computers?

ZEMANEK

Relays, yes. And only later he switched over to tubes.

DAVIS

I have an opinion, personal opinion, of Von Neumann and I wonder whether you agree or disagree. I think that his importance in the development of computers is overrated.

ZEMANEK

No, I would not agree with you.

DAVIS

Not agree?

ZEMANEK

You cannot overrate him; however, you have to distinguish what you are talking about. You see, mathematicians did not have a high opinion about numerical calculations –

DAVIS

In those days that's correct.

ZEMANEK

That's something which the house master does; it was necessary to have John von Neumann make mathematicians understand that there was a scientific revolution and not simply one in technology of numerical calculations, that's number one. Number two, he, like Aiken, was an architect, but moreover he understood that an architect at that point in time had to spread knowledge. And that explains why he wrote two, you would say today, computer architectures, after which full sets of computers, not only in the States, were built.

DAVIS

These are called von Neumann architectures, that's what they call them.

ZEMANEK

The von Neumann architecture, God has invented. That in essence is trivial, that is the point. In this sense,

von Neumann is overrated, yes. Sometimes Americans claim, if there is a genius, he has invented everything, which is certainly not applicable to John von Neumann.

DAVIS

I think this is what I was referring to, this tendency to overload everything on him. I remember there was an International Congress of Mathematicians in Cambridge, in 1950. It was the first international congress after the war, and I had just gotten my degree. Von Neumann gave a talk and it was full of the number of tubes and the number of brain cells in the head, and so on, and so on, that kind of thing. In the business of assigning credit to a development that is as complicated as the current computer, how do you assign credit to individuals? Many of them are brilliant individuals and their names are not known to the public.

ZEMANEK

Oh, computer history, of course, it is rich in detail. You just referred to the year 1950. If you check the literature of the time, you will find that one of the big subjects was "Can machines think?"

DAVIS

Absolutely, yes.

ZEMANEK

I can give you [the names of] a number people, at least ten important people, who wrote about the subject at that time. John von Neumann, as you know, worked in that direction. Only he couldn't finish. You know the story about this set of lectures he intended to give which he couldn't give because his disease had already caught him.

DAVIS

No, I don't know that story. I know about the disease, I think he died in '56, '55 or '56[3].

ZEMANEK

He had an invitation to give a series of lectures. He reduced them to one, and finally he couldn't give it. He wrote the manuscript, but it came out after his death, and it is my conviction that he would not have agreed to the publication because it has a misleading title.

DAVIS

What was the title, do you remember?

ZEMANEK

"The Computer and the Brain"[4].

DAVIS

Oh, "The Computer and the Brain".

ZEMANEK

He doesn't talk about the brain. He only talks about the computer, or he talks about the brain as seen as a computer, which is not the full story.

DAVIS

Well you know there's still discussion on this question. Is the computer a brain?

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[3] John von Neumann died on February 8, 1947

[4] John von Neumann, *The Computer and the Brain*. (New Haven/London: Yale University Press, 1958.) This is a published version of the Silliman lectures at Yale which he intended to deliver in 1956.

ZEMANEK

It is not –

DAVIS

And does the computer think, and the people that get involved in this [question] include technologists, artificial intelligence people, philosophers of science, and so on. There is one artificial intelligence man at MIT; his name escapes me at the moment -

ZEMANEK

Are you speaking of Minsky?

DAVIS

Yes, Minsky. Marvin Minsky said that people are meat machines, that was his expression, meat machines.

ZEMANEK

Yes, that is simply wrong.

DAVIS

Can you say just a little more about the machines thinking and so on?

ZEMANEK

That is of course a matter of definition. If you restrict the notion of thinking to what the machine does, the sentence becomes right. But, we think now for some ten thousand or more years, and to come in and to say oh you have to restrict that to the machine's [capabilities] that is not correct, in

view of history first of all. Secondly, Mr. Minsky cannot explain the phenomenon of mind. A machine has no mind.

DAVIS

What is mind?

ZEMANEK

You don't know? You know better. You know what mind is before you start your studies. Therefore you should not ask afterwards. This is a similar to asking what is time. Don't ask for the nature of elementary notions or you're into philosophy and then things change totally.

DAVIS

You know there's a joke that comes from Bertrand Russell. It makes sense, I think, only in the English language but maybe it could be translated into German. The joke was that the philosopher, when he was a student, asked the question "What is mind" and the answer was "Never matter", and "What is matter", "Never mind". Do you know that joke?

ZEMANEK

No, no.

DAVIS

Well as I say I didn't know if it translates.

ZEMANEK

No, it does not translate.

DAVIS

It doesn't translate, because there's a pun in the thing.

ZEMANEK

Don't mind.

It has no good translation.

DAVIS

But going a little bit, maybe going back to '35 or '36, I am reminded of [Alan] Turing. Now how influential was Turing in the computer business? I think that his reputation is also overrated in America.

ZEMANEK

Americans have the tendency of concentrating a full field on one person. That is the constant tendency Americans apply because it's clear. They are not used to complicated patterns like Europe. America is a nation that has few neighbors.

DAVIS

Well, that is true, Americans over simplify, and they reduce things.

ZEMANEK

Let me talk to the question of Turing. Turing has done a lot for computing, first of all with the deciphering machine, Colossus.

DAVIS

Yeah, well this was during the war.

ZEMANEK

It was during the war, and it was not a real computer. It did not calculate. Look at the structure and you will find out. If you want to look into this you'd better talk with Brian Randall[5]. He was shown the full material even that which is not permitted to be published. He could tell you a lot. Well, again, this is a fine structure about which one can discuss. We need not discuss it.

DAVIS

No, I don't want to go into the structure of the cryptography.

ZEMANEK

The next is his Gödel paper, which he gave the wrong title, intelligent machines or so[6], I don't like to quote because I have a bad memory for that. The fact is, if you read the paper, you will find that "intelligence" appears in the title and nowhere in the text. Secondly, his introduction is absolutely the contrary for a man who is a logician, because he said scientific definitions can be made by democratic election, so to say, by voting.

DAVIS

By votes –

ZEMANEK

By votes. If you take the whole population, they will vote that a whale is a fish -

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[5] Brian Randall, "Of Men and Machines", pp. 141-149 in B. Jack Copeland editor, *Colossus: The Secrets of Bletchley Park's Codebreaking Computers*, Oxford University Press, 2006

[6] Alan Turing, "Computing Machinery and Intelligence", *Mind*, vol. LIX, no. 236, October 1950, pp. 433-460.

DAVIS

A whale is not a fish –

ZEMANKEK

It is not a fish. So whatever some people think, they would likely be wrong if they made the decision by vote. He invents this game where a human being is sitting and there is a switch and the human being has to decide whether there is a computer or a human being –

DAVIS

This is called the Turing test –

ZEMANEK

The Turing test, yes. And what he concludes from the fact that one cannot distinguish between answers that they are equal. At once, you can convince yourself it is logically pure nonsense.

DAVIS

Oh, the philosophers have agreed with you on this.

ZEMANEK

Maybe I mix two papers. Let me see there is one paper by Turing on the decision problem[7] and there's the other one on the problem can machines think. And you know those four volumes about mathematics[8]?

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[7] Alan Turing, *On computable numbers, with an application to the Entscheidungsproblem*, Proceedings of the London Mathematical Society, Series 2, 42 (1936), pp 230-265.

[8] *Collected Works of A. M. Turing: Mechanical Intelligence, Morphogenesis, Pure Mathematics,* North Holland (Amsterdam, London), volumes 1-3, 1992; vol 4, 2001.

DAVIS

Which ones? I know of four volumes in Russian. You're thinking of an English language volume?

ZEMANEK

An American volume, it was printed on 5th Avenue. What's the big bookshop in New York?

DAVIS

MacMillan? Do you mean a scientific publisher?

ZEMANEK

It was a collection of papers. In the last volume, Turing's paper appears under the title of "Can Machines Think", and that is to be separated from his Gödel paper, where he shows nondecidability.

DAVIS

Yes, that's a totally different issue.

ZEMANEK

Only what people call a Turing machine is not a computing machine it's a proof machine, and these are two very different things.

DAVIS

Well I think this confusion still persists. Let me change the subject a little bit and get a little more personal. In computer development, what do you consider your significant accomplishments?

ZEMANEK

That I got a computer going in Vienna at this time at all.

DAVIS

What year was this?

ZEMANEK

I started with considerations in '54, and it ran in '58. The real construction time was '56 to '58. First, I did a small relay model, but it was clear to me that a relay machine was not what I was interested in, simply because at that time it was already obsolete. With tubes you cannot start in a poor location like Vienna [after the war], you can get tubes, but it was much more difficult, you get a lot of energy in and you have to get it out again because it was transformed into heat. I knew about the problems in other countries, mainly in Germany. I saw a lot, and that was not the way to go. So I needed transistors, I had to find out who can give me transistors for nothing, that was problem number two. I found Phillips to give them to me. But they said I can only get hearing-aid transistors. The fast ones we still had to buy ourselves. And therefore I came to a conference in Darmstadt fifty years ago and said I will build a transistorized computer in Vienna. Since I have, however, only hearing-aid transistors, it will not be very fast, a whirlwind will not be possible. But it will be sufficient for the Viennese "Mailüfterl"[the first fully transistorized computer in Continental Europe]. I realized that I had to be slow, but we developed methods so that we were not so slow, and the transistors were finally better than we thought. We had a ten hundred thirty three kilo cycles switching speed, and that was not bad.

DAVIS

In order to build a computer you have assemble a team of people.

ZEMANEK

That was the smaller problem because I had all the students at hand and I could give out diploma work to those who I suspected could be a member of the team and that was, in fact, the way I organized the team. Only you cannot develop a computer with diploma work only, it is a full business to develop a computer so I needed some money to get it done over time.

DAVIS

So it was successful though.

ZEMANEK

I got it right.

DAVIS

Did the computer that you make have a name?

ZEMANEK

Mailüfterl.

DAVIS

Oh yes, yes, you told me, right.

ZEMANEK

The people who doubted it were absolutely wrong; the fact was the Americans had to learn how to spell the name Mailüfterl. [Laughter].

DAVIS

Speaking of hearing aid transistors, I think the problem of hearing aids is not yet solved properly, and the reason I say this is that I have an older sister who has a hearing aid and it gives her much trouble.

ZEMANEK

They have now hearing aids that distinguish between noise and language and so on. But, I have another answer to your question is the computer a brain. Where is the brain [in this]? In this case, you have the problem that the brain is not a computer and you cannot serve it with a simple computer input.

DAVIS

Speaking personally, you get an idea to do something. Have you every thought about where ideas come from? Do they come from experience, intuition, or what?

ZEMANEK

You are coming again to the same point. You ask me what is thinking? The point is this, there are people who believe that the computer can replace the human being and can become even stronger. They have never considered how does a program come into existence. You can write a computer program in logic, but you cannot write a program that develops a program from the illogical example, from the illogic situation in which you start. And that's the true answer to your question. There is something in our brain called mind and this funny thing makes it possible to conceive a new idea, and after a while you can sit down and write equations, or a formula.

DAVIS

So this is a mystery, mind is a mystery?

ZEMANEK

Yes. And I'll tell you why. First of all you cannot really observe yourself.

DAVIS

There are a lot of people now who think that they're getting closer to understanding mind. I don't believe it –

ZEMANEK

Getting closer is something, but it is different to arrive.

DAVIS

Well that's true. Let me change the subject again.

ZEMANEK

No, let me make one more one more remark to this. Who can be sure if the human being, if the human brain is enough to understand the human brain?

DAVIS

Well is this is a question of self-reference, and so on?

ZEMANEK

Not only that, because in this case what comes in is the number of building elements, it's ten to the tenth, no.

DAVIS

Ten to the tenth, yes.

ZEMANEK

And you know that the single unit is not the bit, first of all the brain is not a digital device. You know the paper by McCulloch and Pitts[9]. I have discussed it more than once.

DAVIS

Did you know Pitts?

ZEMANEK

No.

DAVIS

He was a strange person.

ZEMANEK

I can imagine.

DAVIS

Yes, a very strange person. I met him once, McCulloch I didn't [meet].

ZEMANEK

Gödel was also a strange person. I met him once; it was the hardest hour of my life.

[Laughter].

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[9] McCulloch, W. and Pitts, W. (1943). A logical calculus of the ideas immanent in nervous activity. *Bulletin of Mathematical Biophysics*, 7:115 - 133.

DAVIS

I never met Gödel, I heard him give a lecture and I didn't understand a word. And the lecture was in English too.

ZEMANEK

Yes. That happened to me with Planck and Lauer.

DAVIS

You heard Max Planck?

ZEMANEK

Yes, and understood every word. Then I heard Lauer and understood not a single word.
Let us come back only to this paper [by McCulloch and Pitts] and then I stop my comments. This paper needs improvement. Since the brain has no rhythms, you must define what is the moment at which a connection is made. And you get three inequalities. They tell you when it is too early; from then to then can contribute and after then it's too late. And if you add those inequalities to the paper of McCulloch and Pitts, you cannot make any sense of that paper.

DAVIS

McCulloch and Pitts were assembled into a group by Norbert Weiner. Now actually I was a student in one course of Weiner's. He was another character, obviously a very brilliant man. Now someone recently, perhaps ten years ago, wrote a book comparing von Neumann and Weiner and making the equation that Weiner was analog and Von Neumann was digital, and the digital won over the analog. And now I read somewhere that the analog is coming back in certain cases. Can you comment on this conflict between the two?

ZEMANEK

I don't agree with what you just said, from the point of truth and so on. Because if you think you don't think digitally what are concepts, you process concepts, you have ideas that far away from what is it called *** logic.

DAVIS

Oh, zero-one logic, outside of that.

ZEMANEK

And additionally, you never must forget that, yes, no logics requires points of time in which to work. You have in between in the real world transitions and in the time of the transition you do not look at the logic. Okay, but these are all long lectures which we cannot prove on the paper; there is no question that you find in Norbert Weiner's book, Cybernetics, chapters on the digital computer, only with Norbert Weiner's description you couldn't build one. I doubt they were assembled by Norbert Weiner. You over estimate his ability to organize.

DAVIS

Well he had great trouble with these people, as a matter of fact.

ZEMANEK

Because he is not organized –

DAVIS

With McCulloch –

ZEMANEK

McCulloch was in misery also –

DAVIS

And then Pitts disappeared from the scene –

ZEMANEK

I didn't know about that –

DAVIS

He was self-educated, Pitts was a self-educated young genius, and so on –

ZEMANEK

A formal education produces fewer fools.

DAVIS

Produces fewer fools?

ZEMANEK

Fools in the sense of not knowing, the university produces a lot, that's another point.

DAVIS

Yeah, but self instruction produces more. That's very interesting, I've never thought about that.

ZEMANEK

Okay, coming back to Norbert Weiner and John von Neumann. Norbert Weiner in many cases throws an idea into the air and Shannon grasped it and made something of it. That is true for

information theory and to a certain degree you can tell a similar story with the computer, only not with Shannon. By the way we could talk about switching algebra, are you aware of the fact that the Japanese were first?

DAVIS

No.

ZEMANEK

I could show you. We should have made the interview in my room. I have a volume, in English translation of course, all Japanese papers that go back before Shannon's statement. In other words, when the Japanese moved into the computing field they had their own switching algebra.

DAVIS

Are you referring to Shannon's work on information measurement and so on? Is that the work of Shannon you're referring to?

ZEMANEK

No, Shannon wrote his first thesis was on switching algebra, that is the merely the work of relay contacts.

DAVIS

I met Shannon once, he was working at Bell Labs, and I had just gotten my degree. I went for a job interview, and he interviewed me. I had some questions about what they do, and so on. And I think he wanted to hire me, but I was not in love with the kind of material they were doing there since my degree was in pure mathematics and in approximation theory. And then I got the offer

to The Bureau of Standards where they were developing in the first generation of computers, what's the right way of doing this and what's the right way of doing that.

ZEMANEK

I propose not to forget that Shannon was by his whole nature an engineer, only he was a master of looking into the warehouse of mathematics and picking the right device. You know this story of information theory with Gabor?

DAVIS

No.

ZEMANEK

I met Gabor very early in his career when he was not yet a full professor and worked in London.

DAVIS

What was his first name?

ZEMANEK

Dennis Gabor.

DAVIS

He worked in the University of London?

ZEMANEK

No, he worked at the Imperial College.

And you know with the hologram he made his Nobel Prize[10]. When he started, a little before Shannon, he developed an information theory[11]. He also went to the warehouse of mathematics, but he grasped the wrong item. Instead of using the sin(x)/x, he grasped [modulation and translation] of a Gaussian.

DAVIS

An exponential?

ZEMANEK

Yes, in the problem, the difference is the following.

The sine function has a true zero every two pi, okay, that function gets very small but not zero, and if you add up infinitely many it is not zero. And that was the breakdown of his theory. Shannon was by his nature an engineer. If you come with the mind of a prepared pure mathematician you are on the wrong spot.

DAVIS

Well, I, from what you say, I think I was lucky not to go to under his direction.

ZEMANEK

Yes, exactly, so I would say.

DAVIS

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[10] In 1971, Dr. Dennis Gabor was awarded the Nobel Prize in Physics for his discovery of holography in 1947.

[11] D. Gabor, Theory of communication. *J. IEE (London)*, 93(III):429-457, November 1946.

Right, because as I say I had just been a pure mathematician, but prior to that my Army service was at NASA, and I was there an aerodynamicist, and that was the first time I learned about numerical methods, and so on. We were still using slide rules.

ZEMANEK

Yeah, I can image. You know the advantage of the slide rule in comparison to the computer?

DAVIS

Tell me.

ZEMANEK

You have to think about the powers of ten –

DAVIS

Absolutely, and it's terrible. And now the students make computations and they come up with ten to the sixteenth cows in Austria, things like that, they don't think. Could you say a word about what you think of the field of artificial intelligence, let's go back to the brain again.

ZEMANEK

You want a one sentence answer?

DAVIS

Why not, then you can make two sentences.

ZEMANEK

One sentence is, it is either intelligent or artificial, never both.

DAVIS

Never both. Okay now make an elaboration.

ZEMANEK

Here is an elaboration to that story. It goes back to the time we talked about already, around the 50s, when the computer came along and it was difficult to explain to people what the computer really does. Have you every met Mr. Berkeley?

DAVIS

Edmund Berkeley? No, I never met him.

ZEMANEK

I met him. We were even on the point that he would have given me one of his models, but then he died and it could not be realized. He wrote that book "Giant Brains or Machines That Think"[12]. But his intention was not to assume that the computer really thinks, but what he wanted to show is that machine power enters a new field. Then came all those papers about can machines think or not. McCarthy –

DAVIS

John McCarthy?

[12] Edmund Berkeley, *Giant Brains, or Machines That Think* (1949), Wiley & Sons.

ZEMANEK

Yes, he was at my first IFIP computer conference in '64. When McCarthy coined this sentence at Dartmouth College –

He should have been wiser.

DAVIS

Well, maybe we all should be smarter than we are, but –

What was that [sentence]?

ZEMANEK

You see what was meant by artificial intelligence is quite clear; you do programs that are not of a numerical nature. They resolve problems that you have to be intelligent to solve. That's okay. Now on one hand, if you use more complicated mathematics you also have to be intelligent, an unintelligent man cannot do more substantial mathematics. But here it was in the context quite clear that they went out of numerical mathematics and went into a kind of problem solving. Another man, whom I don't have here on the list, is of course Popper, the philosopher.

DAVIS

I read Popper's stuff.

ZEMANEK

I have met him several times. I was at q summer school and I heard the last discussion between Lawrence and Popper –

DAVIS

Carl Lawrence, the biologist?

ZEMANEK

The biologist.

DAVIS

Popper was for many years in London, but I think he was originally from Vienna.

ZEMANEK

Yes, born in Vienna, but he was Sir Karl Popper in the United Kingdom. He created the sentence, "all life is problem solving". But he's absolutely wrong. That is the view of a philosopher who specialized in problem solving, and who finds that whatever he thinks of can be turned into problem solving. But that's not what you and I do. It is not what students do. It is not what a child does.

DAVIS

There's a tendency that if you know something, if you know a certain field, then you see the whole world in terms of that field. This is a terrible limitation of vision, of thinking.

ZEMANEK

You've just given an excellent definition of artificial intelligence. You have to be very intelligent to write those programs but the program in itself is not intelligent.

DAVIS

Was McCarthy the inventor of the phrase "artificial intelligence"? –

ZEMANEK

Yes.

DAVIS

Again, I want to change the subject. What do you see as the future and development in hardware, and also what are your observations about the interaction between hardware and software?

ZEMANEK

There is an interesting point that I do not understand. You know that if you write software you write in the methodology to move hardware (Are we okay on this tape?) –

DAVIS

Yes.

ZEMANEK

Since hardware by necessity is based on, and now I use the term, propositional logic –

DAVIS

Propositional logic, yes.

ZEMANEK

A computer can do nothing but propositional logic, and you have to be careful how you treat time. There are ways of having analog time, but today we have only quantized time. You can do asynchronous circuitry. But, actually when you want to stay with real computing, you have to look at only distinct points, when something happens. I could go into it, but there's no need to go into too much detail. So now I need my thread again, yes, hardware and software –

DAVIS

Hardware and software, the interaction.

ZEMANEK

So, we have to agree that both software and hardware are based on propositional logic. We can even be sure that nothing has happened because nothing is in the machine instructions. All is done using zero-one connections. In principle, you could transform everything into four elements, that is, time, a shift of a fixed amount of time, negation, conjunction and disjunction.

DAVIS

Time is the clock?

ZEMANEK

Time is the clock. So you have a perfect order, and, indeed, the computer works so reliably and can do so much, and can go so fast, that you don't see anymore. The secret is this kind of safe, simple logic. There were times in computing where multi –

DAVIS

Multi-valued logic?

ZEMANEK

Yes, was under observation. Have you ever looked into this?

DAVIS

No.

ZEMANEK

If you go only from two to three [valued] logic, you get so many basic functions that you cannot work with it.

DAVIS

Now they talk about fuzzy logic.

ZEMANEK

That's another method, that's another topic.

That is my friend Lofti Zadeh. The point is there that the logic is not fuzzy. It's a strict logic that you apply to fuzzy situations, and he clarifies how to do that.

DAVIS

That's good.

ZEMANEK

Logic is always clear. The funny thing is that hardware can be made reliable, and incredibly reliable, but not software. How does it come that two fields of knowledge that are so similar, that are based on exactly the same propositional logic, behave so differently? When a computing program goes wrong, it's always software. If the hardware was wrong in 99 of 100 cases, and I say that very roughly, it stops totally.

DAVIS

That's very interesting that you make this remark, because going back to the first days of the digital computer when they had tubes, that even people like Von Neumann were talking about the probability of a tube failure, and so forth, now we don't have this question.

ZEMANEK

Because they found out it was not worthwhile to look on it. I can show you one of my publications where I developed circuits with probabilities and so on. You asked about my diploma work, which was telegraphic by time divisions, therefore, total digitalization. Then I had to write a habilitation to become a docent. There I failed with my first subject because when I went to look into the warehouse of mathematics I did not find the tool I needed. The idea was the following; you have information theory as Shannon conceived, that is, essentially in time. I wanted to construct a parallel theory in the complex frequency domain. I would have needed the mathematics, how are they called, something functions, a man's name, Welch functions?

DAVIS

Walsh functions?

ZEMANEK

I didn't find it at the time.

DAVIS

Walsh functions. I was a student of [Joseph L.] Walsh, as a matter of fact, and I wrote two joint papers with him. He did his Walsh functions in 1922, or '23.

ZEMANEK

I believe so.

DAVIS

Yeah, and then in the last years of his life they suddenly became important. His whole life, professional life, was [devoted to] approximation theory in the complex plane. It is a very paradoxical situation. But then very interesting -

ZEMANEK

Well, in any case, I wanted to create an information theory in the complex plane and I didn't find the tools. I was already at the end of my ten years period as an assistant, so I had to find something else, and I did the following. You know John von Neumann's theory about the nervous network where he ended up with bundles of so and so much and those democratic functions? I introduced feedback into this, and I could reduce the number of lines from this ten to the fifth to one hundred, and that was a bit closer to the reality, and it was sufficient for my habilitation.

DAVIS

Okay, shall we continue, are you getting tired?

ZEMANEK

No, we can continue.

DAVIS

Let's continue for a few more minutes.

ZEMANEK

We have not finished the question of software.

DAVIS

It's still working (referring to tape). The relation between software and hardware.

ZEMANEK

Why are there so many wrong things in software than there are in hardware? There are two kinds of explanations. The one is the environmental explanation; software is the point where you need to connect the idea with the real world. And the real world is not logical. If people say that this is the "logic", that's far away from any prepositional logic, it's often contrary to it. So you need the computer to bridge between the formal world of computing and informal reality. Yesterday, I made a joke, if you heard it; one should before using a computer define a human formally, because only then you would have no problems with the bridge between the computer and the real world. But this is not the real explanation. It is part of the whole problem, but the real explanation is this, human imperfection applies to software in a much different way than to hardware. In hardware you can afford to check the correctness of the circuits because if you do it once for a full production line and you can be sure it's okay. I have to tell you an interesting [piece of] information I got from my IBM friends, I came there at the time when they first started designing circuitry by programs, and they found always afterwards mistakes, and they had to correct them. The funny thing is that the number of discoveries they made went down, but they had not reached zero. They said if there are only four we can [still] use it.

DAVIS

Well this is like trying to achieve perfection. Perfection is inherently difficult.

ZEMANEK

No, in principle, it worked. [Laughter] Software is of different nature, you don't control that much, you don't check that much, you write it. I give the full story, I consider the reason for that [problem] in software is that mathematicians have done it. You see a mathematician is used to the fact that behind him is the big building of clear mathematics, and whatever he does somebody looks over his shoulder and says fine or not so. The moment you go outside numerical calculations, there is no one anymore to assure them. And today how software is organized is already not the way hardware is organized. We have accepted it; we believe in it. I would say I see one way to remove the difficulties and that would be to stop worldwide programming, return it to the universities, and have one giant institution charged to develop an engineering program, one which is as safe as engineering.

DAVIS

What about the fact that a program, a large program, is made by many different people and they have to do this, they have to connect –

ZEMANEK

Well, I have to give you a long primitive answer, and I could say hardware is also produced by more than one man. But your question is absolutely right, you have too many people involved and moreover actually you can't see everything. With hardware you don't see anything either because it's so small, but you make excellent checks and you are absolutely sure that hardware is okay. But a program you never know really exactly what happens in the computer because you don't see it. There are so many question marks that software is not okay.

DAVIS

I just want to take up two more topics and then we can bring this to a close, because I'm sure you're getting tired, I'm getting tired. I noticed in one of the talks that you've given in the "Stetterfest" mention was made of Moore's law.

(Tape SIDE B)

ZEMANEK

In the smallest computer chip, you need interconnections and you cannot afford to lose too much time on such an interconnection. If you go to a femtosecond, you can investigate what is the smallest wire I can print, and the answer is it consists of 1200 by 120 atoms, to get safe computations. Otherwise, you are not sure that enough electrons pass by to properly work. So the femtosecond is the absolute end. There are physical reasons too; I've checked with physicists, that it is the absolute end of electronics. You need a more flexible way to become faster and smaller. And the first answer is not the quantum computer, the first answer is light. Moreover, we have already a number of things, using light. There is already a device which can store, I memory, we have logic circuits. What you need is not only amplification, you need reshaping of the signal, otherwise it gets less and less reliable. It's now the task of physicists to develop those possibilities and understand they have good chances of achieving them. So around 2015, when the femtosecond is reached they should be far enough along to say forget electronics we can do it now with light technology. I would say six powers of ten are easily attainable by this change. Then your real question becomes what does that mean to humans?

DAVIS

Precisely.

ZEMANEK

So we don't even have to discuss whether a quantum computer is reasonable or not, let the physicists try it. That will take some forty years before it really works, so should they start now. But let us turn back to the size of memory, the speed of operation we have discussed already. Now first of all we come back to the question of software, we are not using software in a reasonable sense. Switch on your computer; what do you see, and what is your requirement. You first see a lot of information which is no information for you, each time they tell you which company has done it, a number of numbers, and of codes and so on, which tell you nothing. And you don't have to know. Before you get your computer to really work for you, you have to wait while they copy in programs. They have not yet realized that they are on the wrong track as far as programming is concerned. And you come to the conclusion, which is true already today, the computer requires of its user more discipline than it has. You know, yourself, you use unsystematic names for your files and you are unable to find them again. I can give you hundreds of examples. If you sit yourself before the computer, the discipline you personally bring is not enough to make proper use of the computer. Now you can generalize to society. Is it really true that the computer has in these fifty years of existence helped us to improve the work of technology? It has increased the number of application fields, yes, but in any single one that you pick out it has not become easier to use, because very rarely is there or improvement of adaptation to real human needs. That is still missing.

DAVIS

Well, let me ask you one final question that is an extension of what you just said, and then we can terminate this interview which I found very revealing and I hope that you found stimulating. The question is, as a young man who went into the computer field, did you ever foresee that a half century later that the computer would affect everyone's life on earth to the extent that it has, and even to the remotest mountains of Afghanistan?

ZEMANEK

The answer is no. What I did realize, in my very early years, was that the computer is not restricted to computing. For me, the computer never was a mathematical machine it was an information technology machine.

DAVIS

Now of course that's the difference between you and me because I always thought of the computer as a mathematical machine.

ZEMANEK

Well, I can even prove it to you. [Laughter]. You know what the first text was we moved into the computer?

DAVIS

No, what.

ZEMANEK

Wittgenstein's Tractatus [Logico-Philosphicus].

DAVIS

Oh, my goodness.

ZEMANEK

The background to this was the following. I had to study Wittgenstein. You know there is a house which he built in Vienna.

DAVIS

Yes, I've never seen it; he was a bit of an architect.

ZEMANEK

Yes he was a bit of an architect. Wittgenstein as you know, was a colleague of mine, not in philosophy, he was educated as an engineer.

DAVIS

Yes, he had a job in Manchester, England, as a –

ZEMANEK

His start was in engineering. In Vienna, I'm not really sure but in Charlottenburg, in Berlin, and then in England, and what he studied was engineering, generally speaking. His language was not the language of a programmer, that didn't exist yet, and it's even not the language of a philosopher. My idea was to put text into this computer and then make vocabulary replacements to adapt it to the language of the programmer and to the language of the philosopher. And to my big disappointment, we found out that this cannot be done because no single word appears often enough that its replacement would have any effect. But I did something else, I applied the Tractatus to the Vienna street car system, starting with the sentence, "The Vienna street car system is everything that is the case". And can you imagine how this looks. What turned out was absolute nonsense text, but it displayed the methodology. Immediately when I told one of my professors about it, he was a professor for photography and cinematography; he said this is, what's the Jewish system?

DAVIS

The word in Jewish?

ZEMANEK

No, actually he called this Jewish,

DAVIS

Oh, I'm not sure what you mean.

ZEMANEK

You have the holy script in Jewish, but then you have the –

DAVIS

Commentaries? –

ZEMANEK

Yeah, he said this is the method of the commentaries.

DAVIS

I see, I see.

ZEMANEK

And probably, I am not a specialist, I cannot judge it, but probably he was right in this.

DAVIS

Okay, thank you very much Professor Zemanek, it was a great pleasure for me.