Capturing the Past, Inspiring the Future

Professor Kevin Warwick

Interviewed by

Tom Abram

10th June 2019

In

Tilehurst, Berkshire

Right, so we're now recording. So, I'll just do a little bit of an introduction, to say that, it's the 10th of June, and, we're in Tilehurst, at Kevin's house. And, I'm Tom Abram, I'm the editor of the Archives of IT. And, I'm interviewing Kevin Warwick, who is a British engineer known for his studies on direct interfaces between computer systems and the human nervous system. You've done a lot of research on AI and robotics, and, have earned the nickname of Captain Cyborg.

Mhm.

You are an Emeritus Professor of Cybernetics at the University of Reading, and also at Coventry, where you are Deputy Vice-Chancellor for Research.

[00:54]
So, our aim is to, to find out about leaders in technology, what they've done, how their background has influenced, how the people they've worked with have influenced all that, and, what you've learnt along the way perhaps.

Mm.

And lessons for the future. So, I'll… If it's a good place to start, I'll just ask you about your start in life, and, and what kind of a childhood you had.

Yeah. I mean I had a very happy childhood. My father was a primary school teacher. My mother was a, mother, a stay-at-home mother, to start with, although, I would say she had to go to work for a while. I was born in Keresley, Coventry. And, it's now the, what used to be the hospital, is now a pub/hotel type place. But, I don't remember too much of that. What I do remember though, until I was three and a half we lived in a prefab in Coventry, in Cheylesmore, and, it was a great community. I had a… Although we left when I was three and a half, even by that time I had a little pedal car, and used to pedal around. It was a really quite safe environment. So it was a sort of, a network of these prefabs.

Yeah.

They've all been pulled down now, which is a shame. But it was a lovely place. But when I was three and a half we moved to Ryton-on-Dunsmore, which is just outside Coventry, which is really where I grew up. So I went to the local village school there. And, I can remember, I mean this is terrible, but remember the greengrocer used to come along in a horse and cart, and, and OK, we're talking about the Fifties and the Sixties, but, still, they had greengrocers on horse and carts and things like that. And the roads were very quiet, so we could play out in the road. And I spent a lot of my childhood playing football on the recreation ground, which I absolutely loved and still love it.

Yeah? I think football figures in your interests at school, does it not?

Well it, it does, in a number of ways. I used to love playing soccer, the proper football, but I went to my secondary school it was rugby union only, we couldn't play soccer there. In fact you, you were told you would be getting 100 lines and things like that if you were caught kicking a tennis ball around or anything like that. And I don't, I, I played rugby union for a while. I wasn't too bad, and played in the school team. But after a while, I loved soccer, and so I ended up getting away from the school, ended up playing soccer in the Coventry leagues. Even though I went to school in Rugby.

Yeah.

[03:53]
At Lawrence Sheriff, in secondary school. But, but when we lived in Ryton, I was a, an only child first of all, and my parents decided to adopt a daughter. My mother kept telling me that I wanted a sister; I think she wanted a daughter, was more to the point. And we started to adopt a little girl we called Joy, but, at that time my father developed an illness. It was agoraphobia. People might think phobias are just phobias, but this got serious. He had to stop work. And in the end he, he was just stuck at home. He couldn't get out of a room, in fact he was in the lounge, and it was pretty awful. So I can remember him trying to go on the driveway, and he was sweating and screaming and so on. And it just got worse and worse and worse. And in the end, when I was about, eight, I guess, he had an operation, went to Smethwick,

for neurosurgery, and what, as he described it, they drilled a couple of holes in the top of his head, and cut out some of his brain cells. And, this, it very quickly, he, he had a little bit of a temper for a while, but very quickly it cured him of the problem.

Really?

And, this for me was fantastic, because at that age, the small change to the human brain, and, he was a completely different person. And rather than the phobia of not being able to go out anywhere, he would go everywhere. He would talk to everybody. I mean he was completely the opposite. So for him it worked. I think it was highly dangerous, although I didn't realise that at the time, but I can remember being so… They wouldn't let me see him in hospital when he had had his head shaved, but I didn't let that stop me. I wanted to see my dad. So, I ran down the corridor to go and see my dad, which, which he loved.

Was that a well-established treatment in those days?

[hesitates] Well-established…

Was it experimental?

I think it was experimental. I mean it's a lobotomy, or leucotomy. They cut out part of his brain. For him it worked. I mean I, I really don't think they do it now, which in a way is a shame, because for him, it really worked. And, not only had, you know, not only had him back, I had him back better than he was in the first place. I mean, and he went on, and he never had any problems like that again. So, just showing, this, this whole concept of a phobia and the links between some of the connections in the brain, and that had an effect on my later career in terms of what could…

Yeah. That stimulated your interest in the whole brain. Yes.

Oh yes. Oh yes. And small changes to the human body can make big changes to who you are and what you can do.

[06:48]
Yeah. And I see there's reference in, in your notes, the fact that your grandfather had Parkinson's disease as well.

Yes.

Is that another influence in that direction?

It is very much so. My mother's father. I only remember him as… You know, he really had strong tremors. He was a really nice guy. And I can remember watching with him, was it '64, so I was about ten, Miss World, who I'm now Facebook friends with, the same woman [laughs], yeah, Ann Sidney, who won it. But I can remember watching that with him. But he, he as in a terrible situation. He did live till he was about 77, but he had Parkinson's disease for all the time that I can remember. And again, this, later on, the same link, realising that small changes to the brain, electrically possibly, because the brain is electrochemical, you can, well in some cases you can get rid of Parkinson's disease. But it's with electrical stimulation deep in the brain. And I, I still work now with surgeons at Oxford, using artificial intelligence to try and understand what's going on electrically in the brain.

[08:05]
Yeah. OK. Well, we'll come on to that later no doubt. So, would you say that you had a happy childhood then?

Yeah. Um…

Not entirely easy, but…

[laughs] Well I did… We didn't have much money, because my father wasn't working, and my mother wasn't working. We had a mortgage to pay. I guess I didn't realise all of the ins and outs, but I understood it. So when they said, 'Well we haven't really got much for, money for Christmas, we haven't got for presents,' and, we were just going to have this old chicken that we get from the farm that had seen many better days. So it was quite tough, and things like that. But, you just… And

second-hand jumpers, and all of those things, which I guess a lot of people had, that was more, par for the course.

Yes.

But I got used to that. So, it, it put in me, instilled in me, if you want something, you've got to do it yourself.

Yeah.

Don't expect anybody to give you anything. And that's still with me now.

[09:07]
Yeah. Yeah. And I guess it's a common theme with people of our generation, if I may say, who came from working-class backgrounds.

Yes. Yes yes yes, very much was working… My, my father's father, who I admired enormously, was a miner in South Wales. And, I think he also liked to drink a little bit, but I never really saw that side of things. He used to play when… So I, I enjoyed trips to Wales to see my Welsh grandparents. So I, that, that Welshness, I have to say, I've always grown up in England, so I'm not Welsh, other than my father, but my family, my father's family, mostly it's still in Wales. And it's still there, because, whenever the red shirts of Wales came out for a rugby match on a Saturday afternoon on TV, my father would just be glued to the television set, and my mother knew she could not talk to him or say anything, if Wales were playing Rugby. And that got instilled in me. So, I'm English through and through, except for rugby [laughs] union, when I'm one hundred per cent Welsh I'm afraid.

You're Welsh.

So, yes. I mean it works quite well, because they usually have quite a good team, but, I'm Welsh for rugby, and English for everything else.

[10:28]

So apart from the, the football and rugby, how did you feel about school?

[pause] Well at the junior school, I got on very well. It was only a village school, so there were only, sort of, seven or eight of us boys and girls in a year as it were. There was only about 60 children total.

Wow.

And, because of that… I always did quite well, but, I got, passed my Eleven Plus, to go to Lawrence Sheriff, which was great. But at Sheriff, it was very different. First of all it meant, from the age of eleven I had to get on a bus to go to school, from, we lived at Ryton-on-Dunsmore, which is just outside Coventry, but had to go to school in Rugby. So it was like, a 50-minute bus ride. And then a 50-minute bus ride back. But at Sheriff, I, I don't know… It was, I enjoyed the school, but I didn't really cotton on… Maths was always easy for me, and still is, which is annoying to some people, and, and things, English is not, never been too bad. So some subjects I could just get by. But I don't know that I worked hard at all [laughs], particularly at things like sciences, at Lawrence Sheriff, so, which is a shame.

Right.

But I enjoyed other things too much.

Any inspirational teachers that fired your imagination?

I… I don't know. I mean there was a guy which, who we used to call Eggy Lay. He was Lay, so called Eggy by everyone at school. And he, I enjoyed his mathematics teaching. But that was partly, partly because I enjoyed mathematics.

Yeah.

And engineering, drawing. So I, I don't know that it was the teachers. We did have one Philip Larkin, I guess, not the Philip Larkin, the poet, but he took us for English.

But that was more… I don't know. Maybe he did inspire me in terms of some of the, the literature. He might like to know that.

Yes. Yeah.

Because I think I caused him all sorts of trouble.

[12:44]
Mm. So, you left school at what stage?

Sixteen.

Yeah.

Yeah. Which is not normal I guess now, if you're thinking about going on. I, I think I had had enough. Again, partly it was a money thing, and my parents… I can remember, the school had a trip to Germany. And, everybody had to pay for it. And my parents said, 'Well if you want to go, you've got to pay for it.'

Yeah.

The whole concept of them paying for me, wasn't there. So I, I didn't have any money.

Yeah.

So I couldn't go. So, the school, the whole year, went to Germany for a trip, and I had to stay home, and just, I don't know what we did at school, I can't remember. But that was life, I guess. But again, it instilled in me this, if you want something, you've got to go and do it yourself. So I did, when I was at school, I used to go and work on Saturday afternoons in a butcher's shop in Coventry, for a bit of money. I used to collect for Cancer Research, which… So you'd just go around collecting, I can't remember whether it was weekly or biweekly or something like that, and you would keep ten per cent of the money. That was the way they did it. And then the

rest got passed on for Cancer Research. But that brought in an income. So it was doing things like that, from an early age, I guess. But it didn't, you know, it wasn't enough to go to Germany with the school, but it was enough when I got to the age of sixteen to buy my first motorbike.

Right.

Which I paid an astounding £15 for, which sounds terrible now, you know, hardly anything, but at the time it was a lot of money.

So what kind of motorbike was it?

It was a BSA Bantam 175.

Really?

So I had to buy the crash helmet, I had to get the insurance, all myself. The sort of, thought, you know, parents helping their kid; you want it, you've got to pay for it. Because they didn't have the money.

Yes.

So, there we go. And I, oh I absolutely loved… And this was in the day when you didn't have to have a helmet, so I have to say, really loved going down country lanes in the summer when I was sixteen without a crash helmet on, and… I mean highly dangerous of course, but…

Yeah. So, this, this won't be of interest to the, the audience listening to this, but, I was hoping you were going to say that, because, when I was a postgraduate student, I, I had a BSA Bantam 175. [laughs]

Oh! Yeah. Yeah, yeah.

Which I bought so I could go and run round Manchester tutoring A Level students, to earn a bit of money as a, when I was a student.

Ah. OK. Yeah. Yeah. Oh BSA Bantam, lovely bike.

Yeah. It was very popular in those days.

But I had this… For me, it was more because, it was an old one, and it was breaking down quite a bit, and I had to learn how it worked.

Right.

And, and how… Because, a motorbike, from a physics point of view, has a bit of everything. You've got the electricity, with the sparkplug and the battery, and so on, keeping the battery topped up, and what's going on. You've got the, obviously the chemicals, and the combustion, and the power, and everything. And it's a brilliant way of learning physics.

Yes.

Which I did do. But I had the problem that, I was learning, oh, this is a capacitor, and this where, put the screwdriver over the terminals. Boom! Gives you a belt, and so on. So I learnt a lot about science like that. And then in school, they were talking about condensers, and… What, what is the… And, I had to try and make some sort of link. So as far as in school is concerned, oh I didn't really understand the subject. But I was talking about a completely different subject, which I did understand.

Yes. Yes. That's interesting. And, I think, girls are mentioned in your life.

[laughs]

Were they associated with the motorbike? [laughs]

Well, it all linked together. I mean, a teenage boy, not in any order, motorcycles, football, and girls. I think those were my interests at the time. And school life was, sort of, got in the way a little bit.

[17:15]
So you felt an imperative to, get out and earn some money.

Yeah. Yeah, yeah.

And, so…

I was ready for it, and wanted to learn about life and the world. And I, so I left, and got a, an apprenticeship with the GPO, what's now British Telecom, in telephone exchanges, in the telecoms area. And it was absolutely wonderful. I loved every minute of it. And the camaraderie. I mean on the negative side, I started smoking, because that's what you did, and…

Yeah.

And we'd have a block release at Coventry Technical College where I did some City & Guilds study. And eventually got into studying with that. But, lovely, a whole bunch of stories that, I must tell you one or two, which was partly me learning about life, but, we had some fun in the telecoms. I'm not allowed to tell you this, but I will. Did various things. I can remember vividly the one time. There used to be this party line. This is where you'd have two telephones, and they'd have an earth link, and to get a dial tone, to get the line, you'd have to press the button and you get the line. And in the summer, this earth link would dry out often, it would just, the ground would harden up, and the link would not be good. And the solution was, you'd get a, you know, to go out and solve the problem, you'd go and ask the person for a bucket of water, and you'd just chuck it on the earth spike, and that's it.

Yeah.

Yeah. So working again. Now this one time, we had been in the pub, I know I wasn't supposed to have been in the pub, but I was too, you know, there we go. Been in the pub at lunchtime. And we went round, yeah, this is going, this is, the problem is, no dial tone, party line, it's going to be… And, and the, the guy I was with, the technician I was with, decided to relieve himself on the earth spike before we knocked on the door. [laughs] Sure, sure enough, we knocked on the door, and, yeah, it's working now. [laughs] So… And I, I once told that story on a radio programme, many years ago, and I got all sorts of criticism, 'Oh, you're telling, you were peeing on the earth spike to solve a problem,' as though they didn't believe it, as though…

Yeah.

Which is always funny to me, because that was how the… That's a problem. And, people often don't understand science and…

Yes. Yes. Yeah.

But, because they don't understand it, oh it's not possible. There's a problem with it. But that's what we did. Another time, patched, I can remember in the telephone exchange, patching together ten calls at the same time, just to see, experimentation.

Oh right, yeah.

So these were ten calls, all going ahead separately. Patched them all together, whoosh, like that. And, what happened was that, one call continued.

Yeah.

Now the other calls didn't drop out.

Right.

And there wasn't any arguing, 'Oh you're on my line,' or anything like that. But the other ten calls – sorry, nine calls, were listening in to this one call, which continued to go.

Right. Yeah.

And then we patched them back again, so they were back to normal, and there were nine conversations all going something like this: 'Did you hear what she was saying?' 'Oh, and here…' [both laugh] It was really amazing how people are. So, I think I learnt a lot about communication, about how people are, and the importance of communication to people.

Yeah.

And the telephone was an incredible discovery, and I feel really, you know, really grateful that I had a chance to, to work as an apprentice, and then as a technician with British Telecom.

[21:09]
Did you learn a lot technically from that experience?

Oh yeah. Yeah, yeah yeah. But both, both technically and, as I said, about communication.

Yes.

So, people, I think.

Yeah.

One had to interact with people. I worked partly for, on the maintenance side, sorting faults, in the telephone exchange, but also outside sometimes, so… So I learnt an awful lot there, yes.

Did you do any exams or anything as part of that BT experience?

It City & Guilds exams. Which were quite tough, I have to say. You know, they weren't easy. The talk of, oh these A Levels are… But, after a few years, like this was five or six years, so I was in my early twenties, I felt, well in BT, I'm never going to get really well up in the ladder, unless I go to university and get a degree.

Yes. Oh right, yeah.

So that s when I thought, I would like to go and get a degree.

Yes.

But I've got to go and get A Levels to do that.

Yeah.

And what I did was, for the maths, it's always easy, I didn't… Sorry to tell… I'm not trying to be big-headed, but maths has always been easy. But the physics I had to work on. So what I did was get a book out of the library, and read it in lunch breaks, and – coffee breaks, and things like that. So instead of actually having a break, I was reading my physics book. And, it was a great big Nelkon and Parker, I don't know… .

Yes.

Yeah. Big, big book, about 800-odd pages. And I literally had to read this thing, read it to learn it, cover to cover. Because there was no online helps and tools.

Yeah.

So that was really, I, I had to register, because there was some practical involvement on the physics, I went… At this time I was living in Birmingham, because I had got married at the age of 20 to my first wife. And had to go to Waverley School, they let

me go in there to do the, the practical part of it. But, it was getting physics A Level, which, I got the A Levels I needed to get into Aston University.

[23:29]
So, you were largely self-taught on physics then? Reading the standard text.

Yeah. Motorbikes, motorbikes and, and reading the text. Yes.

That's, that's pretty amazing.

Yeah. So I never did a course. But I got, I think it was a grade C, so it wasn't a, the top, but C is quite reasonable, you know.

Yeah yeah.

It used to A, B, C, D, E. E was the lowest pass. And, so I did all right. Quite pleased, given that it was just…

Yeah. I, I think that's a major achievement. I mean speaking as somebody [laughs] who, you know, I always did, did well at school with exams and stuff, because I responded well to being taught, but I'm not so good at self-teaching.

OK.

I, I think the ability to sit down in a coffee break, read a few pages, and absorb it, is a pretty amazing achievement.

Yeah. I was the other way round. I was… [laughs] Preferred doing it myself than having some interaction with this. I didn't really get much interaction. But the maths, I just sort of, did.

Yeah.

I… We... I had been following the City & Guilds course, so, some of it, like the electrical stuff, I guess, again from the motorbike as well, I knew a fair bit of. So the electrical side of things, I did have, you know, it's not, not as though there was nothing there. But, things like nuclear stuff which came in to it, obviously there's nothing like that, and a lot of the mechanical didn't come into what I was doing. So…

[25:00]
So, BT was 1970 to 1976.

Yes.

Just to put the timescales into…

Yes, that's right. Three years' apprenticeship and three years technician. Yes.

And then, in the middle of that you got married.

Yes. '74. Yeah. The same year as Abba won [laughs] the Eurovision Song Contest.

I suppose I, I was going to say, well that's, that's quite a big move at an early age, but, I got married at 21 actually, after doing my finals and before graduating.

Yeah.

So it's not so different.

No, I, I looked at all of the people, the kids that I knew around at that time, and it was very much the norm, 20, 21.

Yes.

Really, if you were not married by the age of, say, 23, you, you were on the shelf. You had passed it.

Yeah. Yeah.

We, we got a semidetached. Again, this is very different. Buying a house then was the top priority. I think my parents had instilled that in me. So you did everything to get the house. Which meant you didn't have much furniture, you didn't have this, you didn't do this, you didn't do that. You put everything in that. So we had to get a mortgage at the time. We were both working, myself, she was a secretary, I was a technician. But we put everything together and got a house in Cranes Park Road, Sheldon, Birmingham.

Yeah.

And that, that was quite an experience at that age, doing something like that.

[26:35]
Yeah. And then off to university.

Yes. That's right. [laughs] So had to… We did have an old car, which I had to sell, and sold various other things too in order to go to university.

Yeah,.

Yeah.

Well that was a brave decision, under the circumstances.

Yeah. But I was, I was ready for it.

Yeah.

Yes. Yeah.

And, and tell me a bit about your, your undergraduate experience then.

Mm. Well it was at Aston University. Which… So, I was living on the edge of Birmingham, Sheldon, and then, just going in and out on the bus. Because we had sold the car to go to university. I, I loved every minute. It was quite a, a relatively practical course. I had gone… I didn't really look around too much, because we were living in Birmingham, I didn't… So I didn't sort of, try to get into universities all over the place. It was really looking at a local one. And I just really looked at Aston and Warwick universities.

Right.

Both, they gave me similar entry requirements, but… And Aston I think was a little bit lower than Warwick, but I, I liked the course at Aston, it seemed to suit me. And I thoroughly enjoyed it, every minute of it, in Aston.

So this was electrical engineering.

Electrical and electronic engineering.

Electric and… Yeah.

Yeah. Yeah. Yup.

And, good degree?

I got a First class, yeah.

Yeah?

Yeah. [laughs] I was always, always near the top of the, the class, yes.

[28:12]
And, and then you decided to do a PhD.

Yeah. There's a slight… Between my, when I finished my first degree, and then before I started the PhD, there was a few months spare. And what I did was, I went to the, whatever the job centre was called, 'Give us a job.' And what I got over that summer period was as a playgroup leader in Sparkbrook, which is inner-city Birmingham. And, really enjoyed it. You know, several months just helping the kids. And, I had the kids, but their parents would come along. And, it, it taught me a fair bit about the culture I guess. Because there were, there were some white English. I know, this is not going to be political correct nowadays, but white English. There were West Indians. There were Indians. And, each would sort of, tend to get into their own groups, their own… But, this was trying to get them all to play together, which was difficult. And it was funny for me. Quite often there would be children who had a, a West Indian and an Indian parent, or an English and a, Indian parent. And it was often quite difficult for those children to, to in- Because they, they didn't technically fit in to any category as it were from the other children. And that, it, it taught me about the difficulties that a lot of those, those children face particularly.

Yeah. Yeah.

But, but a lot of the, the general problems of inner-city life and so on.

Yeah.

But I, I loved, I loved that time.

Yes.

But then I went to do my PhD. Very different, yeah.

[30:02]
So I suppose I should have asked, I mean when you were doing your undergraduate studies, was there any particular aspect of the electrical, electronic engineering that captured your imagination or interest?

Well, what I tried to do, because I had come from a communications background, what I tried to do was, making things more difficult for myself, was to learn more about the other things, rather than say, right, I will just focus on the comms because I know that stuff. So, I got into things like control systems, which, because it was quite difficult for me, because I hadn't done anything like that before. And that led on later then, because, computer control systems, computers were coming in, I have to say. The project that I did in my final year was a microprocessor… And microprocessors were just, they were hot off the press then.

Yes.

And I was doing a converter from analogue signals to digital, and, and so on. But I mean, we, we didn't have in those days personal computers; the only computing were the, the card, the punch cards, and, you'd put your program in and then you would get it back about a week later to say where it had gone wrong, because you had missed a full stop off or something like that.

Yeah.

That, it was very basic, things in that. But I, I was choosing the more difficult, measurement systems, which, I hadn't done anything before.

Yeah.

And I tended not to do the easier subjects for me, like communications, which would have been a walk in the past in a sense. So… But that did spin off, because then later on I did a lot more, it was useful what I had done on the measurement side, and…

And presumably part of the course was the, the power stuff from the machines, and, rotating machines and…

You've got it. Yes, yes, which I hadn't really, [laughs] I hadn't done anything of.

Yes.

But enjoyed… I enjoyed more the light current, the electronics-y stuff. But, but learning about power systems was great, enjoyed it. I, I thoroughly enjoyed it. And Aston, a wonderful university.

Yes.

Suited me down to the ground, enjoyed it. And the friends, I still have some friends from that course.

[32:13]
Yes. And why a PhD then?

Oh, I got into it. I, I loved the whole university life. And found I, even when I was doing my undergraduate project, I was reading round the subject, and in a way some of… I didn't just do what I was supposed to do for the project. I did a control system, then a three-term control, a proportional, integral, derivative control. So I was getting into the research side, even my, for my undergraduate project.

Yes.

So it was quite a, quite a challenging undergraduate project to take on microprocessors, which we were not doing on the course, and, they were very new.

Yes.

This is mid-Seventies.

Yes.

So, it was quite a challenging thing I was doing. And I can remember going up at the end of the course to a research day in UMIST, in Manchester, off my own back, because I, I enjoyed what I was doing. So it wasn't sort of, just… I was already doing research as it were.

Yes.

And felt it, I enjoyed it. I loved it, it sort of, seemed to… Which, research, I have to say, if I had a forte, that was, I, I was good at research. [laughs]

Yeah?

I didn't have to worry about it. Yeah.

[33:34]
So how did you fund your PhD?

I got a, a grant from the EPSRC.

Yeah.

Yes. Standard project research student grant. Not a lot of money, but… And, I was going to do it at Aston originally, but the professor there, Tony Barker, over that summer, when I was due to start with him, he moved to Swansea.

Right.

And I have to say, I thought, well I don't know that I fancy going to Swansea. So I had a word with him, and said, 'What do you think? Where's good for this sort of,' what I was going to do, computer control, with him? And he said, 'Well, the best is Imperial College, London.'

Yes.

So, I applied to Imperial College, and they said, 'Fine, OK.'

Yeah.

So that was where I went, off to London.

And the topic was?

Well computer control systems. It was more… So this is using a computer to control things.

Yup.

And it was… Because it was Imperial, it was partly theoretical, more theoretical than I had been used to, hence mathematical and things like that; but also, actually implementing, to, to make things, such as a heating system, or a robotic system, so that you could actually control them. So, and then how to control it so it doesn't go unstable or go out of control, or whatever. So it was quite practical but also theoretical at the same time.

I mean, was, was there a particular kind of thing that, you were trying to control, or were you…?

I think the, the course that I was doing, the research that I was doing, it was a more gen-, the how to control generally.

Right. Yes.

But then, while I was at Imperial… Because we, we had moved down from Birmingham. And, my wife became pregnant while I was about two years through my PhD. So, we couldn't really afford me being a student any more.

Yes.

So I had to… And I got a research assistant position in Imperial College. And that was more practical. It was saying, here's, to use some of the control systems research that I've been doing, now get it controlling things. And we had to get it controlling,

the heating system, and a robot and so on and so forth. So it became very practical while I was there.

[36:12]
Yeah. So, I mean… Then, it seems to me, looking at your CV, begins a kind of, fairly logical but quite exciting progression…

[laughs] Poor. Yes.

…from, starting from that control stuff, to using clever techniques around that.

Yes.

Like artificial intelligence…

That's, that's right.

…and neural networks and…

Exactly it. Yes.

And, and progressing up to the present day when you're interacting with the brain, as you say.

Yes. Yeah.

And, and controlling that with, with feedback mechanism. Rather than go through the individual establishments, I just wonder whether you've got a story of the career in terms of the, the challenges that you were addressing…

Yeah.

…and, and why.

Well from, from Imperial, I got a lectureship at Newcastle University, in electrical electronic engineering, and it was just after Rowan Atkinson had got his degree and left. So I was in a good situation. And in fact I, I got his, where he used to do his project. I went in, that was the room that I was given. So it was really quite interesting. But when I was at Newcastle, we successfully, myself and another guy, Costas Goutis, successfully got an enormous European Union grant, it was one of the big positives for the European Union, of which there are many, and, for robotics.

Yeah.

But, intelligent robotics. This was for a robot to inspect a pot with lots of different things in it, and decide, yes, it was going to pick that object up, whatever, a bolt or a screw or whatever it happened to be, and then pick it up appropriately. So make a decision, pick up and so on. So it was quite a complex problem at that time. But it was a lot of money. And that, putting the project together, was interesting, because a lot of the abilities that I had got from my first degree and then the research, I had to, to pull those together.

Yeah.

[38:21]
But I enjoyed being in the North East. I, I, you know, could go and watch Newcastle or Sunderland play, which was quite nice. But I, I can remember vividly though, I was there for about three years, and, just about, a week before I left, I was working in the centre of Newcastle and some guy there asked me, some local guy, asked me something. I… Now I had been there three years. I had no idea what he was… I said, 'I'm very sorry.' I tried to listen to what he was saying. 'I'm very sorry. Please could you say again. I don't understand.' And he said it again. And I still don't, to this day, I've no idea. I tried to be adaptive and… I wasn't awkward at all. I just could not understand the strong Geordie accent.

Yeah.

And, mostly I could follow it, but not that time. I've always tried to be, you know, with, with foreigners and so on, adaptive to that. So that was Newcastle. I then…

Just to put that into context.

Mm.

It's helpful to listeners to have the date.

Oh yes.

So, Newcastle was around 1982 to '85.

Yes, November '82 to the summer of '85.

And you mentioned, that was a kind of intelligent robot application.

Yes, that's right.

[39:36]
What was the state of intelligence in machines at that stage then?

Ah. Well, I mean, machines didn't have intelligence as far as most people were concerned. And I guess my view of the thing was, subsequently, I discovered, very similar to Alan Turing's view, in that the way a machine is intelligent is, is different to how a human is intelligent. So for me, the robot, with the computer, could be quite intelligent, but it would be in a different way. I likened it more, like you, you have, a cow is intelligent, but in a different way, or a spider is intelligent in a different way to humans. And a machine, a robot, a computer, is intelligent in a different way. Some of which leads to advantages for the machines, some of which, maybe it's advantages for human. Not sure which advantages, but there we go.

Yeah.

So that, it built up my working with interacting robots, I guess, that take signals in, make decisions, and then, act on those decisions. It also is a question as to what intelligence means.

Yeah.

Which is great. But at the time, to think more broadly about intelligence was not really the thing to do. Machines are not… I can remember books, reading books and being quite annoyed with them, saying, yes, the sort of, field of artificial intelligence, these are the advantages of the human brain; these are the advantages of the machine brain. And amongst the advantages of the human brain was creativity. Machines cannot be creative. And you think, what rubbish. How people can write… But that was, it wasn't just the way of scientific thinking, but it was the way, that this is acceptable. You can think this way now. And, it was such a ridiculous way of looking at it, I couldn't believe it. But, there we are. Now it's, it's a lot broader and you can, AI can be intelligent in all sorts of ways.

Well, my, my friends who know a lot more about this than I do, draw, draw a strong distinction between artificial intelligence and machine learning. People tell me that, that there isn't such a thing yet as artificial intelligence, but there's a, there's a lot of machine learning.

Yes.

I mean, going back to what …

Well I, I would… I would say that, yes, yeah, we, we had to, in this case it was getting the machine, which was linked to a robot and so on, to learn.

Right.

And, what that means though, if you've got a machine that's learning, it can make decisions that you don't know about. Because, a robot has different sensors than a human senses. It will experience different things. It's very much like a small child.

You, you could… You set your child off, and after a while you don't know what decisions they're going to make, or what conclusions they're going to come to, because they've experienced the world in different ways. You can probably understand it some way because you've got eyes and ears and things like they have. But a robot is even more in that direction. It will experience what you think is a pretty straightforward, with nuts and bolts and so on, but it can come up with quite different conclusions.

Yeah.

Because it learns.

Yeah.

Learning is a critical factor. I have to say, in those days, I, people, what is he talking about? But I heard only about a week ago, exactly the same, a person saying, 'Learning is a critical [laughs] factor.' And, it is, it is. And if a, if a machine learns, if an animal learns, or whatever, and their conclusions and decisions are based on what they have learnt, then they may not be as we see them, or we think they should be, the conclusions may well be different, because they've learnt something different.

Right.

And it's true with a machine.

Yeah.

Which, which is positive and negative.

Yes.

It can pertain… If you have a military machine, that is a fighting machine, that is making its decisions through learning, and it learns who are his friends and who are

his enemies, and you are letting that system look after itself, it could well decide, who you think are friends, are actually enemies. Which could be you.

Yup.

And it could do things very negatively. It could decide it doesn't have any friends. You know, you're talking Skynet and the *Terminator*. Just through learning really. It doesn't have to be a super intelligent, enormous linked-in network, it doesn't have to have all the other attributes. A fairly simple machine that learns something that you don't expect it to learn. And I did have later on experiences of exactly that. Not, not the… Nobody, no machine killed me or anything, but a machine learning something you don't expect, and seeing it.

[44:57]
So, there's some important ethical issues in all of that, aren't there…

Mm.

…in terms of, how much you let a machine do on its own, without intervention.

There are, and, and it's worrying nowadays from the point of view, particularly in the military scenario where we don't know too much about what's going on, about ethically, how much should we let the military go ahead with AI systems, particularly for defence.

[45:28]
Yes. So going back to that, that time. You were, you were doing this robotics, machine learning stuff.

Yes.

What was the progression from there on to the later work in terms of interacting with the nervous system side? So, I mean, were there steps in, in your career in that sense, or…?

I, I don't… At that time… It clearly pushed forward a lot of the… The computer control systems subsequently linked with the communications and so on, were what I then used later on. The next hop for me job-wise though was down to Oxford. It was a nice opportunity. It was more research involved. It was linked closely to Somerville College, which is Maggie Thatcher's old college, and I had the, the pleasure of meeting her at a nice dinner in London, partly because of that.

She was an alumnus.

Alumnus. It was. She was… Yes, a sort of, money raising thing for Somerville, and, so I got the chance of meeting the great woman herself.

And what did you think?

Oh, always, totally… I mean she was a true Somervillian. Somerville College is a fantastic college. You know, women doing things, before girl power. So the Somerville power was an awful lot stronger I think. And Maggie Thatcher is a typical Somervillian, was a typical Somervillian. Oh very impressed. She wasn't… I would think that she was this big person, strong and powerful. That's how she came over. But she wasn't; she was quite diminutive, quite, relatively small. But, very powerful in the way of thinking. So it was a pleasure to meet her. And, Daphne Park was the Principal at that time. It was only later that I discovered she was a spy in the Second World War for the UK. [laughs] So I mean she was quite a, this Margaret Rutherford character. I can remember her saying about being stuck in Africa and on a road where the car broke down, or something like that, and a load of people tried to attack her, and she fought them off with an umbrella. She was that sort of a…

Gosh.

…a person. But she was a spy in the Second World War. I, I discovered there was a whole description of what she did in Bletchley Park.

Really?

In fact there still is probably, in the historical section there.
[48:05]
But Somerville was a great experience. I was… It was an all-women's college. And, I ended, I was staying in there for about, three months, when I first got the job. Because we were moving from Newcastle to Oxford. And I can remember vividly, they had a fire alarm one night, and I had, we all had to get up. And it was supposed to be all women, but it was amazing how many men [both laugh] turned up for the, for the fire alarm, when that went off. But that, that let me get in, more into the research, and I, I wrote a book about control systems. But it was going more on the computer control again. So there wasn't any… I, I guess I did, in hindsight, I made my first connections in the medical world, which subsequently came about, whilst I was there. But more, at that time, they were more sort of anecdotal, they weren't, let's do this project together.

Yeah.

It, it was more finding out, what are you doing, and finding out about the Parkinson disease work, finding out about the, the work with external prosthesis, somebody who is paralysed, trying to control technology around them. So I found out, but not directly for the job I was doing. This was talking to the people, again, in the college, and we'd get them for dinner. 'What do you do? ' 'I do this.' And things like that. And really finding that interesting. But subsequently, it, it all came together.

[49:39]
So, there's probably a, a personality trait here, isn't there, which, which is the mark of a, a great academic or something, that, you talked about being interested in reading around things.

Yes. Oh yes.

And, and now you're talking about, you know, having a job that's concerned with one thing, but actually, talking to people about stuff around that.

Very much so.

And more about association..

When I was interested in it, yes. Yes.

Yes. Which…

I'll talk to anybody. Yes.

Which is probably… Isn't that an important trait of somebody who's creative in, in an academic, or research, or invention sense?

I guess so. Being, being open-minded I think is important. And, trying to be. Sometimes you get it wrong I guess, but trying to be open-minded about things, and interested in different things, and so on.
[50:30]
I think also… I mean, Oxford, like Cambridge, it's funny old places. And there's a lot of hierarchical, oh this person's not going to talk to that person, you don't regard… And, I, I was coming in from a non-Oxbridge background, so, I didn't have that Oxford background at all, which makes you acceptable a little bit. But that didn't bother me. You know, if, if somebody wanted to try and be clever and put me down, well, let them do that. But, as long as you don't lie down and let them do it to you, you know, you fight back, or, lie on your back, or ignore them, or, you know, just don't let it get you down. So I never let it get me down, that side of things. I mean it used to be, at dinners, if you went into the Oxford dinner, traditional thing, whichever college it was, you would get somebody who thought themselves were much better than you, and just, they would try and play around, and use a bit of Latin, or whatever it happened to be, just try and make you look small, and make it that you're an idiot. And, I guess I didn't, didn't go for that.

Yeah.

Just didn't, I just, just, just got on with life. So I didn't, didn't sort of, [whaling] oh I'm an idiot, I can't say those words in Latin.

But maybe, because you could overcome that stuff, the Oxford environment, the stimulation, suited you actually.

Oh I enjoyed it, yeah, it was a lovely place to be. To, to experience the whole thing. I mean, Oxford and Cambridge are very lucky, they get really good research students, they're well-funded. You know, if you can't succeed as an academic in Oxford or Cambridge, you, you can't succeed. You know, they, they really are fortunate, and have such an influence, too much of an influence in the UK I feel, on day-to-day life. You know, they are privileged, they very much are.

Yes.

And, and to experience that for a couple of years was really interesting.

Yeah.

Yeah.

[52:40]
So somewhere along your, your career line, there was a transition from applying control techniques to robots and machines on the bench, to getting your body involved in, in that loop.

Yes. Yes, that's right. Well, that was… I, I got to Reading University, in '88.

Yup.

The summer of '88. I had a brief spell, I went for one year to Warwick University, but, I was sort of, in and out, and got my job at Reading when I'd only been at Warwick about three months.

Right.

So, I got to Reading. And, partly, the, the department was not doing particularly well, and I had to pull things together, and try, got in not just as a professor there, but as head of department. So I had to try and revitalise the whole thing.

So this was the department of…

It was Department of Cybernetics, and I was Professor of Cybernetics, and head of department. It was quite small, there was only about, seven academics. It didn't have enough students, so we had to make the course more interesting.

Yes.

So… But also, bring in research income.

Yes.

So it was waving a magic wand, was what was required.

There probably weren't many universities with departments of cybernetics, were there?

No. No, there weren't. Which is wonderful. I mean cybernetics is, humans and machines, interaction. It's looking at the whole system, how it all works together. So it means you can do anything, really, when it comes to research. As long as there's some sort of practical side to it in some way. And, partly that involved me linking with industry quite a bit for a practical bent. And, would try and choose technological companies that I was aware of. But also in the research, this human technology linked together. A lot of the projects that we were doing were, that I got involved with, were robotics related, but intelligent robots, in the sense, robots with a brain, a machine brain, and, making decisions for themselves and so on. And then, humans were very much part of it. And pulling it together was tremendously exciting. And I, I can remember us being, being in the lab talking with about three other researchers there,

and saying, 'Well look, we, we've got this little piece of technology that we use. We used it for the building, which, we had got the building set up as an intelligent building. What that meant was, at different doorways throughout the building the computer could monitor you, through maybe a smartcard, and, so the computer was aware of where you were in the building. And we were looking at the habits of people, what time someone went for a cup of coffee, what time they went to this room, what time they went to that room. And seeing how, with the work, how habitual you were with what you do, and so on.
[56:03]
But, there was the, the arguing between us, saying, well, why don't we try and put this technology inside the person? 'Can't do that.' You know, just, nobody's done anything like that. People had talked about it in science fiction.

When was this?

This was… I guess initially, '96, '97, talking about it. Partly because there was this little glass tube that we had, with a number of memory chips in it, and I, I was saying – from Texas Instruments, so, probably kill me for saying that. But, this was actually put inside computers, so that you could scan the outside, and, yes, this is the identification number for that computer, and this is the one for that one.

Oh right. Yeah.

So that was the intention of them. But, but the thought was, well, well I like to say I had the thought, why not implant it in the person?

Yup.

And we said, well, where could you implant…? Well, to, implant it just about anywhere on a body. And so, all this is, a little chip, which was used in computers. It was in a glass capsule, which, learnt later is quite brittle, to be honest, break very easy. But that, with that, I then went, eventually, to my local GP, George Boulos, and said, 'Look, what we're trying to do is this project, but it involves implanting this little thing inside my body.'

Yup.

I have to say, we had argued about, if we're going to do it, who's going to do it? And could we put it… There was this – oh dear, sound very sexist – quite attractive female research assistant called Alma. Why don't we put it in Alma? The media will be… No, no no. The problem was, what if it goes wrong? Because again, you can put it in any part of the body, so, there we go. And I realised, because it, it could go wrong, this thing was very brittle, it might not work very well. So in a way I had to do it myself. I also wanted to experience what it was like. So, I went to my GP, George Boulos, and said, 'We would like to do this.' And, fortunately, very quickly he said, yeah, he was happy to implant it in me. Which was great from my point of view, because, I was worried about, how do we sterilise it, and, what's going to happen in the body, would there be any problems? And so on. So, then it became partly between him and me, that we were working on it. He was coming, yeah, we can sterilise it like this. We tried, in the lab, you sterilise something, you boil it in water.

Yeah.

So we put this first, one of these implants, became an implant, it wasn't really an implant, put it in water and boiled it, and it exploded. We had bits of chip and glass and everything all over the place. So that was no good.

Yes.

And what George suggested, well, put it in an enclave, this, this oven, and that would be sufficient.

Yes.

And that was what he did. He sorted that bit out for us. But subsequently, in 1998, that was implanted in my left arm. There's still a bit of a mark there, but not much.

And I became the first human in the world to have a radio frequency identification device implanted.

Yes.

And it got a lot of publicity, more than expected. But it worked, importantly. So, the computer could track me around my building, and it opened doors for me, and switched on lights, and said 'Hello Professor Warwick' when I came through the front door.
[1:00:03]
In fact, just before I go on. When we did that project, at the same time we were doing another project where, we had a computer, AI system, creating pop music, writing pop music. And we worked with Manus, who were four younger brothers of Declan MacManus, Elvis Costello, and they did a pop song with us and this computer system, mixed the pop song in a different way, and came up with a different solution and so on. So it was AI coming up with pop music.

Yes.

And I thought, yeah, creativity, this is going to be good. Nobody much was interested in that. But with the implant, it was big news around the world.

[1:00:46]
Yes. And, and you didn't expect it to be big news?

Not that, not that big news, no. No no. No. It was just way beyond all proportion. I mean it, it got, seemed to get, person with an implant. I mean it was…

What do you attribute that interest to?

Well, well some people, I know, I always had a hassle from Sussex University, a particular group down there, and they, I can remember them blogging, 'Oh Warwick and his publicity machine.' What the publicity machine was, was, my sixteen-year-old daughter had finished her O Levels, and she was kicking her heels, and I said,

'Why don't you come and help me with this…' So, so she was my publicity machine. She, what she did was, copy, photocopy some notes on the, the identification device, what we were doing, and so on. And, sent them out to various newspapers and so on. [laughs] So… But it, but it worked. So, walking in the door, 'Hello Professor Warwick,' because of the implant.

Yes.

And I think it was, people were ready for it. OK, we had had things like cochlear implants, heart pacemakers, so there were implants, but having something which did something different, something extra, I think, science fiction had written about it, but nobody had actually gone ahead and done it.

Yeah.

And I did, or we did, you know. And to be the first was, you know. So that, that, with all of that, it was a world first. We beat the Americans, we beat everybody.

Were the Americans working on this?

Well, I, I… Now, there are more people with that sort of transponder… Yeah, I'm, I'm sure they… But nobody had actually done it.

Yes. No, I mean, I just wonder whether there was a, a scientific community around the world that was, you know, talking about these kinds of things.

There… There were people talking about it, but again, nobody saying, right, we're going to go ahead and do it. So, it was more, right place, right time, right GP. You know, other GPs could have said, 'Go away, don't.' But George was brilliant. So it was the whole, the whole package. I mean, what we used, realised, later on, I dropped one of these implants, just, just from sitting, like, doing now, to not, not a great height, and it just broke on the floor. And realising how brittle the implant was. It was only in for, I don't know, about ten days, and then George took it out again. It was never intended to stay in. But, we wanted to see how things went.

Yes.

But it, importantly, it had solved the, you know, we had done it, and ticked the box. And it worked very well. So I, I could walk in… Because it was quite a large thing, it was about an inch long, two and a half centimetres long. The reason it got put in my arm was that we were not sure how it would work, how well it would work. And, the point was, if I walk through the, the front door, and the computer didn't pick me up, I could move my arm around in some funny angle, and it would pick it up.

Yeah.

So that was why it was put in my arm. And now, I mean I am amazed, everybody who has an implant, there are several thousand people with implants, smaller versions now, it always goes in their left arm, or left hand. There's even, in James Bond, in *Casino Royale*, he has this implant, into his left arm. And you think, yeah, [laughs] it doesn't have to… The reason it was put in was because we weren't sure how well it would work. But now we know they work, why they get put in people's arms, I've no idea.

Yes.

It's people not thinking outside the box. But there we go. But it worked. Yeah.

[1:04:39]
So what next then on that on that…?

Well, we realised with that, that, what it was… It… It was just a programmed device that was implanted. And we were sending signals from the computer in the building into the device, and the device was sending signals back. So it was very much, well why can't we change the signals? Could have done something with muscles, but, it seemed, let's, let's really go for it, and work on a system as the next step, to send signals into the nervous system, and for signals from the nervous system to go back the other way. So a bidirectional signalling into the nervous system, can we do that?

And there were two methods. One was, what I call cuff electrodes, so this was to get hold of the nervous system, and almost squash it with a, put a ring round it, a metal ring, and clamp onto it. Which in a way is what they do in British Telecom, with wires and so… So I was familiar with the technique in using wires, not a nervous system, but, the nervous system is amazingly like wires, as it turns out.
[1:05:56]
But there was also, in the US, in Utah, they had come up with this device. Looks a bit like a hairbrush. It was called the Utah Array. 100 spikes, with electrodes on the end. And this was potentially available. It had been used in chicken sciatic nerves, but that was the extent of its use. And it, it obviously wasn't okayed for human use at all. But, we managed to get hold of a whole bunch of these things. I had to sign a little note to say we weren't going to use them for human studies. But at the same time, we were talking, back to Oxford, the link with Oxford, with a guy called Peter Teddy, who was then the consultant neurosurgeon in the John Radcliffe, about the possibility of trying this out. And he was, 'OK, let's go for it.'

Yeah.

So, it took a lot of planning. Because it wasn't just putting the bunch of electrodes into the nervous system, my nervous system. We had to send signals to the computer; we had to pick up signals from the computer and blast them down into the nervous system. So we had to work out all of the electronics to do with that. And I can remember the, this was linked in again, I have to say, though, a whole load of, bunch of links all over the place, another link I have to admit, and this is not so politically OK as it used to be, but, was with Jimmy Saville. And this was at Stoke Mandeville Hospital. And he put us in touch with one of the surgeons there, who was going to help, with Peter Teddy at John Radcliffe, and Ali Jamous at Stoke Mandeville. And we were talking to Ali about… This was, this was about 2000. The year when the story came out on the cover of *Wired* magazine in the US, so publicity going well. And it's nice to have been on the cover of *Wired* magazine. But I can remember talking to Ali, and he said, 'OK, if you're going to implant all of this technology to blast signals in, how big will the implant be? How small can you make it?' And we said, 'Well, we can get it down to about the size of a cigarette packet.' And he said, 'No way am I implanting something the size of a cigarette packet. If you can…' This

is high technology. 'If you can get it down to the size of a cigarette lighter, then I will implant it. But nothing…' So, we gave up the idea of implanting everything.
[1:08:47]
So the array was to be fired into my nervous system, and, then, what was happening… Which you can see here, that there are scars there where the array was fired into my nervous system. And then the plan was, wires coming up my arm. So I've not got to the elbow yet, but there's scars there, where wires came out of my body. And then we have the signal conditioning and, and everything, and a little gauntlet, which I have somewhere, I will show in a few minutes, which I could wear on the outside. So that was the plan of action that we went ahead with, this time with neurosurgeons, four of them in total, a couple of at Stoke Mandeville and a couple at the Radcliffe in Oxford. Which, which happened in 2002.

[1:09:40]
Yeah. And, what was the practical implication of that?

Aha. Well, twofold. One, partly for therapy, was looking for somebody who is paralysed, and clearly they have a break in the nervous system, so signals from their brain don't go to the parts of the body.

Right, yeah.

So this could potentially, the same implant could pick up signals in their brain, or on the nervous system, wherever we could pick the signals up. And then, send them out to a robot arm. So, it helped somebody who's paralysed to control technology around them. But also, it was looking at enhancement, human enhancement, and saying, OK, take a regular human, such as myself, who doesn't have a medical problem as we're talking about there, and, what extra abilities? For example, our senses. We, we sense about, it's estimated, about five per cent of what's going on around us. Vision is OK, but we miss most of what's happening, because we don't sense it. We don't sense in ultrasonics, infrared, ultraviolet, X-ray. We just don't sense those signals. Not to say our brains don't, maybe, pick them up in other ways, but we don't sense them. So could we start to, can, can we have more senses? Will our brain adapt to that? Could I plug my nervous system into the Internet? And hence, rather than, as I'm doing

now, I'm moving my hand around, signals are going down my nervous system from my brain to do that. But if I plug into the Internet, my brain signals can go, some completely different place, and control an arm, or a leg, or, anything. I… I… You know, your, it opened up the possibility that your body can be anything you want. You can have a building as part of your body, effectively. And that can be wherever you want it to be.
[1:11:47]
But the biggest, for me, this goes back to my British Telecom days, was communication, that, could we ultimately send signals from brain to brain, to start to communicate directly electronically in terms of thoughts? And, what we did, or I did, was, was those things. I experienced, with a blindfold on I experienced ultrasonic signals, which is, a good sense of distance, effectively, like a bat. So, as something was coming closer, my brain was receiving more pulses of electric current. I went to Columbia University, to New York, and we plugged my nervous system into the Internet, and, I controlled a robot hand back in, in Reading, In England.

Yes.

So, what was happening, I move my hand, but my neural signals, which we could pick up here, which, they're different, neural signals are different to noise or muscle signals or anything, we could send those signals across the Internet, to the robot hand. And then as the hand gripped an object, signals were sent back from the fingertips, across the Internet, to stimulate my nervous system. So my brain was picking up pulses of current that increased in frequency the more the hand gripped an object.

So. you could feel that, you could feel the hand?

I could feel how much force, in a simple way. You know, not, not like the, the dexterity of the human hand. But I could feel. And the experiment was, trying to get the robot hand to just grip an object.

Yes.

Very successful.

Right.

Yes.

So…

So my, my brain was in New York; part of my body was in Reading.

[1:13:38]
So this opens up possibility, for example, of a surgeon in London…

Oh.

…doing an operation in, Washington.

Yah. Or, and the other… In the military domain, the soldier doesn't have to be on the battlefield.

Yeah.

Soldier can be nice at home, wherever, and, the battlefield can be wherever you want it to be. And, and… But, it doesn't have to be an arm or a leg, or whatever. It can be a tank that's part of their body.

Yes.

So it, it's a completely different way, your brain and your body don't have to be in the same place. The biggest thing of all, I felt, and this is nice, that, because it happened, June the 10th, which is, we're now June the 10th 2019, this happened June the 10th 2002, George Boulos, who helped with the first, he helped again, and he pushed two electrodes into my wife's nervous system. And we went back to the lab, and we linked our nervous systems together. So when she closed her hand, my brain received a pulse. Bing bing bing, bing bing bing, like that.

Yeah.

So what we did was a telegraphic communication between our nervous systems. So this was the first time, well the first time that a human had had a, a BrainGate implant, which is what I had, but this was the first electronic communication between the two nervous systems of, of two human beings.

Yes.

Which for me, it's now a small step, we've done it for the nervous systems; let's do it brain to brain. Which we haven't yet done.

Yeah. Yeah.

But, I, I have to say… And so that was, that's seventeen years ago today, celebrations. We'll have another cup of tea to celebrate. I have to say, when we did that, for me it was like a eureka moment, from a communications point of view. And I thought of Alexander Graham Bell with the first telephone call, and I thought, wow! I've already been on the cover of *Wired* magazine; this is going to be fantastic, you know. It's going to be Nobel Prize and things like that. I have to say, [laughs] I think maybe people don't understand it or something, I don't know. Or they, maybe they don't think the same way as me, but…

[1:15:58]
Presumably, there is a community around the world now that is interested in this stuff, and, I mean, you are clearly a leader in it, but…

Mm.

There are teams in America…

Oh, yeah.

…in China, and…

For therapy, the same implant has been used, five or six people now. It's still a research project. People who are paralysed, in order to allow them to control a robot hand, or, or to control the cursor on a screen, to switch off the heating, and things like that. So the same technology has been used for therapy. But, a lot of people are interested in the enhancement side, but, as far as I'm aware, there's no further experiments yet gone ahead on the enhancement. Which is surprising. So we, you know, we can still say, UK leads the way.

[1:16:55]
Yeah. One of the things that interests me about what you've done is, is the kind of confluence of the artificial intelligence, the robotics, the interaction of the nervous system. How has that all come together?

[laughs] It's…

Or, perhaps what I'm, I'm struggling with to start with. You got interested in AI at some point, in, in conjunction with the robotics. I mean, they don't have to go together, do they? But…

No. No, no. But that was the side of robotics that I enjoyed.

Right.

That was the side that really interested me. And broadened my horizons, the whole field of artificial intelligence. I found it extremely exciting, it, it's very futuristic for sure.

Yes.

And it, yeah, I know there are questions, well is it really intelligent? And that, that is, it's an important question to ask. You know, if it is, if it is intelligent, an artificial intelligence, boy, we have to worry. There could be problems here. Because it makes

its own decisions, and so on. So if we don't have problems, then we don't, can't be intelligent.

But you've tested whether it's intelligent or not, haven't you? You've done the Turing test.

Well, yeah. I mean that's one of my research student's humour. Her main interest was the Turing test, and, so it got me very much… Which is all linked in, to my mind anyway, linked in together. And we have run a series of Turing tests, trying to push the boundaries. The Turing test is really just about communication, and human communication at that. So you're looking at a machine and saying, if I converse with this entity, and it's a machine, and I can't tell whether it's a, a human or machine, I, I can't say definitely, you're a machine, and if there is 30 per cent of the interrogators that can't tell that it's a machine, then the machine has passed the Turing test. Which is, which is quite a tough… It doesn't mean it has to have human level intelligence. It's just a, this falling category of machines in being able to, to converse. Which is quite difficult, wouldn't you think?

Yeah.

Because, you can say anything to the machine, 'What do you feel like today?' 'Oh I feel…' And, and how it comes back, and so on. You could ask specific questions. You can say what you like as the interrogator. And the machine, doesn't have to give right answers or wrong answers, but it has to give the answers that you would expect a human to give.

Yes.

[1:19:42]
And in 2014, in the Royal Society, Eugene Goostman, which is a machine who pretends to be a thirteen-year-old Ukrainian boy, and there's all sorts of issues, some people complained afterwards, oh, he wasn't really… Because he pretended to be Uk- Yeah. So the machine is not supposed to pretend to be anybody. I mean, it's obviously much better, and in fact Turing said it's better if the machine pretends to be

a particular character, because if it's being a human, you are a character, by definition you're a character. But, that passed the test. Just, just about.

Mm.

It, it depends, not just on how good the machine is. It depends on the interrogators not being able to figure it out sometimes.

Mm.

So, it's as much… And, and it also depends… Because, the, the machine is compared directly with another human. It's not just a machine on its own; you're comparing, essentially you're communicating with another human and a machine.

Yeah.

And, the machine effectively is trying to fool you into thinking that it is the human, and the other entity is the machine.

Yeah.

That's, that's… It's… It's tough to do that. Because… So it, it also depends on the human that you're comparing with, and how they communicate.

Yeah.

And amazingly, humans often are pretty stupid [laughs] in how they communicate. And that is all… I, I love the research on that, and how… Again, it's back to the communication.

Yeah.

Reminds me of my old days back with British Telecom and trying to figure out who was on the other end of a phone.

[1:21:32]
So are we on the verge of real artificial intelligence then, if, if the Turing test is, at least almost passed, or is the Turing test not the right test?

Well, I mean, to me… No, to me it's passed. It's, it's, it's a nice test of conversation, but nothing more. It's not the right test if you, you're looking at overall human, sort of human level intelligence, or something like that, if you're looking at, you'd need something much more profound I think, much more difficult.

Mm.

I don't think we're there yet. But, clearly, we're heading in that direction. And, machines, as well as being able to do some things, like pass the Turing test, can do a lot of things better than humans, like mathematical abilities we know about, memory capabilities.

Yeah.

And you think of how machines relate to the past and so on. So… And creativity. I would say a machine can be far more creative than a human brain can. It has lots of advantages, but also maybe, in some ways, the generality, I think, people refer to sort of, artificial 'general' intelligence, that it does a whole bunch of things, is perhaps not, not good at doing that, at the moment. But how important that is, remains to be seen.

[1:22:56]
Yeah. It seems to me there's another philosophical step in your, philosophically important step in your work with, with the stuff you're doing on Parkinson's, where…

Mm.

Where you're sensing something's going on in the body, processing the signals, and then controlling the body with the output of that.

Yes.

Which is a kind of step forward from what you were talking about, controlling a robot hand or whatever. This is like a closed loop within the body.

Well again, this, obviously for me, is directly inspired by my father's situation when I was younger. But I have been for many years now working with Tipu Aziz, who's the consultant neurosurgeon at the John Radcliffe in Oxford, a brilliant guy, and it's an honour to be able to work with him. But what we do, he, he uses deep brain stimulation, which is applying pulses into the person's brain to overcome the effects of Parkinson disease, also for epilepsy, and depression in some examples. So it could tackle a number of issues. But what we do is also record the electrical activity in the person's brain, and feed it into an artificial intelligence system, which… And we try all different types of AI. And that learns to… It even models effectively part of the human brain, for two main reasons. One that it can predict when the, the tremors and the muscle locking that's associated with Parkinson disease, when it's going to start, the AI system can predict, before it starts.

Yeah.

So that, you can then apply stimulation to stop it, only when it's needed, and not all the time. Secondly, it can also classify, it can say, well, it's actually this type of Parkinson disease, type A if you like, or it's type B, and type C, based on the electrical activity in the person's brain. And that helped Tipu and surgeons say, OK, this person's got type A Parkinson disease, therefore, they need this stimulating current, they need this, this need, da-da-da-da-da-da. So from a medical point of view, it's given a diagnosis, which you wouldn't be able to get otherwise.

Yeah.

And that, that for me, I, I mean I have to say, it's wonderful to be part of the research, that you feel that you're actually helping people directly, but it's, it's a horrible disease which, which my grandfather had, and it's just a shame that I can't go back in

time. If someone now invents a time machine, I'll go back and help my grandfather straightaway.

Yes. And that, that's a practical solution now is it, or is it a research thing?

Yeah. No, no, it's, it's practical. Well, the, deep brain stimulation is practical, people… It's relatively expensive, but not enormous, given what it's doing. And, using AI is ongoing research but being pushed into clinical practice as soon as.

[1:26:06]
Yes. Is this a kind of precursor to a, a bigger vision where, you know, you might help people who are, are paralysed below the waist or something, and, you know, bypass the, the break in the nerves and, and teach them to control their legs again, and…?

Well with, with Amjad Shad, who was another one of the surgeons at Oxford at the time, he's now at University Hospital Coventry, the link, my Coventry position there, and he's been made a visiting professor at Coventry as well by me, well, university officially, but I pushed his case through. And that's exactly the topic we've been talking about.

Yes.

Again, it hasn't been done yet. But literally… Because the nervous system, if somebody's paralysed, often through an accident or whatever, it's at a relatively specific point in the nervous system, and if that can be bridged over with two implants effectively, then potentially you can rewire the nervous system. And that's, that's what he would like to do, with my help. So hopefully we can take that step.

Wow.

I mean it would be fantastic, and… Because the person's life… I think Superman, Christopher Reeve, was one prime example, I mean, a really severe case, where the person can be very active and physically out there, doing all, horse riding, all sorts of things, and momentarily, because of one mistake, they can't move.

[1:27:50]

Yes. So, bring together all this, robotics, the artificial intelligence, the interaction with the nervous system. Do you have a vision where all of this is going to take us in the next, I don't know, ten years?

Yeah. Well I have two visions, one of which is very positive and one of which is very negative. On the positive side, clearly with artificial intelligence, it's offering all sorts of great stuff for the future, particularly if we can link human brains with artificial intelligent brains. So, rather than having it act against us in any way, we upgrade, we enhance the human way of thinking, so we can take on board all sorts of different things. I mean, one example that we really don't understand fully, the human brain thinks in three dimensions, so space around us is three-dimensional. But space is not three-dimensional; space is, space. We are imposing a three-dimensional view because of the limitation of the human brain. If we can link the human brain directly with a computer brain, because computers are used to deal with information in hundreds of dimensions, potentially we can understand the world around us in many more dimensions, and in that way perhaps we can start to travel. We've hardly been anywhere. I mean, the Moon is, is nowhere, really, compared to the whole universe out there. But that's because we think in 3D. If we can think in 100D, then it's not an issue, we can travel through, you know we're into the world of *Star Trek* and things like that. But, why not? So, I just hope that in the future we can link human brains with artificial intelligent brains with other human brains; we communicate in terms of thoughts, which, from the communications point of view is tremendously exciting. We communicate then in terms of feelings, emotions, ideas, concepts. From an educational point of view it's incredible. It would completely revolutionise how we are. Would we still be humans any more, is a question. Would we be post-humans. So that's my positive view, communication in terms of thought, and a whole new way of thinking.

[1:30:28]

In the negative, it is that we don't do that, and, we do have AI acting against us, and it becomes some sort of terminator scenario. This is referred to by some people as the singularity, when we build intelligent machines that we can no longer control but

we've already deferred to them enough and, we not only lose control but we lose our lives. They make the decisions. I know it's more of a science fiction scenario, and it's difficult to conceive. When you are thinking about an AI system, it's sitting in the corner and you can switch it off, that's not really what one's talking about here. It's an AI network, which you can't switch off. You can't switch the Internet, practically, you can't switch the Internet off nowadays. So, so that would be the negative scenario.

[1:31:23]
Mm. It sounds to me like you're thinking, quite a few years ahead in, in those examples, are you?

Yeah. I mean, in the short term… I mean, well I, for me it's not many years ahead; for me, it's tomorrow as it were. But we have to make it, make it work, or make it do what you want. In the short term, I think the, the implant that I've tested out, the BrainGate, or similar implants, can be used to help people with different disabilities, such as paralysed people. I think generally, even with the deep brain stimulation, there are a lot of neurological problems that we have at the moment, remembering the brain is electrochemical, that we can tackle electrically. Schizophrenia is another one. If we knew the best position, the right type of signals, I believe potentially we can overcome problems such as schizophrenia, with electronic medicine.

Right.

We just need to find out how to do it.

Yeah.

But surely we've got to be able to do it. So, that's, again, another positive, and it's more short-term. It could be tomorrow. Someone, hopefully they will win the Nobel Prize. But, I think there are a lot of people that have a problem. A lot of people don't even admit that they have such a problem, it's part of the disease you might say.

Yeah.

For a third of people with schizophrenia, they're almost incurable, we just don't know what to do with them. So this overnight… And it's, it's not just the people themselves with the problem. It often affects all of the family around them, because of how the person is, and, people giving up lives to look after them, and so on. So, so I think a lot of neurological problems, and there's one example, will be transformed in the short term years ahead.

So that's kind of, electronic medicine.

Electronic medicine. Yeah, I mean, it could be in, in the future you have a headache, zing!, you put in some electronic signals. A headache, why not? It's just a, a neurological thing.

[1:33:40]
Mm. So, looking back over your career, are there some particular achievements you're, you're most proud of?

Clearly, the world's first nervous system, the nervous system communication experiment. I, I think… Oh the whole bunch of the BrainGate experiment that I talked about with the Utah array, I would say is a, a positive achievement. Lots of smaller ones, such as showing AI has creativity. But then there are some achievements which, probably I'm not supposed to be proud of, but I am, but they taught us a lot. And one with the students, Reading University, they've built, for a project, built a robot, it was a wheeled thing, to do a half marathon.

Yeah.

And how it worked was, I had a bum bag on with an infrared transmitter at the back, and this robot, which was called Roger, named after Roger Bannister, I have to say, great hero of mine, and this, the robot was picking up infrared signals, and it was designed to track me two metres behind. So that's two metres behind me. And it was going to do a half marathon.

Yes.

And what happened on the day of the half marathon, it, it followed me, and it was designed to try and stay two metres behind. But after a while it caught sight of the sun, and went hurtling off towards the sun, trying to get two metres away from the sun. But it crashed on the side of the road. And that was the end of the half marathon.

Yes.

But, the point was with this, I mean some of the students were in tears, this was their project not working, but it taught me how, yeah, we, we set the robot up to do a specific task, but it is looking at the world in a different way to us.

Yes.

And it was just trying to do what we wanted it to do, but it was not doing something that, really what we wanted it to do. So, it, it was great that we got the robot, but we learnt more from it than it actually did.

[1:36:00]
Mm. You mentioned Roger Bannister as a hero.

Yes.

I suppose, you would expect that with his neurological achievements and his athletic achievements and so on. Are there other people that…?

Well I have to say, the story with Roger Bannister. But, yeah, I mean I was born at the time that he did his first four-minute mile. So he was always a great hero, of not only me, my father and so on. And then I had the chance to meet him. I was on a radio programme with Libby Purves and, and Rachael Stirling, who, she's been in *The Bletchley Circle*, actress, and so on, which, I was delighted to meet her. But Roger Bannister, and by this time he was quite old. And I, I got to the radio studios, and, I

walked up to him and said, 'Oh, hello Roger. I've been dying to meet you.' And he, charming as he was, he turned round and said, 'Yes, I've been dying to meet you as well.' [laughs] I thought that was very nice of him to say. Whether... I'd like to think it was true, but he was a really nice gentleman.

Mm.

But it was a great honour to actually meet him.

Yes.

Other people, other people, which was the question. I… Well I think, I grew up in the Sixties, and there's more people that I haven't had a chance to meet, and probably never will. I mean John F Kennedy was a great inspiration, saying at the start of the Sixties, 'We will land a man on the Moon,' and then, go ahead and do it. I mean I, I think that's, from a, for a young kid at that time, was absolutely phenomenal to hear. And even Muhammad Ali, I think, 'I am the greatest,' 'I'm going to walk the sky.' When I was, I don't know how old I was, eight or nine, and got up about three o'clock in the morning to see his Sonny Liston fight live by satellite, I mean it was in sort of, grey and white I think, and very crackly, on, on the TV. But he was very inspirational, that you can do.

Yeah.

You know, even you might not be the richest family in the world, you might not have the best of the opportunity, but that doesn't mean you can't go ahead and, you know, you can beat the person that's bigger than you, sort of thing.

Yeah. And he was another one that ended up with Parkinson's disease.

Yeah. What a shame. What a shame. Yes, a great man.

[1:38:23]

Would you do anything differently if you were starting off? If you were sixteen again, and, done your O Levels, what would you do differently now?

I… I don't know. I can't think of anything offhand. I mean, the small things here that we've found out scientifically. But I enjoyed thoroughly my apprenticeship, and learning what I did, it was…

Yeah, I got that impression.

Yeah, hands-on experience. Great, a great bunch of people, and several of them I'm still in touch with. And the scientific experiments that I did, and I really enjoyed.

Yes. Well that's good to hear.

So, yeah. Little, small things, but not… One or two girlfriends I wouldn't have had, one or two girlfriends I would have liked to have had. My second wife, Irena, we've been married for almost 30 years now, she's great, she helped with the, the project, she had electrodes into her nervous system. And, she's, she's absolutely fantastic. She's Czech, and I love the cultural difference that we get there. [laughs] Gives us occasional arguments, but, mostly it's, it's lovely.

[1:39:34]
Yeah. Because you have a job in Prague as well, don't you.

Yeah. I… Well, quite a bit. We, we have a flat out there in Prague. And the Czech technical university, I go in and lecture to the students. There's a course they enjoy. It's in English, I have to say, my Czech is still… I, I maybe have a brain that's OK for mathematics, but for languages, my brain is absolutely awful, let alone English. I have great difficulty learning any other, foreign language. But, I keep trying with Czech.

Isn't that interesting, that, that you, you learnt A Level physics in the coffee break, but languages are a different thing!

[laughs] Yes.

But languages are a different skill.

I, I've been trying and trying to learn Czech, the language that my, my wife, her first language, and I still haven't grasped it.

But you've got a, a local football team in…

Oh yes. I love football.

…the Czech Republic.

Viktoria Žižkov, who just avoided relegation from the Second Division this season. And I go and watch them whenever I can, home or away. So it means I've been all over the Czech Republic watching them. And I, I thoroughly enjoy sitting down and watching them. Yeah.

[1:40:48]
So if you were, if you were talking to a young person thinking of, let's say thinking of going to university at the moment, and they were considering what to do in, in the area of technology let's say, what advice would you give to a young person setting out on their studies and career now?

Well the big thing I think is try and keep an open mind. You know, big… Things are changing dramatically. And you never know what to expect, what's around the corner. I was told when I worked for British Telecom, cell phones are a great research project, but they're never going to be any practical use. And there was a whole list for these, ten reasons. One, people are not going to want to have the masts positioned everywhere. And of course, we don't, I mean there's now masts everywhere. I think, keeping an open mind on that, because, people change. Ethical standpoints change. But doing… I believe doing a practical course such an engineering degree, you can't do better. It sets you up I think. You're going to get quite a reasonable salary when you leave, because you're going to be in high demand.

And as long as you stay adaptive to changes, don't get stuck in one particular company, or don't get stuck in one particular type of job, change every so often so you're quite versatile, and can adapt to new things. Because things will change. Jobs are going to change dramatically in the future. AI is going to take all, all sorts of jobs, but things that we don't even think of as jobs now, will become jobs.

Yeah.

So, stay adaptive to the future. But, but try and, and try and do it with a bit of fun, enjoy what you are doing. Science is, isn't a serious thing. [laughs] I mean, people can make it serious, and cut the humour out of it, but, you can make it humorous, and have some fun.

Yes.

With the gauntlet arrangement that I had on my arm, the hospital said, 'Here's this white plastic thing that you could use.' It looks horrible.

Yeah.

So we got some digital artist in north London to make this sci-fi arrangement. More, just to have a little bit of fun with it. It didn't have to be as sci-fi arrangement. We thought, if we're going to do it, let's do it with a little bit of style.

Should be fun.

Yeah, should be a bit of fun. So have a bit of fun when you're doing it, and enjoy it. And, be, be open to, to learning about, things that maybe you think, hey, I think this could be possible. Well, try and show, try and show it's possible. Scientists are like mini science fiction writers. This is what it's about. You come up with a hypothesis. You say, 'I believe this is possible.' And then you carry out the, the experiments, or write the equations or whatever it is, to prove that it's possible. And that's what science is about. So, science really is, you are a science fiction person.

Yes.

So let science fiction inspire you, give you ideas. Why not? Don't, don't accept everything it says, but, let it give you some ideas and think, yeah, I could make that happen.

[1:44:15]
Sounds good advice. The thing that, one of the things that strikes me from our chat this morning is that, that you, on the one hand foresee huge potential coming out of the work that you've done, and on the other hand this slightly scary scenario of machines taking over.

Mm.

Is there a mechanism that, that we are going to use, or should be using, to try and make sure that the right outcome is achieved?

[pause] I… I don't know. Other than being aware that there is a potential negative, and not dismissing it, and, and using pink glasses and saying everything is certainly going to turn out OK. I, I wish we were a little more open about how the military is using AI, but I guess part of the thing of the military is secrecy, and doing it in particular, you know, we're never going to be completely open. So, I don't know there's anything can be done about it. One just hopes that people are not going to be so stupid as to allow AI to get out of hand, and to have defence mechanisms that look after themselves and don't have some human involvement somewhere. Yeah, keeping humans in the loop somewhere, is important in the military.

Sounds good. Well thank you very much for your time.

Thank you. It's been enjoyable.

It's been great talking to you, and, and congratulations on, on those wonderful achievements in AI and robotics and interfacing with the nervous system. Thanks very much.

Thank you. Thank you.

[End of Interview]