# Muffy Calder OBE

Interviewed by

**Elisabetta Mori**

11 December 2018

At the

**Royal Academy of Engineering**

*Welcome to the Archives of Information and Technology. It's the eleventh of December 2018 and we are in London at the Royal Academy of Engineering. I am Elisabetta Mori, an interviewer with the Archives of IT.*
*Today I'll be talking to Muffy Calder. She is Vice Principal and Head of College of Science and Engineering at Glasgow University. She is also a Professor of Formal Methods. Her research is in modelling and reasoning about the behaviour of complex software and biochemical systems using computer science, mathematics and automatic reasoning techniques. She has collaborated with electrical engineers, medical scientists, aeronautical engineers to solve problems in a range of systems, from condition monitoring and communication networks and protocols to user interactions in mobile app development, mixed reality systems and biomolecular cell signalling.*
*She is a member of the governing body of EPSRC, Engineering and Physical Sciences Research. She is Chair of the DCMS Science Advisory Committee and a member of REF Main Panel B.*
*Until 2015 she was on secondment to the Scottish Government as the Chief Scientific Adviser, where she also co-chaired the Scottish Science Advisory Council. At the time she was also co-chairing of co-chair of EU FET Science Advisory.*
*She is a Fellow of the Royal Society of Edinburgh, a fellow of the Royal Academy of Engineering, a Fellow of the British Computer Society and, in 2011, she was awarded the OBE for services to computer science.*

*Welcome Muffy.*

Thank you.

*When and where were you born?*

So I was ... sorry, you want to know when? Right. Well, 1958, so you can guess my age, it's a nice round number, and I was born in a very small village in Quebec, Canada, called Shawinigan. Perhaps what's significant is that I was conceived in Chile, because my father was an engineer working in the nitrate mines in Chile, and they were expecting a medical emergency with my birth so they emigrated to Canada

and ended up in this obscure village in the north of Quebec without a hospital. But anyway, as you can see I survived the birth.

*00:02:38*
*So, please, discuss your family and your parents, what were their occupations?*

So, my family very much comes from just about all of northern Europe. So my mother was half-Norwegian, half-Swedish, my father had Scottish, Welsh, Dutch and German, more predominantly Dutch than German, so nearly every country in northern Europe at one point I can point to a relative there. And I have one sister, who is four years older than me.

*What about your grandparents?*

So, I never met them. My parents were early-orphaned only children so I also had no aunts, uncles, cousins or any of that. But I do know my father's family came from a very strong religious family, very non-conformist, no, and that kind of thing, and his mother was very disabled and, I think, never walked after he was born. What else to say, on my mother's side her father was shot when she was very young, so not much else to say, I think.

*So what was your family life like?*

I would say very happy as a young child. I was well known for taking apart everything in the house. I also know that, at some point, my parents took me to the doctor and the doctor said, 'Well, if I kill myself', you know, 'undoing something or falling out of something they weren't to feel too bad about it' because that was just me.

*Which school did you attend?*

Do you want to know something maybe more from my childhood, I always wanted to be a scientist. I always knew I wanted to be a scientist or an engineer. And so I was always building things, making things and sort of studying things and, when I was ...

*What age are we talking about?*

Right, eight or nine. I used to collect rocks, I used to do all that sort of thing. I was quite a tomboy. But when I was about eight or nine ... I always loved animals, I always had lots of animals, and I had two terrapins and the terrapins died. And I thought, my terrapins are always dying, I think they always do. Anyway, I thought I would conduct a scientific experiment about how quickly they decomposed. So I went out the back and I dug a hole and I put them in plastic bags, two different plastic bags, and I buried them because I wanted to dig them up every day and observe how they were decomposing. So I buried them and everything, I even painted a tombstone with glow in the dark paint in case I wanted to make nocturnal observations. But the really interesting thing for me was setting up my notebook. So I set up this lab book with every day and the hours I was going to make the observations. So the first day, I went out in daylight, not at night, and I dug up the first terrapin and, I have to tell you, it was absolutely revolting. So, in the bag, basically there was a shell and a head and his feet all swimming around like on their own [laughs] and it was hideous. So I put it back in the bag, buried it and wrote 'End of experiment'... and I must say that day I decided that life sciences was not for me. I was inanimate objects.

*So, at some point you attended school. Do you have any special memories, like which classes did you most enjoy, which were your favourite subjects?*

So I did quite well at school and I skipped a number of years so I did exams early. It's a bit embarrassing now but I remember my first year marks at secondary school. I can't believe it but I went to the headmaster and complained. I actually don't really remember doing it, and I never spoke to my parents about it, but I said it was boring. So they put me up two years and then I really enjoyed it, so I did all my exams early. So I just loved maths at school, I loved chemistry, I loved physics. I did all the sciences and because I was ahead of my time then I did extra and I did music. I had time to do lots of other ...

*00:07:08*

*Did you play an instrument?*

Yes, I played French horn from an early age.

*And you lived in Canada at the time?*

Yes. And so I won some awards at school, so I had the school prize for sciences and the area prize for the highest award marks.

*What did you do to gain these prizes?*

I just got the highest marks of anyone for hundreds of miles around. [laughs] The thing that's worth saying is, I did really well at maths, I loved trigonometry, I did very well at chemistry, I loved chemistry, but what I really loved was rules. What I loved was manipulating things on the page. I actually didn't care about the chemistry *per se*, I just loved balancing equations. And I look back and I think, I was a computer scientist, just trying to get out. I loved rules and computing with them. I loved calculus because of what you could do with it, not what it philosophically represented.

*Do you think your family would be proud, particularly your father, for instance, in your choices or the subjects at school, and your future choices at university?*

I don't know so much choice, but my father was very influential in maybe the way he talked about science and engineering. He was an engineer and he was really, really passionate about it. And I would ask him questions and he would never tell me the answer, he would never just be simple, 'Here's the answer', he would always 'Let's work out the answer together'. I mean, I used to joke about it and sometimes it really got up my nose, 'Just tell me' you know, 'what's the answer, 52?', 'No', and he was always 'Let's get a clean sheet of paper, let's get a sharp pencil, let's write down everything we know about this and let's see if we can work it out.' And, actually, that stood me in really good stead. I used to, when I taught, I would try and share this with students, you know, 'Take a deep breath, start with a clean sheet of paper, be calm, what do you know about this problem, and let's see what we can work out from the first principles.' Maybe I should say that he didn't want me to study engineering

at university because, he said, ‘I would just be out on dates’, how very quaint, because so many boys did it. Little did he know what kind of boys they are but, anyway, [laughs] he didn’t want me to do straight engineering. Actually I didn’t want to either. I wanted to do maths and physics.

*00:09:48*

*So after high school you spent your late teens working in a Dominican convent in Bodø, Norway, the most northerly convent in the world. What do you remember about that time?*

Oh, it was one of the best times of my life. So it was six Sisters, I was the lay person, and we had one priest. And basically I did a lot of manual work for them and I helped them run a hostel. I lived with the Sisters and I just loved it. It was such a peaceful life, it was such a different life. The joke was, they were always trying to match me with young men in the village [laughs] but I look back and I liked them so much, I just loved that life. I thought of trying to stay and then I realised, of course, I was seeing it from the outside. If you are actually a Sister you actually have to sign up and you have to obey the Church, and then I thought, ‘I’m not so good at the obey bit’, but I’ll never forget it, one of the nicest times in my life.

*So what year did you get your driving licence?*

Ah, I can’t remember the year but I can tell you how I got it. I very, very nearly failed. So, during that time you had to actually drive and then you had to have a verbal test. So I did the driving, that was ok, and then we stopped and he said, ‘Ok, I’m going to ask you some questions.’ So the first question he asked, ‘When wouldn’t you use your horn?’ Oh, ‘Could I answer the negation of that please? – through double negation I know that this is normal ... ‘when wouldn’t I use my horn?’ So I said, ‘Ok, nothing bad has happened’. And he said, ‘What’, so I said, ‘Something bad has happened, so there’s no point in using my horn now’. He looked at me, ‘Are you stupid’ he said. ‘Ok’, if a deaf man is crossing the road I wouldn’t use my horn’. [laughs], so he says, ‘Do you want to fail, Miss?’ ‘Ok’, I said, ‘a drunk

deaf man crossing the road'. He got really angry, he was really furious with me. Do you know what the answer was?

*Tell me.*

Between eleven o'clock at night and seven in the morning. I had this big Venn diagram in my head in which I had drawn all the events in which I would use a horn and then I was trying to describe the complement of that set.

*So, at some point, you chose to go to university?*

Yes.

*What were the key decisions of this choice?*

So, maybe I'm not like other people, the key decision for me was the physical surroundings and I went to Stirling because I loved the hills.

*So Stirling in Scotland?*

Yes. I was already in Stirling at the time and I just applied, I didn't go through UCAS or UCCA at the time, I just went up to the desk and because of my grades I was just accepted. And I went to do maths and physics. A teacher previously had told me ... so, you couldn't do computing in the first year, it wasn't a subject then anyway ... but a teacher had told me not to do computing because she didn't think I'd like it. But I had to pick up computing ... oh, by the way, I did geology, first of all, as my third subject and I just really didn't like it because you just had to memorise all these rocks.. It seemed like there were no rules and you had to memorise these rocks and these eras and I didn't like that. So, then I did a computing course and the first course just infuriated me because it was mostly about buying a computer, because they were really big, expensive things, and it wasn't about programming and I was like, I was furious. But then I did a programming course and it was just fabulous, just fantastic.

*00:13:41*

*And what computer did you use at university?*

Well, the very first one we learned on, it was programming Cobol on punched cards, and there was one computer and it was about a mile away, and a man came with a suitcase every hour and picked up your punched cards. And I'm not sure that I ever got the programme actually compiled that term, because it was so full of syntax errors. The next course, we moved to the Kent online system, with teletypes, it was fantastic. You pushed down the key and '*Chikachika'* [noise of going fast] and that was brilliant, just superb.

*Do you remember the company, was it an IBM or ...*

But we didn't see the computer, we were sitting there half a mile away, yeah. [laughs] Sorry, I've never been very interested in computers, it's computation, it's programming.

*Not in physical machines?*

Yeah, I'm not interested in the physical machine. Is that so bad to say? I'll tell you the first computer that I really loved the machine, is when I took a course in computability and learned about the Turing machine. I still think that was the most fun, beautiful construct in the entire world.

*But the Turing machine is not a real physical machine.*

Yeah, I know, but that's the closest to me getting interested. I quite like the idea of circuit design but, sorry, actual machine, I don't care as long as they do computation. I'm much more interested in how I represent its programming and concepts and data structures. I just love all that aspect of computing.

*So, after your bachelor degree, did you go to Europe for your education?*

So I did a PhD, the title of which was the 'Imperative implementation of algebraic datatypes', at St. Andrews. And actually my PhD is called in Computational Science which was .. those were the last years of that phrase being used and, at the time, I was embarrassed because I thought, you know, computer science is much more modern. Now I look back, I'm actually quite proud it's a PhD in computational science, I actually think my own research now is much more in computational science so it's really very apt.

*Have you got any memory of your supervisor?*

Yeah, so my supervisor was Roy Dyckhoff and he was just superb. I should say I had a few supervisors before I landed on Roy and they hadn't gone so well. And actually Roy came and offered himself ... Roy was a mathematician, a category theorist, he had just moved into computing, and he came and offered to rescue me and supervise me and he was just superb because he was very, very tough, he was really severe. We would meet once a month for a whole day and, often, during that day, we would never move off, we would do about half a page of what I'd written. Because he would look at every single word and every single symbol that I had written. And it's just what I needed, absolutely what I needed. And I remember, when I finished my thesis, the last chapter I gave him, he just like, flicked through it. 'Oh', I thought, 'something's happened, I've arrived.' 'He's taught me now', you know, 'he doesn't need to go through it with a fine toothcomb.' But I will never forget what he did for me, never, never forget. Sadly, he just died a few months ago, but I feel like I owe my entire career to Roy. He turned me into a real computer scientist.

*00:17:27*

*Ursula Martin was the examiner of your PhD thesis, can you tell us more?*

So, Roy asked Ursula. At the time Ursula was the most senior woman in computer science in the UK. She wasn't yet a Professor, she was a Reader, at London University then. And, during my exam, it was a bit odd for me because I had never looked across a table and had a woman critique what I was doing. I realise ... I mean, the whole man thing doesn't bother me at all in computing ... but I was always used to

working with men, and men being my superior. I had not had a woman be my superior and it was actually a bit unnerving. And she was also very tough, really tough. I thought, at the end of the exam, 'Oh my god, I've failed' and then she turned round and said, 'you've got, like, seven typos to fix'. She said afterwards, she wanted to give me a really severe exam to show my fallibility and to give me a proper exam, and she did, she did that. But immediately afterwards we became friends, colleagues, and she's really been my mentor ever since then, she's always, I feel, she's looked out for me and she's suggested things to do, she's given wise advice. She's been great because my own research has never been attached to a professor, so as a young lecturer I was always doing my own thing, I was never part of a group or bigger thing, but I always had Ursula somewhere out there in the world. And she's made a huge difference to me.

*So, during university did you also have part-time jobs?*

Yes, so my first technical job was at British Ship Research Association', it's a big mouthful, known as BSRA.

*What year was that?*

1977, I think. And that was in the shipyards, the Swan Hunter shipyards in Wallsend. I nearly didn't go for the job interview, because I had to walk into the shipyards and there I was, this little girl [laughs] with just thousands of men and these big sheds building ships. But that's what I wanted, was to be in big engineering, making big things. And that's where I saw my first teletype, I had never seen one, not a screen right. Oh, it was very exciting, my first VDU, and I was assistant to the scientific officer for the database.

*Do you remember the company, like of the computer? [laughs]*

Again, I didn't see the computer, you know, I got like two runs a day. It was all on paper. No, I didn't get time in the VDU, I walked into the room, there was one VDU in a room. I saw someone who was sitting at it but I didn't get to touch it. But that

was just a VDU, I don't know whether ... I know there were PDPs but again I didn't ... PDP is probably the answer you're looking for.

*Ok.*

But I really liked working there, and the people were so kind to me, men and women, they treated me so seriously, I really appreciated that. It was the year of the Golden Jubilee ... I'll have to work out my maths ... and we got time out because Britannia came up the Tyne, and we got time out to go out and stand on the docks with big flags and placards saying 'Welcome Queen'. [laughs] I also worked at Burroughs Computers. Now that's where I worked on a B80, you'll be pleased to know about that. What did I do? I rewrote and assembled there. I really enjoyed that work technically but I didn't enjoy the environment at all. I felt very strange there, I was a woman in an office of older men and I just felt 'other', unlike BSRA where I had really fit in and I really, really enjoyed it. I didn't like working at Burroughs although I loved the technical work. I was also a tutor for Open University, T101, microprocessors, which is quite amusing for me. Yeah, I was a specialist tutor on microprocessor programming so I was teaching programming every day. The thing is, I'd go to these summer schools and I'd teach the same thing every day, so by the Friday it was all that I could say was, 'I told you this yesterday'.

*00:22:08*

*And when was your first official position in academia?*

So I suppose my first one was tutor of computer science at the University of Edinburgh. Then I went to Stirling and then, in 1988, I went to Glasgow. I nearly went to Nijmegen, in the Netherlands instead, because I only got offered a temporary job at Glasgow. Suddenly Glasgow was, like, the place to be, there were all sorts of things happening there, lots of money going into computing. It was, like, suddenly I knew it was a buzz. But they only had a temporary job and it was my ex-supervisor, Roy, who said to me, 'Muffy, do you want to be in the Netherlands in three years, now looking over into the UK and saying, "I'm trying to get a job there", or why not

take this job in a very exciting place now and see what happens.' Good advice. Good advice.

*And this was 1988?*

Yep. And look what happened. [laughs] So I was doing this tour of Scottish universities and it came to a halt at Glasgow. But I haven't just been at Glasgow, I was a Research Fellow at BT for two years, I've been on sabbatical to DEC in Palo Alto in California. So maybe, just to say, for someone who ... I do theoretical computer science, I do formal modelling but I'm always trying to do it with industry, with other people. So, that's why I've gone out to, like DEC, why I've gone out to BT. I've always looked for application areas.

*So, working outside the UK was important for you, or was it just an experience for you?*

It was an experience. I'm really glad I did it. I have to say I didn't like it very much. I thought the work I did in DEC was very interesting and I liked many of the people but I didn't like the culture of Silicon Valley at all. And also, sounds perverse, I didn't like the fact the sun shines every day. It was, like, unrelenting, like happiness and beautiful people, I couldn't bear it. When I came back to Scotland it was *Dreich* and I felt like the Pope and I was going to kiss the ground, you know, 'I'm back', in the home of irony and sarcasm. [laughs] And less beautiful people.

*00:24:39*

*You also received industrial grants and you were a consultant for industries from 1988 to 1992, you were a consultant for British Telecom Research and Technology at Ipswich.*

Yep, a word about that. So I was asked to write a semantics, to work on a language for protocol descriptions. So one thing I'm very interested in, I like protocols. They're rules, yeah, I love protocols. So this was a language for describing protocols, it was called the ASN1. And they asked me to write a semantics of it. So I spent ages

doing this algebraic semantics, I mean, I loved it, it was, like, fifty pages of symbols and black ink and I just thought it was the bees' knees. And I passed it over to them, I was really pleased, and do you know what happened? Like, nothing. Like, zero. So then, I don't remember why I thought of it, but I thought, 'Why don't I write an interpreter', because basically I had a denotational semantics. I could turn that into an interpreter, I'll do this in a functional language. I actually started off writing it in imperative language ... I think I started writing it in C ... and I thought, the whole notion of state was really getting in the way. So then I decided, I'm going to rewrite this - it was actually in Miranda because it was before Haskell - and within, like, twenty-four hours, it was during the Christmas holidays so it was a bit sad, it was before I had a relationship, I think I spent Christmas Day at my kitchen table writing this interpreter. But I had such a ball doing it. And then I wrote the software and then I gave it to BT and then, you know what happened? All sorts of things, because people started using it. Also, when I wrote my interpreter I found several mistakes in my semantics and that was quite a shock to me because, and it shows you the power of implementation, you bring it to life. It's so easy with black ink to think, you know, you have a mistake on line 33, who notices? unless you take it out and really exercise it. The implications of what you write, it's so easy to write stuff that looks really impressive to people but actually means not much. And that's the beauty of computing, you make it come alive, you animate it, people will then type in it, submit ASN1 specifications and see what happened. So it was a great lesson to me and I've never forgotten it and, almost to this day, ever since then, I never just write symbols without making them come to life. So that's what I'm really into, computational models, models that you can compute with.

*00:27:19*

*So, you got married. [laughter]*

A shock, a shock to all.

*Dave Calder, was he the boyfriend who couldn't spend Christmas with you?*

No, no, I didn't know him then. So, we actually knew each other for nearly ten years but only from a distance, through the same running club. He happens to be an engineer but we met through running and we decided, we started a relationship and got married within a matter of weeks. [laughs] I didn't tell anyone, we just went and got married.

*So what year was this?*

1998.

*So you got married within weeks?*

Yep, probably too much information but he kissed me on the Friday and asked me to marry him on the Sunday.

*Great.*

Yep.

*Do you still run with him?*

Yep. Except, I used to be ten percent slower than him, I'm now about thirty. The trend is not good.

*So there's always space for improvement.*

Yep.

*So, you went to work alongside specialists at the Beatson Institute for Cancer Research, investigating biochemical pathways along which signals pass from the brain cells into their nucleus.*

Yep.

*And your idea was to transfer the methodology behind phone networks into molecular biology.*

So the idea was just taking the way we, or I, had been modelling communication networks, so not necessarily telephone networks but I had been working in PSTNs. So the commonality is, you have a signal and the signal has possible routes to get to a destination. And, in molecular biology, the signals foster a relation as you go from ATP to ADP. And the route that the phosphore relation takes to get to the nucleus affects the effect it has. So that's the sort of basic thesis. And then, I could start using all sorts of tools from modelling in comms networks to model these cell signalling networks and then start looking at how these networks can interfere and overlay with each other. It's a really, really rich metaphor, I think. So, a lot of people, when they think about computing and biochemistry or biology, they think of data and bio-informatics. And I was, like, going from completely the opposite end, I was going from control. So, basically, what I've been doing is modelling the control mechanisms and reasoning about the control mechanisms, and one reason to do that is, the more you understand the biomolecular pathway in control you can start to think about, well, these are the places where we could interfere through some molecular intervention, for example, drug therapy, because why you want to do this is when pathways go wrong. And so, then, what you want to do is, maybe, change the rate of a reaction or you want to remove a reaction, you want to overcome a reaction completely. So it's very important to understand, for example, where a feedback loops because you don't want to make an intervention in the middle of one of those. I think it's a really good metaphor. It came out through serendipity, I was introduced to this cancer researcher - and many biologists in the past, I have found ... of course, I like them as people but, you know, we didn't have much common ground – and this guy, Walter Kolch, he and I, we just got on really well and I then found out that at something like age fourteen he was Austrian chess champion. And that tells me a lot, it's actually he was thinking algorithmically himself from a young age and I think that's why we got on so well. I just wonder what he says about me. [laughs]

*From 2004 to 2011, you were involved in the UK Computing Research Committee, UKCRC, as part of the Executive Committee, and from 2001 to 2011 also as the Chair. Can you tell us more about that.*

Yeah, a really important time in my life and I have Ursula to thank for me originally getting involved in UKCRC. So I was involved right in the formation from the beginning. It started out, EPSRC was running an international review of research in computer science and they wanted a description of research going on in the UK and there was no one to provide this. And that's how UKCRC originally formed, to construct this landscape of where is research in the UK now. And then it started to grow into the body that was looking after research in computing science and representing it to government and to policy makers. I feel it's just so important that it's so important, not that I'm particularly good at it but someone needs to do it, so that's why I got involved in doing it. And then, to my surprise, I was asked if I would become the Chair and I was quite taken aback but then I did it and I just loved it and I think I learned so much doing it. I learned a lot and it was really satisfying doing it as well.

*00:32:58*

*In 2011 you were appointed an OBE in the New Years Honours List. You are also a Fellow of the Royal Academy of Engineering and the Royal Society of Edinburgh and you were appointed many honours and prizes. What is your proudest achievement?*

I don't know, each one of those fellowships has been really meaningful to me, very significant. I think the OBE was just the total shock, absolute total surprise, I had no idea. When I got the envelope I thought it was something else, I didn't believe it. When I opened it up I actually took a photograph of the letter because I didn't believe it. [laughs] And it was kind of a turning point because, at that time, I was thinking, maybe ... I was just finishing as UKCRC Chair ... maybe I should just go back to research. Maybe this isn't for me, this kind of contribution to society, maybe I've done my bit. But, actually, when I got that I thought, 'No', I feel even more obliged to keep giving, to keep thinking about how is our science funded, what are the policies for it, what are the impacts on society, who speaks for our science in government and policy makers and more broadly for science and engineering.

*Do you have any other memories of your fellowships that you received then or any particular results that you want to tell us about?*

Maybe, I would also say the Royal Academy of Engineering, where we are today. I do feel really sad that my father never knew about that. He would have been so proud. I don't know what his reaction would have been but I wish he could know. Maybe I could say, you know, I said I always wanted to be a scientist. I always called myself a scientist. Yet, when I started looking more at the breadth of science and engineering and working with the biologists I realised, I wasn't a scientist, I was an engineer. I don't look at systems that have evolved through physical circumstances. I am dreaming of systems and building them, that's what engineering is, and then I realised I really am an engineer. But now I've gone another step further, as now I'm starting to think, 'but we can use scientific method to study and to understand the objects that we have engineered' so I think this is beautiful interplay between science and engineering and I try and be scientific about the things we've engineered. Because now they're evolving, like the Internet, like communications systems. We constructed these things yet now we don't always, we can't remember all the intricacies, we haven't got all the abstractions about them and, as they evolve and become more and more complex, sometimes we need scientific method perhaps to study them. So, I'm a scientist and an engineer.

*00:36:08*

*Great. You are also the leader of the Science of Sensor Systems Software. It is a programme for the EPSRC and involves Glasgow University, the University of St. Andrews, Liverpool University and Imperial College in London. It runs since January 2016 and it's a four years project so we are ...*

It's a five year project. [laughs]

*So we are in the middle, so maybe you want to share?*

Oh, it's one of the greatest things that I do, great in the sense that it's most meaningful to me. So this is a big programme grant and the question I'm asking is, we have

sensors at the basis of so many systems today that are networked together. And the question that I always want to ask is, 'To what extent can we trust and rely on the data and the information that we're getting back from the system.' Because sensors, both individually and collectively, they break down, they lie - you know - they lie, they cheat, they move, they decalibrate, the protocols break down, the mediums break down. Yet increasingly we are using these systems, we are relying on the data and information that's coming back from them and I want to ensure, 'How can we trust these and how can we make sure that we can ask meaningful questions and be assured of the answers?' You know, sometimes you have complex trade-offs, like the amount of energy or power that's being consumed in the system versus how often we're expecting sampling to be taken care of. And the smarter systems, of course, were powered at some centres when things aren't changing and power them back up, but can we be assured that they are powering up when something is changing? Can we tell a change in the environment as opposed to a security hack? Or as opposed to the sensor just not working anymore? How can you tell all those scenarios? Those are the kinds of questions that I'm looking at. And I so like my colleagues. Michael, Julian and Simon, who are the other four co-eyes at the other universities, they make my day. I really enjoy doing research with them.

*So, formal methods are traditionally used for specifying the behaviour and also the hardware, but you are showing us that you open up a total new problem. So you are experiencing and developing and applying models in domains as diverse as communication systems, biology, human computer interaction and you've worked on models all your life with different applications. Can you tell us more?*

So maybe another application of models that I haven't mentioned so far is, we build systems and people use them and interact with them. So I'm not thinking just strictly HCI in the classical sense but these are interactive systems. And, although we design the system to perform a function, human users often end up using systems in ways that we never imagined; they appropriate the system. So one thing I've been involved in, with others, is, if we instrument their interactions we now then have streams, traces, of all their interactions, and I can use machine learning techniques to infer models from those interactions over which I can then start to reason, and reason about different kinds of sub-populations of users. It's almost like the idea of precision

medicine, it's like precision software, you can start to think about, 'Can I tailor this piece of software for this class of user?' But it gets more complicated than that because users aren't static. How I use a system may depend on where I am - am I on a train, am I at a desk? Have I used it last week? Did I use it three months ago? You know, how good am I at it, it depends on the goals of why I might be using that software. So again, it's this theme of, 'I want to model systems that we've already built but that are evolving because they're not just pure black boxes, they're actually evolving interactions.' Now, I just talked about human users but that could be another system. It's basically, the system becomes evolved into other kinds of systems because we've put it in some environment. And models can then help us re-design, re-engineer what we have built to more accommodate, either to make it harder for users to do something we don't want them to do or make it easier for them to do something that we find that they are doing. So, instead of having a long computation path to carry out something we could make it a one-step action to get to that state.

*00:41:28*

*And it says here, it came out of also the Blackett Review of computational modelling capabilities in the UK. Do you want to talk about that?*

Yeah, I loved being part of that review. So, the goal of Blackett Reviews is to write a report on a piece of recent science that could be of relevance to policy makers, to government, and to give future directions. So, I think one of the great things that came out of this modelling review ... first of all, although we were all modellers we didn't know each other, we hadn't worked together before, and it just showed the wide range of modelling from, like, logic modelling, algebraic modelling, to differential equations to machine learning, AI to economic forecasting to weather forecasting, we were all in the same room together. But some of the things that we explored was very much about being very clear about what is the purpose of a model. What questions do you want to ask of it? Because if we're not clear about that, models can take on lives of their own, and we can end up using models in years into the future, and asking questions for which they were never designed to give sound answers. So we can become quite misled by a model if we're not clear about what is the purpose of it, who has responsibility for maintaining it, who has responsibility for

commissioning it? There's a lot of 'who', who has responsibility, all through this chain, from commissioning right to design, to maintenance, to use, to interpretation of questions.

*00:43:09*

*You've already told us about machinery models, would you like to explain?*

So machine milling has been around for a long time. It's very nice to see, you know, it's having its day in the sun. And many of the techniques are brilliant. I think we just have to remember, what is machine learning about? We often use it when we don't understand the mechanism, we don't understand control. It's because all we have is evidence and we're trying to infer some mechanism. But I thought someone from BT said something really interesting to me a wee while ago. They were looking at the number of machine learning models, embedded models, that they have in some of their communication networks and the numbers - I won't tell you the numbers, but already it was a lot of them - and he said to me, 'But, you know, in ten years time, when this system is still running and it's got bigger and bigger and bigger, how are we going to know, who's documented and how do we know what each model does and what role it plays and what algorithms it's using?', once it becomes so embedded. And the phrase he used, he said, 'little model', 'that little model there, model number twenty-two, little model, where did you come from?', and I just think that's a really good catchphrase, 'Little model, where did you come from?' How do we document, who do we know? You know, everyone's getting caught up in making these little models but they're gonna have huge implications, and how are we recording? Where did they come from? I think you can wrap that up in a word called 'provenance' but I think it's really important and it might come back to bite us in the next decade.

*Ok. So, let's go back to talk about you and what role did your colleagues and friends play in your career?*

So I would say, colleagues and friends, you know, are almost synonymous in many cases, and my colleagues have just always been so friendly. I've really, really enjoyed working at Glasgow University. But I should pick out someone, my very

first PhD student, Carron Shankland, hmm, nearly thirty years ago. We play music together. She's now a professor of computer science. And she was always a good musician; she was a clarinettist, I played French horn. But, I don't know, about fifteen, twenty years ago, we both decided to take up string instruments and we now play in the same string quartet; we play trios, we play duets, I see her nearly every week to play music of one form or another. And that's just such a rich aspect of my life, I really appreciate it. And I really enjoy playing with Carron because I don't need to ... .well, (a) she's better than me, but I sort of don't need to think how I'm playing with her, I just play with her. And it's a lovely aspect, a wonderful impact of research in computer science.

*Recently, in last October, you were invited to give the BCS Karen Spärck Jones lecture and I'd like to ask you: Karen Spärck Jones said, 'Computing is too important to be left to men' and you said that you happened to be in the room. Can you tell us more about that?*

So I think it was at a meeting that Ursula had organised, at Cambridge, and Karen was there when she said that. I didn't know Karen very well, you know, I looked at her from a distance and had great respect for her. It's a lovely phrase and I think it's one that we latch onto as a community but I would say something further, as computing is too interesting to be left to men. And that's why I do it. It happens to be important, at the same time, it's great, well it's a beautiful career because it's important, it pays well, there are lots of jobs, but the really important thing is, it's just so interesting. And you can do it any time you like. I mean, that's the beautiful thing, I think for me, compared to chemistry or physics. I don't need an elaborate lab, I don't need to stand there titrating, you know, [laughs] I sort of didn't care about that kind of stuff. You can write a programme at three in the morning, you can write it in the bathtub, you construct data structures in your head, it's all in your head and then you type it in and you create this thing. And there's nothing more powerful than that, I think, and that is why we don't want to just leave it to men because I want women to actually be able to experience that as well, if they want to.

*Of course. Finally, can I ask you what advice would you give to someone entering the computer science today.*

The obvious thing is, just do it. But I think the really obvious thing is, do you like programming? Find out if you do, and if you do then computing is for you. And enjoy programming. And don't be put off by the speed at which someone else programmes. It's just like mathematics, you know, just do it yourself, it doesn't matter how fast they do it or what their programme looks like, it's your programme, just take the sheet of paper, do it quietly, it's your programme and it's loaded into your head. I think there's sometimes a bit of competition, when people are programming together. Well, I used to feel it, I didn't particularly like to be in a room when other people were doing it at the same time, I didn't find it terribly easy, and I don't actually find it easy to work on other peoples' code. And I don't want to use someone else's library, I just want to create one myself. But, you know, it's like doing maths, it's your problem, it's your solution.

*Thank you very much, it's been a real pleasure talking to you.*

Thank you very much, it's been very enjoyable talking about me [laughs] but talking about computing as well.

[recording ends at 00:49:38]