An interview with Harry Buhrman, Professor of Computer Science at University of Amsterdam and Executive director of QuSoft and leader of the Quantum Software Consortium.

Quantum computing: the new frontier

BIO HARRY BUHRMAN

Born
1966, Amsterdam, the Netherlands

Degree program
Computer science at University of Amsterdam
PhD in 1993 at the University of Amsterdam

Job
1994-now Group leader Algorithms & Complexity CWI
2001-now, Professor of algorithms, complexity theory, and quantum computing at the University of Amsterdam
2015 – now, executive director of QuSoft and leader of the Quantum Software Consortium

→ You've made a journey from studying computer science to research into theoretical quantum computation – how did you end up where you are now?
I was always interested in computers. Back then, there was only a single computer at my whole secondary school. I was lucky to have my own - a TRS80 with 16K RAM, a lot in those days. I thought it was fantastic that you could programme this machine and it would do exactly as you told it to do. I was fascinated by the endless possibilities. I was also extremely interested in science in general, reading books about doing experiments in physics and chemistry at home.
Computer science had just started as a degree programme at the UvA in 1985. So, I studied computer science, taking a few extra math exams on the side, and remained broadly interested in other disciplines. For example, I bought syllabi from the physics department next door to read up about quantum mechanics. For me the sheer scale of what there was to study was great, compared to the high school material. All in all, I am now really pleased I didn't listen to my high school math teacher who said "Harry, don't do maths, it's not your thing".

This sounds like a lot, how long did this all take you?
Less than four years.

So, did you have much of a 'life' outside studying?
Oh yes, I was into music. I went to bands and also played guitar in one. The band was called The Exist. It was a 60's-style pop band with what we called an 'empty highway sound'. I am proud of my entry as a guitarist in the Dutch Pop Encyclopaedia [www.muziekencyclopedie.nl/action/entry/Harry+Buhrman). I sucked, but it was a lot of fun.

What proofs or results of yours are out there being used by others?
Not me on my own, but with collaborators: we were proving lower bounds for quantum algorithms called the quantum polynomial method. Also, the idea to use quantum bits for communication and showing you have an advantage was something we did for the first time.

Do you think you've made the right career choices? Getting bought out by a big company or setting up your own one: isn't this the modern way to go for quantum computation scientists?
Many people ask me how my company is doing. I don't have one. QuSoft (see infobox) is a research institute and is not commercial. Although there are a lot of quantum software companies starting now. I don't regret for a moment that I went into science as it is fantastic.

QuSoft is the Dutch research center for quantum software. Its mission is to develop new protocols, algorithms and applications that can be run on small and medium-sized prototypes of a quantum computer. QuSoft was launched jointly by CWI, UvA and VU in December 2015 and builds on the institutions' excellent track record in quantum computing and quantum information. QuSoft's start-up funding came from the UvA and Science Faculty's Research Priority Area programs and from the CWI.

How do you divide your time these days?
What time? I feel I have little time for research anymore. That said I am working on a number of manuscripts for publication and still work with my PhD students, but all this is less than it used to be. So QuSoft takes a lot of my time, but I want to see it through and cement Amsterdam's place on the world map. When QuSoft can be passed on, I'll maybe then head off to somewhere new, some years for now. But to be honest Amsterdam is really a great place to be, both scientifically and in terms of the rest of life. Why should I even want to move?

Do you see quantum computing as a new frontier? Is it now how classical computing was when you were growing up?
Absolutely, that's exactly how it is. Quantum computation's now like regular computers were in their infancy in the '50's. People had no clue what to do with them. Famously, IBM's boss is quoted as saying he didn't see a world-wide market for more than five computers. Now there are 10-15 computers in everyone's house: no-one saw that coming. We are now at similar cross roads, where today's quantum computers now have 10-15 qubits, with bigger versions just around the corner. Although we have some ideas of what we can do with this, a lot is still unknown. Quantum Computation will open up doors like classical computing did, and that is extremely fascinating.

We read Harry the website blurb for the recently granted NWO Gravitation consortium he heads (see infobox on the QSC): "QC will predict new materials and medicines". What do you mean we don't yet know what to do with it? Buhrman admits these soundbites are somewhat stabs in the dark. When asked whether this kind of 'application' is proven to be significantly better using a QC he starts to formulate with care.
Harry: A QC is the right machine to deal with the exponential overhead that occurs when simulating physical quantum systems on a classical machine. In this sense, a QC can be used to perhaps search for new materials and better medicines, as quantum computation can provide access to understanding what is going on, for example in the interaction between molecules. This is what we Dutch call a 'dot on the horizon', something that may or may not work. Quantum chemistry is one area we are very confident great results can be achieved in.

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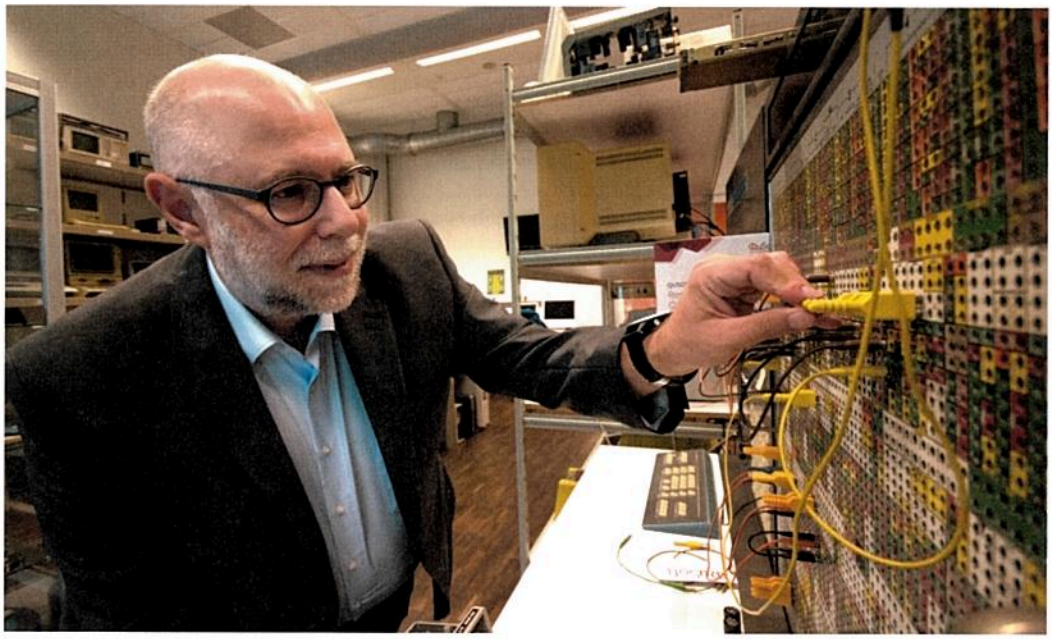
You're a pretty mathematical guy, how does that work, do we need to pay serious attention to things that are not proven?
The field of complexity theory – the stuff of my PhD research - deals with the question: what is the power of computation? Can I solve a problem in a reasonable amount of time or will it take an eternity before I have an answer? For example, a couple get divorced. Each of their (previously jointly owned) N items is tagged with its current value. How to split all these objects between the divorcees to give equal total value for each? This is a problem for which we only have algorithms that take an eternity, as essentially the only way we know how to do this is to write down all possible ways of splitting up their N things (that would be 2N possibilities) and check the values are equal. The computational effort required grows exponentially, as each time you add an item to the list there are two extra possibilities (it goes to one ex-partner or the other) and so the total number of possibilities to keep track of doubles each time. Thus, although checking the total value of each person's pile is easy, finding the best way to divide the stuff seems insoluble by a brute force calculation. In complexity theory, we call identifying this type of situation the P vs. NP problem. Being able to prove the non-existence of an efficient algorithm for solving NP problems on a classical computer is one of the seven Millenium Problems (www.claymath.org/millennium-problems) in mathematics. Many clever people have tried, but as yet this kind of problem suffers from an exponentially growing computational overhead, and this should be where a quantum computer can help.

When was your first concrete connection to experimentalists in your field of quantum computation? Is this a recent new dimension?
No, it's not recent. Joint conferences and workshops mean we have long been able to have a dialogue with experimentalists, such as I have done with Nicolas Gisin (U. Geneva).
However, the huge recent growth in experimental possibilities is really exciting. Not that long ago, it was deemed impossible to overcome the engineering problems in making more practical qubit platforms. The seemingly insurmountable barrier to making more scalable systems meant there was little money in the field. Back then I though the field would last 10 years and then the money would dry up. Now, 20 years later, there is more funding than ever and the words quantum computer are heard regularly on Dutch TV and radio. It seems the field is here to stay.



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The Dutch ministry for Education, Culture and Science recently awarded a 18.8M€ Gravitation grant research into quantum software, uniting researchers from QuSoft, CWI, Leiden University, QuTech, TU Delft, and the UvA. The Quantum Software Consortium (QSC), which is led by Harry Buhrman, bundles the expertise of researchers from computer science, mathematics and physics to develop and demonstrate quantum software.

Was the research that has become QuTech important for this development?
In the 90's Hans Mooij in Delft had one or two qubits, we talked, trying to identify common projects but it was still too early. Now, 25 years on, the people at Delft have more qubits and more interesting objects such as quantum networks, with this work embedded in QuTech (the advanced research centre for Quantum Computing and Quantum Internet, a collaboration between TU Delft and TNO). In this sense, the experimentalists have caught up with us theoreticians, and this is really great. It is to bring these things together – QuSoft and QuTech – that we wrote this new grant for the project called the Quantum Software Consortium, which just got funded (see infobox). Both parties were required for this to be a success. This is the next level, aiming to bridge the gap between algorithms on the one hand and qubit implementations on the other. The seed money for QuSoft –part of the University's research propriety area Quantum Mater & Quantum Information – together with CWI and Science Faculty support acted as a catalyst for the success of the QSC's bid for an NWO Gravitation award: fantastic!

QuTech develops hardware for the QC and works closely with Microsoft. At present QuSoft is 'only' a scientific, academic institute. Is this set to change?
Yes. That will change and is already changing. Big companies are seeing the light and realising that they need software on this quantum computer. Companies like SAP, ATOS or Alibaba don't desire to build (classical or quantum) hardware, but they do make software.

"QC is a different way of doing computation, and for some problems this different way is more suitable." →

You can make more money, in total, writing software than building computers. So, the question what these kinds of companies could do with the QC is a software question, and so a typical one for QuSoft to answer. These companies wonder when they should start their own, small Quantum Software groups, getting ready for the QC itself, as the prognosis is that the number of qubits will grow exponentially in the coming years.
QuSoft can be an invaluable partner for the private sector. My advice to them is 'start now!': start small, with one or two PhDs and so get accustomed to the field. Upscaling will be easier later, and - if progress disappoints - downscaling is also something the companies master.

You lead the recently funded Quantum Software Consortium. Should this Dutch initiative, together with QuSoft, seek to valorise their ideas on quantum software?
A lot of the recent Dutch policy – for example the top sectors, but also the deal between Microsoft and QuTech – foresees industry picking up all the IP in such a public private partnership. In a certain sense that is only fair as that is why they are in the partnership in the first place. So, injecting (for example) Microsoft into the Dutch landscape and giving them all the IP: we have to ask ourselves whether this is how we want to do it? The QuTech model shows how this way of working can help set-up a competitive laboratory, here in the Netherlands, and this high-level know-how here in the Netherlands is certainly a very positive thing. An opposing model in which Dutch funded science remains in the country is also somehow antithetical to science and its wish to give credit to those doing the original work, but then sharing that knowledge in an open access way, encouraging international collaboration. As a scientist these are aspects I am very sympathetic towards.

What do you miss in the Dutch science landscape?
Maecenas figures like Mike Lazarides of Blackberry. In North America there may be lower taxation, but the upside is that people like Lazarides have pumped hundreds of millions into theoretical physics and quantum computing and this has completely changed the picture in Canada. This kind of money can be used to prise matching funding from the university, or regional government, and can lead to a huge shift in resources to particular research subjects or even people. Obviously, this is a pro when the choice is made for your area of research and is a con when it is not. On balance, I welcome this kind of initiative as, in the end, it's extra money for science. Here, in the Netherlands, we tax higher and such private benefactors are not part of the research landscape. We should take it as a challenge to tackle this. Why is there this kind of culture high-tax Denmark - for example Carlsberg and window-maker Velux sponsor fundamental quantum research - but not here?
In terms of what I don't miss: I find the CWI (Center for Mathematics and Computer Science) in the Science Park to be a great place to work. Now CWI is part of the NWO-i organisation and I hope the good things will remain. I also enjoy being affiliated to the ILLC institute for Language Logic and Computation at which I am professor, and the same goes for connections with the math department in the form of the Korteweg de Vries Institute, and the institute of physics.

Do you find outreach important?
Yes, very much so. There is a big challenge here, too. I was just at Lowlands, taking part in a science activity in one of the smallest tents. In the biggest tent five or ten thousand people were all enthused for a band. Shouldn't we take on the challenge to see if we – as scientists – can't get it to this level at a future lowlands?
I worked hard for my YouTube series for the Universiteit van Nederland (UvN) (www.youtube.com/playlist?list=PLZodf6wQ5oO_Si_ehFoI9aB11hcFQS6nJ). Of the five films, I am very proud that the most watched was – besides the practical sounding 'Why is a computer sometimes so slow?' - the more fundamental question 'Is there something beyond infinity?' This goes to show that we need to expose the public to the beauty of scientific questions, also from the youngest age.

What does the fact that the words 'Quantum Computer' have become part of the mainstream media's vocabulary mean for the field?
Of course, this is a good thing. It can help polarise young people to choose for theoretical computer science and mathematics, as well as for physics. We do have to make sure we manage expectations. Outrageous claims such as that a QC can lead to an exponential speed up of any computation are simply false, and I think this is not good for the field. It's my job to explain that QC is a different way of doing computation, and for some problems this different way is more suitable, but this is not the case for all problems. For example, for breaking the codes used to protect our banking transactions today, it is proven that a QC is much better, and this realisation is fuel for the field quantum cryptography, one of QuSoft's research pillars. Ω

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