

From loop jumps to quantum leaps

by ETH Zurich, Globe Magazin



ETH alumna and former Excellence Scholar Bettina Heim: "I'm optimistic that quantum computers will eventually live up to their potential, even if it's still hard to say what exactly that potential is."

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Bettina Heim won the Swiss figure-skating championships before developing an interest in quantum computing. She studied physics at ETH and now develops software for the computers of the future.

Bettina Heim is at the forefront of efforts to achieve a breakthrough in quantum computing. Employed by US company Nvidia, this 35-year-old former ETH researcher is helping to develop the computers of the future - and it's hard to envision her in a more fitting job. Just like quantum computers, Heim cannot easily be described in terms of either/or attributes - the ones and zeros, or "bits", used by conventional computers. The systems she works on use quantum bits, or qubits, as the smallest unit of information - and qubits can exist in a state of superposition, in which they can be zero and one simultaneously.

Heim, too, manages to be many things at once. A brilliant quantum physicist, she wrote her dissertation on quantum computers while studying for her Bachelor's degree in Physics, a work that was subsequently accepted for publication by the scholarly journal *Science*. Yet Heim is also a gifted figure skater and sportswoman, someone who was attracting attention for her pirouettes, loop jumps and Salchow jumps long before she embarked on her academic and professional career. Aged 21, she won the Swiss Figure Skating Championships, which marked both the culmination and conclusion of her sporting career.

Skating from the age of two

Heim is sitting at the dining table of her home in the Swiss canton of Aargau. She and her husband moved in only a week ago, and there are still boxes stacked up all over the house. Every now and then, one of her two Sphynx cats leaps onto the table hoping for a stroke. "I'm just a naturally passionate person," says Heim. "Give me a hobby, and I'll end up transforming it into a career!"

She recalls getting hold of a pair of skates at a flea market when she was two. "And I just wouldn't let go!" she laughs. The ice rink was a short walk from the family home, so her parents let her have her way and supported her new hobby. Later, long after discovering her interest in the natural sciences, Heim would earn money from her figure-skating skills: early on in her degree programme, she gave lessons to people hoping to become more confident on the ice, from two-year-olds to physics professors. Working on a self-employed basis, she dedicated 50 to 60 percent of her time to coaching.

From appenzellerland to ETH

Heim's involvement in the quantum leap of computer technology was far from a foregone conclusion. During the computer gold rush of the 1990s, she was still living in the Appenzell town of Herisau, far from the cutting edge. Her parents worked in sales – tractors and the retail trade – and the family didn't even own a computer until the mid-2000s.

It was only when Heim was about to take her baccalaureate that she realised she was not only a whizz at science but also had a knack for programming. She applied to study physics at ETH and was then awarded an Excellence Scholarship. "That allowed me to give up my job at the rink and focus all my attention on my studies," she says. In her Bachelor's dissertation, she took her first plunge into quantum computing with an investigation into why the world's first commercial quantum computer, D-Wave, fared so poorly in so many areas when pitted against conventional computers. She managed to get her paper published in the scholarly journal *Science*, succeeding straight off at something that others take years to achieve. After finishing her degree, she completed a doctorate under the supervision of Matthias Troyer, then Professor of Computational Physics at ETH. Eventually, she followed her mentor into the tech industry, spending four years living in Seattle and working for Microsoft. Two years ago, she returned to Switzerland. Her husband feels more at home here, and she wanted to be closer to her mother after the death of her father.

Software for quantum computers

At Nvidia, Heim got the opportunity to build her own team from scratch to develop software for quantum computers. "For too long, experts in quantum computing have focused solely on hardware and just assumed that the software would take care of itself," she says. "But normal software wouldn't even work on a quantum computer!" The first significant achievement by Heim and her team was the development of an interface called CUDA-Q, which allows researchers to write programs for quantum computers using conventional programming languages such as Python and C++.

Heim has already set up her office upstairs. The curved widescreen monitor seems surprisingly compact given the field she works in, and her computer is of a normal modern type. "When I need to run quantum simulations, I connect to a powerful computer in our office on Europaallee in Zurich," she says. Heim spends most of her time working from home, just like her colleagues. And with most of the team living in the US, she tends to start work at midday and continue into the late evening. Asked what she learned from her sporting career, she says it taught her how to deal with setbacks. Yet the ice rink was also very much a lone-warrior experience, and she relishes the opportunity offered by her current job to help people get the best out of themselves. The majority of her working day is spent on calls to colleagues, and any programming she wants to do tends to be relegated to her free time or weekends. Heim works hard and has always been passionate about what she does, but she is increasingly aware that it can sometimes be good to take a step back. "I've actually started doing a bit of gardening," she says.

Heim comes straight to the point when asked what she hopes to achieve in her career: "I'd like to help get us to the stage where we can do something useful with quantum computers." It's true that these new computers have not yet proved to be particularly good at anything, and that conventional computers are still far better at most everyday computational tasks. But nobody would deny that the theoretical potential of quantum computing is vast. For example, it would take a normal computer millions of years to find the prime factors of a 2,048-bit number, while a quantum computer, working with qubits, could perform the calculation in a matter of minutes. "There's a perfectly realistic chance that, in a few years' time, quantum computers will be better than conventional

computers at tackling certain tasks," says Heim.

But what purpose will they serve? This is a tricky question, and researchers are currently trying to identify ways of putting the technology to practical use. "The aim is not to run Microsoft Word on quantum computers, but to use them to solve very specific problems," says Heim. In other words, quantum computers will never replace ordinary PCs, but they could help shoulder the burden of extremely complex computational tasks.

Many observers remain confident that advances in quantum computing will have a revolutionary impact – for example, by transforming drug development. Heim remains cautious, though she concedes that quantum computers could help drive the machine-learning aspects of AI. "I'm optimistic that quantum computers will eventually live up to their potential, even if it's still hard to say what exactly that potential is," she says. In the meantime, she feels it's an exciting time to be working in this field. "I missed out on the development of computer technology by a generation, but being part of the blossoming of quantum computing is a very similar feeling!" she enthuses.

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Promoting talent at ETH Zurich

About

Bettina Heim is a team leader at US company Nvidia, where she develops software for quantum computers. After studying physics at ETH and obtaining a doctorate in Computer Physics, she spent six years working for Microsoft in the US, before moving back to Switzerland. Prior to her career in science and industry, Heim was a professional athlete who won the Swiss figure-skating championships and competed in two world championships.

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