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Summary

My current scientific research focuses on quantum computing and more specifically on the definition and implementation of a **scalable quantum micro- and system architecture**. This involves specifying what the micro-architectural support is for the control of the quantum instructions and how the quantum accelerator is connected and integrated in a larger system design where classical logic is combined with quantum logic. There are two dimensions that are being followed: the first is to define and develop the micro-architecture for the experimental quantum chip. This work is basically done, and we need to expect a higher number of qubits. The second dimension wants to focus more on quantum accelerators and how they can be implemented in any quantum accelerator technology. That work is based on the full-stack definition that the QCA lab has defined and developed. In this context, we have defined a programming language, OpenQL, a template for the micro-architecture and the QX simulator platform to execute any quantum logic that can be defined. I personally am no longer involved in the Intel project as the main challenges for the architecture group have been solved. In that context, I am looking at one quantum accelerator applications, called Quantum Genome Sequencing. There is potential collaboration with the Lawrence Berkeley National Laboratory on that topic.

More specifically, we are studying the challenges of mapping a quantum circuit on a 2D qubit plane and what qubit state routing is needed. To this purpose, we assess to what extent the current, classical NoC algorithms can be modified such that it is useful for any particular 2D quantum chip. We are also building a large-scale simulation model for a very elaborate study of the micro-architecture assuming a very large number of qubits. Evidently, we need to expand the OpenQL language such that any logic can be implemented and tested.

In the past, I was involved in electronic system level design aiming at supporting the entire design process of both software and hardware components for heterogeneous multi-core platforms. This line of research is now also increasingly relevant for Big Data applications and emerging high-performance computing platforms from IBM, Convey and Intel. I started multiple companies, one of which is a spin-off, BlueBee, that applies these technologies in a cloud-service for genome sequencing.

I was recently appointed full professor at the University of Porto, Portugal and I start in Porto a new company, called QBee, to work on quantum genomics.

SCIENTIFIC OUTPUT

7 books as editor, 37 journal publications and more than 160 peer reviewed conference papers. 30 PhD students graduated with me and I currently supervise 3 students. Organisation of 11 international workshops and conferences as program or general chair. Started 5 companies in various fields. Citation index is 31.

Publications in the Quantum Computing Domain (23)

2016

1. X. Fu, L. Riesebos, L. Lao, C. G. Almudever, F. Sebastiano, R. Versluis, E. Charbon, and K. Bertels, A Heterogeneous Quantum Computer Architecture, Proceedings of the ACM International Conference on Computing Frontiers (CF'16), ACM, 2016, pp. 323-330.

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2017

3. N. Khammassi, I. Ashraf, X. Fu, C. G. Almudever, and K. Bertels, QX: A High-performance Quantum Computer Simulation Platform, Proceedings of Design, Automation & Test in Europe Conference & Exhibition (DATE'17), IEEE, 2017, pp. 464-469.

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5. L. Riesebos, X. Fu, S. Varsamopoulos, C. G. Almudever, and K. Bertels. Pauli Frames for Quantum Computer Architectures, Proceedings of the 54th Annual Design Automation Conference (DAC'17), ACM, 2017, p. 76.

6. R Versluis, S Poletto, N Khammassi, B Tarasinski, N Haider, DJ Michalak, A Bruno, K Bertels, L DiCarlo, Scalable quantum circuit and control for a superconducting surface code, Physical Review Applied, vol. 8, p. 034021, 2017.

7. X. Fu, M. A. Rol, C. C. Bultink, J. van Someren, N. Khammassi, I. Ashraf, R. F. L. Vermeulen, J. C. de Sterke, W. J. Vlothuizen, R. N. Schouten, C. G. Almudever, L. DiCarlo, and K. Bertels, An Experimental Microarchitecture for a Superconducting Quantum Processor, International Symposium on Microarchitecture (MICRO-50). IEEE/ACM, 2017, pp. 813-825. [Best Paper Award].

2018

8. Savvas Varsamopoulos, Ben Criger, Koen Bertels, Decoding small surface codes with feedforward neural networks, Quantum Science and Technology, vol. 3, p. 015004, 2018.

9. X. Fu, M. A. Rol, C. C. Bultink, J. van Someren, N. Khammassi, I. Ashraf, R. F. L. Vermeulen, J. C. De Sterke, W. J. Vlothuizen, R. N. Schouten, C. G. Almudever, L. DiCarlo, and K. Bertels, A Microarchitecture for a Superconducting Quantum Processor, IEEE Micro, vol. 38, pp. 40-47, 2018. [Top Picks from the 2017 Computer Architecture Conferences].

10. N Khammassi, GG Guerreschi, I Ashraf, JW Hogaboam, CG Almudever, K Bertels, cQASM v1. 0: Towards a Common Quantum Assembly Language, arXiv:1805.09607, 2018.

11. X. Fu, L. Riesebos, M. A. Rol, J. van Straten, J. van Someren, N. Khammassi, I. Ashraf, R. F. L. Vermeulen, V. Newsum, K. K. L. Loh, J. C. de Sterke, W. J. Vlothuizen, R. N. Schouten, C. G. Almudever, L. DiCarlo, and K. Bertels, eQASM: An Executable Quantum Instruction Set Architecture, arXiv:1808.02449, 2018.

12. L. Lao, B. van Wee, I. Ashraf, J. van Someren, N. Khammassi, K. Bertels, C. G. Almudever, Mapping of Lattice Surgery-based Quantum Circuits on Surface Code Architectures, arXiv preprint arXiv:1805.11127 2018.

13. C. Vuillot, L. Lao, B. Criger, C. G. Almudever, K. Bertels, B. M. Terhal, Code Deformation and Lattice Surgery Are Gauge Fixing, arXiv:1810.10037, 2018.

14. S. Varsamopoulos, K. Bertels, and C. G. Almudever. "Designing neural network-based decoders for surface codes." arXiv preprint arXiv:1811.12456 (2018).

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15. L. Lao, B. van Wee, I. Ashraf, J. van Someren, N. Khammassi, K. Bertels, C. G. Almudever, Mapping of Lattice Surgery-based Quantum Circuits on Surface Code Architectures, Quantum Science and Technology, 4, 015005 (2019)

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17. K. Bertels et al, Quantum Computer Architecture: Towards Full-Stack Quantum Accelerators, arXiv to be published on Sept 17, 2019.

18. P. Cadareanu, N. Reddy C, C. G. Almudever, A. Khanna, A. Raychowdhury , S. Datta, K. Bertels, V. Narayanan, M. Di Ventra, P.-E. Gaillardon, Rebooting Our Computing Models, DATE 2019

19. X. Fu, L. Riesebos, M. A. Rol, J. van Straten, J. van Someren, N. Khammassi, I. Ashraf, R. F. L. Vermeulen, V. Newsum, K. K. L. Loh, J. C. de Sterke, W. J. Vlothuizen, R. N. Schouten, C. G. Almudever, L. DiCarlo, and K. Bertels, eQASM: An Executable Quantum Instruction Set Architecture, IEEE International Symposium on High Performance Computer- Architecture (HPCA), pp.224-237, IEEE, 2019.
20. X. Fu, L. Lao, K. Bertels, C.G.Almudever, A control microarchitecture for fault-tolerant quantum computing, Microprocessors and Microsystems, Volume 70, Oct. 2019, pp 21-30.

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21. K. Bertels, A. Sarkar, T. Hubregtsen, M. Serrao,A.A. Mouedenne, A. Yadav, A. Krol, I. Ashraf, C. Garcia Almudever, Quantum Computer Architecture - Towards Full-Stack Quantum Accelerators, IEEE Transactions on Quantum Engineering, to be published

22. X. FU, eQASM v1.0 Architecture Specification, QuTech, Delft University of Technology

23. L. Lao, C.G. Almudever, Fault-tolerant quantum error correction on near-term quantum processors using flag and bridge qubits, March 2020, 10.1103/PhysRevA.101.032333

Presentations

- Dennis Tardan: https://anchor.fm/dennis-tardan/episodes/A-Conversation-with-Koen-Bertels-ee3n0u
- Harrisburg University: https://www.youtube.com/watch?v=GeScRan0QSA
- Eamonn Darcy, University of Perth, Australia, https://www.youtube.com/watch?v=yv_f6oRe2Uc&feature=youtu.be