Potentials of Quantum Computing and First Applications in Computed Tomography

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Quantum Computing (QC) technology has obtained a lot of attention recently. First QC-devices are available as test beds for real-world applications. In this field, the Fraunhofer Gesellschaft has started a close collaboration with IBM in 2020. Since then, Fraunhofer Development Center X-ray Technology (EZRT) has access to a real-world NISQ-device (Noisy Intermediate Scale Quantum), although the number of available qubits is still low (typically less than 100). Basically, there are two types of QC-devices, the above mentioned NISQ-systems and the class of Quantum Annealers which are restricted mostly to optimization problems, but today already provide several thousands of qubits with each device. On the other hand, the NISQ-systems provide a certain set of "commands", called quantum gates, which can be combined in any arbitrary way to form an elaborated quantum circuit. A quantum circuit may be seen as an analog to a program, although there are decisive differences. The Fraunhofer EZRT is involved in three projects concerning quantum computing, dealing with general research questions in this field, but also specifically with industrial research activities. In them, we research and apply existing quantum computing solutions to numerical problems as they often occur in the field of X-ray Computed Tomography (CT), as well as experimentally determine practical limits to the existing theoretical works. In our talk we review the current state of QC-technology and give a short overview of the theoretical background. The concept of qubits, superposition, entanglement and measurement of quantum states will be explained. Quantum gates and circuits built out of these gates will be introduced. In the second part, we will report on the current state of our research. The three running projects include an implementation of cross-sectional image reconstruction for CT imaging based on a QUBO-method (Quadratic Unconstrained Binary Optimization), used to find a mathematical minimum of a metric. Another topic, we are working on, is optimization of X-ray source trajectory in CT with respect to image quality achievable by a restricted number of angular positions. In addition, we evaluate common problems of image processing for instance noise reduction and search for ways to implement respective methods on the QC. Acknowledgement The mentioned quantum projects are funded by the Bavarian Ministry of Economic Affairs, Regional Development and Energy.