International Workshop
“Basic Principles of Quantum Computational Mechanics”

Multimedia Room, Laboratory L2, Department of Civil Engineering, University of Salerno.

Fehmi Cirak
Department of Engineering
University of Cambridge, UK

Day 1: March 10, 2025

Fernando Fraternali, h 10.30: Welcome speech

Fehmi Cirak, h 11:00-12-00:
Design and modeling of shape-programmable structures – 1/2

The advent of quantum computers, operating on entirely different physical principles and abstractions from those of classical digital computers, sets forth a new computing paradigm that can potentially result in game-changing efficiencies and computational performance. Specifically, the ability to simultaneously evolve the state of an entire quantum system leads to quantum parallelism and interference. Despite these prospects, opportunities to bring quantum computing to bear on problems of computational mechanics remain largely unexplored. This lecture shows how quantum computing can indeed be used to solve representative volume element (RVE) problems in computational homogenisation with polylogarithmic complexity of $O((\log N)^c)$, compared to $O(N^c)$ in classical computing.

Teams link:
https://teams.microsoft.com/l/meetup-join/19%3ameeting_NWIwOWE4ZTgtZGUwZi00ZWJiLTk5NDAtOTk1NDViYTk1MDNj%40thread.v2/0?context=%7b%22Tid%22%3a%22c30767db-3dda-4dd4-8a4d-097d22cb99d3%22%2c%22Oid%22%3a%22f059d004-0906-4b4b-9104-286d8b39201a%22%7d

Day 2: March 14, 2025

Fehmi Cirak, h 11:00-12-00:
Design and modeling of shape-programmable structures – 2/2

This second lecture illustrates a quantum RVE solver that combines conventional algorithms such as a fixed-point iteration for a homogeneous reference material and the Fast Fourier Transform (FFT). However, the quantum computing reformulation of these algorithms requires a fundamental paradigm shift and a complete rethinking and overhaul of the classical implementation. We employ or develop several techniques, including the Quantum Fourier Transform (QFT), quantum encoding of polynomials, classical piecewise Chebyshev approximation of functions and an auxiliary algorithm for implementing the fixed-point iteration and show that, indeed, an efficient implementation of RVE solvers on quantum computers is possible. We additionally provide theoretical proofs and numerical evidence confirming the anticipated $O(\log N)^c$ complexity of the proposed solver

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Short bio of Fehmi Cirak

Fehmi Cirak is a Professor of Computational Mechanics and joined Cambridge in March 2006. Before that, he spent five years as a Senior Scientist at the Center for Advanced Computing Research at the California Institute of Technology. He has a PhD in Computational Mechanics from the University of Stuttgart and was a Postdoctoral Fellow in Aeronautics at the California Institute of Technology.