NITheCS
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NITheCS MINI-SCHOOL:

An Introduction to the Quantum Simulation of Closed and Open Quantum Systems

Ian Joel David (University of KwaZulu-Natal)

Wed 3, 10, 17, 24 & 31 July 2024 | 14h00-15h00 SAST

Attend online or in the NITheCS Seminar Room, University of KwaZulu-Natal – Westville Campus, 3rd Floor, H-Block, School of Chemistry and Physics

--- A certificate of attendance will be awarded to registrants who attend all the lectures ---

ABSTRACT

Quantum Simulation, the emulation of quantum system dynamics with quantum computers, is an application of quantum computing which showcases a clear advantage over classical computing. This advantage arises from the inherent difficulty in simulating quantum dynamics on classical systems, a challenge that originally inspired Feynman and others to propose quantum computing.

The efficient simulation of quantum dynamics on quantum computers promises profound insights into various physical systems including many-body physics, quantum chemistry and quantum field theory. Quantum Simulation has also been pivotal in developing new quantum algorithms for state preparation and for solving both ordinary and partial differential equations on quantum computers.

The goal of Quantum Simulation is to construct a quantum channel that approximates the evolution operator of a quantum system within some specified precision. This channel should be constructed such that it can be efficiently implemented on a quantum computer. We focus on two primary types of quantum systems: closed quantum systems, which evolve via unitary evolution, and open quantum systems, which interact with their environment and experience dissipation and decoherence.

This mini-school will convey the essential concepts and principles underlying the Quantum Simulation of both closed and open quantum systems. Attendees will gain sufficient working knowledge to engage with and understand contemporary research literature on this cutting-edge topic.

PREREQUISITES

- Basic understanding of quantum mechanics (undergraduate level)
- Basic knowledge of quantum computing (see older mini-schools)
- Linear algebra (undergraduate level)

LECTURE 1 3 July	In this lecture we will discuss what is Quantum Simulation, provide a brief motivation and then outline all of the basic preliminary knowledge one will require for the rest of the school. We will also introduce the quantum mechanics describing the evolution of closed quantum systems.
LECTURE 2 10 July	We will introduce the key ideas behind using Trotter-Suzuki product formulas for simulating closed quantum systems. We will show how one derives the error bounds for using Trotter-Suzuki product formulas to simulate unitary evolution. We will also provide a basic example of how one uses this method and constructs a quantum circuit to implement these Trotter-Suzuki product formulas.
LECTURE 3 17 July	This lecture will focus on the state-of-the-art methods that have been developed to simulate closed quantum systems. We shall discuss methods such as linear combination of unitaries, truncated Taylor series, Quantum Signal processing and QDRIFT.
LECTURE 4 24 July	This lecture aims to introduce some basic information about the theory of open quantum systems and how we describe their dynamics. We will then provide an overview of a few methods to simulate open quantum systems.
LECTURE 5 31 July	In the last lecture we will focus on the specific examples of simulating single qubit open quantum systems. We will discuss the use of Trotter-Suzuki product formulas for simulating open quantum systems.

BIOGRAPHY

Ian studied Physics at the University of KwaZulu-Natal (UKZN) and has obtained a Masters degree in Physics. He is currently completing a PhD in Physics at UKZN under the supervision of Prof I. Sinayskiy and Prof F. Petruccione , focusing on the digital simulation of Quantum Systems. He has spent several years as a research assistant in Prof Petruccione's Quantum Research Group. He has given several introductory and advanced quantum computing talks and mini-courses at various institutions and conferences.

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