Semester Report

Author: Gabriel Henrique Souza Cardoso

E-mail: gabrielhsc95@gmail.com / gabrielhsc95@caesar.elte.hu

Ph.D. Program: Doctoral School of Physics - ELTE

Supervisor: Prof. Dr. Gábor Vattay

Ph.D. Thesis Title: Quantum Computing for Finance: Quantum Bond Pricer

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Introduction

It was being pointed out by different researchers a lot of improvements that quantum computing could bring to many fields of studies. The quantum mechanical properties of matter can be used to solve difficult calculations and exponential speedups algorithms [1].

One of the simplest, but widely used, financial instruments are bonds. They are a good foundation for quantitative finance since there is no need for a lot of data as input. To calculate the price of a bond, in general, it is only required information is its properties under contract and interest rate curves. The bond price P is simply

$$P = \sum_{i=1}^{n} CF(t_i) \cdot D(t_i),$$

where CF is the cash flow (a coupon or the principal) and D is a discount factor, both are time-dependent. The rules about the cash flow and the discount factor are under contract. This is different, for example, from stocks and their derivatives that require a time series of the price and have different methods to computes its price [2].

The idea is to create a quantum code that calculates the price of a bond. It is not a problem that would necessarily speed up by the use of quantum computing, but it is the keystone for a quantitative finance program. The foundations of such program could be used to implement more complicated financial products where quantum computing would exponentially make computations faster.

However, just by having a robust bond pricer, the risks can be calculated by Monte Carlo-based methods, or a portfolio of bonds can be optimized for the best return. Those two situations are cited as prospects in the finance quantum computing field [1].

To emphasize, to get to the point of applying Monte Carlo methods and Optimization models it is necessary a well-structured code base that handles the instrument prices and their properties. The goal is to build a generic code that uses the principles of oriented object programming to calculate the price of a bond and that easily allows implementations for future work.

Research Work

I have switched field, my MSc was in Cosmology (the thesis was Mapping the Peculiar Velocity in the Local Universe); therefore, this semester was mostly to catch up in quantum information theory and finance.

Quantum Computing

I studied the basis of quantum computing, so I can develop a quantum algorithm in the next semesters. To accomplish that I studied the book “A Short Course in Quantum Information Theory: An Approach From Theoretical Physics” by Lajos Diósi and his course [3]. To complement I also studied the book “Quantum Computation and Quantum Information” by Michael A. Nielsen and Isaac L. Chuang [4]. There is more to learn, but the foundation was acquired during this semester.

Finance

For finance, my main source of studies was the book “Options, Futures, and Other Derivatives” by John C. Hull [2] and my internship as Quantitative Model Validation at MSCI. Both helped me build a solid foundation to develop a bond pricer; however, there is always more to learn so different features could be implemented, such as value at risk and credit models.

Studies

FIZ/3/060E - Quantum Information Theory

Credits: 6
Professor: Dr. Lajos Diósi
Description: Introduction. Foundations of classical physics. Semiclassical - semi-Q-physics. Foundations of q-physics. Two-state q-system: qubit representations. One-qubit manipulations. Composite q-system, pure state. All q-operations. Classical information theory. Q-information theory. Q-computation.

FIZ/2/021E - Introduction to General Relativity I

Credits: 6
Professor: Dr. Mátyás Zsolt Vasúth
Description: Topology, Differentiable Manifolds. Tangent and dual spaces. Tensors. Covariant. Curvature. Geodesics. Maps of Manifolds, Lie Derivative, and Killing Field. Differential forms, Integration, and Frobenius Theorem.

Professional Activities

Quantitative Model Validation Intern

Company: MSCI Inc.
Period: September 2020 - February 2021
Hours: 24 hours a week
Description: Test python library by validating results. Validate bug-fixes and new implementations. Find and report bugs. Develop tools for automated testing. Suggest improvements in the development of the python library.

References

[1] Orus, Roman, et al. “Quantum Computing for Finance: Overview and Prospects.” Reviews in Physics, vol. 4, Nov. 2019, p. 100028. arXiv.org, doi:10.1016/j.revip.2019.100028.
[2] Hull, John. Options, Futures, and Other Derivatives. Ninth edition, Pearson, 2015.
[3] Diósi, L. A Short Course in Quantum Information Theory: An Approach from Theoretical Physics. Springer, 2007.
[4] Nielsen, Michael A., and Isaac L. Chuang. Quantum Computation and Quantum Information. Cambridge University Press, 2000.