Developing a Machine Learning Algorithm to Price American-Style Stock Options

ENPH 455 – Engineering Physics Thesis

Student Author: Nathan Pacey

Supervising Professor: Ryan Martin

Problem Definition

Background Information

Stock options are contracts allowing investors to buy or sell company shares at predetermined prices. This project specifically explores call and put options as leveraged tools for traders. Call options are used when anticipating share price increases, granting the right to buy shares at a strike price within the contract's duration. Put options are used when anticipating share price decreases, providing the right to sell shares within the contract's term. In addition to option types, two styles exist: American and European. American options allow exercise at any time during the contract, while European options only permit exercise on the expiration date [1].

Stock prices are influenced by numerous factors, making predictions challenging yet financially rewarding. Despite numerous attempts, creating profitable prediction models remains a challenge [1]. The Black-Scholes formula is one such model designed for European-style options contracts; involving differential equations with five crucial input parameters: strike price, current stock price, time to expiration, risk-free interest rate, and volatility. However, the Black-Scholes model cannot predict American options due to its dependency on expiration time [2].

Problem Statement

To address forecasting challenges for American-style stock options, this project aims to use a Recurrent Neural Network (RNN). RNNs are designed for handling sequential data by utilizing hidden states to capture temporal dependencies, making them well-suited for pricing stock options. These hidden states retain information from previous time steps while incorporating current information to make accurate predictions as displayed in Figure 1 [3].

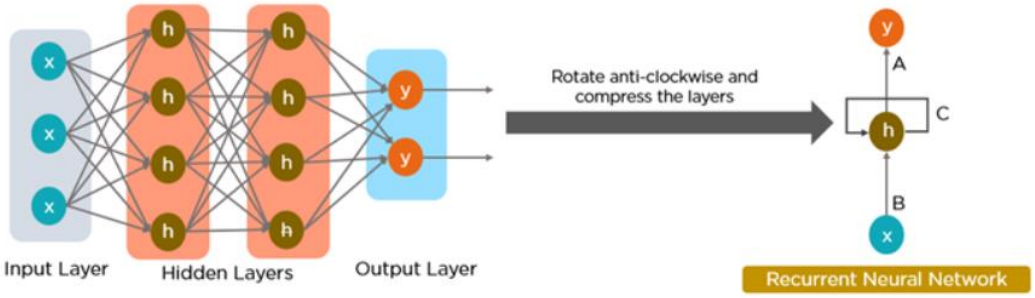

Figure 1. Visualization of a general form RNN displayed as a many to many RNN [4].

In time series prediction using a many-to-many (synced) RNNs, each time step corresponds to a layer, with the output offering predictions for each corresponding time step. The model learns predictive patterns at each time step, improving its ability to forecast subsequent values based on the accumulated data [5].

Scope

To maintain project focus and ensure its success, the RNN will be trained and validated using historical data of North American large-cap equities and their associated options. The model will focus on 'at the money' (near the strike price, minus the premium) options with a short-term expiration. The model will then predict the options value at the expiration date, with the potential inclusion of more predicted intervals during the contract's duration. The project will employ the TensorFlow framework in Python to

implement a synced RNN, with parameters such as stock price, volatility, and interest rates. These parameters may change during model iterations, guided by iterative model validation using recent stock data to assess prediction accuracy [6].

Project Goals

The primary aim is to forecast stock option prices, ensuring a prediction and error that aligns within the future bid-ask spread. Successful project completion involves comprehensive documentation of the RNNs' development, implementation, and result presentation. Expanding this predictive capability to encompass multiple companies' options would boost the model's utility.

Annotations

J. Chen, "What are Options? Types, Spreads, Example, and Risk Metrics," Investopedia, 24 April 2023.

This web article provides an overview of options trading, introducing key terminology and trading strategies. It will be used to enhance comprehension of financial jargon and trading strategies in the context of the project. Investopedia has many informative articles to aid in finical literacy however is not an academic and peer revied source so may contain significant bias and some misinformation.

I. Jahan, "Stock Price Prediction Using Recurrent Neural Networks," North Dakota State University, Fargo, 2018.

A graduate thesis paper detailing a similar project involving stock price prediction using RNNs. This source will be an invaluable guiding reference throughout RNN development and implementation, ensuring the project remains on the right track and providing insights into RNN implementation using TensorFlow for time series stock data. This source is reliable as it was published by a graduate student at North Dakota State University and reviewed by a supervisory committee in their faculty of Computer Science.

V. Madisson, "Stock market predictions with RNN using daily market variables," Towards Data Science, 11 June 2019.

This paper outlines an RNN-based approach to daily market variables for stock price prediction, serving as a reference for testing and validation in this project. It provides insights into data parsing, RNN implementation with TensorFlow, and validation procedures, including comparisons with methods like K-Nearest Neighbors Algorithm. Although this isn't an academic source, it provides a wealth of valuable information pertaining to the code implementation of a similar project. It is worth noting that this source is somewhat reliable, as it is published on "Towards Data Science," a Canadian company known for sharing and editing informative articles within the realm of software and data science.

M. Lesuisse, "What are the advantages of pricing American options using artificial neural networks?," Université de Liège, Liège, 2022.

A masters' thesis outlining the challenges in pricing American-style stock options compared to European options, providing insights into the Black-Scholes Model's implementation. It's a valuable resource for understanding the model, the difficulties in pricing American options, and mathematical models and neural networks used in stock option prediction, especially American-style options. This is a reputable source as it was published by the HEC Liège School of Management a well-respected university in Belgium known for its finical studies, by a graduate student of finical engineering.

Tensorflow, "Time series forecasting," Tensorflow, 27 July 2023.

An introduction tutorial to Convolutional and Recurrent Neural Networks for time series data forecasting. This source serves as a tutorial to familiarize with the TensorFlow toolset, helping to select, parse, and train an RNN. It also aids in understanding RNN parameters and their implications, which can be applied to the stock options prediction. While this tutorial might be very useful to the project it may present significant bias as it is published by TensorFlow on their own technology. Furthermore, if there was a solution in another programming framework outside of TensorFlow it may be in their best interest to not mention and not include that information.

Quant Next, "Artificial Neural Network for Option Pricing with Python Code," Youtube, July 2023.

A YouTube tutorial demonstrating how to use Artificial Neural Networks (ANN) to price stock options using Python. It offers a specific example of implementing ANN in TensorFlow and comparing it to the Black Scholes formula. This source serves as a practical guide for both RNN and TensorFlow implementation in stock data research, as well as for comparing results analytically with the Black Scholes Model. The video, while informative, lacks reliability as the publishing channel has minimal content and no academic background. Nevertheless, it does present working code and references a guide at the end of the video, adding some credibility.

References

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[8] Tensorflow, "Time series forecasting," Tensorflow, 27 July 2023. [Online]. Available: https://www.tensorflow.org/tutorials/structured_data/time_series. [Accessed 9 October 2023].

[9] Quant Next, "Artificial Neural Network for Option Pricing with Python Code," Youtube, July 2023. [Online]. Available: https://www.youtube.com/watch?v=r6KTnKim_BA&ab_channel=QuantNext. [Accessed 3 October 2023].