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2 authors:

Sanjana Ahmed Chaity
East West University
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Md. Ahsan Shoishob
East West University
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Artificial Intelligence in Enhancing High Frequency Trading Strategies

Sanjana Ahmed Chaity[1], Md. Ahsan Shoishob[1]

Abstract

In the world of trading and complex market transactions, technology has greatly revolutionized and adapted to the fast-growing data and complexities of modern trading strategies (Singireddy et al., 2021). Computers and advanced algorithms have paved the way for a more digitalized world where virtual transactions are common place. Not only can people buy and sell products online, but can also do these transactions automatically. However, thanks to complex AI and ML algorithms; high-frequency trading or HFT strategies can be formulated for highly efficient and optimized automated trading. There are various HFT firms that uses complex ML and AI algorithms to identify and dynamically adjust buying or selling prices according to available market data to maximize profit and save time. Various businesses can take advantage of HFT strategies to optimize selling and buying frequencies. Relevant data is required for executing a HFT strategy properly, along with a sophisticated AI algorithm which is capable of handling vast amounts of data dynamically. The key features of HFT makes it a compelling route for optimized trading and buying. These key features include: lightning-fast transactions, dynamic market data analysis and execution of numerous transactions at once (Balaji, Revolutionizing High-Frequency Trading: The Impacts of Financial Technology and Data Science Innovations, 2025). This research paper aims to understand how AI and ML algorithms can dynamically optimize HFT strategies to further take leverage of available market data. The research paper discusses the implementation of Deep Reinforcement Learning or DLL framework for optimizing HFT strategies. In particular, the implementation discussed adopts a multi-time scale DRL for improved dynamic data processing. This research paper aims to shed light into the effectiveness of an AI-driven solution for improving HFT efficiency for better and faster trading using a simple deep reinforcement learning or DRL machine learning algorithm.

Keywords: Deep Reinforced Learning, Algorithms, Market Trend Analysis, Predictive Analysis, Order Book Data.

Significance |This research underscores the capacity of Artificial Intelligence-facilitated Deep Reinforcement Learning to enhance high-frequency trading, thereby facilitating accelerated, more intelligent, and financially advantageous decision-making.

*Correspondence. Sanjana Ahmed Chaity, Department of Business Administration, East West University, Dhaka, Bangladesh.

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1. Introduction

In the realm of trading and technology, high frequency trading or HFT can be defined as a method of automated transactions using high-end computers and powerful algorithms to detect changes in the market and adjusting transactional behavior based on those changes. Typically used for markets where prices fall and rise quickly, HFT strategies stands out in such circumstances. Artificial intelligence can greatly enhance HFT strategies by providing refined insights into the market patterns through predictive data analysis (Gang, 2024). PDA or predictive data analysis is crucial for HFT strategies to accurately estimate an expected price drop or increase on a relevant market. Hence, the quality and integrity of data processed by an ML algorithm for HFT strategy needs to be of high quality. HFT strategies can be greatly improved by integrating

Author Affiliation.
[1] Department of Business Administration, East West University, Dhaka, Bangladesh.

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appropriate ML algorithms like LSTM (Long-Short Term Memory), CNN (Convolutional Neural Network) or even RF (Random Forest). These are all potent ML algorithms capable of processing vast amounts of data to find anomalies, detect patterns, predict events etc. However, the accuracy of the output from these algorithms relies heavily on the quality of data. The proposed algorithm in this research paper suggested using DRL or Deep Reinforced Learning algorithm to optimize HFT strategies as it does not directly rely on pre-labeled data. HFT strategies are often reliable and highly profitable if implemented correctly. However, the implementations can be tricky and often requires high-end hardware for all the complex data processing and outputs (Poblocka, 2019). The servers and hardware like the processors, CPUs and even GPUs (for accurate visual data rendering) are required as HFT strategies can execute large number of transactions in millisecond or even in microseconds. Low-latency, high-bandwidth and a highly reliable and superfast network can ensure that the HFT method is working as intended. Bangladesh is still lagging behind in such optimized, smart and automated transactions. The global economy and the stock market of Bangladesh could potentially greatly benefit from optimized HFT practices integrated with ML algorithms. A simple example of HFT application in Bangladesh can be the fall or rise of Dhaka Stock Exchange or DSC compared to the Chittagong Stock Exchange or CSE. If the stock of DSE was 1000.5 TK (Per Stock) and the stock of CSE was 1000.0 TK (Per Stock), an HFT firm or an integrated HFT model can automatically by the stock at DSC and sell it to CSE for 0.5 TK worth of profit. To an uninformed individual, the profit can seemingly appear to be negligible. However, an optimized HFT strategy integrated with an appropriate ML algorithm like DRL can detect these stock price changes and automatically transact across thousands or even millions of transactions. Effectively amassing large sums of profit via automated micro transactions. Making HFT strategies highly robust and reliable.

1.1 Background and Context

In the realm of any market like clothing, stock exchange, virtual products etc. the price falls and rises constantly due to various factors and changes in the financial market environment. Prediction of price drops or rises are crucial for businesses to maximize profits and gain a competitive advantage over their competitors. The prediction of market values is hard to predict even with powerful algorithms. An HFT integration can only be effective with the correct implementation that must consist of potent hardware, reliable and fast networking and an appropriate ML algorithm to process the data (Bello et al., 2024). In the world of large financial markets, the profit or loss consensus often depends in seconds or lower. This means, profit gained or lost amounting up to millions of dollars depends on such narrow margin of time. HFT strategies tries to exploit this thin margin by trying to understand the market to the highest degree imaginable. ML algorithms alone cannot produce a super optimized HFT strategy capable of accurately predicting market trends. There are other very crucial components which HFT strategies demand. These are: Order Book Data (also referred to as In-Memory Order Books) and FPGA (Field Programmable Gate Arrays) accelerators. *In-Memory Order Books* are responsible for providing dynamic real-time activities or snapshots of market trends in a specific time frame (Levin, 2024). These instant snapshots contain summarized and quantified information regarding the market. The FPGA accelerators are then responsible to speed up computational processes for maximizing performance, reducing latency and maintaining cohesiveness for optimized HFT functioning (Liu et al., 2024). All of these data of course, has to be analyzed by an appropriate algorithm to perform predictive analysis. After which appropriate transactions can take place depending on the market and relevant data. Making HFT a highly convenient trading technique which is fast, automated and highly sustainable.

Clearly HFT techniques are praised for their speedy transactional capabilities, impressive predictive market analysis and overall potential to maximize profits according to changing market trends. HFT strategy implementation can still be further enhanced with AI and ML implementations. The capability of AI to enhance market insights and predictions can greatly improve the potency and accuracy of HFT strategies. Bangladesh is still new to HFT frameworks and implementations (Babu, 2022). However, Bangladesh is slowly adapting AI and ML tools that promotes optimization and efficiency. HFT is no different in this case as AI and ML integrations have huge potential to help the financial markets on Bangladesh like stock markets and international markets to enhance profits. Based on the context of the stated research on HFT enhancement using AI integration, some scopes and objectives have been stated below:

- Distinguishing how an AI-driven solution can enhance HFT strategies towards better market analysis and improved profits.
- Understanding the effectiveness of AI in the realm of HFT optimization for enhanced transactional potency.
- Understanding the position of Bangladesh in terms of AI integrated HFT optimization.

The above scopes and objectives were formulated for gaining a deeper insight into how AI and ML applications can enhance and optimize already existing solutions like HFT. It seems AI and ML has the potential to greatly enhance already effective solutions by making them better. This research paper aims further strengthen HFT solutions to maximize its effectiveness.

HFT strategies continually evolves as time goes by. Advancements in such fields requires extensive testing, research and practical implications. The research on HFT strategies enhancement using

AI is still not as common as other research topics, which makes it a compelling topic to discuss about. HFT strategy formulation falls in a more niche category of market analysis and transactional business. Thanks to the ever-growing source of data and information in the internet, relevant and effective research on the topic is possible. However, understanding how HFT can function in the real-world with real dynamics of market trends can lead to a solution where HFT can be greatly improved. This research is unique because of the proposed AL algorithm and its related methodology. The proposed algorithm is DRL or Deep Reinforced Learning algorithm. The algorithm combines RL (Reinforced Learning) algorithm with Neural Networks (NN) to form DRL, which is a dynamic algorithm which learn through trail and error to give increasingly better and better output. The uniqueness of this algorithm stems from the fact that it does not directly require any pre-labeled data to perform predictive analysis. As previously stated, HFT strategies require data of high integrity to perform properly. But, the integration of DRL allows monitoring and analyzing data dynamically in real-time based on the snapshots of market trends provided by the relevant market order book (Kalusivalingam et al., 2020). Mitigating the need for old or historical data which other algorithms like CNN (Convolutional Neural Networks) and RF (Random Forest) typically requires. This makes DRL infused HFT strategy more robust with higher chances of accuracy as it strictly relies on dynamic real-time data.

2. Literature Review

Most people might consider the concept of high-frequency trading to be a part of more modern-era of technological concepts. However, such concept of automated transaction according to market data actually surfaced in the early 1980s. A technological trading company named ***NASDAQ (National Association of Securities Dealers Automatic Quotation System)*** which was founded during 1971 in the United States (US) is widely credited for being the pioneer of the first electric stock trading (Hamilton et al., 1978). Before stock trading and other kinds of trading was mainly done in a method called "Open Outcry", which basically meant that people had to shout out various information to each other for keeping track of market trends and other market related data. A figure has been given below which encompasses the evolution of electric trading and HFT in the realm of markets and finance:

The ***Figure 1*** from above shows a timeline from early 17th century to late 2023 which shows mankind's evolution of electronic stock trading and HFT integrations. It would seem that after the manual methods of high frequency trading were established in the late 17th and 18th century, considerable changes in financial markets came through as a result of electronic stock trading. This prompted the growth and the eventual boom of stock markets which started the rise HFT strategies in the 2000s with the start of algorithmic trading. From 2010 and onwards, algorithmic trading in the realm of enhancing HFT practices greatly picked up as the usage of complex algorithms became more and more common (Carè et al., 2024). Thanks to humanity's vast progress over the last few decades, the emergence of AI and ML algorithms has once more started to change everything; including HFT practices. Now HFT strategies are far superior and effective. Powerful hardware with induced FPGA accelerators, blazing fast networking and AI algorithms capable of handling vast amounts of data to perform predictive data analysis of market trends has allowed HFT strategies to improve exponentially. There are various HFT firms all around the world which uses AI and ML algorithms to efficiently buy and sell stock in markets in the right time and in huge batches (often in millions) of transactions at a time (Balaji, Revolutionizing High-Frequency Trading: The Impacts of Financial Technology and Data Science Innovations, 2025). There are various HFT firms that uses these ML and AI algorithms to buy and sell stocks in such manner. As of 2025, the big players in the realm of AI infused HFT trading are Virtu Financial, Citadel Securities, Jane Street Capital and many more. All of these HFT firms employs and integrated bleeding-edge sophisticated technologies that helps them to rapidly and accurately scan the market to gain valuable insights for improving market liquidity and volume.

2.1 Case Study: Jane Street's Expansion into India's Market Through Optimized HFT Strategies

When it comes to innovative HFT strategies formulated by bleeding-edge technologies like advanced AI and ML oriented algorithms, Jane Street is one of the leading pioneers. They are quite secretive and refrains from disclosing too much information regarding their exact usage of tools and software used for HFT optimization. However, Jane Street is often mentioned as one of the best HFT firms that brings in huge profits through their optimization and ML model integrations in stock exchanges. Big players in in HFT like Jane Street primarily uses strategies like statistical arbitrage and market-making (Morgan, 2013). These statistical calculations are directly linked with using complex algorithms to find tiny price drops or gains to attaint insight in the dynamically changing market trends. This in turn, allows HFT firms like Jane Street to effectively sell or buy stocks in the best possible rate for that exact time frame. Such HFT optimization was done by Jane Street through various algorithms like Deep Reinforced Learning (DRL) and Random Forest (RF) to perform predictive analysis of market data. This summarizes how an HFT firm like Jane Street uses ML and AI algorithms to further polish their HFT strategies. In 2023, the HFT company expanded their operations to India called Jane Street's India or JSI Investments Private Limited due to their vast derivatives market. The operations regarding JSI company generated $1 billion in profits in 2023 which

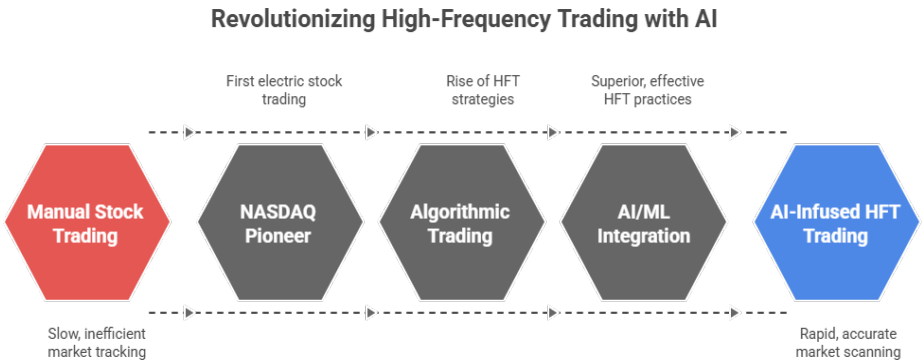

Figure 1. The Evolution of Electronic Stock Trading and High-Frequency Trading (HFT)

Figure 2. Raw Data Filtering and HFT Training Framework using DRL to perform Exploratory Data Analysis (EDA)

got them noticed in India's stock exchange market. Even tough the profits generated by JSI dropped to 50% in March of 2024, other HFT firms like Optiver and Citadel Securities have helped India to reshape their stock exchange and HFT strategies in a positive manner. HFT implemented quantitative training models and market-making algorithms that uses ML and AI to generate accurate market data (Devi et al., 2024). These AI and ML driven algorithms allows for statistical arbitrage, allowing Jane Street to accurately buy and sell stocks at the best price possible in large sums of transactions (Mer et al., 2024). Bangladesh's regulatory framework has not yet matured enough to fully implement these HFT strategies. However, the review of literature clearly signifies the importance of AI oriented HFT strategies that can greatly help Bangladesh's Market and Stock Exchange.

2.2 Research Objectives

Upon the review of literature and the context of the research, it is easy to grasp the potential of AI in terms of HFT strategy enhancement. Bangladesh is quite new to such complex integrations; however, the rest of the world is quickly trying to implement and optimize high frequency trading strategies due to their reliable and fast market predictions and transactions. In the light of the given context, some research objectives are given below:

Understand how an AI algorithm like Deep Reinforced Learning or DRL can be used to optimize HFT strategies.

Understand how Deep Reinforced Learning or DRL works in terms of high frequency transactions.

Formulate some recommendations for further improvement and potential future applications in the realm of AI driven HFT strategies.

The above research objectives were formulated based on the best interest of the research. The goal is to understand the implementation and the impact of DRL algorithm for enhancing high frequency trading strategies through predictive market analysis and smart batch transactions.

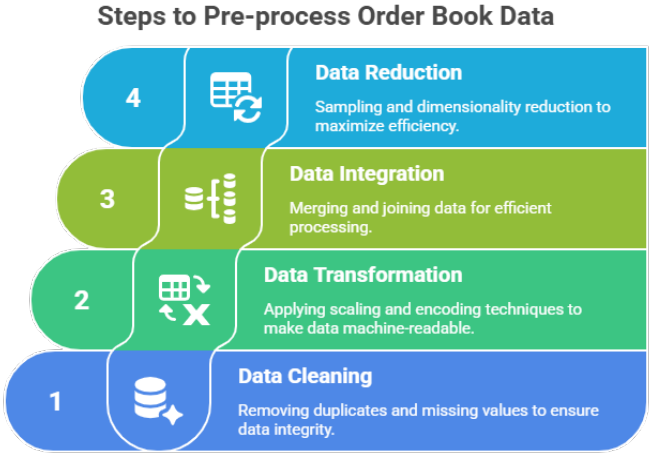

Figure 3: Four Steps of Data Pre-Processing

3. Research Methodology

There are several algorithms can be used for performing predictive data analysis. LSTM, CNN, RF etc. are all capable algorithms which can offer pretty good optimization for high frequency trading. However, these algorithms rely heavily on corruption free and high integrity data. Hence, the output can be negatively impacted if the data collected is unreliable (Oladoyinbo et al., 2024). The proposed DRL algorithm is a combination of Convolutional Neural Network (CNN) and Recurrent Neural Network (RNN) that does not directly rely on pre-labeled data. Instead, the algorithm relies on trial and error to find the best possible solution. This nature of the algorithm allows it to perform predictive data analysis with higher accuracy where RNN handles lower-frequency data and CNN handles higher frequency ones. The proposed methodology has been based around this DRL framework.

3.1 Data Collection

The Proposed Deep Reinforced Learning or DRL HFT training framework is given below:

The above ***Figure 2*** shows how the proposed DRL model (Model Factory) can be trained using raw data gathered from order book of stock markets (Alpha Factory). The market data being explained in this framework is in the context of Chinese Stock Market HFT. These data can be fed to the model dynamically for the DRL framework to adjust to the trends to give better outputs as time passes by. This also allows for data sampling where the raw data is slowly being shaped into more useful information. The resampled data can then be processed by the DRL algorithm framework to accurately predict market trends. Then this DRL model can be applied in the back testing system where it can learn from order book data to adapt to the current market. The gathered data can be pre-processed for further clarity.

3.2 Data Pre-Processing

Order book data can be pre-processed for making the data more usable and removes redundancy. The 4 crucial steps of data preprocessing have been given below:

The ***Figure 3*** from above shows the 4 crucial steps of data pre-processing. In the first step of data pre-processing, the data needs to be cleaned by removing potential duplicate data and omitting missing values. Then the data can be transformed by applying scaling and encoding techniques to make the data readable by a machine learning model. The next step is to join and merge the data for more efficient processing; a step commonly known as data integration. And finally, the filtered data is reduced for maximizing efficiency by sampling and dimensionality. These steps ensure the integrity of the gathered data which results in accurate outputs.

3.3 Data Analysis

For data analysis through the proposed HFT training framework using DRL for performing exploratory data analysis or EDA to predict market behavior, the proposed DRL framework and its components have been given below for further clarity:

The above ***Figure 4*** shows the inner architecture of the proposed DRL framework. It consists of 3 main modules. The ***temporal fusion module*** is used for combining market data from various time scales. The ***decision-making module*** implements statistical arbitrage to the data. Finally, the ***feature extraction module*** employs the CNNs and RNNs for order book data processing. Where CNNs handles high-frequency data and RNNs handles low-frequency data respectively. After data is processed through these modules, the following information regarding the market can be extracted:

The above given ***Figure 5*** displays the various features which shows crucial market data that the HFT framework can use to perform high-speed intelligent transactions to buy and sell stock in the best price possible. Features like volume imbalance and order book

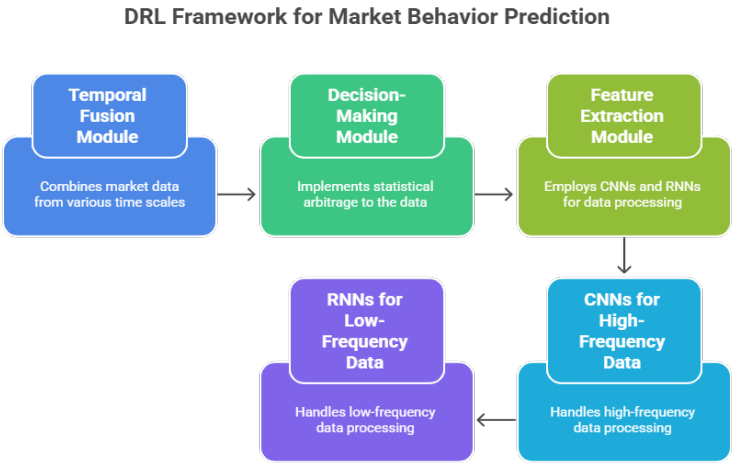

Figure 4. The Proposed DRL Framework for HFT Optimization

pressure can give crucial information regarding market trends (Tripathi et al., 2020). The time scales also allow for the most optimal time of transaction of stocks. Making the HFT framework highly robust and dynamic. The real-time data extraction from order books of any market can allow this framework to adjust due to DRL implementation.

4. Results and Discussion

Upon the review of literature and methodological discussions regarding HFT strategy enhancement using a sophistical AI algorithm like DRL, it is clear that high frequency trading can be improved immensely with the aid of AI and ML algorithms. DRL algorithm was chosen for its dynamic nature, combination of other smart algorithms like RNN and CNN, does not directly depend on pre-labeled data and has high accuracy in the realm of predictive data analysis (Adadi, 2021). Findings from these discussions and technical explorations regarding HFT strategy enhancement using AI and ML has been discussed further below in the context on this research:

The above bar chart as shown in ***Figure 6*** shows the win rates and profit factor as a result of HFT optimization using 3 algorithms: Proposed DRL, random forest (RF) and Long-Short Term Memory (LSTM). Based on the same training framework of HFT as discussed in methodology section, these algorithms were tested to see how they would process data. It seems that the proposed DRL performed better than both RF and LSTM in terms of both win rates of stock exchange and profit factor. It makes complete sense, as DRL combines RNN and CNN and other modules to perform better predictive analysis, which gives the HFT system integrated with DRL more refined information regarding crucial market trend elements. Clearly, compared to other algorithms, DRL performed better with a win rate of 62.80% with 2.4 profit factor. This makes the proposed HFT strategy work much better with higher chances of profit and win rate in stock exchange. The data used for the above algorithm comparison was also same as Chinese Stock Exchange HFT market data as mentioned previously.

4.1 High-Speed Bulk Transactions:

The research on HFT strategy enhancement using AI algorithms allows HFT systems to predict market trends to both buy and sell stocks at the best price possible in the right time (Shaikh et al., 2024). Allowing HFT firms to accurately transact for optimized profit making. In the world of high frequency trading, only seconds can determine gaining or losing millions of dollars. Hence, lightning-fast speed is required to gain a competitive advantage. As a result of integrating the proposed DRL framework for HFT optimization, the probability of profits and the speed of transaction can both be improved.

4.2 Technological Costs of Attaining High-quality AI integrated HFT System:

Upon the review of literature and technical discussions, it is clear that a properly integrated DRL HFT system will not be cheap (Han, 2025). Often times big HFT firms does not hesitate to invest millions of dollars in technological and algorithmic implementations to gain even a small advantage over their competitors. High-end HFT systems like the proposed DRL HFT system requires very powerful hardware, capable of processing and collecting mountains worth of data, lightning-fast networking and implementation of a highly complex algorithm capable of accurate real-time market trend prediction.

It is clear from the discussion and findings that Bangladesh can greatly improve their stock exchange profits with the help of HFT systems integrated with AI. But as seen from the above discussions, the huge cost and investments required by HFT systems is keeping Bangladesh from attaining its usability. Perhaps in the future

Feature	Description	Time Scale
Price Momentum	Rate of change in price	1s, 5s, 30s
Volume Imbalance	Bid-ask volume ratio	100ms, 500ms
Order Flow Imbalance	Net order flow	1s, 5s
Volatility	Realised volatility	1min, 5min
Bid-Ask Spread	Normalised spread	10ms, 100ms
Order Book Pressure	Cumulative volume at price levels	100ms

Figure 5. Smart and Optimized Features as a Result of DRL Implementation *(Source: Researchgate.net, 2024)*

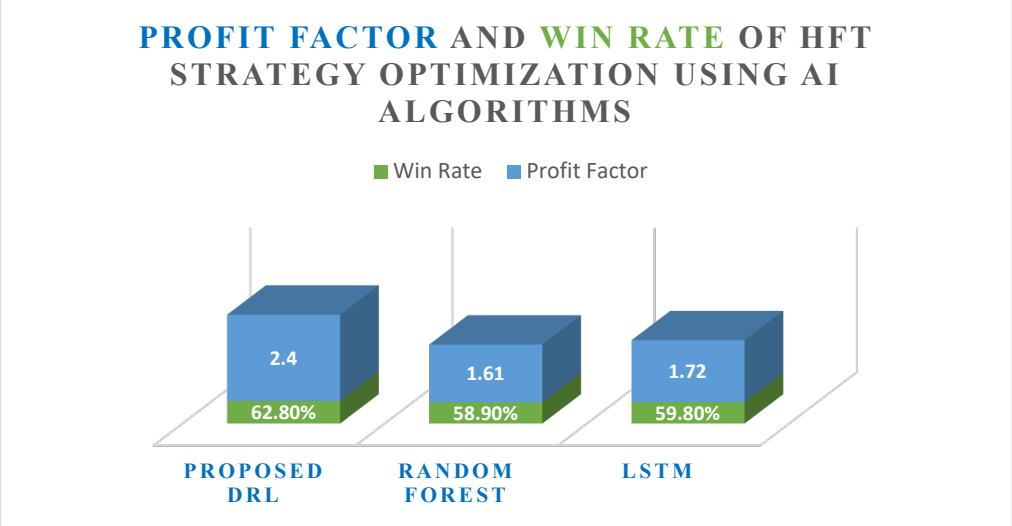

Figure 6. Bar Chart of comparison of DRL, LSTM and RF for HFT Optimization Effectiveness *(Source: Researchgate.net, 2024)*

through technological and market diversification, Bangladesh can adopt HFT systems.

5.Recommendations

In the light of research objectives, technical discussions and overall findings from the research relating to HFT strategy enhancement using AI, some recommendations have been formulated. These recommendations have been mentioned below:

Usage of AI models with Deep Learning capabilities should be adopted more often for HFT system optimization as it can predict market trend much better.

AI and ML algorithms specifically designed for pattern and anomaly detection can be used to detect unlawful changes in the stock exchange markets.

The usage of high-quality computing hardware coupled with super-fast networking is highly recommended as HFT systems are meant to transact millions of transactions in a couple of seconds.

Bangladesh should consider HFT systems integration as these systems can greatly books stock market performance.

The technological firms and government bodies of Bangladesh should consider the usage AI and ML tools to improve their electronic trade sector. This can allow Bangladesh at some point soon to adopt AI integrated HFT systems.

Rather than depending on pre-labeled data, HFT systems with AI integration should focus on live-dynamic data as it can give more accurate output. Pre-labeled or historical data should only be used for model training.

The above recommendations were formulated in the context of the research, objectives of the research and overall effectiveness of HFT strategy enhancement using AI. Perhaps these recommendations could become useful pointers for better HFT strategy formulation.

5.1 Limitations of The Study

This research paper was produced in the context of HFT strategy optimization using AI. There are lots of other algorithms which can perform in a similar manner, but DRL was chosen for its reliability. Almost all information and data discussed in this research paper were derived from already existing sources. The research materials were tried and tested, but this research paper revised and explained

those materials in a more specific context. No personal opinions were given without academic considerations. All conclusions and discussions in this research paper relating to high frequency trading strategy improvement using AI was based upon actual sources and reliable information.

6. Conclusions

The integration of AI and ML technologies in the domain of high frequency trading is an impressive pursuit of speed, precision and predictive market trend analysis (Arora et al., 2025). Such implementations were previously thought of as nothing more than fiction, but thanks to complex AI and ML algorithms; prediction and complex pattern recognition can be done with these algorithms. HFT systems can greatly help any stock market that uses it. HFT systems with AI integration takes its effectiveness to another level with smart transactions based on market data. Bangladesh can greatly benefit from AI infused HFT system strategies (Mohammad et al., 2024). However, Bangladesh is not yet ready for such complex integrations. On the other hand, Bangladesh is indeed moving in the right direction towards more technological progress and can eventually adopt complex and highly efficient AI oriented HFT systems for optimized stock market performance.

Author contributions

S.A.C. and M.A.S. jointly conceived and designed the study. S.A.C. was primarily responsible for data collection and initial drafting of the manuscript. M.A.S. conducted the data analysis and contributed to the interpretation of the findings. Both authors reviewed, revised, and approved the final version of the manuscript for submission.

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Competing financial interests

The authors have no conflict of interest.

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