

CHAPTER 5 Conclusion and Future Work

5.1 Introduction

This final chapter presents the conclusions of this research study, as well as suggestions for future research that can be performed in the field of which this research is conducted.

The research that is presented in this thesis investigates whether an end-to-end framework for integrating technical and financial information and fusing their probabilities can enhance the performance of artificial intelligence models for the purpose of predicting the movements of the stocks in the Saudi Stock Exchange.

The remainder of this chapter will present the findings of the research, the contributions of the research, the implications of the research, limitations of the research, and future recommendations for the research.

5.2 Summary of the Research

The research that is performed within this thesis seeks to develop an end-to-end framework for the prediction of the movements of the stocks within the Saudi Stock Exchange by integrating technical and financial information.

This framework includes the collection of a dataset that includes both technical and financial information of the Saudi Stock Exchange, the validation of the data that is collected, the development of models that utilize the information for the prediction of the movements of the stocks, and the evaluation of the framework's predictions from both a machine learning and investment perspective.

The results of the research indicate that the proposed framework is successful in the prediction of the movements of the stocks within the Saudi Stock Exchange.

5.3 Achievement of the Research Objectives

The objectives of this research study were to develop a framework for integrating both technical and financial information of the stocks traded within the Saudi Stock Exchange, to investigate the predictive capabilities of deep and machine learning models when used separately within the framework, to develop and test a framework for integrating the probabilities of the predictions of those separate learning models, and to evaluate the developed framework from an investment perspective.

The research fulfilled the objectives established for this study. The framework was developed for integrating the technical and financial information of the stocks within the exchange. The deep and machine learning models were developed and tested to determine their separate abilities in predicting the movements of the stocks. An AI framework for integrating the probabilities of those models was developed and tested for improvements in the classification of information that the separate models provided. Finally, the framework's decisions were evaluated within the portfolio to determine their success as investments.

Thus, it is evident that the objectives of this research study have been fulfilled.

5.4 Main Research Contributions

The study contributes to the existing financial AI literature by presenting a novel framework for short-term stock market prediction in the Saudi Stock Exchange. Unlike previous research that has focused upon evaluating the performance of individual prediction algorithms, the current research develops an entire framework for fulfilling such a function.

The main contributions of the research are presented below.

5.4.1 Contribution 1: Development of an End-to-End Hybrid Artificial Intelligence Framework

The main contribution of the presented research is the development of a complete end-to-end framework for financial prediction.

Rather than proposing a prediction algorithm, the framework was developed to include each of the stages of financial market prediction, from data collection to evaluation of the resulting investment portfolio.

The framework integrates data engineering, feature engineering, learning models, and investment evaluation into a single framework.

By integrating these components of the framework, the framework is not only readily reproducible but also includes a methodology for applying the framework to other financial market prediction problems.

5.4.2 Contribution 2: Chronological Financial Data Engineering Framework

Due to the potential for financial data to be compromised during its collection, pre-processing, or publishing, a data engineering framework was developed that ensured the chronological integrity of the financial data prior to its use in the prediction models.

Where most financial AI research has focused upon the development of prediction algorithms, this research has focused upon the importance of data integrity prior to the development of AI models.

The data engineering framework ensures the credibility and reproducibility of the results of the study.

5.4.3 Contribution 3: Specialized Learning Architecture

Beyond the development of the framework itself, another main contribution of the study was the creation of a method for specializing the learning of the AI algorithms according to the type of financial data being analyzed.

Instead of applying the same algorithm to all financial data, each learning algorithm was applied only to data of a certain type. For instance, the BiLSTM was learned from technical indicators of the market, while the XGBoost was learned from the financial variables of the market.

Each of these models was developed to best learn the characteristics of the financial data to which it was applied.

5.4.4 Contribution 4: Probability-Level Hybrid Fusion

Another contribution of this research is the use of a method for fusing the prediction probabilities generated by each of the individual learning models.

Rather than utilizing majority voting to determine the decision of each model, fusion of the prediction probabilities allows for the optimization of the learning of each model.

This strategy increases the flexibility of the framework while maintaining the independence of each of the learning models.

5.4.5 Contribution 5: Separation Between Prediction and Investment Evaluation

Another contribution of the study is the separation between the supervised learning models and the evaluation of the financial investments created with the predictions of those models.

The learning models were developed only using historical market data. The methods utilized for evaluating the financial portfolios were developed after the creation of the prediction models.

This separation ensures the integrity of the learning models and their ability to stand alone from the evaluation of financial investments.

5.4.6 Contribution 6: Comprehensive Evaluation Framework

In contrast to many financial AI research studies that employ only machine learning models to evaluate the success of the prediction algorithms, this research also employs a framework for evaluating the financial investments that were created with the predictions of the models.

This framework allows for the models to be evaluated both as machine learning models and as financial investment models.

5.4.7 Contribution 7: Application to the Saudi Stock Exchange

Finally, another contribution of this research is the application of the framework to the data from the companies listed on the Saudi Stock Exchange.

Few research studies have been performed on financial markets like the Saudi market, and thus the application of financial AI to such a market helps to expand the area of research for financial AI technologies.

Table 5.1 Summary of Research Contributions

Contribution	Description
C1	End-to-End Hybrid AI Framework
C2	Chronological Data Engineering Pipeline
C3	Specialized Learning Architecture (BiLSTM + XGBoost)
C4	Probability-Level Hybrid Fusion
C5	Separation Between Learning and Portfolio Evaluation
C6	Integrated Machine Learning and Portfolio Evaluation Framework
C7	Validation on the Saudi Stock Exchange

5.5 Practical Implications

Beyond the academic contribution of proposing and testing the new framework for financial market prediction, the research also has some implications regarding the use of such a system in practice.

For investors, the framework allows for the integration of technical and financial analysis to provide a more complete picture of financial markets that can be utilized to make investment decisions.

Portfolio managers could use the findings of the study to evaluate prediction models according to investment-oriented metrics to ensure that the models they select for their investing portfolios are in accordance with their investment objectives.

For researchers looking to expand upon the present framework, the architecture of the framework allows for future researchers to implement new models in various stages of the framework to test their effectiveness within the system without having to redesign the framework as a whole.

Finally, the developers of financial technology can utilize the artificial intelligence models incorporated into the framework as a means of creating technological advances within the area of investing that can be utilized by various investors and financial companies.

5.6 Limitations of the Research

In spite of the implications of the study and the valuable information that the framework can provide for investors, there are still some limitations to the research that should be acknowledged.

The framework was tested using the data from 35 companies listed on the Saudi Stock Exchange. While these represented a variety of industries, the conclusions drawn from these markets may not be able to be generalized to other markets across the world.

In addition, the information that was used to train the models was limited to the information that is published by the companies each day (their financial statements) and the technical indicators that can be calculated from the markets. Other information was intentionally ignored in the creation of this framework.

The framework was only tested for the prediction of short-term stock market movements. The framework could not be used to predict medium-term or long-term stock market movements.

In addition, while the virtual portfolio was utilized to test the effectiveness of the framework, it was simulated. Other factors that may have influenced the investing in those companies (market impact, transaction costs, etc.) were ignored in the development of this study.

Finally, the framework was tested using the specific BiLSTM and XGBoost models. While the results were favorable, other models may provide different results when utilized within the framework.

While these limitations to the study may reduce the value of the framework in some ways, they do not reduce the validity of the framework itself. Instead, they help to define the scope of the research that was performed, and contribute to the suggestion of future research that could extend the framework in new ways.

5.7 Future Research

In addition to the research that has been performed with the framework that was proposed in this thesis, there are still a variety of ways in which the framework can be extended in the future to provide even more value to investors and financial technology developers.

One suggestion for the future is to expand the information that is used to train the models used within the framework. For example, financial news feeds from the companies could be used to provide additional information to the models. Additionally, other information sources could be developed as well.

Another future research study that can be performed is testing other deep learning models within the framework. For example, models like Transformers and Temporal Fusion Transformers are more sophisticated deep learning models that could potentially be used in place of BiLSTM.

Another future research study is testing other probability fusion strategies for the models. For example, the weights of each model could be dynamically adjusted based on various market conditions.

In addition, the framework can be extended in terms of its investment features. For example, incorporating information like portfolio optimization, transaction costs, or dynamic position sizing could lead to the creation of even more sophisticated investing technologies.

Another area of future research is testing the framework on different markets around the world. Testing the same framework on stocks from different countries and different markets could contribute to the understanding of the generalizability of the framework.

Finally, another future research study is incorporating online learning capabilities into the framework. By allowing the framework to update its models with new financial information, it can lead to the creation of trading technologies that are able to provide their predictions in real time.

Table 5.2 Future Research Opportunities

Research Area	Potential Extension
Data Sources	sentiment analysis, macroeconomic indicators
AI Models	Transformer-based architectures, TFT, Graph Neural Networks
Hybrid Learning	Dynamic probability weighting
Portfolio Management	Dynamic position sizing and capital allocation
Market Validation	Cross-market evaluation
Real-Time AI	Online learning and continuous model updating

5.8 Final Conclusion

This thesis presented the design, implementation, and evaluation of a framework for short-term stock market prediction within the Saudi Stock Exchange.

The framework integrated chronological data engineering, learning models, probability fusion, and portfolio evaluation into a framework that provided improved short-term stock market prediction.

The framework was constructed to include each of these elements in a manner that would ensure that information would not be leaked from the models, that the data would be of high quality, and that the evaluation of the models would be separate from the models themselves.

Results from the framework indicated that the technical and financial market indicators each had some predictive power in the markets, but that integrating their predictions at the level of probability created a framework with superior market prediction capabilities.

In addition, the virtual portfolio indicated that the improvements in market prediction also led to improvements in investment performance. Thus, evaluating artificial intelligence models for financial markets according to both prediction and investment metrics is essential to understanding their true value.

Beyond its implementation of specific machine learning models for stock market prediction, the main contribution of this research is the creation of a framework that integrates each of these elements into a cohesive research and development framework. By following this proposed model, other developers can create their own artificial intelligence models that can be utilized for improving investment performance.

Finally, the findings of this research support the conclusion that incorporating artificial intelligence models into financial market prediction is a promising area of study for the development of improved technologies for investors, traders, and financial companies around the world.