

ALAMSYS: DEVELOPMENT OF STOCK MARKET  
PRICE FORECASTING SYSTEM USING DYNAMIC  
MODE DECOMPOSITION, LONG SHORT-TERM  
MEMORY WITH ARNAUD LEGOUX MOVING AVERAGE  
CONVERGENCE-DIVERGENCE INTEGRATION

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# Chapter 1

## Introduction

### 1.1 Background and Rationale

The stock market is a type of market that allows businesses to raise capital by selling stock shares to investors. These shares represent a portion of the company's ownership and entitle the holder to a portion of the company's profits as well as voting rights. The stock exchange also serves as a marketplace for investors to buy and sell these shares, allowing for the efficient trading of company ownership. The stock market plays an important role in the growth and development of the economy by allowing companies to raise capital and investors to buy and sell shares (Chen, 2022; The Economic Times, n.d.).

The stock market, contrary to popular belief, is not a form of gambling. It necessitates a significant amount of analytical thinking and risk management, and the returns are determined by supply and demand for a specific stock, rather than false promises or assurances. In other words, rather than being a scam or a gamble, the stock market is a legitimate platform for investing and generating returns (Schwab-Pomerantz, 2021; Adams, 2022; Summers, 2022).

### **1.1.1 The Philippine Stock Exchange (PSE)**

The Philippine Stock Exchange (PSE), Inc. is the country's official stock exchange market. It is a non-stock company founded in 1992 that manages and operates the country's stock market. Individuals who are registered with the PSE can participate in market exchanges (The Philippine Stock Exchange, Inc., n.d.-a).

Furthermore, the Philippine Stock Exchange Index (PSEI) is the main index of the PSE. (PSEI). The PSEI is a market capitalization-weighted price index composed of the PSE's 30 largest and most actively traded companies. These businesses have been pre-selected based on strict criteria such as liquidity and market capitalization. The PSEI is frequently used as a proxy for the overall performance of the Philippine stock market. (Bangko Sentral ng Pilipinas, n.d.) These PSEI companies are often referred to as blue-chip companies because they are typically large, well-established companies with a track record of strong financial performance. In total the PSE has 286 companies listed as of October 2022, offering investors a diverse range of investment opportunities (Fayed, 2022; The Philippine Stock Exchange, Inc., n.d.-b).

### **1.1.2 Economic Relevance and Benefits of Stock Market Investment**

The stock market is widely acknowledged to play an important role in economic growth because it allocates and provides capital to businesses, which drives economic activity and growth. This is evident from the fact that stock market performance is frequently correlated with the gross domestic product (GDP) of the country. (Trade Brains, 2022; Hall, 2022; Bae & Kang, 2017) Furthermore, historical stock price trends can provide insight into broader economic movements (Campbell, 2021).

In a study conducted by Balaba (2017), they discovered that the stock market



has a positive impact on the Philippines' economy. The study's findings showed that as the stock market rose, the unemployment rate fell. This is because the performance of the stock market leads to job creation, which in turn leads to economic growth. This, in turn, drives economic growth. This relationship was observed in the Philippines from 2007 to 2017.

### **1.1.3 Benefits of Investing for the Individual**

Individuals in the Philippines can trade shares of publicly traded companies on the Philippine Stock Exchange. Investing in the stock market can provide several advantages to an individual, including:

- (a) Protects an individual's money from inflation: Inflation in the Philippines was 6.9% as of September 2022 (Trading Economics, n.d.), while savings account deposit interest rates are only 1-3% annually, (Bureau of the Treasury Bangko Sentral ng Pilipinas, n.d.). This means that savings in deposit banks may not keep pace with inflation, potentially reducing an individual's purchasing power over time. (Royal Bank of Canada Direct Investing Inc., n.d.; EdwardJones, n.d.).
- (b) Capital growth opportunities: Investing in the stock market can provide individuals with the opportunity for significant capital growth without the need for direct investment involvement in business operations. This may benefit individuals. Students and working professionals, for example, can increase their capital while remaining focused on their studies or careers. (U.S. Securities and Exchange Commission, n.d.).

### **1.1.4 Utilization of Machine Learning in Stock Market Trading**

In recent years, there has been a surge in interest in the use of machine learning. Learning techniques for predicting stock market movement in the short and long term. As a result, numerous studies and practical applications investigating the use of machine learning in stock market prediction have been conducted.

These efforts aim to improve prediction accuracy and assist investors in making informed decisions (Kumbure, Lohrmann, Luukka, & Porras, 2022; Strader, Rozycki, Root, & Huang, 2020; Soni, Tewari, & Krishnan, 2022; Rea, 2020; Guo, 2022). In this regard, one of the common techniques used is the Long Short-Term Memory (LSTM). LSTM is a deep learning model that is widely used to forecast the stock market. A study by Budiharto (2021) found that LSTM was effective in predicting the Indonesian stock market with 95% accuracy using a short-term data. Which suggests that LSTM can be a useful tool for making short-term stock market forecasts.

The use of Dynamic Mode Decomposition (DMD) for predicting stock market price trends has recently gained traction in the financial industry. DMD is a mathematical method for identifying patterns and trends in large data sets, such as stock market data. It is possible to make more accurate predictions about future stock price movements by applying DMD to stock market data. This can help investors make more informed investment decisions and potentially generate higher returns. However, a study by Lu and Tartakovsky (2020) found that DMD is faster than Proper Orthogonal Decomposition, but it is less accurate.

Other studies have shown that DMD can be effectively applied to the Turkish and Indian stock markets to predict market price trends (Savaş, 2017; Kuttichira, Gopalakrishnan, Menon, & Soman, 2017). These studies show that DMD is simple to implement and can be used as a useful enhancer for making stock market predictions.

## 1.2 Statement of the Problem

Economic growth in the Philippines is expected to slow in the coming years as a result of the global pandemic, high inflation, and low employment rates (Alegado, Lopez, & Calonzo, 2022; Canto & Romano, 2022; Reuters, 2022).

The lack of free and publicly available stock market predictive systems or tools currently creates a gap in the information available to the public when compared to large private individuals or institutions. These large institutions have the resources to spend a significant amount of money on stock market research, giving them a significant advantage in the investing market. Where, the public is disadvantaged by this lack of access to the same information (Kim, 2022).

Furthermore, the lack of publicly available stock market prediction tools can lead to individuals, particularly first-time investors, making unwise investment decisions, resulting in significant losses and discouragement from investing in the stock market. This is a significant issue because the number of local investors in the Philippine Stock Exchange is already quite small, accounting for only about 1% of the total population. In addition, there has been a significant decline in foreign investment in the Philippines in recent years (Business World, 2022), leading to a corresponding decline in investment volume. As suggested in the study of Balaba (2017), this is expected to have a negative multiplier effect on the country's economic development in the future.

As a result, the creation of a publicly available, simple-to-use, and accurate stock market price trend prediction system could aid in closing the information gap and leveling the playing field for individual investors. This system could help to increase transparency and fairness in the stock market by providing the public with timely and reliable information, resulting in more informed and confident investing decisions and, ultimately, a more stable and prosperous market. Furthermore, such a system could help to increase individual investor participation in the market, resulting in a more diverse and stable market overall. (Statista Research Department, 2022; Commission on Population and Development, 2021).

However, despite the clear and functional benefits of investing in the stock market, many Filipinos remain hesitant to do so for the following reasons:

- (a) The difficulties that come with learning the fundamentals of effective stock

investing.

- (b) The time-consuming nature of technical and fundamental analysis, especially for students and working people on a tight schedule; and
- (c) The increased financial risk associated with stock market volatility, as well as the potential for emotional decision-making to jeopardize investments.

These factors (*along with other external and internal factors not listed above*) contribute to a lack of confidence and understanding among potential investors, making it difficult for them to take advantage of the opportunities offered by the stock market.

As such the development of this system, aims to address the following:

- (a) The lack of free and publicly available stock market prediction systems or tools.
- (b) The time and resources required to study complex traditional market analysis tools, such as fundamental and technical analysis.
- (c) The potential for inaccurate market decisions leading to significant investment losses; and
- (d) The hesitancy of the Filipino public to begin investing in the Philippine stock market.

### 1.3 Significance of the Study

The significance of this particular problem lies in the developed system to greatly benefit the stock market, individual investors, and the economy as a whole. Contributions of the system to data-driven investing, financial protection and management, and economic development could provide a valuable resource for investors while also promoting financial stability and growth. Furthermore, the creation of publicly accessible data-driven investing tools or systems may enable

more Filipinos to participate in the market and take control of their own financial future. Overall, this special problem has the potential to have a significant impact on the Philippine stock market and economy.

Specifically, this study is significant for the following reasons:

- (a) The development of the alamSYS aims to provide the following benefits to the Filipino people:
  1. Access to simplified yet accurate information – The proposed system could provide Filipino investors with fast, accurate, and relevant information necessary for effective decision making in the stock market. Using a deep learning model such as LSTM, the system could provide users with the two most important pieces of information: which stocks to buy, and which stocks to sell. This simplified investing model could help investors to make informed decisions and navigate the stock market with confidence.
  2. Provide an application interface to facilitate data-driven market decisions – The system could provide users with an intuitive and user-friendly application interface to facilitate data-driven investment decisions, particularly during times when the market is unpredictable or experiencing a downturn. Whereas traditional market analysis tools may not be sufficient to navigate these challenging conditions, the system’s forecasting model could provide investors with the insights and guidance they need to make informed and wise decisions. Which would help to promote confidence and stability in the market, even during times of uncertainty.
  3. A platform for accessible stock market investment – The system aims to provide all investors, regardless of their investment knowledge, educational attainment, and societal status, with a platform for participating in the stock market. By offering a simplified yet accurate model for investment decision making, the system could empower users to make informed decisions and invest with confidence. This could help to democratize access to the stock market and promote financial inclusion for all Filipinos.

- (b) The development of the alamSYS, aims to provide the following benefits to the future developers or researchers:
1. Extension of functionality to other financial markets – The system can be easily adapted or expanded to address related problems in other financial markets, such as investing in government bonds or personal finance management. This flexibility and versatility could make the system a valuable tool for a wide range of investment and financial management scenarios.
  2. Testing of new trading algorithms and other machine learning models – The system provides a platform for introducing and testing new data-driven trading algorithms and machine learning models. This could allow future researchers and developers to continually improve the system and keep it at the forefront of data-driven investing technology.
  3. Development of a graphical user interface – To further improve the public accessibility of the system, a user-friendly graphical user interface can be developed as a web or mobile application. This could make the system easy to use and intuitive for all users, regardless of their technical expertise.
- (c) The development of the alamSYS could help to stimulate economic recovery and development in the country by increasing the number of local investors. As discussed in previous sections, the benefits of the system could encourage more people to invest in the stock market, leading to a multiplier effect that could benefit the economy in several ways. For instance, the increased participation in the market could lead to the creation of jobs and a lowering of unemployment rates. Additionally, the influx of capital into the market could drive fast developments and innovations in various industries. Finally, the increased consumer spending that results from successful investing, stimulates economic growth as well. Overall, the development of the alamSYS could have a positive and far-reaching impact on the economy of the Philippines.

## 1.4 Objectives

This special problem aims to develop a system that makes investing easier, more publicly available, data-driven, and more approachable by minimizing both the time required for stock price trend analysis, and potential financial risk by using DMD-LSTM and integrate Arnaud Legoux Moving Average Convergence-Divergence (ALMACD) as a trading algorithm. More specifically, it aims to do following:

- (a) Develop a Data Preprocessor. Which includes a Data Collector Module (DCM), which collects the end-of-day historical data of a stock from Mondays to Fridays. The data collected is then processed by the Data Processor Module (DPM), which applies the deep learning model and integrate the trading algorithm to the data. Finally, the processed data is given to the Database Updater Module (DUM).
- (b) Develop a RESTful API, referred to as alamSYS, using the combination of Python's FastAPI and MongoDB for API endpoints and database, respectively.

Specifically, this was done by doing the following:

1. Develop the following API endpoints:

- 1.1 **Home** – This API endpoint outputs a welcome message. Which should inform the user that they have successfully connected to the alamAPI.

- 1.2 **Stocks to Buy** – This API endpoint outputs a list of suggested stocks to buy based from the current market price and the predicted price up-trend.

- 1.3 **Stocks to Sell** – This API endpoint outputs a list of suggested stocks to sell based from the current market price and the predicted price down-trend.

- 1.4 **Stocks Info** - This API endpoint outputs a list of stocks included in the alamSYS and their corresponding information.

**1.5 ML Model Info** - This API endpoint outputs a list of the Machine Learning Models used in the alamSYS and their corresponding information.

**1.6 Stocks Risks Info** - This API endpoint outputs a list of the stocks included in the alamSYS and their corresponding risks values based on value at risk (%), volatility (%), and drawdown (%).

2. Develop a database that stores the results provided by the DPM, and other essential data such as stock information, deep learning model information, and stock risks information about the stock market that is needed to be provided.
- (c) Develop a Stock Market Price Trend Forecasting Deep Learning Models by utilizing the dynamic modes in DMD as an additional input parameter to an LSTM model. Afterwards, integrate the forecasting with ALMACD as a trading algorithm and basis for entry and exit positions.
- (d) Finally, develop a mobile-based test application, which from hereon maybe referred to as: alamAPP, to showcase the main functionalities of the developed RESTful API. Specifically which stocks to buy and to sell for a given period of time.

## 1.5 Scope and Limitations

This study was limited only within the companies listed in the Philippine Stock Exchange. Specifically, 20 high volume trade stocks from the year 2021 to 2022 were selected, which are as follows: (1) MEG, (2) JGS, (3) BDO, (4) FGEN, (5) ICT, (6) ALI, (7) SMC, (8) TEL, (9) GLO, (10) BLOOM, (11) RLC, (12) MER, (13) AC, (14) PGOLD, (15) LTG, (16) MPI, (17) AP, (18) RRHI, (19) URC, and (20) PSE Index will be included in the system, instead of the total 286 listed under the Philippine Stock Exchange.



# Chapter 2

## Results and Discussions

This chapter presents results and discussions from this special problem. Its goal is to provide a comprehensive analysis and interpretation of the data collected for alamSYS's internal and external components. As a result, this chapter is divided into the following sections:

- (a) Documentation for alamSYS
- (b) DMD-LSTM Results and Discussions
- (c) ALMACD Results and Discussions
- (d) alamSYS System Tests Results and Discussions
- (e) Results and Discussions for the Real World Application of alamSYS

### 2.1 alamSYS Documentation

The goal of this section is to thoroughly document the current state of the alamSYS in order to facilitate meaningful discussions.

**2.1.1 Documentation for alamAPI and Database**

xxx

**2.1.2 Documentation for alamSYS Preprocessor**

xxx

**2.1.3 Documentation for alamAPP**

xxx

**2.1.4 Build and Deployment Guide**

xxx

**2.2 alamSYS System Tests Results and Discussions**

Table 2.1: Idle System Average Resource Usage Statistics

	alamAPI	alamDB	alamPREPROCESSOR
CPU Utilization (%)	0.168125	0.254313	0.009769
Memory Utilization (MiB)	45.718311	166.775377	312.798300

xxx

Table 2.2: Internal Load Average Resource Usage Statistics

	Data Collector	Data Processor	alamSYS PREPROCESSOR (Data Collector & Data Processor)
Failure Rate (%)	0	0	0
Success Rate (%)	100	100	100
Average Runtime (s)	41.72398	8.38061	48.30466
Average CPU Utilization (%)	11.40659	92.71117	20.03138
Average Memory Utilization (MiB)	3.64200	57.09545	794.29436
Average Network Utilization (Mb)	232.73640	154	77.27655

xxx

Table 2.3: Deployment Load Test Results (Buy Requests)

	Number of Requests		
	10	100	1000
Success Rate (%)	100	100	100
Average Processing Time (s)	11.905222	139.618550	1159.773569

xxx

Table 2.4: Deployment Load Test Results (Sell Requests)

	Number or Requests		
	10	100	1000
<b>Success Rate</b> (%)	100	100	100
<b>Average Processing Time (s)</b>	13.384126	130.119867	1642.995011

xxx

## 2.3 DMD-LSTM Model Results and Discussions

This section presents and discusses the Deep Learning Model’s training, testing, and cross-validation results.

In Table 2.5 the training error metrics are shown for each of the window sizes tested.

Table 2.5: DMD-LSTM Training Error Metrics Scores for Different Window Sizes

Error Metrics	<i>Window Sizes</i>			
	5	10	15	20
<b>MSE</b>	0.000037	0.787877	0.006917	0.057851
<b>RMSE</b>	0.006106	0.887624	0.083166	0.240522
<b>MAE</b>	0.004175	0.755407	0.067645	0.202746
<b>MAPE</b>	<b>0.000001</b>	0.000194	0.000017	0.000053

Where it is observed that the best performing model based on having the lowest MAPE score is the DMD-LSTM with a window size of 5. Moreover, we can see the differences from each MAPE score for each window size in the Figure 2.1

shown below.

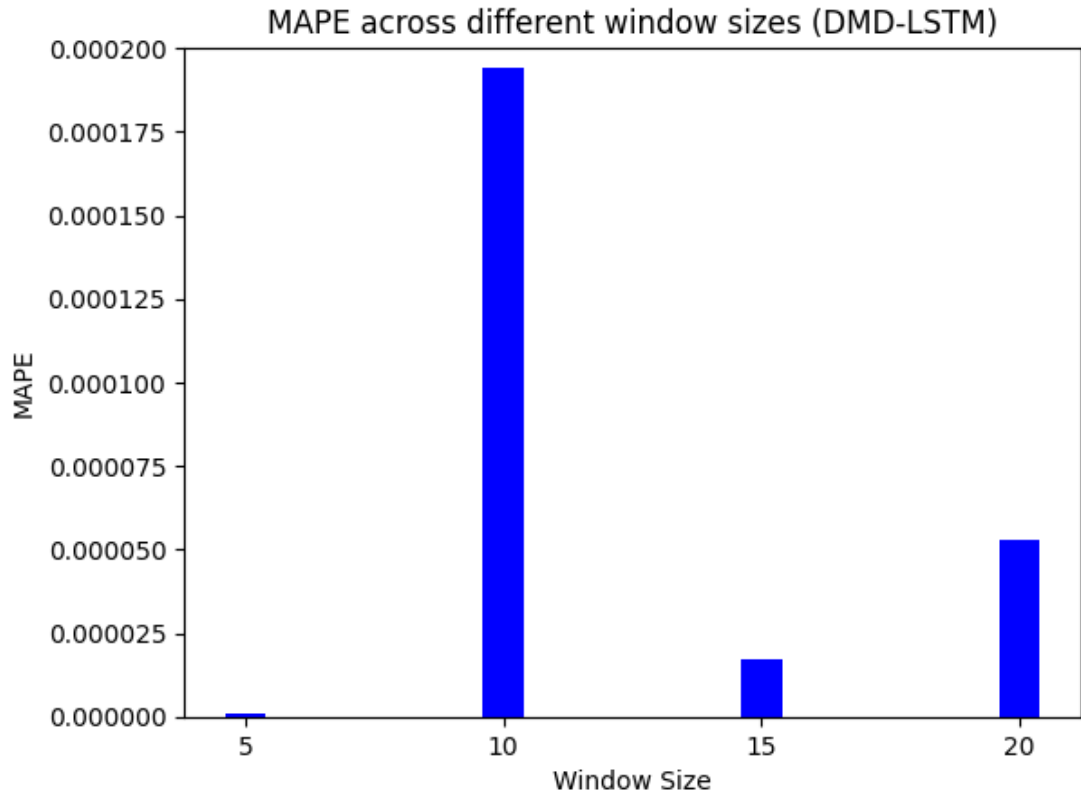


Figure 2.1: Comparison of MAPE Scores for DMD-LSTM Model Training Across Different Window Sizes

The figure above also shows that the MAPE score for window sizes 15 and 20 is higher than the MAPE score for window size 10. MAPE score increases from window size 15 to size 20, indicating that increasing window size may result in a lower performing model.

Furthermore, as previously stated, the window size of 5 results in the best MAPE score being the lowest. Where it outperforms the worst performing model (DMD-LSTM with window size 10) by 0.000193 units. As illustrated clearly in Figure 2.1.

Knowing that the DMD-LSTM model performs as expected based on the training data scores, it is critical that we also examine the training data results from a baseline LSTM. The baseline LSTM is, as the name implies, a simple LSTM model lacking the DMD component. The table below shows the results of the baseline LSTM training.

Table 2.6: Baseline LSTM Training Error Metrics Scores for Different Window Sizes

<b>Error Metrics</b>	<i>Window Sizes</i>			
	<b>5</b>	<b>10</b>	<b>15</b>	<b>20</b>
<b>MSE</b>	2912.840703	191.935882	1118.183283	706.136814
<b>RMSE</b>	53.970739	13.854093	33.439248	26.573235
<b>MAE</b>	35.301888	9.480864	22.099720	18.285352
<b>MAPE</b>	0.009618	<b>0.002527</b>	0.006024	0.005004

According to the table above, the baseline LSTM with window size 10 performs the best, with the lowest MAPE score of 0.002527 when compared to the other baseline LSTM models.

However, the DMD-LSTM model with window size 5 outperforms it by 0.002526. As a result, the alamSYS makes use of the DMD-LSTM model, specifically the one with a window size of 5. Where from now on, the DMD-LSTM model refers to the DMD-LSTM model with a window size of 5.

Nonetheless, the DMD-LSTM model’s performance is limited to the training dataset from PSEI, and it must be cross-validated using data from other stocks, which includes the PSEI validation dataset. The results of this cross-validation is presented in Table 2.7. It should also be noted that cross-validation uses logarithmic normalization as a data preprocessing technique to make the dataset more normal, which aids in analyzing the model’s performance with the given dataset. Normalization techniques, in particular, allow for closer variation within the forecasted data. (S.Gopal Krishna Patro, 2015).

Table 2.7: DMD-LSTM Cross-Validation Error Metrics Scores

<b>Stocks</b>	<b>MSE</b>	<b>RMSE</b>	<b>MAE</b>	<b>MAPE</b>
<b>PSEI</b>	0.00002	0.00419	0.00328	1.510000e-03
<b>AC</b>	0.00236	0.04856	0.03414	6.110000e-03
<b>ALI</b>	0.00255	0.05054	0.03645	1.597000e-02
<b>AP</b>	0.00129	0.03596	0.02515	9.220000e-03
<b>BDO</b>	0.00160	0.03999	0.02799	7.250000e-03
<b>BLOOM</b>	0.01883	0.13721	0.06901	1.052898e+12
<b>FGEN</b>	0.00224	0.04733	0.03265	1.197000e-02
<b>GLO</b>	0.00211	0.04595	0.03149	4.680000e-03
<b>ICT</b>	0.00335	0.05785	0.03731	3.005818e+11
<b>JGS</b>	0.00331	0.05752	0.03992	2.009923e+11
<b>LTG</b>	0.01567	0.12518	0.05858	3.583335e+12
<b>MEG</b>	0.00431	0.06565	0.04422	1.393042e+11
<b>MER</b>	0.00326	0.05708	0.03770	9.170000e-03
<b>MPI</b>	0.00273	0.05230	0.03390	2.497000e-02
<b>PGOLD</b>	0.00149	0.03865	0.02818	7.880000e-03
<b>RLC</b>	0.00338	0.05817	0.03978	6.922000e-02
<b>RRHI</b>	0.00131	0.03618	0.02699	6.390000e-03
<b>SMC</b>	0.00137	0.03702	0.02317	5.690000e-03
<b>TEL</b>	0.00178	0.04214	0.03002	4.240000e-03
<b>URC</b>	0.00297	0.05447	0.03742	1.798000e-02

As shown in the table above, the chosen DMD-LSTM model performs well across all other stocks, demonstrating that the model is not overfitted to the training dataset. This score additionally suggests that the model works with non-training data.

The figures below show a 100-day worth of predicted prices versus actual prices to better visualize the performance of the DMD-LSTM model for each stock.

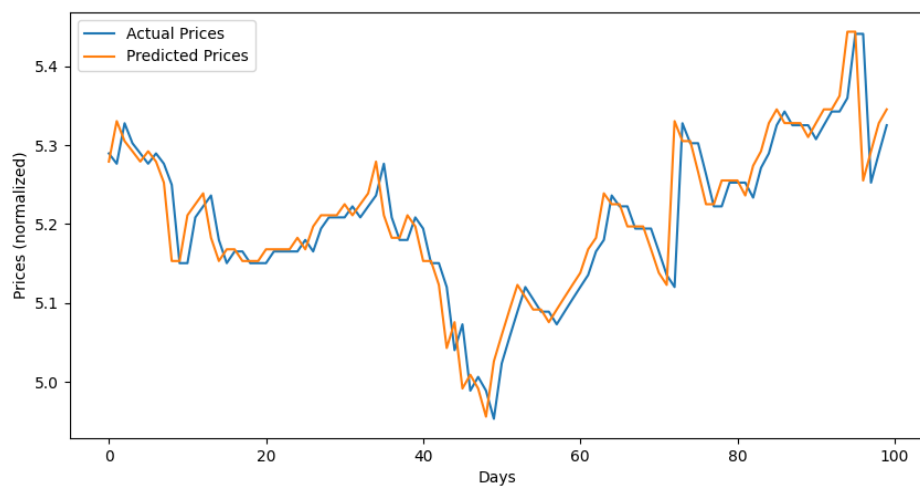


Figure 2.2: Actual vs Predicted Prices on AC for 100 days

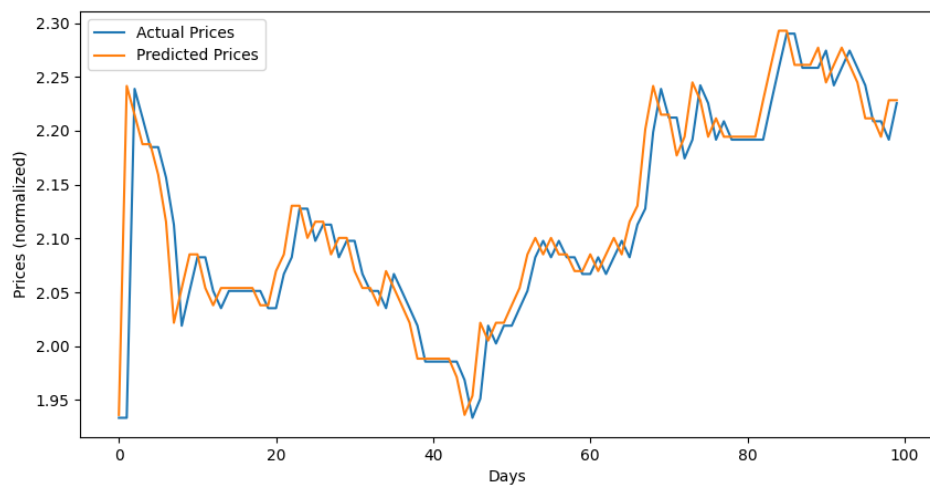


Figure 2.3: Actual vs Predicted Prices for ALI over 100 days



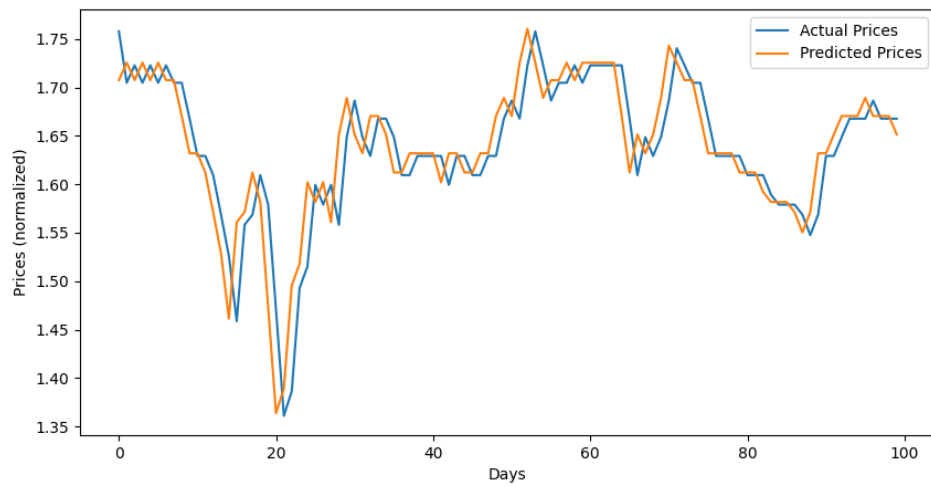


Figure 2.4: Actual vs Predicted Prices for AP over 100 days

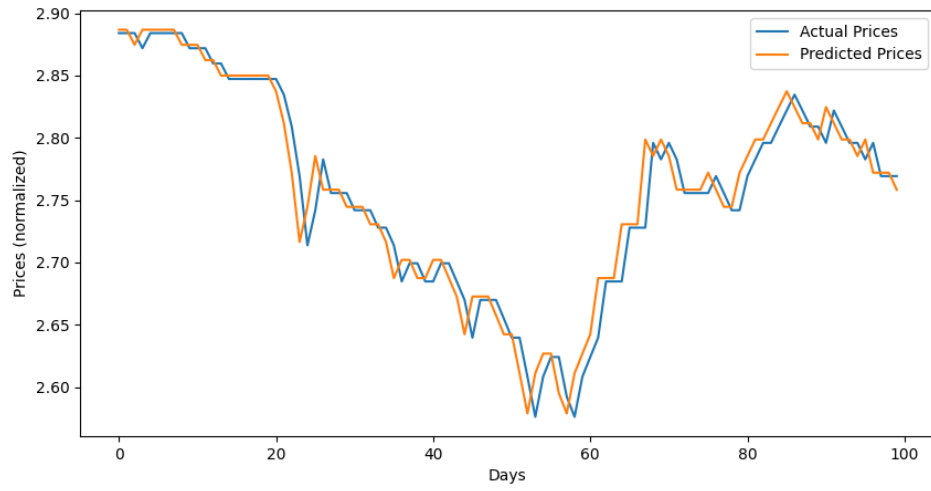


Figure 2.5: Actual vs Predicted Prices for BDO over 100 days

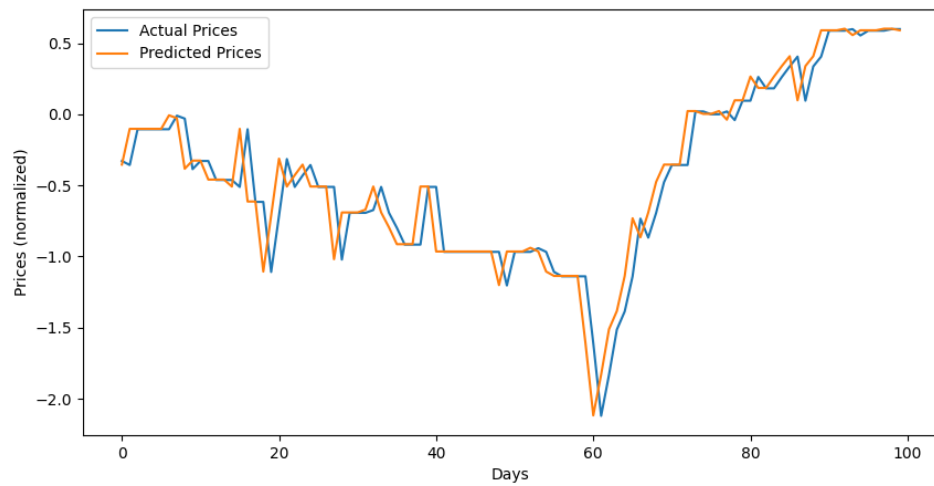


Figure 2.6: Actual vs Predicted Prices for BLOOM over 100 days

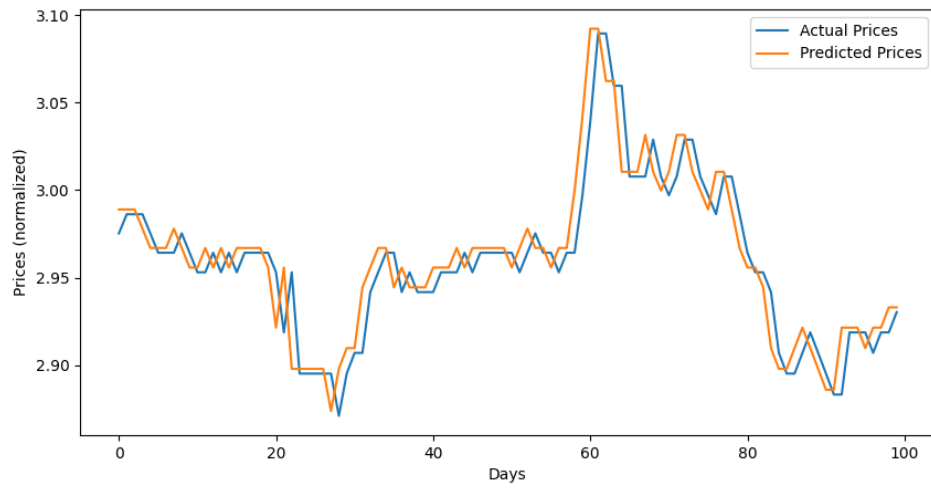


Figure 2.7: Actual vs Predicted Prices for FGEN over 100 days

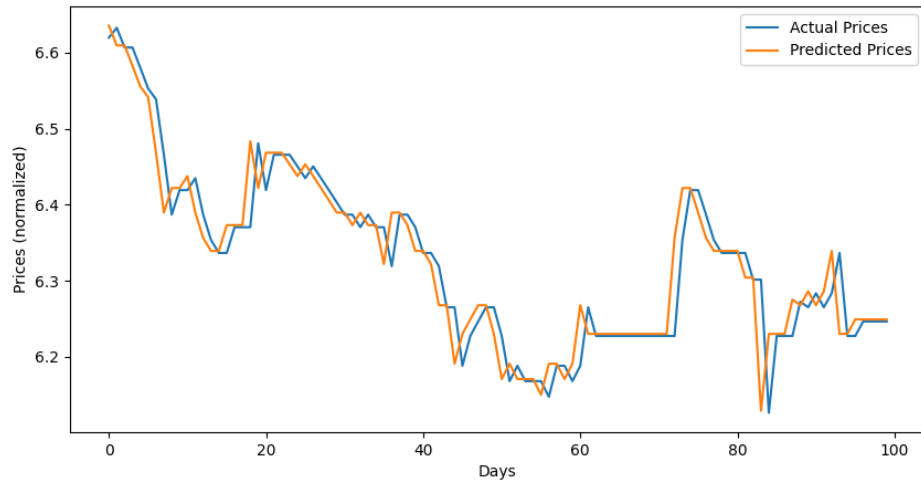


Figure 2.8: Actual vs Predicted Prices for GLO over 100 days

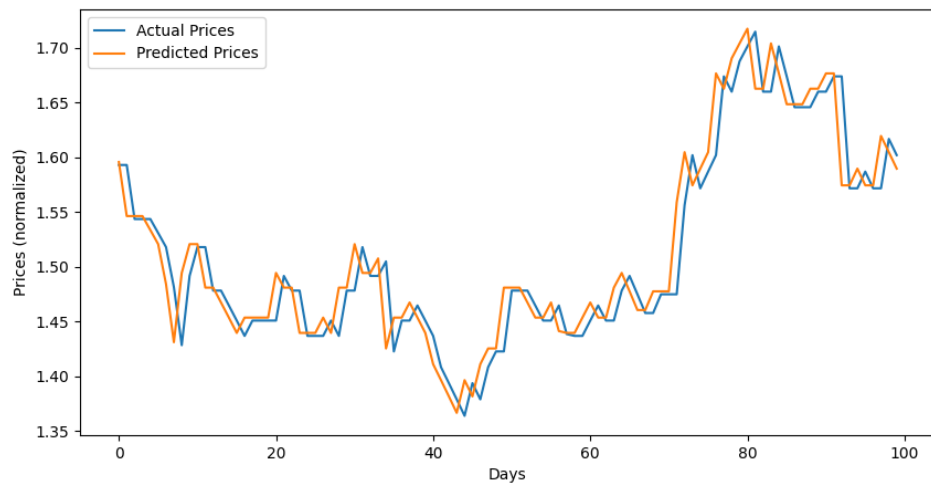


Figure 2.9: Actual vs Predicted Prices for ICT over 100 days

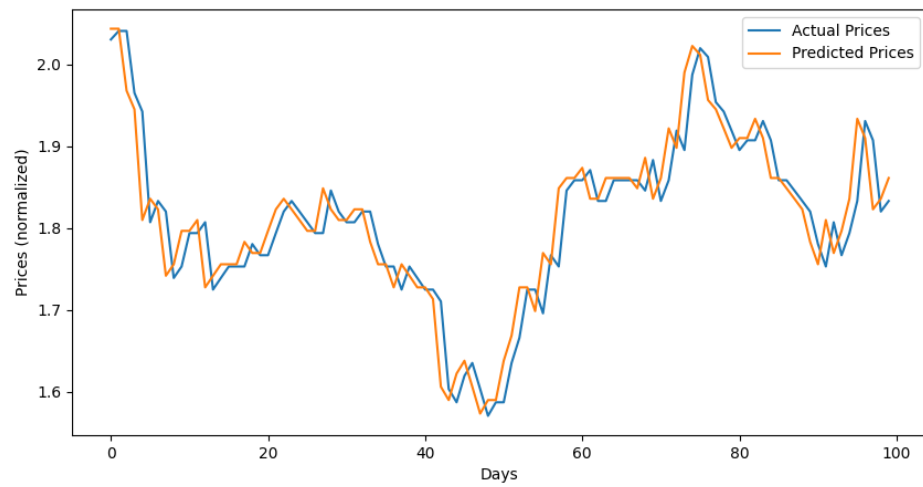


Figure 2.10: Actual vs Predicted Prices on JGS for 100 days

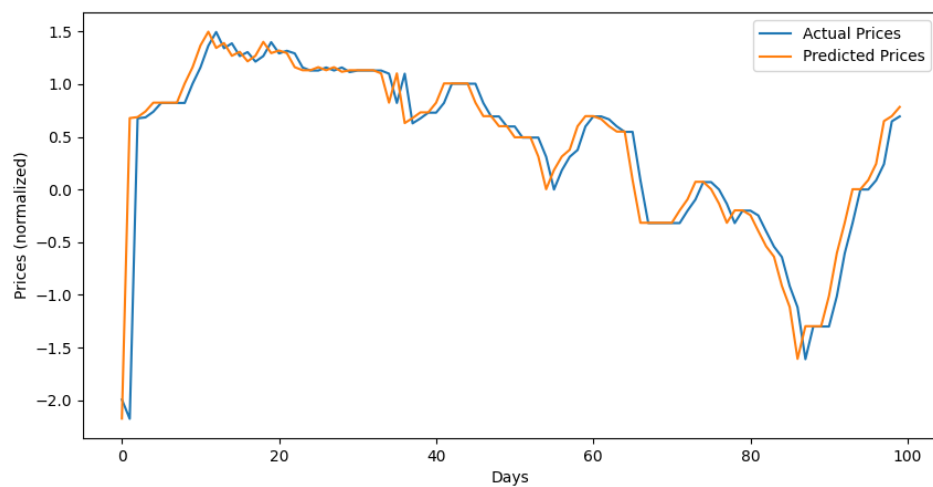


Figure 2.11: Actual vs Predicted Prices on LTG for 100 days

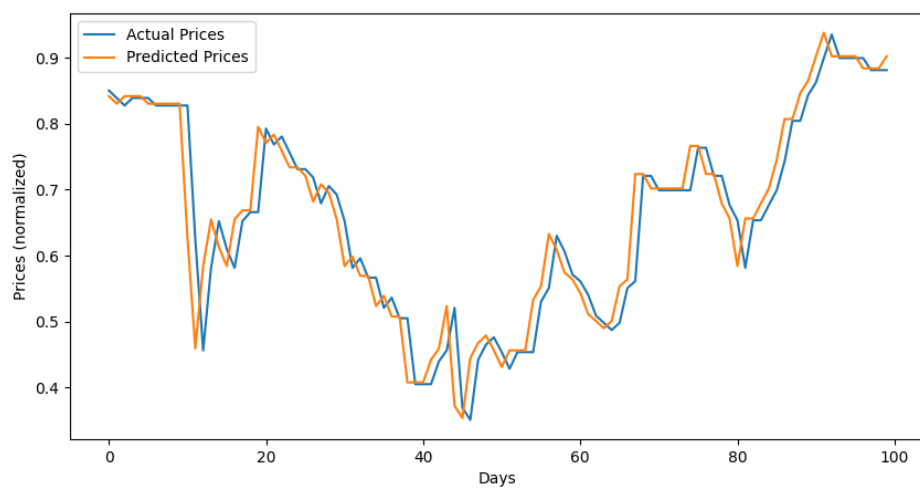


Figure 2.12: Actual vs Predicted Prices on MEG for 100 days

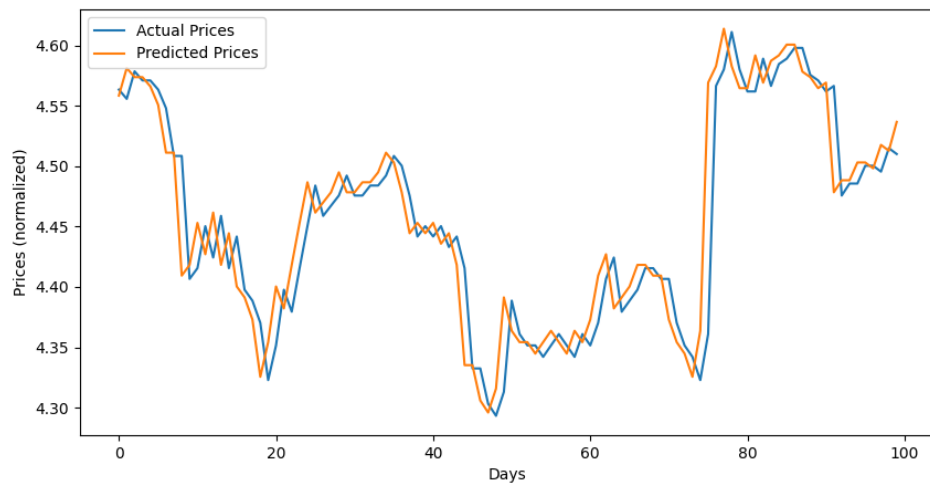


Figure 2.13: Actual vs Predicted Prices on MER for 100 days

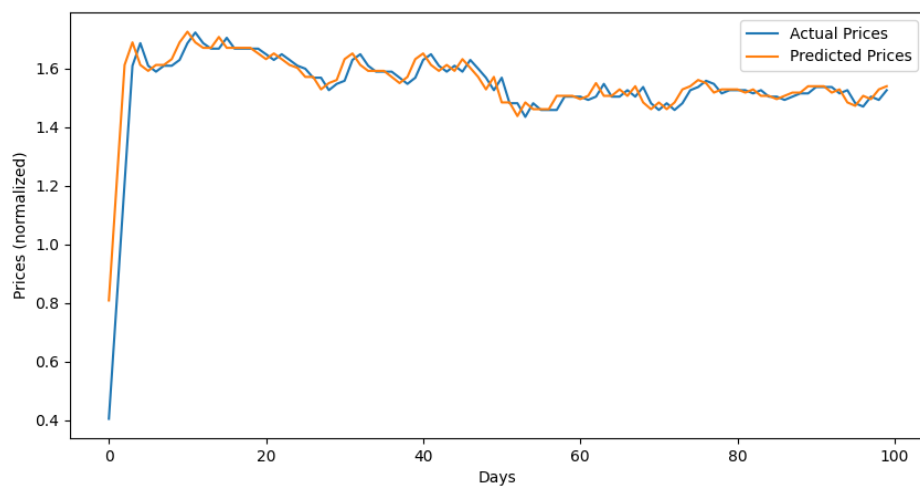


Figure 2.14: Actual vs Predicted Prices on MPI for 100 days

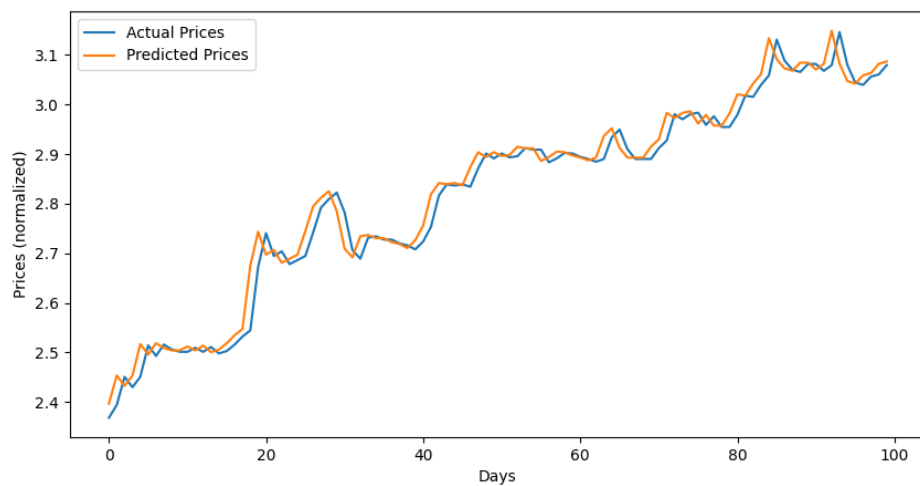


Figure 2.15: Actual vs Predicted Prices on PGOLD for 100 days



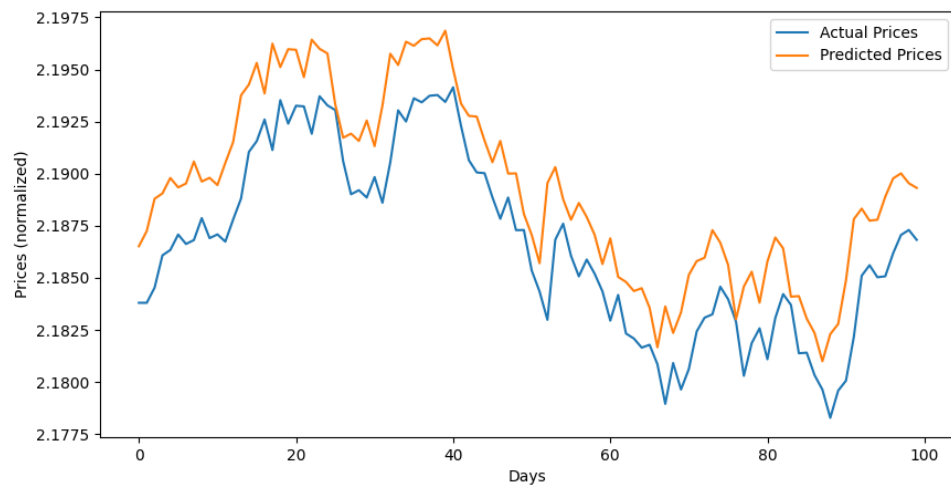


Figure 2.16: Actual vs Predicted Prices on PSEI for 100 days

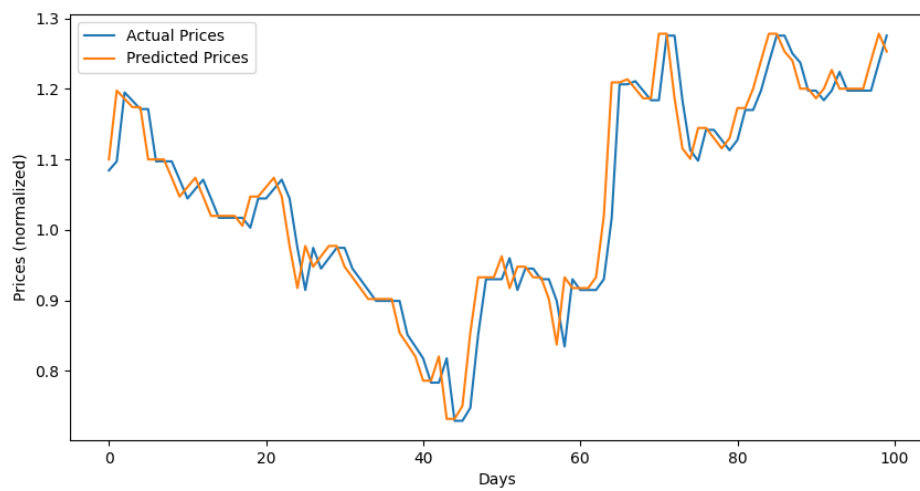


Figure 2.17: Actual vs Predicted Prices on RLC for 100 days

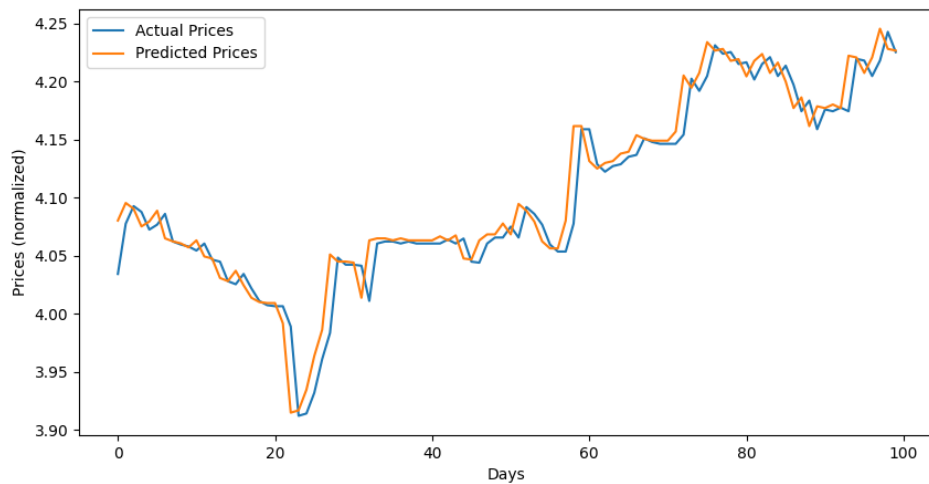


Figure 2.18: Actual vs Predicted Prices on RRHI for 100 days

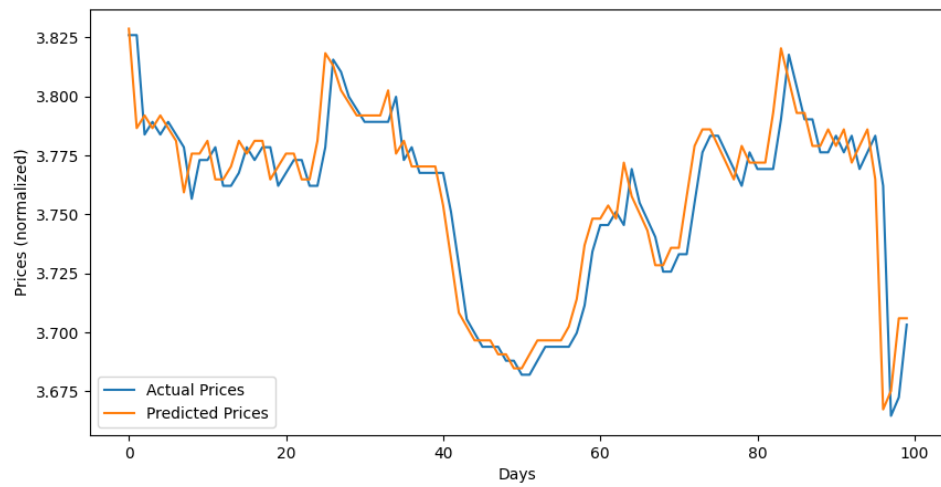


Figure 2.19: Actual vs Predicted Prices on SMC for 100 days

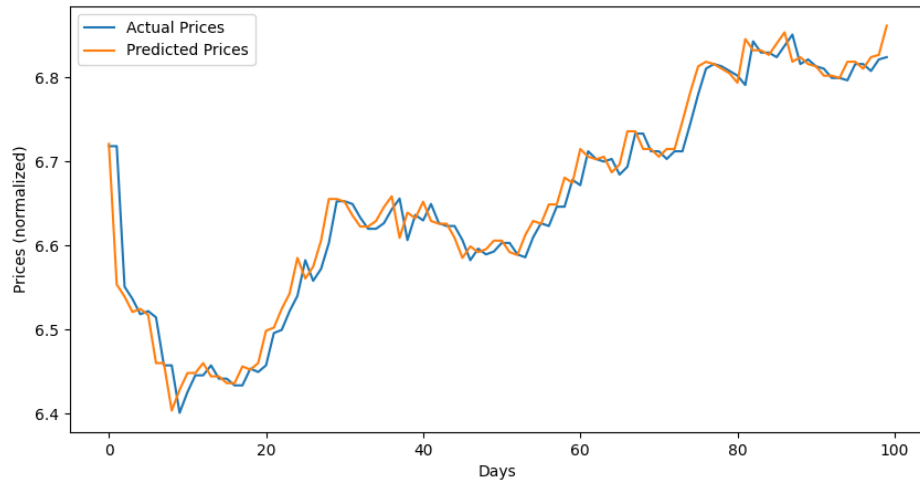


Figure 2.20: Actual vs Predicted Prices on TEL for 100 days

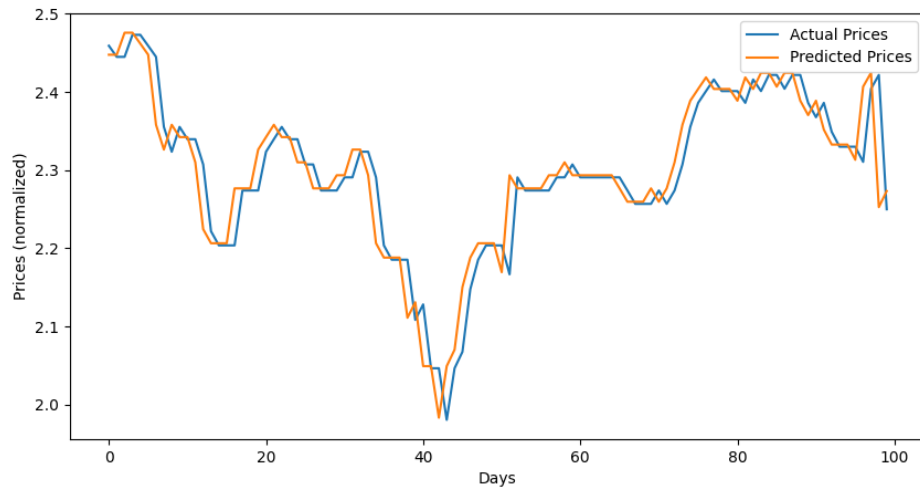


Figure 2.21: Actual vs Predicted Prices on URC for 100 days

The figures above show that the predicted prices follow the actual price trend. In addition, the discrepancy between predicted and actual prices is relatively small, as evidenced by the error metrics scores shown in Table 2.7.

However, the MAPE scores for BLOOM, ICT, JGS, LTG, and MEG range from ten billion to hundred billion. This outlier in the data is, fortunately, just the result of the applied logarithmic normalization, where some of the data in the datasets of the aforementioned stocks are in the negative range, that influence the calculation of the MAPE scores using the scikit-learn library. Because this library handles the calculation of the MAPE scores, there is no way to fix this bug. Moreover, if we take a look at the graphs of the 100 days prediction versus the actual for the aforementioned stocks in Figures 2.6, 2.9, 2.10, 2.11, and 2.12, respectively, it can still be observed that the model performs well on these stocks.

Not to mention that the other error metrics used show the same performance levels across the different stocks when the DMD-LSTM model is utilized. Meanwhile when the data normalization is removed, the MAPE scores for BLOOM, ICT, JGS, LTG, and MEG become 0.068108, 0.037207, 0.039754, 0.057332, and 0.044411 units, respectively.

Another observation from the graphs comparing actual and predicted prices over 100 days is that the predicted values appear to be higher than the actual prices. This indicates the possibility of loss because the model overestimates its prediction.

The successive predictions for the following day and up to ten days were tested using the price data from PSEI in order to make the system's predictions more useful for actual utilization. Table 2.8 shows the MAPE scores for the successive predictions of the DMD-LSTM for each days.

Table 2.8: DMD-LSTM Successive Predictions

Successive Days Predicted	Actual and Predicted Data Ratio	MAPE Score
1	100%	0.00973
2	80%	0.13403
3	60%	0.15782
4	40%	0.15646
5	20%	0.13910
6	0%	0.12494
7	-20%	0.11283
8	-40%	0.10014
9	-60%	0.08914
10	-100%	0.08976

From the table above it must be noted that the ratio values highlighted in red is to demonstrate that, despite the fact that negative ratio values shouldn't exist, doing so simply indicates that the data used to forecast the subsequent price data was overlapping by 2 to 5 times, depending on the ratio, and no longer used any actual data.

Moreover, in the integration of the DMD-LSTM model to the alamSYS, the 5 days successive predictions was utilized. Where it is shown from the Table 2.8 that it still performs well, even if the actual and predicted data ratio is only at 20%. This is also to limit the effect of stock market volatility that might affect the accuracy of the successive predictions of the model.

However, it can also be observed that the MAPE scores for successive days with zero to negative actual and predicted data ratio outperforms the MAPE scores from successive days 2 to 5 as illustrated in Figure 2.22, shown below.

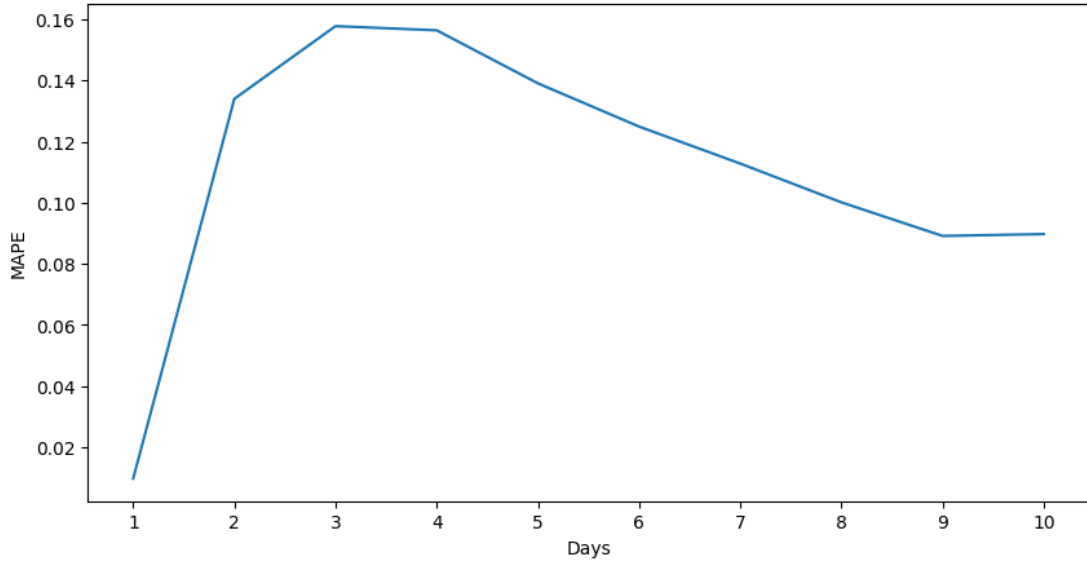


Figure 2.22: MAPE Scores for 1 to 10 (Days) Successive Predictions

Yet, since doing so might result in a poor generalization of data, they were not chosen to be the maximum consecutive days of predictions to be integrated in the alamSYS. As a matter of fact, it could be argued that these data's MAPE scores are overfitted, rendering them unreliable. On the contrary, it might also imply that the model maintains its accuracy for a longer time, even if the majority of the data used are those produced by the model itself. This could be a good thing, and may be attributed to the use of the dynamic modes, as first suggested in the study of Mann and Kutz (2015). In light of these considerations, additional testing is required to establish which of the two claims is true.

Overall, the results from the model training, evaluation, and cross-validation shows that the DMD-LSTM model developed in this special problem performs on par with the other studies that utilizes dynamic modes, as mentioned in Chapter ?? of this paper.

## 2.4 ALMACD Results and Discussions

The ability to predict consecutive days in the stock market is useless without a trading strategy - which allows risk mitigation and increases the probability of

positive returns over time. Trading strategies, in particular, are based on a pre-defined set of rules and criteria that are used to determine when to buy and sell stocks. (Hayes, 2022).

A variety of algorithmic trading, on the other hand, refers to the use of mathematical and computational techniques to determine the best position to take for a specific set of stocks. Additionally, the possibility of loss due to the influence of human emotion is eliminated. (WallStreetMojo, n.d.).

Whereas, the author used the Arnaud Legoux Moving Average Convergence and Divergence (ALMACD) trading strategy in this special problem and integrated it into the alamSYS as the system’s internal trading algorithm. ALAMCD uses predicted prices for the next 5 days, as well as 200 days of actual stock price data, to track the signals and output a simple flag indicating whether to buy or sell that stock at that time.

The compounded expected return after return backtesting is provided for each stock in Table 2.9 using the optimized parameters for the fast and slow ALMA. This was done to validate the potential returns for all stocks, not just the PSEI, from which the best ALMA parameters were derived.

Table 2.9: Optimal Alma Parameters Validation Results

<b>Stock</b>	<b>Compounded Expected Return</b>
<b>PSEI</b>	113966.8500
<b>AC</b>	20893.1914
<b>ALI</b>	1072.1418
<b>AP</b>	690.7100
<b>BDO</b>	2541.9970
<b>BLOOM</b>	495.4600
<b>FGEN</b>	581.0804
<b>GLO</b>	60538.0035
<b>ICT</b>	2815.6103



**Table 2.9 continued from previous page**

<b>Stock</b>	<b>Compounded Expected Return</b>
<b>JGS</b>	1569.8650
<b>LTG</b>	397.2854
<b>MEG</b>	149.2233
<b>MER</b>	8586.0306
<b>MPI</b>	146.0200
<b>PGOLD</b>	721.2700
<b>RLC</b>	649.4767
<b>RRHI</b>	1050.7000
<b>SMC</b>	2557.0770
<b>TEL</b>	72070.5000
<b>URC</b>	3207.5394

Based on the table of expected returns above, all stocks are expected to return a positive yield over time when these optimal ALMA parameters are used. It is also worth noting that the expected return is calculated for each unit of stock, which means that if we use the expected compounded return value of MPI at PHP 146.02, which appears to be the lowest - the actual return could be at least PHP 146,020, assuming the minimum board lot required for the stocks is 1000 shares (Pesobility, n.d.).

However, despite the high potential returns, investors should proceed with caution for two reasons. First, the expected return is based on historical price data, which may not follow the trend of future price data, potentially rendering the trading algorithm obsolete (Quantified Strategies, 2023). Second, the return calculation does not account for and compensate for the additional fees associated with buying and selling the stock, which can affect the overall actual returns. Moreover, the author investigated the potential for returns by following the alam-SYS predictions, as discussed further in the succeeding section.

## 2.5 Results and Discussions for the Real World Application of alamSYS

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Table 2.10: Return Performance Comparison Between alamSYS and PSEI

	Realized Profit (PHP)	Realized Gain (%)
<b>alamSYS</b>	7,839.75	1.51
<b>PSEI</b>	-22,788.90	-13.810

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