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Original Article

Genetic-Based Algorithms Towards Effective Stock Price Prediction: Case Study of Dar es Salaam Stock Exchange

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ABSTRACT

Predicting the movement of stock prices in financial markets has become a challenging task. This is due to the fact that stock prices are dynamic and volatile, exhibiting a stochastic behaviour. Hence, it requires a well-constructed predictive model capable of determining the probable cause of the price of a stock in the future. In an attempt to address the challenge, this study has explored prediction parameters and proposed a Genetic Algorithm (GA) approach. The proposed predictive model is capable of determining future stock price trends. The proposed approach involves identifying patterns using statistical concepts and predicting stock prices. The approach has been deployed and evaluated using the dataset (2014–2018) collected from the Dar es Salaam Stock Exchange (DSE). The evaluation results proved that the proposed Genetic Algorithm (GA) approach achieved a prediction accuracy of 94.86% when used as a natural selection algorithm to find the optimal stock price. Hence, the effectiveness of the proposed algorithm has been confirmed, and this study is a milestone towards the improvement of stock price prediction in the Stock Exchange financial market.

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INTRODUCTION

Financial markets have undergone a remarkable transformation over the past two decades due to advances in information and communication technology. These advancements include faster and cheaper computers, greater connectivity, and, most importantly, sophisticated trading algorithms [1]. Furthermore, most major financial markets in the United States (US), the United Kingdom (UK), Asia, and mainland Europe have embraced computer-generated trading, accounting for approximately 30%, 50%, and, in some cases, nearly 75% of all trades [2]. In any stock market, there are two main methods of analysing stocks: technical and fundamental analysis [3]-[8]. Fundamental analysis focuses on the health determinants of a business, such as earnings, dividend prospects, future interest rates, risk evaluation of the firm, and so on [7], [9]. Technical analysis is essential for identifying and forecasting potential market behaviours, based largely on the actions and dynamics of the market itself. Recently, various algorithms have been proposed to predict stock prices in financial markets [10][11]. Despite the crucial role played by such evolving algorithms. However, finding a suitable algorithm and precise parameters for stock price prediction is still an open research area due to the fact that stock prices are not only dynamic but also volatile, behaving in a stochastic manner [12][13]. Hence, it requires a well-constructed predictive model capable of determining the probable cause of the price of a stock in the future. In an attempt to address the challenge, this study has proposed a Genetic Algorithm (GA) based approach. GA is inspired by the principles of natural selection and evolution, and has emerged as a powerful tool for solving optimisation problems [12]. GAs are adaptive, robust, and capable of exploring large and complex solution spaces, making them well-suited for modelling stock price behaviour [13]. By evolving a population of candidate solutions over successive generations, GAs can optimise predictive models, feature selection, or trading rules in a way that is responsive to changing market conditions.

The proposed Genetic Algorithm-based models for effective stock price prediction, focusing on a case study of the Dar es Salaam Stock Exchange (DSE), in Tanzania. With the growing economic relevance of the DSE, research and application of advanced computational models in this market is inevitable. Thus, the study has developed and evaluated a GA-based prediction framework tailored to the characteristics of the DSE. Therefore, the overall objective of this study is to improve the accuracy of stock price predictions by leveraging the optimisation capabilities of Genetic Algorithms (GA). Specifically, the research seeks to generate new stock price data through GA operators; to develop a predictive model that incorporates GA optimisation features; to simulate the newly generated data using the designed model; and to compare the performance of Genetic Algorithms against traditional Moving Average (MA) methods in forecasting stock prices. In pursuit of these objectives, the study addresses several key research questions, including: What is the most applicable method for generating new stock price data retrieved from the Dar es Salaam Stock Exchange? How does incorporating GA features into model development enhance prediction accuracy? In what way can the simulation of stock price data using GA be effectively achieved? And how do the forecasting performances of GA and MA

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algorithms compare when applied to stock price prediction?

The rest of this paper is organised as follows: Section II will provide the background information, study significance and works related to this study. Next, in Section III, the proposed system will be explained in detail. Then, in Section IV, Methodology, Section V, the evaluation of the proposed approach through experimental results will be shown and discussed in Section VI. Finally, in Section VII, this paper will be concluded, and future work directions will be provided.

BACKGROUND INFORMATION, SIGNIFICANCE AND RELATED WORK

Background Information

Stock market prediction is a critical component of financial analysis, providing investors and policymakers with insights to make informed decisions. Accurate forecasting of stock prices can significantly enhance investment strategies and contribute to market stability. In addition, the Dar es Salaam Stock Exchange (DSE), established in 1996, is the primary securities exchange in Tanzania and plays a pivotal role in the country's financial sector development. Despite its growing importance, the DSE faces unique challenges inherent to emerging markets, including relatively low liquidity, limited availability of timely and comprehensive financial data, and market inefficiencies. Furthermore, these factors increase the complexity of modelling and predicting stock price movements within the exchange. Recently. Traditional forecasting techniques, such as moving averages and autoregressive models, have shown limitations in capturing the nonlinear, dynamic, and often volatile behaviour of stock prices at the DSE.

Study Significance

There is a growing interest in leveraging advanced computational techniques to enhance forecasting accuracy. Among these, Genetic Algorithms (GA) have demonstrated significant potential due to their adaptive nature, robustness, and computational efficiency. GAs are particularly valuable in environments characterised by uncertainty and constant change, as they require less structured data and offer faster convergence compared to many traditional optimisation methods. These attributes make GAs especially suitable for solving dynamic, stochastic, and complex problems such as stock market analysis, weather prediction, and other optimisation challenges. By integrating GA into stock price forecasting models, researchers aim to address the limitations of conventional methods and develop more reliable and adaptive predictive systems tailored to markets like the DSE.

Related Work

Recent studies have explored the application of computational intelligence techniques for stock market prediction, particularly focusing on enhancing accuracy and adaptability in volatile market conditions. Genetic Algorithms (GAs), inspired by the principles of natural selection and evolution, have emerged as powerful optimisation tools in financial forecasting due to their ability to efficiently search large, complex solution spaces.

The study conducted by Burak Gulmez (2015) [14] demonstrated the potential of hybrid models combining Genetic Algorithms with neuro-fuzzy systems for stock price prediction, highlighting GA's role in optimising feature selection and network parameters. Similarly, Kyung et al. (2013) [15] explored rule-based prediction models where GAs evolved decision rules for stock movement prediction, achieving promising results in terms of adaptability and interpretability. Unlike Burak and Kyung, this study has deployed GA in real market environments at the Dar es Salaam Stock Exchange (DSE).

More recent studies, such as Xiaoning et al. (2022) [16], have examined the integration of Genetic Algorithms with machine learning models like Support Vector Machines (SVMs), showing that GA-based feature selection improves prediction

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accuracy in diverse financial markets. These hybrid systems are often compared with traditional statistical models, consistently outperforming them in non-linear and dynamic market environments. Besides the comparison analysis, this study has done further exploration to find precise parameters for stock price prediction.

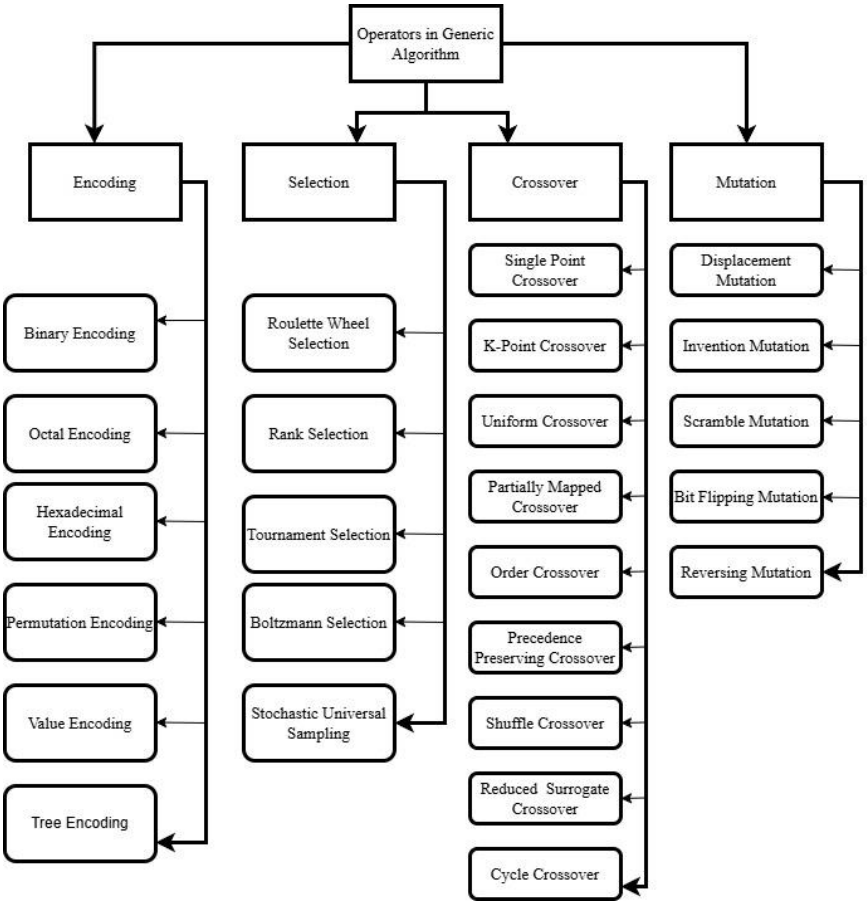
In the current literature, [17],[18] have shown that GAs can effectively manage the unique challenges posed by limited historical data, lower liquidity, and high market inefficiency. However, there is limited literature [19] focusing on the exploration of appropriate parameters for stock price prediction on GAs. Hence, this highlights a significant research gap.

Therefore, unlike previously mentioned approaches, this study seeks to address the above-mentioned research gap and apply Genetic Algorithms to predict stock prices in real market environments. In this regard, DSE, which is a relatively under-researched yet increasingly important financial market in East Africa. The proposed approach builds on existing methodologies while tailoring them to the structural and informational characteristics of the DSE, thus contributing both theoretically and practically to the domain of financial prediction in emerging markets.

PROPOSED GENETIC ALGORITHM APPROACH

The proposed predictive model was designed, and its architecture was used to simulate data from the DSE repository. Figure 1 shows the proposed GA predictive Model.

Figure 1: The Proposed GA Predictive Model



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COMPONENTS OF THE PROPOSED MODEL

The proposed Genetic Algorithm (GA)-based predictive model for stock price forecasting at the Dar es Salaam Stock Exchange (DSE) integrates several key components to process and analyse historical stock data effectively. The model's architecture encompasses data acquisition, feature extraction, and the application of GA operators, culminating in a fitness evaluation mechanism.

Components

Data Acquisition (ETL Process): Extraction: Historical stock data for companies listed on the DSE, spanning from 2014 to 2018, is collected. This data includes variables such as opening and closing prices, daily highs and lows, and trading volumes.

Transformation: The data undergoes pre-processing steps, including data cleaning and normalisation using Min-Max scaling, to prepare it for analysis.

Loading: The processed data is organised into structured formats for further analysis.

Feature Extraction: Technical indicators, such as Moving Averages (MA) and Relative Strength Index (RSI), are computed to enrich the feature set, providing additional insights into market trends.

Genetic Algorithm Operators

Selection (Roulette Wheel Selection): This method probabilistically selects individuals for reproduction based on their fitness scores. The selection process is akin to a roulette wheel, where each individual occupies a segment proportional to its fitness, allowing for a diverse gene pool.

Crossover (Uniform Crossover) In this operator, genes from two parent solutions are combined to produce offspring. Each gene is randomly selected from one of the two parents, promoting genetic diversity and the exploration of new solutions.

Mutation (Flip Mutation): A small probability is assigned to randomly flipping bits in the chromosome, introducing small variations that help maintain genetic diversity and prevent premature convergence.slideshare.net+21library.net+2sciencedirect.com+2algotradinglib.com+2appliedaicourse.com+2en.wikipedia.org+2

Fitness Evaluation: The fitness of each individual is assessed using the Mean Squared Error (MSE) between the predicted and actual closing prices. A lower MSE indicates a better fit, guiding the evolutionary process toward more accurate predictions. In this study, the Mean Squared Error (MSE) was selected as the fitness function to evaluate and guide the optimisation process of the Genetic Algorithm (GA) model. MSE measures the average squared difference between predicted and actual stock prices, making it highly sensitive to large prediction errors. This characteristic is particularly valuable in financial forecasting, where even small deviations can result in significant investment consequences. Compared to alternative metrics such as Mean Absolute Error (MAE) or Root Mean Squared Error (RMSE), MSE offers a smoother and differentiable loss surface, which is beneficial for convergence in optimisation algorithms. Additionally, MSE penalises larger errors more heavily, aligning with the study's objective of achieving high precision in stock price forecasting. Its computational simplicity and widespread use in regression-based prediction models further support its suitability as a robust and interpretable fitness function for GA-based optimisation in the context of the Dar es Salaam Stock Exchange (DSE).

This GA-based model iteratively evolves a population of candidate solutions, optimising the parameters of the stock price prediction model. The evolutionary process continues until convergence criteria are met, such as a fixed number of generations or a satisfactory fitness level. The final optimised model is then evaluated on a reserved portion of the dataset to assess its predictive

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performance. By leveraging the principles of natural selection and evolution, this model aims to enhance the accuracy and robustness of stock price predictions in the dynamic environment of the DSE.

PARAMETER ESTIMATIONS AND FEATURES EXTRACTIONS

Genetic Algorithms Operator

Selection (Roulette Selection), Segments allocated relative fitness score

Crossover (uniform crossover) a

gabin_uCrossover ().

Mutation (flip mutation).

gabin_raMutation ().

Fitness evaluation

Closing price < = Opening price

METHODOLOGY

In this study, the process is designed from the prediction concept of an empirical study of machine learning algorithms for a daily stock trading strategy. Furthermore, historical stock data for selected companies listed on the DSE, covering five years, was collected from official financial sources. The data included variables such as opening and closing prices, daily highs and lows, and trading volumes. Pre-processing steps involved data cleaning, normalising numerical data using Min-Max scaling, and generating relevant technical indicators such as Moving Average (MA) and Relative Strength Index (RSI) to enrich the feature set. Moving Average (MA) and the Relative Strength Index (RSI) were chosen due to their widespread use and proven effectiveness in time series forecasting and financial analysis. The Moving Average smooths out price fluctuations by averaging stock prices over a specified time window, helping to identify underlying trends and reducing noise in the data. On the other hand, the RSI measures the speed and change of price movements, providing insights into potential overbought or oversold conditions in the market. These indicators were integrated into the feature set alongside normalised numerical data using Min-Max scaling, which ensured that all features contributed equally to the model's learning process. A genetic algorithm was then designed to optimise the selected parameters, which are binary encoding, roulette wheel selection, uniform crossover and bit flipping mutation of a prediction model where each chromosome represented a potential configuration of model parameters. An initial population of potential solutions was generated randomly and evolved over successive generations through selection, crossover, and mutation operations; refer to Figure 2.

The fitness of each chromosome was evaluated using Mean Squared Error (MSE) as the objective function, with elitism applied to retain the best solutions. The training process continued until convergence criteria were met, such as a fixed number of generations or a threshold improvement in fitness. The optimised model was then tested on a reserved portion of the dataset, and its predictive performance was evaluated. Finally, the results were compared to those of traditional machine learning models to assess the effectiveness of the genetic algorithm approach in forecasting stock prices within the context of the DSE.

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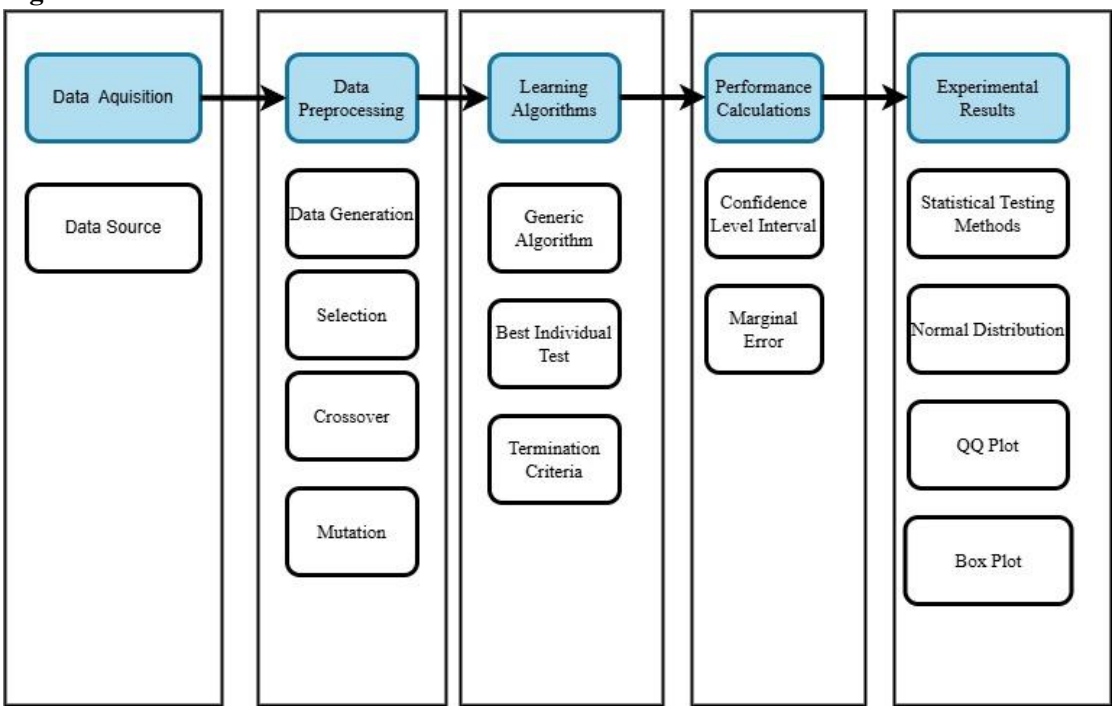
Figure 2: Framework for the Prediction Process



EVALUATION OF THE PROPOSED APPROACH

In order to evaluate the effectiveness of the proposed method, the daily market report data were downloaded from the official website of the Dar es Salaam Stock Exchange (DSE) for five years from 2014 to 2018. Moreover, the Central Depository System (CDS) of the Dar es Salaam Stock Exchange (DSE) acts as a securities bank, holding various deposited securities to facilitate trade settlements on the exchange. Data was obtained from the following listed companies: NMB Bank, Swala Energy Tanzania, Tanzania Oxygen Limited (TOL), Swissport, Tanzania Cigarette Company (TCC), and Tanzania Portland Cement Company (Twiga).

Moreover, Microsoft Power Query for Excel is used as an efficient tool for removing, updating, inserting, deleting, and merging data, as well as organising and manipulating information for analysis. It also allows users to save data in relevant formats such as CSV and XLS. In addition, Microsoft Visio 2013, along with the Gane-Sarson flow diagram sub-tool, was used for modelling, designing, and planning.

The data types used are financial, including open price, closing price, high price, low price, volume, open interest, bid price, and others.

Simulation

In order to demonstrate the performance of the Genetic Algorithms in the process of improving predictions of stock price in a financial market, a predictive model is designed to integrate the proposed algorithms. The Predictive Model is designed and the architecture is then used to simulate data from the DSE repository.

a) Components

Data acquisition process (ETL),

DSE.txt <- read.table (“File directory”, header =TRUE, “\t”).

ClosingPrice.txt <- data.frame (DSE.txt$ClosingPrice)

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OpeningPrice.txt <- data.frame (DSE.txt$ClosingPrice)

Parameter Estimations and Features Extractions:

Genetic Algorithms operator

Selection (Roulette Selection), Segments allocated relative fitness score

Crossover (uniform crossover) a gabin_uCrossover ().

Mutation (flip mutation). gabin_raMutation ( ).

Fitness evaluation Closing price <= Opening price

Source Code

The R computing tool is used to develop source code with the library Genetic Algorithms in R. The package is used in this research due to its flexible computing, a general-purpose toolbox to implement GA optimisation problems and the binary representation of the data. The source code for the analysis with both algorithms is available on my GitHub account.

Summary (GA)

GA settings:

Type = binary

Population size = 1085

Number of generations = 200

Elitism = 54

Crossover probability = 0.8

Mutation probability = 0.1

GA results

Iterations = 200

Fitness function value = 1

Solutions = NMB.Closing. Price.TZS.

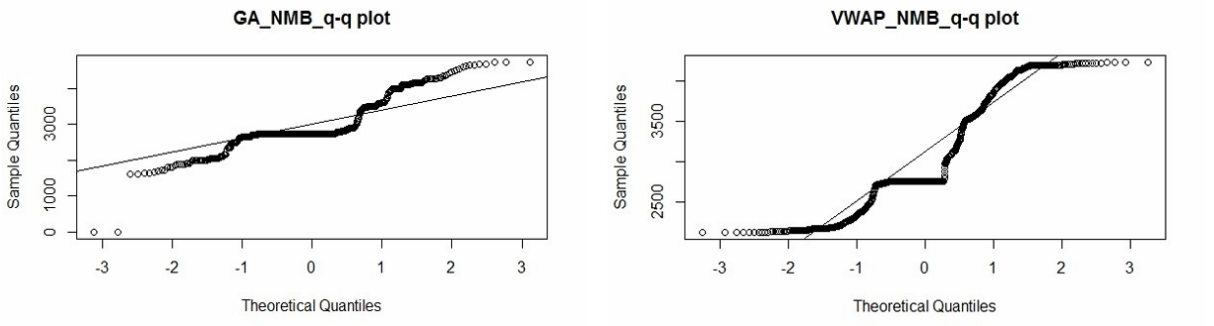
[1,] 0

[2,] 1

Simulation Results

Statistical representations by box plot, qq histogram and normal distribution graph are used to describe the results of companies' data. An example of the simulation results for one company, NMB shown in Figure 3 below. The graphical interpretations obtained from the simulation of data with descriptive statistics play a huge part in the final analysis, the qq plot, probability density and histograms. The graphs below are one example of data analysed from for company NMB. The qq plot test normality of the data and the integrity of the data, and validates the data if it comes from the same source.

Figure 3: Data Distribution for NMB for Testing the Normality of the Data with qq Plot



The histogram and overlaying density plot below determine the skewness of the data. The skewness in the stock price data describes the market reflections.

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RESULTS

Following the simulation of the algorithm, the two aspects of descriptive statistics are used to analyse the results of Genetic Algorithms (GA) and the Volume Weighted Moving Average (VWAP). The confidence interval and the measures of variability. These two tables have information which compares the performance of the two algorithms:

a) Confidence Interval Analysis

b) Measure of variability

Table 1: Comparative Analysis of Forecast Intervals for Selected Companies Using Genetic Algorithms (GA) and Volume Weighted Average Price (VWAP)

No.	Company	Method	Lower Limit	Higher Limit	Diff	% Interval
1.	NMB	GA	3433.559	3619.541	185.982	94.86
		VWAP	3299.278	3522.222	222.944	93.67
2.	SWALA ENERGY	GA	3419.884	3617.816	197.932	94.53
		VWAP	3299.278	3522.222	222.944	93.67
3.	SWISS PORT	GA	3696.917	4025.783	328.866	91.83
		VWAP	3852.664	4181.261	328.597	92.14
4.	TCC	GA	3245.823	3447.477	201.654	94.15
		VWAP	1784.262	2224.838	440.576	80.20
5.	TOL	GA	3602.447	4264.653	662.206	84.47
		VWAP	1784.262	2224.838	440.576	80.20
6.	TPCC	GA	3245.823	3447.477	201.654	94.15
		VWAP	3220.724	4257.076	1036.352	75.66
		Volume Weighted Average Price (VWAP)				73.65
		Genetic Algorithms (GA)				**92.33**
		Relative err				5.63

a) Confidence Interval Analysis

Table 1 presents the lower and higher forecast limits, interval differences, and percentage intervals for six companies using two forecasting methods: Genetic Algorithms (GA) and Volume Weighted Average Price (VWAP). The average percentage intervals are 92.33% for GA and 73.65% for VWAP, with a relative error of 5.63%.

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Table 2: Statistical Comparison of Forecast Interval Variability Using Genetic Algorithms (GA) and Volume Weighted Average Price (VWAP)

Measure of variability					
GENETIC ALGORITHMS (GA)			**VOLUME WEIGHTED AVERAGE PRICE (VWAP)**		
% Interval	% Interval-mean	(% Interval-mean)^2	% Interval	(% Interval-mean)	(% Interval-mean)^2
94.86	2.5283	6.39	93.67	7.75	60.011
94.53	2.1983	4.83	93.67	7.75	60.011
91.83	-0.5017	0.25	92.14	6.22	38.647
94.15	1.8183	3.31	80.2	-5.72	32.757
84.47	-7.8617	61.81	80.2	-5.72	32.757
94.15	1.8183	3.31	75.66	-10.26	105.336

Result					
Sum	0.00	79.90	Sum	0.00	329.52
Mean		92.33	Mean		85.92
Variance		15.98	Variance		65.90
Standard deviation		3.997	Standard deviation		8.118

Table 2 illustrates the variability of percentage forecast intervals for the GA and VWAP methods across six companies. It includes deviation from the mean and squared deviations, leading to calculated variance and standard deviation. GA shows lower variability (SD = 3.997, Variance = 15.98) compared to VWAP (SD = 8.118, Variance = 65.90), indicating greater consistency in GA's forecast intervals.

RESULTS AND DISCUSSION

The study aimed to address the challenges of the dynamic and volatile nature of financial markets by using a Genetic Algorithm (GA)-based approach to predict stock prices on the Dar es Salaam Stock Exchange (DSE). GA's optimisation capabilities enabled the model to achieve a detection accuracy of **92.33%,** outperforming traditional methods like VWAP, which had an accuracy of **73.65%.**

By integrating GA with statistical techniques, effective feature selection and parameter tuning were achieved, which increased the model's adaptability to market fluctuations. The study's focus on the DSE is noteworthy because it adds to the limited literature on financial forecasting in emerging markets. The application of advanced computational models in regions with unique market characteristics can provide valuable insights provided by this context.

While the findings of this study demonstrate the potential of Genetic Algorithms (GA) in forecasting stock prices on the Dar es Salaam Stock Exchange (DSE), several limitations must be acknowledged. First, the dataset used in this research includes a limited number of listed companies and covers a relatively narrow time frame, which may not fully capture the diverse market dynamics or account for long-term patterns. This constraint introduces potential bias and limits the generalizability of the results to broader or more volatile financial environments. Additionally, although GA proved effective in optimising model parameters and achieving competitive accuracy, the study did not include a comprehensive comparison with advanced machine learning models such as Long Short-Term Memory networks (LSTMs) or Gated Recurrent

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Units (GRUs), which are known for their strong performance in time series forecasting. Without such comparisons, it is difficult to conclusively position GA's relative advantages or disadvantages in stock price prediction tasks.

To address these limitations, future work should aim to expand the dataset by incorporating a broader selection of companies, a longer historical time period, and higher-frequency data where available. Moreover, a comparative analysis between GA-based models and deep learning approaches like LSTMs and GRUs should be conducted using consistent evaluation metrics (e.g., MSE, RMSE, MAE) to provide a more robust assessment of model performance. Incorporating additional technical indicators and macroeconomic variables could also enrich the feature set and improve forecasting accuracy. Finally, deploying the model in a real-time prediction environment with continuous updates and retraining mechanisms would enhance its practical applicability in decision-making for investors and financial analysts operating in emerging markets like Tanzania.

CONCLUSION AND FUTURE WORKS RECOMMENDATIONS

Conclusion

The effectiveness of Genetic Algorithms (GAs) in predicting stock prices at the Dar es Salaam Stock Exchange (DSE) is demonstrated in this study. The GA-based model, which used historical market data, achieved an impressive detection accuracy of 92.33%, which was better than traditional methods like the Volume Weighted Average Price (VWAP), which had an accuracy of only 73.65%. Effortlessly navigating the complexities of the DSE's market dynamics is possible due to the GA's adaptive nature, which makes it robust. The findings demonstrate the value of GAs in improving predictive accuracy in emerging markets, providing valuable insights for investors and analysts. In addition, implementing regular updates involves routinely refreshing the model with the latest market data to maintain its predictive accuracy and adapt to changing market dynamics. This would be achieved by scheduling automated data collection from the Dar es Salaam Stock Exchange (DSE) at predefined intervals—such as daily or weekly—depending on the frequency of trading activity and the use case. Once new data is retrieved, it undergoes the same pre-processing pipeline, including data cleaning, normalisation using Min-Max scaling, and recalculation of technical indicators like Moving Average (MA) and Relative Strength Index (RSI). The Genetic Algorithm model is then retrained or fine-tuned using the updated dataset to ensure that the evolved parameters remain relevant. To streamline this process, task automation tools such as cron jobs, Python scripts with scheduled execution and version-controlled retraining pipelines can be deployed. Additionally, model performance metrics (e.g., MSE) are monitored after each update to evaluate whether retraining has improved forecasting accuracy, allowing for dynamic model management based on performance thresholds.

Recommendations/Future Works

Combining GAs with other machine learning techniques, including Long Short-Term Memory (LSTM) networks, could be explored when integrating with hybrid models to improve prediction accuracy and adaptability.

Practical insights into the GA-based model's performance and reliability during live market conditions could be gained by implementing it in real-time trading scenarios.

The understanding of market psychology can be enhanced by integrating social media sentiment analysis with GA models, resulting in more accurate predictions.

Expanding to other emerging markets can help validate the GA-based model's generalizability and effectiveness across different financial environments.

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The GA model's sustained accuracy and relevance will be assured through regular updates and refinements, which incorporate new market data and evolving trading patterns.

By implementing these recommendations, stakeholders can use GA-based models to make more informed and strategic investment decisions in the DSE and beyond.

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