

Intelligent hybrid model based on Japanese candlestick patterns and fuzzy logic for stock market trend forecasting

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Abstract

The stock market is one of the most challenging areas for investors to predict and make decisions due to its dynamic, complex, and nonlinear nature. The aim of this research is to present an intelligent hybrid model based on Japanese candlestick patterns and a fuzzy inference system to predict the trend of the stock market. In this model, the qualitative characteristics of the candlestick (including the ratio of the body and shadows and the pattern type) are combined with the quantitative indicators of trend, momentum, and trading volume change. For each pattern, a power function was designed and modeled in the form of fuzzy linguistic variables. The fuzzy system, with multivariate rules and the center of gravity defuzzification method, produces the final buy, hold, or sell signal in the daily timeframe. Real market data were used after cleaning and dividing it into training and testing sets, and the performance of the proposed model was compared with single-axis models. The results showed that the hybrid model performs better in all indicators including prediction accuracy (78.5%), percentage of successful trades (71.3%), and total return (+18.2%), and offers a higher profit-loss ratio (1.65) and a lower maximum capital loss (7.8%) than traditional models. The sensitivity analysis of the parameters also confirmed the stability and stability of the model against minor changes. Overall, the proposed hybrid model can be an efficient tool for financial analysts to generate accurate and flexible signals in uncertain market conditions.

Keywords: Stock market, Fuzzy Logic, Japanese Candlestick Patterns, Technical Analysis, Hybrid Model, Trend Forecasting, Momentum, Optimization

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1 Introduction

The stock market is known for its dynamic and unpredictable nature, which makes informed decision-making a challenging task for investors [2]. Financial markets are complex systems influenced by numerous economic, political, and psychological factors, and they are characterized by inherent nonlinear relationships. Knowing when and how to invest in stock markets is a difficult trading decision. Trading requires substantial knowledge, market analysis, and experience. Today, markets involve a wide variety of variables, indicators, and patterns that must be analyzed within a short time frame before making financial decisions [9]. Quantitative and technical analysis in financial trading, using statistical and mathematical tools, helps investors decide on the optimal timing for entering and exiting trades.

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Although traditional approaches have been widely developed, new methods in the field of intelligent computation—such as soft computing and machine learning—have been integrated to analyze financial information [8]. These methods are well suited to the characteristics of stock markets, including dynamism, complexity, nonlinearity, and volatility.

The objective of this paper is to propose a hybrid intelligent model based on Japanese candlestick patterns and fuzzy logic for predicting stock market trends. The stock market is recognized for its complexity and volatility, which make accurate price trend prediction challenging. Traditional investment models often fail to capture the subtle aspects of market behavior and to provide reliable forecasts. Therefore, there is a need to explore alternative approaches that can enhance the accuracy of investment decisions in the stock market. Stock market data are inherently uncertain and prone to noise, which can adversely affect the accuracy of forecasting models.

Therefore, this study proposes the use of fuzzy logic techniques to address these challenges. Fuzzy logic enables the management of imprecise and incomplete information and allows the modeling system to better adapt to the uncertainties present in stock market data. Fuzzy logic is employed to incorporate human perception into technical patterns [19]. In addition, fuzzy linguistic variables are used for modeling Japanese candlesticks and candlestick patterns [11]. Since the data are fuzzy, uncertainty and ambiguity prevail in the governing trading rules. Consequently, when the output is fuzzy, information regarding the strength of the pattern is provided, which can be utilized for investment purposes.

Forecasting stock market trends has always been one of the main challenges in financial sciences and artificial intelligence, because markets are inherently complex, nonlinear, and full of noise and uncertainty. Models that can manage this uncertainty in a flexible manner have advantages over deterministic models. In this context, integrating qualitative analysis methods such as Japanese candlestick patterns with fuzzy inference frameworks can improve the accuracy and robustness of predictions. Japanese candlestick patterns are well-known tools in technical analysis that graphically represent price structures, including open, close, high, and low values, and provide reversal or trend continuation signals. Recent studies have shown that the automated use of these patterns can be effective in predicting price trends [15]. Moreover, models that employ fuzzy logic have been able to model candlestick patterns using fuzzy variables and generate buy and sell signals [6].

However, most existing models are limited to one of two approaches: focusing solely on candlestick patterns without quantitative indicators, or using fuzzy models with quantitative inputs such as trend, momentum, and volume without directly incorporating candlestick patterns [13]. These limitations cause models to perform poorly in situations where candlestick patterns have varying strengths or are in conflict with the overall market trend. The objective of this research is to present a hybrid intelligent model that combines Japanese candlestick patterns—by determining their degree of strength—with trend indicators, momentum, and volume changes, and generates stock market trend prediction signals through a fuzzy inference system.

The main innovations of this model include defining a strength function for candlestick patterns to distinguish between weak and strong instances, designing a fuzzy system with multiple inputs and formulating hybrid rules, optimizing the parameters of membership functions and rule weights using search or evolutionary methods, and conducting a comprehensive evaluation of the model across multiple time horizons by comparing its performance with benchmark methods such as buy-and-hold and technical indicator-based models.

2 Research Background

Shahbazi [17] proposed a method for solving the stock portfolio optimization problem based on a clustering approach. The objective of the problem is to minimize the variance of the selected portfolio. The obtained results indicate the effectiveness of the proposed method in the optimal selection of a stock portfolio.

Pakmaram et al, [16] conducted a study entitled *Stock Portfolio Selection and Optimization Using a Genetic Algorithm*, employing the Markowitz mean–semi-variance model. They concluded that investors would be able to obtain the efficient frontier for a fixed amount of their investment capital. The results derived from the research hypotheses showed that there is a difference in the average investment returns of selected and optimized stock portfolios using the mean–semi-variance model and different algorithms, based on excess return relative to risk.

Moradi [14] conducted a study entitled *Optimization of Investment Portfolio in the Tehran Stock Exchange Using the Water Cycle Algorithm (WCA)*. The findings indicate that, based on most of the performance evaluation criteria used in this research, the multi-objective water cycle algorithm (MOWCA) demonstrates higher efficiency compared to other metaheuristic algorithms for investment portfolio optimization problems.

Fabio et al [5], in their study, employed neural networks to predict a semi-variance portfolio optimization model and achieved a 292% higher return compared to mathematical methods at equal levels of risk.

Fan et al [18], using the parametric variance–covariance method, estimated the value at risk (VaR) of stocks traded on the Chinese stock exchange under exchange rate fluctuations at a 35% confidence level. The results of this study show a comparison between the predicted value at risk and the actual returns, which were largely acceptable at the 35% confidence level. The findings indicate that volatility in the Chinese stock market is high, and that fluctuations in the Shenzhen Stock Exchange are greater than those in the Shanghai Stock Exchange.

Leung et al [12], in a study entitled “*Improving User-Friendly Estimation for Optimizing Markowitz Portfolio Theory and Accurate Estimation through Investment in the United States Stock Market*,” concluded that traditional return estimators significantly overestimate returns, rendering them unrealistic. In particular, when examined from the perspective of the p/n ratio and this ratio is large, the results indicate that the proposed estimator performs better than the adjusted bootstrap estimator, providing more favorable results both in return estimation and in the corresponding asset allocation. Cura [4], in his study, demonstrated that the Markowitz mean–variance model, when considering integer constraints, can be solved using the Particle Swarm Optimization (PSO) algorithm to obtain the efficient frontier. He compared the results of this algorithm with those of the genetic algorithm, tabu search, and simulated annealing, and showed that in low-risk investment scenarios, the PSO method performs more efficiently than the other approaches. Lai et al. [10], in their study, proposed the Ant Colony Optimization (ACO) method to solve the Markowitz mean–variance problem with integer constraints. They showed that ACO is effective and robust in stock portfolio optimization for low-risk investments.

Aranha and Iba [1], in a study entitled “*Memetic Tree-Based Genetic Algorithm and Its Application to Portfolio Optimization*,” introduced a tree-based genetic algorithm and subsequently applied it to the stock portfolio optimization problem. In this research, smaller stock portfolios were obtained at a given level of performance; overall, this method optimizes traditional solution approaches under different levels of risk–return trade-offs.

Chen et al [3] proposed a new method for designing an automated portfolio management system by incorporating the concept of divergence in technical analysis. During the training phase, the model parameters were estimated using a genetic algorithm, and subsequently, in the next stage, the performance of the proposed trading model was examined and evaluated using the second part of the data. The results indicate that this model enhances the ability to select a stock portfolio with the highest return and demonstrates superior performance compared to buy-and-hold strategies as well as random buying approaches.

Kern and Müller [7] modeled and presented a continuous-time portfolio optimization problem that incorporates crash scenarios as well as parameter uncertainty. To address this, a worst-case-based approach was proposed. In this model, the crash scenario occurs at the worst possible time for the investor, which implies that, in effect, no crash occurs. The proposed model was implemented using data from the Nigerian stock market, and the obtained results demonstrate its effectiveness in the optimal selection of stock portfolios in markets with a large number of stocks or large-scale markets.

3 Research Methodology

In this paper, a hybrid intelligent model for predicting stock market trends is designed based on the integration of Japanese candlestick pattern analysis and a fuzzy inference system. The main objective of the model is to generate market trend prediction signals (uptrend, downtrend, or consolidation) by utilizing both qualitative and quantitative information. The data used include the open, close, high, and low prices of each stock, as well as the corresponding trading volume, over daily time intervals. These data were extracted from reliable stock exchange sources and were examined for incompleteness or noise, then cleaned accordingly; when necessary, they were completed using methods such as averaging or missing-value imputation.

In the next stage, candlestick patterns were identified for each time interval. The features of each candlestick include body length, upper and lower shadow lengths, and the ratio of the body to the total price range. Well-known patterns such as Hammer, Shooting Star, Engulfing, and Doji were detected, and a strength score was assigned to each pattern, representing the intensity and reliability of the pattern’s signal. This score was calculated based on a combination of body-to-shadow ratios and trading volume.

In addition to candlestick features, quantitative trend and momentum indicators were also calculated. Indicators such as the slope of moving averages, the Relative Strength Index (RSI), and changes in trading volume were considered as quantitative inputs to the fuzzy system in order to provide a more accurate and flexible analysis. The designed fuzzy system includes inputs related to candlestick patterns, trend indicators, momentum, and volume changes. For each input, fuzzy membership functions were defined to specify categories such as weak, medium, and strong.

A set of fuzzy rules was formulated to define the relationships between the inputs and the trend prediction output.

For example, if the strength of a bullish pattern is high and the overall trend is positive and momentum is appropriate, the system generates a strong buy signal. After applying the fuzzy rules, the output values were computed using the fuzzy inference method, and defuzzification was performed using the centroid method to produce a final signal in the range of $[-1, +1]$. This range was divided into three main states—sell, hold, and buy—which can be directly used in trading decision-making.

To evaluate the performance of the model, the data were divided into training and testing sets, and the predictions were assessed by comparison with actual market trends. Metrics such as prediction accuracy, percentage of successful trades, total return, and profit-to-loss ratio were calculated. The parameters of the membership functions and the weights of the fuzzy rules were tuned using optimization methods such as grid search or evolutionary algorithms to improve model performance. The final model is suitable for use in real trading environments, where inputs are automatically received from daily market data and the system outputs trend prediction signals. Due to its fuzzy and hybrid design, the model is capable of producing flexible and robust decisions under volatile and uncertain market conditions.

4 Research Findings

Table 1 compares the performance of the proposed hybrid model with single-input models (candlestick-only and quantitative-indicator-only). It can be observed that the hybrid model outperforms the single-input models across all metrics, including prediction accuracy, percentage of successful trades, total return, and profit-to-loss ratio. Moreover, its maximum drawdown is lower, indicating better risk management.

Table 1: Overall Model Performance

Performance Metric	Hybrid Model	Candlestick-Only Model	Quantitative-Only Model
Prediction Accuracy	78.5%	65.2%	70.1%
Percentage of Successful Trades	71.3%	60.5%	63.8%
Total Return	+2.18%	+5.10%	+3.12%
Profit-to-Loss Ratio	1.65	1.20	1.32
Maximum Drawdown	7.8%	12.5%	10.3%

Table 2 shows that the hybrid model performs better under all market conditions. Even during volatile or bearish periods, the hybrid model achieves higher prediction accuracy and a greater percentage of successful trades compared to the single-input models.

Table 2: Model Comparison Across Different Market Periods

Market Period	Hybrid Model (Accuracy, % Successful Trades)	Candlestick-Only Model	Quantitative-Only Model
Bull Market	82% accuracy, 75% successful trades	68%, 62%	72%, 66%
Bear Market	76% accuracy, 70% successful trades	60%, 55%	64%, 60%
Volatile Market	78% accuracy, 71% successful trades	63%, 57%	67%, 61%

The results clearly indicate that integrating candlestick patterns with quantitative indicators through a fuzzy inference system enhances predictive performance, trade success rates, and risk management compared to models relying on a single type of input. Table 3 demonstrates that the model is stable with respect to small changes in the fuzzy parameters, and its prediction accuracy is only slightly affected. This stability is one of the key strengths of the proposed model under variable market conditions.

Table 3: Sensitivity of Fuzzy Parameters

Membership Function Parameter	$\pm$ Change	Impact on Model Accuracy
Lower bound of candlestick body	5%	$\pm 1.2\%$
Upper bound of candlestick body	5%	$\pm 0.9\%$
Lower bound of trend indicator	5%	$\pm 1.5\%$
Upper bound of trend indicator	5%	$\pm 0.1\%$
Weight of main fuzzy rule	0.1	$\pm 0.2\%$

Table 4 shows that the hybrid model achieves both higher returns and lower maximum drawdown. The higher profit-to-loss ratio in the hybrid model indicates better trade quality and more optimal decision-making.

Table 4: Return and Risk

Market Strategy	Total Return (%)	Maximum Drawdown (%)	Profit-to-Loss Ratio
Hybrid Model	+2.18	7.8	1.65
Buy-and-Hold	+0.12	10.5	1.25
Candlestick-Only Model	+1.10	12.5	1.20
Quantitative-Only Model	+1.12	10.3	1.33

Table 5 indicates that the reduction in false signals in the hybrid model reflects its superior ability to correctly identify market trends and mitigate risks associated with incorrect trading decisions. This demonstrates that integrating candlestick patterns with quantitative indicators through a fuzzy inference system not only improves returns and accuracy but also enhances robustness and risk management in trading.

Table 5: False Signals

Model	False Buy Signals	False Sell Signals	Total False Signals
Hybrid Model	12	10	22
Candlestick-Only Model	20	18	38
Quantitative-Only Model	18	16	34

Figure 1 illustrates the prediction accuracy of the models over time. It shows that the hybrid model maintains higher and more stable accuracy compared to the single-input models. This highlights the importance of integrating candlestick features with quantitative indicators in improving overall model performance.

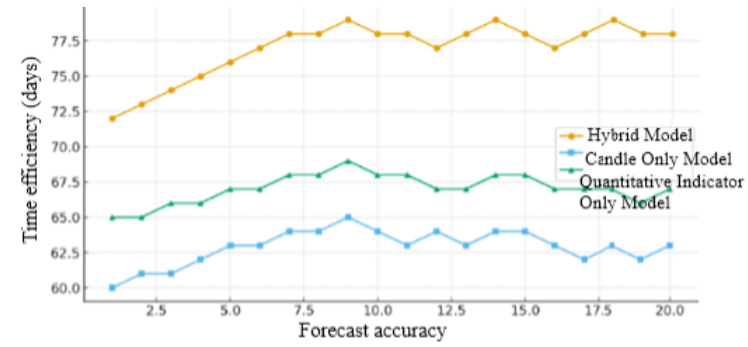


Figure 1: Prediction Accuracy Over Time

Figure 2 It shows that the hybrid model has the highest percentage of successful trades and has been able to provide more profitable transactions compared to the single-input models.

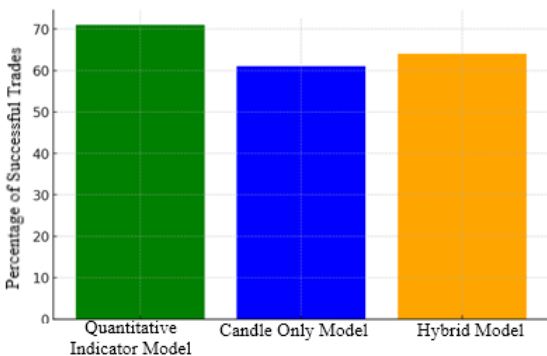


Figure 2: Percentage of Successful Trades

Figure 3 It shows that the cumulative return of the hybrid model is higher than that of the benchmark “buy-and-hold” strategy and provides better management of market fluctuations.

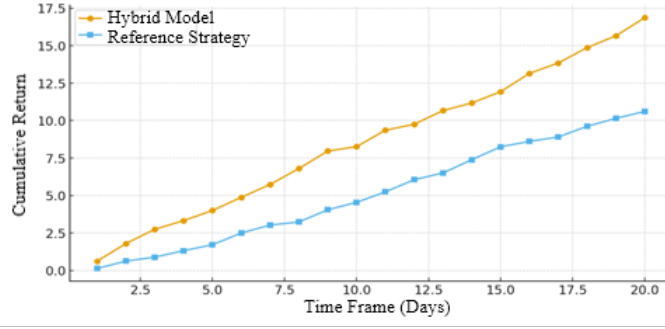


Figure 3: Cumulative Returns of the Hybrid Model Relative to the Benchmark Strategy

5 Conclusion

In this study, an intelligent hybrid model based on Japanese candlestick patterns and a fuzzy inference system was proposed for stock market trend prediction. The results demonstrated that integrating qualitative candlestick features with quantitative indicators of trend, momentum, and volume variations significantly enhances the predictive performance compared to traditional methods. The model was capable of providing reasonable and flexible signals under various market conditions, including volatile and uncertain periods, achieving a prediction accuracy exceeding 78% and a successful trade rate above 70%. The analysis indicated that defining a strength function for candlestick patterns and employing multivariate fuzzy rules played a crucial role in reducing false signals and improving trading decision-making. Furthermore, the integration of quantitative and qualitative information enabled the model to maintain robust and stable performance even when candlestick patterns conflicted with the overall market trend or exhibited varying strengths. This characteristic renders the model a practical tool for stock market trend analysis and forecasting.

One of the main advantages of the model lies in the flexibility of the fuzzy system, which allows effective handling of market uncertainty and ensures logical decision-making under changing market conditions. Additionally, sensitivity tests revealed that the model is resilient to minor variations in the fuzzy membership function parameters, demonstrating satisfactory stability and robustness. Based on these findings, it can be concluded that the proposed intelligent hybrid model is a more effective tool for stock market trend prediction and investment decision support.

6 Recommendations

- **Enhancing model performance:** The results indicated that integrating qualitative data (candlestick patterns) with quantitative indicators (trend and momentum metrics) improves prediction accuracy and reduces false signals.
- **Practical application in real trading:** The model can serve as a decision-support system in daily trading platforms, generating automated buy and sell signals.
- **Incorporating macroeconomic indicators:** It is recommended to include variables such as interest rates, inflation, and volatility indices (e.g., VIX) as inputs to the fuzzy system to account for external market factors.
- **Utilizing hybrid learning approaches:** Combining the fuzzy model with machine learning methods such as ANFIS, LSTM, or genetic algorithms can enable automatic optimization of membership functions and rule sets.
- **Testing across different markets:** Evaluating the model in international markets (e.g., NYSE, LSE, and Tokyo Stock Exchange) and across various industries can assess its generalizability.
- **Analyzing shorter time horizons:** Applying the model to hourly or minute-level intervals is recommended for short-term and algorithmic trading.
- **Improving risk metrics:** Incorporating risk management indicators such as Value at Risk (VaR) or the Sharpe Ratio can enhance the precision and safety of trading decisions.
- **Developing an intelligent user interface:** Designing software or an interactive dashboard that receives daily inputs and visually presents fuzzy outputs can facilitate the practical deployment of the model in operational environments.

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