

Enhancing FOREX Market Predictions: A Comparative Study of Candlestick Patterns and the MIDDAM Patterns

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ABSTRACT

Candlestick patterns are widely recognized as tools for predicting price movements, gaining popularity in the stock market. However, their applicability in the FOREX market, which operates continuously 24 hours daily, remains uncertain. This study assesses the accuracy of widely known candlestick patterns, particularly Doji patterns, in the FOREX market. We analyze the top eight most-traded currency pairs—EUR/USD, EUR/GBP, GBP/USD, GBP/JPY, USD/JPY, USD/CHF, AUD/USD, and XAU/USD—using 13 years of data. The findings reveal that Doji patterns are unreliable indicators of reversals in the FOREX market. Instead, this research introduces a new candlestick pattern, *Minimal Difference in shadow for Directional Analytical Movement* (MIDDAM), which is designed for both uptrends and downtrends and significantly improves predictive accuracy. Extensive experiments demonstrate that the proposed patterns outperform traditional ones in profitability and trade success. By comparing the effectiveness of these patterns in real market simulations involving over 38 million 1-minute historical candles, MIDDAM patterns yield 138 times more profitable than Doji patterns, achieving a win-to-loss ratio of 6:2 across the tested currency pairs. This study underscores the potential of MIDDAM patterns for more reliable predictions and superior trading performance in the FOREX market.

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1. INTRODUCTION

Candlestick patterns, developed in the 16th century by Japanese rice traders, have long been used to predict market movements. These patterns gained prominence in the stock market for their ability to graphically represent price movements and provide directional signals based on open, close, high, and low prices.

Commonly used candlestick patterns include the Standard Doji, Dragonfly Doji, Gravestone Doji, Hammer, Hanging Man, Shooting Star, Marubozu, Engulfing, and Harami. Fig.1 and Fig.2 illustrate well-known single and double candlestick patterns, respectively.

Doji patterns characterized by small bodies and long shadows, often signify market indecision and potential reversals. When a Doji appears after a series of bullish or bearish candles, it indicates a potential market reversal. As shown in Fig.1, patterns such as

the Dragonfly Doji (b) and Hammer (d) are bullish, while patterns like the Gravestone Doji (c) and Inverted Hammer (f) are bearish. The standard Doji (a) signals caution, indicating the price could reverse or continue.

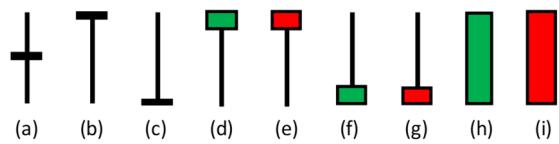


Fig. 1: Single candlestick patterns: a) Standard Doji, b) Dragonfly Doji, c) Gravestone Doji, d) Hammer, e) Hanging Man, f) Inverted Hammer, g) Shooting Star, h) Bullish Marubozu, i) Bearish Marubozu.

Double candlestick patterns involve two consecutive candlesticks that, together, indicate a possible market reversal or continuation. As shown in Fig.2,

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patterns such as Bullish Engulfing (a) and Bullish Harami (c) are considered bullish, indicating a potential upward reversal, while patterns like Bearish Engulfing (b) and Bearish Harami (d) are considered bearish, indicating a potential downward reversal. These patterns provide additional confirmation and are widely used to enhance trading strategies.

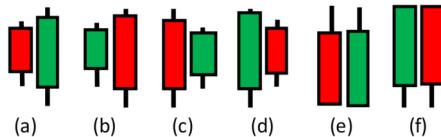


Fig.2: Double candlestick patterns: a) Bullish Engulfing, b) Bearish Engulfing, c) Bullish Harami, d) Bearish Harami, e) Tweezer Bottom, f) Tweezer Top.

The foreign exchange (FOREX) market, which involves trading currency pairs, operates nearly 24 hours a day, providing opportunities for high profitability while posing significant risks due to its volatility. This research aims to identify and validate candlestick patterns that perform well in the FOREX market.

The effectiveness of candlestick patterns in predicting market movements has been a subject of extensive debate [2][3]. Significant profitability has been observed in certain cases, particularly in S&P500 stocks [9]. Research has also shown positive results in other markets, such as the Chinese SSE50 Index [5] and European stock markets [8], though findings in the Brazilian stock market [6] have been less consistent. Moreover, some studies have revealed only a limited correlation between candlestick patterns and profit gains, as demonstrated by analyses of the Japanese equity market [10] and broader financial contexts [4].

In the context of the FOREX market, substantial returns have been associated with using candlestick patterns [1]. Exploratory studies on adaptive candlestick patterns in FOREX trading [12] have further underscored this potential. Moreover, combining candlestick chart patterns with technical indicators has proven to be an effective strategy for identifying trend reversals, as demonstrated by Noertjahyana *et al.* [11]. These studies collectively illustrate differing viewpoints on the reliability of candlestick analysis for market prediction, suggesting that while some research points to potential profitability, others recommend a cautious approach to their application.

This study will therefore conduct a comparative analysis to determine whether candlestick patterns are effective in the FOREX market. Given the potential and variety of candlestick patterns, this study focuses on Doji-like patterns, the most well-known and easily recognized, and evaluates their behavior in the FOREX market. The primary contributions of this paper are as follows:

1. *Introducing the new candlestick pattern, MIDDAM, and demonstrating its effectiveness:* Pre-

senting enhanced candlestick patterns and evaluating their predictive power and profitability.

2. *Evaluating the accuracy and effectiveness of Doji-like patterns in the FOREX Market:* Analyzing the predictive power of various Doji patterns and comparing their performance over a decade of data from the top eight FOREX pairs. This will assess the ability of Doji patterns to predict market reversals as well.
3. *Investigating the performance of Doji-like patterns and the proposed patterns under real market condition:* Conducting an exploratory study to determine the effectiveness of Doji-like patterns when applied to real data in market simulations.

The rest of the paper is organized as follows. Section 2 reviews related work on using candlestick patterns for market prediction. Section 3 defines the candlestick patterns and introduces the proposed patterns. Section 4 presents the data along with the experimental setup. Section 5 describes the discovery process of MIDDAM patterns and their initial results. Section 6 provides an in-depth analysis of MIDDAM on six timeframes for eight currency pairs. Section 7 presents the results of the proposed patterns in a market simulation. Finally, Section 8 provides conclusions and discusses future work.

2. RELATED WORKS

The use of Doji patterns in market prediction has been extensively studied, with varying conclusions about their effectiveness. This section reviews significant works that have applied Doji patterns to predict market trends, highlighting both supportive and critical perspectives.

Several researchers have found minimal or no correlation between raw stock prices and profit gains using candlestick patterns. Marshall *et al.* [10] demonstrated that candlestick patterns did not yield profits in the Japanese stock market over a 30-year period, irrespective of market conditions. Similarly, Yassini *et al.* [16] found no significant predictive power for nine candlestick patterns in various scenarios, though they noted that confirmed patterns could lead to substantial trading profits. These findings imply that raw patterns alone may not be reliable, but their validation could enhance their usefulness.

Contrarily, a significant portion of research supports the profitability of candlestick patterns. Udagawa [15] proposed a retrieval algorithm for NASDAQ's daily stock data to define reverse trade criteria based on negative stock price changes. This algorithm, considering parameters such as body length, price changes, and moving averages, demonstrated that certain patterns could achieve statistically significant profitability.

In 2018, Jamaloodeen, Heinz, and Pollacia [7] demonstrated the predictive power of two specific

candlestick patterns, the Shooting Star and the Hammer, using S&P500 index data over six decades. Their study substantially revealed that these patterns had higher forecasting reliability when using high prices for the Shooting Star and low prices for the Hammer, compared to closing prices. They measured the success rate by examining the patterns over several scenarios (5, 7, and 10 subsequent days) with and without trends, defined by a 70% increase in moving averages. The predictive power of the Hammer was statistically significant in every scenario when high prices were considered instead of closing prices.

In a notable study, Lu and Chen [8] systematically analyzed two-day candlestick patterns in European stock markets, categorizing two-day prices into 24 patterns, in Fig.3. Their results showed that for FTSE100, DAX30, and CAC40 stocks, the most profitable patterns achieved annual returns ranging from 109-133% with winning rates between 59-61%. This research underscores the potential profitability of candlestick patterns in various markets, although their effectiveness can vary significantly across different market conditions and timeframes.

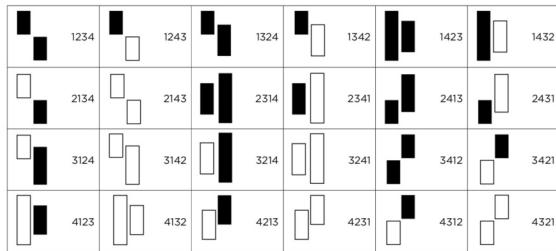


Fig.3: Two-Day Candlestick Pattern Categories from [8].

Prado *et al.* [6] investigated 16 candlestick patterns in the Brazilian stock market over ten stocks from 2005 to 2009. They found that some patterns, like the Bullish Harami, were statistically significant predictors of stock prices, while others, such as the Hanging Man, were frequently observed but ineffective in predicting price movements. This highlights the importance of contextual factors in the effectiveness of candlestick patterns.

Sang sawad and Fung [13] studied the Thai SET index and noted that, while candlestick patterns are widely used, some significant features are not well-defined. They proposed an unsupervised approach using k-means clustering to extract these features and solve issues with upper shadow, lower shadow, body of the candlesticks, and directions of candlestick patterns. Although their approach provided a structured method to define these features, they did not demonstrate whether the extracted features could enhance predictive power.

In another work on the Thai stock market, Tham makesorn and Sornil [14] developed trading strategies based on candlestick patterns to predict the prices of

ten stocks over two years. Using the Chi-square Automatic Interaction Detector (CHAID) algorithm, they generated 26 features and found that their proposed strategy outperformed other popular trading strategies such as EMA, RSI, MACD, STO, and ADX.

The application of candlestick patterns extends beyond stock markets to the FOREX market. Alanazi [1] examined over 112,000 candlesticks from 24 currency pairs between 2000 and 2018. They found that patterns like the Piercing Line and Dark Cloud Cover were highly profitable, achieving over 600% returns in some cases. Alanazi's study showed that a trader starting with a \$1,000 investment could grow their capital to \$7,420 over 19 years using these patterns.

Noertjahyana *et al.* [11] combined candlestick patterns with the Stochastic indicator to detect trend reversals in the EUR/USD pair. Their approach, which focused on single candlestick patterns, successfully identified market trends and increased profit gains, suggesting that integrating candlestick patterns with other technical indicators can enhance predictive accuracy and trading profitability.

Yassini *et al.* [16] studied nine candlestick patterns, including five Doji-like patterns: Hammer, Hanging Man, Long-legged Doji, Gravestone Doji, and Dragonfly Doji. They experimented on three FOREX market pairs (EUR/USD, USD/JPY, and GBP/USD) over a decade, using 1-hour, 4-hour, and 1-day timeframes. Their findings reiterated the earlier conclusions that while raw predictive rates were low, the inclusion of confirmed patterns significantly improved trading profits.

Overall, the literature indicates that while candlestick patterns, including Doji patterns, offer valuable insights and potential profitability, their effectiveness heavily depends on the market context, the specific patterns used, and the methods of validation. In this study, we aim to expand on the evaluation of Doji patterns in the FOREX market and introduce new patterns to enhance predictive accuracy and profitability.

3. PATTERN DEFINITIONS

In this section, we focus on the intricacies of defining candlestick patterns, which is crucial for accurate analysis. Fig.4 illustrates the components of a single candle. Each candle consists of an upper shadow (the extension above the main body) and a lower shadow (the extension below the main body). The combined length of the body and shadows constitutes the range of the candle.

Although Doji patterns are relatively straightforward, being single-candle formations as shown in Fig.1 (a)-(f), several nuances require clarification. For instance, distinguishing between a Hammer and a Dragonfly Doji, or determining the appropriate length of the lower shadow for a Shooting Star, are critical distinctions. These seemingly minor parame-

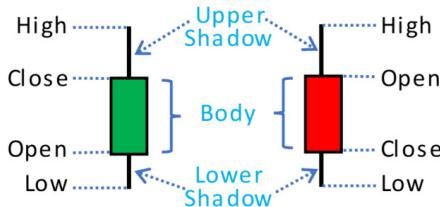


Fig.4: Components of a Single Candlestick.

ters can significantly influence the identification and frequency of patterns.

Table 1: Definitions of MIDDAM and Related Candlestick Patterns.

Range = High-Low
BodyP = $\text{abs}(\text{Open}-\text{Close}) / \text{Range}$
OpenP = $(\text{Open} - \text{Low}) / \text{Range}$
CloseP = $(\text{Close} - \text{Low}) / \text{Range}$
UpperP = $\max(\text{OpenP}, \text{CloseP})$
LowerP = $\min(\text{OpenP}, \text{CloseP})$
Dragonfly Doji:
$(\text{BodyP} \leq 5\%) \& (\text{LowerP} \leq 5\%)$
Gravestone Doji:
$(\text{BodyP} \leq 5\%) \& (\text{UpperP} \geq 95\%)$
Doji:
$(\text{BodyP} \leq 5\%) \& (40\% \leq \text{LowerP}) \& (\text{UpperP} \leq 60\%)$
Hammer:
$(5\% < \text{BodyP} \leq 25\%) \& (\text{LowerP} \leq 5\%) \& (\text{Open} < \text{Close})$
Hanging Man:
$(5\% < \text{BodyP} \leq 25\%) \& (\text{LowerP} \leq 5\%) \& (\text{Close} < \text{Open})$
Inverted Hammer:
$(5\% < \text{BodyP} \leq 25\%) \& (\text{UpperP} \geq 95\%) \& (\text{Open} < \text{Close})$
Shooting Star:
$(5\% < \text{BodyP} \leq 25\%) \& (\text{UpperP} \geq 95\%) \& (\text{Close} < \text{Open})$
Bullish Marubozu Full:
$(\text{Open} = \text{Low}) \& \& (\text{Close} = \text{High})$
Bullish Marubozu Close:
$(\text{Close} = \text{High})$
Bullish Marubozu Open:
$(\text{Open} = \text{Low})$
Middam Up (Our proposed pattern):
$(\text{OpenP} \geq 30\%) \& (\text{CloseP} \leq 20\%)$
Middam Down (Our proposed pattern):
$(\text{OpenP} \leq 70\%) \& (\text{CloseP} \geq 80\%)$

To illustrate the variability in pattern identification, consider the study by Yassini *et al.* [16], which found only four Hammers and two Dragonfly Doji patterns among 2,605 daily candles over ten years of EUR/USD data. Similarly, in a decade of USD/JPY data, they identified five Hammers in 2,605 daily candles, 23 Hammers in 11,582 four-hour candles, and 78 Hammers in 61,929 one-hour candles.

In contrast, a study by Jamalooddeen, Heinz, and Pollacia [7] detected 289 Hammers in 16,635 one-hour candles observed in the S&P500 index. The frequency of Hammer patterns differed significantly—around 0.2% in [16] and 1.7% in [7]. These discrepancies underscore the importance of precise pattern definitions, even for basic patterns.

In this paper, we do not redefine existing candlestick patterns but instead, ensure reproducibility by providing detailed parameters in Table 1. By maintaining consistent definitions, this work aims to enhance clarity and reliability in pattern identification, facilitating the replication and verification of findings. This approach strengthens the validity of the research and contributes to a deeper understanding of candlestick patterns in the FOREX market. The proposed patterns, *MINimal Difference in shadow for Directional Analytical Movement* (MIDDAM), in both Up and Down versions, are designed to enhance predictive accuracy and profitability.

4. EXPERIMENTAL DESIGN

This section provides an overview of the experimental setup, covering data preparation, methodology, and subsequent analysis results. The experiments are designed to assess the predictive power of Doji-like patterns in the FOREX market, focusing on three key aspects. Section 4.1 addresses data preparation. Section 4.2 details initial exploratory experiments, while Section 4.3 describes the experimental setup used throughout Sections 5, 6, and 7.

4.1 Data Collection and Preparation

The data for the experiments were sourced from historical records of the top eight most-traded FOREX currency pairs: EUR/USD, EUR/GBP, GBP/USD, GBP/JPY, USD/JPY, USD/CHF, AUD/USD, and XAU/USD. Spanning from January 1, 2010, to December 31, 2022, this dataset provides an extensive period for analysis. The 1-minute data were obtained from publicly available historical data repositories¹. The experiments used various timeframes, including 5-minute, 15-minute, 1-hour, 4-hour, and 1-day candles to capture diverse trading dynamics. The data sizes for each currency pair are presented in Table 2.

Table 2: Number of Candlesticks for Eight FOREX Pairs (2010-2022).

FOREX Pair	1 min	5 min	15 min	1 hour	4 hour	1 day
EUR USD	4,796,061	969,857	323,392	80,865	20,888	4,058
EUR GBP	4,673,927	954,362	318,400	80,866	20,873	4,054
GBP USD	4,785,741	969,522	323,370	80,864	20,889	4,057
GBP JPY	4,819,528	909,651	323,366	80,870	20,889	4,057
USD JPY	4,785,741	969,522	323,397	80,875	20,889	4,058
USD CHF	4,674,716	953,961	318,367	80,876	20,567	4,054
AUD USD	4,704,840	954,676	318,392	80,865	20,567	4,055
XAU USD	4,586,117	924,210	308,914	78,018	20,788	4,044

It is important to note that while the stock market typically has 252 trading days in a year, the number of trading days in the FOREX market can vary depending on different servers and time zones.

¹<https://www.histdata.com/>

4.2 Preliminary Analysis of Doji Patterns

Preliminary experiments were conducted to assess the frequency and predictive accuracy of Doji patterns. Table 3 summarizes the occurrences and predictive accuracy of Doji patterns across different currency pairs and timeframes. The accuracy percentages represent the proportion of correct predictions (up or down) out of the total Doji occurrences.

In this initial experiment, a price movement is considered “up” if the closing price of the next day’s candle is higher than the closing price of the current day’s candle. Conversely, it is considered “down” if the closing price of the next day’s candle is lower than the closing price of the current day’s candle. The brief results of this initial experiment are shown in Table 3.

Table 3: Doji Pattern Frequencies and Predictive Accuracy Across Eight Currency Pairs.

FOREX Pair	Number of 1-day Candles	Doji Occurrences	Predicted Up	Predicted Down	Accuracy (%)
EUR/USD	4058	15	8	7	53
EUR/GBP	4054	14	7	7	50
GBP/USD	4057	12	6	6	50
GBP/JPY	4057	18	10	8	56
USD/JPY	4058	5	3	2	60
USD/CHF	4054	9	5	4	56
AUD/USD	4055	10	5	5	50
XAU/USD	4044	20	12	8	60

However, the traditional definition of “up” and “down” as the difference between the closing price of the next day and the current day is not strong enough to be profitable in the market because, in the real market, commissions or spreads must also be considered. Therefore, a stronger version of “up” and “down” is used in our experiments which is explained in Section 4.3.

4.3 Experiment Setup for Testing Proposed Patterns

The experiments involving single candlesticks in Sections 5 and 6 were implemented in Python. Section 5 discusses the discovery of the proposed patterns, MIDDAM, whereas Section 6 evaluates their effectiveness and predictive power compared to other well-known candlesticks, such as Doji-like patterns.

The analysis aims to demonstrate the predictive power of individual Doji-like patterns in forecasting market movements by evaluating the direction of the next candle (bullish or bearish). To measure a single candlestick’s effectiveness, the next candle is labeled as “up,” “down,” or “neutral.” This labeling process involves calculating a rolling average of the candle body size over the past 100 candles, including the current one (Equation 1). The criteria for labeling are as follows:

- **Up:** The candle is labeled “up” if the next closing price is higher than the current closing price plus

the fixed ratio of the average size of the last 100 candles.

- **Down:** The candle is labeled “down” if the next closing price is lower than the current closing price minus the fixed ratio of the average size of the last 100 candles.
- **Neutral:** The candle is labeled “neutral” if it does not meet the criteria for “up” or “down.”

The experiments in Section 7 demonstrate the practical applicability of the proposed candlestick patterns over 13 years of historical market data. All experiments were conducted on MetaTrader4, a widely used platform for FOREX trading. These tests on real market data simulate the profitability and effectiveness of the proposed patterns in real-world trading scenarios.

In real trading scenarios, spreads for each currency pair can vary significantly depending on the broker, typically ranging from 0.01 to 10 pips. For consistency, a fixed spread of 5 pips was set for all FOREX pairs in the experiments, with no commission fees assumed, as recommended by broker websites.

5. EXPERIMENT SET I: MIDDAM DISCOVERY

To visualize all possible candlesticks, a simple approach is to consider the ratio of the candle *body* size to the size of the entire candle, referred to as the *range*. A single candle is green when the closing price is higher than or equal to the opening price and red when the closing price is lower. Fig.5 illustrates all possible green candles, with rows representing the candle body size as a percentage of its range (i.e., the price ranges from low to high) and columns indicating the middle price position.

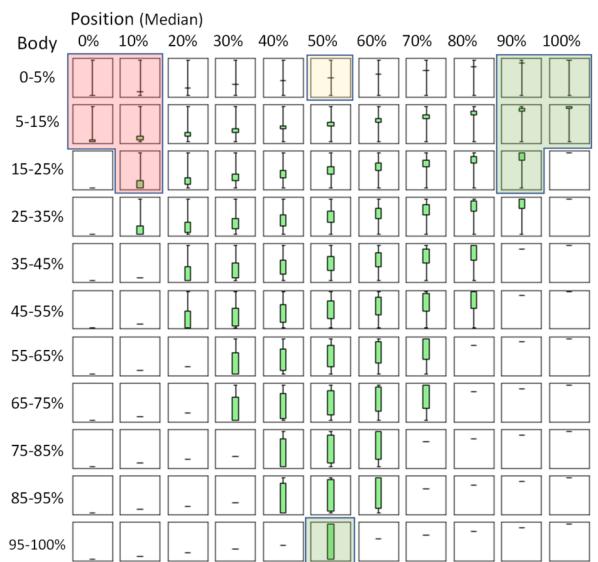


Fig.5: Distribution of Green Candlestick Patterns Based on Body Size and Position.

When visualizing all candles by body size and position, Doji patterns can be easily identified. In Fig.5, the Dragonfly Doji and Gravestone Doji are located in the top-left and top-right corners, respectively, while standard Dojis are centered on the top row. The Hammer and Inverted Hammer appear in the second and third rows, and the full bullish candle (i.e., Bullish Marubozu) is positioned in the center of the last row.

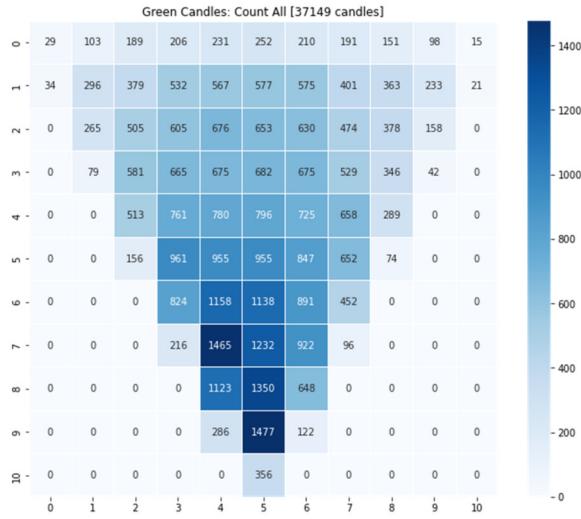


Fig.6: Frequency of Green Candlestick Patterns in 1-Hour EUR/USD Data (2010-2023).

Fig.6 shows the occurrences of all 1-hour candles for the EUR/USD currency pair from 2010 to 2023. Over these 13 years, the identified candlestick patterns include 132 green Gravestone Dojis (29 in one category and 103 in another), 113 green Dragonfly Dojis (15 in one category and 98 in another), 595 Hammers (34, 296, and 265 in three different categories), and 412 Inverted Hammers (21, 233, and 158 in three different categories).

One of the main contributions of our paper is to determine whether information from a single current candlestick can be used to predict the next candlestick. To achieve this, the analysis focuses on the size of the difference between the closing price of the current candle and the next candle. By examining this difference, we aim to assess the predictive power of the current candlestick's characteristics, such as its body size, shape, and position within its range. This analysis provides valuable insights into how well a single candlestick can forecast the market's next move, which is crucial for traders and analysts. The methodology and results of this measurement are detailed below.

$$label_t = \begin{cases} \text{Up} & \text{if } close_{t+1} > close_t + \rho \hat{b}_t \\ \text{Down} & \text{if } close_{t+1} < close_t - \rho \hat{b}_t \\ \text{Neutral} & \text{otherwise} \end{cases} \quad (1)$$

where \hat{b}_t is defined as:

$$\hat{b}_t = \frac{1}{\alpha} \sum_{i=t-\alpha+1}^t |close_i - open_i| \quad (2)$$

Essentially, \hat{b}_t represents the average body size of the last α candles. The candle is labeled as “up” (+1) if the closing price of the next candle is significantly higher than the current closing price. Conversely, it is labeled “down” (-1) if the closing price is significantly lower. If the price is not significantly different from the previous one, the label is 0. In the experiments, α was set to 100 and ρ was set to 0.5. This means the average body size is computed from the last 100 candles, and the price is considered “up” if the next day's closing price is higher than the current day's closing price by half of this average.

Next, an evaluation is conducted to determine whether the current candles can be used to predict the label by calculating the probability difference between an upward and a downward movement:

$$p_{cell} = Pr[\text{label} = Up] - Pr[\text{label} = Down] \quad (3)$$



Fig.7: Probability Distribution (p_{cell}) for Green Candlestick Patterns.

In summary, if there is a higher probability that the next closing price will rise, p_{cell} values will be positive. Conversely, if the price is more likely to fall, p_{cell} values will be negative. The p_{cell} values for all single candlestick patterns are shown in Fig.7. Positive p_{cell} values indicate that the closing price is significantly higher than the current closing price, while negative p_{cell} values indicate that it is significantly lower. In other words, the p_{cell} values reflect the likelihood that the next candle's prices will move up or down.

Similar to Fig.5, which presents all green candlesticks, Fig.8 shows the shape of all red candlesticks. Fig.9 displays the p_{cell} values of each corresponding

cell when the candlesticks are red.

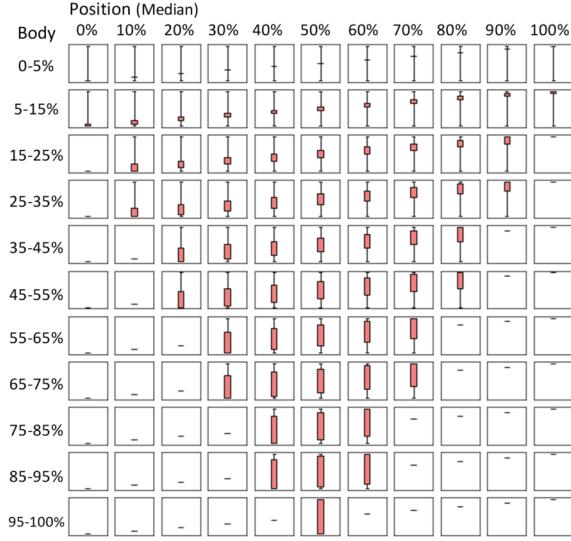


Fig.8: Distribution of Red Candlestick Patterns Based on Body Size and Position.

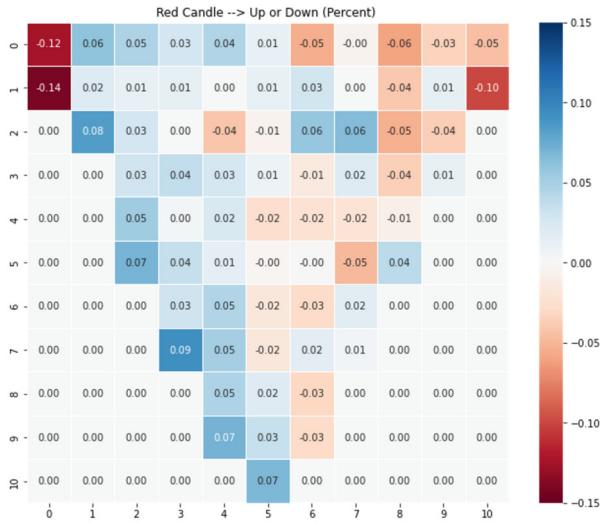


Fig.9: Probability Distribution (p_{cell}) for Red Candlestick Patterns.

Readers may observe fluctuations around Doji patterns, particularly in the top-left and top-right corners of Figures 7 and 9. These fluctuations are consistent across different currency pairs and timeframes. Due to space limitations, results for fluctuations in other timeframes and currency pairs are omitted.

Furthermore, Figures 7 and 9 reveal zones that exhibit either negative or positive trends. In Fig.7, the p_{cell} values of cells along the right diagonal tend to be negative, while in Fig.9, the p_{cell} values of cells along the left diagonal tend to be positive. These zones in the green candlesticks suggest a downward trend with likely negative p_{cell} values, whereas the zones in the red candlesticks indicate an upward trend. We define these zones as our proposed MIDDAM Up and

MIDDAM Down, as illustrated in Fig.10.

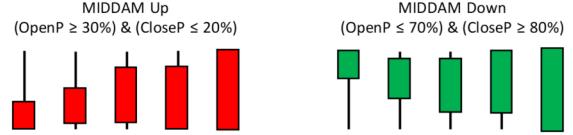


Fig.10: Visualization of Proposed MIDDAM Patterns: MIDDAM Up and MIDDAM Down.

6. EXPERIMENT SET II: BEHAVIOR OF INDIVIDUAL CANDLESTICKS

In the previous section, candlesticks were analyzed by the size of their bodies (i.e., $|close-open|$) and their ranges (i.e., high-low). In this section, we focus on the effectiveness of all candlesticks, both green and red, which are plotted together in the same figure.

Fig.11 illustrates the shape of all candlesticks, with rows representing the opening prices and columns representing the closing prices. Note that Doji-like patterns appear around the top-left and bottom-right corners.

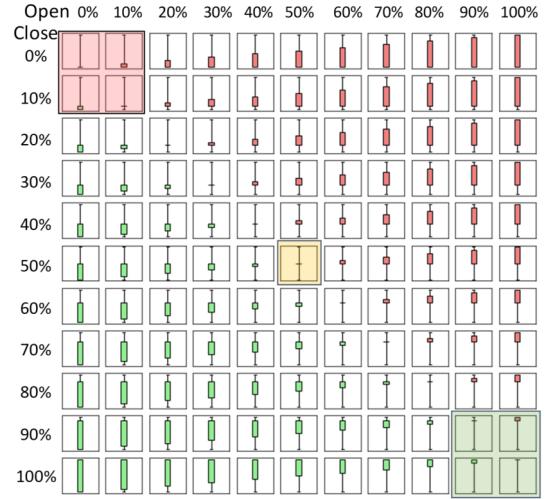


Fig.11: Shape of All Candlestick Patterns Based on Opening and Closing Positions, Highlighted Doji-like Patterns.

Fig.12 shows the probabilities that the next candlestick will be up, formally represented as $\text{Pr}[\text{label} = \text{Up}]$, when considering the current candlestick in each cell. Similarly, Fig.13 presents the probabilities that the next candlestick will be down, represented as $\text{Pr}[\text{label} = \text{Down}]$.

After combining both figures (Fig.12 and Fig.13), the p_{cell} values for all candlesticks are shown in Fig.14. As mentioned earlier, a positive p_{cell} value indicates that the next candlestick is more likely to be up than down, whereas a negative p_{cell} value suggests that the next candlestick is likely to be down. Interestingly, in Fig.14, the p_{cell} values for the top-left and bottom-right corners, which correspond to

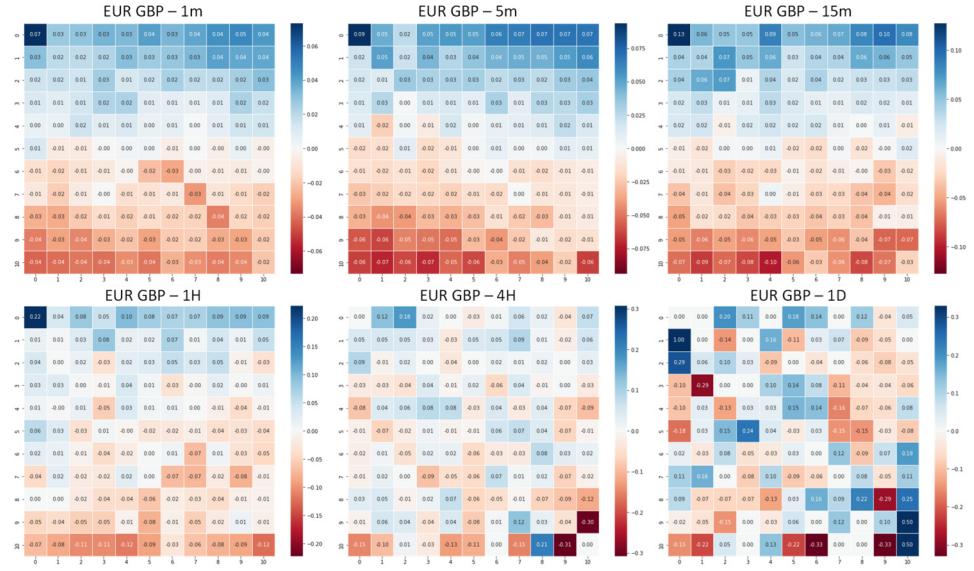
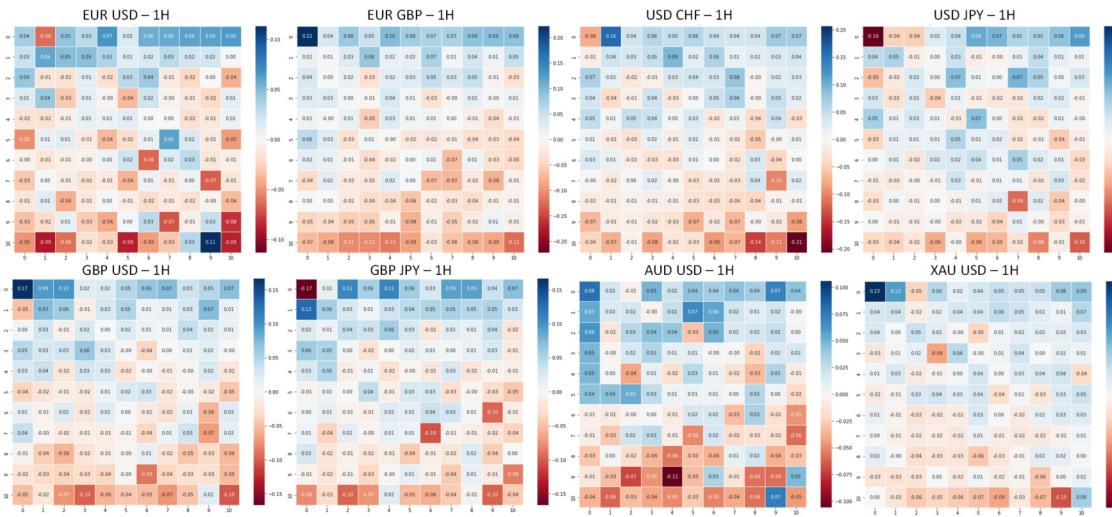
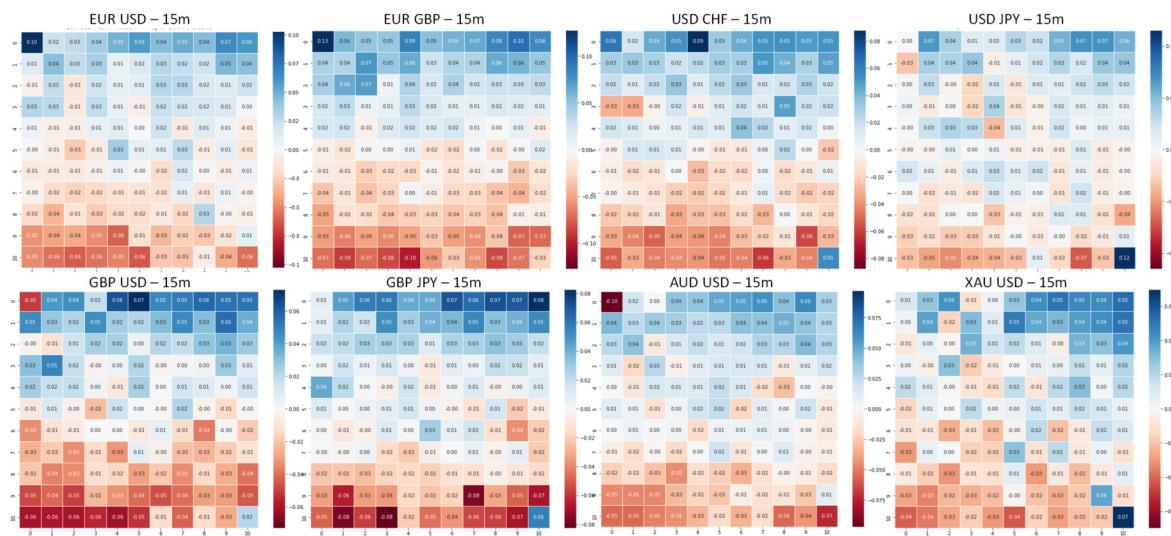
Fig. 15: p_{cell} Value Distribution for EUR/GBP Across Multiple Timeframes.Fig. 16: p_{cell} Value Distribution Across Eight Currency Pairs (1-Hour Timeframe).Fig. 17: p_{cell} Value Distribution Across Eight Currency Pairs (15-Minute Timeframe).

Table 4: p_{cell} Values of Upward and Downward Candlestick Patterns (Bold Numbers Indicate Maximum and Minimum Values for Upward and Downward Patterns).

	Patterns	EUR USD	EUR GBP	GBP USD	GBP JPY	USD JPY	USD CHF	AUD USD	XAU USD	Avg p_{cell}	Avg Occurrence
Upward	Dragonfly Doji	-0.78	-5.85	-3.57	-7.84	-3.08	-11.67	4.23	-2.61	-3.90	128
	Hammer	-4.07	-5.09	-4.24	-2.34	-1.14	-7.24	-3.04	-4.45	-3.95	1,070
	Inverted Hammer	1.82	2.61	2.74	4.10	-1.14	1.24	2.11	0.52	1.75	1,351
	MIDDAM Up	3.18	5.47	4.20	5.20	3.43	4.26	3.31	4.53	4.20	11,561
Downward	Gravestone Doji	-0.33	4.16	3.88	2.09	-3.11	2.13	4.78	11.09	3.09	150
	Shooting Star	4.11	5.97	3.50	4.56	-0.62	4.89	1.47	1.32	3.15	1,121
	Hanging Man	-3.38	-2.46	-3.89	-2.76	-0.83	-8.00	-3.32	0.55	-3.01	1,184
	MiDDAM Down	-2.83	-5.53	-4.00	-2.65	-2.16	-3.35	-3.82	-3.11	-3.43	10,404

7. EXPERIMENT SET III: REAL MARKET IMPLICATIONS

In this section, the proposed single candlestick pattern, MIDDAM, is applied to determine its profitability in real market conditions. The effectiveness of this candlestick was demonstrated in the previous section. Although statistical data suggest the proposed candlestick can help predict the next candlestick's direction, relying on a single candlestick alone is insufficient for consistent profits. The proposed method's effectiveness will be compared against competitor patterns. These experiments are conducted on all eight FOREX pairs using real historical data, as outlined in Section 4.

To succeed in the market, patterns involving more than a single candlestick are necessary for better predicting price direction. In the experiments, a base pattern combined with a specific candlestick is used to form a comprehensive prediction. To isolate the effectiveness of the proposed candlestick from other individual candlesticks, all tested patterns consist of four candlesticks, beginning with the same base pattern, such as three white soldiers or three black crows, while only the last candlestick varies. All multiple candlestick patterns used in the experiments are illustrated in Fig.18. The explanation of each pattern is as follows:

Pattern 1 [Base Pattern]:

Three white soldiers and three black crows.

These three candles represent a small price trend. If all three candles are green, it is commonly believed that the price will rise. Conversely, if all three candles are red, it is expected that the price will fall.

Pattern 2: *Four white soldiers and four black crows.* Extending the sequence to four candles strengthens the trend. If four consecutive green candles appear, the next candle is expected to continue upward. Similarly, four consecutive red candles suggest the next candle will continue downward.

Pattern 3: Base pattern followed by a Doji (Gravestone Doji or Dragonfly Doji).

Doji candlesticks are often used to predict price reversals. If a Doji appears at the end of a trend, a reversal is anticipated. Specifically, if a Gravestone Doji follows three white soldiers, the price is predicted to fall. Conversely, if a Dragonfly Doji follows three

black crows, the price is predicted to rise.

Pattern 4: *Base pattern followed by a hammer-like candle (Hammer, Hanging Man, Shooting Star, or Inverted Hammer).*

Like Dojis, hammer-like candles are also used to predict reversals at the top of a trend. If a Shooting Star or Inverted Hammer follows three white soldiers, the price is predicted to fall. If a Hammer or Hanging Man follows three black crows, the price is predicted to rise.

Pattern 5 [Proposed Pattern]:

Base pattern followed by a MIDDAM candlestick.

For the proposed candlestick, if MIDDAM Up (see Fig.10) appears after three white soldiers, the price is predicted to rise. Conversely, if MIDDAM Down appears after three black crows, the price is predicted to fall. Although these patterns may seem similar to the four white soldiers and four black crows, the experiments demonstrate that they yield significantly different results in real market data.

Although all patterns, from Pattern 1 to Pattern 5 in Fig.18, appear similar, their performance in the real market varies significantly. Surprisingly, Pattern 1 (three ups or three downs) and Pattern 2 (four ups or four downs) performed poorly, leading to significant losses across all currency pairs. As expected, the number of trades for Pattern 2 is roughly half that of Pattern 1, reflecting the additional candlestick required. The win rate for Pattern 2 is not better than Pattern 1, indicating that the fourth candle does not improve predictive accuracy.

Pattern 3, a reversal Doji after the three soldiers, exhibits the highest win rate approximately 54.5% across all currency pairs. However, over a decade of data, the number of matched patterns is extremely limited. The average number of matched patterns is only 21 matches across all currency pairs, equating to less than two matches per year. Although the win rate is high, the average profit per currency pair over the tested period is approximately \$79, or about \$6 per year, with profits on four currency pairs and losses on the other four.

Pattern 4, involving a hammer or shooting star after three soldiers, performs similarly to Pattern 3. While its win rate is slightly lower, this pattern also yields profits on four currency pairs and losses on four. It is easier to find matched patterns during the

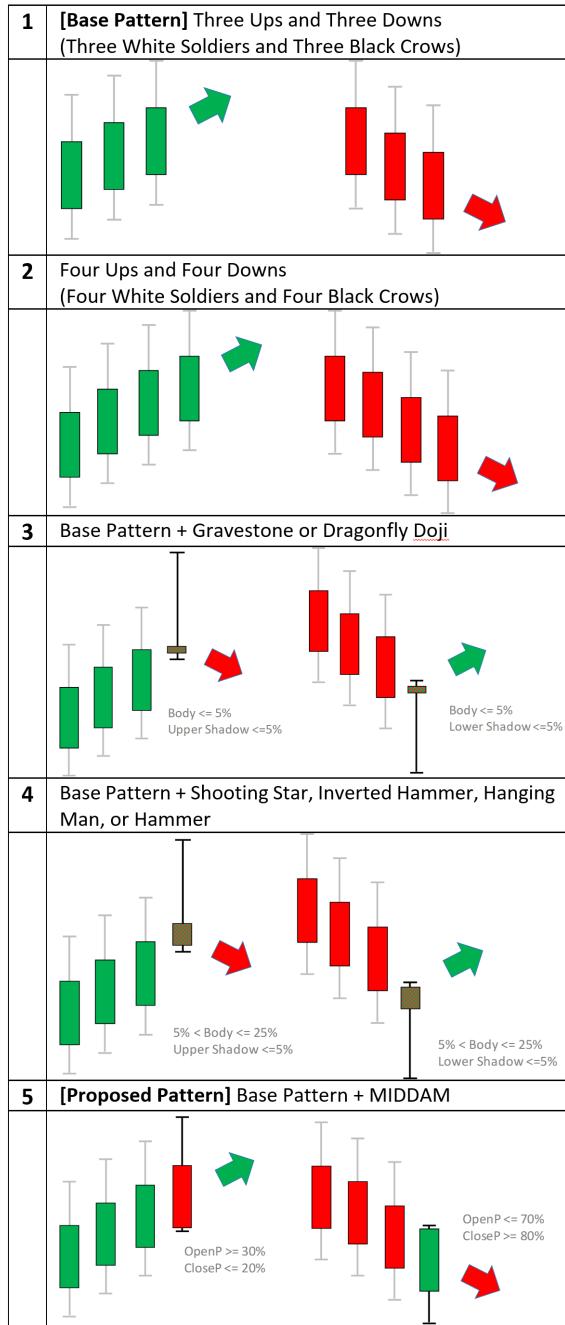


Fig.18: Multiple Candlestick Patterns Used in the Experiments.

test period, with around 14–15 per year per currency pair, resulting in a modest average profit of about \$8 per year.

The proposed pattern, Pattern 5, delivers the highest profitability among all patterns, as shown in the last column of Table 4. Overall, this pattern yields profits on six currency pairs and losses on two. The average profit is approximately \$10,999 per currency pair over the last decade, or about \$916 per year per currency pair, which is substantially higher than the competitors. Although the win rate is only 51.3%, lower than Patterns 3 and 4, the profit per trade

is much higher, indicating that when the pattern matches, the profit far exceeds the loss.

The profit per trade for the proposed pattern is \$3.08, which is six times higher than Pattern 4's \$0.59 per trade. Compared to Pattern 3, the number of trades is 169 times higher. In other words, the proposed pattern executes approximately 22.8 trades per month, or about one trade per trading day, whereas Pattern 3 executes only 0.13 trades per month, or about one trade every 7.5 months. The low number of trades for Pattern 3—just 21 trades over 13 years—makes its statistical significance questionable in real-world trading.

Table 5 shows the profit and loss of all trades for all eight currency pairs during the tested period. Due to the substantial losses of Patterns 1 and 2, their results are omitted to conserve space. The equity of Patterns 3, 4, and 5 is shown in Fig.19, where the x-axis represents the number of trades in chronological order and the y-axis represents equity, showing the remaining balance during each trade.

As depicted in the first column of Fig.19, Pattern 3 has a very short plot due to the limited number of trades, with these Doji patterns appearing only 13 to 40 times over a decade. The middle column shows the results for Pattern 4, where the win rate of 53.2% does not significantly translate into profits. This pattern performs well for some currency pairs, such as USD/CHF and AUD/USD, but poorly for others, like EUR/GBP. The proposed pattern, Pattern 5, performs similarly well on pairs like EUR/GBP, GBP/JPY, and GBP/USD, but shows losses on pairs like USD/JPY.

Therefore, it is important to note that none of the patterns, including the proposed ones, can consistently outperform the market. While some methods can generate profits for certain currency pairs, there is no guarantee of consistently winning in the market. This study demonstrates that the proposed method performs better than competitors under the same conditions and can generate profits in a market simulator using historical data.

8. CONCLUSION AND FUTURE WORK

This paper introduces the MIDDAM candlestick pattern, available in two versions: one for uptrends and another for downtrends. Our proposed patterns, MIDDAM, are derived from statistical evidence, specifically the p_{cell} value, which measures the probability of the next candlestick's direction. Several sets of experiments are conducted to evaluate different aspects of the patterns. First, the preliminary experiment in Section 4.2 shows that Doji patterns are not effective for predicting the direction of the next candlestick. The experiments in Section 5 detail the performance of individual candlesticks, focusing on candlestick body size, leading to the identification of MIDDAM patterns.

Table 5: Profit and Loss Summary of Patterns 1 to 5 Across Eight Currency Pairs (Including Trades and Win Rates).

id	Forex Pair	Pattern 1			Pattern 2			Pattern 3			Pattern 4			Pattern 5		
		3 Ups, 3 Downs			4 Ups, 4 Downs			Doji: Dragonfly, GraveStone			Hammer, ShootingStar, etc			MidDam		
		Profit	#Trades	Win Rate	Profit	#Trades	Win Rate	Profit	#Trades	Win Rate	Profit	#Trades	Win Rate	Profit	#Trades	Win Rate
1	XAU USD	-72851.80	11,557	45.6%	-75499.40	5,169	45.6%	-1226.40	40	45.0%	-309.10	126	50.0%	27257.80	3,337	53.8%
2	EUR USD	-128288.69	11,818	43.7%	-38439.06	5,224	42.9%	1066.00	22	77.3%	636.93	169	55.0%	9134.10	3,651	51.0%
3	EUR GBP	-119532.33	11,523	43.4%	-58886.85	5,120	41.7%	-12.12	19	42.1%	-2158.21	153	49.0%	12108.03	3,504	51.7%
4	GBP JPY	-100684.24	11,998	45.0%	-56696.84	5,432	44.0%	616.21	13	69.2%	-597.25	148	56.1%	23504.33	3,527	54.0%
5	GBP USD	-121893.32	11,856	44.2%	-31372.47	5,268	44.4%	-415.00	14	35.7%	698.95	177	55.9%	29241.08	3,658	51.6%
6	USD JPY	-92418.78	11,655	43.4%	-52574.87	5,195	42.0%	392.82	16	68.8%	-970.09	157	48.4%	-13468.99	3,366	48.8%
7	USD CHF	-120905.31	11,797	42.7%	-55289.31	5,179	43.3%	343.30	19	57.9%	1684.30	178	56.7%	-1466.22	3,747	49.2%
8	AUD USD	-101753.54	12,141	44.7%	-57084.24	5,528	43.8%	-130.00	25	40.0%	1782.36	174	54.0%	1682.27	3,735	50.0%
Total		-858328.01	94,345	-	-425843.04	42,115	-	634.81	168	-	767.89	1,282	-	87992.40	28,525	-
Average		-107291.00	11,793	44.1%	-53230.38	5,264	43.5%	79.35	21	54.5%	95.99	160	53.2%	10999.05	3,566	51.3%
Win : Loss		0 : 8			0 : 8			4 : 4			4 : 4			6 : 2		

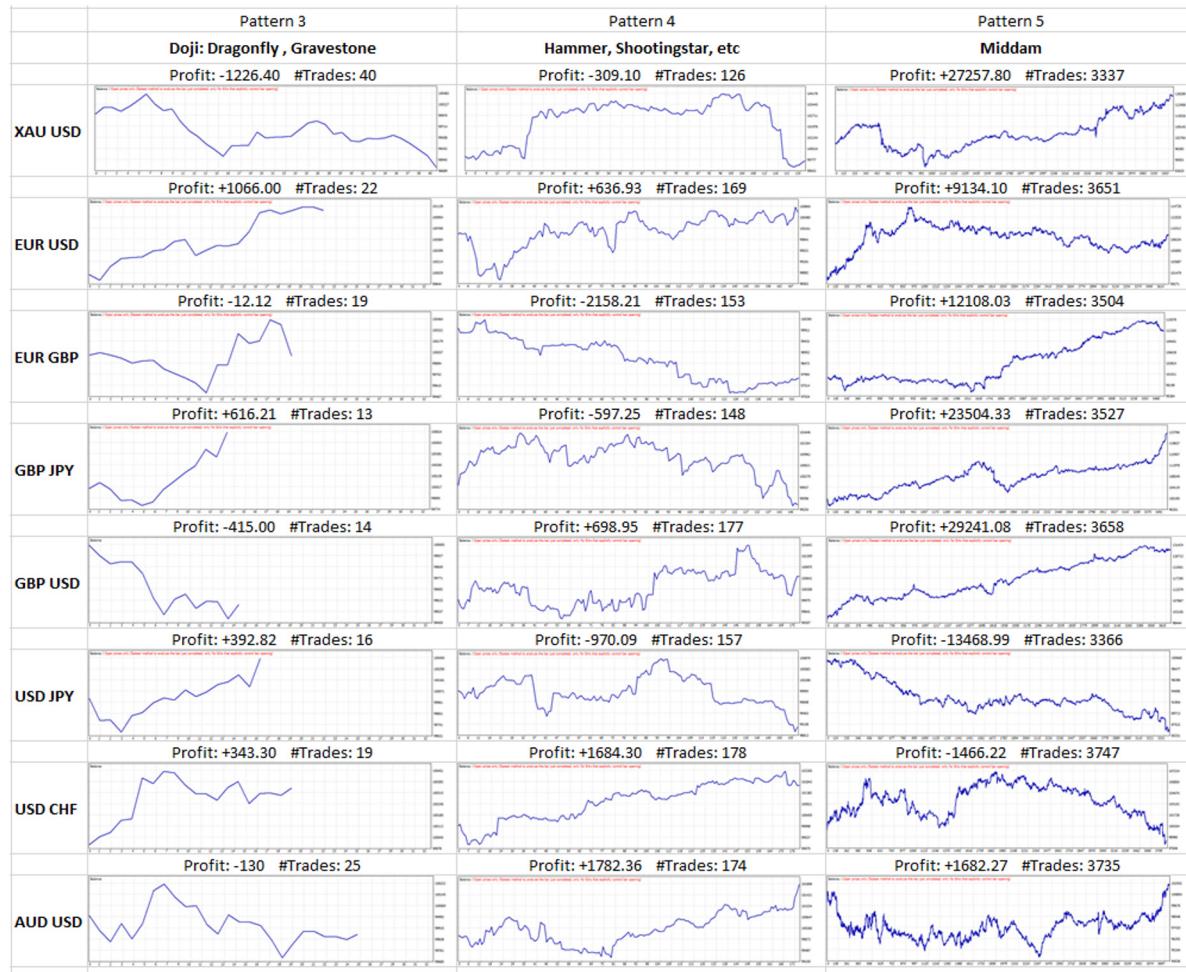


Fig.19: Trade Equities for Patterns 3 to 5 Across All Currency Pairs (Patterns 1 and 2 are Omitted Due to Heavy Losses).

The performance of MIDDAM candlesticks is rigorously tested in Section 6 across eight currency pairs and six timeframes. The statistical results indicate a correlation between the direction of the next candlestick and the current candlestick, especially in areas around certain patterns, including the proposed MID-DAM patterns.

The effectiveness of our proposed patterns and competitor patterns is further demonstrated in a real

market simulation in Section 7. Thirteen years of historical data from eight currency pairs are used for testing on a well-known FOREX trading platform, with spreads included.

The performance of the proposed method stands out in terms of the number of trades and total profits. Specifically, the proposed patterns (Pattern 5 in Section 7) were shown to be 138 times more profitable than Doji patterns (Pattern 3), with 169 times

more trades (one per trading day versus one per 7.5 months). Additionally, the win-to-loss ratio across eight currency pairs was 6:2, compared to the Doji patterns' 4:4 ratio.

From the extensive simulations and analyses, several additional insights emerged in three key areas:

- *Market Adaptability:* The MIDDAM patterns demonstrated adaptability across different market conditions and timeframes, maintaining consistent profitability across various scenarios.
- *Pattern Robustness:* The robustness of the MIDDAM patterns was evident, as they outperformed traditional patterns even in highly volatile market environments.
- *Statistical Significance:* The high number of trades executed by the MIDDAM patterns provided a statistically significant sample size, reinforcing the reliability of the results.

Future work stemming from this study includes the following:

- *Extending Testing to Other Markets:* Applying the patterns to other financial instruments to validate their versatility and effectiveness beyond the market.
- *Incorporating Machine Learning:* Integrating machine learning techniques could help dynamically adjust the patterns based on evolving market conditions.
- *Developing Risk Management Strategies:* Implementing risk management strategies alongside the MIDDAM patterns could further mitigate potential losses and improve trading performance.

This study demonstrates that the proposed method outperforms competitors under the same conditions and can generate significant profits in a market simulator using historical data. Future research may focus on refining these patterns and exploring their application across different markets and trading environments.

AUTHOR CONTRIBUTIONS

Conceptualization, P.W.; methodology, P.W.; software, P.W.; validation, P.W. and W.P.; formal analysis, P.W.; investigation, P.W.; data curation, P.W.; writing—original draft preparation, P.W. and W.P.; writing—review and editing, P.W. and W.P.; visualization, P.W.; supervision, W.P.; All authors have read and agreed to the published version of the manuscript.

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