

Optimizing Stock Markets Trading with Poisson Process Simulation

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Abstract. Industrial and Operations Research (IEOR) is an interdisciplinary field that leverages mathematical, statistical, and computational techniques to design, analyze, and optimize complex systems. In the context of the Simulation for Enterprise-Scale Systems course, the knowledge gained from IEO can be applied to address a range of issues related to financial modeling, risk analysis, and decision-making within financial corporations. One area where simulation is particularly prevalent is in the financial markets, where price fluctuations can create significant arbitrage opportunities. The focus of this inquiry is on utilizing simulation systems to facilitate stock market trading, considering factors such as market noise, information asymmetry due to information lag, and other elements in order to optimize portfolio performance through arbitrage operations in the current market state.

Keywords: Poisson Process Simulation, Quantitative Finance, Prediction Model, Arbitrage Strategies

1. Introduction

In this research, we will examine the stock market from a business perspective and apply the Poisson process theory in order to optimize our approach. Additionally, we will utilize Industrial and Operations Research (IEOR) knowledge in the field of quantitative finance to enhance the accuracy and effectiveness of financial decision-making through the application of rigorous mathematical and statistical techniques [1-2]. Some specific examples of how Industrial and Operations Research (IEOR) principles can be applied in the field of quantitative finance include: Utilizing optimization techniques to design and implement optimal portfolio construction and asset allocation strategies that maximize returns and minimize risk. Developing and implementing algorithms for high-frequency trading, as well as automating financial decision-making processes through the use of computational methods[3-4].

1.1. Background and Preliminary

Business cycles impact stock prices, reflecting economic expansion and recession. Investors like Warren Buffett hold during downturns, while short-term traders capitalize on volatility. The double-moving average strategy simplifies trading styles, using short-term and long-term moving averages to identify buying and selling signals known as the golden cross and death cross. In a long-only market, traders enter a long position on a golden cross and exit on a death cross, waiting for the next golden cross. Parameters vary; the 2560 Method, with a 5-day above 25-day moving average, achieved a 45.38x return in 4 months. Golden crosses signal upward trends, while death crosses indicate downward trends[5].

Technical analysis employs golden crosses, death crosses, and cross cycles as indicators. Golden Cross occurs when a short-term moving average rises above a long-term moving average, signaling a bullish trend. Death Cross happens when a long-term moving average rises above a short-term one, indicating a bearish trend. Cross Cycle measures the duration between golden and death crosses, guiding traders' analysis and decision-making. The example shown in Figure 1.

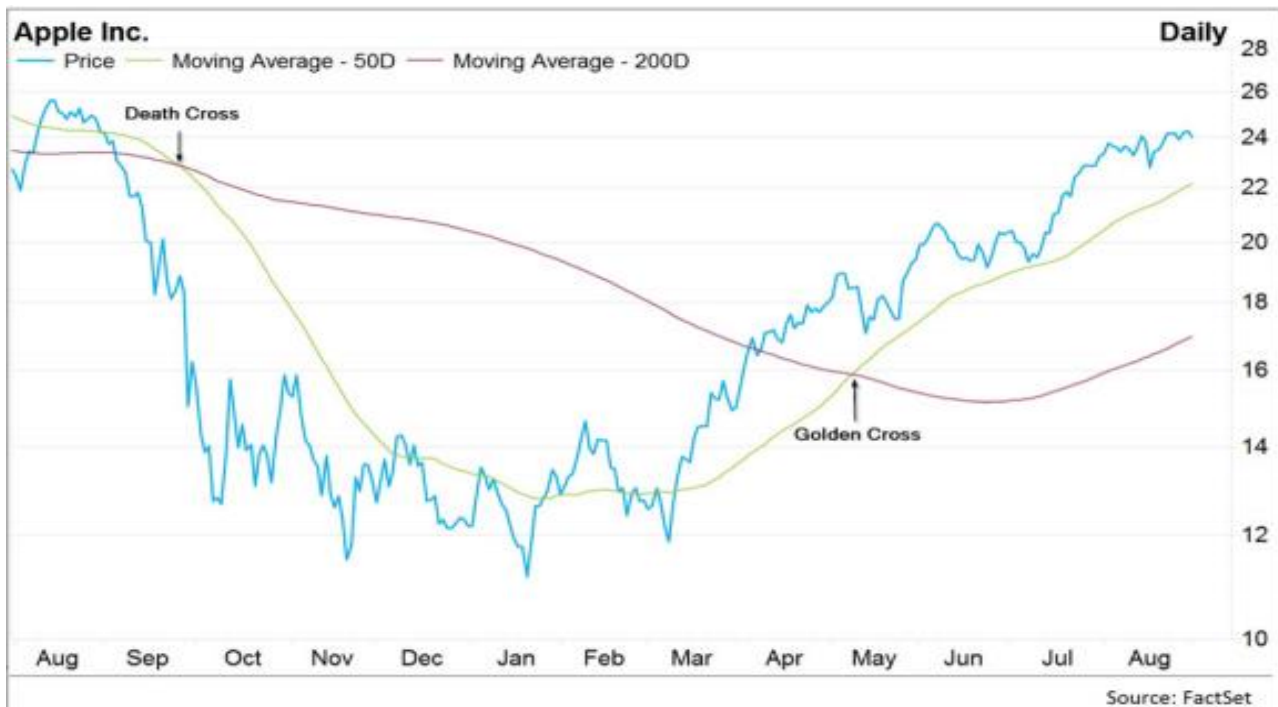


Figure 1. Illustration for Golden Cross and Death Cross as well as Cross Cycle.

1.2. Definitions

In this section, we introduce the definition [6-7] of the Counting Process, homogeneous Poisson Process, and Exponential Distribution. We state a proposition of the split of the Poisson Process that inspired us to develop the trading strategy in this paper.

Definition 1. A Counting Process, $N(t)$, is any integer valued process with the following properties:

$$N(0) = 0, N(t + s) \geq N(t). \quad \forall s \geq 0 \quad (1)$$

We will use often the notation $N(t, t + s] \triangleq N(t + s) - N(t)$ to denote the number of points counted in the interval $(t, t + s]$ and in general $N(A)$ to denote the number of points counted in a general set $A \in \mathcal{B}(\mathbb{R}^+)$

Definition 2. A homogeneous Poisson Process, $N(t)$, with the rate λ is defined as a counting process with independent and stationary increments with the property that the number of points counted in an interval $(t, t + s]$ is given by a Poisson distribution with parameter λs , i.e. $N(t, t + s] \sim \text{Po}(\lambda s)$. The property of independence and stationary of the increments implies that the number of points counted in any two disjoint intervals is given by two independent Poisson random variables whose parameters are proportional to the size of the corresponding intervals by the proportional constant λ .

Proposition 1.

Let $\{N(t), t \geq 0\}$ be a homogeneous Poisson process with the rate λ , then the inter-arrival times $\{X_n, n \geq 1\}$ are independent random variables, each of them distributed as an exponential distribution with parameter λ .

Definition 3. A Poisson process, $N(t)$, with rate $\lambda(t)$ is defined as a counting process with independent increments with the property that the number of points counted in an interval $(t, t + s]$ is given by a Poisson distribution with parameter $\int_t^{t+s} \lambda(s) ds$, i.e. $N(t, t + s] \sim \text{Po}(\Lambda[t, t + s])$, where Λ is defined as the intensity measure, with $\Lambda(A) = \int_A \lambda(t) dt$

Proposition 4 (Splitting of a Poisson Process). Assume that you have a homogeneous Poisson process, $N(t)$, with the rate λ , and that each time there is an arrival point that is colored

in red or blue with a probability that depends on its arrival epoch and independently of the colors the other points were painted. For example, if S_n denotes the position of the n -th point, then it will be colored red with probability $p(S_n)$ and blue with probability $q(S_n) = 1 - p(S_n)$. Define $N_R(t)$ and $N_B(t)$, the processes that count respectively only the "red" and the "blue" points. Then $N^R(t)$ and $N^B(t)$ are non-homogeneous Poisson processes with intensity rates $\lambda^R(t) = \lambda p(t)$ and $\lambda^B(t) = \lambda q(t)$.

The points in red and the points in blue correspond to the golden crosses and the death crosses in our paper. We assume that the complete cycle comprising golden and death crosses follows a homogeneous Poisson process. This implies that, if we consider only the golden and death crosses, they form a non-homogeneous Poisson process. This finding suggests that strategies that rely solely on golden crosses for buying and opening long positions or death crosses for selling short are unlikely to be stable and profitable. This helps explain why simple averaging strategies in financial markets today often struggle to achieve stable returns, even for stocks with long-term bullish trends, such as Kweichow Moutai[8-9]. We can also corroborate this observation by the experimental statistics that follow.

1.3. The implementation and problem of non-robust moving average strategy

The moving average, introduced by Joseph E. Granville in the mid-20th century, is a key indicator for trading signals widely used today. It represents the historical average of stock prices over N days. Granville's Eight Rules of Buying and Selling, introduced in 1962, utilized moving averages for timing opportunities, gaining popularity for its simplicity. The golden cross and death cross signals remain relevant. The moving average strategy, foundational for quantitative approaches, relies on mean reversion theory. Its main limitation is lag, hindering real-time tracking. Excessive steepness can lead to aggressive forecasts and losses. The double moving average strategy faces false signals, impacting trading decisions, especially in range-bound markets, causing capital losses.

Research uses Akshare for Chinese stock market data, emphasizing privacy protection. Pandas, Numpy, and Python process and implement the double moving average strategy on 50 institutional stocks. A Poisson process-based wait time filter enhances decision-making patience, reducing low-quality trading. Pandas Data Frame and NumPy aid simulation, employing a two-layer loop structure. Results show patience improves risk-adjusted returns and decreases maximum drawdown. The study aims to confirm this intuition, develop error mitigation methods, and enhance investment returns and net worth stability[10].

2. Robust Double Moving Average Strategy: Waiting based on the Poisson Process

2.1. Intuition Verified by Basic Data Analysis

As an example, let's consider Kweichow Moutai. As Figure 2 shown, we plot the orange curve as the short-term average with a parameter of 60 and the blue curve as the long-term average with a parameter of 200. As shown, this is a stock that has been in an overall uptrend for a significant period of time. However, in the recent trend, it has pulled back (seen in the top right corner of the chart). During this time, the short-term averages repeatedly form golden crosses or death crosses with the long-term averages as the stock price fluctuates wildly, indicating a lack of clear direction in the market. In this situation, following the golden cross and death cross signals would result in buying at the top and selling at the bottom, going long due to the golden cross signal when the trend is about to decline, and going short or closing positions due to the death cross signal when the trend is about to rise.

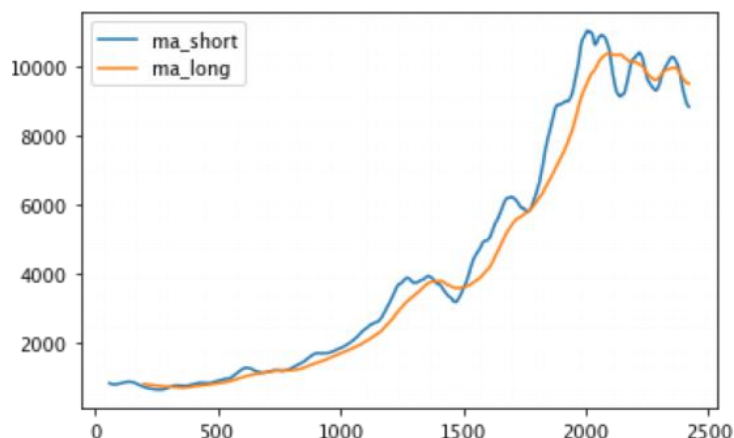


Figure 2. Visualization for Short-term ($N_1 = 60$) Moving Average and Long-term ($N_2 = 200$) Moving Average of the historical price of Kweichow Moutai.

This is because the market lacks sufficient momentum to sustain the recently formed trend, resulting in movement in the opposite direction. In this repeated oscillation, investors will incur substantial losses. Our argument is not that the law of moving averages is invalid, but that investors are not patient enough to capitalize on the rapid initial gains in the hope that the stock's growth story will continue, which, as demonstrated by the facts, is often incorrect. Therefore, we believe that it is advisable to exit the market temporarily after a profit-taking death cross signal and wait a sufficient period before reentering the market. In this study, this is modeled as the waiting time of the Poisson process, i.e., waiting for the next truly valid profit-taking signal (event) before entering the market. As we assume that the Poisson process is homogeneous, i.e., its parameters are constant, we can predict the duration of the waiting period with a certain level of reliability.

To verify this seemingly simple intuition, we perform a basic analysis of historical data to determine whether this intuition holds true in the actual market. We assume that the short-term moving average has a parameter of 5 and the long-term moving average has a parameter of 10, simulating a double moving average strategy used by an aggressive trader. Upon observing the chart, this trader would notice that the two moving averages are constantly intertwined, with constant golden cross signals or death cross signals. We aim to understand the pattern of the occurrence of these golden cross signals and death cross signals.

Therefore, we first calculated the average trend of Kweichow Moutai over the past 10 years and applied the counting process to the frequency of golden cross signals. In the chart below, we plotted the cumulative number of golden cross signals as a line in chronological order. At the same time, we also plotted a red straight line for comparison. It is evident that the occurrence of golden crosses is generally smooth and consistent, but there is a period of time (between approximately day 1500 and day 2000) during which its frequency changes. Counting Process of Golden Crossovers are shown in figure 3.

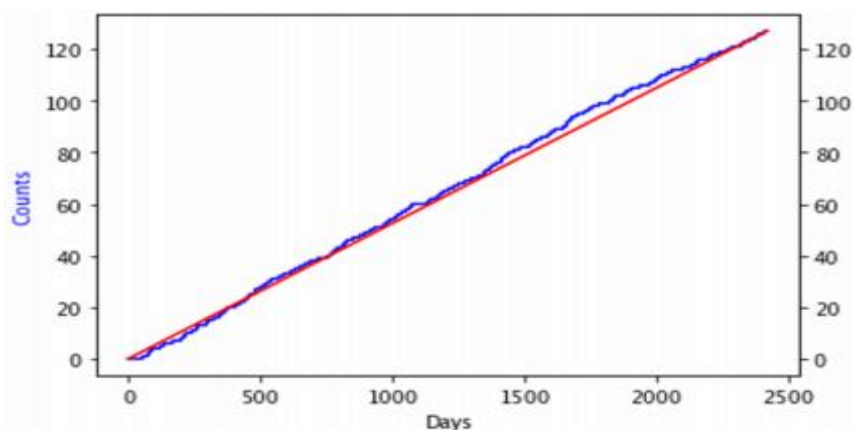


Figure 3. Counting Process of Golden Crossovers ($N_{\text{short}} = 5$, $N_{\text{long}} = 10$).

Upon examining the counting process for dead cross signals, a similar pattern is observed (figure 4).

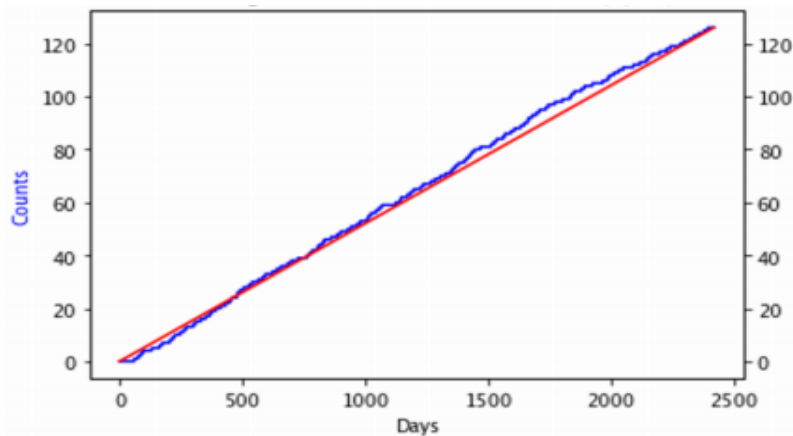


Figure 4. Counting Process of Death Crossovers ($N_{\text{short}} = 5$, $N_{\text{long}} = 10$).

If we change the parameters of the long and short term averages, we find similar results, as shown in figure 5 and figure 6.

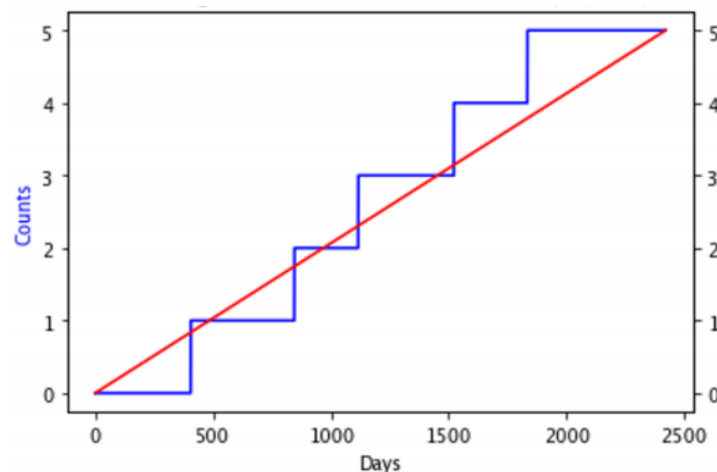


Figure 5. Counting Process of Golden Crossovers ($N_{\text{short}} = 60$, $N_{\text{long}} = 200$).

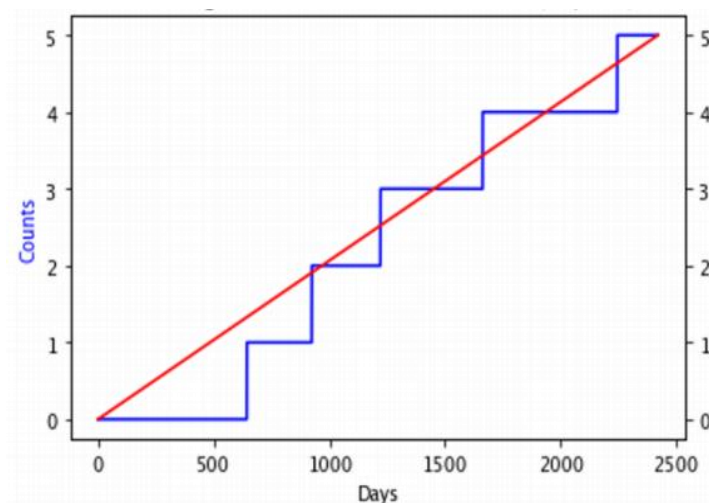


Figure 6. Counting Process of Death Crossovers ($N_{\text{short}} = 60$, $N_{\text{long}} = 200$).

The distribution of intervals between consecutive golden crosses (or dead crosses) for a double moving average strategy with short-term moving average parameter of 5 and long-term moving average parameter of 10 appears to follow an exponential distribution, as shown in the histograms depicted in the figure 7 and figure 8.

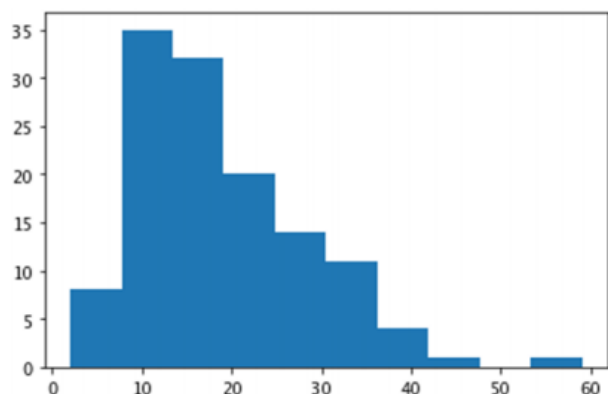


Figure 7. The Distribution of Intervals between Consecutive Golden Crosses

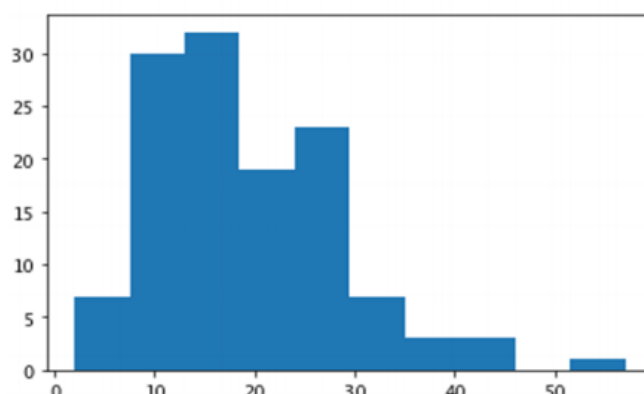


Figure 8. The Distribution of Intervals between Consecutive Death Crosses

The intervals between golden and dead cross signals in a double moving average strategy with short- term and long-term moving average parameters of 5 and 10, respectively, exhibit an exponential distribution that is right-skewed. This suggests that there are a small number of signals that occur frequently in the short term, which may be best avoided by adopting a more patient approach based on the Poisson process. By waiting for the next valid signal, traders can avoid entering the market during oscillating trends, where multiple forces may not have sufficient momentum to launch a strong attack. This philosophy of waiting until the appropriate moment to enter the market is reflected in the positively skewed distribution of the waiting time between golden and dead cross signals.

2.2. Cross Cycles are Homogeneous Poisson Processes but Golden/Death crosses Are Not.

In this study, we have previously define the cross cycle is a technical indicator that is formed by the convergence of a short-term and a long-term moving average. It is characterized by the occurrence of a golden cross, followed by a death cross, or vice versa. In trading software, the cross cycle appears as a circular pattern formed by the intersection of the short-term and long-term moving averages. we investigate the occurrence and characteristics of cross cycles in the financial market using the example of the Chinese A-share market. Specifically, we analyze the distribution of the duration of cross cycles and the returns generated by trading according to cross cycles. Our analysis aims to understand whether cross cycles can provide a more robust and profitable trading strategy compared to solely relying on golden crosses or death crosses.

This brings us to our concerns, which are: what is the distribution of the duration time of golden-to- death cross cycle?

And this interval is measured from the point at which the short-term moving average first crosses above the long-term moving average (the golden cross) to the point at which the gap between the short-term and long-term moving averages subsequently closes (the death cross). Understanding the distribution of these intervals can provide insight into the frequency and duration of these cross cycles in the financial market.

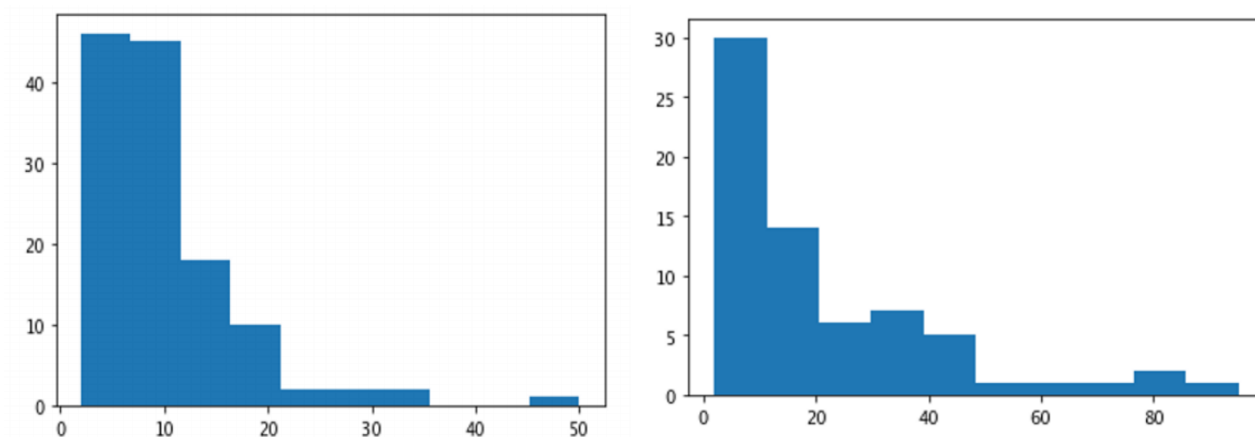


Figure 9. The Duration of Crossovers ($N_{\text{short}} = 5$, $N_{\text{long}} = 10$).

As the above figure 9 shows, the duration of crossover (say between MA5 and MA10) is exponentially distributed.

One way to improve the robustness of a moving average strategy is to increase the parameter of the long-term moving average while maintaining the parameter of the short-term moving average. This can lead to a clearer exponential distribution of the duration of golden-to-death cross cycles, as shown in the figure 10 below. This suggests that there may be false positive signals that can be eliminated in order to improve the reliability of the strategy.

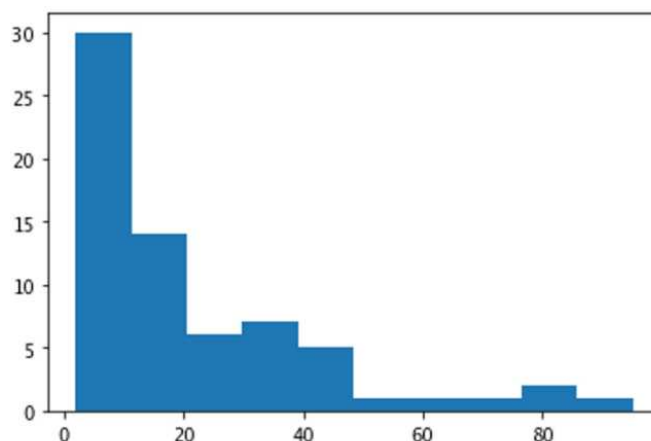


Figure 10. The Duration of Crossovers ($N_{\text{short}} = 5$, $N_{\text{long}} = 10$).

The analysis of the cross cycle duration constructed using the moving average indices MA5 and MA20 reveals that the distribution of the indices decays rapidly. In approximately 75% of cases, the golden cross is followed by a dead cross within 30.25 days of trading. However, there are instances where the closing price of the stock experiences such strong upward movement that the long-term averages are unable to catch up to the short-term averages, resulting in the prolongation of the cross cycle for more than 80 days. This scenario, while uncommon, presents an opportunity for significant profit through the extended holding of the stock without the need to sell. However, this typically only occurs during bull markets.

2.3. SMA strategy w/ or w/o Poisson Waiting Time on SSE 50 Index

Our research focuses on improving the results of the double mean strategy for rejecting low quality false positive signals. To achieve this goal, we utilize our knowledge of Poisson processes and exponential distributions.

There are several other approaches that have been proposed for improving the double mean strategy, such as: Using oscillators like the RSI(Relative Strength Index) to trade only in highly volatile markets, whether the market is overbought or oversold; Using faster or more averages like the

Exponential Moving Average (EMA) or Guppy Multiple Moving Average (GMMA) to generate more deterministic signals; Adjusting parameters to better fit certain stocks.

Our method differs from these approaches in that it does not require the incorporation of additional information. Instead, it relies on analysis of the signals generated by the averaging system itself to make trading decisions. We believe that our method is both novel and efficient in comparison to these other approaches.

Having completed the aforementioned analysis and drawing upon our experience, it is now appropriate to compare the traditional double moving average strategy to the enhanced double moving average strategy based on the Poisson process waiting time. The sample chosen for this comparison consists of the components of the SSE 50 index, which comprises 50 stocks that are representative of the fundamentals of China and are often favored by institutional investors due to their solid trends and higher liquidity. The inclusion of these stocks in the sample is justified by their proven pricing model, which aligns their stock price movements with the overall market trend and minimizes noise resulting from the influence of individual investors.

The double moving average trading strategy is a straightforward approach involving the portfolio manager of 50 traders, each responsible for a specific stock. The strategy involves initiating a full position in the corresponding stock when a golden cross is formed through the crossing of the short-term and long-term averages. In the event of a dead cross, the trader will evaluate the presence of a position in the corresponding stock and choose to sell if one exists, or take no action if it does not. As the Chinese stock market does not permit short selling, this scenario is not considered in the strategy.

To conclude the trading period, the historical records of all traders are examined and their net performance is calculated. The results of each trader are then reported to their respective superiors, and the final performance of the managers is used to determine the overall performance of the strategy. It is worth noting that due to the differing listing dates of the 50 stocks, some traders may not engage in trading during the early days.

The effectiveness of the strategy is assessed through the use of a net worth curve to analyze the amount of money earned over time and by examining the maximum drawdown, which reflects the potential loss that could have been incurred. The maximum drawdown is a crucial consideration as it determines the psychological state of the owner, in this case, the psychology of the individual implementing the strategy. If the maximum drawdown is excessively high, it may lead to the discontinuation of the strategy in a losing position, thereby forfeiting the opportunity for subsequent gains and returns. In extreme cases, a maximum drawdown that is too large may even result in bankruptcy, making it impossible to regain financial stability.

The results of the double moving average strategy, with the short-term moving average set to 20 and the long-term moving average set to 120, are as below:



Figure 11. The Total Market Value and Maximum Drawdown of Traditional Double Moving Average Strategy ($N_{\text{short}} = 20$, $N_{\text{long}} = 120$).

We will get a return of approximately 2.88 times over 2,500 trading days with a starting capital of \$10 million, with a maximum drawdown of 24.52% over the period in figure 11.

To improve the performance of the strategy, a mechanism inspired by the Poisson arrival of trading opportunities is introduced by incorporating waiting time into the strategy and the traders' approach. Specifically, following the triggering of a dead cross signal, traders will evaluate the presence of long positions in the 50 stocks and close them if necessary. This marks the completion of a cross cycle, after which the traders enter a period of waiting. It is assumed that golden cross signals that occur during this waiting time are likely false positives, and traders will therefore not respond to them.

Once the waiting time exceeds N days, trading is initiated upon the occurrence of a golden cross signal. This involves the acquisition of a full position in the corresponding stock that triggered the golden cross signal, which is then held until the subsequent dead cross signal is triggered, forming a cross cycle.

We found interesting phenomena by setting different $N = 10; 20; 40$. By setting N to 10 days, our traders will wait 10 days after the completion of a cross cycle formed by the MA20 and MA120 moving averages before responding to a new golden cross signal. As shown in the chart, this approach resulted in a return of approximately 2.94 times and a reduction in the maximum drawdown from 24.52% to 21.56% compared to the traditional double moving average strategy. This outcome supports the viability of the proposed approach and demonstrates that in chaotic and unpredictable markets, simple laws governing the cross cycle and the waiting time of the Poisson process can be identified. However, it is important to recognize that the operation of the market is influenced by various other factors, such as policies, unexpected events, and company announcements, and therefore it is necessary to filter out the noise of the market and avoid premature formation of the next cross cycle. The Total Market Value and Maximum Drawdown of Robust Double Moving Average Strategy is shown in figure 12.

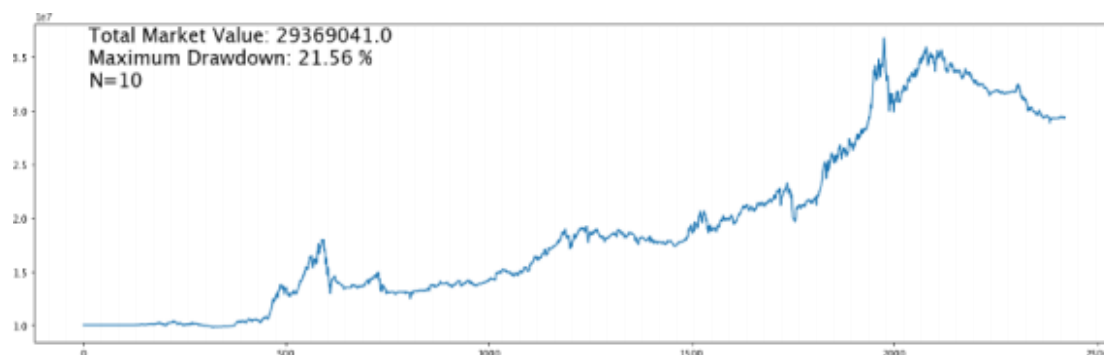


Figure 12. The Total Market Value and Maximum Drawdown of Robust Double Moving Average Strategy ($N_{\text{short}} = 20$, $N_{\text{long}} = 120$, $N_{\text{waiting}} = 10$).

As demonstrated in the below images figure 13, when N is set to 20 and 40 days, the total market value of the account decreases slightly while the maximum retracement decreases significantly from 21.56% to 18.70% and 17.67%. This represents an impressive relative improvement of 18.04% calculated as $(21.56 - 17.67) / 21.56$.

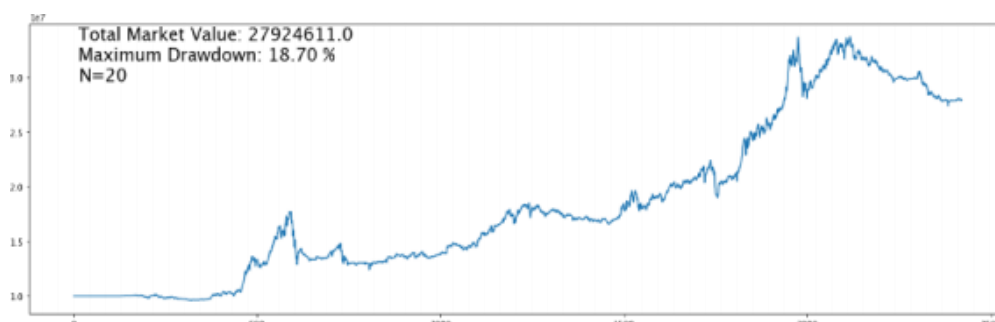


Figure 13. The Total Market Value and Maximum Drawdown of Robust Double Moving Average Strategy ($N_{\text{short}} = 20$, $N_{\text{long}} = 120$, $N_{\text{waiting}} = 20$).

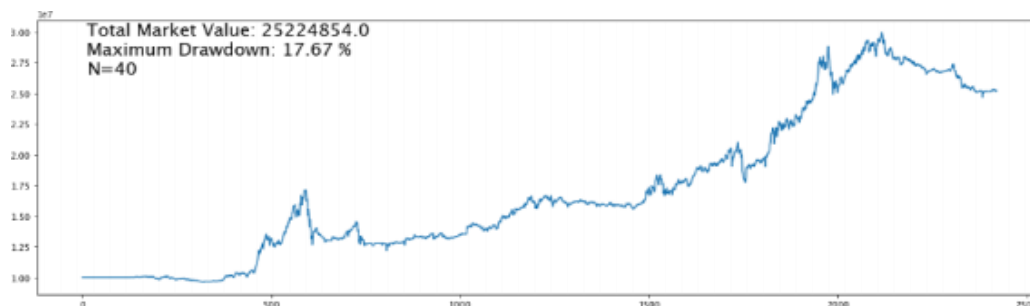


Figure 14. The Total Market Value and Maximum Drawdown of Robust Double Moving Average Strategy ($N_{\text{short}} = 20$, $N_{\text{long}} = 120$, $N_{\text{waiting}} = 40$).

These results in figure 14 indicate that by incorporating a waiting period and filtering out low quality trading opportunities, the double moving average strategy is able to achieve a rate of return while taking on less risk, resulting in higher risk-adjusted returns. This demonstrates the value of adopting a more cautious approach and rejecting frequent but potentially unprofitable trades.

3. Conclusion

The traditional double moving average strategy, foundational for quantitative approaches and backtesting, performs better with increased patience, yielding a more robust curve and improved returns. This patient approach also fosters a risk-aware mindset during actual trading, potentially applicable to other backtested quantitative strategies. Addressing the challenge of false positives in stock market signals, our research emphasizes patience to filter out low-quality signals, enhancing the overall performance of the double moving average strategy. Our research's main objective is to innovate and overcome the limitations of the double moving average strategy by incorporating a Poisson process-based trading waiting time. Further exploration involves determining optimal parameters for individual stocks, rational capital allocation, and validating results in broader markets beyond the initial 50 stocks studied. Through these investigations, we aim to develop an effective strategy for improving financial decision-making in the stock market.

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