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Investment model based on BP neural network and dynamic programming

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Abstract: In order to provide investors with some effective strategies to adapt their investments to various objective conditions, increase their returns and reduce their losses as much as possible, we develop mathematical models for the changes in the value of the two assets and derive the optimal investment strategies and evaluation rationale. First, this thesis build time series forecasting models on the value of gold and bitcoin; then use BP neural network prediction model on the values of gold and bitcoin. Then we build dynamic programming based optimal decision optimization algorithm model.

1. Introduction

In history, gold, as the general equivalent of the role of the world for a long time, is the real economic life of the real means of purchase and means of payment. After the collapse of the gold standard and gold coins stop circulation, gold still maintain its monetary properties until the 1970s gold demonetization. After the demonetization, gold is still part of the international reserve assets of each country.

The world's first international gold market in the early 19th century in London. After the outbreak of the Second World War, because the free trade of gold was greatly restricted, the London gold market had closed for 15 years. The world gold market re-called completely free trading market, is in the Bretton Woods system after the collapse.

Under the Bretton Woods system, the official exchange price of gold was $35 per ounce of gold. 1980s, the price of gold had climbed to a high of $850 per ounce. since the late 1990s, the international market had a rare gold selling wave, especially the central banks of all countries have reduced gold reserves. the price of gold on July 6, 1999 had fallen to $256 per ounce. Since then it began to rise gradually, and on March 18, 2008, it reached 1002.8 U.S. dollars.

The international gold market circulation system, is a multi-level, multi-form market collection. There are inter-bank invisible gold market, gold spot trading tangible market, gold retail market and so on[1].

The worldwide financial crisis that spread from the United States to the world in 2008 made more people aware of the important impact of the evolution of the monetary system on a country's economy and even on world finance. Thereafter, a man calling himself Satoshi Nakamoto emailed a paper on virtual currencies, describing his vision of a decentralized electronic currency, and the beginnings of Bitcoin were revealed. In early 2009, Satoshi Nakamoto, the "father of Bitcoin," introduced the concept of Bitcoin on the Internet. According to Satoshi Nakamoto's vision of

Bitcoin, the most important features of Bitcoin are its finite total number, open information, all transactions are recorded by Internet nodes, and decentralization without government or third-party institutions to restrict its development.

With the development of the economy, people also have more idle funds in their hands, and the demand for investment and financial management has also increased greatly. However, in today's world financial investment market there is a mismatch between the supply and demand of financial management channels and levels, and the supply level cannot meet the growing demand for investment and financial management, especially in the world's universal virtual market, there is a lack of such virtual products investment goods. Therefore, the emergence of bitcoin has greatly filled the gap in the world's financial investment market products. Therefore, Bitcoin will have more functions as a virtual market investment product in the future development. In addition, bitcoin also plays the role of a value preserver for financial market turmoil. While the world economy continues to grow in absolute terms as productivity advances, the world's financial markets are becoming more volatile, so the existence of a collateral function brings a huge market for bitcoin[2].

At the request of market traders, basing upon the trading prices of gold and bitcoin on a five-year trading period from November 9, 2016 to October 9, 2021, we need to solve：Validate the validity of the time series model using intrinsic trend analysis and smoothness verification of known data. Develop a neural network model about the trading strategy based on the price data of the day that gives the best daily trading strategy. And use the model to derive how much an initial investment of $1,000 starting on October 9, 2021 is worth. Perform a dynamic programming based optimal decision optimization algorithm on this model and prove that the model is the most efficient.

2. Optimal trading strategy modeling and results

2.1 Time series forecasting and bp neural network forecasting on gold and bitcoin

Plot of the original data, model fitted values[3], and model predicted values for this time series model is shown as figure 1.

Figure 1 Time series forecasting

Comparison of predicted and actual values of the given bitcoin price after training by bp neural network model is shown as figure 2.

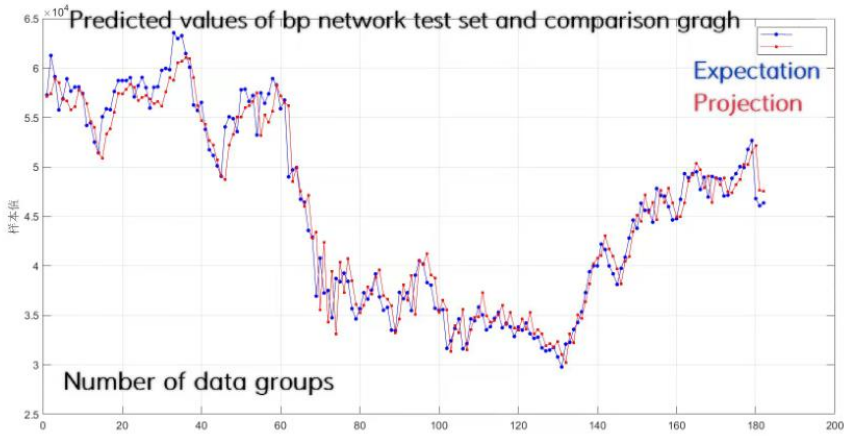

Figure 2 BP neural network prediction

2.2 Comparing the predictions of both

By comparing the predictions of both, we finally chose the time series analysis (ARIMA) for prediction.

Table 1 ADF Inspection Form

Variables	Difference order	t	p	AIC	Threshold		
					1%	5%	10%
Value	0	-0.238	0.934	29168.936	-3.434	-2.863	-2.568
	1	-8.535	0.000***	29151.816	-3.434	-2.863	-2.568
	2	-15.723	0.000***	29187.267	-3.434	-2.863	-2.568

Note: ***, **, * represent 1%, 5%, 10% significance level respectively

The above table shows the results of the ADF test, including variables, difference orders, t-test results, and AIC values, which are used to test whether the time series is smooth.

● The model requires that the series must be a smooth time series data. By analyzing the t-value, it is analyzed whether it can significantly reject the original hypothesis that the series is not smooth

● if it presents significance ($p<0.05$ or 0.01), it indicates that the original hypothesis is rejected and the series is a smooth time series, and vice versa, it indicates that the series is an unstable time series[4].

● Comparison of the statistical values of critical values 1%, 5%, 10% different degrees of rejection of the original hypothesis and ADF Test result, ADF Test result less than 1%, 5%, 10% at the same time means that the hypothesis is very well rejected.

● Difference order: essentially the next value, minus the previous value, mainly to eliminate some fluctuations to make the data smooth, non-smooth series can be transformed into smooth series by difference transformation.

● AIC value: a measure of the goodness of fit of the statistical model, the smaller the value the better.

● Critical value: The critical value is a fixed value corresponding to a given level of significance.

The results of this serial test show that based on the field Value:

At the difference of order 0, the significance P-value is 0.934, the level do not present significance, the original hypothesis cannot be rejected and the series is an unsteady time series.

At the difference of order 1, the significance P-value is 0.000***, the level of significance is presented, the original hypothesis is rejected, and the series is a smooth time series.

At the difference of order 2, the significance P-value is 0.000***, which presents significance at the level, and the original hypothesis is rejected, and the series is a smooth time series.

Table 2 Model parameters table

	Coefficient	Standard deviation	t	p>|t|	0.025	0.975
Constant	25.067	18.656	1.344	0.179	-11.498	61.632
ma.L1.D.Value	-0.076	0.023	-3.233	0.001	-0.122	-0.03
ma.L2.D.Value	0.068	0.023	2.955	0.003	0.023	0.113

Note: ***, **, * represent 1%, 5%, 10% significance level respectively

The above table shows the results of this model parameters, including the coefficients and standard deviations of the model, t-test results, etc., which are used to analyze the model formula.

Based on the field Value, the model results for the ARIMA model (0,1,2) test table and based on 1 difference data, the model equation is as follows.

$$y(t)=25.067-0.076*\varepsilon(t-1)+0.068*\varepsilon(t-2)$$

Table 3 Predicted value

Order (time)	Predicted results
1	46263.803
2	46327.68
3	46352.747
4	46377.814
5	46402.881
6	46427.948
7	46453.014
8	46478.081
9	46503.148
10	46528.215
11	46553.282
12	46578.349
13	46603.416
14	46628.483
15	46653.549
16	46678.616
17	46703.683
18	46728.75
19	46753.817
20	46778.884
21	46803.951
22	46829.018
23	46854.084
24	46879.151
25	46904.218
26	46929.285
27	46954.352
28	46979.419
29	47004.486
30	47029.552
31	47054.619

The above table shows the time series model for the last 31 periods of data prediction.

3. Optimal decision optimization algorithm based on dynamic programming

3.1 Overall idea

For the daily optimal trading strategy problem, we build an investment decision model with the objective of maximizing daily returns and solve it using dynamic programming. Firstly, we establish a linear programming model and prove that the problem is an NP problem; secondly, we transform the original problem into a dynamic programming model and design a dynamic programming algorithm to solve it; finally, our computational experiments prove that the computational efficiency of the dynamic programming-based algorithm is better than other algorithms, and the quality of the algorithm solution is also better guaranteed.

3.2 Dynamic planning modeling

Decision variables: C,G,B

$$\begin{aligned} \mathrm{R} &= \propto * \max(\mathrm{C}+\mathrm{G}+\mathrm{B}-1000-0.01\mathrm{g}-0.02\mathrm{B}) \quad (1)\\ &= \propto * \max(\mathrm{C}+0.99\mathrm{G}+0.98\mathrm{B}-1000) \end{aligned}$$

Capacity:C=1000
Item selection vector:$\mathrm{X}=\{x_1,x_2\}$
Buying at x_i>0.
Item value vector $\mathrm{P}=\{P_1,P_2\}$
Constraints:

$$\sum x_i p_i \le C-0.01G-0.02B \quad (2)$$

Objective function:

$$\max \sum x_i p_i \quad (3)$$

Define $V_n * C$ matrix, each $V_{(i,j)}$is a subproblem that represents the optimal combination of the first i elements when the current capacity is j.

$$V_{(1,j)} = p_1, j \ge x_1 p_1(1) \quad (4)$$

$$0 < \mathrm{j} < x_1 p_1 \quad (5)$$

$$V_{(i,j)} = MAX(v_{(i-1,j)}, v_{(i-1,j-x_1 p_1)}) \quad (6)$$

$$j \ge x_1 p_1(2) \quad (7)$$

$$0 < \mathrm{j} < x_1 p_1 \quad (8)$$

Since bitcoin is up and tradable every day, we spend all $1,000 on bitcoin trading, and by our algorithm, the account balance is $65,200 on October 9, 2021, for a final return of 6520%[5].

4. Optimality arguments for optimal strategy models

Artificial neural network, also referred to as neural network or called connectivity model, is an algorithmic mathematical model that mimics the behavioral characteristics of animal neural networks for distributed parallel information processing. This kind of network relies on the complexity of the system to process information by adjusting the relationship between a large number of internal nodes interconnected with each other.

Gold and bitcoin using neural networks are more accurate and more stable relative to time series.

Thus, it provides accurate data as the basis for the strategy selection model.

Dynamic programming is mainly used to solve the optimization problem of dynamic processes divided into phases by time, but some static planning (such as linear planning, nonlinear planning) that is not related to time can be solved conveniently by dynamic programming methods as long as the time factor is artificially introduced and it is considered as a multi-stage decision process.

Therefore, in this problem, dividing the investment decision into multiple stages and using dynamic planning can solve this problem well, thus making the model optimal.

5. Conclusion

The buying and selling of volatile assets often occurs among market traders with the aim of maximizing total returns. Almost every transaction will have a transaction cost occur. Two of these assets are gold and bitcoin. The difference in value changes between the two assets results in different returns and risks for the investor, which increases the presence of risk while providing substantial returns for the investor, and wrong decisions will have adverse effects for the investor. In order to provide investors with some effective strategies to adapt their investments to various objective conditions, increase their returns and reduce their losses as much as possible, we develop mathematical models for the changes in the value of the two assets and derive the optimal investment strategies and evaluation rationale.

After using this model for planning, it can be concluded that the subject matter with a large increase, theoretically all the existing assets should be used to invest in this kind of subject matter, but based on the uncontrollable risk of the financial market and the consideration of the perceived factors, some assets should be used to invest, within the measurable range, with relatively certain returns to offset part of the risk, in order to achieve the prevention and control of risk.

References

[1] Shen C, Zhang W. Economic analysis on tax model based on BP neural network[C]//2009 International Conference on Communications, Circuits and Systems. IEEE, 2009: 569-572.

[2] Zhou W, Zhao Y, Chen W, et al. Research on investment portfolio model based on neural network and genetic algorithm in big data era[J]. EURASIP Journal on Wireless Communications and Networking, 2020, 2020(1): 1-12.

[3] Cao J, Wang J. Exploration of stock index change prediction model based on the combination of principal component analysis and artificial neural network[J]. Soft Computing, 2020, 24(11): 7851-7860.

[4] Qun Liu, Shuxin Liu, Guoyin Wang, Shuyin Xia. Social relationship prediction across networks using tri-training BP neural networks[J]. Neurocomputing, 2020, 401(prepublish).

[5] Minrong Chen, Bipeng Chen, Guoqiang Zeng, Kangdi Lu, Ping Chu. An adaptive fractional-order BP neural network based on extremal optimization for handwritten digits recognition[J]. Neurocomputing, 2020, 391(prepublish).