A price prediction model for gold and Bitcoin based on Long Short-Term Memory

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Abstract. We built a price prediction model for gold and Bitcoin based on LSTM. For the first 30 days, we adopted a wait-and-see strategy without any transactions. Starting from the 31st day, we first trained the model with the data of all past trading days. Then use the trading data of the past 30 days to forecast the market price for the next 6 days. Then, we established a trading strategy model based on linear programming and made this week's trading decisions based on the predicted value of the market price in the next 6 days. Finally, we plotted the yield curve based on asset value.

Keywords: LSTM, dynamic-linear programming, Entropy weight method.

1. Introduction

Today, when the real economy continues to slump, more and more people tend to deposit money in banks [1]. However, the interest rate of banks does not change much. To obtain more profits, families with slightly better conditions tend to invest part of their money to buy stocks and futures, but high benefits are often accompanied by high risks, so they will expect to find investment products with high returns but relatively low risks. However, is there such an investment product meeting the conditions? Fortunately, two common investment products fit it [2-3].

1.1 Background and Restatement of problems

We commonly consider Bitcoin and Gold as global safe-haven assets [4-5]. Now, we have obtained all transaction data of Gold and Bitcoin from September 11, 2016, to September 10, 2021, and the dates without statistics from September 11, 2016, to September 10, 2021, are closed days. To get the maximum return under the condition of a certain principal, we need to establish a reasonable model to analyze the trading situation of Bitcoin and gold and formulate corresponding trading strategies [6-8].

1.2 Assumptions

(1) If we want to make a profit, we can only do it by buying and selling gold and bitcoin, with zero gains in bank deposits and stocks (due to no information on bank deposit rates and stocks)

(2) The total amount of gold is fixed and large enough, and the total amount of Bitcoin is also fixed and large enough (if the amount of gold and Bitcoin changes all the time, the data is not easy to obtain and difficult to analyze, if the total amount is not enough, it will have a greater impact on maximizing the profits)

(3) In addition to the value of gold and Bitcoin itself, we do not consider the impact of other factors on the price (the data provided is limited, and the data on other factors is not easy to obtain)

(4) Short selling is not allowed in asset investment, that is, investors are only allowed to sell the assets they hold (if short selling is possible, the total amount of assets invested cannot be fixed, and it is difficult to predict)

(5) Our decisions are based solely on the risks and rewards of trading gold and bitcoin. We do not consider the possibility of obtaining information from other sources (because it is difficult to determine its influence on decision-making)

(6) In the transaction process, to get free assets after the transaction, it takes one day to wait, and the free assets obtained are based on the transaction status of the previous day (this assumption is based on the fact that Chinese asset investment market cannot obtain free assets on the day of the transaction, and the free assets obtained the next day are based on the previous day's market price)

During the market closing, the price of the asset is equal to the price on the last day[9-14].

1.3 Variable Description

The variables are shown in table 1.

Table 1. The variables

VARIABLE NAME	EXPLANATION
a_{gold}, a_{bit}	Quote rate of change
z	Total assets held
r_{gold}, r_{bit}	Gold Yield, Bitcoin Yield
T_{gold}, T_{bit}	Gold trading volume, Bitcoin trading volume
V_{gold}, V_{bit}, V_{free}	The total value of gold assets currently held, Current value of Bitcoin assets held, Current free funds held
E_{value}	Equivalent Free Fund

2. Best investment strategy

Determining the best investment strategy will require looking into the future, so we disassemble the required model, that is, a prediction model for predicting the price of gold and bitcoin for a certain period in the future, and a decision model for buying and selling the gold and bitcoin based on the predicted price of them.

2.1 Data Processing

After comparing and analyzing the two data files: B CHAIN-MKPRU.csv and LBMA- GOLD.csv, we have drawn the following conclusions:

(1) Bitcoin price data is complete with no missing values

(2) Gold has missing values every Saturday and Sunday because the market is closed on Saturdays and Sundays

(3) In addition to Saturday and Sunday, gold also has missing values on other non-Saturday and Sunday dates, and this happens from Monday to Friday. It is speculated that it is due to special circumstances that cause W

Based on the above, we processed the provided dataset as follows:

Remove the data of Bitcoin 2016-09-11 to keep the starting time of the dataset consistent

Make up for the missing date of gold, the market value of gold on the corresponding day of the missing date is the same as the previous day

Consolidate Bitcoin and Gold market cap tables by date

At the same time, considering the impact of data fluctuations on model training, we normalized all the data of gold and Bitcoin in advance.

2.2 Prediction model based on LSTM

We first tried to use the gray prediction model to predict the price trend of gold and bitcoin, but after testing, the relative deviation of the model prediction was as high as 58.9%, and when the effect of the prediction model was poor, our decision based on it can be difficult to get better results. Therefore, to achieve a better prediction effect, we decided to use a more complex but better neural

network model to build a prediction model. Considering that when predicting price trends, we should pay more attention to recent data. So we tried to build our prediction model based on the LSTM network based on long short-term memory.

LSTM (Long short-term memory, LSTM) is a special RNN. The difference between the two is that the ordinary RNN has only one state inside a single loop structure. In contrast, there are four states inside a single recurrent structure (aka cell) of LSTM. Compared with RNN, the LSTM recurrent structure maintains a persistent unit state that is continuously passed on, which is used to decide which information to forget or continue to pass.

An RNN containing three consecutive cyclic structures is shown in the figure below, and each cyclic structure has only one output. The concrete structure is as figure 1.

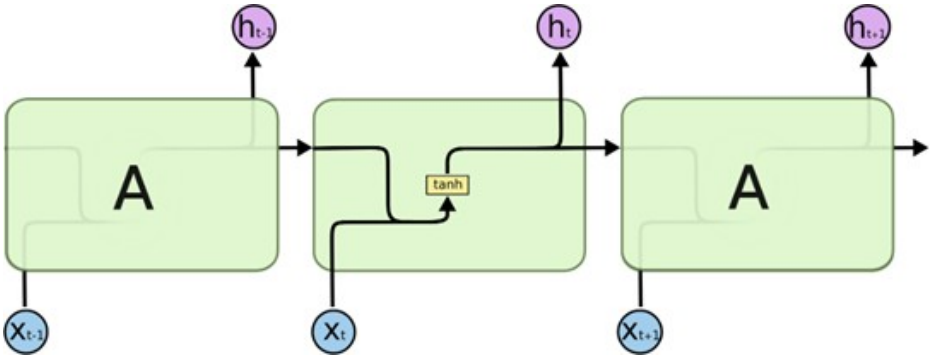

Figure 1. The concrete structure

Instead for LSTM, each cyclic structure has two outputs, and the following is the structure. The results are shown in figure 2.

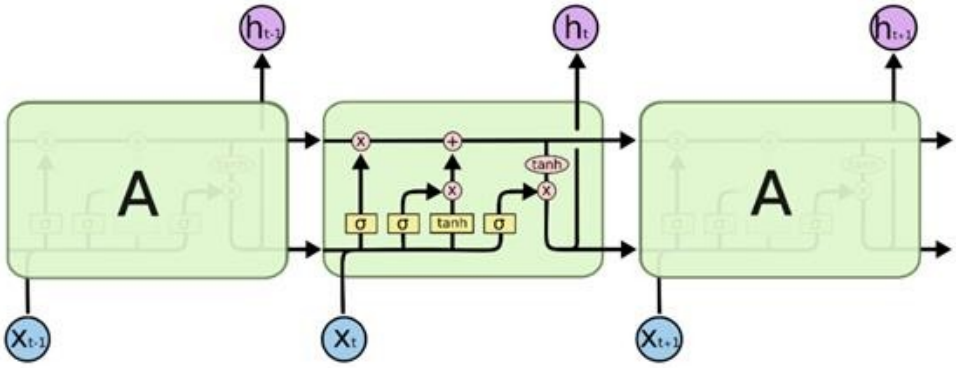

Figure 2. Instead for LSTM, each cyclic structure has two outputs, and the following is the structure

- LSTM cells consist of input gates, forget gates, output gates, and cell states.
- Input gate: Determine how much of the input data of the network at the current moment needs to be saved to the cell state.
- Forget gate: Determine how much of the cell state at the previous moment needs to be retained to the current moment.
- Output gate: Controls how much of the current cell state needs to be output to the current output value.

2.2.1 Model Establishment

LSTM models are based on the concept of time windows, so we need to process the data before we can train the model and make predictions. The specific method of data processing is shown in the following figure 3.

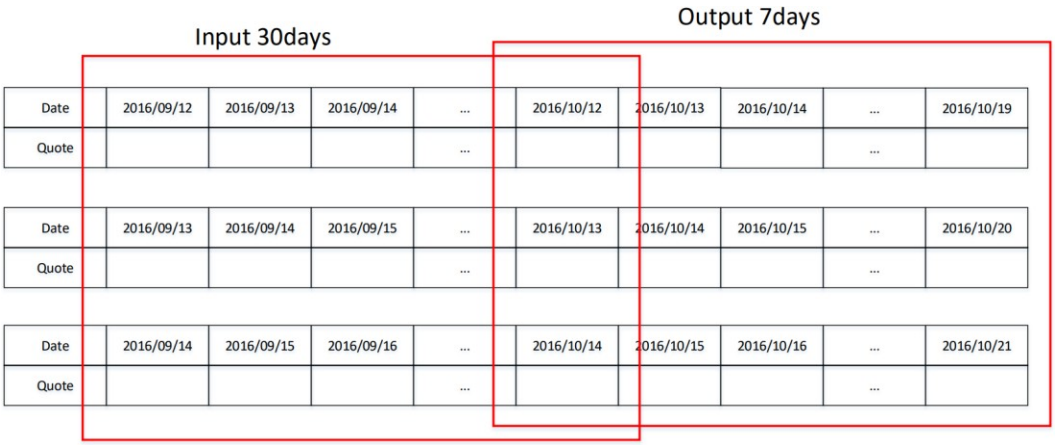

Figure 3. The specific method of data processing

2.2.2 Model parameter adjustment

To determine whether the prediction effect of LSTM is good enough, we consider starting from the simplest neural network, constructing one layer of input and one layer of output, using 8 neurons as a time window of thirty days, and evaluating the feasibility of the LSTM model. Finally, it is found that the deviation between the predicted value and the actual value is only 20 %. This result has a great advantage compared with the grayscale model.

After that, we use the grid method to optimize the parameters and try to adjust the number of input layers, the number of output layers, the time window, and the number of neurons.

Finally, we determine two sets of optimal parameters for the price trends of gold and Bitcoin. The specific model information is shown in the following table 2.

Table 2. The specific model information

Layer(type)	*Output Shape*	*Param*
LSTM_1	(None, 30, 12)	672
Droupout_1	(None, 30, 12)	0
LSTM_2	(None, 12)	1200
Dropout_2	(None, 12)	0
Dense	(None, 7)	91

Considering that we can predict the daily price changes of the trading market through the LSTM model, we decide to use the dynamic programming model to make decisions on the daily market transactions of gold and bitcoin.

2.3 Decision model based on dynamic and linear programming

2.3.1 Theoretical basis of a model

Dynamic programming is a branch of operations research, which is the process of solving the optimization of the decision-making process. In the early 1950s, American mathematician Bellman (R. Bellman) and others proposed the famous optimization principle when studying the optimization problem of a multi-stage decision-making process, thus creating dynamic programming. The application of dynamic programming is extremely wide, including engineering technology, economics, industrial production, military and automation control, etc., and in the knapsack problem, production and operation problems, capital management problems, resource allocation problems, shortest path problems and complex system reliability problems, etc. achieved remarkable results

Dynamic programming algorithms are often used to solve problems of some optimal nature. In this type of problem, there may be many feasible solutions. Each solution corresponds to a value, and we want to find the solution with the optimal value. Gold and Bitcoin are risk assets, their daily price changes will affect the decision-making, and the determination of each decision will often have an impact on subsequent decisions. If we want

to decide on the highest return, it is equivalent that in the decision-making process, we have to find the best solution.

In addition, the use of dynamic programming to solve problems must meet two preconditions, one is the principle of optimization, and the other is the principle of no aftereffect

(1) Optimization principle: The optimization principle can be stated as follows: An optimization strategy has the property that, regardless of past states and decisions, for the state formed by the previous decisions, the remaining decisions must constitute the optimal strategy. In short, a sub-policy of an optimization policy is always optimal. A problem that satisfies the optimization principle is also called an optimal substructure property

(2) No aftereffect principle: After the stages are arranged in a certain order, for a given stage state, the state of its previous stages cannot directly affect its future decision-making, but only through the current state. In other words, each state is a complete summary of history. This is known as the retrospective principle

2.3.2 Model Establishment

After analyzing the problem, we found that the decision-making process of gold and bitcoin satisfies the two premises of dynamic programming, and frequent transactions will lead to higher transaction fees during the transaction process, which will affect the final income, so we consider the seven-day as a unit predict, build a model and use it to make decisions. The decision-making process is shown in the following figure 4.

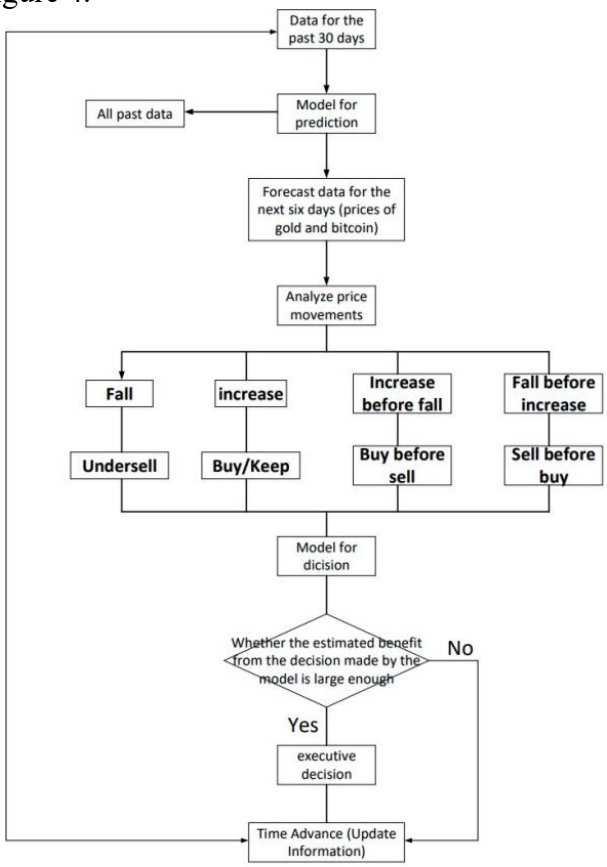

Figure 4. The decision-making process

The decision model is as follows:

$$\max z = [(1 + r_{gold})(1 - \alpha_{gold}) - 1]T_{gold} + [(1 + r_{bit})(1 - \alpha_{bit}) - 1]T_{bit} + \tag{1}$$

$$(1 + r_{gold})(1 - \alpha_{gold})V_{gold} + (1 + r_{bit})(1 - \alpha_{bit})V_{bit} - |\alpha_{gold}T_{gold}| - |\alpha_{bit}T_{bit}|$$

$$\text{s. t.} \begin{cases} T_{gold} + T_{bit} \leq V_{free} \\ T_{gold} \geq -V_{gold} \\ T_{bit} \geq -V_{bit} \end{cases}$$

z is the total amount of assets held, r_{gold} is the yield of gold r_{bit} is the yield of bitcoin T_{gold}, T_{bit} is the trading volume of gold and bitcoin respectively, $V_{gold}, V_{bit}, V_{free}$ is the gold currently held Total Assets, Current Bitcoin Asset Value held and Free Funds currently held α_{gold}, α_{bit} is the gold fee and the bitcoin fee respectively.

3. Analysis and Evaluation of results

To evaluate the returns of investment strategies more intuitively, we introduce a new concept: Equivalent Free Fund E Value

$$E_{Value} = V_{free} + (1 - \alpha_{gold})V_{gold} + (1 - \alpha_{bit})V_{bit} \quad (2)$$

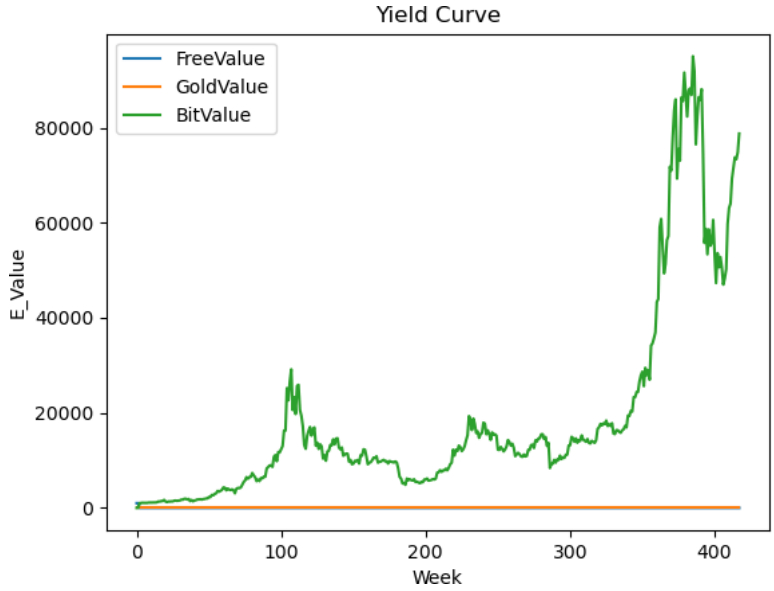

Figure 5. Yield Curve

Based on the establishment and solution of the above model, we obtained the following trading week-equivalent free capital return curve, and finally obtained the equivalent free capital of 73311.46 US dollars. The results are shown in figure 5.

4. Conclusions

To maximize returns, investors will often buy and sell volatile assets, and each transaction usually requires a certain commission. The time, frequency, and quantity of the purchase and sale will have a key impact on the investor's return rate. This paper establishes a prediction and decision-making model based on data from all past trading days for us and provides investment advice for investors to maximize returns. Based on the establishment and solution of the above model, we obtained the following trading week-equivalent free capital return curve, and finally obtained the equivalent free capital of 73311.46 US dollars

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