Problem Chosen	2022 MCM/ICM Summary Sheet	Team Control Number
C		2215557

Summary

Facing the traditional type of gold investment and the new type of bitcoin investment, it is the dream of many people to develop a scientific investment strategy to make the maximum benefit. In this paper, we explore the maximum return an investor can achieve with an initial capital of $1,000 over a five-year period, and the impact of daily trading profiles and trading prices on the model, using a predictive model and a planned trading model as the main subjects.

We first perform data pre-processing to analyze the daily trading conditions and label whether gold can be bought or sold on the trading day. To improve the accuracy of prediction models, the data are processed using **wavelet noise reduction** techniques. Then a **linear regression prediction model**, a **grayscale prediction model**, and a **recurrent neural network prediction model** are built to predict the data of the following day by using the historical data before the day of trading. Among them, the recurrent neural network uses an improved version of the **GRU model** based on the **LSTM model**, which makes the calculation faster. In order to make the prediction more reasonable and in line with the law of work and rest, we use 30 days as a cycle to make the prediction. After a detailed comparison and analysis of the three models, we finally use the grayscale forecasting model in the case of short-term forecasting and the GRU model in the case of long-term forecasting.

We then build a planning trade model where we put ourselves in the shoes of a real investor, and we analyze in detail all the strategies that an investor can undertake that day, after concluding that the investment situation can only be all cash or all bitcoin or all gold. We then used the idea of **greedy algorithms** and iterative planning to constantly update the amount of investments, making it possible to trade at the optimal choice every day. From November 9, 2016 to October 9, 2021, in a simulated real trading scenario, our total assets were significantly increased from the initial $1,000 to eventually **$230,31703.09**.

We inferred that our model is the optimal solution for a known one-day forecast, and visualized the final trading scenario for each year, each month and each day. In terms of sensitivity analysis, we analyze the impact on the final asset in terms of changes in trading principal and changes in trading price, respectively, and draw some conclusions from them between gold trading and bitcoin trading. Ultimately we communicated our results, models and techniques to traders from an economics and investment maximization perspective.

We wrote a large amount of code, all of which has been open-sourced, that will be more enlightening for subsequent investors in predicting price changes in other financial products and planning complex trades.

Key words:GRU, Greedy algorithms, Wavelet noise reduction

Contents

I. Introduction

1.1 Problem Background

Money management is to manage one's own wealth to further increase the value of one's own capital. With the development of global economy and the improvement of people's quality of life, there are more and more "manageable wealth", more "manageable places", and more "willing to manage people". The existing financial management methods are savings, funds, gold and other categories, among which gold is a mainstream financial management methods, because of its international recognition, the lightest tax burden and easy to transfer characteristics, won the attention of investors. The opposite of gold, a traditional mainstream financial product, is bitcoin, a digital currency that has become an "overnight sensation" in recent years. Compared to gold investments, investing in bitcoin carries a high level of risk. While virtualization avoids the cost of trading gold off-site, its price is extremely volatile.

This paper will further investigate how investors should formulate a reasonable and scientific investment strategy to maximize the benefits of traditional gold investment and new bitcoin investment.

1.2 Restatement of The Problem

This project involves designing a quantitative investment model for bank traders to help them make buy, hold and sell decisions for their portfolios (gold, bitcoin). The model will simulate daily trades from September 11, 2016 to September 10, 2021 based on asset price data provided on the official website, using a principal amount of $1,000 and solving the following problems.

- Optimal: information as of that date that the investment strategy is optimal and maximizes the value added of the investment on September 10, 2021.
- Robust: test the sensitivity of the model to changes in transaction costs under different at different transaction costs.
- Practical: visualizing the daily trading results and communicating the model, strategy and results to traders in a simple and understandable manner.

1.3 Our approach

In order to be able to maximize the interest rate of our investment strategy, we firstly performed data analysis and pre-processing of the data to differentiate whether gold is tradable on a daily basis, and secondly, after data mining, we found that the rise and fall of bitcoin is a highly complex non-linear system, and due to the complexity of the market, bitcoin's price series can be mixed with occasional noise, to which we applied the technique of wavelet noise reduction.

The main body of the model is the forecasting model and the trading model. For the noise reduction data, we stand in the investor's perspective and make forecasts based on the historical prices of bitcoin and gold, we compare linear regression forecasts, grayscale forecasts, and GRU forecasts with periodic recurrent neural networks, and the final results are short term using grayscale forecasts and long term

using GRU forecasts. After getting the prediction results, for the trading model, we used the idea of greed to get the recursive relational equation for asset update in the current optimal context.

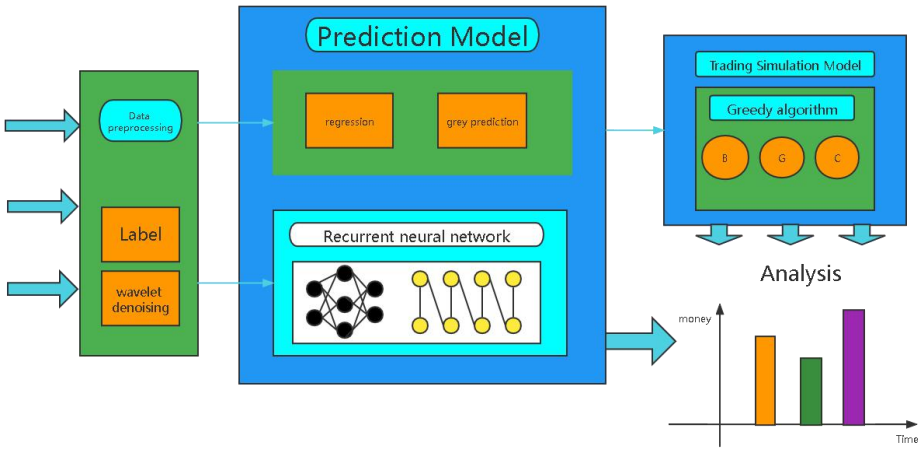

Fig 1 Analysis Process

Innovation point.

- We analyzed the characteristics of gold and bitcoin trading times and optimized the data using wavelet noise reduction
- We compare prediction models with different characteristics to obtain excellent prediction results
- On top of the classical LSTM model for forecasting, we optimize it in many ways, using the periodic GRU model, which is experimentally proven to give better results faster with less computational resources
- After our planning and iterations, we obtained better results and our assets reached 23031703.09
- We analyze the sensitivities and characteristics of gold and bitcoin from a professional economics perspective and give investment recommendation

II. Assumptions and Symbols

2.1. Assumptions

In order to simplify our model and eliminate complexity, we make the following main assumptions in this paper.

- The assumption that the price in the annex is the only price of the day, disregarding stock market rules such as opening and closing prices.
- That the market is weakly efficient, i.e., influencing that only the historical price of the investment product is effectively reflected in its present price.
- Investors are quantitatively invested based on the logic of value investing, i.e. "the price of an investment product will not always be lower than its intrinsic value, and effective market competition will automatically eliminate all excess returns".

- The assumption of relative invariance of social reality in terms of space and time. That is, the occurrence, development and changes of investors' psychological phenomena and the social policy environment have intrinsic regularity and certainty, which are assumed to have little impact on gold and bitcoin

The following symbols and related parameters are set in this paper.

2.2 Terms, Definitions and Symbols

Table 1 Symbols and parameter settings

Symbols	Meaning
W_n	Asset account value at day n
$g_{new\ price}$	New price of gold
$g_{old\ price}$	The previous price of gold
$b_{new\ price}$	new price of bitcoin
$b_{old\ price}$	Bitcoin previous price
i	The principal is i
j	The principal is j
P_i	Income when the principal is i
P_j	Income when the principal is j

III. Data processing part

3.1 Transaction labeling

Since Bitcoin is tradable on a daily basis, while in most cases, gold is only tradable during the working week, we label the daily trading conditions. We label the days when both gold and Bitcoin are tradable as 0, and the days when only Bitcoin is tradable as 1. After we ran the statistics we got the bar chart below. From November 9, 2016 to October 9, 2021. The days where gold can be traded consist of 1255 days and the days where gold cannot be traded have 571 days.

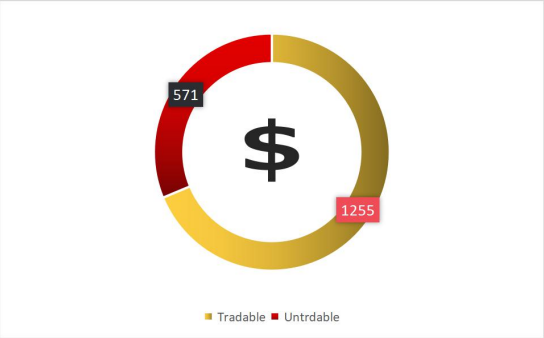

Fig2 Statistics on whether gold is tradable or not

3.2 Noise reduction processing

Stock rise and fall is a highly complex nonlinear system, and due to the complexity of the market, the price series of stocks will be mixed with occasional noise. If we first perform noise reduction on the original stock series before making

predictions, the accuracy of the prediction will be greatly improved.

Based on the traditional noise reduction methods, we decided to use wavelet theory for noise reduction. Since the price of gold our more stable compared to the price of bitcoin, here we mainly perform noise reduction on the price information of bitcoin. Soft thresholding, hard thresholding and fixed thresholding are used for the processing respectively. Among them, the fixed-threshold noise reduction processing is the most effective, and the comparison graph of the noise reduction data and the original data is as follows.[1][2]

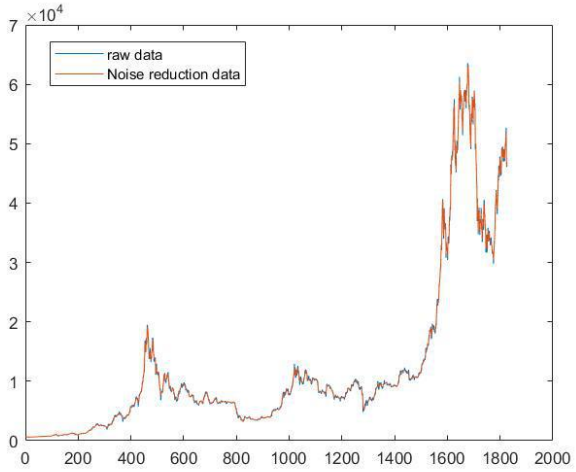

Fig3 Comparison chart of the noise reduction processing data and the original real data

IV.Model 1: Prediction

4.1 Brief description

From the perspective of real investment, the data we can get is not all the price information of bitcoin and gold, but the historical price information up to that day, so our prediction model will be constantly updated according to the growth of time. And this investment product price is human made and will follow the human habitat, so we use a cyclical approach for long term forecasting, using 30 days as a time slice for our forecasts. And some forecasting models are suitable for short-term forecasting, such as gray forecasting and least squares. Some models are suitable for long-term forecasting, such as LSTM forecasting and GRU forecasting. We will use a combination of the above forecasting methods and compare them in detail.

4.2 Specific process

4.2.1 GRU forecasting

4.2.1.1 Brief description of the algorithm

Neural network prediction is one of the classical ideas in prediction. The recurrent neural network is mainly used to process serial data, and its most important feature is that the output of a neuron at a certain time can be input to the neuron again.

One of the main problems of RNNs is that the gradients may disappear rapidly as they are back-propagated along the sequence. To solve this problem, a classical optimization is the LSTM[5][6][7][8], which implements a more fine-grained internal processing unit for efficient storage and updating of contextual information through input gates, forgetting gates, and output gates. Since we need to make predictions for many days, we use a variant of the LSTM, the GRU model, in order to reduce time and computational effort.

4.2.1.2 Network Structure

For a given sequence x = (x1, x2, ..., xn), after applying a GRU layer, a hidden layer sequence h = (h1, h2, ..., hn) and an output sequence y = (y1, y2, ..., yn) can be calculated by iterating equations (1) to (2).

$$h_t = f_a(W_{xh}x_t + W_{hh}h_{t-1} + b_h) \tag{1}$$

$$y_t = W_{hy}h_t + b_y \tag{2}$$

Where: W is the weight coefficient matrix (e.g., Wxh denotes the weight coefficient matrix from the input layer to the hidden layer); b is the bias vector (e.g., bh denotes the bias vector of the hidden layer); fa is the activation function (e.g., tanh function); and the subscript t denotes the time

In order to incorporate the human factor of setting prices, we use a cyclic forecasting approach, i.e., we take 30 as the time slice for each round of forecasting. As shown in the figure below, a recurrent network layer will have thirty GRU neurons, expanded in time steps, to predict the outcome of the thirty-first day, with each neuron having the price input Xt for that day, taking the intermediate output result H(t-1) of the previous GRU neuron as the second input of the current neuron as well. The output result of each neuron is later fed into the fully connected layer to obtain the final result.

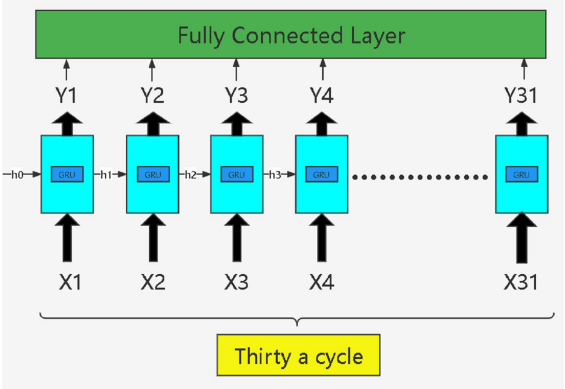

Fig 4 Network Architecture

Inside the GRU neuron, the GRU has no peephole connections and output activation functions, and no linearly self-connected memory units, but accumulates directly and linearly on the hidden state h. Using two gates to control the information flow, the input and forgetting gates in the LSTM unit are coupled as update gates in the GRU. The update gate is used to control the update of the hidden state, i.e., when ut = 0, the information in the initial time step is maintained regardless of how long the

sequence is. The reset gate determines whether to ignore the previous hidden state, using u and r to denote the update gate and the reset gate, respectively.

The GRU forward propagation is calculated as follows[4]:

$$\begin{cases} u_t = \sigma(W_{xu}x_t + W_{hu}h_{t-1} + b_u) \\ r_t = \sigma(W_{xr}x_t + W_{hr}h_{t-1} + b_r) \\ h_t = \tanh(W_{xt}x_t + W_{hh}(r_t \odot h_{t-1}) + b_h) \\ h_t = u_t h_{t-1} + (1-u_t) \odot \tilde{h}_t \end{cases} \tag{3}$$

The internal structure of GRU is illustrated as follows

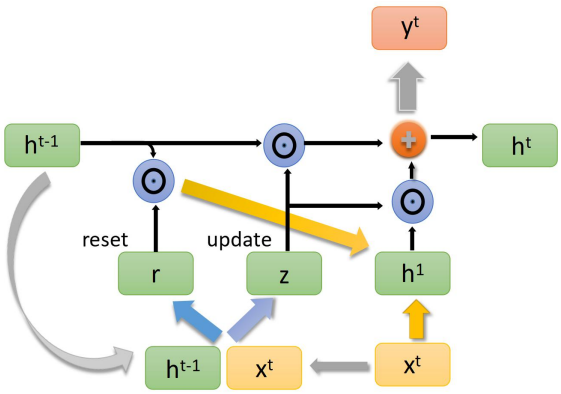

Fig 5 Neuron internal structure

4.2.2 Other prediction methods

In order to make comparisons and solve the problem of few historical data and missing sequence integrity, we also build other prediction models, such as grayscale prediction model and linear regression model. Since these models are relatively simple, we do not elaborate on them.

4.3 Results

4.3.1 Computation time and hyper-parameter settings

Under the hardware device of 128GB memory, 8*RTX2080, 20 cores and 40 processes, the prediction result of Bitcoin is obtained close to 2 hours, and the prediction result of gold is obtained close to 1 hour, where the hyper-parameters are set as follows.

Table 2 The hyper-parameters of GRU

Bitcoin	Gold
Batch_size=1	Batch_size=1
Start_input=100	Start_input=30
Hidden_size=20	Hidden_size=20
Output_size=1	Output_size=1
Layers_size=3	Layers_size=3
Learning Rate=10	Learning Rate=10
Num_epochs=1000	Num_epochs=500

4.3.2 Comparison of Prediction Results

The following two graphs show the results of bitcoin and gold under the comparison of linear regression model, grayscale prediction model and GRU prediction model, respectively.

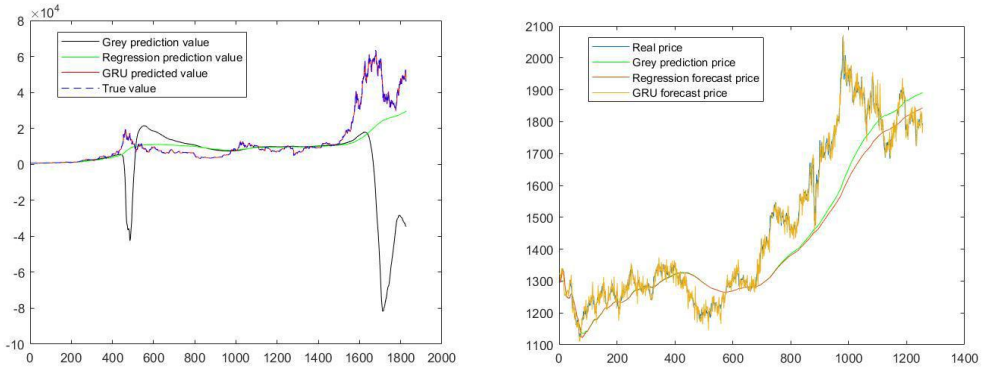

Fig 6 Predicted Price vs. Actual Price for Bitcoin and Gold

As you can see from the comparison chart for Bitcoin on the left, for the first 200 days of forecasting, the predicted values of all three forecasting methods are very close to the true values. However, after 400 days, the LSTM forecasts are significantly better than the gray and regression forecasts. This result is due to the poor performance of regression forecasting in long-term forecasting and the simplicity of regression forecasting.

As can be seen from the comparison of the gold forecasts on the right, in the first 100 days, the forecasts of all three forecasting methods are very close to the true values. However, after 100 days, the LSTM prediction is significantly better than the gray prediction and regression prediction.

Gray forecasting does not require a lot of data to solve the problems of little historical data and sequence integrity, and is suitable for short- and medium-term forecasting. The least squares method is suitable for linear fits and good short-term trend fits. GRU model prediction can get better results on longer time series, finally we take the data of the first 100 days of grayscale prediction and the data of the 101st to 1826th days of GRU prediction as the final prediction data of Bitcoin. We take the data of the first 30 days of grayscale forecast and the data of the 31st day to 1255th day of GRU forecast as the final forecast data of gold.

4.4Analysis of the model

Strength

- We perform a comparison of a large number of common prediction models.
- The final forecast results combine the long-term forecasting method and short-term forecasting method, taking into account both long-term and short-term, and the accuracy of the forecast is high.
- In order to comply with the market law, we adopt the periodic forecasting method for long-term data

- In order to reduce the amount of neural network computation, we use the lighter GRU model based on LSTM.

Weakness

- Initially, the accuracy of the prediction results may be affected by the small amount of real information.
- Only the results of the later day are predicted, and the prediction range is short

V. Model 2: Trading simulation model

5.1. Brief description of the problem

After the above work each day the investor gets the predicted bitcoin price and gold price for the day after, how to use this price for decision making, we used the idea of greedy algorithm and analyzed each situation of the day in detail to iterate and plan. Each day is the optimal result after the choice is made.

(notes:For ease of calculation, we keep two decimal places for each day's post-trade assets.)

5.2 Processing Steps

- **Step1:**

Since we want to earn as much as possible, if we want to buy bitcoin or gold (later referred to as investment products), we will definitely use all the money to buy the investment product with the highest possible return, thus there is no case of holding two investment products or holding investment products while holding cash. At the same time, if we predict that both Bitcoin and gold will fall on the next day, or if the total return from purchasing another investment product minus fees is lower than the return from liquidating the investment product, we may also only hold cash in both cases. So all in all, our total assets can only exist in two forms: holding one investment product or holding cash.

- **Step2：**

Regardless of the rise or fall of the price of gold and bitcoin, when holding cash on the first day, our investment trading choices on the second day must not exceed the following three scenarios:

a. Buy shares of gold.
b. Buy Bitcoin shares.
c. Continue to hold cash.

Join the first day when holding a stock, the next day our investment transaction choice must not exceed the following three:

a. Continue to hold the current stock.
b. Exchange all shares for cash.
c. Buy another stock.

Note that we cannot buy gold stocks if they are not tradable.

- **Step3：**

Based on the above analysis, we believe that there are three states of investors' assets: holding cash, holding gold stocks and holding bitcoins. We specifically discuss the different decisions of investors in these three states and the capital value after the change of the nature of the assets held, where W_n refers to the value of the asset account on day n and W_{n+1} is the value of the asset account on Day $n+1$. The specific decisions and the change of the asset account value are shown in the following figure.

Taking the conversion of cash to gold as an example, when it is converted to gold on Day $n+1$, the new value of gold it can be converted to on Day $n+1$ is the adjusted price change on the basis of day n. In addition taking into account the handling fee issue, an additional 1% of the Day $n+1$ gold value is required, so the final value is $230,31703.09.

As shown below, first of all the model of our transaction is divided into two cases according to whether gold can be purchased on that day or not. When gold can be purchased on the same day, we further divide the discussion into whether the asset held is gold, bitcoin or cash:

a. When holding cash, we can continue to hold cash or purchase bitcoin or gold depending on the predicted price.

b. When holding bitcoin, depending on the forecasted price, we can choose to continue to hold bitcoin, or switch all of it to cash, or switch all of it to hold gold.

c. When holding gold, depending on the predicted price you can choose to continue to hold gold, or exchange it all for cash, or exchange it all for holding bitcoin.

If you can't buy gold on the same day, we will also discuss it as cash, bitcoin or gold:

a. If you hold cash, you can only buy bitcoin or continue to hold cash.

b. When holding bitcoin, you can only hold bitcoin or exchange it all for cash.

c. When holding gold, you can only continue to hold gold.[3]

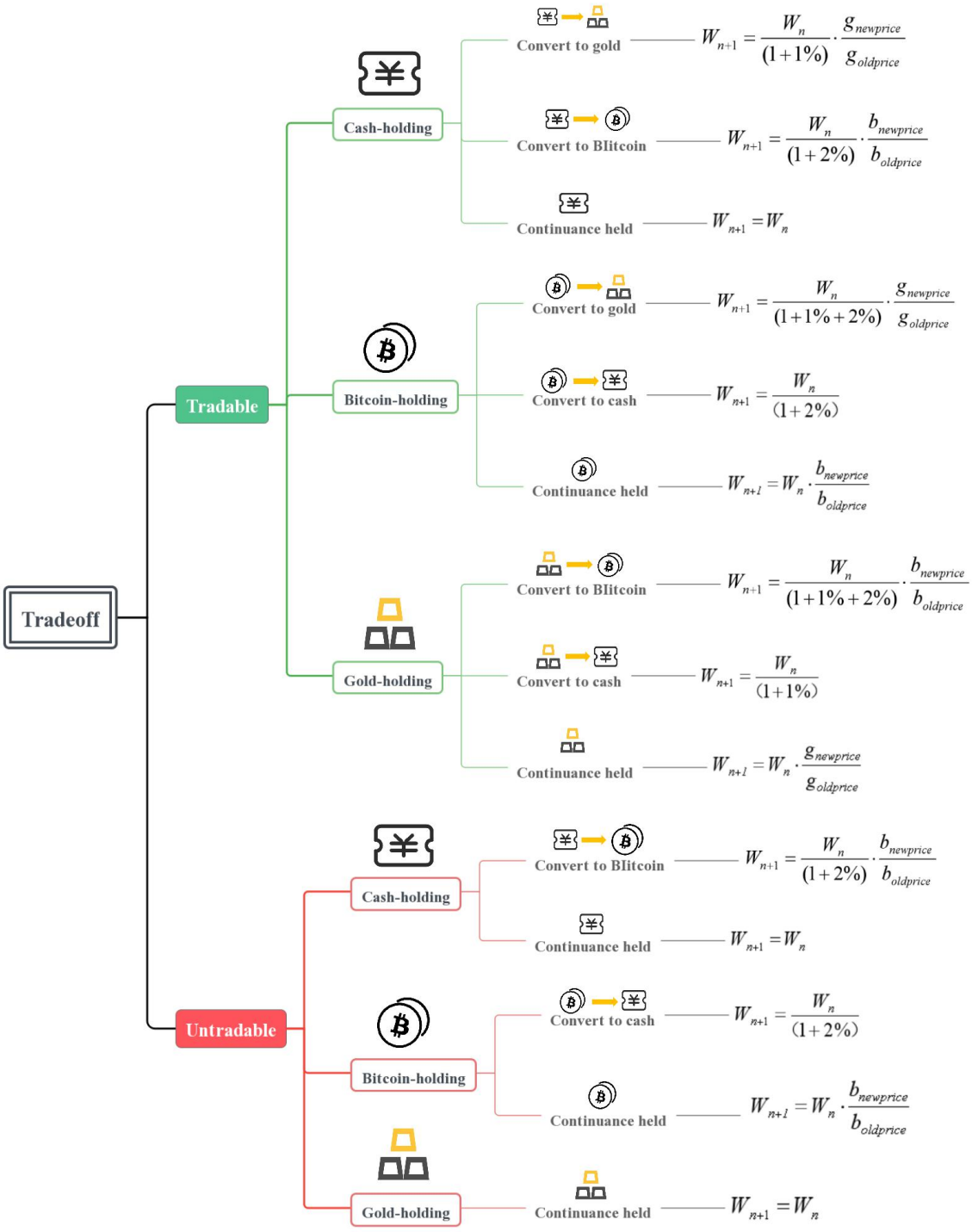

Fig 7 Schematic diagram of transaction selection

5.3Analysis of the Result

5.3.1 Final Transaction Results

Based on the actual prices, the highest returns from the optimal portfolio can be obtained using our model. However, in the process of predicting the price of gold and

bitcoin, the prediction cannot be exactly the same as the real price, but can only be optimized to be infinitely close to the real price. Therefore, the highest return obtained by using our predicted prices in the trading model will only be infinitely close to the highest return achieved by the true price.

Based on our price predictions for gold and bitcoin, the initial $1,000 on September 11, 2016, and simulated by the model we designed, the final maximum value of the asset achievable on September 10, 2021 is $230,31703.19.

5.3.2 Annual Trading Status

Statistics on the annual trading decisions reveal that there is a high number of bitcoin holdings in each year due to the high profit margin of bitcoin. The largest number of bitcoins were held in 2017 and 2020 . The holdings of each asset in 2018 and 2017 are more evenly split .

Fig 9 Number of days invested in each product each year

The specific annual transactions are shown above, where 0 represents cash holdings, 1 represents bitcoin holdings, and 2 represents gold holdings, and the horizontal axis represents the day *x* of the year.

5.3.1 Daily Transaction Status

Similar to the annual trading situation, we have visualized the daily trading situation, where 0 represents cash holdings, 1 represents bitcoin holdings, 2 represents gold holdings, and the horizontal axis represents the day x of the year, where neither 2016 nor 2021 has reached a full year.

Fig 10 Annual distribution of specific investment

5.4Analysis of the model

Strength

- Using the idea of greed algorithm, the highest return of the day is taken, thus ensuring the maximum return.
- The results of all investment trading methods for that day are classified and discussed in detail.

Weakness

- We only use the day-after price to determine the best choice for the day, without taking into account long-term factors.
- We are planning by forecasting results, and errors in forecasting results will have a large impact on our planning decisions.
- Considering from the perspective of investment trading methods, it is not possible to visualize the amount of gold and bitcoin that needs to be purchased

VI. Model sensitivity analysis

6.1 Optimal solution test

According to our analysis above, there are only two possible ways for all of our assets to exist: cash or holding an investment product. When buying investment products can bring returns, all of our assets will be used to buy the most profitable one, and there is no asset that cannot increase in value. And when both investment products fall and the loss from the fall is greater than the fee for switching to cash, or when the current holding falls and the gain from switching the holding is less than the fee required, switching all to cash will minimize our losses. Thus, each day's investment method can maximize returns or minimize losses, and each day's choice of trade method is optimal, and ultimately, the highest returns are sure to be obtained.

6.2 Sensitivity analysis of trading principal changes

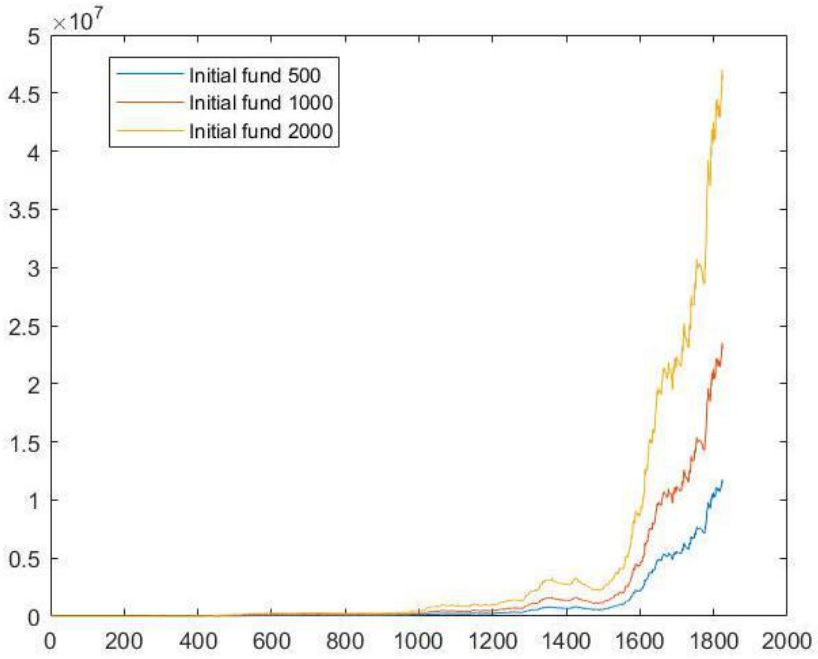

Fig 11 Changes in returns for changes in principal

For the sensitivity analysis of the principal amount, we use the principal amount of 1000 as the standard group, and additionally choose the principal amount of 500 and the principal amount of 2000 as the control. As can be seen from the above graph, when the rate of fees is constant, the slight difference in returns in the first period is not significant because the unit interval of the vertical coordinate is too large. On the 1600th day, there is a huge difference in the returns due to the difference in the previous principal amount, which shows that the principal amount has a significant impact on the returns. The ratio between the different returns from different principal amounts is approximately equal to the ratio between different principal amounts. That is, as shown in the following equation.

$$\frac{i}{j} \approx \frac{P_i}{P_j} \tag{4}$$

(i,j where denotes different principal amounts and denotes the returns from different principal amounts p_i,p_j.)

6.3 Sensitivity analysis of changes in transaction costs

We first use the control variable method to control the fee rate of bitcoin and the fee rate of gold at certain levels respectively, and analyze the impact of their fee rate changes on the final total trading revenue separately, and then combine the two to analyze.

a. When bitcoin transaction costs are fixed

When the bitcoin commission rate is fixed at 2%, the results from our trading simulation model show that the final asset value of the account varies less with the fluctuation of the gold commission rate. We believe that the profit margin for gold

is relatively small and that investors are less sensitive to changes in gold's transaction costs. When the gold transaction cost decreases, investors adopt a new investment strategy that has no impact on the value of their total account assets; when the gold transaction cost rises, investors' switching costs increase and rational investors choose to continuously hold the most profitable asset, i.e. bitcoin, when the final asset value is influenced by the bitcoin currency value.

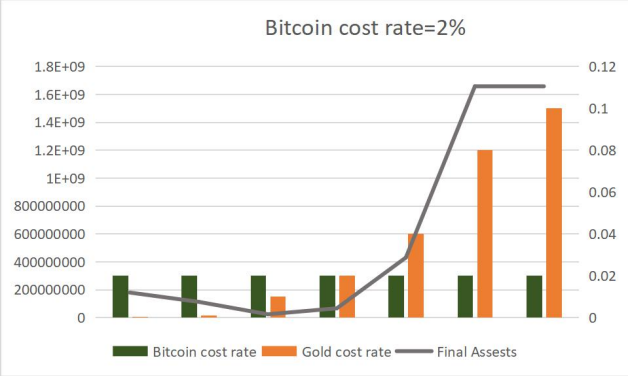

Fig 12 The final asset changes with the gold exchange rate

b. When gold trading cost is constant

When the trading commission rate for gold is fixed at 1%, the results from our trading simulation model show that as the bitcoin trading commission rate increases, the final asset value of the account decreases. The sensitivity of the final asset value is very high when the bitcoin commission rate is at a low level and decreases as the bitcoin commission rate grows and changes to a certain level.

We believe that the higher rate of return on bitcoin is a double benefit for investors when the cost of bitcoin transactions is very low. Investors have a lower cost of changing hands, and they can also transfer out at a lower cost at any time when they are exposed to higher risk, which is more flexible and favored by investors. As a result, rational investors will purchase bitcoins at the right time to earn high profits and their final asset accounts are worth more. Investors are generally risk averse, and when the transaction cost of bitcoin increases to a certain level, its turnover rate will then decrease and the return profile will be more stable.

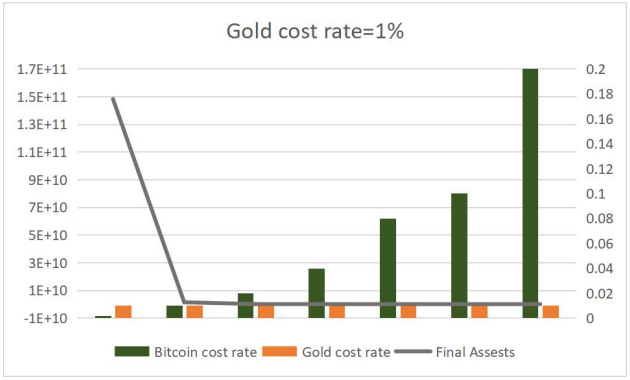

Fig 13 The final asset changes with the bitcoin exchange rate

c. When the transaction costs of gold and bitcoin move in tandem

When the transaction costs of gold and bitcoin move in tandem, the following results are obtained from our trading model analysis. When the transaction costs of

gold and bitcoin are low, rational investors have the flexibility to pick the most profitable product at any given time to increase the value of their asset accounts because of their low switching costs; and when the transaction costs rise, the changes are smaller and the returns tend to stabilize.

Combining the analysis of the first two scenarios shows that the final asset value of an investor's account is mainly affected by the transaction cost of bitcoin.

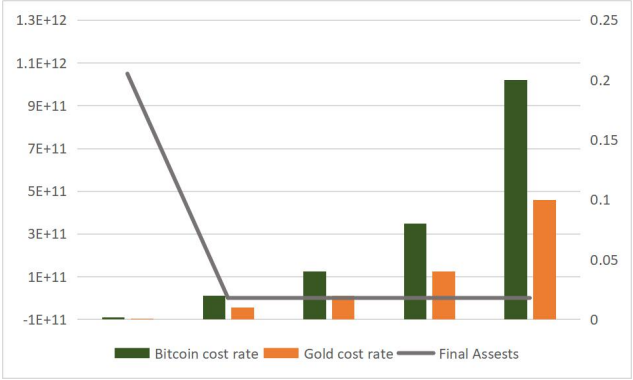

Fig 14 The final asset changes with both
the bitcoin exchange rate and the gold exchange rate

VII. Conclusion and Future Work

7.1 Conclusions of the problem

We realistically recreate the scenario chosen by the investor, using the forecasting model and the planning transaction model as the main body. Firstly, we make short or long term forecasts based on the data that can be obtained on that day, relying on the GRU model and the grayscale forecasting model to obtain better results with shorter computation time. In the planning model, we use the idea of greed and discuss in detail all possible situations of investment during the day to obtain the optimal investment choice. We analyzed all the results in detail and summarized the characteristics of bitcoin or gold investments from an economic point of view through sensitivity analysis, and finally gave a specialized investment recommendation.

7.2Future work of our models

1. In fact, investing should be a process of making decisions based on long-term risk, and subsequent decisions can be made today based on the state of the future for many days.

2. The data given in the question is only the price of bitcoin and gold. Our model can go further to predict the future price of investment products by digging out the factors that affect the investment products, such as the economic level, social stability, technological capability, etc., to improve the accuracy of the prediction.

Memo

To: The Public Investors

From: Team 2215557

Date: February 21, 2022

Subject: An investment model for optimal decision making in Bitcoin and gold

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Money management is an important way to increase the value of idle funds. With the rise of the financial boom, more and more ordinary people are entering the trading market to buy various investment products .So a reasonably designed investment portfolio plan is the key to effective asset appreciation.

In this regard, our team designed simulated trading models with two different risk levels of gold and bitcoin products and analyzed forecasts to test the accuracy and sensitivity of the models based on data from September 11, 2016 to September 12, 2021. We use the model with the best fit and the lowest error as our experimental model. At the same time, we further optimize the classical forecasting model LSTM based on indicators such as periodicity, and optimizing to obtain the periodic GRU model as our main forecasting model.

In terms of trading simulation, we believe that rational investors will use all their money to buy investment products with the highest possible returns out of the motive of earning as much profit as possible, thus there is no case of holding two investment products or holding cash while holding investment products. A scientifically sound optimal decision scheme is designed, which eventually increases the value of $1,000 assets to $2,303,703.09. The specific decisions are shown in the following chart.

Investment decisions.

- Investors should hold bitcoin in 2016 and a moderate amount of gold at the end of the year.
- hold primarily bitcoin in 2017, 2020 and 2021, and buy gold and cash at appropriate time periods to enhance returns (e.g. bitcoin devaluation, etc.).
- more flexibility in 2018 and 2019 to adjust investment products at any time based on the market.
- See the appendix for details of the investment decisions for each month.

Model recommendation.

- Decision optimality ⋆ ⋆ ⋆ ⋆ ⋆ : simulated trading decision data for maximum yield results, as verified by discussions.
- Model sensitivity ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ : good results verified in terms of both trading principal and trading cost.
- Practicability ⋆ ⋆ ⋆ ⋆ ⋆ ⋆ : the combination of theory and practice effectively improves the scientific nature of investors' decision making.

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Appendix

1-Monthly trading simulation

2016	
9.11-12.31	Hold bitcoin, with cash on the 23rd, 27th, 30th and 31st
2017	
Jan	Hold gold, bitcoin and cash alternately, and hold gold continuously from 6th to 11th with short time bitcoin holding
Feb	Hold bitcoin mainly, hold gold on 24th-27th, with short-cash holding
Mar	Hold cash at the beginning , bitcoin at the previous stage; Hold gold in the middle and bitcoin in the second half
Apr	Hold bitcoin mainly with short-term cash holding
May	Hold bitcoin for the first time; Hold gold in the middle; In the second half of the day, alternately hold bitcoin, gold, short cash
Jun	Alternate holdings of bitcoin, gold and cash

Jul	Hold bitcoin for 5 days at the beginning of the month, and hold gold in the middle of the month, with short-term cash holdings; In the second half of the month, bitcoin is mainly held and cash is short held
Agu	Hold mostly bitcoin,Hold gold in the first half then bitcoin in the last half
Sept	Early hold gold, with short-term cash holding and bitcoin; Hold bitcoin in the second half of the year, with short-term cash holding
Oct	Hold bitcoin mainly, hold gold on 9th, 16th, 18th days with short-term cash holding
Jan	Hold bitcoin for 4 days, cash for 3 days, gold for 6 days, and then hold bitcoin continuously
Feb	Respectively hold bitcoin mainly, cash mainly, gold mainly
2018	
Jan	Alternately hold bitcoin and gold, hold gold on 1st, 10th, 24th, 25th;
Feb	mainly hold bitcoin and gold for 5 days at the beginning and hold gold on the 22nd.with short-term cash holding
Mar	Alternately hold bitcoin and gold，hold gold on 8th,21-28th
Apr	Hold mostly bitcoin，hold gold for 5 days at the beginning of the month and hold gold on the 25th,with short-term cash holding
May	Hold mostly bitcoin，with short-term cash holding at begin；hold mostly gold in the middle and late period of the year ,hold bitcoin from 19 to 21;with short-term cash holding
Jun	Alternately hold cash and gold in the first half of the month；Alternately hold bitcoin and gold in the mid-to-late，with short-term cash holding
Jul	Hold mostly bitcoin，hold gold on 15th,25th，with short-term cash holding
Agu	with short-term cash holding and gold in the first half of the month；Hold mostly bitcoin，hold gold on 22th,in the mid-to-late
Sept	Alternate holdings of bitcoin, gold and cash
Oct	Hold mainly gold，with short-term cash holding
Jan	Hold mainly gold，with short-term cash holding in the early； Alternate holdings of bitcoin, gold and cash in the late
Feb	Hold mainly gold，with short-term cash holding in the early； Hold mostly bitcoin，with short-term cash holding in the late
2019	
Jan	Hold mainly gold，with short-term cash holding in the first half of the month ； Hold bitcoin for 6 days in the middle of the month；Alternately hold bitcoin and gold in the last half of the month
Feb	Alternate holdings of bitcoin, gold and cash in the early； Hold mostly bitcoin in the last half of the month，with short-term cash holding
Mar	Hold mostly bitcoin, gold on 25th，with short-term cash holding；
Apr	Hold mostly bitcoin， and gold on11th、25th-28th，with short-term cash holding
May	Alternate holdings of bitcoin, gold and cash
Jun	Hold mostly bitcoin，and gold on 10th，with hort-term cash holding；

Jul	Alternate holdings of bitcoin, gold and cash
Agu	Hold mainly gold，with short-term cash holding and bitcoin
Sept	Alternate holdings of bitcoin, gold and cash
Oct	Hold mostly bitcoin in the first half of the month，with short-term cash holding；Hold mainly gold in the mid-to-late ， with short-term cash holding and bitcoin-holding
Jan	Alternate holdings of bitcoin, gold and cash
Feb	Alternate holdings of bitcoin, gold and cash，Hold mostly bitcoin in the middle;Hold mainly gold in the begin and last；
2020	
Jan	Hold mostly bitcoin， Hold mainly gold on1th、2th、22th、31th，with short-term cash holding
Feb	Hold mostly bitcoin，with short-term cash holding in the first half ； Hold mainly gold，with short-term cash holding in the last half；
Mar	Hold mainly gold，with short-term cash holding in the first half；Hold mostly bitcoin，with short-term cash holding in the last half；
Apr	Alternate holdings of bitcoin, gold and cash in the middle
May	Hold bitcoin in the begin； Alternate holdings of bitcoin and cash；Hold cash mainly with bitcoin-holding in short-term held in the second half of the month
Jun	Hold mainly gold，with short-term cash holding
Jul	Hold mostly bitcoin，hold gold on 24th-26th
Agu	Alternately hold cash and gold
Sept	Alternately hold cash and gold in the begin； Hold mostly bitcoin，with short-term cash holding in the last
Oct	Hold mostly bitcoin and hold gold on the first six day of the month
Jan	Hold mostly bitcoin，hold gold on 25th
Feb	Hold mainly gold in the first half of the month ，with short-term cash holding； Hold mostly bitcoin in the mid-to-late，with short-term cash holding
2021	
Jan	Hold mostly bitcoin at begin，with short-term cash holding； Alternate holdings of bitcoin, gold and cash at last
Feb	Hold mostly bitcoin，hold cash on 9th，with short-term cash holding
Mar	Alternate holdings of bitcoin and cash
Apr	Alternate holdings of bitcoin, gold and cash
May	Hold mainly gold，with short-term cash and bitcoin holding
Jun	Hold mainly gold，with short-term cash and bitcoin holding； hold cash and gold alternatively in the last half of the month
Jul	Hold mainly gold in the first half of the month，with short-term cash holding； hold cash and gold alternatively in the last half of the month
Agu	Hold bitcoin and cash alternatively,and gold on 12th
Sept	Alternate holdings of bitcoin and cash

2-Code

Prediction model

```
import pandas as pd
import csv
import numpy as np
df=pd.read_csv("C 题处理后的中间文件2.csv")
height,weight=df.shape
df1=pd.read_excel("比特币的预测价格.xls")
df1=np.array(df1.values)
df4=[]
for i in range(1,df1.shape[0]):
    tmp=[]
    tmp.append(df1[i][0])
    df4.append(tmp)
df4=np.array(df4)
df1=df4
df2=pd.read_excel("黄金的预测价格.xls")
df2=np.array(df2.values)
df3=[]
df3.append([1324.6])
for i in range(0,df2.shape[0]):
    df3.append(df2[i])
df3=np.array(df3)
m=df.values
huangjin=[]
for i in range(0,height):
    if(m[i][2]==0):
        huangjin.append(m[i][3])
k=1 #k 代表现在持有的是黄金还是比特币
n=0 #黄金统计
rateG=0.01
rateB=0.02
oldprice_G=0
oldprice_B=0
newprice_G=0
newprice_B=0
target=1000
res=[]
height=height-1
for i in range(1,height-1):
    res1=[]
    print("第%d天的资产为：%f"%(i,target))
    res1.append(target)
    res.append(res1)
    #如果黄金不能交易
    if(m[i][2]==1):
        #持现
        if(k==0):
            oldprice_B=df1[i-1][0]
            newprice_B=df1[i][0]
            tmp=target /(1+rateB) * newprice_B / oldprice_B
            tmp=round(tmp,2)
            target1=max(target,tmp)
            if(target1==target):
                target1=target
                k1=0
            else:
                target1=round(target /(1+rateB) * m[i+1][1]/ m[i][1],2)
                k1=1
        #持比特币
        if(k==1):
            oldprice_B = df1[i-1][0]
            newprice_B = df1[i][0]

            tmp1=target*(newprice_B/oldprice_B)
            tmp1=round(tmp1,2)
            tmp2=target/(1+rateB)
            tmp2=round(tmp2,2)
            target1=max(tmp1,tmp2)
            if(target1==tmp2):
                k1=0
                target1 = round(target / (1 + rateB), 2)
            else:

                target1=round(target*(m[i+1][1]/m[i][1]),2)
                k1=1
        #持黄金
        if(k==2):
            target1=target
            k1=2
        k=k1
```

```
            target=target1
        if(m[i][2]==0):
            oldprice_B1 = m[i][1]
            newprice_B1 = m[i + 1][1]
            oldprice_G1=huangjin[n]
            newprice_G1=huangjin[n+1]
            oldprice_B = df1[i-1][0]
            newprice_B = df1[i][0]
            oldprice_G=df3[n][0]
            newprice_G=df3[n+1][0]
            if(k==0):

tmp1=target/(1+rateG)*newprice_G/oldprice_
G
                tmp1=round(tmp1,2)

tmp2=target/(1+rateB)*newprice_B/oldprice_
B
                tmp2=round(tmp2,2)
                target1=max(tmp1,tmp2,target)
                if(target1==target):
                    target1=target
                    k1=0
                else:
                    if(target1==tmp1):

target1=round(target/(1+rateG)*newprice_G1/
oldprice_G1,2)
                            k1=2
                    else:

target1=round(target/(1+rateB)*newprice_B1/
oldprice_B1,2)
                            k1=1
            if(k==1):

tmp1=target*newprice_B/oldprice_B
                # print(tmp1)
                tmp1=round(tmp1,2)
                tmp2=target/(1+rateB)
                tmp2=round(tmp2,2)

tmp3=target/(1+rateB+rateG)*newprice_G/ol
dprice_G
                # print(tmp3)
                tmp3=round(tmp3,2)
                target1=max(tmp1,tmp2,tmp3)
                if(target1==tmp1):

target1=target*newprice_B1/oldprice_B1
                    k1=1
                else:
                    if(target1==tmp2):
                        target1=round(target
/ (1 + rateB),2)
                        k1=0
                    else:
                        k1=2

target1=round(target/(1+rateB+rateG)*newpri
ce_G1/oldprice_G1,2)
            if(k==2):
                tmp1 = target * newprice_G /
oldprice_G
                tmp1=round(tmp1, 2)
                tmp2 = target /(1+rateG)
                tmp2 = round(tmp2, 2)
                tmp3 = target /(1+rateB+rateG)
* newprice_B / oldprice_B
                tmp3 = round(tmp3, 3)
                target1 = max(tmp1, tmp2,
tmp3)
                if (target1 == tmp1):
                    target1=round(target *
newprice_G1 / oldprice_G1,2)
                    k1 = 2
                else:
                    if (target1 == tmp2):
                        k1 = 0
                        target1=round(target
/(1+rateG),2)
                    else:
                        k1 = 1
                        target1=round(target
/(1+rateB+rateG) * newprice_B1 /
oldprice_B1,2)
            n=n+1
            k=k1
```

```
            target=target1
tmp=[]
tmp.append(target)
res.append(tmp)
res=np.array(res)
# print(res.shape[0])
print("第%d天的资产为：%f"%(height-1,target))
# f=open('最终版初始资金为500的资金变化.csv','w',encoding='utf-8',newline="")
# csv_writer = csv.writer(f)
# csv_writer.writerow(["资金（少一天）"])
# csv_writer.writerow([500])
# for i in range(0,1824):
#         csv_writer.writerow(res[i])
# f.close()
```

GRU model

```
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import time
from sklearn import linear_model
from d2l import torch as d2l
import torch
import torch.nn as nn
import csv
path="/home/jishengpeng/美赛的模拟练习"
BCHAIN_MKPRU=pd.read_csv(path+"/BCHAIN-MKPRU.csv",dtype={"Date":np.str,"Value":np.float64})
LBMA_GOLD=pd.read_csv(path+"/LBMA-GOLD.csv",dtype={"Date":np.str,"Value":np.float64})
Data=pd.read_csv(path+"/C题处理后的中间文件2.csv")
def to_timestamp(date):
    return int(time.mktime(time.strptime(date,"%m/%d/%y")))
#将日期变为自然数
start_timestamp=to_timestamp(Data.iloc[0,0])
for i in range(Data.shape[0]):

Data.iloc[i,0]=(to_timestamp(Data.iloc[i,0])-start_timestamp)/86400
print(Data)
batch_size=1 # 应该只能为1
start_input=30
input_size=Data.shape[0]# 训练：通过前input_size天预测input_size+1天，预测：通过2到input_size+1天预测第input_size+2天
hidden_size=20
# input_size=200
output_size=1
layers_size=3
lr=10
num_epochs=1000
class GRUModel(nn.Module):
    def __init__(self, input_size, hidden_size, output_size, layers_size):
        super().__init__()
        self.GRU_layer = nn.GRU(input_size, hidden_size, layers_size)
        self.linear = nn.Linear(hidden_size, output_size)
    def forward(self, x):
        x, _ = self.GRU_layer(x)
        x = self.linear(x)
        return x
device=torch.device("cuda")
gru=GRUModel(30, hidden_size, output_size, layers_size).to(device)
criterion = nn.L1Loss()
optimizer = torch.optim.Adam(gru.parameters(), lr)
ji=np.array(Data.iloc[0:input_size,3].dropna())
input_size=ji.shape[0]-2
trainB_x=torch.from_numpy(ji[input_size-30:input_size].reshape(-1,batch_size,30)).to(torch.float32).to(device)
trainB_y=torch.from_numpy(ji[input_size].reshape(-1,batch_size,output_size)).to(torch.float32).to(device)
losses = []
for epoch in range(num_epochs):
    output = gru(trainB_x).to(device)
    loss = criterion(output, trainB_y)
```

```
        losses.append(loss)
        optimizer.zero_grad()
        loss.backward()
        optimizer.step()
        print("loss" + str(epoch) + ":", loss.item())
# 预测，以比特币为例
#
pred_x_train=torch.from_numpy(np.array(Data.iloc[1:input_size+1,1]).reshape(-1,1,input_size)).to(torch.float32).to(device)
pred_x_train=torch.from_numpy(ji[input_size-29:input_size+1]).reshape(-1,1,30).to(torch.float32).to(device)
pred_y_train=gru(pred_x_train).to(device)
print("prediction:",pred_y_train.item())
print("actual:",ji[input_size+1])
# 预测代码
losses = []
predictions = []
actuals = []
for i in range(start_input, input_size + 1):
        print("进行到 input_size=", i)
        # gru=GRUModel(i, hidden_size, output_size, layers_size).to(device)
        gru = GRUModel(30, hidden_size, output_size, layers_size).to(device)
        criterion = nn.L1Loss()
        optimizer = torch.optim.Adam(gru.parameters(), lr)
        # 数据，以比特币为例
        trainB_x = torch.from_numpy(ji[i - 30:i].reshape(-1, batch_size, 30)).to(torch.float32).to(device)
        trainB_y = torch.from_numpy(ji[i].reshape(-1, batch_size, output_size)).to(torch.float32).to(device)
        loss = None
        for epoch in range(num_epochs):
                output = gru(trainB_x).to(device)
                loss = criterion(output, trainB_y)
                optimizer.zero_grad()
                loss.backward()
                optimizer.step()
                # print("loss"+str(epoch)+":", loss.item())
        losses.append(loss.item())
        # 预测，以比特币为例
        pred_x_train = torch.from_numpy(ji[i - 29:i + 1].reshape(-1, 1, 30)).to(torch.float32).to(device)
        pred_y_train = gru(pred_x_train).to(device)
        # print("prediction:",pred_y_train.item())
        # print("actual:",Data.iloc[i+1,1])
        predictions.append(pred_y_train.item())
        actuals.append(ji[i + 1])
plt.plot(losses)
plt.plot(predictions)
plt.plot(actuals)
print(np.array(predictions).shape[0])
print(np.array(actuals).shape[0])
print(input_size-29)
f=open(path+'/周期 lstm 黄金预测 1000 版本.csv','w',encoding='utf-8',newline="")
csv_writer=csv.writer(f)
csv_writer.writerow(["实际价格","预测价格"])
for i in range(0,input_size-29):
        tmp=[]
        tmp.append(actuals[i])
        tmp.append(round(predictions[i],2))
        csv_writer.writerow(tmp)
f.close()
```