Problem Chosen	2022 MCM/ICM Summary Sheet	Team Control Number
C		2205621

Based on LSTM Price Forecast and RSI Long-term Trading Strategy

Currently, gold and bitcoin are representatives of popular investment products. Our team needs to provide some advice to the traders for the given data. The specific tasks can be divided into three issues.

For Question 1, we first find some normal and abnormal null values in the original data for data preprocessing. Next we use the LSTM model to train the two groups of processed data, and then use the sliding window method to predict. After that, the model forecast data are analyzed by using the conventional data error indicators. It can be seen that the short-term prediction accuracy of the model is high, especially in the case of large-scale rise in price.Similarly, we use real data to predict the price on the next trading day, calculate its increase or decrease, and obtain the corresponding growth rate on the trading day as one of the bases for making decisions to buy or sell bitcoin and gold.At the same time, we use the predicted price value to calculate a series of economic related indicators as another condition of decision-making. Finally, we find the maximum value of the final income by changing the purchase standard line.

For Question 2, we started from a simple decision to invest in a single asset and a portfolio of assets taking into account only the daily growth rate. This approach is highly risky and not in line with actual transactions. Therefore, we use the financial investment indicators RSI and KDJ to optimize the strategy. Judging from the final number of transactions, transaction costs and final benefits, the strategy under the RSI index not only induces the risks, but also guarantees the benefits, while the KDJ index only decreases the risks and cannot achieve significant benefits. Therefore, we choose the comprehensive investment strategy under the RSI index as our optimal strategy.

For Question 3, we changed the transaction fee and analyzed the potential relationship among bitcoin fee, gold fee and optimal revenue through visual processing. In addition, it is found from the transaction costs of gold and bitcoin that there is a huge difference in the best daily increase caused by the transaction costs in different stages, with bitcoin handling fees ranging from 1.5% to 2.5% having the greatest impact. To sum up, the impact of bitcoin fees on the best returns is far greater than that of gold.This shows that the handling fee price of bitcoin is highly sensitive to the model, which also corresponds to the characteristics of great changes in the price data of bitcoin. Similarly, the change of handling fee price also has a considerable impact on the selection of buying standard line.

Finally, we systematically analyze our model, explain the reasons for developing the model from the aspects of advantages and disadvantages, selection of neural network and evaluation indicators, and also analyze the impact of transaction fee and daily growth rate on how to make decisions.

Keywords: LSTM RSI KDJ Trading standard line

Contents

1 Introduction

1.1 Background

With the rise of cryptocurrency market, people's traditional investment field has gradually become diversified, and the investment channel and content are no longer single. Meanwhile,as more and more traders participe in the investment field,Analysis and evaluate comprehensively play an important role in making relevant strategies and matching traders' preferences.

For investors, it has always been a difficult problem to complement the investment of risk products and conservative products.Generally speaking, yellow metal is regarded as an effective haven for storing value throughout civilization.In contrast,Bitcoin is generally chosen as an attractive investment.The extremely volatile and speculative behavior enable investors and traders to earn supernormal returns in a short-time span[1].

1.2 Clarification and restatement

In this issue, we have obtained the information about the trading days and closing prices of gold and bitcoin from 2016 to 2021.A reasonable portfolio investment strategies should be provided to achieve the purpose of investor who holds the initial $1000 in 2016 to achieve the maximum return after five years. We should only use the above data to solve the problem.

- According to the professional knowledge in the financial field,we analyze the product data set, qualitatively or quantitatively measure and describe the data to guide the portfolio investment strategies.
- Based on the above analysis,the following special requirements need to be further solved.
  - Predict the relevant data of the next day through the past data set.
  - A model using only the past stream of daily prices to date needs to be established to predict the prices trend of the next day, so as to make the best trading strategies come true.
  - Find the relationship between transaction strategies ,transaction cost and return.
- Write a letter to the trader by summarizing the model results and strategies effects to reach the needs.

1.3 workflow

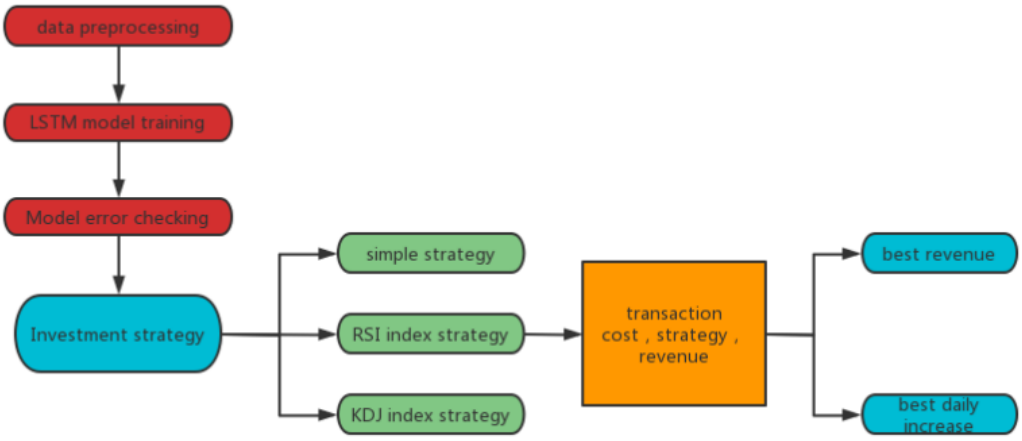

Figure 1: workflow

The above picture reflects all our work.

2 Assumptions and Justification

To simplify the problem and make it convenient for us to simulate real-life conditions, we make the following basic assumptions, each of which is properly justified.

- **From 2016 to 2021, no economic crisis or other financial catastrophic events occurr**. The strong black swan event will have unpredictable destructive power on the financial system and affect the normal financial operation.
- **The interaction between gold and bitcoin is not enough to affect its own future trend**. The correlation between gold and Bitcoin is low, ranging from -0.5 to 0.5 most of the time. And while it was positive on average during 2020, it is still by no means consistent in one direction[2].
- **The cash converted on the day of the transaction can be used for other transactions or waiting for an opportunity**. Such trading rules facilitate investment and modelling calculations.
- **We decided that traders didn't invest in the first month**. Due to the lack of financial industry experience and the understanding of past ups and downs, traders can't confirm whether their investment strategies are optimal or not.
- **Traders' investment strategies are subject to significant market volatility**.The trader's judgment and decision-making ability will continuously improve with time and market fluctuations.
- **There is no direct trade between gold and bitcoin**.Gold and bitcoin are always considered assets that are traded in cash.

3 Notations

Symbols	Unit
z^y, z^f, z^0	The weight metrix
σ	The sigmoid function
$tanh$	The hyperbolic tangent function
x^t	Time series input
u_i	The mean of the future
σ_i	The standard deviation of the future
lr	learning rate
α	Transaction cost
y_{1i}	The true gold trend
y_{2i}	The true bitcoin trend
$\hat{y}_{1i}$	The forecast gold trend
$\hat{y}_{2i}$	The forecast bitcoin trend
x_{1i}	True gold closing price
x_{2i}	True bitcoin closing price
$\hat{x}_{1i}$	Forecast gold closing price
$\hat{x}_{2i}$	Forecast bitcoin closing price

where we define the main parameters while specific value of those parameters will be given later.

4 Daily gold and bitcoin forecasts

4.1 Data analysis

We analyze the information in LBMA-GOLD.csv , BCHAIN-MKPRU.csv and got the following conclusions:

1. Since bitcoin can be traded every day, it can be considered no null value.what's more, it can also be determined that there is no bad value.

2. The gold trading is not allowed on weekend, and there is bound to be a null value.Meanwhile,there is no relevant data on some working days, resulting in wrong values.

4.2 Data processing

In order to build the time series prediction model, we eliminate the null value in the gold price data. At the same time, in order to make comprehensive decisions at the same time with bitcoin data, we set the gold price of missing time to 0, which does not affect the prediction results on the trading day.

5 LSTM prediction model for closing price

As a traditional recurrent neural network model, RNN often has gradient disappearance and gradient explosion, which often leads to too small memory value. Therefore, RNN is often ineffective in dealing with long-term timing problems.

As a special cyclic neural network, LSTM introduces gating unit system on the basis of RNN, including input gate, forgetting gate and output gate. These three kinds of gates respectively control the update and output of current input data and historical data to the state value of memory unit, and the information is selectively controlled by different gate pairs, So that network learning can appropriately forget the historical information and update the cell state according to the new information[3][4].

5.1 Correlation analysis

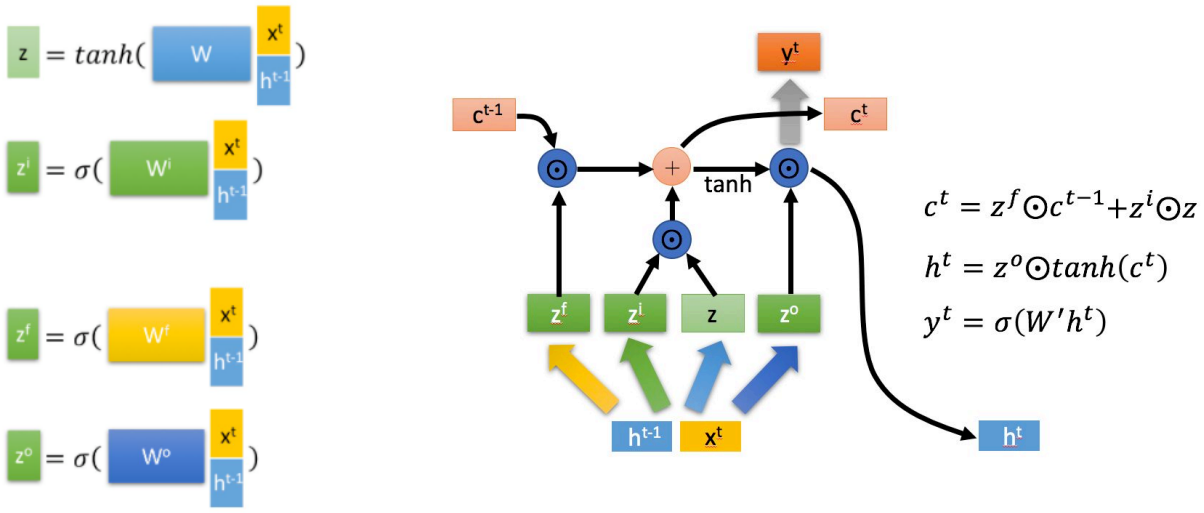

Figure 2: Predict model

Firstly, the current input $\boldsymbol{x^t}$ of LSTM and the $\boldsymbol{h^{t-1}}$ passed down from the previous state are used for splicing training to obtain four states.

Among them,$\boldsymbol{z^f}$, $\boldsymbol{z^i}$, $\boldsymbol{z^o}$ is multiplied by the splicing vector by the weight matrix, and then converted into a value between 0 and 1 through a $\boldsymbol{sigmoid}$ activation function as a gating state. The $\boldsymbol{z}$ is to convert the result into a value between -1 and 1 through a $\boldsymbol{tanh}$ activation function (the $\boldsymbol{tanh}$ is used here because it is used as input data rather than gating signal).

There are three main stages within LSTM:

1. Forget the stage. This stage is mainly used to forget the input from the previous node $\boldsymbol{selectively}$. Specifically, the calculated $\boldsymbol{z^f}$(F for forget) is used as the forgetting gating to control the previous state$\boldsymbol{c^{t-1}}$ which needs to be left and needs to be forgotten.

2.Select the memory stage. This stage selectively "remembers" the input of this stage.It mainly selects and memorizes the input $\boldsymbol{x^t}$ to record important data mainly. The current input content is represented by the $\boldsymbol{z}$ calculated above.Besides,The selected gating signal is controlled

by z^i (I represents information).The results obtained in the above two steps to obtain the c^t which will transmit to the next state

3. Output phase.This stage will determine which will be treated as the output of the current state.It is mainly controlled by z^o.The c^o obtained in the previous stage is also scaled down (changed by a tanh activation function)[5].

The closing price time series of investment products such as gold and bitcoin are nonlinear, nonstationary and noisy. In addition, due to the dynamic change of time, it is difficult for the traditional time series model to accurately predict the closing price of futures.

LSTM model can deal with the problems of long-distance dependence, nonlinearity and non stationarity. In recent years, the model has been widely used in financial series prediction, and the prediction effect has been greatly improved.

We use this model, the input is the data of the first five days, and the output is the predicted value of the sixth day. And continuously slide the prediction with the width of the sliding window of five days and the step of one day, and no transaction will be carried out in the first month.

5.2 Improving model accuracy

To improve our prediction model precision, we did the following analyses.

5.2.1 loss function

During the training.we use mean square error(MSE) as the loss function

$$MSE(y, \hat{y}) = \frac{1}{N}\sum_{i=1}^{N}(y_i - \hat{y}_i)^2 \tag{1}$$

where is the true target value and $\hat{y}$ is the predicted feature value and is the number of dimension.

5.2.2 normalization

In the multi index evaluation system, due to the different nature of each evaluation index, it usually has different dimensions and magnitude. When the level of each index varies greatly, if the original index value is directly used for analysis, it will highlight the role of the index with higher value in the comprehensive analysis and relatively weaken the role of the index with lower value level. Therefore, in order to ensure the reliability of the results, it is necessary to normalize the original index data[6].

$$x_i = \frac{x_i - u_i}{\sigma_i} \tag{2}$$

where u_i and σ_i are the mean and standard deviation of the feature.

5.2.3 training data

We use 30 continuous time series to train,the learning rate lr is 0.001 to predict the data of one day by conducting the training with one step size.The following is the predict result.

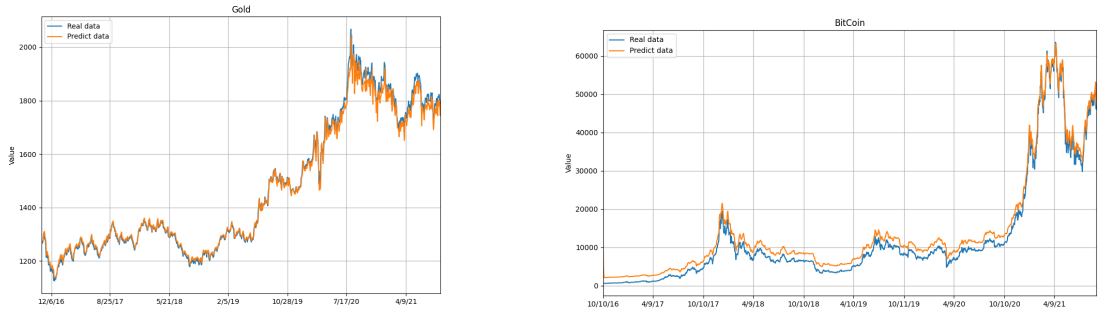

Figure 3: predictions

When the scale and range of time series such as the closing price of gold bitcoin are very large, the prediction performance evaluation index of the experimental model uses mean square error (MSE), root mean square error (RMSE) and mean absolute error (MAE) to evaluate the accuracy of the experimental results. The smaller the values of MSE, RMSE and MAE, the higher our accuracy is proved. The calculation formula of MSE, RMSE and MAE is as follows:

$$MSE = \frac{1}{m}\sum_{i=1}^{m}(y_{test}^{(i)} - \hat{y}_{test}^{(i)})^2 \tag{3}$$

$$MAE = \frac{1}{m}\sum_{i=1}^{m}|y_{test}^{(i)} - \hat{y}_{test}^{(i)}| \tag{4}$$

$$RMSE = \sqrt{\frac{1}{m}\sum_{i=1}^{m}(y_{test}^{(i)} - \hat{y}_{test}^{(i)})^2} = \sqrt{MSE_{test}} \tag{5}$$

In addition, It is vital for our forecast of gold bitcoin is the forecast of their future trend. The forecast precision of closing price can be lower than that of trend forecast. Therefore, we use the forecast data of future trend as our test data source. The trend test data source uses: the trend data equals to the value on the second day/the data on the first day.

It can be seen that the prediction accuracy for the future trend of gold and bitcoin is relatively high, which plays a very important role in our daily decisions. Furthermore, it can be seen that the forecast of the closing price of both is also very impressive.

True gold trend: $y_{1i} = x_{1(1+i)}/x_{1i}$

Forecast gold trend value: $\hat{y}_{1i} = \hat{x}_{1(1+i)}/\hat{x}_{1i}$

True bitcoin trend:$y_{2i} = x_{2(1+i)}/x_{2i}$

Forecast bitcoin trend value:$\hat{y}_{2i} = \hat{x}_{2(1+i)}/\hat{x}_{2i}$

x_{1i}:True gold closing price

$\hat{x}_{1i}$:Forecast gold closing price

x_{1i}:True bitcoin closing price

$\hat{x}_{2i}$:Forecast bitcoin closing price

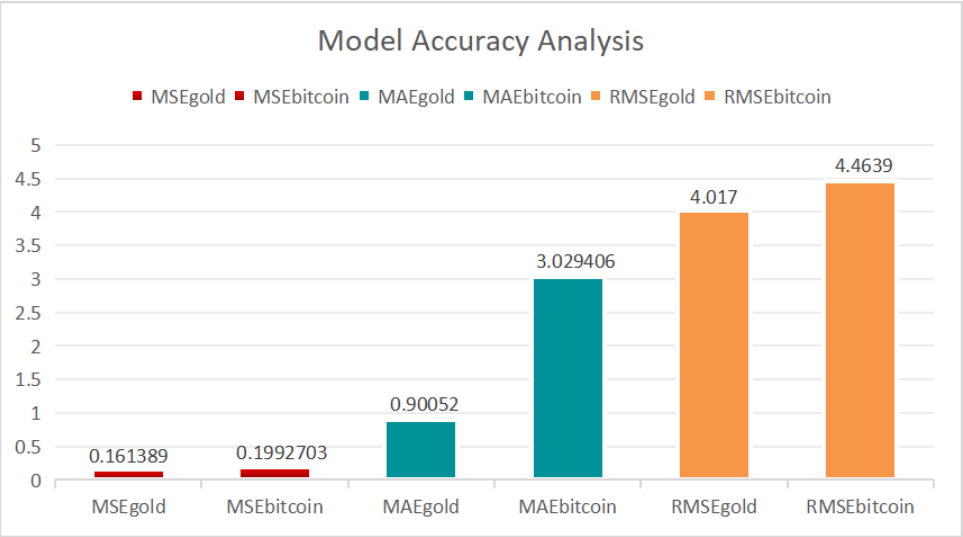

Figure 4: Model Accuracy Analysis

The data in the figure are presented at 100 times magnification.The true evaluation index values are obtained from the above detection formula and data.

$$MSE_{gold} = 0.00161389, MSE_{Bitcoin} = 0.001992703,\ MAE_{gold} = 0.0090052$$

$$MAE_{Bitcoin} = 0.03029406, KMSE_{gold} = 0.04017\ , KMSE_{Bitcoin} = 0.044639.$$

6 investment strategy

Investment strategy needs comprehensive and complex consideration. In this problem, how to consider buying and selling is very important. Since the LSTM model can only predict one day's data, we only judge whether to trade based on (the predicted value of the second day / the real value of the first day - trading rate). We consider bitcoin separately, gold separately and gold bitcoin comprehensively. Under the change of (the predicted value of the second day / the real value of the first day), analyze the following indicators: transaction times, transaction loss and final benefit.

6.1 Simple strategy

We use tomorrow's forecast/today's actual value as an independent variable y to analyze relevant strategies by analyzing Final benefits, Transaction losses, and Number of transactions

- **Gold-cash transactions only**.As we can see from the graph, when the y is close to 1.4%, the ultimate benefit is about $1634 and it will even lose money if y is big enough, which shows that the return on gold investment alone is not ideal.In addition, from the number of transactions, as y increases, the number of transactions will obviously become less, and the maximum transaction cost is obtained in the y close to 0.52% how much. Certain transaction costs can even lead to negative returns, so investing in gold alone is not considered.

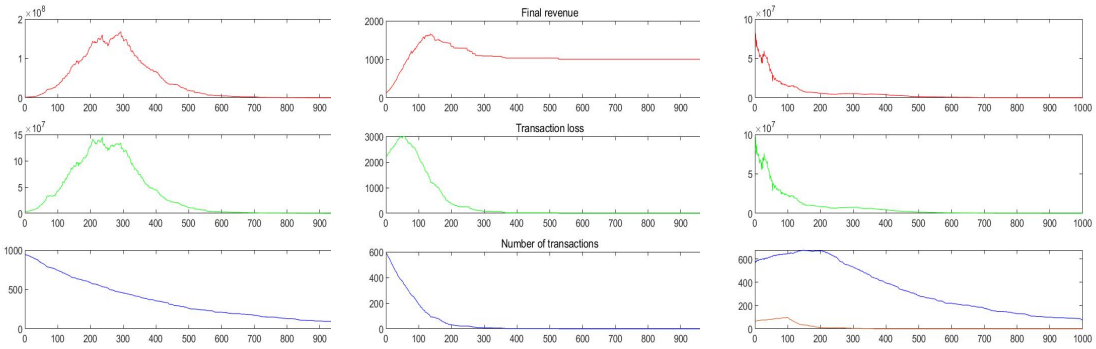

Figure 5: only Bitcoin:only Gold:Gold and Bitcoin

- **Bitcoin-cash transactions only**. It is eay to see that the low unit price of bitcoins is bound to the low transaction cost even if there are many transactions. As the price of bitcoins soars, transaction costs and ultimate benefits increase dramatically.Therefore,as long as there is an early willingness to invest in bitcoins, there will be huge returns. But in reality, investing in bitcoins is risky and unpredictable, making it difficult to buy and sell completely, so this is just a reference.

- **Bitcoin-Gold-cash transactions**.Compared with a single investment, the best benefit of a portfolio investment is concentrated at 0.28%, before which transaction costs,the number of transactions and the ultimate benefit are significant.The risk of this investment instrument is much lower than that of Bitcoin.In general,it is the best strategy between three single strategy.From the number of transactions bitcoin is much higher than gold, it can be confirmed that bitcoin investment risk is very high.

6.2 RSI-strategy

Relative strength index RSI is a kind of technical index which is based on the principle of balance between supply and demand in the gold market. It is used to analyze and judge the strength of the buying and selling forces of both the long and short sides in the market by comparing the fluctuation range of individual gold price or the fluctuation range of the index of the whole market in a period of time, so as to judge the future market trend.

Judging from the principle of its structure, the RSI index is the same as the trend indicators such as MACD and KDJ in that it analyzes the basic change trend of the gold index, while the RSI index is different from MACD and KDJ in that it first obtains the strength of the closing price of a single gold at certain times, instead of directly processing or smoothing the closing price of gold.

The relative strength index RSI is the ratio of the market's increase to the increase plus decrease over a period of time. It is a quantitative and graphical representation of the buying and selling power. Investors can predict the future trend of gold prices based on the market movements and tracks reflected by it. In practice, people usually use it together with moving average to improve the accuracy of market forecast[7].

We use the following RSI calculation method: suppose a is the sum of the positive closing prices in n days and b is the sum of the negative closing prices in n days multiplied by (1)In this

way, a and b are both positive. if a and b are substituted into the formula for calculating RSI, then $RSI(n) = a/(a+b) * 100$.

Available from economic principles, the RSI index ranges from 0 to 100. The values of the strong and weak indicators are generally in the range of 20-80. when the RSI indicator between 0-20,We conclude that the investment has strong appreciation potential and all cash inputs. 20-50, we think there may be a downward trend of volatility, selling half of the shares held. 50-80, we confirm there may be a growth trend in the future, buying half of the cash held. 80-100, we predict it will soon plummet and sell all the shares.

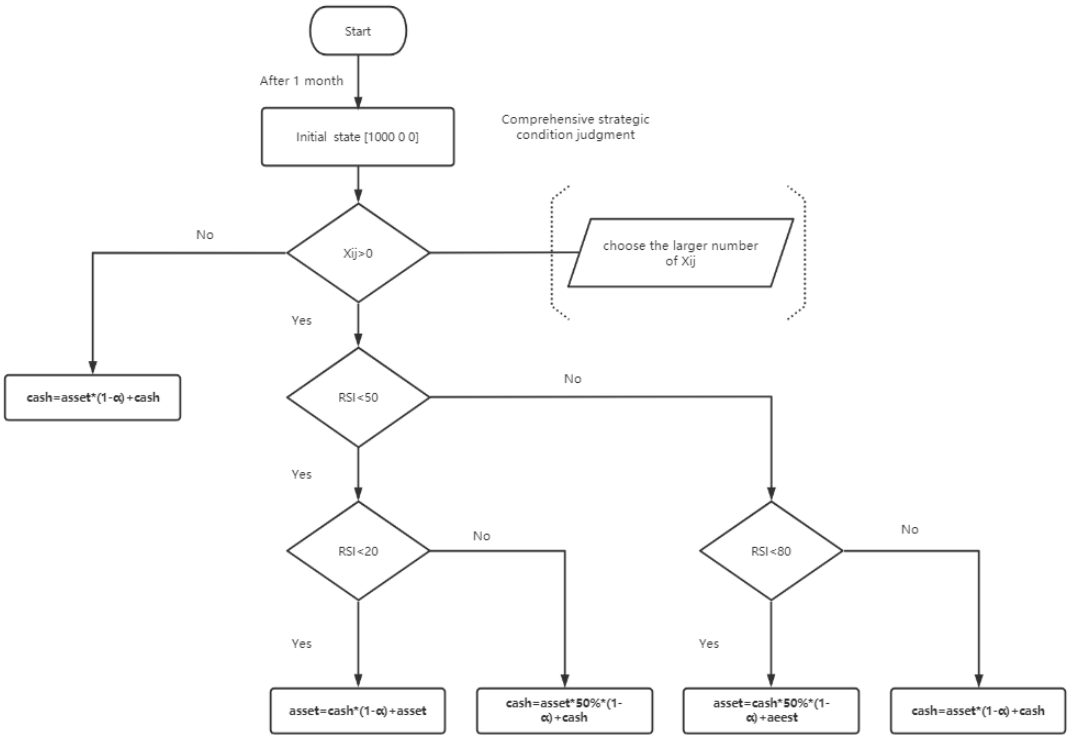

Figure 6: RSI strategy

Based on our assumptions, no investment is made in the first month.Based on our assumptions, no investment is made in the first month. $\boldsymbol{asset}$ in the figure represents the amount of gold or bitcoin held on the same day, $\boldsymbol{cash}$ represents the money in hand toda,$\boldsymbol{yields}$ represents tomorrow's forecast value/today's actual value.and $\boldsymbol{a}$ represents the handling fee in the process of gold or bitcoin transaction.

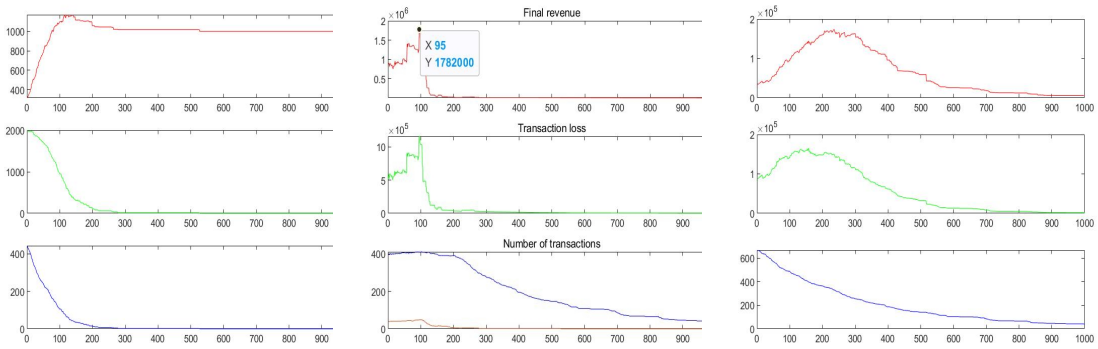

Figure 7: RSI-Gold:RSI-Bitcoin and gold:RSI-Bitcoin

The RSI model is suitable for short-term trading. Compared with ordinary simple trading, the RSI model is more in line with the actual situation and can reduce the risk coefficient of investment.From the above three images, under the guidance of the RSI model, the final revenue, transaction costs and the number of transactions have decreased. Although the final return is not as high as it would have been if the investment had been made alone, the decline in the number of transactions reflects the significant reduction in risk in this investment scenario. In this case, the final revenue of the comprehensive model can reach about 1782000.

The most important function of the RSI indicator is to show the basic situation of the current market, indicate whether the market is in a strong or weak position, or is in the process of consolidation, and can also roughly predict whether the top and bottom are coming. However, there are also some problems. The RSI has no obvious regular buy or sell signals. When the pointer is at a high level, it can only indicate that the probability of reversal of the situation is higher, but there is no way to further specify the time point. Besides, as RSI is an indicator of ratios, it is weak in trend analysis.

6.3 KDJ-strategy

In addition to the RSI index, KDJ is also one of the classic investment strategy indexes. KDJ is suitable for short-term and medium-term trend forecast. We also use it to design a comprehensive trading strategy model.

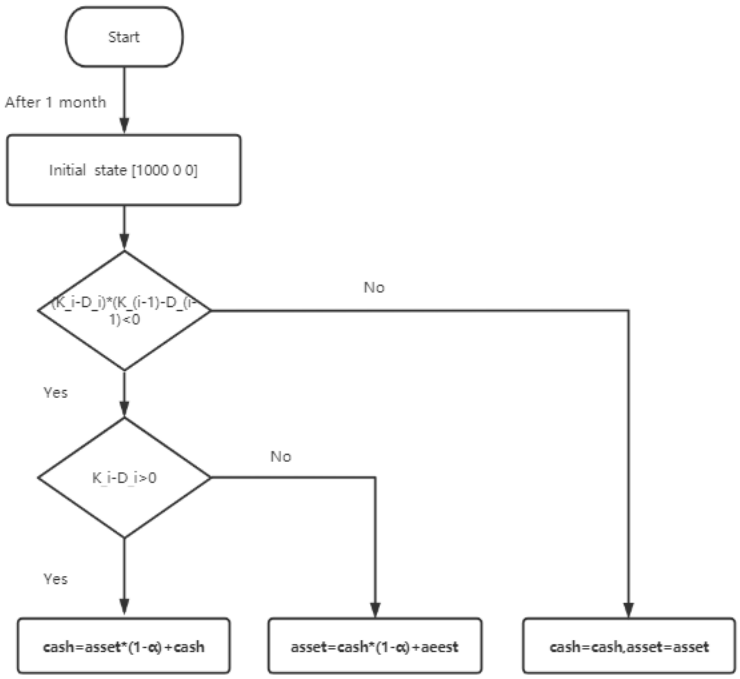

Figure 8: KDJ strategy

The calculation of KDJ is rather complicated. First, the cycle (n days, n weeks, etc.) should be selected, then the raw stochastic value (RSV value) of the current day should be calculated, and then the K value, D value, J value, etc. should be calculated.

The calculation formula of RSV is:

$$RSV = \frac{C - L_n}{H_n - L_n} * 100 \tag{6}$$

In the formula,C is the closing price of the day; Ln is the lowest price for the previous n days; Hn is the highest price in the previous n days.

K value of a certain day =2/3 k value of the previous day +1/3 RSV of the current day:

$$k_i = \frac{2}{3}K_{i-1} + \frac{1}{3}RSV_i \tag{7}$$

K_i and RSV_i represent the K value and RSV value of the day on a certain day respectively; K_{i-1} represents the K value of the previous day, and if there is no K value of the previous day, 50 is used instead.

D value of a certain day =2/3Œ D value of the previous day +1/3Œ K value of the current day, namely

$$D_i = \frac{2}{3}D_{i-1} + \frac{1}{3}K_i \tag{8}$$

D_i and K_i represent the values of D and K for the current day respectively; D_{i-1} represents the D value of the previous day, and if there is no D value of the previous day, 50 is used instead.

J =3K value of the day - 2D value of the day:

$$J_i = 3k_i - 2D_i \tag{9}$$

Through the KDJ investment strategy we designed, we got the following data about gold and bitcoin respectively.

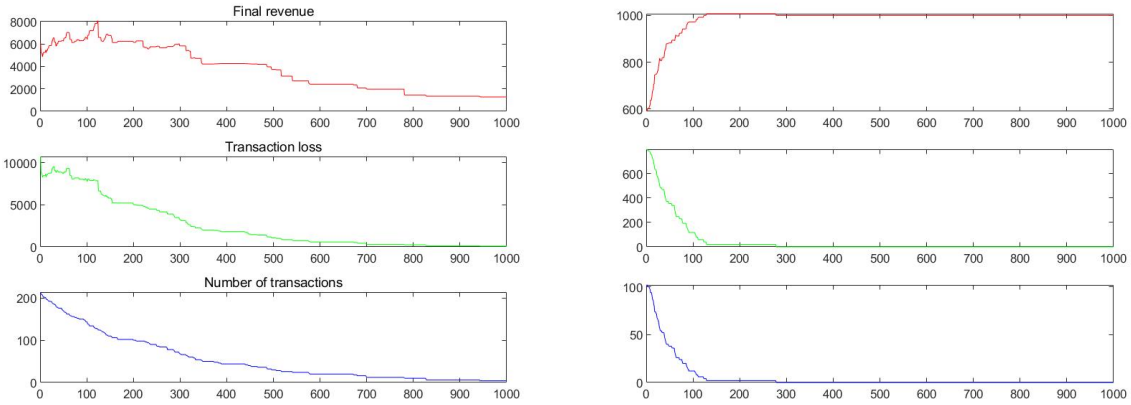

Figure 9: KDJ-Bitcoin:KDJ-Gold

In the design process, the KDJ index mainly studies the relationship among the highest price, the lowest price and the closing price. At the same time, it also integrates some advantages of momentum concept, strength index and moving average. Therefore, it can quickly, quickly and intuitively judge the market situation and is widely used in the short and medium term trend analysis of the stock market. The judgment method of KDJ index should be changed with the change of market. As a model for predicting long-term investment, KDJ model is hardly a single criterion for long-term investment.

When we are prepared to invest in one asset for a period of time, we are not able to cater for the trend of the rise or fall of another asset over that period of time. For example, if you invest in bitcoin on the first day and still hold bitcoin on the second day, you cannot take into account the changing trend of gold until bitcoin is sold.

6.4 Final strategy

After the above analysis, a reasonable portfolio investment decision is to cross-invest gold and bitcoin under the guidance of RSI indicators. Finally, through the RSI decision, the return on investment can reach 1782000 and the risk can be guaranteed to a certain extent. However, there are still some problems in this decision. In terms of investment allocation, we only adopt half or all of the rough strategies. Optimizing the relevant allocation is the future improvement point of this strategy.We may use Barrier policies Stochastic optimal control or Variational inequality[8] to improve policy integrity.

7 Transaction Costs and Strategic Outcomes

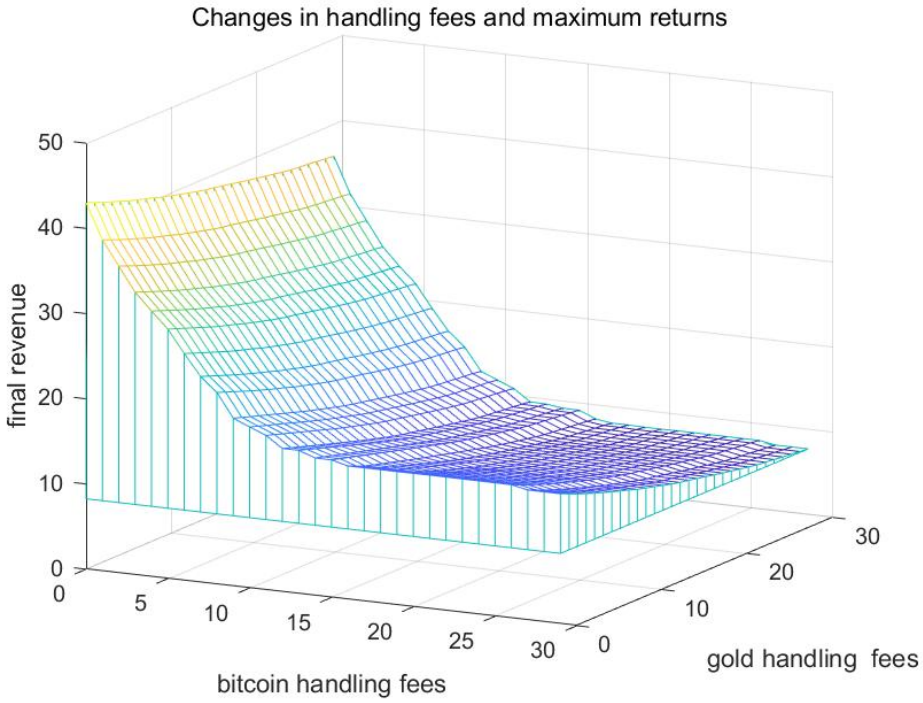

Figure 10: Changes in handling fees and final revenue

For sensitivity between strategies and transaction costs, how transaction costs affect strategies and outcomes. We adopted the RSI strategy to change the transaction fees of gold and bitcoin, ranging from 5% to 3% in steps of 1% and taking the logarithm of the final maximum revenue as shown in the figure above. As can be seen from the figure, the impact of the change in gold's handling fee on the maximum revenue is far lower than that of bitcoin. It is not difficult to understand that under extreme conditions, when the handling fee is zero, as long as there is an increase in one investment product, it will make a profit and will sell if it drops slightly. As a result, the investment is almost risk-free. As fees continue to rise, profits can only be secured by soaring prices.

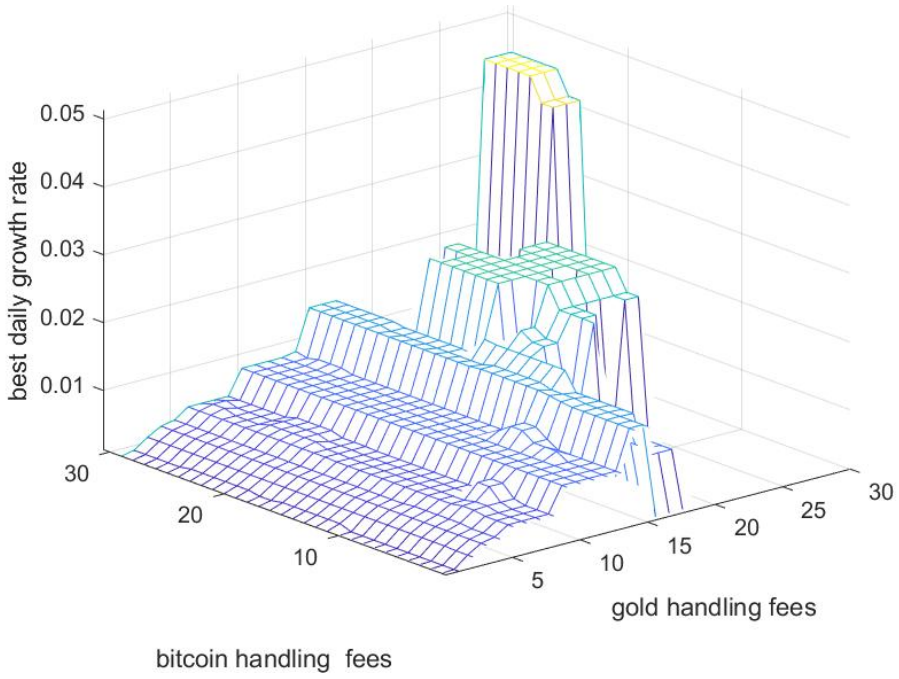

Figure 11: Changes in handling fees and maximum returns

The above shows the impact of gold and bitcoin fees on the daily rate of increase chosen to maximise revenue. The X-axis represents gold fees, the Y-axis represents bitcoin fees, and the Z-axis represents daily service rates.When the bit rate handling fee is 0-15%, the gold handling fee has little impact on the transaction, while the 15%-25% gold handling fee has great impact on the transaction. When the handling fee is more than 25%, it is basically unprofitable. By contrast, no matter how much gold fees, bitcoin fees have a big impact on it.

8 Strengths and weekness

8.1 Strengths

- We fill the null values with the data from the day before the golden null value day, and normalize the data when training the LSMT model, which improves the training accuracy.
- We use the daily gain rate to train the model and calculate RSI parameters to better predict the price growth trend, and choose a more reasonable transaction decision-making scheme to reduce the loss of handling fees.
- We start with simple strategies to analyze the advantages and disadvantages of various investment models, and further use RSI and KDJ indicators as portfolio investment guidance, which greatly reduces the investment risk.
- We expand the scope of trading, and thus clearly get the daily growth rate corresponding to the best return through visualization.

8.2 weekness

- Our prediction model is limited to a single-layer LSTM network and has potential for further optimization.
- The investment allocation in our investment strategy is not sufficiently professional and persuasive.

9 Conclusion

Nowadays, investors in financial products pay more and more attention to investment strategies, and have a set of excellent and reasonable investment strategies that investors can meet but not seek.

In this project, we first processed the data and reflected the accuracy of the model through a number of indicators. The investment strategy from simple to difficult is adopted to analyze the best investment strategy. During this period, the LSTM model, relevant financial assessment indicators, risk assessment indicators, iterative testing and other means are used to provide a more reasonable investment strategy for investors.

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Memorandum

To:Trader

From:MCM 2022 Team

Date:2022

subject:investment strategy

Nowadays, investment is becoming more and more diversified. A reasonable investment strategy can have a certain ability to resist risks while obtaining considerable returns. The market tends to let traders invest in high-risk and high return types. It is always a difficult problem for traders to analyze the investment allocation of risky and conservative assets. In order to meet your requirements, we start from the following three aspects.

1) We analyzed a variety of prediction models. In the time series model, we tried to predict with the traditional RNN model, but compared with the prediction effect of LSTM, we finally chose the LSTM model. In this project, we use LSTM to predict the closing price of two investment products, and use MSE, Mae and rsme to test the prediction accuracy. We can see that the prediction effect under this model is excellent, so it can be adopted.

2) We started with a simple investment strategy analysis. Under this condition, the three cases are very representative. In order to solve the disorder and high risk of simple investment, we use RSI and KDJ indicators in financial expertise as the guidance of complex investment strategy. Under the constraints of relevant indicators, we not only achieve acceptable final benefits, but also ensure that the investment risk is within a certain level. Therefore, portfolio investment will be the best investment strategy

3) All of the above are based on the gold and bitcoin handling fees of 0.01 and 0.02. Due to the passage of time, we have to consider the impact of the change in handling fees on the overall trading strategy and even the final revenue. Based on the visual analysis of the relationship among gold handling fees, bitcoin handling fees and daily growth rate, we get the answer on how to adjust our specific strategies under different handling fees.

We thank you very much for allowing us to provide you with relevant strategies. We hope that our strategies can improve your investment income. Please contact us at any time to further solve relevant problems.

Appendices

Here are simulation programmes we used in our model as follow.

Input python source:

```
import torch
import torch.nn as nn
import itertools
import seaborn as sns
import numpy as np
import pandas as pd
import matplotlib
import matplotlib.pyplot as plt
import matplotlib.dates as mdates
fig, ax = plt.subplots()

gold_data = pd.read_csv('./data/LBMA-GOLD-A.csv')
gold_data.head()

all_data = gold_data['USD (PM)'].values.astype(float)
date_data=gold_data['Date'].values.astype(str)
test_data_size = 1235

train_data = all_data[:-test_data_size] #size=60
test_data = all_data[-test_data_size:] #size=1205

from sklearn.preprocessing import MinMaxScaler

scaler = MinMaxScaler(feature_range=(-1,1))
train_data_normalized = scaler.fit_transform(train_data.reshape(-1,1))
train_data_normalized = torch.FloatTensor(train_data_normalized).view(-1)

all_data_normalized = scaler.fit_transform(all_data.reshape(-1,1))
all_data_normalized = torch.FloatTensor(all_data_normalized).view(-1)

train_window=5

def create_inout_sequences(input_data,tw):
    inout_seq = []
    L = len(input_data)
    for i in range(L-tw):
        train_seq = input_data[i:i+tw]
        train_label = input_data[i+tw:i+tw+1]
        inout_seq.append((train_seq,train_label))
    return inout_seq

train_inout_seq = create_inout_sequences(train_data_normalized,train_window)

class LSTM(nn.Module):
    def __init__(self, input_size=1, hidden_layer_size=100, output_size=1):
        super().__init__()
        self.hidden_layer_size = hidden_layer_size

        self.lstm = nn.LSTM(input_size, hidden_layer_size)
```

```
        self.linear = nn.Linear(hidden_layer_size, output_size)

        self.hidden_cell = (torch.zeros(1,1,self.hidden_layer_size),
                            torch.zeros(1,1,self.hidden_layer_size))

    def forward(self, input_seq):
        lstm_out,
        self.hidden_cell = \
            self.lstm(input_seq.view(len(input_seq) ,1, -1), \
            self.hidden_cell)
        predictions = self.linear(lstm_out.view(len(input_seq), -1))
        return predictions[-1]

model = LSTM()
loss_function = nn.MSELoss()
optimizer = torch.optim.Adam(model.parameters(),lr=0.001)

epochs = 30

for i in range(epochs):
    for seq, labels in train_inout_seq:
        optimizer.zero_grad()
        model.hidden_cell = (torch.zeros(1,1,model.hidden_layer_size),
                            torch.zeros(1,1,model.hidden_layer_size))

        y_pred = model(seq)

        single_loss = loss_function(y_pred, labels)
        single_loss.backward()
        optimizer.step()

    if i%5 ==1 :
        print(f'epoch:{i:3} loss:{single_loss.item():10.8f}')
print(f'epoch:{i:3} loss:{single_loss.item():10.8f}')


fut_pre = 1235

test_inputs = train_data_normalized[0:-1].tolist()

model.eval()
for i in range(fut_pre):
    seq = torch.FloatTensor(all_data_normalized[i+25:train_window+25+i])
    with torch.no_grad():
        model.hidden = (torch.zeros(1,1,model.hidden_layer_size),
                            torch.zeros(1,1,model.hidden_layer_size))

        test_inputs.append(model(seq).item())

actual_predictions = \
    scaler.inverse_transform (np.array(test_inputs[-test_data_size:] ) \
    .reshape(-1, 1))
A =  list(itertools.chain.from_iterable(actual_predictions)) \
    - all_data[-test_data_size:]
```