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Abstract

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Background

The naive Bayesian classification algorithm is based on Bayes' theorem, and it is a statistical classification method to calculate the probability that the target belongs to which category. A comparative study of classification algorithms shows that the classification performance of the naive Bayesian classification algorithm is comparable to that of decision trees and artificial neural network classification algorithms

The basic principle of the naive Bayesian classification algorithm is as follows

1. Each data sample uses a Van dimension vector ={x1, x2 x3, … , xn}, they are respectively for attributes of the sample {A1, A2, ⋯, An}
2. Assume that there is *m* category C1, C2, …, Cm­. Given a data sample X of an unknown category and known attributes. The classifier predict X belongs to the category with the largest a posteriori probability. In other word, classify the sample into category Ci, if only if : P( Ci | X) > P( Cj | X), 1 ≤ j ≤ m, i ≠ j. According to Bayes’ theorem:

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1. Base on Bayes’ theorem

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P(X) is constant for all categories, so we only need to find the largest P(X|Ci)P(Ci). P(Ci) is called the prior probability of the class, calculated by the formula P(Ci)=Si/S, where Si is the number of samples in the training sample with category Ci, and S is the total amount of samples in the training sample set

1. C:\Users\cjrjh\AppData\Local\Temp\WeChat Files\af7a2aef47fb7ea807c4e16608b1d4c.pngGiven a data set with multiple attributes, the cost of directly computing P(X|Ci) can be very large. To reduce the computational cost, the Bayesian classification algorithm usually assumes that all attributes happens independent, so for a category:
2. If attribute Ak is a non-contiguous quantity, there is P(xk | Ci) = Sik / Si, where Sik is the number of samples in the training sample set with category Ci and attribute Ak, and Si is the sample in the training sample set with category Ci.
3. If attribute Ak is a continuous quantity, then we usually assume that the attribute has a Gaussian distribution:
4. We can predict the sample X belongs to category Ci, if only if : P( Ci | X) > P( Cj | X), 1 ≤ j ≤ m, i ≠ j

An n-gram model is a type of probabilistic language model for predicting the next item in such a sequence in the form of a (n − 1)–order Markov model. N-gram models are now widely used in probability.

For example: we have a string: …to\_be\_or\_not\_to\_be…

1-gram sequence: …, t, o, \_, b, e, \_, o, r, \_, n, o, t, \_, t, o, \_, b, e, …

2-gram sequence: …, to, o\_, \_b, be, e\_, \_o, or, r\_, \_n, no, ot, t\_, \_t, to, o\_, \_b, be, …

3-gram sequence: …, to\_, o\_b, \_be, be\_, e\_o, \_or, or\_, r\_n, \_no, not, ot\_, t\_t, \_to, to\_, o\_b, \_be, …

Related Work

Instead of Naïve Bayes, many people have attempted using a different model to predict the stock trend and make trading decisions. The most popular algorithm is Deep-Q learning. In the Q-Learning Algorithm, there is a function called Q Function, which is used to approximate the reward based on a state. We call it R = Q(s,a) + discount \* Q’(s,a), where Q is a function which calculates the expected future value from the state s and action a, Q’ calculates the future reward after doing this action and the discount usually is a constant between 0 and 1. The discount means how valuable for future reward. This is very hard to decide. For the stock, sometimes the current make you lose in the future. Maybe the stock goes up today, and you buy it. But its price decreased sharply the next day. But if you overweight the future value, the system may just buy the stock and hold it forever. Maybe it thinks it can win back in the future, but you may not have enough time to wait this dream comes true. So, the discount is very important. But most of the times, people just set it 0 or randomly. It too complicated to find a good way to decide the discount value. Thus, I give up the Deep-Q learning.

Project description

For Naive Bayes

For the Bayesian model, the most important part is the selection of attributes. First, I chose six attributes, which are the opening price, the closing price, the highest price, the lowest price, the difference between the opening price and the closing price, and the slope of the difference (which is the deference divide by the opening price). This attribute is very classic to present the stock information. I also use the N-gram algorithm to filter the sample:

1. Get the stock data for N days:

*Figure 1,the example of data*

For the example above: we classify them by data. Therefore, we can get data set D ={d1, d2, …, d7} where d1 = {555.6547, 565.3414, 555.6547, 564.0585, -8.4038, -0.01512}, d2 = {555.6547, 565.3414, 555.6547, 564.0585, -8.4038, -0.01512}, …, d7= {556.5598, 562.2783, 549.9262, 561.055, -4.4952,0.008077}

1. Use N-gram to rebuild the data set

For the example above, assume n = 3, we can fix the data set to D’ ={ d1’, d2’, …, d7’} where d1’ = [d1, d2, d3], d2’ = [d2, d3, d4], …, d5’ = [d5, d6, d7]

1. Then generate the sample with the attribute S={s1, s2, s3, s4, s5}. Cause we want to predict the label for the third day, so we need assume we don’t have the information of the third day, then the si is:
   1. si\_opening\_price = di+1\_opening\_price - di\_opening\_price
   2. si\_closing\_price = di+1\_opening\_price - di\_opening\_price
   3. si\_highest\_price = di+1\_highest \_price - di\_ highest \_price
   4. si\_lowest\_price = di+1\_ lowest \_price - di\_ lowest \_price
   5. si\_diff\_price = di+1\_ closing\_price - di\_ opening\_price
   6. si\_diff\_slope = di+1\_diff\_slope - di\_ diff\_slope.
2. Get the label set L = {l1, l2, l3, l4, l5}, if the closing price of the third is higher than the opening price of the first day , So: li = di+2\_ closing\_price - di\_ opening\_price
3. Because the data is a continuous quantity, we need use

Gaussian distribution then train the model. Both formula we talked above.

1. Make the trade policy base on the predict result.

**Naïve Bayes policy( L’(predicted Label):**

* 1. profit = 0, sumOfCost = 0, amountOfStock = 0
  2. For li in L:
     1. if the li is 1:
        1. sumOfCost = sumOfCost + di\_open\_price
        2. amountOfStock = amountOfStock +1
     2. if the li is 0 and amountOfStock > 0:
        1. profit = profit + amountOfStock \* di-1 \_close\_price – sumOfCost
        2. sumOfCost = 0, amountOfStock = 0
  3. output profit

Experiment

My experiments base on different features. First, I choose 6 features from the sample, like I talked above. So, I make the experiment like this:

1）  only the opening price

2）  only the highest price

3）  only the lowest price

4）  only the closing price

5）  only the price difference

6）  only the difference of slope

7）  opening price and the highest price

8）  opening price, highest price and lowest price

9）  opening price, highest price, lowest price and closing price

10）        opening price, highest price, lowest price, closing price, and the price difference

11）        opening price, highest price, lowest price, closing price, price difference and the difference of slope.

The result of prediction accuracy is shown in figure 3, which is the Lc/Ls, Lc is the number of prediction which is correct and Ls is the size of the real label set

*Figure 2, prediction for different feature*

From figure 2, for the single feature, the difference between closing price get 0.787234043 accuracy, which is the highest accuracy of the single feature. The lowest accuracy is 0.670212766 whose corresponding feature is the price difference. We also can find the accuracy is increasing as the amount of features increase. The accuracy for 4 features, 5 features, 6 features is 0.840425532, 0.840425532, 0.842553191. So, when we evaluate the sample with the price difference feature, the accuracy does not decrease and when we add the difference of slope feature, the accuracy is increasing. Which means the more feature we have, the better the accuracy we got.  

The next step is generating a trading policy with the prediction result. When the label is 1, we take the action to buy one share stock and sell all stock when the label is 0. The buy price is the open price for that day. And the selling price is the close price of the day before that day, which means we sell all the stock before the price goes down.

*Figure 3 Profit of different features*

The profit is shown in figure 3. We can find that if we only consider the closing-price feature, the profit is better than some feature combinations. The highest profit we make is experiment No.9, which is $1321.15. Then for the experiment No.10 and No.11, although the accuracy is increased, the profit is less than experiment No.9 about $500. Their profit is also less than the experiment No.4. This means the accuracy may influence the profit but not linear.

In Figure 4, we can see the profit curve. The profits of Experiments No.6, No.5, No.10, and No.11 fell sharply at the beginning. This has a big impact on their overall profit.

After manually looking at the policy generated by these experiments, I found that they made a wrong prediction at several key points. For experiment 10:

* 1. action 8 buy 731.530029
  2. action 9 buy 750.460022
  3. action 10 buy 784.5
  4. action 11 buy 722.81
  5. action 12 buy 703.87
  6. action 13 buy 667.85
  7. action 14 sell 682.74

*Figure 4 profit changes for different features 2*

The prediction labels for action 11 -13 are wrong. The stock price goes down starting at action 11. It keeps going down from action 11 to action 13. However, the prediction label for these actions is 1, which make the system buy more stock until action 14. At action 14, the stock price raises, but the prediction label is 0. Therefore, the trade system sells all stock, which causes a huge loss (about -$332.67). The experiments No.6, No.5, No.10 also have similar situations. Therefore, although the accuracy is increased, the profit may decrease by some action base on the wrong prediction. For experiments No.10, it has 232 actions and its own $890.43 in totals. So, about 1.71% action make the whole system lose about 37.36% profit.

Conclusion

From the experiments on Naïve Bayes model, we can find the most efficient combination of features is opening price, highest price, lowest price and closing price. These features are classic attribute considered by people in stock market trading. The Naïve Bayes model gets 84% accuracy on the prediction, which means it can make trend prediction for stocks. However, the accuracy does not equal to profit. The Naïve Bayes model trades every prediction equally. So, you may get the correct result on some You may be able to get the right results at some worthless point and get the wrong result at some key point. In this case, you will lose money on your trading. Another flaw is the naive Bayesian model is not suitable for more detailed predictions. In our experiments, the selling price is the closing price, but you may get more profit if you sell at the highest price. It is very difficult to predict the highest price by using Naïve Bayes. Because the feature will be too complicated to decide. Choosing features is the most important part of this model. As the experiments above, the price difference and the difference of slope are the bad features. All the test who involved them lose a lot of money in the early game. Thus, without a good feature, the Naïve Bayes model will fail.

References

Margaret H Dunham. eds. 2006. Data Mining: Introductory And Advanced Topics.

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