Research on Maximization of Bank Loan Final Income Based on QUBO Model

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Abstract: The risk assessment and income calculation of bank credit service has always been the focus of attention in the industry. Banks need to evaluate the credit of borrowers during the loan process, and credit score card is a common evaluation method. Different credit score cards adopt different thresholds in the evaluation process, and the combination of score cards and the selection of thresholds will directly affect the bank's loan profit. This paper discusses how to select the combination of scorecard and its corresponding threshold to maximize the bank's income, builds a target optimization model around the bank's final income and converts it into QUBO form for solving. Based on bank data, this paper uses Excel to calculate the final income under different thresholds in each credit score card group, and then obtains the income value of the group with the highest final income in each credit score card group and its corresponding threshold. In addition, binary variables are introduced to construct the objective function and establish the constraint conditions, and the established objective optimization model is converted into QUBO form, and the objective function and constraint conditions are expressed through the Hamiltonian. When the corresponding threshold value of the 49th credit score card group is 1, the final income is the maximum.

Key words: bank loan,quantum computing,QUBO combination optimization,

1.Introduction

Nowadays, credit score card is an important tool for banks to evaluate customers' credit rating. Banks score customers on a single or multiple credit score cards before they qualify for credit or loans[7]. Each credit score card contains multiple thresholds, but only one threshold takes effect. Different credit score cards correspond to different pass rates and bad debt rates under different thresholds. Generally speaking, the higher the approval rate, the more customers qualified for loans, the more interest income of the bank, but the corresponding bad debt rate is also higher, which leads to the risk of capital loss. Thus, a bank's final income is the difference between interest earned on loans and losses on bad loans. In this case, it is required that in the scenario of bank lending, a single credit score card or a number of different credit score cards should be selected to achieve the best risk control strategy and maximize the final income of the bank, considering the mutual influence of the pass rate and bad debt rate. Based on the above background, we establish a mathematical model, and the simplified calculation method of the final income of the bank makes the final income of the bank the highest[3]. Please establish a relevant mathematical model and convert this model into the form of QUBO for solving.

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2. Symbol description and noun definition

Table 1 Symbol description and noun definition

symbol	definition
Z	Loan funds
t_i	The pass rate corresponding to the threshold selected by the I-th credit score card
L	Select the loan interest income from the bank this time
H	Select the bad debt loss of the bank this loan
W	Select the bank's final income from the loan
Q	QUBO matrix
$\mathcal{H}$	The Hamiltonian
C	Penalty term

3. Establishment and solution of the model

3.1 The calculation of the bank's final income is simplified

Under the mutual influence of the pass rate and the bad debt rate, a bank's final income can be defined as the difference between the loan interest income and the bad debt loss[9]. Different combinations of credit score cards, accompanied by different pass rate and bad debt rate, thus affect the final revenue value of the bank. However, in real life, credit score card combination is a very complicated process[8]. In order to facilitate the follow-up modeling and solving work, this problem can be simplified as follows.

We assume that the loan fund is Z yuan, and the bank loan interest income rate is l, taking n (n=1, 2, 3... , 100) credit score cards as selected credit score card portfolio to measure the bank's final revenue[4]. Only one threshold can be selected for each credit score card[5], so it is assumed that the ith (i=1, 2, 3... The threshold selected by n credit score cards corresponds to ti and hi respectively.

The expression of the total pass rate is:

$$t = \prod_{i=1}^{n} t_i \tag{1}$$

The total bad debt rate is the average of the bad debt rate corresponding to n credit cards, and the expression is:

$$h = \frac{1}{n}\sum_{i=1}^{n} h_i \tag{2}$$

The expression of this bank's loan interest income for this loan is:

$$L = Zlt(1-h) \tag{3}$$

The expression of bad debt loss of this bank's loan is:

$$H = Zth \tag{4}$$

The expression of the bank's final income from this loan is:

$$W = L - H \tag{5}$$

3.2 Introduction to QUBO model

QUBO refers to a model of Quadratic Unconstrained Binary Optimization, which is a mathematical model solving quadratic unconstrained binary optimization problems and is one of the most widely used optimization models in quantum computing [1]. In QUBO model, the decision variable is a binary variable and the objective function is a quadratic function. This model can be accelerated by quantum computer, and compared with traditional methods, it can solve combinatorial optimization problems more efficiently and quickly. Its basic expression is as follows [2] :

$$y = x^T Qx \tag{6}$$

Where, Q is QUBO matrix; x is a vector of binary variables, each of which has a value of 0 or 1.

In solving combinatorial optimization problems, the ultimate goal of QUBO model is to find an x that minimizes y.

3.3 The ultimate income maximization model of bank lending based on a single credit score card

3.3.1 Establishment of model

According to the simplified process and example of solving the bank loan profit given in the question[6], it is assumed that the loan fund is 1,000,000 yuan, the interest income rate of bank loan is 8%, and the final income under different thresholds in each credit score card group is calculated to obtain the income value of the group with the highest final income in each credit score card group, as shown in Table 2.

Table 2 Highest income by credit score card group

Number of groups	Maximum income value
1	50129.6
2	32716.8
3	54087.2
⋮	⋮

:	:
98	53814.8
99	51092
100	44531.2

Excel processes the above data to obtain the threshold corresponding to the highest income in each credit score card, as shown in Table 3.

Table 3 Lists the thresholds corresponding to the highest income in each credit

Number of groups	Maximum income value
1	1
2	1
3	2
:	:
:	:
98	1
99	1
100	1

Record the highest income in each credit score card group as a1, a2, a3,... a99, a100. Since it is required in the question that the constructed model should be converted to QUBO form for solving, binary variables x1, x2, x3 are directly introduced in the construction of the model... , x99, x100, each x corresponds to a credit score card group. If x is 1, the credit score card group is adopted. If x is 0, the credit score card group is not adopted. Taking the bank's final income E as the objective function, the model is constructed, and the expression is:

$$E = \sum_{i=1}^{100} a_i x_i \tag{7}$$

Since the question requires that one credit score card and its corresponding threshold should be found out among 100 credit score cards to maximize the final income of the bank, it is necessary to construct constraint conditions. The objective function of the constructed model is constrained, and the expression of constraint conditions is:

$$\sum_{i=1}^{100} x_i = 1 \tag{8}$$

The mathematical model finally constructed is expressed as follows:

$$\begin{cases} E = \underset{x \in \{0,1\}^N}{\text{minmize}} \sum_{i=1}^{N=100} -a_i x_i \\ \sum_{\mathrm{i}=1}^{100} x_i = 1 \\ x_i \in \{0,1\} \end{cases} \tag{9}$$

3.3.2 Solving the model

According to the objective optimization model established in the previous section, the objective function is converted to QUBO form.

$$\mathcal{H} = \mathcal{H}_{obj} + w_1 \mathcal{H}_a \tag{10}$$

Where, $\mathcal{H}$ represents the Hamiltonian after transformation of the target optimization model; $\mathcal{H}_{obj}$ Represents the Hamiltonian after transformation of the objective function; $\mathcal{H}_a$ Represents the Hamiltonian after constraint transformation; w_1 Represents the penalty coefficient. $\mathcal{H}_{obj}$ $\mathcal{H}_a$ and the expression is:

$$\mathcal{H}_{obj} = \sum_{i=1}^{100} - a_i x_i \tag{11}$$

$$\mathcal{H}_a = \sum_{i=1}^{100} (1 - x_i)^2 \tag{12}$$

In order to solve the QUBO model, pyqubo library and dwave.system library in python are introduced to convert the target optimization model into QUBO model, and QUBO model is solved based on D-wave method.

The final result obtained through python is as follows: When the corresponding threshold value of the 49th credit score card group is 1, the final income of the bank is the highest, as shown in Figure 1.

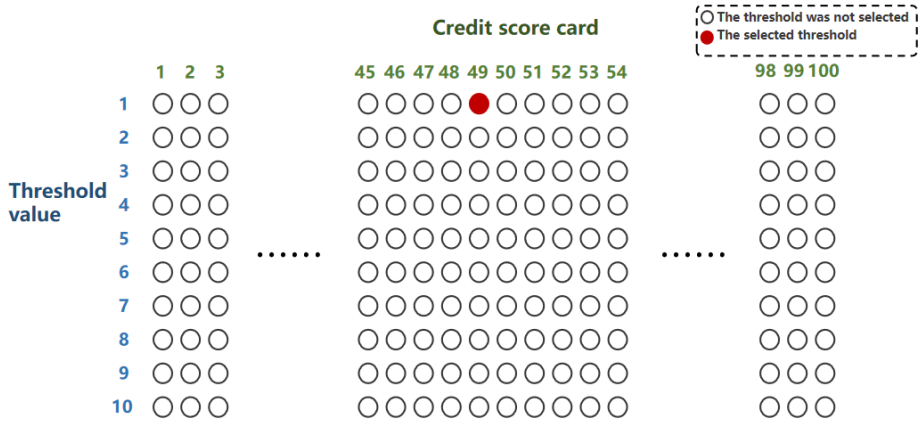

Figure 1 Solution results

4 Conclusion

In exploring how to combine different credit score cards to maximize the bank's final income, this paper adopts QUBO model (unconstrained quadratic binary optimization model) and MILP model (mixed integer linear programming), which are the most widely used models in quantum computing. Compared with traditional methods, when solving such combinatorial optimization problems, The two models can solve the combinatorial optimization problem more efficiently and accurately.

In this paper, the model combines the actual bank lending situation, comprehensively considers the threshold value of credit score card, pass rate, bad debt rate and other factors, which can better solve the combination-optimization problem, indicating that the established model has strong practicability and extensibility, and has certain universality in solving the problem of maximizing the final income of bank lending. In this paper, the application and transformation methods of QUBO model (unconstrained quadratic binary optimization model) and MILP model (mixed integer linear programming) can be extended to the solution of most combinatorial optimization problems with large computation and complicated steps.

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