AN OPTIMIZATION MATCHING APPROACH FOR DIGITAL LENDING USING CONSTRAINT SATISFACTION PROBLEM MODELS

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Abstract - Electronic brokers (e-brokers) in digital lending aim to match borrowers and lenders to conduct transactions via digital platform. The paper proposes a matching model between borrowers and lenders through electronic brokerage after determining interest rate and other requirements. The main contributions of the paper are as follows: (i) Building the framework of matching process through an e-broker; (ii) Building a formula system to calculate borrowers' satisfaction degree for interest rate and other hard constrains attributes for loans as per lenders' information; and (iii) building a matching model based on an artificial intelligence method to find the optimal matching solutions between borrowers and lenders to maximize borrowers' satisfaction degree. The experimental results show that the proposed approach is flexible and effective under the different simulations using constraint satisfaction problem models (CSP).

Key words - Digital lending; borrowers' satisfaction degree; e-broker; matching process; CSP

1. Introduction

In the context of the industrial revolution 4.0 along with the strong development of information technology, digital transformation has been appeared in every aspect of business transactions. The availability of e-brokers which match between buyers and sellers, then earn profit has become more popular. Conducting business transactions between buyers and sellers through brokers creates many unique advantages, such as high service quality, low information costs... Brokers are finding the optimal match between buyers and sellers by considering the sellers' supply and buyers' requirements [1], as shown in Figure 1:

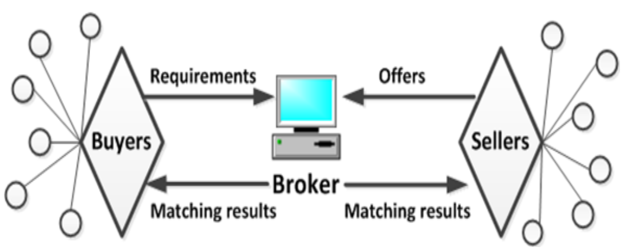

Figure 1. *The trading process through e-broker*

The research on brokers or intermediaries as the third party of trading processes in e-marketplaces has drawn many interests in recent years [2-5]. Li et al. [6] propose a method to coordinate buyers and sellers in B2B e-marketplaces through brokers using multi-objective optimization. A multi-objective genetic algorithm based on the preferences of buyers and sellers on their partners is applied to solve the target optimization, finding the optimal matching, and carrying out the simulation to verify the effectiveness of the proposed method. Alpár [7] proposes a model of coordination through electronic brokerage in the B2B market. The study presents a method for modeling buyers' requirements and seller's proposals using hard and soft constrained attributes. Brokers have two important functions: to find possible combinations and to identify the most profitable solution. The matching process consists of four steps: analysis, modeling, implementation and optimization. Jiang et al. [8] propose an optimization model that coordinates commodity trading with quantity discounting in electronic brokerage. Relevance in a multi-attribute exchange is considered from the point of view of both buyers and the sellers. The proposed multi-objective optimization model not only maximizes transaction volume, but also maximizes coverage. Jiang et al. [9] propose a coordination model between buyers and sellers for real estate transactions in China. The transaction price is determined by constructing the buyers and sellers satisfaction function. The model is to determine the matching outcome with the objective of maximizing the weighted sum of buyers' and sellers' satisfaction. Then, several criteria are defined and used to measure the performance of the proposed method.

Digital lending with e-brokers has been gradually becoming an inevitable trend. Brokers have received requests from borrowers and lenders. Their responsibilities are to coordinate the credit relationship between many borrowers based on lenders' requirements to satisfy the borrower and maximize the mutual benefit of the borrower. Digital transformation is changing lending from inside by faster credit decisions, lower cost and more secure. Research related to brokers in digital lending has been recently an active research direction. Due to the huge amount of information in the digital environment, it will not be easy for both borrowers and lenders to discern what information is correct or not to support final credit decision-making. Such difficulty is an opportunity for brokers to participate in the digital environment to settle credit relations. Brokers helps individuals or organizations gain useful information on the digital platform. Thus, building an optimization matching approach is necessary, contributing to the expansion of digital lending all over the world in general and in Vietnam in particular.

In this paper, we propose a method of matching between borrowers and lenders through electronic brokerage based on interest rate and other attributes. In addition, matching results are determined based on constrain satisfaction problems (CSP) model to maximize borrowers' total benefits.

2. The proposed method of matching between borrowers and lenders through e-brokers

2.1. The framework of matching process

The matching process between borrowers and lenders is implemented through e-brokers. The issue of interest in this study is the borrowers-lenders matching to maximize borrowers' satisfaction degree based on interest rate and other attributes. The process of borrowers-lenders matching through an e-broker is shown in Figure 2 as follows:

Step 1: Lenders provide the reservation and ideal interest rate and other requirements for loans to e-brokers.

Step 2: Borrowers also provide the offer interest rate and other requirements for loans to e-brokers.

Step 3: E-brokers estimate the interest rate of existing loans based on lenders and borrowers' information.

Step 4: E-brokers calculate borrowers' satisfaction degree based on trade interest rate and other attributes

Step 5: E-brokers obtains the matching results between lenders and borrowers based on constraint satisfaction problem models.

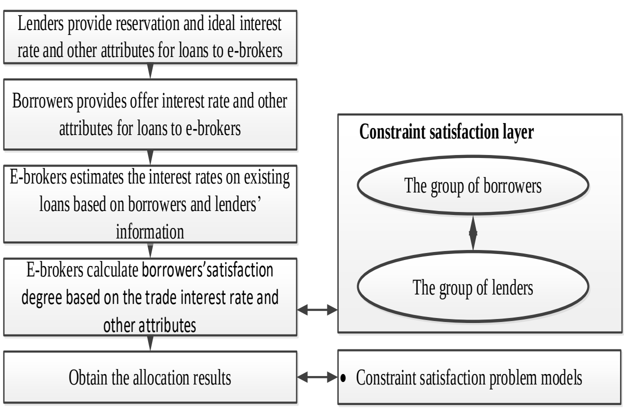

***Figure 2.** The matching process for digital lending*

2.2. The calculation of borrowers' satisfaction degrees

Let $\{B_1;\ B_2;\ \ldots;\ B_n\}$ denotes the set of borrowers, $\{L_1;\ L_2;\ldots;\ L_m\}$ denotes the set of lenders, $\{H_1;\ H_2;\ \ldots;\ H_m\}$ denotes the set of loans. Each lender L_j offers the loan H_j and each borrower B_i need the loan H_j. An e-broker will estimate borrower B_i's satisfaction based on the requirements of borrower B_i and the lender S_j for loan H_j related to hard constraint attributes [10] and interest rate and other attributes are not considered in this study.

q_j^s and $\tilde{q}_j^s$ represent the reservation interest rate and the ideal interest rate of the lender S_j for the loan H_j and $\tilde{q}_j^s \geq q_j^s$. The interest rate of borrower B_i for loan H_j is called as q_{ij}^b. If borrower B_i is not interested in the loan H_j then q_{ij}^b="-". q_j^e denotes the estimated interest rate provided by broker for loan H_j and generally, $q_j^e \geq q_j^s$. q_{ij} represents for trade interest rate between borrower B_i and lender L_j. $q_{ij} \geq q_j^s$ indicates that borrower B_i and lender L_j reach a transaction agreement with $i = 1, 2, \ldots, n$ and $j = 1, 2, \ldots, m$.

Based on notations above, the calculation method of borrowers' satisfaction degree based on hard attributes and the interest rate is presented as follows:

2.2.1. Calculating borrowers' satisfaction degree based on the hard constraint attribute

$a_{ij}^{b(h)}$ denotes borrower's satisfaction degree based on hard constraint attribute t_h. The hard constraint attributes must be satisfied between the borrower and the lender and then to be considered for transaction matching [10]. Borrowers' satisfaction degree based on the hard constraint attribute is determined as follows:

$$a_{ij}^{b(h)} = \begin{cases} -1 \text{ if } B_i \textit{ does not match with } L_j \\ 1 \text{ if } B_i \textit{ matches with } L_j \end{cases} \quad (1)$$

$a_{ij}^{b(h)} = -1$ indicates lender L_j does not satisfy the requirements of borrower B_i for attribute t_h while $a_{ij}^{b(h)} = 1$ indicates lender L_j satisfies the requirements of borrower B_i for attribute t_h.

2.2.2. Calculating the degree of borrowers and lender's satisfaction degree based on interest rate

- Borrowers' satisfaction degree function: $f(q_{ij})$ denotes borrower B_i's satisfaction degree function and can be calculated using equation (2) in the following:

$$f(q_{ij}) = \begin{cases} 1, q_{ij} < q_{ij}^b \\ \rho_i + (1-\rho_i)[(q_j^e - q_{ij})/(q_j^e - q_{ij}^b)]^{\gamma_i},\ q_{ij}^b \leq q_{ij} \leq q_j^e, \\ 0, q_{ij} > q_j^e \end{cases} \quad (2)$$

where ρ_i represents the satisfaction degree of borrower B_i when trade interest rate $q_{ij} = q_j^e$ with $0 < \rho_i < 1$. $\gamma_i > 0$ is the sensitivity coefficient on interest rate of borrower B_i. If the borrower B_i is more sensitive to higher interest rates, then $0 < \gamma_i < 1$. If borrower B_i is more sensitive to all acceptable interest rates, then $\gamma_i = 1$.

- Lenders' satisfaction degree function: $g(q_{ij})$ denotes lender L_j's satisfaction degree function and can be calculated using equation (3) in the following:

$$g(q_{ij}) = \begin{cases} 0, q_{ij} < q_j^s \\ \sigma_j + (1-\sigma_j)[(q_{ij} - q_j^s)/(\tilde{q}_j^s - q_j^s)]^{\delta_j},\ q_j^s \leq q_{ij} \leq \tilde{q}_j^s, \\ 1, q_{ij} > \tilde{q}_j^s \end{cases} \quad (3)$$

where σ_j represents the satisfaction degree of lender L_j when interest rate $q_{ij} = q_j^e$ with $0 < \sigma_j < 1$. $\delta_j > 0$ is the sensitivity coefficient on interest rate of lender S_j. If the lender L_j is more sensitive to lower interest rates, then $0 < \delta_j < 1$. If lender L_j is more sensitive to all acceptable interest rates, then $\delta_j = 1$.

- Parameter Determination $\rho_i, \gamma_i, \sigma_j, \delta_j$

Borrowers' satisfaction degree function on trade interest rate in equation (2) includes two parameters ρ_i and γ_i. Lenders' satisfaction degree function on trade interest rate in equation (3) also includes two parameters σ_j and δ_j. The determination of ρ_i and γ_i is conducted as follows:

The value of ρ_i is recommended from borrower B_i to calculate the borrower's satisfaction degree in different interest rates. The value of ρ_i represents borrower B_i's satisfaction at various interest rates.

The value of γ_i is determined based on the satisfaction of borrower ρ_i. By the least square method, the value of γ_i is determined with the specified ρ_i. Let $q_1^i = q_{ij}^b$, $q_2^i, \dots, q_l^i = q_j^e$ represent equally spaced interest rate points within the interval $\left[q_{ij}^b, q_j^e\right]$ and let $r_1^i = \rho_i, r_2^i, \dots,$ $r_l^i = 1$ represent the specified degree of satisfaction for each interest rate. The value of γ_i is examined as follows:

$$min \sum_{k=1}^{l}[(\rho_i + (1-\rho_i)[(q_k^i - q_{ij}^b)/(q_j^e - q_{ij}^b)]^{\gamma_i}) - r_k^i]^2 \quad (4)$$

s.t $\gamma_i > 0$

The value of σ_j and δ_j is determined in the similar way of ρ_i và γ_i.

- Trade interest rate determination

The optimal trade interest rate is to optimize the satisfaction of both borrowers and lenders. The solution of the bi-objective mathematical model in equation (5) and (6) is the interest rate between borrower B_i and lender L_j:

$$\max f(q_{ij}) \quad (5)$$

$$\max g(q_{ij}) \quad (6)$$

$$\text{s.t. } q_j^s \le q_{ij} \le q_j^e \quad (7)$$

$$q_{ij} \ge 0 \quad (8)$$

The bi-objective mathematical model in equation (5) and (6) could be solved by max-min method [11-12] to calculate trade interest rate q_{ij}.

After trade interest rate q_{ij} is calculated, the degree of borrower's satisfaction is represented, called a_{ij}^b, as follows:

$$a_{ij}^b = f(q_{ij}), i = 1,2,\dots,n, j = 1,2,\dots,m \quad (9)$$

where $f(q_{ij})$ is presented in equation (2). If borrower B_i and lender L_j cannot reach a transaction agreement, then $a_{ij}^b = -1$.

2.3. Matching process between borrowers and lenders through e-brokers using CSP

To model CSP for matching processes, an e-broker needs to determine constraints based on the calculation of borrowers' satisfaction degree. Relationships between borrowers and lenders through borrowers' satisfaction degree are presented in Table 1 as follows.

Table 1. *Borrowers' satisfaction degree as per lenders' information in CSP model*

	L_1	L_2	L_3	…	L_m
B_1	a_{11}^b	a_{21}^b	a_{13}^b	…	a_{1m}^b
B_2	a_{21}^b	a_{22}^b	a_{23}^b	…	a_{2m}^b
…	…	…	…	…	…
B_n	a_{n1}^b	a_{n2}^b	a_{n3}^b	…	a_{nm}^b

where a_{nm}^b is B_n's satisfaction degree as per L_m's offers under the consideration of trade interest rate q_{nm} for loans. If L_m does not satisfy B_n for interest rate then $a_{nm}^b = -1$. It means that L_m does not satisfy B_n and the constraint between L_m and B_n in a CSP model is created for matching processes. Matching through a broker between n borrowers and m lenders under the consideration of constraints in this paper are solved using CSP techniques. Thus, variables, domain of variables and constraints are defined in the CSP model for matching process as follows.

- Variables and domain of variables

$$x_{ij} = 1 \text{ } or \text{ } 0, \forall i \in n, \forall j \in m \quad (10)$$

- Constraints

$$\sum_{i=1}^{n} x_{ij} \le 1, j = 1,2,\dots,m \quad (11)$$

$$\sum_{j=1}^{m} x_{ij} \le 1, i = 1,2,\dots,n \quad (12)$$

$$x_{ij} = 0 \text{ } if \text{ } a_{ij}^b = -1 \text{ } or \text{ } a_{ij}^{b(h)} = -1 \quad (13)$$

Constraints in Equation (10) is decision variable constraints, if borrower B_i matches with lender L_j then $x_{ij} = 1$; otherwise $x_{ij} = 0$. Constraints in Equation (11) and (12) are that each borrower (lender) only matches with each lender (borrower) maximally. Constraints in Equation (13) determine a constraint satisfaction layer. After an e-broker defines variables and determines the domain of variables and constraints, an e-broker uses the CSP techniques to find out the optimal matching solutions to satisfy borrowers' requirements as per lenders' information.

3. Experiments

In this section, an experiment is developed to demonstrate that the proposed approach through e-brokers is flexible and provides optimal solutions in the business environment to support decision making. Specifically, the experimental setting is presented in subsection 3.1 and the experimental results are evaluated in subsection 3.2.

3.1. Experimental setting

In the experiments, an artificial data of borrowers and lenders in the digital lending environments are generated. The interest rate and other attributes in borrowers and lenders' requirements are considered in the experiments. The lenders will provide information about the reservation interest rate q_j^s and the ideal interest rate $\tilde{q}_j^s$ for their loans. Borrowers place offer interest rate q_{ij}^b for loans they are interested in. Information on borrowers' satisfaction ρ_i and lenders' satisfaction σ_j with interest rate is determined the value of the interest rate sensitivity coefficient parameters. Interest rate sensitivity coefficient of the borrowers and that of the lenders are examined by equation 3 presented in part 2.

In these experiments, the proposed matching method for electronic brokerage is deployed to find the optimal pair allocation under different situations in the online business environment of lending. More specifically, the experimental results and analysis are presented in section 3.2.

3.2. Experimental results

In these experiments, an e-broker applies CSP method in Python to find out the matching solution by the consideration of the requirements of borrowers and lenders based on interest rate and not considering borrowers' satisfaction degree with other attributes. In particular, the electronic brokerage calculates each borrower's satisfaction degree on the interest rate after receiving information from borrowers and lenders. Based on the satisfaction degree of borrower, the constraints for the CSP model are determined before the matching process is implemented.

With data on the requirements of borrowers and lenders for loans in section 3.1, an e-broker found 120 solutions for transaction matching. The specific results with borrowers' satisfaction degree and the number of matching solutions are presented in Figure 3. Figure 3 indicates the relationship between borrowers' satisfaction degree and the number of matching solutions. Thereby, we see that the higher the borrowers' satisfaction degree, the lower the number of matching solutions and vice versa.

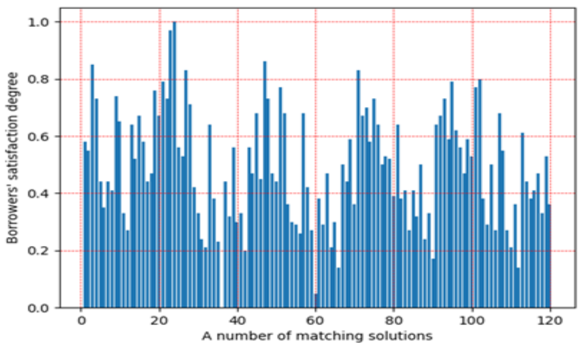

Figure 3. *The matching solutions based on CSP*

Based on the experimental results, the e-brokers consider which solution to choose from the matching solutions to achieve the objective; it depends on each business situation. For example, if the e-broker wants to choose a matching solution from among 120 solutions to maximize borrowers' satisfaction, then matching solution 24 is perfect because borrowers' satisfaction degree in this solution is equal to 1. The specific matching solution for the highest degree of borrowers' satisfaction are presented in Figure 4. If you want to consider borrowers' the lowest satisfaction degree, the electronic brokerage chooses the matching solution 36, Borrowers' satisfaction degree in this solution is 0. The specific matching solutions are presented in Figure 5. In addition, based on the graphs in Figures 4 and 5, it shows that the interest rate results from matching model are rational because the interest rates are always between the reservation interest rate and the ideal interest rate.

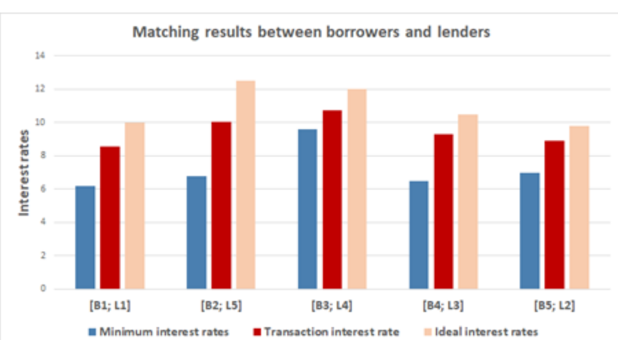

Figure 4. *The matching solutions with the highest degree of borrowers 'satisfaction*

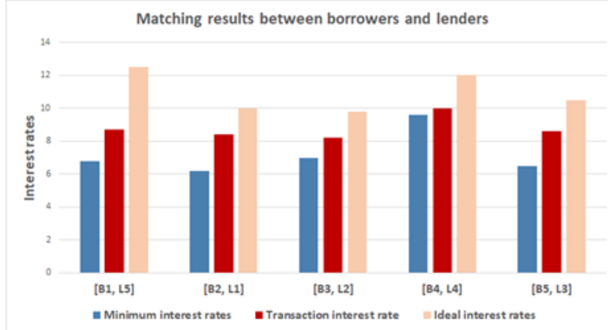

Figure 5. *The matching solutions with the lowest degree of borrowers 'satisfaction*

In addition, the purpose of other experiment is to maximize borrowers' total satisfaction degree under the consideration of different lenders. Based on the artificial dataset above, an e-broker chooses an incremental number of lenders to carry out matching between borrowers and lenders. Figure 6 shows that the impact of the number of lenders on borrowers' total satisfaction degree. In general, as the larger the number of lenders participating, an e-broker has many opportunities to select lenders' offers which satisfy borrowers' requirements and increase a borrowers' total satisfaction degree.

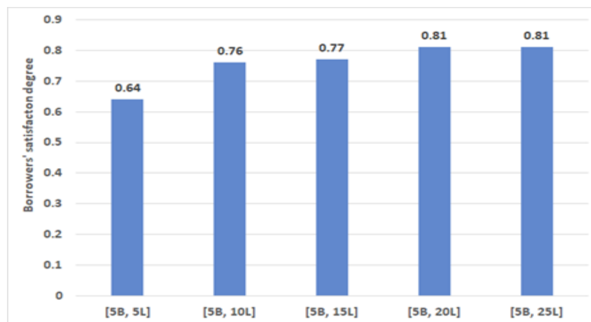

Figure 6. *Borrowers' total satisfaction degree under different number of lenders*

In summary, the proposed approach for matching between borrowers and lenders is well-executed in different business situations. In general, the higher the satisfaction degree of borrowers is, the lower the number of matching solutions is, and the higher the total satisfaction degree of borrowers is, the larger the number of lenders in business environment is.

4. Conclusion and Future work

This paper proposes a matching approach between borrowers and lenders through electronic brokerage based on interest rate and other attributes in order to maximize the overall satisfaction of borrowers. This proposed approach is new because (i) building an intelligent matching mechanism through an electronic brokerage based on the trade interest rate and hard constraint attributes, (ii) building a formula system to calculate borrowers' satisfaction degree after determining the trade interest rate based on the information of borrowers and lenders, and (iii) building a matching model using CSP to find the optimal matching solutions between borrowers and lenders to maximize borrowers' total satisfaction degree. In addition, the experimental results have proved that the proposed matching model has been sufficient in fitting the requirements of borrowers and lenders and maximizing borrowers' total satisfaction degree.

The upcoming expanded research direction is to maximize benefits for all parties as well as consider soft constraint attributes and competitive factors in the market. In addition, the transaction matching model through electronic brokerage would be implemented on the website platform to facilitate the execution of transactions between borrowers and lenders.

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