Broker-Based Trade Allocation in Agent-Based E-commerce*

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Abstract. Online business environment represents complex systems where the business transactions between buyers and sellers are carried out based on multiple constraints from buyers and sellers. The complexity of the online business environment between buyers and sellers has encouraged the use of modelling broker to solve allocations. Thus, this paper proposes a novel approach for a broker agent to allocate buyers' requirements to sellers' offers using the method of artificial intelligence. The major contributions of this paper are that (i) a proposed framework for a broker agent is divided in four stages: receiving, calculation, filtering and allocating; (ii) a novel calculation method is to calculate buyers' satisfaction degree as per sellers' offers to determine a constraint satisfaction layer; and (iii) CSP model for trade allocation is built to help a broker agent to find an optimal allocation solution to satisfy buyers and sellers' various preferential requirements. Finally, the results of the simulation experiment demonstrate the proposed approach is flexible and effective under the consideration of different constraints.

Keywords: Buyers' satisfaction degree, Allocation process, Multi-attribute trading.

1 Introduction

E-commerce has recently made remarkable achievements in the era of globalization together with rapid technological changes. Especially, the emergence of artificial intelligent technology makes e-commerce systems more intelligent so it is convenient for buyers and sellers to carry out business transactions via brokers in digital business environments [1-2]. A broker is responsible to receive requirements of buyers and sellers and to implement trade allocation procedures with regard to the consideration of different situations in complex business environments [3-5]. Research on brokers or

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intermediaries as the third party of the trading processes in e-commerce has been active directions in recent years. Jiang et al. [6] proposed an optimization approach to solve matching problems through a broker using a single objective function under the consideration of estimated prices. A matching model for a broker is built to maximize the weight sum of the sellers' and buyers' satisfaction degree based on requirements of buyers and sellers. Li et al. [7] proposed a new approach to allocate buyers to sellers using a multi-objective optimization model through a broker. Furthermore, an agent-based framework was built to carry out matching processes in three layers: the interface layer, the matching layer and the database layer. Jiang et al. [8] built an optimal matching approach for brokers under the consideration of multi-attribute trading with fuzzy information and indivisible demand considerations.

As mentioned above, such approaches have focused on studying brokers as the third party to allocate buyers' requirements to sellers' offers in business environments. However, there are few theories and guidelines to help a broker agent in intelligent e-commerce systems to find out optimal allocation solutions using CSP techniques and multi-attribute trading. Most current brokers in e-marketplace only provide buyers' or sellers' trade information and do not really employ artificial intelligence techniques to allocate buyers to sellers. The lack of a comprehensive optimization approach on allocation could not provide a solid foundation to improve market efficiency in digital business environments. Therefore, how to allocate buyers to sellers using CSP techniques under the consideration of constraints between buyers and sellers is one of the most important challenges for a broker agent. The novel approach in this paper is proposed to solve this challenge.

The rest of this paper is organized as follows. Problem description is presented in Section 2. The proposed approach for a broker agent is introduced in Section 3. An experiment is described in Section 4. Section 5 gives conclusions and points out our future work.

2 Problem description

There are three members in the trading process with multi-attribute trading, i.e., buyers, sellers and a broker. The broker is often called a facilitator, who acts as an intermediary between buyers and sellers in multi-attribute trading. The consideration of the seller-buyer matching problem through a broker agent is shown in Fig. 1.

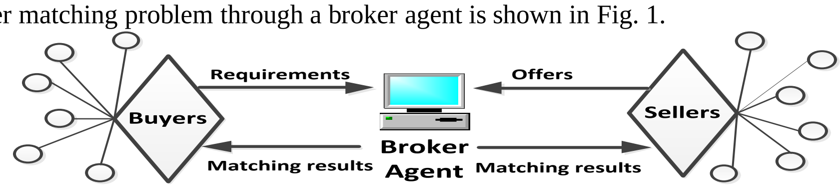

Fig. 1. The seller-buyer matching problem through a broker agent

The broker agent's responsibility is to match n $(n \geq 1)$ buyers with m $(m \geq 1)$ sellers for the same commodity with multi-attribute trading in order to satisfy buyer's requirements and it is assumed that each buyer (seller) can buy (sell) commodities for each seller (buyer) at most.

Let a set of buyers $\boldsymbol{B} = \{B_1, B_2, \dots, B_n\}$, a set of sellers $\boldsymbol{S} = \{S_1, S_2, \dots, S_m\}$, buyers' requirements and sellers' offers are related to multi attributes which are divided to attributes with hard constraints and soft constraints [9]. Buyers' requirements with multi-attributes are split into a set of attributes with hard constraints $\boldsymbol{H} = \{h_1, h_2, \dots, h_z\}$ and set of attributes with soft constraints $\boldsymbol{A} = \{a_1, a_2, \dots, a_k\}$. Let n be number of buyers, $i \in [1,2 \dots n]$ is the index of B_i's requirements and $C_{ii'}(i' \in z + k))$ is the crisp value of the i'^{th} attribute of B_i's requirements. Similarly, let m be number of buyers, $j \in [1,2 \dots m]$ is the index of S_j's offers and $Q_{ji'}(i' \in z + k))$ is the crisp value of the i'^{th} attribute of S_j's offers.

Based on the above analysis, the key problem is how to help a broker agent to achieve the optimal allocation results between trading (buyers and sellers) agents in agent-based e-commerce using CPS model. Therefore, the proposed allocation approach for a broker agent can solve this problem and is presented in Section 3.

3 A proposed approach for a broker agent

3.1 Framework of the proposed approach

The framework of the proposed approach for a broker agent to allocate buyers' requirements to sellers' offers using constraint satisfaction problem models is presented in Fig. 2 as follows.

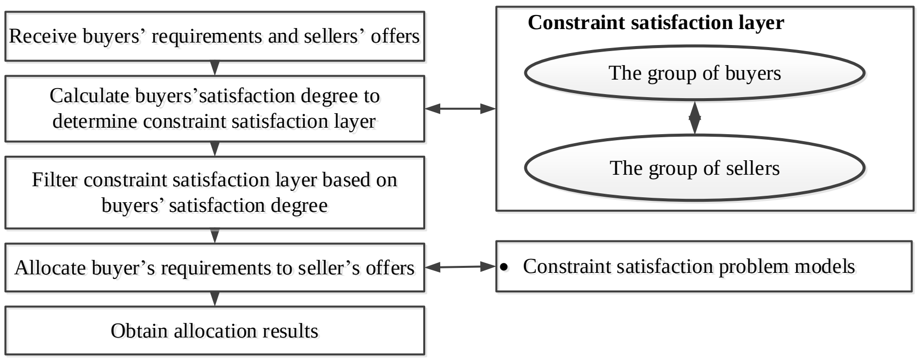

Fig. 2. The framework of proposed approach for a broker agent

In the framework, trading information related to buyers' requirements and sellers' offers is submitted to a broker agent. Then, buyers' requirements are classified into attributes with three kinds of constraints, i.e., attributes with hard constraints, benefit soft constraints, and cost soft constraints. Based on attribute classification, buyers' satisfaction degree for each type of attribute is calculated as per sellers' offers to determine constraint satisfaction layer. After that, a broker agent can filter a constraint satisfaction degree layer based on buyers' satisfaction degree to achieve a broker agent's goals.

Finally, a broker agent carries out trade allocation using constraint satisfaction problem models to obtain the optimal allocation results to satisfy buyers' requirements as per sellers' offers.

3.2 Calculation of buyers' satisfaction degree based on sellers' offers.

Based on notations of buyers' requirements and sellers' offers in Section 2, the calculation method of buyers' satisfaction degree for all attributes is presented as follows:

(i) for an attribute type with hard constraints:

$$\beta_{ij}^{h_g} = \begin{cases} -1 & \text{if } C_{ig} \neq Q_{jg} \\ 1 & \text{if } C_{ig} = Q_{jg} \end{cases} \tag{1}$$

$\beta_{ij}^{h_g} = -1$ means that B_i does not match with S_j for attribute $h_g (g \in z)$ and $\beta_{ij}^{a_g}=1$ means that B_i matches with S_j for attribute h_g.

(ii) For an attribute type with benefit soft constraints: if $Q_{jl} < C_{il}$ then $\beta_{ij}^{a_l}=-1$. It means that B_i does not satisfy S_j. If $Q_{jl} \geq C_{il}$, then $\beta_{ij}^{a_l}$ is calculated as follows:

$$\beta_{ij}^{a_l} = \left(\frac{Q_{jl} - Q_{min\text{-}l} + \varphi}{Q_{max\text{-}l} - Q_{min\text{-}l} + \varphi}\right)^{t}, \tag{2}$$

where $t = {C_{il}}/{Q_{min-l}}$, $Q_{min\text{-}l}$ is the minimal value of seller in the set of values for the attribute a_l and $Q_{max\text{-}l}$ is the maximal value of a seller in the set of values for the attribute a_l. A value $t \in (0,1]$ helps a broker agent to carry out comparing a buyer's satisfaction degree when t is used to calculate $\beta_{ij}^{a_l}$. $\varphi = Q_{min\text{-}l}/2$, φ helps a broker agent to solve some special cases such as only one seller in e-commerce systems or $Q_{max\text{-}l} = Q_{min\text{-}l}$. $\beta_{ij}^{a_l}$ means that B_i matches with S_j for attribute a_l with a buyer's satisfaction degree $\beta_{ij}^{a_l}$. $\beta_{ij}^{a_l}$ is in-between 0 and 1. If $\beta_{ij}^{a_l}$ is near 1, it means that S_j is highly satisfied by B_i for attribute a_l $(l \in k)$.

(iii) for an attribute type with cost soft constraints: if $C_{il} < Q_{jl}$ then $\beta_{ij}^{a_l}=-1$. It means that S_j does not satisfy B_i. If $C_{il} \geq Q_{jl}$, then $\beta_{ij}^{a_l}$ is calculated as follows:

$$\beta_{ij}^{a_l} = \left(\frac{Q_{max\text{-}l} - Q_{jl} + \varphi}{Q_{max\text{-}l} - Q_{min\text{-}l} + \varphi}\right)^{\frac{1}{t}}, \tag{3}$$

3.3 Applying CSP for a broker agent to carry out trade allocations

To model CSP for allocation processes, a broker agent needs to determine constraints based on the calculation of buyers' satisfaction degree. Relationships between buyers and sellers through buyers' satisfaction degree are presented in Table 1 as follows.

Table 1. Buyers' satisfaction degree as per sellers' offers in CSP model

	S_1	S_2	S_3	...	S_m
B_1	β_{11}	β_{12}	β_{13}	...	β_{1m}
B_2	β_{21}	β_{22}	β_{23}	...	β_{2m}
...	...	...	...	...	...
B_n	B_{n1}	B_{n2}	B_{n3}	...	β_{nm}

where β_{nm} is B_n's satisfaction degree as per S_m's offers under the consideration of multi-attribute trading. If S_m does not satisfy B_n for a certain attribute then $\beta_{nm} = -1$. It means that S_m does not satisfy B_n and the constraint between S_m and B_n in a CSP model is created for trade allocation processes. Trade allocation through a broker agent between n buyers and m sellers 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 trade allocation as follows.

- Variables and domain of variables

$$x_{ij} = 1 \; or \; 0, \forall i \in n, \forall j \in m \tag{4}$$

- Constraints

$$\textstyle\sum_{i=1}^{n} x_{ij} \leq 1, \;\; j = 1,2, \dots, m \tag{5}$$

$$\textstyle\sum_{j=1}^{m} x_{ij} \leq 1, \;\; i = 1,2, \dots, n \tag{6}$$

$$x_{ij} = 0 \; if \; \beta_{ij}^{a_l} = -1 \; (l = 1,2, \dots k) \; or \; \beta_{ij}^{a_g} = -1 \; (g = 1,2, \dots z) \tag{7}$$

Constraints in Equation 4 is decision variable constraints, if buyer B_i matches with seller S_j then $x_{ij} = 1$; otherwise $x_{ij} = 0$. Constraints in Equation 5 and 6 are that each buyer (seller) only matches with each seller (buyer) maximally. Constraints in Equation 7 determine a constraint satisfaction layer. After a broker agent defines variables and determines the domain of variables and constraints, the broker agent uses the CSP techniques to find out the optimal allocation solutions to satisfy buyers' requirements as per sellers' offers.

4 Experiments

In this section, experimental results demonstrate that the proposed approach for a broker agent is flexible and provides reasonable allocation solutions in business environments to support decision making. In particular, the experimental setting is presented in subsection 4.1 and the experimental results are evaluated in subsection 4.2.

4.1 Experimental setting

In the experiments, we generate an artificial data of 10 buyers and 10 sellers in the digital business environments of the real estate in Vietnam. Buyers' requirements and sellers' offers for goods contain five attributes, i.e., *location (a1), price (a2), building size (a3), number of payment days (a4), property (a5)*. Based on buyers' requirements related to five attributes, *location (a1) and property (a5)* are attributes with hard constraints because their constraints must be satisfied while *price (a2)* is an attribute with cost soft constraints and *building size (a3), number of payment days (a4)* are attributes with benefit soft constraints because buyers can be accepted to relax the values of the attributes to achieve their satisfaction degrees.

In the experiments, the proposed allocation approach for a broker agent is employed to find out optimal pair allocations under the different situations in the digital business environments of real estate in Vietnam. More specifically, two representative experiments are presented below to demonstrate the proposed approach effectively.

4.2 Experimental results

Experiment 1: Trade allocations without filtering buyers' satisfaction degree

In this experiment, a broker agent applies CSP in Python to find out the trade allocation results under the consideration of 10 buyers' requirements and 10 sellers' offers related to 5 attributes and without filtering buyers' satisfaction degree. In particular, a broker agent calculates each buyer's satisfaction degree based on each seller's offers to determine the layer of constraint satisfaction and based on each buyer's satisfaction degree as per each seller's offers, a broker agent determines constraints for the CSP model before a trade allocation process is carried out. Based on data of 10 buyers' requirements and 10 sellers' offers for goods with 5 five attributes in subsection 4.1, a broker agent finds out 145,421 solutions for trade allocation. The specific results without filtering buyers' satisfaction degree are presented in Fig. 3.

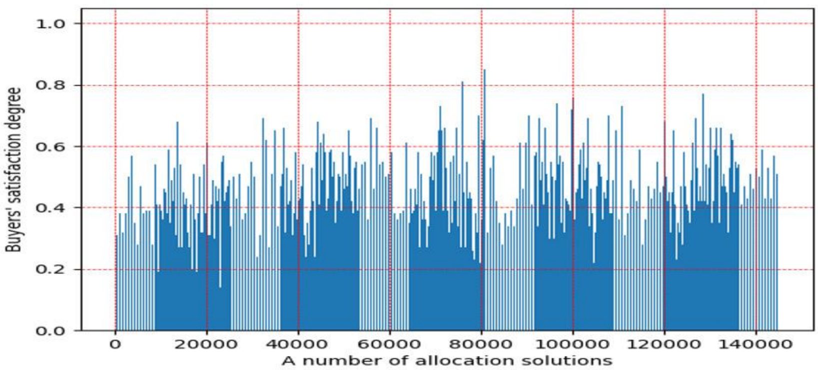

Fig. 3. The number of allocation solutions using CSP in Python

Based on experimental results, a broker agent considers to select which solutions from allocation results to achieve a broker agent's goals as per the constraints of buyers or sellers or both. For instance, if a broker agent wants to choose an allocation solution from 145,421 solutions to maximize buyers' satisfaction degree, solution 128,861 of allocation is perfect because the normalization of buyers' satisfaction degree in this solution equals 1. The specific allocation result in this solution is $B_1 \leftrightarrow S_{10}, B_2 \leftrightarrow S_3, B_3 \leftrightarrow S_8, B_4 \leftrightarrow S_7, B_5 \leftrightarrow S_9, B_6 \leftrightarrow S_2, B_7 \leftrightarrow S_1, B_8 \leftrightarrow S_6, B_9 \leftrightarrow S_5, B_{10} \leftrightarrow S_4$.

Experiment 2: The consideration of relationship between buyers' satisfaction degree and a number of allocation solutions

In the second experiment, the relationship between buyers' satisfaction degree and a number of allocation solutions was studied. Buyers' satisfaction degree is set to increase gradually to find out a number of allocation solutions. In particular, 8 levels of buyers' satisfaction degree are set for this experiment, and a number of allocation solutions as per each level of buyers' satisfaction degree is found. The specific results are presented in Fig. 4. Based on allocation results in Fig. 4, it is clear that if the requirement of buyers' satisfaction degree is high, the number of allocation solutions is low and vice versa. It demonstrates that the proposed approach works effectively. In summary, a broker agent can take off flexible allocation solutions to satisfy buyers' requirements as per sellers' offers based on the constraints of buyers' satisfaction degree.

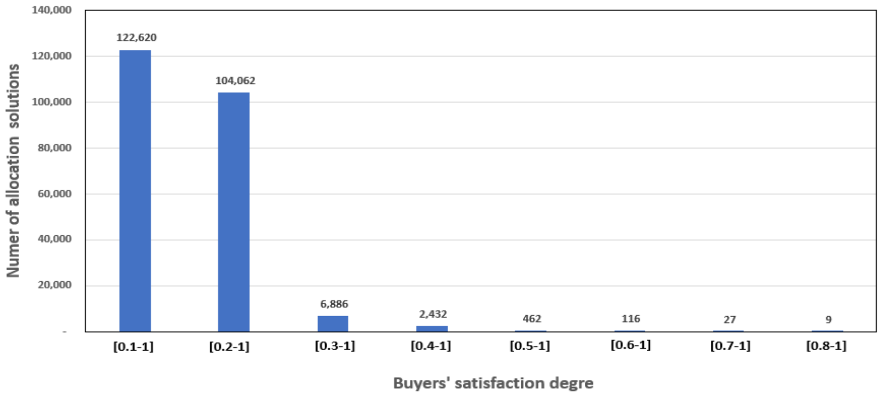

Fig. 4. The relationship between buyers' satisfaction degree and a number of allocation solutions

5 Conclusion and Future work

This paper proposes the allocation approach for a broker agent in agent-based e-commerce using the CSP model. The proposed approach is novel because (i) the design of allocation approach for a broker agent is general so it can be applied into broad domains such as real estate, banking, education, etc.; (ii) the formula system is built to calculate buyers' satisfaction degree as per sellers' offer for multi-attribute trading; and (iii) a broker agent's allocation process is implemented based on the constraint satisfaction process using CSP. CSP helps a broker agent to find out an optimal solution by means of satisfying various preferences of buyers and sellers. The experimental results demonstrate the promising performance of the proposed approach in aspects of satisfying buyers' requirements as per sellers' offers and finding out optimal allocation results based on constraints. Furthermore, future research would extend the proposed approach to solve complex business environments such as the consideration of negotiation, price policies, etc.

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