Bilateral Matching Decision for UGC Platform: A Simulation Analysis Using the Simulated Annealing Algorithm

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Abstract: In the unique context of sudden global public health events, the fragmented time of a vast number of users has transformed into a substantial influx of attention resources onto user-generated content (UGC) platforms. The escalating contrast between the swift expansion of decentralized content and the immense user attention resources has brought forth heightened demands for effective platform matching. This study addresses the bilateral matching challenge on UGC platforms by introducing the concepts of attention resource pool and content pool. A one-to-many bilateral matching framework is proposed under the attention resources theory, and a multi-objective matching model is constructed based on the dual satisfaction of UGC content creators and consumers, with a central focus on platform evaluation. To optimize the multi-objective function, a simulated annealing algorithm is devised, and MATLAB software is employed to simulate real data from a short video platform. The findings demonstrate that platform evaluation plays a pivotal role in UGC platform bilateral matching, and efficient UGC bilateral matching can be achieved by leveraging the intermediary role of the platform. Overall satisfaction, as perceived by bilateral users, surpasses that from the standpoint of individual users. Additionally, this study reveals that variations in the upper limit of content generation users' matching have negligible impact on overall satisfaction, suggesting that UGC platform enterprises' emphasis on content generation exposure levels does not enhance bilateral matching efficiency but may lead to excessive traffic skew and harm the industry ecology.

1. Introduction

User-generated content (UGC) emerged during the Web2.0 era. UGC broadly encompasses various types of content—images, text, audio, and videos—created by users on the internet, often referred to as user-created content. Since 2005, UGC has seen substantial growth and garnered significant attention. A UGC platform serves as a net-work-based platform that hosts user-generated content. Rather than generating media content itself, the platform empowers users to create, collaborate on, distribute, customize, and develop content [1]. UGC platforms encompass internet platforms predominantly driven by UGC, such as graphic, video, audio, and live streaming. Users and content form the core resources of these platforms, and the bilateral users engaged with the platform are both content producers and content consumers. With the steady progress and prosperity of the mobile internet industry, coupled with the dividend of China's mobile internet user population, UGC platforms have experienced explosive growth in recent years in China.

The ongoing advancement and maturation of mobile inter-net technology, particularly the advent of 5G technology and the rise of augmented reality (AR) and other advanced interactive forms of information dissemination driven by new infrastructure, in combination with content generation technology augmented by platform artificial intelligence, have propelled the explosive expansion of mobile internet content. The landscape of network information content is becoming increasingly diverse, even reaching a state of oversaturation. On the UGC platform side, there's a burgeoning community of content consumers, showing rapid growth both in terms of user numbers and the amount of time each user spends. The fragmented time of the vast user base is ignited by user-

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generated content, such as short videos, leading to a significant influx of attention resources into these platforms. This environment, where network information content is expanding, and user attention resources are growing at an exponential rate, has propelled a key concern: how to effectively match UGC platform content generation with the content consumption needs of bilateral users. Factors influencing the satisfaction of platform bilateral user matching have become a focal point in network platform management, particularly within the realm of UGC platform management.

Existing research predominantly focuses on the content consumer side, with limited consideration for the content generation side users. Graham Vickery et al. divided users into two sides—content production and content consumption—in their study on the network value chain of UGC platforms [2]. Content generation users provide the essential content resources that UGC platforms rely on for their survival, and their growth trajectory directly influences platform development [3]. Both sets of bilateral users play pivotal roles on UGC platforms. Content generation users also need suitable content consumers to match with in order to ac-quire incentives, thus enhancing their motivation for content generation and elevating content quality [4]. UGC platforms must consider the overall satisfaction of both user groups more comprehensively and address the various problems inherent in traditional content distribution.

This study introduces the theory of bilateral matching, focusing on the overall bilateral user satisfaction encompassing both content generation and content consumption on UGC platforms. Utilizing platform evaluation as a bridge, a model is developed to facilitate bilateral UGC platform user matching. The study examines the influence of different case matching decisions on bilateral user satisfaction, providing a foundational basis for matching decision making and governance within UGC platform management.

2. UGC platform bilateral matching problem

2.1. Conceptual model of bilateral matching in UGC platform

In the context of the two-sided matching problem in the UGC platform, the inherent complexity arises from the heterogeneity, scope, and individual intricacy of individual users [5]. This is not a straightforward matching be-tween the two user groups within the platform, which encompass content generating users and content consuming users. In other words, there's no direct one-to-one matching relationship between platform users. It is the us-er-generated content within the platform that serves as the link, connecting the bilateral users of the platform. The crux of the bilateral user matching in the UGC platform revolves around user-generated content and the allocation of attention resources.

Hence, this study endeavors to introduce the notions of an "attention resource pool" and a "content pool," abstracting the user segments on the content consumption side of the UGC platform into multiple units within the attention resource pool. Similarly, the user groups on the content generation side of the platform are transformed into distinct content pools. Consequently, the two-sided matching issue within the UGC platform entails matching the platform's attention resource pool with its content pool. This forms the primary focus of the bilateral matching framework, involving content consumers (in the attention resource pool), content generation users (within the content pool), and the decision-making entity (the UGC platform).

A visual representation of this concept is depicted in Figure 1, illustrating the bilateral user matching issue in the UGC platform.

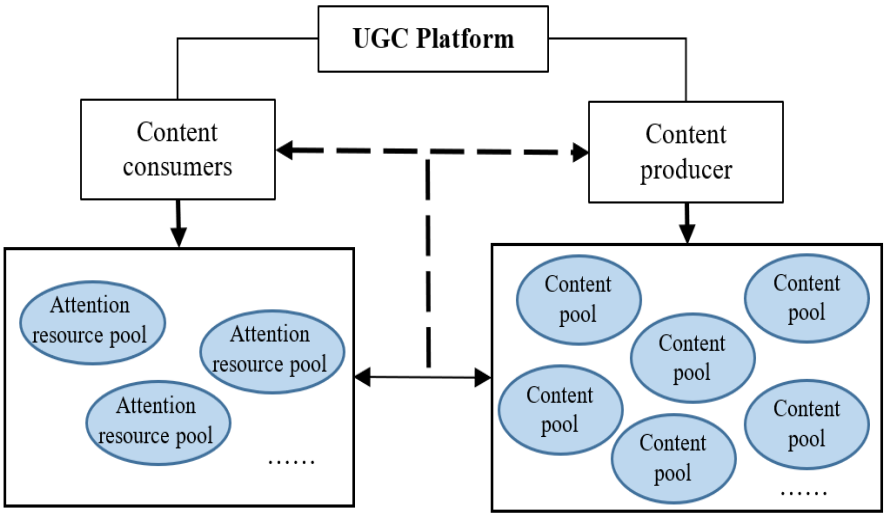

Figure 1. Conceptual model of two-sided matching problem in UGC platform

2.2. Problem description of two-sided matching in UGC platform

Based on the above analysis of the conceptual model of bilateral user matching on UGC platform, this study specifically describes bilateral user matching on UGC platform as follows:

- Suppose the set of content consumers (attention resource pool) is: $A=\{a_1,a_2,\cdots\cdots,a_m\}$, Where a_i is type i content consumer (attention resource pool), i=1,2,$\cdots\cdots$,m; Assume that the set of content producers (content pool) is: $C=\{c_1,c_2,\cdots\cdots,c_n\}$, Where c_j is type j content producer (content pool), $j=1,2,\cdots\cdots,n$.
- Suppose the set of content producer metrics that content consumers are concerned about is: $X=\{x_1,x_2,\cdots\cdots,x_k\}$, Where x_g is type g of indicators, g=1,2,$\cdots\cdots$,k; Assume that the set of content consumers metrics that content producer are concerned about is: $Y=\{y_1,y_2,\cdots\cdots,y_l\}$, Where y_h is type h of indicators, $h=1,2,\cdots\cdots,l$.
- The preference information of bilateral users is the preference order of each other's user indicators they pay attention to, that is, the weight value they assign to different indicators. Here, it is assumed that the weight vector of content consumer a_i to index set X is: $W_i=(w_{i1},w_{i2},...,w_{ik})^T$, Where w_{ig} represents the weight of content consumer a_i on index x_g, which satisfies $0\le w_{ig}\le 1$ and $\sum_{g=1}^{k} w_{ig}=1$; Similarly, assume that the weight vector of content producer c_j on index set Y is: $W_j=(w_{j1},w_{j2},...,w_{jl})^T$, Where w_{jh} represents the weight of content producer c_j on index y_h, which satisfies $0\le w_{jh}\le 1$ and $\sum_{h=1}^{l} w_{jh}=1$.
- For index set X, it is assumed that the expectation matrix of content consumers is: $P=[p_{ig}]_{m\times k}$, Where p_{ig} represents the expectation of content consumer a_i for index x_g; Similarly, for index set Y, it is assumed that the expectation matrix of content producers is: $U=[u_{jh}]_{n\times l}$, Where u_{jh} represents the expectation of content producer c_j for index y_h.
- Accordingly, for index set X, let q_{jg} be the evaluation value of UGC platform on the content producer c_j on the index of class g; for index set Y, let v_{ih} be the evaluation value of UGC platform on the content consumer a_i on the index of class g.

Utilizing the concepts of the attention resource pool and content pool, a one-to-many bilateral

matching relationship emerges, connecting the bilateral users (content consumers and content producers) within the UGC platform. Serving as the orchestrator of this bilateral matching, the UGC platform ultimately presents a matching strategy for the bilateral users, grounded in the interplay between each user's expectations regarding the indicators of the opposing side and the platform's evaluation of the corresponding indicators. The outlined decision-making process for two-sided user matching in the UGC platform is illustrated in Figure 2.

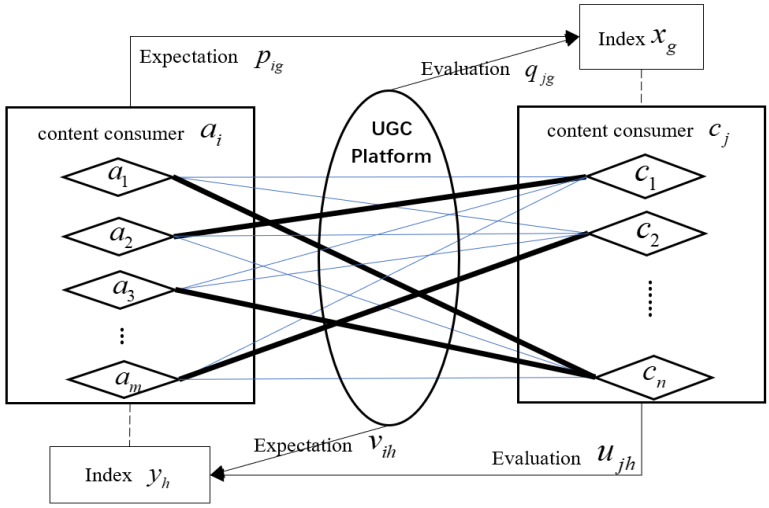

Figure 2. The decision-making process of bilateral user matching in UGC platform

3. Decision method of two-sided matching in UGC platform

Consider that the satisfaction of content consumer a_i with category g index of content producer c_j is e_{ijg}, whose value depends on the relationship between content consumer a_i's expectation p_{ig} of the index and platform's evaluation value q_{jg} of the index. In the actual matching process, UGC platform forms a matching object ranking based on the evaluation value of a certain kind of index of content producer c_j, and builds a satisfaction function according to the position of content consumers in the evaluation ranking queue.

In this study, the expected value equal to the evaluation value was set as the reference point, and the satisfaction of the reference point was set as 0. Based on the above assumptions, the value range of satisfaction is: When $p_{ig} = q_{jg}$, $e_{ijg} = 0$; When $p_{ig} < q_{jg}$, $e_{ijg} \in (0,1]$; When $p_{ig} > q_{jg}$, $e_{ijg} \in [-1,0)$. Content consumer a_i's satisfaction with content producer c_j, e_{ij}, is the weighted sum of all indicators expected by a_i to c_j. Based on this, the satisfaction function of content consumers is constructed as Formula (1):

$$e_{ij} = \sum_{g=1}^{k} w_{ig} e_{ijg}, \text{ where, } e_{ijg} = \begin{cases} \dfrac{q_{jg} - p_{ig}}{q_{\max g} - p_{ig}}, p_{ig} < q_{jg} \\ 0, p_{ig} = q_{jg} \\ \dfrac{q_{jg} - p_{ig}}{p_{ig} - q_{\min g}}, p_{ig} > q_{jg} \end{cases}, \ g \in \{1,2,3,\cdots k\} \tag{1}$$

The satisfaction function of the content generator is shown in Equation (2):

$$f_{ji}=\sum_{h=1}^{l} w_{jh} f_{jih}\text{, where, } f_{jih}=\begin{cases}\dfrac{v_{ih}-u_{jh}}{v_{\max h}-u_{jh}}, u_{jh}<v_{ih}\\ 0, u_{jh}=v_{ih}\\ \dfrac{v_{ih}-u_{jh}}{u_{jh}-v_{\min h}}, u_{jh}>v_{ih}\end{cases},\ h\in\{1,2,3,\cdots l\} \tag{2}$$

In summary, with the maximum satisfaction of content consumers and content producers as the ultimate goal, the multi-objective function is constructed as the UGC platform bilateral user matching model. The 0-1 variable α_{ij} is introduced as the matching variable. When $\alpha_{ij}=1$, the content consumer a_i matches the content producer c_j. When $\alpha_{ij}=0$, the content consumer a_i does not match the content producer c_j. Let E be the overall satisfaction of UGC platform content consumers under the target matching scheme, and let F be the overall satisfaction of UGC platform content producers under the target matching scheme. Further, based on satisfaction constraints and stable matching results, the UGC platform bilateral user matching decision model is shown as follows:

$$\max E=\sum_{i=1}^{m}\sum_{j=1}^{n} e_{ij}\alpha_{ij} \tag{3a}$$

$$\max F=\sum_{i=1}^{m}\sum_{j=1}^{n} f_{ji}\alpha_{ij} \tag{3b}$$

$$s.t.\ \sum_{j=1}^{n}\alpha_{ij}=1 \tag{3c}$$

$$\sum_{i=1}^{m}\alpha_{ij}\le d \tag{3d}$$

$$\alpha_{ij}+\sum_{s:e_{is}\ge e_{ij}}\alpha_{is}+\sum_{r:f_{rj}\ge f_{ij}}\alpha_{rj}\ge d_j,\ a_r\in A,\ c_s\in C \tag{3e}$$

$$\alpha_{ij}=0 \text{ or } 1,\ i=\{1,2,3,\cdots m\},\ j=\{1,2,3,\cdots n\} \tag{3f}$$

In this context, equations (3a) and (3b) serve as objective functions, each representing the cumulative satisfaction of content consumers and content generators, respectively. Equations (3c) through (3e) are constraint functions, with Equation (3c) specifying that the maximum matching capacity for content consumers is limited to 1. Equation (3d) stipulates that the maximum matching capacity for content generators is denoted as "d" (assuming uniform matching capacity for all content generators). Furthermore, Equation (3e) enforces a stability constraint on the matching outcome [6], indicating that the matching outcome is restricted by the upper limit of "d" under various decision upper limit values. Lastly, Equation (3f) defines the range within which the decision variables must fall.

4. Model solving and simulation analysis

Given that this study addresses the holistic satisfaction and stability matching concerns of bilateral users on the UGC platform, and considering the multi-way matching of content generation users, the nature of this matching problem is one-to-many. Furthermore, incorporating constraints transforms the bilateral user matching issue on the UGC platform into a generalized assignment problem with resource limitations, which has been established as an NP-hard problem. Due to these complexities, we have chosen to employ a well-known local search me-ta-heuristic algorithm

known as the simulated annealing algorithm to tackle this challenge.

The simulation examples utilized in this study are derived from previous survey data collected from a short video platform in China. The UGC platform encompasses a diverse array of content, including images, personal updates, evaluations of network products and services, encyclopedias, reference websites, videos, news articles, crowdfunding comments, sharing platforms, social payments, discussions, Q&A, blogs, and other similar categories [7]. Based on the findings of this study, UGC platforms primarily consist of four distinctive categories: graphic and text, video, audio, and live broadcasts, with the short video platform dominating a significant portion of the market share. Consequently, this study employs the short video platform as a representative example for in-depth analysis.

Using the UGC platform bilateral user matching decision model, the simulated annealing algorithm has been developed to simulate and analyse the data from the previously mentioned example. The simulation operations were conducted using MATLAB (R2018b) software on a personal computer running the Windows 10 operating system and equipped with an Intel Core i5-6200U processor.

5. Conclusion

- **Platform Evaluation Importance:** The evaluation value of bilateral user indicators significantly influences the matching results and the final overall satisfaction of bilateral users. Enhancing the objectivity and accuracy of platform evaluation emerges as a crucial factor for the effective bilateral user matching on the UGC platform. Lever aging core algorithmic technologies, big data, and AI, the platform should establish a transparent, equitable, and precise evaluation system, ensuring that bilateral users receive reliable index evaluations and fostering the effectiveness of bilateral matching results.
- **Objective Function for Overall Satisfaction:** The objective function model, which prioritizes the overall satisfaction of bilateral users, not only reflects the fairness for content consumers and content producers on the UGC platform but also yields much higher overall satisfaction compared to decision models focusing on the maximum satisfaction of individual subjects. This approach aims for a win-win situation among multiple parties. During the process of bilateral user matching, the UGC platform should proactively consider the fairness and stability of over-all satisfaction from the perspective of both bilateral subjects.
- **Impact of Matching Limits:** Altering the content producer's matching limit does not significantly affect the final outcome of the UGC platform's two-sided user matching. The platform should shift its operational focus from merely increasing content producers' exposure to guiding them in enhancing their own capabilities and content quality. The study finds that modifying the matching upper limit for content generators does not influence the overall satisfaction of bilateral users. Conversely, an excessive matching upper limit might lead to a decline in plat-form content quality due to resource imbalance on the content generation side. UGC platforms should not over-rely on exposure but should guide content producers to improve key indicators such as content sharing, content quality, and user engagement. By doing so, the platform can effectively enhance overall user satisfaction and ultimately foster sustainable platform development.

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