Research on the Pricing Problem of Cloud Platform 3D Printing Service based on Reverse Auction

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Abstract. As 3D printing technology continues to mature, customer demand for 3D printing tends to be more personalized, and cloud manufacturing models innovate and expand 3D printing product and service transaction methods. At present, the research on the pricing of 3D printing services on cloud platforms is relatively lacking. Based on the theory of reverse auction, this paper takes into account the price transparency brought by the network environment, fierce competition in parallel markets, and personalized and diversified customer needs, and introduces service demand-side personalized sensitivity and price sensitivity are modeled, and the transaction is regarded as a game process between the two parties based on the reverse auction model, and reasonable pricing is given to ensure the successful completion of the transaction order.

Keywords: Cloud Platform, 3D Printing Service, Reverse Auction, Pricing.

1. Introduction

3D printing technology is continuously favored by consumers because of its "additive manufacturing" molding principle, which can complete the manufacture of complex products and high material utilization. On the one hand, due to the increasing demand for 3D printing services, on the other hand, enterprises and production units have a large number of idle and scattered 3D printing resources and production capabilities. With the continuous development of cloud manufacturing, "Internet of Everything" and big data, the use of 3D The print cloud platform service can effectively schedule these idle resources to meet the needs of heterogeneous and huge 3D printing services.

The current research on cloud platform 3D printing services mostly discusses the system architecture, transaction mode, and order matching methods of the 3D printing cloud platform. There is less research on the pricing of 3D printing services in the cloud manufacturing mode. Existing researches are mostly based on traditional pricing methods based on cost. The pricing process that often takes into account the profits of manufacturers and retailers is lacking in the consideration of individual customer demand and market competition. Ren Liming innovatively proposed a "many to many" market for intellectual property rights transfer, and used a two-way auction model to price intellectual property rights in that market [1]. Wang Canyou, Su Qin et al. researched product pricing, designer effort level decision-making, and supply chain coordination issues between 3D printing platforms and designers based on a supply chain perspective [2]. By establishing a centralized and decentralized decision model, different decision modes were derived and then compare and analyze the impact of consumer preference customization sensitivity on product pricing and designer efforts. DEWAN et al. Studied the pricing of customized products [3], and Mendelson et al. [4] studied the pricing of different types of products. Hao Lifei based on the SAT model and used the general steps of data mining for research [5].

The current cloud platform 3D printing service transaction is usually a fixed-price or low-priced pricing model. There is less research on the price game and reasonable pricing of service supply and demand sides, and the real market environment is usually a service provider who compete with multiple homogeneous opponents, the service demander has multiple external options. The process of customer selection is usually a dynamic game process. The service demander hopes to maximize the effectiveness of the service at a lower cost. Service providers hope to obtain reasonable or even higher returns through labor. Therefore, the transaction pricing process of the 3D printing cloud platform service is considered as a price game between the supply and demand sides, and the auction mechanism is introduced to study the transaction pricing model, taking into account information asymmetry, bargaining power, parallel market competition, and customer price sensitivity. Degree, consumer preference customization sensitivity, number of homogeneous services, supply and demand based on multi-factor valuations, etc. to reasonably price 3D printing cloud platform service transactions.

2. The Problem Description

2.1 The Present Situation of Cloud Platform 3D Printing Service

The transaction of 3D printing services under the cloud platform is generally completed based on technology-driven and demand-driven. Driven by technology, service providers look for orders that match existing solutions on the cloud platform or service demanders look for service solutions that meet their needs and complete transactions with service providers. When driven by demand, customers publish personalized service requirements through the platform. The service provider considers multiple factors to provide the service price and service plan, usually the lowest price. This model is more flexible in pricing and there are more factors to be considered, the reasonableness of the price becomes the key to the completion of the transaction. This article will study the reasonable pricing based on demand-driven service pricing.

Construct a platform framework model consisting of 3D printing service demanders, service providers, and platform parties as shown in Figure 1. Among them, service providers can be divided into software service providers and hardware facility service providers. Software service providers usually For technical services such as model design and data conversion, hardware service providers usually provide printing resources such as printing equipment and consumables. The platform side is responsible for the supervision and control of the platform. Under some frameworks, the platform is also responsible for the logistics of 3D printing products and the distribution of orders. Unlike many existing supply chain-based pricing models, this article considers 3D printing design service providers and hardware service providers as 3D printing service providers, and studies the reasonable quotation and final pricing process of 3D printing service providers.

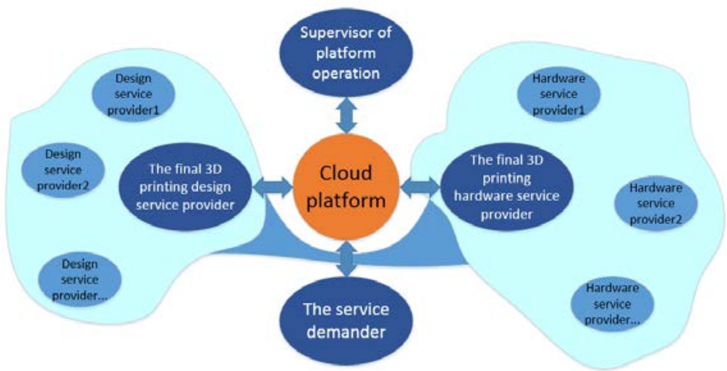

Figure 1. 3D printing service cloud platform framework

2.2 Demand Characteristics of 3D Printing Service Demand

Service demanders have heterogeneous requirements for 3D printing services:

(1) The technical requirements due to traditional processing industry's inability to meet processing needs.

(2) The cost of choosing a 3D printing service is lower than the cost of purchasing a complete set of equipment separately.

(3) 3D printing can shorten product delivery cycles and generate demand for delivery.

(4) Early adopter mentality needs to meet customers' understanding of new technologies.

(5) Following the mentality needs of the trend, due to the continuous promotion of 3D printing technology, some consumers choose 3D printing technology just to follow the trend.

3D printing service demanders usually choose 3D printing services for the purpose of cost, time, and personalized customization requirements. Therefore, when considering pricing issues, we must fully consider the price sensitivity and personalization of different service demanders based on the needs of the service demander. To customize the degree of preference and the market competition environment to price, can we effectively promote the completion of the transaction. As consumers of 3D printing services have valuation errors caused by their unfamiliarity with 3D printing technology, the research in this article considers the valuation of target customers as a uniform distribution in a parallel market to fully consider the effect of errors of 3D printing service demander's valuation of 3D printing services.

2.3 3D Printing Service Pricing based on Reverse Auction

In the traditional forward auction, after the seller provides the product, the buyer bids at a high price, and the high price is awarded [5]. The flowchart is shown in Figure 2. In the reverse pricing model of the cloud platform 3D printing service, it is considered that the service demander as the buyer raises the task demand, the service provider (seller) quotes, and the normal situation is the lowest price, and provides services, as shown in Figure 3. Therefore, the reverse pricing problem can be likened to the reverse auction process. There is a buyer and mostly a seller. After the buyer requests, the seller bids at a low price, and usually completes the transaction with the low price.

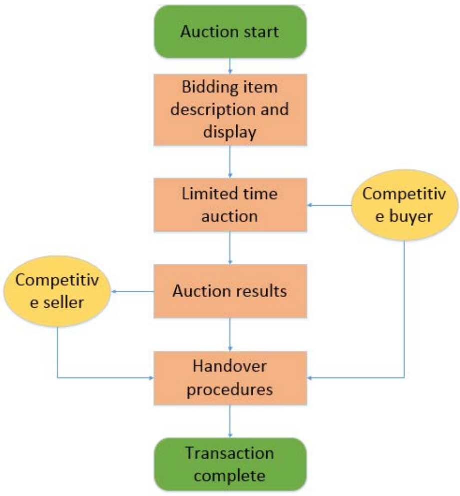

Figure 2. Traditional auction process

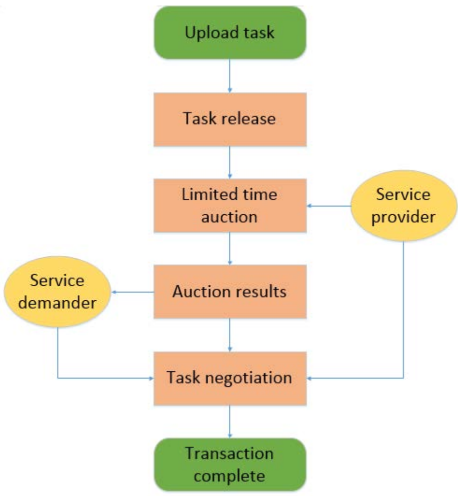

Figure 3. Cloud platform reverse auction process

3. Cloud Platform 3D Printing Service Transaction Reverse Pricing Model

The cloud platform 3D printing service pricing model includes valuation, price adjustment, quotation, and transaction pricing. When the service supply and demand sides give or accept each other's quotations, they should take into account possible quotations of other participants in the parallel market. Introduce price sensitivity coefficient, personalized customization sensitivity coefficient and bargaining power coefficient due to information asymmetry, research the optimal quotation of 3D printing service, and get the transaction completion pricing of 3D printing service.

3.1 Definition of Service Demand and Service Provider Benefits

Assume that after the service demand bidding ends, the service demand has a combination of n pre-selected schemes and designers to generate a pre-selected service provider set $W = \{w_1, w_2, w_3, \dots, w_n\}$, where w_i represents the service provider who issued the service provision request during the demand release period. Usually, only one service provider ends up with the service demander to conclude the transaction.

Service demand-side benefits: The difference between the utility that can be obtained by itself and the price at which the transaction is concluded, defined as the formula:

$$E_R = \begin{cases} U - P^* & There\ is\ a\ deal \\ 0 & There\ is\ no\ deal \end{cases} \tag{1}$$

Benefits of the service provider w_i : The difference between the rational valuation(P_{si}) and the price of the transaction, defined as the formula:

$$e_i = \begin{cases} P^* - P_{\mathrm{si}} & There\ is\ a\ deal \\ 0 & There\ is\ no\ deal \end{cases} \tag{2}$$

It can be seen from the income function that a reasonable P^* in the pricing process, that is, the final pricing must make both $E_R > 0$ and $e_i > 0$, and in the reverse auction model, usually $P_{si} = min\{P_{s1}, P_{s2}, P_{s3}, \ldots, P_{sn},\}$. This means that the service provider's offer must be sufficiently reasonable.

3.2 Construction of 3D Printing Service Pricing Model based on Reverse Auction Model

Model assumptions:3D printing service supply and demand both seek supply and demand through the cloud platform. Before the transaction, both the service provider and the service demander make a rational valuation of the target task, and the valuation information is private information. Personalized sensitivity coefficient α, $0 < \alpha < 1$. Price sensitivity coefficient β, $0 < \beta < 1$. Cloud platform 3D printing service provider price generation includes the process of valuation, price adjustment, quotation, and pricing. Based on the comprehensive factors of market, technology, time, etc., and considering the cost C, the minimum value of the service provided by the service provider is P'_s. Considering the price sensitivity coefficient and the personalized custom sensitivity coefficient, the final lowest valuation is the price adjustment $P_s = (1 + \alpha)(1 - \beta)P'_s$. In the parallel market, the highest valuation of a service demander for a homogeneous 3D printing service considering market, technology, and time is P'_c. Other factors such as national policy, platform policy, and market conditions have the same impact on the valuation of the supply and demand sides, all of which are R_o. Let service provider w_{i} evaluate the service as P_{si} and obey a uniform distribution$(R_o, P_s + R_o)$, that is, $(R_o, (1 + \alpha)(1 - \beta)P'_s + R_o)$is uniformly distributed. Assume that the service demander evaluates the service asP_C and obeys the uniform distribution $(R_o, P'_c + R_o)$.

Model establishment. According to the above model assumptions, in the case of their respective rational valuation and taking into account the quotations of other service providers in the platform environment, the service provider, that is, the seller's quote is GP_{si}; the service demand side, that is, the buyer's starting price is GP_c, and the relationship between the quote and valuation Is a linear function. The quote function is as follows:

$$\begin{cases} GP_{si} = A_s + B_s P_{si} \\ GP_c = A_c + B_c P_c \end{cases} \tag{3}$$

The above formulas B_s and B_c are both greater than 0, which means that the quotation is positively related to the valuation, and the quotation increases as the valuation increases. GP_{si} follows uniform distribution on$(A_s + B_s R_o, A_s + B_s(1 + \alpha)(1 - \beta)P'_s + B_s R_o)$, and GP_c follows uniform distribution on$(A_c + B_c R_o, A_c + B_c P'_c + B_c R_o)$.

The consumer surplus is defined as $GP_c - GP_{si}$. When $GP_c - GP_{si} > 0$, the service demander is willing to conclude a transaction. In the auction model, the critical value $GP_c = GP_{si}$ is defined as the starting price of the auction, the highest price acceptable to service demanders in a reverse auction. Generally, the larger the $GP_c - GP_{si}$, the more the service demander will accept the bid to complete the transaction. When $GP_c - GP_{si} < 0$, there is any service provider's offer higher than the service demand's offer, and the transaction cannot be completed; when $GP_c \geq GP_{si}$, there is at least one service provider's offer equal to or less than the service demand's offer, the transaction may be completed, and define the transaction price as $P^* = (1 - \gamma)GP_{si} + \gamma GP_c$, $0 < \gamma < 1$, which indicates the bargaining power of the service demander, $(1 - \gamma)$ indicates the bargaining power of the service provider. The magnitude of γ largely depends on how well the supply and demand sides understand the information of the 3D printing service, that is, the prevailing information asymmetry. The larger γ, the stronger the bargaining power of the service demander, the smaller the transaction price P^*, and the greater the utility of the service demander.

4. Solution of Cloud Platform 3D Printing Service Transaction Reverse Pricing Model

According to the revenue function and final pricing function of the supply and demand sides of the 3D printing service defined in the previous section, the transaction can be completed only when the returns of the supply and demand sides are greater than zero. And reasonable pricing should maximize returns.

The service provider w_i achieves the most revenue. Let the income of the 3D printing service provider w_i be e_i, then we can know that:

$$e_i = \{[\gamma GP_{si} + (1-\gamma)E(GP_c|GP_c \geq GP_{si})] - P_{si}\} * P(GP_c \geq GP_{si}) \quad (4)$$

In the formula, $E(GP_c|GP_c \geq GP_{si})$ refers to the service provider w_i's expectation of the service demander's offer when the quote from the service provider w_i is less than or equal to the offer from the service demander. The reference expectation is due to the assumption that the service provider's quote is not known when measuring the service provider's revenue. $P(GP_c \geq GP_{si})$ refers to the probability that the price quoted by service provider w_i is not higher than the price quoted by service demander, and represents the probability that the cloud platform transaction may be successful. For any valuation P_{si} subject to a uniform distribution$(R_o, (1+\alpha)(1-\beta)P'_s + R_o)$, in order to maximize the benefit of the service provider w_i, the maximum value of e_i is sought.

P_c obeys the uniform distribution on $(R_o, P'_c + R_o)$, and because B_c is greater than 0, we get:

$$P(GP_c \geq GP_{si}) = \mathrm{P}(A_c + B_cP_c \geq GP_{si}) = (P'_cB_c + A_c + R_oB_c - GP_{si})/P'_cB_c \quad (5)$$

Since GP_c obeys the uniform distribution on $(A_c + B_cR_o, A_c + B_cP'_c + B_cR_o)$. Got:

$$E(GP_c|GP_c \geq GP_{si}) = \frac{A_c+B_cP'_c+B_cR_o+P_{si}}{2} \quad (6)$$

Bringing the results of (5) and (6) above into the revenue e_i function of 3D printing service provider w_i, got:

$$e_i = \frac{\left\{\left[\gamma GP_{si}+\frac{1}{2}(1-\gamma)\left(B_cP'_c+B_cR_o+P_{si}\right)\right]-P_{si}\right\}*P(GP_c \geq GP_{si})*(A_c+B_cP'_c+B_cR_o)}{B_cP'_c} \quad (7)$$

Derive the above formula to get the best quote from the service provider:

$$GP_{si} = \frac{\gamma\left(A_c+B_cP'_c+B_cR_o+P_{si}\right)}{1+\gamma} \quad (8)$$

From the above calculation and analysis, when $GP_{si} = \frac{\gamma\left(A_c+B_cP'_c+B_cR_o+P_{si}\right)+(1+\alpha)(1-\beta)P'_{si}}{1+\gamma}$, e_i achieves the maximum value, which can fully guarantee the benefits of the service provider, and is the best offer of the service provider.

Therefore, when there is actually a target service demander's quotation as $GP_c = P^*_c$, the final pricing of 3D printing service P^*, $P^* = (1-\gamma)\frac{\gamma\left(A_c+B_cP'_c+B_cR_o+P_{si}\right)+(1+\alpha)(1-\beta)P'_{si}}{1+\gamma} + \gamma P^*_c$.

The assumptions and establishment of the model are based on the real cost of the 3D printing service provider, taking into account the personalized customization sensitivity and price sensitivity of the service demander, giving a reasonable quotation, and considering the bargaining power due to the information asymmetry and the service demander giving Starting price, to find the final price.

5. Conclusion

Based on the reverse auction model, this paper discusses the price of cloud platform 3D printing service transactions in the cloud manufacturing environment. The pricing process of supply and demand sides is regarded as a game process. Considering information asymmetry, market competition, price sensitivity, and personalized consumer needs, advise service demanders and service providers on quotations and final pricing of transactions. The constructed model includes the quotations, bargaining power coefficients, personalized custom sensitivity coefficients, and price sensitivity coefficients of both the supply and demand sides, and the model is solved to obtain the optimal quote and reasonable final pricing from the service provider. The price has been reasonably priced and has certain reference significance. At the same time, in order to simplify the problem, the entire 3D printing service supply chain is regarded as a service provider. However, there is no detailed implementation method for the reasonable acquisition of coefficients. In addition to the differences in coefficients, the actual coefficient values may be affected by a variety of factors, and these work need to be further expanded in subsequent studies.

Acknowledgements

The authors gratefully acknowledge the financial support from Research on Key Technologies of 3D Printing Network Zhongchuang Platform (2017YFB1104202).

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