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Design Task Representation and Automated Evaluation Method in the Context of Crowdsourcing

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Abstract. Under the development of the Internet, the number of user requirements has exploded, personalized requirements are diverse, and new design models such as crowdsourcing design have emerged. The design task is the core element that distinguishes the new design models from traditional ones. The design task evaluation process is the core driving force that drives the downstream design stage such as the matching of resources on design platforms, the evolution of design teams and the self-iteration of user requirements. However, most evaluation methods are based on expert scoring or traditional calculation theory. Not only are there subjective deviations, but also some necessary parameters of the evaluation algorithm have to rely on manual identification, which makes it difficult to be integrated in automatic crowdsourcing application platforms. Therefore, this article proposes design task representation and automated evaluation methods in the context of crowdsourcing: First, for the problem of crowdsourcing design task representation, relying on the crowdsourcing design platform, propose a multi-domain representation method of design tasks based on requirements mapping; Second, for the evaluation of functional tasks and technical tasks in the context of crowdsourcing design, a task evaluation system is constructed, including: functional task scale measurement based on design entropy, functional and technical contradiction analysis based on TRIZ and axiomatic design, and automated analysis of technology maturity based on domain knowledge graph; Third, in response to the diverse needs of multi-agents for task evaluation in the context of crowdsourcing design, a multi-index integrated evaluation method for crowdsourcing design tasks is proposed; Finally, through the development of task evaluation application tools and a case study from a crowdsourcing platform, the degree of automation of the evaluation method is verified.

Keywords: Crowdsourcing design, design task evaluation, functional task evaluation, technical task evaluation

1. Introduction

Nowadays, with the explosion in the number of user requirements and the diversification of personalized requirements due to the development of the Internet, some new design models such as crowdsourcing design[1], swarm-intelligence collaborative design[2] and open design[3] have emerged.

The sources of user requirements are complex, and the structures of requirements are diverse, with the characteristics such as complexity, dynamics, and fuzziness[4], user requirements are too complex to be used directly in the crowdsourcing design process. Therefore, multi-domain and multi-granularity user requirements need to be represented as a crowdsourcing task. In theory, the crowdsourcing model is more suitable to mobilize group intelligence to solve a large number of microscopic and simple tasks[5], but the design tasks are often more complex, in view of the inherent physical conflicts of the crowdsourcing design tasks, accurate task generation and comprehensive evaluation is one of the signature behaviors in crowdsourcing design ecology: On the one hand, the process of accurate task generation should be based on the characteristics of complex tasks and show the dependency relationships between (sub) tasks and (sub) tasks; on the other hand, the comprehensive evaluation of tasks should also be based on the restriction/promotion relationships between subtasks, and make reliable evaluation for task publishers and

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task implementers at the same time. In this context, the automatic generation of design process-oriented tasks and the evaluation of design tasks are important links to distinguish new design models from traditional ones, they are also the core driving force that drives that drives the downstream design stage such as the resource matching on design platform, the evolution of design teams and the self-iteration of user requirements. How to generate and evaluate design tasks accurately in the context of crowdsourcing design has become a research hotspot of scholars.

Previous studies have shown that the release process of crowdsourcing design tasks is a balance process between cost, time and expected quality for design problems[6], and it is a complex multi-objective optimization problem[7]. Some researches proceed from the management level, set task evaluation index based on the above three aspects of cost, time and expected quality[8] to consider the workload of the task[9], the urgency of the construction period[10] and the degree of economy[11] and so on.

However, there are few researches on crowdsourcing task evaluation for back-end designers. This kind of evaluation should be based on multiple design domain, considering the complexity of functional tasks, the degree of contradiction between structural tasks and technical tasks, and the technology maturity involved in these tasks. In some related researches, most evaluation methods are based on expert scoring[12] or traditional calculation theory[13], which not only causes subjective deviations, but also needs to use manual identification for some necessary parameters of the algorithm. as a result, it is difficult to be integrated automatically in crowdsourcing application platforms or systems.

In this article, a method of design task representation and automated evaluation in the context of crowdsourcing is proposed: first, crowdsourcing design requirements are classified based on axiomatic design and Kano model, and based on the pre-constructed requirements map, the multi-domain user requirements are transformed into crowdsourcing design tasks. Second, based on the method of information entropy, with the combination of the classical design theory and the domain knowledge graph constructed in the previous stage, the automated evaluation of the function scale, contradiction degree between function and technology, and technology maturity of crowdsourcing design task is realized. Based on the above evaluation index, the comprehensive evaluation of the design task can be finished. Finally, the application tool is developed and a case study of crowdsourcing design requirements is given to verify the automation, accuracy and effectiveness of this method. The overall process proposed in this study is summarized as shown in Fig.1:

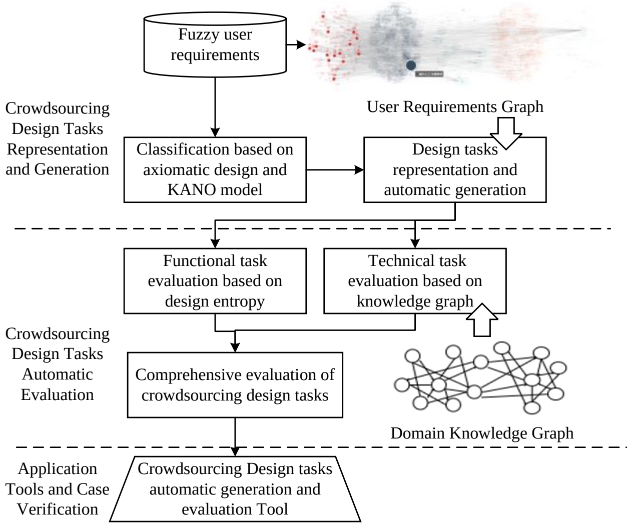

Fig. 1: Process of multi-domain tasks representation and automated evaluation in the context of crowdsourcing.

2. Crowdsourcing Design Task Representation Method Based On Multi-Domain User Requirements

This chapter introduces the process and method of how to generate crowdsourcing design tasks accurately from fuzzy user requirements. First, the categories and implications of user requirements from the perspective of axiomatic design and Kano model are explained. Second, the representation of crowdsourcing design tasks is defined based on the classification of requirements.

2.1. Classification of User Requirements Based on Axiomatic Design and KANO Model

User requirements can be divided into four dimensions based on the axiomatic design[14] theory and the real user demand data: functional requirements, structural requirements, technical requirements and other requirements:

- Functional requirements. It refers to the utility and acceptance ability of the product expected by the user.
- Structural requirements. It refers to the undertaker of the function of the product, including the need for the organizational form of the various parts of the product.
- Technical requirements. It refers to the user's demand for the realization of the structure and shape of the product, including the computer software and the knowledge used in the design process, and the manufacturing methods used in the product production process, etc.
- Other requirements. It refers to the user's requirements for the cost of the product, the budget of the product design, the consideration of human factors or forms, and the time limits for the production or design of the product.

Add the attribute category tag to the requirements. the user requirements can be divided into: basic requirement, expected requirement, charismatic requirement, undifferentiated requirement, and reverse requirement based on the KANO model[15] theory.

- Basic requirements. It refers to the requirement that a product must meet, it is indispensable.
- Expected requirements. It refers to the requirement that the level of user satisfaction is proportional to the degree to which the product meets the requirement. The higher the degree of meeting the requirement, the more satisfied the user.
- Charismatic requirements. It refers to the requirement that users will not put forward with some rigid restrictions, but once this kind of requirements are met, user satisfaction will be greatly increased, and if not met, user satisfaction will not be significantly reduced.
- Undifferentiated requirements. It refers to the requirement that can’t affect user satisfaction, regardless of whether the product meets the requirement or not.

Reverse requirements. It refers to the requirement which will make users disgusted and reduce their satisfaction once the product meets it.

2.2. Crowdsourcing Design Task Representation Based on Multi-Domain Requirements

On the one hand, based on the classification method for multi-domain user requirements from the perspective of axiomatic design, crowdsourcing design tasks can be divided into five parts: basic task information (including task ID, task name, initiator, reward, task start and end time, etc.), functional design task, structural design task, technical design task and other design tasks. On the other hand, among the functional, structural, technical and other design tasks, the necessity and importance of each sub-task are marked based on the user requirement attributes from the perspective of KANO model.

According to the above content，from the perspective of mathematical model, the crowdsourcing design tasks can be represented as follows:

$$TASK = \{Ta_B, Ta_F, Ta_S, Ta_T, Ta_O\} \tag{1}$$

$$Ta_B = \{ID_T, NA_T, PU_T, RE_T, ST_T, ET_T\} \tag{2}$$

$$Ta_F = \{FT_1, \dots, FT_i, \dots, FT_k\} \tag{3}$$

$$Ta_S = \left\{ST_1, \dots, ST_j, \dots, ST_m\right\} \tag{4}$$

$$Ta_T = \{TT_1, \dots, TT_x, \dots, TT_n\} \tag{5}$$

$$Ta_O = \{OT_1, \dots, OT_y, \dots, OT_l\} \tag{6}$$

$$FT_i = \{ID_{Fi}, NA_{Fi}, NC_{Fi}, IM_{Fi}, ST_{Fi}, ET_{Fi}\} \tag{7}$$

$$ST_j = \{ID_{Sj}, NA_{Sj}, NC_{Sj}, IM_{Sj}, ST_{Sj}, ET_{Sj}\} \tag{8}$$

$$TT_x = \{ID_{Tx}, NA_{Tx}, NC_{Tx}, IM_{Tx}, ST_{Tx}, ET_{Tx}\} \tag{9}$$

$$OT_y = \{ID_{Oy}, NA_{Oy}, NC_{Oy}, IM_{Oy}, ST_{Oy}, ET_{Oy}\} \tag{10}$$

TASK refers to a set of crowdsourcing design tasks. Ta_F refers to a set of functional tasks. Ta_S refers to a set of structural tasks. Ta_T refers to a set of technical tasks. Ta_O refers to a set of other tasks. *FT, ST, TT, OT* refers to functional, structural, technical, and other types of subtasks, respectively. *ID* indicates the ID of a task or subtask. *NA* indicates the name of a task or subtask. *PU* indicates the crowdsourcing platform task publishing account. *RE* indicates the reward for the task. *ST* indicates the start time of a task or subtask. *ET* indicates the deadline of a task or subtask. *NC* indicates the necessity of subtasks. *IM* indicates the importance of subtasks.

Table 1: The title should be in Capitalization of the first word

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3. Comprehensive Evaluation Method of Multi-index Crowdsourcing Design Task

This chapter introduces how to realize automated evaluation of crowdsourcing design task package. First, for the functional crowdsourcing design tasks, designers tend to pay more attention to the functional scale needed to achieve the complete design task, and this article proposes an automated evaluation method of functional scale based on the design entropy. Second, for the technology methods involved in the technical crowdsourcing design task, the technology complexity and technology maturity evaluation are realized based on the domain patent knowledge map constructed in the early stage and combined with the relevant theory of TRIZ. Finally, based on the above evaluation results, a multi-index integrated crowdsourcing design task comprehensive evaluation method is proposed.

3.1. Crowdsourcing Design Functional Task Evaluation Based on Design Entropy

In the crowdsourcing design ecosystem, the roles and abilities of multiple subjects are different, therefore, the difficulty and quantity of crowdsourcing design tasks should be considered when they are published. This article intends to measure these two indexes of crowdsourcing design tasks by evaluating the scale of functional design tasks. The of information axiom in axiomatic design holds that: on the premise of satisfying the axiom of independence, the less information contained in the design activity, the better the design results [14].It can be inferred that the smaller the amount of information contained in the functional class design task, the smaller the task scale.

Shanno proposed the concept of information entropy to measure the amount of information of random events, which is defined as:

$$H(X) = -\sum_{i=1}^{n} p(x_i) \log p(x_i) \tag{11}$$

There are n possible results for event X, which are $x_i(i = 1,2, \ldots, n.)$, and the probability of each result is $p(x_i)$. the unit of information entropy is bit.

For a design object, its function can be regarded as a set of functional modules, including determining the necessary functional modules and unnecessary functional modules, and the necessary functional module design can be divided into two results: design success and design failure. The design result of unnecessary functional modules is only the increment of the overall design results. According to the above content, define the amount of possible results for functional class design tasks:

$$N = 2^{n_r} + \sum_{i=1}^{n_u} C_{n_u}^{i} \tag{12}$$

n_r is the amount of necessary functional modules, n_u is the number of non-essential functional modules.

During the process of crowdsourcing design implementation, the probability of each variable is $p(x) = \frac{1}{N}$, and the actual probability of successfully implementing the design in the order of necessary functional modules is $p(x_i(i = 1,2, \ldots, n.)) = \frac{1}{N^{n_r}}$. Therefore, the total design scale of functional tasks can be defined as:

$$H(F) = -\sum_{i=1}^{N} p(x_i) log\, p(x_i) = n_r \cdot \log N \tag{13}$$

3.2. Crowdsourcing Design Technical Task Evaluation Based on Domain Knowledge Graph

In this article, the evaluation of technical tasks in crowdsourcing design tasks can be divided into two aspects: technology complexity evaluation and technology maturity evaluation. The realization of the two evaluation indexes of technology needs to rely on the domain knowledge graph constructed in the previous stage based on patent information, which contains the knowledge of basic patent information, functional words, technical words, structural words and relationships between information nodes [16]. The part of the domain knowledge graph is shown in the following figure:

Fig.2: Domain knowledge graph based on patent information.

- Evaluation of the technology complexity

The technology complexity evaluation value *CP(T)* is defined as the absolute value of the sum of all negative elements in the technical task complexity vector. The technical task complexity vector R_{T-S} is defined as the product of the association complexity between the necessary technical task and the necessary structural task $\omega_{R(T-S)}$ and the correlation complexity within the structural tasks R_S, specifically:

First, build a house of quality for the technical-structural tasks according to the above definitions, as is shown in the following figure:

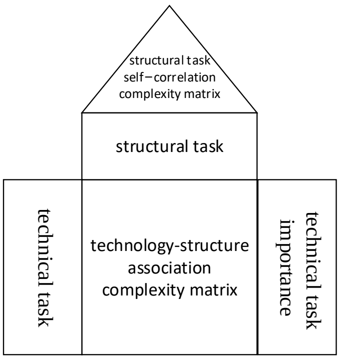


Fig.3: Schematic diagram of the house of quality for the technical-structural tasks.

Second, fill in the technology-structure association complexity matrix ω_{T-S} and the structural task self−correlation complexity matrix ω_S based on the collinear and inclusive relationship in the domain knowledge graph, in which the value of ω_{T-S} can be divided into three types: strong association (5), weak association (3) and association (1), while the value of ω_S can be divided into three types: positive correlation (1) and negative correlation (-1).

Finally, calculate the technical task complexity vector:

$$\omega_{R(T-S)} = \omega_T \times \omega_{T-S} \tag{14}$$

$$R_S = \begin{pmatrix} 0 & & \omega_S \\ & 0 & \\ \omega_S & & 0 \end{pmatrix} \tag{15}$$

$$R_{T-S} = \omega_{R(T-S)} \times R_S \tag{16}$$

ω_T refers to the technical task importance vector. Normalized all the results.

According to the definition of technology complexity:

$$CP(T) = |\sum_i^{R_{T-S(i)}<0} R_{T-S(i)}| \tag{17}$$

- Evaluation of the technology maturity

The technology maturity C(T) evaluation is based on the S-shaped curve theory of technology evolution proposed in TRIZ theory. Based on the domain knowledge graph, and combined with the four-parameter method in TRIZ[17], the relationships between the number of technology-related patents and the time of patent publication are analyzed，and then the technology can be divided into four stages: infancy period, growth period, maturity period and recession period to realize the evaluation for the technology maturity.

The relationship between technology maturity evaluation and the number of technology-related patents and the time of patent publication is shown in the following figure:

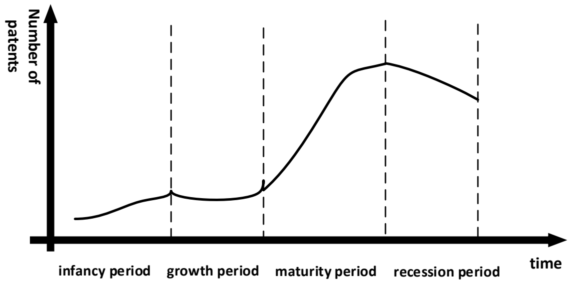


Fig.4: Technology maturity - patents number - patent publication time Diagram

3.3. Comprehensive Evaluation of Crowdsourcing Design Tasks Based on Multi-Index Integration

Through the normalization and weight distribution of the evaluation values of the above three indexes, the comprehensive scale evaluation of crowdsourcing design tasks can be defined. First, the normalization of the three index values is as follows:

- Considering the quantitative relationship between functional scale and clear structural tasks, the normalized value of functional scale is defined as follows:

$$NOM(H(F)) = \begin{cases} 1, when \sqrt{\frac{H(F)}{log\,2}} - m \geq 15 \\ 0.75, when\ 15 > \sqrt{\frac{H(F)}{log\,2}} - m \geq 10 \\ 0.5, when\ 10 > \sqrt{\frac{H(F)}{log\,2}} - m \geq 5 \\ 0.25, when \sqrt{\frac{H(F)}{log\,2}} - m < 5 \end{cases} \quad (18)$$

- If the technical complexity evaluation is greater than the proportion of complex tasks, it is considered that the technical tasks are extremely complex, and its normalized score is 1, and so on:

$$NOM(CP(T)) = \begin{cases} 1, when\ CP(T) \geq \frac{NUM(i)}{m}, R_{T-S(i)} < 0 \\ 0.75, when\ \frac{NUM(i)}{4m} > CP(T) \geq \frac{NUM(i)}{2m}, R_{T-S(i)} < 0 \\ 0.5, when\ \frac{NUM(i)}{2m} > CP(T) \geq \frac{NUM(i)}{4m}, R_{T-S(i)} < 0 \\ 0.25, when\ \frac{NUM(i)}{4m} > CP(T) \geq 0, R_{T-S(i)} < 0 \end{cases} \quad (19)$$

If the technology is in infancy, it is recorded as 1. By analogy, the average results of all technology maturity evaluation values are taken as the normalized value of technology maturity evaluation

$$NOM(C(T)) = \frac{1}{n}(1 \times NUM_{infancy} + 0.75 \times NUM_{growth} + 0.4 \times NUM_{maturity} + 0.6 \times NUM_{recession}) \quad (20)$$

Then, the comprehensive scale evaluation value of the crowdsourcing design tasks can be defined as (ET):

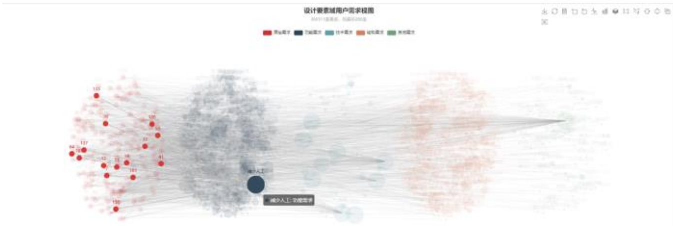
$$ET = [\omega_1 \cdot NOM(H(F)) + \omega_2 \cdot NOM(CP(T)) + \omega_3 \cdot NOM(C(T))] \times 100\% \ (\textstyle\sum_{i=1}^{3} \omega_i = 1, \omega_i \geq 0.) \quad (21)$$

4. Development of the Application Tools and Case Verification

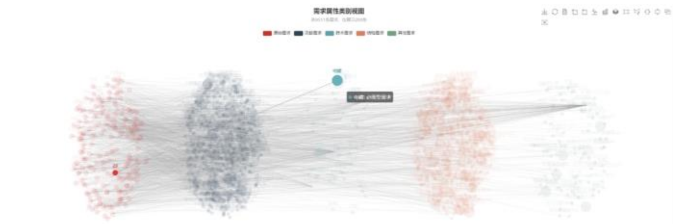
4.1. Development of the application tools

In order to confirm the scientific nature of the crowdsourcing design task representation method and the automated degree of the task evaluation method proposed in this article, a crowdsourcing design task automated generation and evaluation tool is developed, which relies on the multi-domain crowdsourcing design requirement graph. The tool integrates the functions of design task automatic generation, task interaction and adjustment, as well as automatic evaluation, etc.

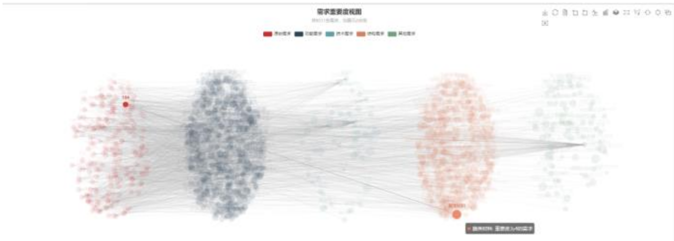
First, this research obtained the real requirements data set of crowdsourcing design on the commercial crowdsourcing application platform, then divided the data set into training set and test set, marked the multi-domain requirement elements and attributes in the training set based on BIO marking method, constructed a pre-training model based on BERT technology, and successfully extracted user requirement knowledge from the data set, including multi-domain requirement words, requirement attribute words and requirement importance, which was used to construct the multi-domain crowdsourcing design requirements graph. The multi-domain demand graph is shown in the following figure:



(a) Multi-domain requirements view



(b) Requirements attribute view



(c) Requirements importance view

Fig.5: Multi-domain and multi-perspective crowdsourcing design requirements graph

Second, relying on the multi-domain requirement graph, the cross-domain transformation from users' original requirements to functional requirements, structural requirements, technical requirements and other requirements was realized. Based on the crowdsourcing design task representation model proposed in this research, the development of the crowdsourcing design task automated generation tool was realized, and the interactive function with the user was also realized in the front-end interface, which supports the iterative adjustment and completion of the design task.

Finally, based on the technical methods described in Chapter 3, the integration of the task automated comprehensive evaluation function proposed in this article was realized, and the development of the automated evaluation tool for crowdsourcing design tasks has been completed.

4.2. Case Study

In order to verify the effectiveness of the crowdsourcing design task automation evaluation method proposed in this article, the real user requirements from a crowdsourcing design was evaluated automatically based on the developed platform.

- Original user requirements input:

Our company now need a fully automatic assembly line for sheet metal processing of anti-theft door leaves and fire-proof access door leaves. It includes sucker feeding (110*225), laser cutting machine, single hole punching machine, robot bending, upper assembly line screw fixing plate, robot welding, automatic glue spraying, filling fireproof door core board, automatic gluing machine, semi-automatic surface coating, assembling hardware accessories and locks, semi-automatic cardboard packaging, automatic lower assembly line, etc. Need to complete the overall planning and design of the assembly line, entrust professional technicians to talk to the scene, and those who have relevant experience are preferred.

- Output of task packages after automatic generation and interactive adjustment:

Table 1: Basic Task Information of the Case.

NA_T	PU_T	RE_T	ST_T	ET_T
Automatic assembly line for sheet metal processing of anti-theft door leaves and fire-proof access door leaves	****	NULL	NULL	NULL

Table 2: Functional Task of the Case.

ID_F	NA_F	NC_F	IM_F	ST_F	ET_F
1-F1	sheet metal processing	Y	5	NULL	NULL
1-F2	Sucker feeding	Y	4	NULL	NULL
1-F3	hole punch	Y	4	NULL	NULL
1-F4	bending	Y	4	NULL	NULL
1-F5	upper assembly line	Y	4	NULL	NULL
1-F6	fixing plate	Y	4	NULL	NULL
1-F7	welding	Y	4	NULL	NULL
1-F8	glue spraying	Y	4	NULL	NULL
1-F9	filling fireproof door core board	Y	4	NULL	NULL
1-F10	surface coating	Y	4	NULL	NULL
1-F11	assembling hardware accessories and locks	Y	4	NULL	NULL
1-F12	cardboard packaging	Y	4	NULL	NULL
1-F13	lower assembly line	Y	4	NULL	NULL
1-F14	complete the overall planning and design	Y	3	NULL	NULL

Table 3: Structural Task of the Case.

ID_S	NA_S	NC_S	IM_S	ST_S	ET_S
1-S1	fully automatic assembly line for sheet metal processing	Y	5	NULL	NULL
1-S2	laser cutting machine	Y	4	NULL	NULL
1-S3	single hole punching machine	Y	4	NULL	NULL
1-S4	robot	Y	4	NULL	NULL
1-S5	plate	Y	4	NULL	NULL
1-S6	automatic gluing machine	Y	4	NULL	NULL

Table 4: Technical Task of the Case.

ID_T	NA_T	NC_T	IM_T	ST_T	ET_T
1-T1	sheet metal processing of anti-theft door leaves and fire-proof access door leaves	Y	5	NULL	NULL
1-T2	laser cutting machine	Y	4	NULL	NULL
1-T3	robot bending	Y	4	NULL	NULL
1-T4	screw fixing	Y	4	NULL	NULL
1-T5	robot welding	Y	4	NULL	NULL
1-T6	automatic glue spraying	Y	4	NULL	NULL
1-T7	semi-automatic surface coating	Y	4	NULL	NULL
1-T8	semi-automatic cardboard packaging	Y	4	NULL	NULL
1-T9	automatic lower assembly line	Y	4	NULL	NULL

Table 5: Other Task of the Case.

ID_O	NA_O	NC_O	IM_O	ST_O	ET_O
1-O1	talk to the scene	N	4	NULL	NULL
1-O2	relevant experience	N	4	NULL	NULL

The evaluation results of the developed crowdsourcing design task automated evaluation tool are as follows:

Table 6: Task Evaluation from Automatic Evaluation Tool.

H(F)	CP(T)	C(T)	ET
59.002bit	0.087	Growth: 3 Maturity: 6	59%

Through the analysis, it can be seen that the crowdsourcing design task automated evaluation method proposed in this article is practical and effective, it can be used to solve the integration problem of the design task automated evaluation function for application platform.

5. Conclusions

In this paper, a series of solutions and technical methods are proposed to solve the problem that crowdsourcing design tasks are difficult to be generated and evaluated automatically for the design process. Firstly, the design requirements are classified and labeled based on axiomatic design theory and Kano model, and the representation and automatic generation of crowdsourcing design tasks for design process are further realized; Secondly, for the indispensable function integrated application platform in the context of crowdsourcing, an automatic computational evaluation method of function scale, technical complexity and technical maturity is proposed, and a multi index integrated crowdsourcing design task comprehensive evaluation method is proposed; Finally, a crowdsourcing design task automatic generation and evaluation tool is successfully developed to support the process of task publication, evaluation and iteration in the context of crowdsourcing, and an example of crowdsourcing design requirements is used to verify the effectiveness of this research result.

However, due to the small amount of data of crowdsourcing design task evaluation examples, the weight definition and critical point determination process of task evaluation index normalization and comprehensive evaluation are subjectively determined by researchers. Although automation is realized, there is still a lack of dynamic adjustment based on the amount of data in accuracy.

6. Acknowledgements

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7. References

[1] J.V. Nickerson, Y. Sakamoto & L. Yu, 2011 Structures for Creativity: The crowdsourcing of design. Workshop on Crowdsourcing and Human Computation: Systems, Studies, and Platforms. CHI 2011 (May 8, 2011). Vancouver.

[2] E. B. N. Sanders & P. J. Stappers, Co-creation and the new landscapes of design[J]. CoDesign 4 (1), 5–18, 2008.

[3] E. Boisseau, J. F. Omhover & C. Bouchard, Open-design: a state of the art review[J]. Design Science, vol 4, e3. 2018.

[4] Jin J, Liu Y, Ji P, et al. Review on Recent Advances in Information Mining From Big Consumer Opinion Data for Product Design[J]. Journal of Computing and Information Science in Engineering, 2019, 19(1): 010801.

[5] NAKATSU R T, GROSSMAN E B, IACOVOU C L. A taxonomy of crowdsourcing based on task complexity. Journal of information science, 2014, 40(6):823－834.

[6] YANG Y, CHEN P, PAVLOU P. Open innovation: An empirical study of online contests. ICIS 2009 proceedings, 2009: 13.

[7] BRABHAM D C. Moving the crowd at threadless: motivations for participation in a crowdsourcing application. Information, communication ＆society, 2010, 13(8):1122-1145.

[8] BLOHM I，RIEDL C，LEIMEISTER J M，et al. Idea evaluation mechanisms for collective intelligence in open innovation communities: Do traders outperform raters? Proceedings of 32nd International Conference on

Information Systems. 2011.

[9] KITTUR A. Crowdsourcing, collaboration and creativity. ACM crossroads, 2010, 17(2) : 22-26.

[10] IPEIROTIS P G. Analyzing the amazon mechanical turk marketplace. XRDS: crossroads, The ACM magazine for students, 2010, 17(2):16-21.

[11] MASON W，WATTS D J. Financial incentives and the performance of crowds. ACM SigKDD explorations newsletter, 2010, 11 (2) :100－108.

[12] AMERI F, SUMMERS J D, MOCKO G M, et al. Engineering design complexity: An investigation of methods and measures[J]. Research in Engineering Design, 2008, 19(2-3): 161-179.

[13] ZHENG Qing, DING Guofu. Design activity complexity measurement model and methods of crowd intelligence collaborative innovation[J]. Journal of Southwest Jiaotong University, 2020, Publication on the net.

[14] Suh N P. Axiomatic design theory for systems[J]. Research in engineering design, 1998, 10(4): 189- 209.

[15] Chen K, Jin J, Luo J. Big consumer opinion data understanding for Kano categorization in new product development[J]. Journal of Ambient Intelligence and Humanized Computing, 2021: 1-20.

[16] Ye Fan. Research on the Assistance Technology of Product Conceptual Design based on Domain Knowledge Graph[D]. Beijing Institute of Technology, 2021.

[17] Altshuller G S. Creativity as an exact science: the theory of the solution of inventive problems[M]. Gordon and Breach, 1984.