Human–computer interaction experience evaluation method of intelligent electronic product interface

Hai-Xia Yan

Shaanxi University of Technology,
Hanzhong 723001, Shaanxi Province, China
Email: haixiay@36haojie.com

Abstract: Aiming at the problems of large evaluation error and low correlation of evaluation indexes in the evaluation of human-computer interaction experience of intelligent electronic product interface, the evaluation method of human-computer interaction experience of intelligent electronic product interface is proposed. Firstly, the characteristic data of balance, conciseness and integrity of intelligent electronic product interface are extracted and pre-processed. Secondly, according to the divided experience dimension, the evaluation indexes of sensory experience, interactive experience and emotional experience are determined. The entropy value of the evaluation index is calculated through the score matrix to determine the weight of the evaluation index. Finally, the membership function is combined with the experience evaluation index weight set to build a fuzzy experience comprehensive evaluation model, and the evaluation results are modified by the correction function to realise the experience evaluation. The results show the evaluation method in this paper can effectively reduce the evaluation error.

Keywords: intelligent electronic product interface; human-computer interaction experience; dimension; score matrix; variation factor.

Reference to this paper should be made as follows: Yan, H-X. (2022) ‘Human–computer interaction experience evaluation method of intelligent electronic product interface’, *Int. J. Product Development*, Vol. 26, Nos. 1/2/3/4, pp.193–205.

Biographical notes: Hai-Xia Yan received the degree of Doctor of Philosophy in Design from Korea Dong-Eui University in 2019. Currently, she is a Lecturer of Shaanxi University of Technology. Her research interests include user experience design, digital product design, cultural and creative design.

1 Introduction

With the continuous development of electronic information technology and network technology, intelligent electronic products have become an indispensable part of people’s life (Moia et al., 2019). The emergence of smart phones marks the arrival of the era of smart electronic products and promotes the development of electronic products. With the increasing number of intelligent electronic products, the sense of user experience is declining, and users are constantly impacted by new functions in the experience. The experience degree of human-computer interaction of intelligent products needs to be continuously improved. In this process, the evaluation of user experience is the driving force for its improvement (Zhao et al., 2020). User experience refers to the cognitive level and feeling of users on intelligent products in the process of using products according to their needs and expectations. It is all the feelings of users in experiencing human-computer interaction of intelligent products (Li et al., 2019a). Comprehensively mastering the user experience is of great significance to improve the human-computer interaction function of the interface of intelligent electronic products (Li et al., 2021). Therefore, relevant researchers have done a lot of research on the evaluation of experience degree of intelligent products.

Xue and Zhao (2020) proposed a user experience evaluation method of mobile music app based on the theoretical framework of perceptual expressiveness, which was applied to the experience evaluation of intelligent electronic products. Firstly, with the help of the perceptual demonstrability framework of mobile electronic products, this method constructs the experience evaluation index system, determines the weight coefficient of the index through the AHP entropy weight method, and completes the experience evaluation through the evaluation of intelligent products. This method improves the accuracy of experience degree of intelligent products, but it does not take too much into account the characteristics of human-computer interaction interface of intelligent products, resulting in a certain one sidedness in the evaluation. (Li et al., 2019b) proposed a game user experience measurement method based on coefficient of variation. This method first analyses the basic principle of eye movement technology, and then scores the experience of the game through the expert scoring method. In this scoring process, the experience of different characters is determined with the help of the coefficient of variation to complete the research of the method. The operation process of this method is relatively simple, but its evaluation indicators have not been determined, so it is impossible to directly determine the effectiveness of experience evaluation, and there are some deficiencies.

In view of the shortcomings of the above methods, this paper proposes a human-computer interaction experience evaluation method of intelligent electronic product interface. The specific route of this paper is as follows:

- Firstly, the balance, conciseness and integrity characteristic data of intelligent electronic product interface are extracted as the basic data of experience evaluation;
- Secondly, according to the divided experience dimension, the evaluation indexes of sensory experience, interactive experience and emotional experience are determined,
- Then, by constructing the score matrix and standardising it, the entropy of the evaluation index is calculated and the weight of the evaluation index is calculated;
- Finally, by constructing the score matrix and standardising it, the entropy of the evaluation index is calculated and the weight of the evaluation index is calculated; On this basis, set the evaluation index weight set, determine the variation factor, combine the membership function with the experience evaluation index weight set, construct the fuzzy experience comprehensive evaluation model and modify the experience evaluation results through the correction function to realise the experience evaluation.

2 Evaluation method of human-computer interaction experience of intelligent electronics interface

2.1 Human computer interaction feature data extraction of intelligent electronic product interface

In the design of human-computer interaction experience evaluation method of intelligent electronic product interface, due to the diversity of intelligent electronic product interface, there is no unique evaluation method in its evaluation. Therefore, this paper first determines the product interface balance, integrity and simplicity in human-computer interaction of intelligent electronic product interface and determines the characteristics of intelligent electronic product interface to provide data support for subsequent experience evaluation (Tandon et al., 2019).

The balance degree of intelligent electronic product interface is the first feature felt in the user experience. It refers to the balance feeling presented by elements in different directions. The balance degree of intelligent electronic product interface can be expressed by formula (1), that is:

$$P = 1 - \frac{|V_i| + |V_j|}{2} \in [0,1] \tag{1}$$

In formula, V_i represents the equilibrium value from top to bottom direction, V_j represents the equilibrium value in the horizontal direction. The degree of balance in different directions can also be expressed as:

$$V_i = \frac{B_l - B_R}{\max\left\| B_l \right|, \left| B_R \right\|} \tag{2}$$

$$V_j = \frac{B_l - B_R}{\min\left\| B_l \right|, \left| B_R \right\|} \tag{3}$$

In formula, B_l represents vertical pixels, B_R represents the pixels in the horizontal direction.

The interface simplicity of intelligent electronic products is also a key link in user experience. The interface simplicity presented to users mainly refers to the small number of interface elements (Friberg et al., 2019), complete functions, simple and reasonable layout of interface elements, and its simplicity can be expressed as:

$$S = \frac{n}{a_i + b_i + m} \in [0,1] \tag{4}$$

In formula, a_i represents the alignment point of the longitudinal interface elements of the interface, b_i represents the lateral interface element alignment point, m represents the functional points presented by the interface.

The integrity of the interface of intelligent electronic products includes the balance and simplicity of the interface. Therefore, the integrity of the interface of intelligent electronic products is determined on the basis of the above characteristics of human-computer interaction interface. Its characteristics can be expressed as:

$$E = \frac{|E_j| + |E_r|}{2} \in [0,1] \tag{5}$$

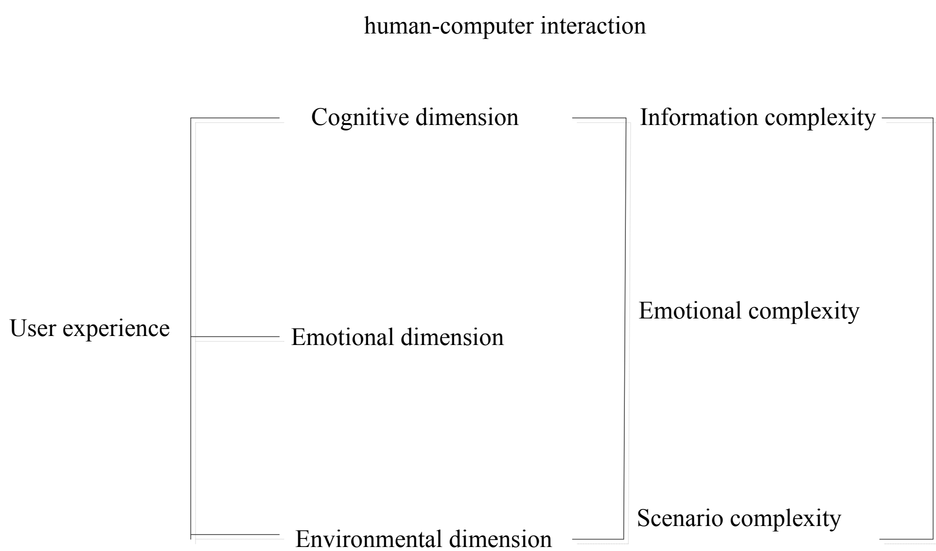
In formula, E represents the overall degree of element correlation of the interface, E_j represents the degree of correlation of the element space, E_r represents the overall Eigen-scale value of the interface.

In the determination of human-computer interaction characteristics of intelligent electronic product interface, the balance, simplicity and integrity of the interface are determined, and the determined Eigen values are used as the key data for subsequent evaluation. On this basis, the user experience evaluation index is determined and the relevant evaluation index system is constructed.

2.2 The index of human-computer interaction experience evaluation of intelligent electronic products is determined

According to the above determined human-computer interaction characteristics of intelligent electronic product interface, determine the evaluation index of human-computer interaction experience of intelligent electronic product interface and construct the index system. There is a large amount of data in the indicators of human-computer interaction experience evaluation of intelligent electronic product interface (Wang et al., 2021). In order to improve the evaluation effectiveness of this method, first divide the user experience, as shown in Figure 1.

Figure 1 Division of user experience



As can be seen from Figure 1, the human-computer interaction experience of intelligent electronic product interface mainly includes three dimensions: sensory experience, interactive experience and emotional experience. The evaluation indicators reflected in different dimensions have a certain complexity. In the dimension of human emotion, human emotion has the most direct impact on the experience of goods or anything. Therefore, in determining the evaluation indicators in this paper, the evaluation indicators are mainly determined from the perspective of user emotion. The evaluation indicators of human-computer interaction experience of intelligent electronic product interface are shown in Table 1.

Table 1 Evaluation index of human-computer interaction experience of intelligent electronic product interface

Assess the situation	*Evaluation indicators*
Sensory experience	Gender, age, preference, knowledge and cultural level, economic ability, etc.
Interactive experience	Area, convenient information conditions, use environment, spatial layout, etc.
Emotional experience	Use time, dimension time, dynamic use time, user quality, interaction quality, device state, network state, etc.

From the human-computer interaction experience evaluation indicators of intelligent electronic product interface determined in Table 1, it can be seen that there are many factors affected in the experience evaluation, resulting in a large number of evaluation indicators. In order to improve the accuracy of evaluation, it is necessary to deal with unimportant evaluation indicators and indicators of attribute pixels such as repetition. In this paper, the evaluation index judgment matrix (Wang and Zhou, 2021) is constructed, with the help of this matrix, the final evaluation index of human-computer interaction experience is determined, namely:

$$Q = \left(q_{ij}\right)_{m \times n} \tag{6}$$

In formula, q_{ij} represents factors of greater relative influence , Represents the n judged evaluation index data.

In the determination of human-computer interaction experience evaluation index of intelligent electronic products, the evaluation index is determined according to the divided human-computer interaction experience dimension of intelligent electronic product interface, and the judgment matrix is constructed to determine the final human-computer interaction experience evaluation index of intelligent electronic products (Pandya and Boricha, 2019), so as to lay a foundation for subsequent evaluation.

2.3 Weight calculation of interactive experience evaluation index of intelligent electronic product interface machine

According to the above-mentioned evaluation index of intelligent electronic product interface machine interaction experience, in order to improve the accuracy of experience evaluation in this paper, calculate the weight of intelligent electronic product interface machine interaction experience evaluation index before evaluation. This paper mainly uses entropy weight method to calculate its weight. Entropy weight method is a method to calculate the information of the evaluation index data in direct proportion to the degree of variation, which can determine the weight value of different evaluation index data (Mi et al., 2019). When the information entropy of the evaluation index is smaller, the weight disorder of the representative index is lower and its weight is higher. Entropy weight can reflect the information superiority of the bid winner in the evaluation. It is an objective and authentic evaluation method.

In the weight calculation of this paper, a score matrix containing *N* sample evaluation indexes, namely:

$$D_j = \begin{bmatrix} d_{11}, d_{12}, \ldots, d_{1n} \\ d_{21}, d_{22}, \ldots, d_{2n} \\ d_{n1}, d_{n2}, \ldots, d_{nn} \end{bmatrix} \tag{7}$$

In formula, nn indicates the number of the evaluation index, d represents the interface experience factor value.

Based on this basis, the constructed score matrix is standardised to obtain the processed score matrix, it is:

$$U = \left(u_{ij}\right)_{n\times m} \tag{8}$$

In formula, U represents the standard values, u_{ij} represents the scale factor.

At this point, the entropy of the evaluation index is calculated, let this entropy value be K_i. This entropy value (Han et al., 2019) reflects the utility value of the evaluation index:

$$K_i = -l\sum_{i=1}^{n} h_{ij} \ln g_{ij} \left(i = 1, 2, \ldots, m, j = 1, 2, 3, \ldots, n\right) \tag{9}$$

In formula, h_{ij} represents the correction function, g_{ij} represents the entropy correction coefficient. Based on this basis, the weight value of the evaluation index is calculated to obtain:

$$\varepsilon_i = \left(1 - K_i\right) \Big/ \sum_{i=1}^{m} \left(1 - K_i\right) \tag{10}$$

In formula, ε_i represents the weight value.

In the weight calculation of intelligent electronic product interface machine interaction experience evaluation index, after constructing the score matrix and standardising it, calculate the entropy of the evaluation index to complete the weight calculation of intelligent electronic product interface machine interaction experience evaluation index.

2.4 Implementation of human-computer interaction experience evaluation of intelligent electronic product interface

After calculating the weight of the above evaluation index of human-computer interaction experience degree of intelligent electronic product interface, in order to realise the evaluation of final experience degree, this paper constructs the human-computer interaction experience degree evaluation model of intelligent electronic product interface with the help of fuzzy comprehensive evaluation method (Du et al., 2019), and completes the human-computer interaction experience degree evaluation of intelligent electronic product interface. The evaluation model process is as follows. Set the weight set of interactive experience evaluation indexes as:

$$F = \{f_1, f_2, ..., f_m\} \tag{11}$$

Determine the factors with variation in the weight set of experience evaluation indicators, namely:

$$O_i = 1 - k_i \tag{12}$$

In formula, O_i represents the coefficient of variation. The greater the coefficient of variation represents the greater the degree of influence. The interactive experience of the user interface is constructed into an index feature matrix to:

$$\beta = \begin{bmatrix} \beta_1, \beta_2, ..., \beta_n \\ \beta_2, \beta_3, ..., \beta_{n-1} \\ ... \\ \beta_{n-1}, \beta_{n-2}, ..., \beta_{n-m} \end{bmatrix} \tag{13}$$

According to the influence degree of the determined index, the fuzzy comprehensive evaluation model of interface machine interaction experience of intelligent electronic products is constructed by combining it with the weight set of evaluation index of interface machine interaction experience of intelligent electronic products with the help of membership function, that is:

$$y = [y_1, y_2, ..., y_m] \begin{bmatrix} e_{11}, e_{12}, ..., e_{1c} \\ e_{r1}, e_{r2}, ..., e_{2c} \\ ... \\ e_{m1}, e_{m2}, ..., e_{mc} \end{bmatrix} \tag{14}$$

In formula, y_m represents a fuzzy operator, e represents the fuzzy factor, σ represents the membership function.

Since the above-mentioned fuzzy intelligent electronic product interface machine interaction experience comprehensive evaluation model has a certain deviation from the evaluation results, it is necessary to correct the deviation (Yu and Zhao, 2021). According to the membership degree of the evaluation index, the evaluation results are comprehensively sorted, and the following results are obtained:

$$A = \max(a_1, a_2, ..., a_c) \tag{15}$$

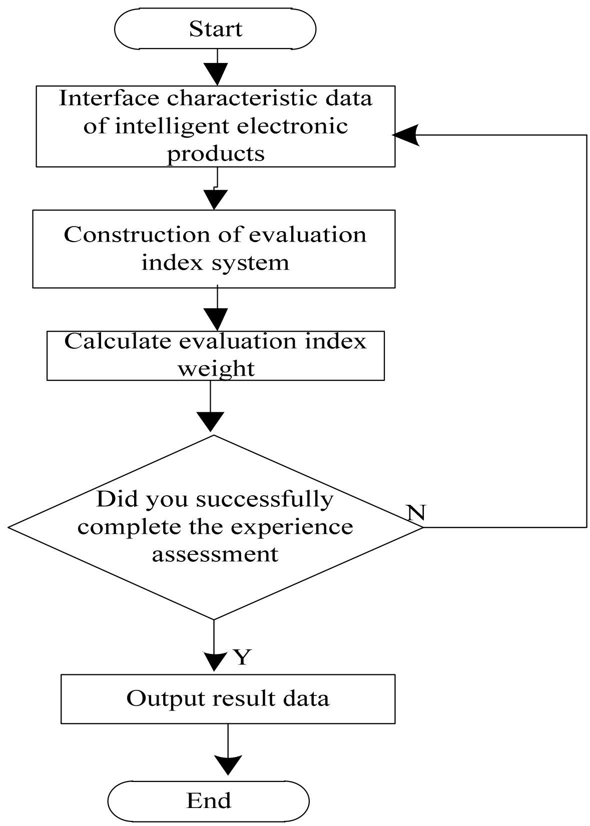
After the final ranking, combined with the weight coefficient of the evaluation index, the revised interactive experience degree of intelligent electronic product interface is obtained as follows:

$$T = \sum_{N}^{M} (A_c \times Z_n) \tag{16}$$

In formula, T represents the overall experience of users, A_c represents the total number of user experience impact indicators, m represents the weight factor of each evaluation index, Z_n represents the score of the experience evaluation factor.

The evaluation process of intelligent electronic product interface is shown in Figure 2.

Figure 2 Human-computer interaction experience evaluation process of intelligent electronics interface



In the realisation of human-computer interaction experience evaluation of intelligent electronic product interface, by setting the weight set of human-computer interaction experience evaluation index of intelligent electronic product interface, determining the factors with variation, constructing the characteristic matrix of experience evaluation index, and combining the membership function with the weight set of experience evaluation index, Build a comprehensive evaluation model of human-computer interaction experience degree of fuzzy intelligent electronic product interface, and modify the experience degree evaluation results through the correction function to realise the human-computer interaction experience degree evaluation of intelligent electronic product interface.

3 Experimental

3.1 Scheme design

In this experiment, Apple brand iPad is taken as the research object and the human-computer interaction experience of the product is evaluated. In this evaluation, KaixinXiaole game is the object of human-computer interaction experience. In the experiment, 30 students of grade 20 in the Department of electronic computer in a university are selected, of which 15 are boys and the rest are girls. The selected research objects have certain knowledge and views on intelligent electronic products, which can improve the effect of experience evaluation. In this experiment, through the 20 minute experience of the sample game, score the integrity, simplicity and balance of the human-computer interaction interface of the game, design the scoring table, remove the highest score and the lowest score and evaluate the experience through the experience score of professional users. Relevant parameters in the experiment are shown in Table 2.

Table 2 Experimental parameters

Parameters	*Number*
Human-machine interaction time/min	30
Rate error value	[0, 1.0]
Number of iterations / times of the evaluation	100
efficient of variation	0.5–0.8
Electronic product response time is long/s	0.2
Index weight error value	[1–5%]

3.2 Experimental indicators

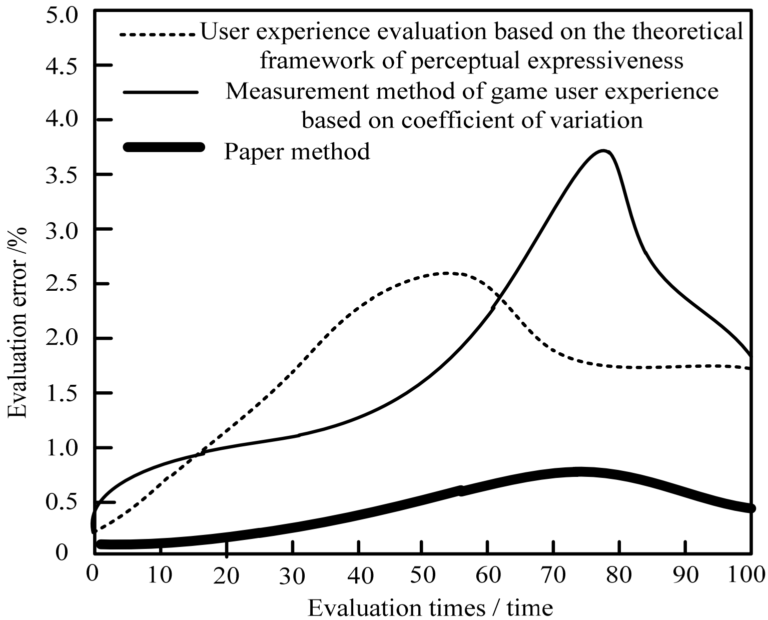
According to the above experimental scheme, to highlight the effectiveness of the method, the comparison of the method is the experience evaluation error and the correlation of the evaluation index.

3.3 Result

3.3.1 Experience degree evaluation error analysis

The evaluation error of human-computer interaction experience of intelligent electronic product interface is the key index to measure the accuracy of evaluation method. The smaller the error value of this index, the better the evaluation effect. Therefore, the experiment compares the error of this method, the mobile music app user experience evaluation method based on the theoretical framework of perceptual expressiveness and the game user experience measurement method based on coefficient of variation in the evaluation of human-computer interaction experience of the sample intelligent electronic product interface. The results are shown in Figure 3.

Figure 3 Experience evaluation error of different methods



By analysing the data in Figure 3, it can be seen that the error of human-computer interaction experience evaluation of sample intelligent electronic product interface by the three evaluation methods in the experiment is constantly changing. Among them, the evaluation error of this method is the lowest fishtail 0.1%, while the evaluation error of the other two methods is always higher than that of this method. This is because this method sets the evaluation index weight set, determines the variation factor, combines the membership function with the experience evaluation index weight set, constructs the fuzzy experience comprehensive evaluation model and modifies the experience evaluation results through the correction function to realise the experience evaluation, which improves the effectiveness of this method.

3.3.2 Correlation analysis of evaluation index selection

In the human-computer interaction experience evaluation of intelligent electronic product interface, the main reason for the poor evaluation effect of the evaluation method is the low correlation of the selection of evaluation indicators. Therefore, this paper experimentally compares the correlation of the selection of human-computer interaction experience evaluation indicators of the sample intelligent electronic product interface by three methods, and the results are shown in Table 3.

Table 3 Analysis of correlation coefficient results of evaluation indexes selected by different methods

Selection / times	*Method of this paper*	*User experience evaluation based on the theoretical framework of perceptual expressiveness*	*User experience measurement based on coefficient of variation*
10	0.91	0.89	0.87
20	0.92	0.89	0.88
30	0.95	0.88	0.88
40	0.95	0.86	0.89
50	0.96	0.86	0.85
60	0.96	0.85	0.89
70	0.95	0.84	0.84
80	0.96	0.86	0.86
90	0.96	0.83	0.84
100	0.95	0.83	0.86

By analysing the data in Table 3, it can be seen that there are some differences in the correlation coefficient selected by the three methods for the evaluation index of human-computer interaction experience of the sample intelligent electronic product interface. Among them, the correlation coefficient of the human-computer interaction experience evaluation index of the sample intelligent electronic product interface selected by this method is high, up to 0.96, while the correlation coefficient of the other two methods is less than that of this method. This is because this method determines the evaluation indicators of users' internal factors, environmental factors and use scene factors and determines the experience evaluation indicators through the judgment matrix. These indicators are the key evaluation indicators, which improves the effectiveness of this method.

4 Conclusions

In order to improve the performance of intelligent products and meet the needs of users, a new human-computer interaction experience evaluation method of intelligent electronic product interface is designed in this paper. Determine the characteristic values of balance, simplicity and integrity of intelligent electronic product interface as the basic data of experience evaluation; According to the divided human-computer interaction experience dimension of intelligent electronic product interface, the evaluation indexes of user internal factors, environmental factors and use scene factors are determined, and the experience evaluation indexes are determined through the judgment matrix; After constructing the score matrix and standardising it, calculate the entropy of the evaluation index and complete the weight calculation of the evaluation index; On this basis, set the evaluation index weight set, determine the variation factor, combine the membership function with the experience evaluation index weight set, construct the fuzzy experience comprehensive evaluation model and modify the experience evaluation results through the correction function to realise the experience evaluation. This method has the following advantages.

1) The minimum error of human-computer interaction experience evaluation of sample intelligent electronic product interface by this method is about 0.1%, which is feasible.
2) Using this method to evaluate the human-computer interaction experience of the sample intelligent electronic product interface, the maximum correlation coefficient is about 0.96, which verifies the effectiveness of this method.

Acknowledgement

This paper is supported by PhD start-up fund program in Shaanxi University of Technology (No. SLGRC15).

References

Du, S., Li, H. and Sun, B. (2019) 'Hybrid Kano-fuzzy-DEMATEL model based risk factor evaluation and ranking of cross-border e-commerce SMEs with customer requirement', *Journal of Intelligent and Fuzzy Systems*, Vol. 37, No. 6, pp.8299–8315.

Friberg, D., Sundman, J. and Browaldh, N. (2019) 'Long-term evaluation of satisfaction and side effects after modified uvulopalatopharyngoplasty', *The Laryngoscope*, Vol. 25, No. 15, pp.154–160.

Han, S.J., Park, S.Y. and Lee, D.H. (2019) 'Influence on job satisfaction by front-line employee's emotional labor: Using organizational culture as moderating effects', *Asia Life Sciences*, Vol. 1, No. 1, pp.255–264.

Li, Q., Chen, Q.Y. and Liu, Z. (2021) 'Public transport customer satisfaction evaluation using an extended thermodynamic method: a case study of Shanghai, China', *Soft Computing*, Vol. 45, No. 2, pp.1–14.

Li, X-J., Tu, J. and Zhang, H. (2019b) 'Game user experience measurement method based on CV', *Packaging Engineering*, Vol. 40, No. 8, pp.136–140.

Li, Y., Zou, F. and Xie, W. (2019a) 'Customer satisfaction measurement combining with preference and unbalanced linguistic evaluation', *Computer Integrated Manufacturing Systems*, Vol. 25, No. 1, pp.165–172 .

Mi, C., Chen, Y. and Cheng, C.S. (2019) 'Exploring the determinants of hot spring tourism customer satisfaction: causal relationships analysis using ISM', *Sustainability*, Vol. 11.

Moia, D., Gelmetti, I. and Calado, P. (2019) 'Ionic-to-electronic current amplification in hybrid perovskite solar cells: ionically gated transistor-interface circuit model explains hysteresis and impedance of mixed conducting devices', *Energy and Environmental Science*, Vol. 12, No. 4, pp.1296–1308.

Pandya, C. and Boricha, S. (2019) 'Service quality and customer satisfaction of the GPERI library users: an analytical study', *International Journal of Medical Informatics*, Vol. 9, No. 2, pp.57–60.

Tandon, U., Kiran, R. and Sah, A.N. (2019) 'Customer satisfaction as mediator between website service quality and repurchase intention: an emerging economy case', *Operations Research*, Vol. 59, Nos. 1/2, pp.155–156.

Wang, B., Wang, P. and Tu, Y. (2021) 'Customer satisfaction service match and service quality-based blockchain cloud manufacturing', *International Journal of Production Economics*, 2021(2, pp.108220.

Wang, T. and Zhou, M. (2021) 'Integrating rough set theory with customer satisfaction to construct a novel approach for mining product design rules', *Journal of Intelligent and Fuzzy Systems*, Vol. 15, No. 5, pp.1–25.

Xue, X. and Zhao, X. (2020) 'Research on user experience evaluation of mobile music app based on the theory of perceived affordances', *Document, Information and Knowledge*, Vol. 14, No. 6, pp.88–100,156 .

Yu, C-P. and Zhao, Z-G. (2021) 'Information storage optimization of electronic archive system based on information fusion', *Computer Simulation*, Vol. 38, No. 6, pp.455–459.

Zhao, Y., Ruan, P., Liu, X. and Shan, X. (2020) 'Study on user satisfaction evaluation based on online comment', *Management Review*, Vol. 32, No. 3, pp.179–189.