EVALUATION AND OPTIMIZATION OF AGRICULTURAL MANAGEMENT CLOUD PLATFORM BASED ON AHP/FCE

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基于 AHP/FCE 的智慧农业管理云平台评价与优化

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ABSTRACT

UI design and user interaction optimization of smart agricultural management cloud platforms are key research directions for enhancing the overall value of the system. However, there is still room for improvement in terms of functionality and visibility of the platform interface. This study constructs a UI design evaluation model by combining the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE), systematically evaluating and optimizing three UI design schemes of the platform. First, AHP was used to allocate weights to design factors, and then FCE was applied for comprehensive evaluation of each scheme, ultimately selecting the optimal one. Based on user heatmap data, the visual design of high-click areas was further optimized, improving the platform's score from 80.524 to 86.927. The study demonstrates that the combined AHP and FCE method has significant effects on UI design evaluation and optimization, providing scientific evidence and practical guidance for enhancing user experience in other smart agricultural management cloud platforms.

摘要

智慧农业管理云平台的 UI 设计与用户交互优化是提升系统整体价值的关键研究方向。然而，目前平台界面在功能性与可视性方面仍有改进空间。本研究通过结合层次分析法（AHP）与模糊综合评价法（FCE）构建了 UI 设计评价模型，对平台的三种 UI 设计方案进行了系统评估与优化。首先，采用 AHP 对设计因素进行权重分配，然后运用 FCE 对各方案进行综合评价，最终筛选出最优方案。基于用户热力图数据，进一步优化了高点击区域的视觉设计，使平台评分从 80.524 提升至 86.927。研究表明，AHP 与 FCE 结合的方法在 UI 设计评价与优化中具有显著效果，为其他智慧农业管理云平台的用户体验提升提供了科学依据和实践指导。

INTRODUCTION

With the integration of the Internet of Things (IoT) and big data technologies, smart agricultural management cloud platforms have emerged as the "brain" of agricultural production, enabling precise allocation of energy resources and driving industrial upgrades. The platform integrates multi-source data such as smart irrigation, greenhouse energy consumption, and agricultural machinery operations, achieving real-time monitoring of the entire agricultural production process. It provides data analysis and decision support, helping practitioners improve efficiency, reduce costs, and promote green, sustainable development.

The user interface (UI) design of the platform plays a crucial role in connecting users with the system. A high-quality UI design can enhance the user experience and ensure the efficient operation of the platform; whereas poor design can lead to operational difficulties, decision-making errors, and decreased platform effectiveness. Therefore, using scientific methods to evaluate and optimize UI design has become a key research focus in the field of smart agriculture. The interface design adheres to principles of simplicity, vitality, liveliness, and fashion, and must integrate users' functional, psychological, and interactive needs through icons, colors, and interactions. Continuously improving the design will further promote the development of smart agriculture *(Huijun et al., 2020)*.

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The methodological landscape has evolved through successive innovations in decision-making frameworks, beginning with the development of the Analytic Hierarchy Process (AHP) as a transformative tool for quantifying qualitative challenges *(Yongfeng et al., 2012)*. Subsequent advancements emerged through the integration of grey relational analysis with fuzzy mathematical principles to create comprehensive product evaluation systems *(Guodong et al., 2009)*, followed by the application of TOPSIS techniques for human-computer interface assessment *(Huiliang et al., 2016)*. Recent technological implementations demonstrate enhanced sophistication, particularly in ergonomic evaluations combining AHP-fuzzy comprehensive methods with TRIZ-based optimization for agricultural drone controllers *(Shuxing et al., 2022)*. Concurrent developments in consumer product research achieved breakthroughs through multimodal methodologies blending sensory analytics, morphological deconstruction, and fuzzy AHP for automotive seat design *(Qinglan et al., 2025)*. The methodological frontier further expanded through hybrid architectures integrating AHP-entropy weighting with fuzzy assessment systems, establishing multi-criteria evaluation frameworks for micro-irrigation filtration technologies *(Feng et al., 2025)*. This progression reflects three paradigm shifts: increased hybridization of classical decision tools, domain-specific framework adaptation, and theoretical-practical integration across engineering disciplines.

Traditional UI design evaluation methods often rely on user feedback and expert judgment, which makes it difficult to systematically and comprehensively reflect the strengths and weaknesses of the design. To address this issue, this paper introduces the combination of the Analytic Hierarchy Process (AHP) and Fuzzy Comprehensive Evaluation (FCE) to construct a scientific and objective evaluation model. AHP determines the weight of each evaluation indicator through expert scoring, while FCE uses fuzzy mathematics to handle the uncertainties and ambiguities in the evaluation process. This enables a comprehensive evaluation of the UI design for the smart agricultural management cloud platform, providing theoretical support and practical guidance for the development and improvement of the platform.

MATERIALS AND METHODS

Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) was developed in the 1970s by the American operations researcher (*Saaty et al., 2008*). It is a scientific method that combines qualitative and quantitative approaches by determining weight factors, which decompose complex evaluation problems into quantifiable evaluation objects that can then be synthesized. By combining AHP with fuzzy mathematics, it is possible to better handle the uncertainty inherent in the UI design process of a smart agricultural management cloud platform, ultimately leading to the optimal design solution. The evaluation method and process are shown in Figure 1.

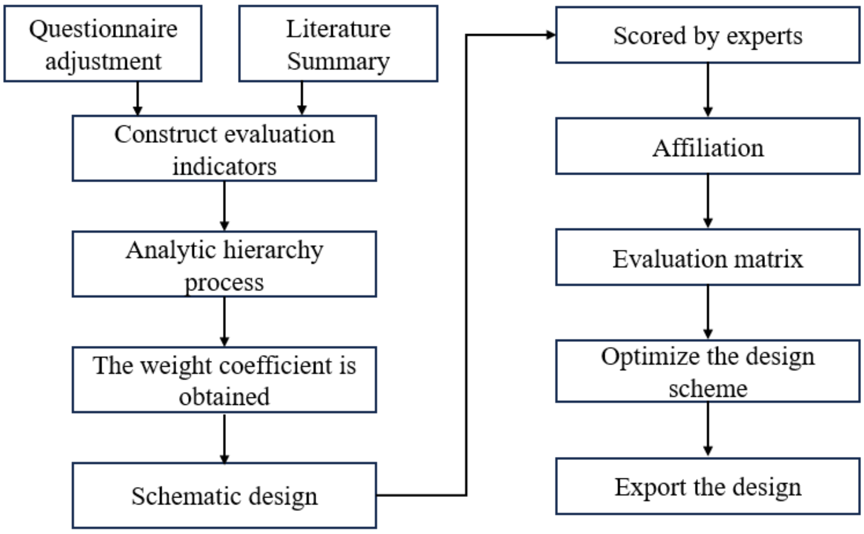

Fig. 1– Evaluation Method and Process

Hierarchical Structure Model of Agricultural Management Cloud Platform

The objectives, influencing factors, and analysis objects that need to be evaluated using the Analytic Hierarchy Process (AHP) are categorized into the highest, middle, and lowest levels according to their interrelationships. A hierarchical structure diagram is drawn (*Tongxin et al., 2019)*.

The smart agricultural management cloud platform is placed at the goal level, with functionality experience and appearance as the criterion layer of the evaluation system (*Xiangsheng et al., 2019*). The criterion layer is further subdivided into seven indicator layers, as shown in Figure 2.

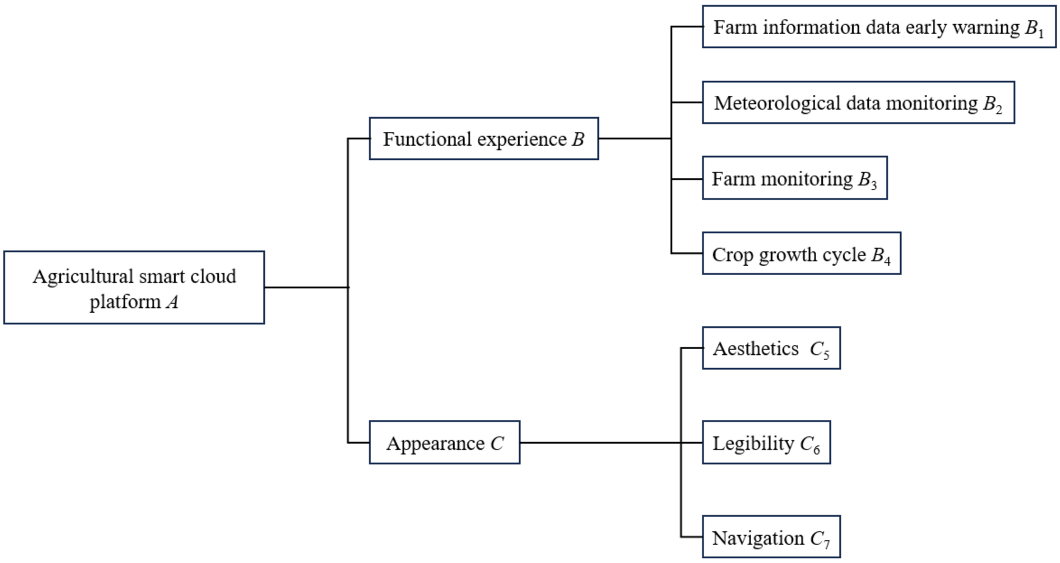

Fig. 2 – Design demand indicators for agricultural management cloud platform

Based on the design elements, the 9-point scale method can be used to construct a judgment matrix. The judgment matrix is used to compare pairwise relationships between indicators at the same level, with comparisons made at both the criterion layer and sub-criterion layer. A relative scale from 1 to 9 is assigned to each comparison, with the values reflecting the relative importance of the design elements. An example of the judgment matrix scale table is shown in Table 1 *(Lin et al., 2024; Haibiao et al., 2019; Hui, 2019; Yimin et al., 2017; Qianrong et al., 2017)*.

Table 1

Judgment Matrix Scale

Relative Importance Assignment *(i/j)*	Implication	Scaling instructions
1	Equal Importance	Indicator *i* is equally important as Indicator *j*
3	Slightly More Important	Indicator *i* is equally important as Indicator *j*
5	Strongly More Important	Indicator *i* is noticeably more important than Indicator *j*
7	Very Strongly More Important	Indicator *i* is strongly more important than Indicator *j*
9	Extremely Important	Indicator *i* is extremely more important than Indicator *j*
2，4，6，8	The Intermediate Value of Two Adjacent Judgments	The importance is determined based on adjacent scale values
$A_{ij}=1/a_{ij}$	Reciprocal	

Arithmetic averaging is used to find weights

Based on the constructed judgment matrix, the arithmetic mean method is used to calculate the weight of each element. The steps are as follows:

1) Normalize each column of the judgment matrix so that the elements in each column are comparable in terms of their relative proportions. That is:

$$\bar{x}_{ij} = \frac{x_{ij}}{\sum_{i=1}^{n} x_{ij}} (i = 1, 2, 3, \ldots, n) \tag{1}$$

2) Sum the rows of the processed matrix to obtain the total sum of the elements in each row, and then calculate the average value of the relative weights of each element, that is,

$$\widetilde{w}_i = \sum_{i=1}^{n} \bar{x}_{ij} (i = 1, 2, 3, \ldots, n) \tag{2}$$

3) Process the results after summation, and then the weight vector can be obtained.

$$w_i = \widetilde{w}_i / n \tag{3}$$

Consistency Test

After obtaining the relative weights of each design element, a consistency test is required. Firstly, calculate the maximum eigenvalue of the judgment matrix based on these weights, and obtain the consistency index CI through this eigenvalue. Then, use the standard RI values in Table 2 to calculate the consistency test coefficient of the judgment matrix. This process aims to evaluate the consistency level among the various elements in the judgment matrix and ensure the reliability of the weight relationships.

1) The maximum eigenvalue of the judgment matrix.

$$\lambda_{max} = \sum_{i=1}^{n} \frac{(Aw)_i}{(nw)_i} \tag{3}$$

2) The consistency test values of each indicator.

$$V_{CI} = \frac{\lambda_{max}}{n-1} \tag{5}$$

3) The test coefficient of the judgment matrix

$$C_{CR} = \frac{V_{CI}}{V_{RI}} \tag{6}$$

In the formula:

n—Order of Judgment Matrix;

w—Eigenvector of the Normalized Judgment Matrix;

Aw—It is the product of matrix A and vector w, and the resulting new vector.

Table 2

Standard Value of RI

N	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
RI	0.00	0.00	0.52	0.89	1.12	1.26	1.36	1.41	1.46

Judgment matrix

Questionnaires were distributed to five experts. In accordance with the rules of the 9-point scale method, the experts were invited to evaluate and score each design element. Based on the scoring results provided by the experts, a judgment matrix was constructed, which reflects the experts' judgments on the relative importance among different elements. This judgment matrix will serve as the basis for weight calculation and consistency testing, supporting the systematic decision-making analysis process.

The judgment matrix of the intelligent agricultural management cloud platform is:

A	B	C
B	1	1/2
C	2	1

The judgment matrix among the various indicators of the functional experience criterion layer is:

B	B_1	B_2	B_3	B_4
B_1	1	2	5	8
B_2	1/2	1	3	4
B_3	1/5	1/3	1	3
B_4	1/8	1/4	1/3	1

The judgment matrix among the various indicators of the appearance - criterion layer is:

C	C_5	C_6	C_7
C_5	1	2	5
C_6	1/2	1	4
C_7	1/5	1/4	1

Results of Weights and Consistency Tests

Based on the calculations of Formulas (1) - (6), the weights of each evaluation indicator in the design of the intelligent agricultural management cloud platform were obtained, and the specific values are shown in Table 3. Through this weight distribution, it is possible to have a more comprehensive understanding of the contribution degree of each indicator to the design of the intelligent agricultural management cloud platform, so as to optimize the design in a more targeted manner *(Ying et al., 2024).*

Table 3

Index Weights of the Design Evaluation System for the Smart Agricultural Management Cloud Platform

Criterion layer	Weights of the Criterion Layer	Indicator layer	Weights of the Indicator Layer	Comprehensive Weight	λ_{max}	CR
Functional Experience B	0.3783	Farm Information Data Warning B1	0.5394	0.2040	4.0684	0.0256<0.1
		Meteorological Data Monitoring B2	0.2823	0.1067		
		Farm Monitoring B3	0.1206	0.0456		
		Crop Growth Cycle B4	0.0576	0.0217		
Appearance C	0.6217	Aesthetics C5	0.5695	0.3540	3.0246	0.0236<0.1
		Readability C6	0.3331	0.2070		
		Navigability C7	0.0974	0.0605		

The consistency ratio (CR) values in Table 3 are all less than 0.1, indicating that the judgment matrices have passed the consistency test and the data used are valid.

Design Scheme of the Smart Agricultural Management Cloud Platform

Based on the weight ranking of each item in the above text, a fuzzy comprehensive evaluation is conducted on the design scheme of the smart agricultural management cloud platform. Three different schemes are designed as evaluation objects, as shown in Figure 3 - Figure 5.

Fig. 3 – Preliminary Design Scheme 1 of the Smart Agricultural Management Cloud Platform

Fig. 4 – Preliminary Design Scheme 2 of the Smart Agricultural Management Cloud Platform

Fig. 5 – Preliminary Design Scheme 3 of the Smart Agricultural Management Cloud Platform

Fuzzy Comprehensive Evaluation of the Smart Agricultural Management Cloud Platform

The Fuzzy Comprehensive Evaluation Method is suitable for the comprehensive evaluation of multiple indicators and elements. It can reduce the problem of uncertainty in evaluation results caused by subjective factors, handle fuzzy information better, and enhance the effectiveness of decision-making results. The Fuzzy Comprehensive Evaluation Model is shown in Figure 6. The specific operation process is as follows:

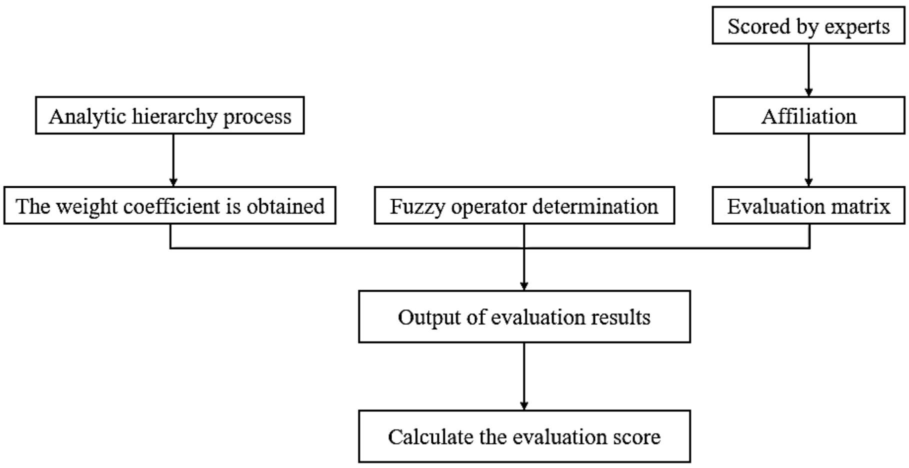

Fig. 6 – Fuzzy Comprehensive Evaluation Model

1) In this study, the UI design of the smart agricultural cloud platform is taken as the overall goal, with the goal layer being the UI design of the smart agricultural cloud platform. The evaluation is conducted from two sub-aspects, namely, functionality and appearance design, which form the criterion layer of the evaluation system. The criterion layer is further subdivided into seven indicator layers, as shown in Table 4.

2) The evaluation objects are categorized based on the various possible states, $M = \{M_1, M_2, M_3, ..., M_N\}$, corresponding to four evaluation levels: 'Excellent', 'Good', 'Average', and 'Poor'. Then, corresponding numerical values are assigned to each evaluation grade, resulting in the value set $\{90, 80, 60, 50\}^T$. The score range and grade division criteria are as follows: Excellent for scores above 90, Good for scores between 80 and 89, Average for scores between 60 and 79, and Poor for scores below 69. These standards allow the evaluation objects to be assessed and assigned corresponding grades.

3) Weights reflect the relative importance of each indicator within the evaluation system, and the setting of these weights will directly influence the scientific validity of the final evaluation results. In this study, the AHP method is used to determine the weights for the evaluation system. As shown in Table 3, the weight for the criterion layer is w_A = (0.3783, 0.6217), while the weight vector for the indicator layer is w_B = (0.5394, 0.2823, 0.1206, 0.0576), and w_C = (0.5695, 0.3331, 0.0974).

4) The fuzzy comprehensive evaluation matrix is composed of the degree of membership between each evaluation indicator and the evaluation set. For the three design schemes, fuzzy comprehensive evaluation matrices are established based on the scores provided by 20 experts for the criterion layer and indicator layer.

Table 4

Membership Degree of Indicators

***Scheme* 1 R_{F1}**	0	0.20	0.35	0.45
	0.05	0.10	0.45	0.40
	0	0.15	0.55	0.30
	0.05	0.15	0.40	0.40
***Scheme* 1 R_{F2}**	0	0.20	0.55	0.25
	0.05	0.25	0.25	0.45
	0	0.35	0.35	0.30
***Scheme* 2 R_{S1}**	0.15	0.35	0.25	0.25
	0.10	0.45	0.15	0.30
	0.15	0.30	0.25	0.30
	0.10	0.20	0.30	0.40
***Scheme* 2 R_{S2}**	0.10	0.40	0	0.50
	0.10	0.30	0.15	0.45
	0.15	0	0.50	0.35
***Scheme* 3 R_{T1}**	0.10	0.75	0.15	0
	0.25	0.50	0.15	0.10
	0.30	0.60	0.05	0.05
	0.10	0.75	0.10	0.05
***Scheme* 3 R_{T2}**	0.25	0.65	0.10	0
	0.20	0.60	0.10	0.10
	0.30	0.55	0.15	0

After obtaining the fuzzy comprehensive evaluation matrix for each factor, the next step is to synthesize the matrix by combining the weights of each indicator w_i with the corresponding fuzzy comprehensive evaluation matrix, thus constructing a first-level evaluation matrix.

First-level Fuzzy Evaluation of Each Scheme

1. Scheme 1:

$$B_{B1} = R_{F1} \cdot w_B = [0.0170 \;\; 0.1628 \;\; 0.4052 \;\; 0.4149]$$
$$B_{C1} = R_{F2} \cdot w_c = [0.0167 \;\; 0.2313 \;\; 0.4306 \;\; 0.3215]$$

2. Scheme 2:

$$B_{B2} = R_{S1} \cdot w_B = [0.1330 \;\; 0.3635 \;\; 0.2246 \;\; 0.2788]$$
$$B_{c2} = R_{S2} \cdot w_c = [0.1049 \;\; 0.3277 \;\; 0.0987 \;\; 0.4687]$$

3. Scheme 3:

$$B_{B3} = R_{T1} \cdot w_B = [0.1665 \; 0.6613 \; 0.1350 \; 0.0371]$$
$$B_{C3} = R_{T2} \cdot w_c = [0.2382 \; 0.6236 \; 0.1049 \; 0.0333]$$

The first-level fuzzy evaluations of Scheme 1, Scheme 2, and Scheme 3 are as follows:

$$R_F = \begin{bmatrix} 0.0170 \; 0.1628 \; 0.4052 \; 0.4149 \\ 0.0167 \; 0.2313 \; 0.4306 \; 0.3215 \end{bmatrix}$$

$$R_S = \begin{bmatrix} 0.1330 \; 0.3635 \; 0.2246 \; 0.2788 \\ 0.1049 \; 0.3277 \; 0.0987 \; 0.4687 \end{bmatrix}$$

$$R_T = \begin{bmatrix} 0.1665 \; 0.6613 \; 0.1350 \; 0.0371 \\ 0.2382 \; 0.6236 \; 0.1049 \; 0.0333 \end{bmatrix}$$

Second-level Fuzzy Rating of the Smart Agricultural Management Cloud Platform

The second-level fuzzy evaluations of Scheme 1, Scheme 2, and Scheme 3 are as follows:

$$B_F = [0.0168 \; 0.2054 \; 0.4210 \; 0.3568]$$

$$B_S = [0.1155 \; 0.3381 \; 0.1463 \; 0.3969]$$

$$B_T = [0.2111 \; 0.6379 \; 0.1163 \; 0.0347]$$

Finally, the percentage scores for Scheme 1, Scheme 2, and Scheme 3 are 68.822, 71.498, and 80.524, respectively. The evaluation levels of Scheme 1 and Scheme 2 are "Average," while the evaluation level of Scheme 3 is "Good." Therefore, Scheme 3 is the best scheme.

RESULTS

Optimization of Evaluation Results

The evaluation level of the smart agricultural cloud platform is the result of the combined effect of the indicator layer weights and the scheme scores. In summary, by analyzing the indicator layer weights, two key indicators, 'Aesthetics' and 'Readability,' were identified as needing optimization. This provides a clear direction for UI optimization of the smart agricultural cloud platform. By combining actual user heatmaps, high-frequency click areas can be analyzed, and visual enhancements can be made in these areas to improve the platform's aesthetics and readability. The optimized interface will be re-evaluated using the fuzzy comprehensive evaluation system to verify the effectiveness of the improvements, ultimately yielding the optimized evaluation level. This method not only scientifically quantifies the improvement in user experience but also provides data support and practical guidance for future UI design optimization.

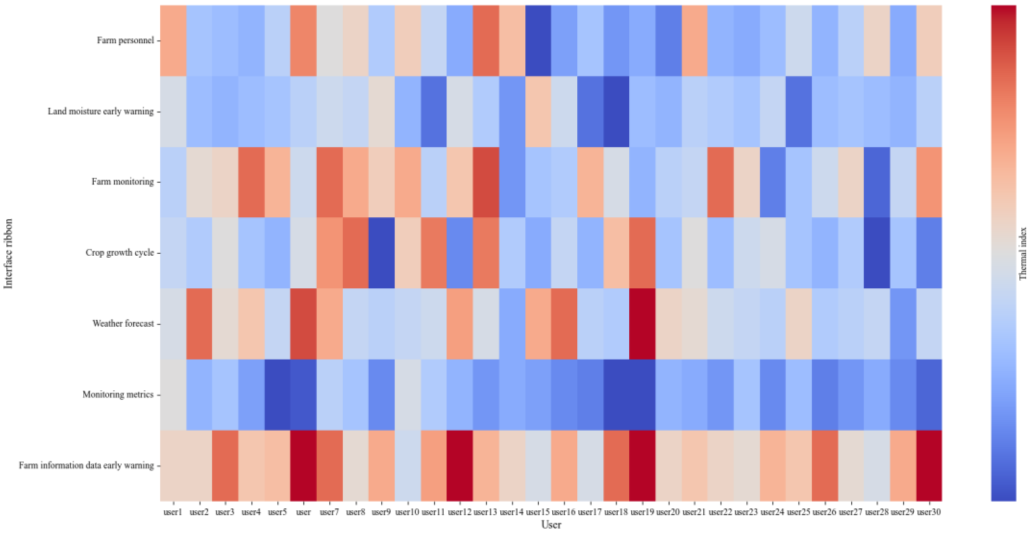

Fig. 7 – User Click Heatmap

Based on the analysis of the click heatmap in Figure 7, the area with the highest click frequency was identified as the "Farm Information Data Warning" section, while the area with the lowest click frequency was the "Land Use" section. In response to these high-click areas, improvements were proposed for the UI interface's "Aesthetics" and "Readability" indicators.

To further optimize the overall user interface (UI) effect, this study implemented a series of targeted improvements. Firstly, a visual optimization was applied to the functional area background by brightening the background tone, creating a fresher and more open visual experience, effectively enhancing operational convenience. At the same time, the interface at the top of the Smart Agricultural Management Platform dynamically displays weather scenes based on real-time weather conditions, not only enriching the interface's information but also greatly enhancing its visual appeal.

In terms of font design, to meet users' needs for information clarity, the font was adjusted to a bold style to ensure that users can quickly grasp the information while browsing, reducing visual fatigue and improving information retrieval efficiency. For the high-click area "Farm Information Data Warning," its design details were optimized. The alarm icon and related text colors were changed to prominent red, and the font size was increased and made bolder, creating a clear contrast with other information, highlighting the importance of the warning information, and making the key data in this area clearer and more readable. This ensures that users can quickly detect anomalies and take timely actions.

Considering the differences in user attention to different information modules, the low-click frequency "Regulatory Indicators" module was replaced with the "7-Day Weather Forecast." In this module design, a color-coding strategy was adopted to distinguish state information, with abnormal weather conditions highlighted in red text, helping users quickly identify key weather changes and enhancing the practicality and convenience of the information. Additionally, the "Farm Monitoring" module was subdivided into "Farm Greenhouse Monitoring" and "Farm Field Monitoring," with the display method of various farm information data optimized in the interface layout to increase visibility. Through reasonable layout and highlighting key data, users can quickly and accurately access the detailed farm information they need. The improved UI design interface is shown in Figure 8.

Fig. 8– Optimized Interface of Scheme 3

By using the established UI design evaluation system, the optimized UI of the smart agricultural management cloud platform was re-assessed, with the overall score increasing from 80.524 to 86.927, nearing the excellent level. This study focused on optimizing two key indicators: "Aesthetics" and "Readability." The optimization yielded ideal results, verifying the feasibility of this method in improving the human-computer interaction experience of the platform. In future optimization stages, the smart agricultural cloud platform can refer to this process and prioritize gradual improvements on the indicators that have the greatest impact on the final evaluation results.

CONCLUSIONS

Through the AHP method, the weights of interface design factors were quantified, and a comprehensive evaluation model was established using FCE. This model was used to compare and analyze three UI design schemes, ultimately selecting the optimal one. Based on this, the selected UI design was further optimized using user heatmap data and indicator layer weights. The following conclusions can be drawn:

1) During the UI design optimization process, the font size and color of the high-click areas were adjusted based on user click heatmaps, significantly improving the data visualization and user experience. This optimization not only simplified the operational workflow but also enhanced the overall operational efficiency and energy management efficiency. In particular, the optimization of the “Farm Information Data Alerts” section improved the clarity and readability of information in this area, thereby enhancing the functionality and real-time capabilities of the system.

2) The UI design score of the optimized smart agricultural management cloud platform increased from 82.396 to 87.471, demonstrating the scientific validity and effectiveness of the AHP/FCE method in evaluating the UI design of the platform and providing a reference for future smart agricultural management cloud platform designs.

3) The UI design evaluation and optimization system developed in this study provides valuable reference points for the decision-making stage of UI design. It helps identify and optimize deficiencies in design and offers data support and practical experience for future UI design improvements.

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