Research Article

Evaluation of Cloud Computing Copyright Protection Based on AHP

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To increase the protection level of copyright in cloud computing environment, aiming at the problems that the indicators in the copyright protection evaluation system are difficult to accurately define and cannot be quantified, a comprehensive evaluation model of copyright protection based on the combination of analytic hierarchy process and fuzzy comprehensive evaluation is proposed. First, using the analytic hierarchy process (AHP), the copyright protection evaluation system is constructed and the weight of each evaluation index is determined through the judgment matrix. Then the quantitative evaluation result is fuzzy operated through index weight and evaluated data. Finally, the simulation evaluation results on specific example show that this model is reasonable and effective, and it can provide the evaluation basis and practical reference for copyright protection evaluation in cloud computing environment.

1. Introduction

Cloud computing is a computing model that uses the internet to realize access to a shared resource pool anytime, anywhere, on demand, and conveniently. It has features such as on-demand self-service, extensive network access, resource pool, being fast and flexible, and metered and paid services [1–3]. As a new information technology, it not only provides great convenience for people's live, but also brings severe challenges to traditional copyright protection, which is manifested in the continuous disputes over copyright protection in the cloud computing environment such as Cablevision case in USA, EMI suing MP3tunes case, and infringement reprint of headline today case. The problem of copyright protection in cloud computing environment is becoming more and more prominent. The main reason is the lack of effective copyright protection measures of cloud platform, copyright protection awareness and perfect copyright protection evaluation index system. And it is impossible to evaluate the current status and development trend of copyright protection on cloud computing platforms.

Copyright protection in cloud computing environment is an important part of intellectual property protection. Its protection evaluation index system has not been systematically studied. However, some scholars have studied the protection and evaluation of intellectual property rights. Wang [4] analyzed copyright infringement of SAAS model, PAAS model, and IAAS model of cloud computing, established evaluation system of intellectual property protection, and verified the effectiveness through the fuzzy comprehensive evaluation method, providing a new evaluation method for intellectual property protection under cloud computing mode. Yuan and Zhang [5] established copyright risk assessment system of network information resources on WBS-RBS in copyright risk of acquisition, processing, storage, transmission, and management, which provided an evaluation basis for the copyright protection of network information resources. Zhang and Liu [6] established index system of intellectual property risk evaluation of digital library on resources, environment, and personnel according to the characteristics of digital library, providing an evaluation method for the protection of library intellectual property rights. Li et al. [7] established evaluation

index system of copyright infringement of network information resources and constructed comprehensive evaluation model of extension AHP on defining the subject of infringement, providing effective assessment tools for the copyright infringement risk of network information resources.

The above research results provide an important basis for infringement risk decision and copyright protection evaluation. However, it does not combine the environmental characteristics and management methods of cloud computing. There are some problems, such as difficulty in defining evaluation index and unquantifiable evaluation result. As a result, they cannot be directly applied to copyright protection evaluation in the cloud computing environment. Therefore, based on the in-depth analysis of the influencing factors and evaluation process of copyright protection, this paper aims at copyright protection issues in the cloud computing environment and constructs a comprehensive evaluation model of copyright protection on information factors, environmental factors, and management factors. First, this paper uses the AHP to layer each evaluation index and calculates the weight of each level of evaluation index. Then, the final quantitative evaluation result is obtained by fuzzy calculation of index weight and membership degree. Finally, the validity and practicability of the evaluation model are verified by a concrete example.

To process our discussion, the remainder of this article is listed as follows: Section 2 reviews the content of copyright protection evaluation under cloud computing environment. Section 3 presents the fuzzy evaluation model based on AHP. In Section 4, a case study is presented and a comparison is given. In last section, some conclusions are derived.

2. Content of Copyright Protection Evaluation under Cloud Computing Environment

Copyright protection in the cloud computing environment refers to information technology such as data encryption, identity authentication, license authorization, and protecting data work's legal and reasonable usage, and when infringement occurs, technical means are used to track infringements, the source and attribution of works are identified, and evidence for court rulings is provided, thereby effectively maintaining the legitimate rights of copyright owners [8]. Under cloud computing environment, after copyright owner uploads digital works to cloud server, in order to improve the reliability and availability of data, cloud service provider uses distributed redundancy mode to save works on different nodes of the same data center and even save works on different nodes of different data centers [9–11]. With authorization, the user gets works related services by the client. Therefore, it is either uploading digital works or distributing cloud servers, which are realized through the Internet. While the virtuality and looseness of the network will greatly increase the difficulty in protecting the right of reproduction, the right of information network dissemination, and the right of works lease, evaluating the

level of copyright protection is mainly to evaluate the protection level of reproduction right, information network dissemination right, and works lease right.

2.1. Protection of Reproduction Right. In the cloud computing environment, the reproduction right refers to a right of a digital work owned by the owner, which is copied by oneself or by authorizing others. It is the fundamental core right of copyright [12]. Enforcing the protection of reproduction right is to safeguard the right holders to more effectively control the distribution, dissemination, and use of their works. Main factors of impacting protection evaluation of reproduction rights are as follows. (1) Direct copy: it is a simple and direct reproduction of the original work. (2) Temporary copy: it is the instantaneous replication behavior of some pieces of works in the cloud virtual storage area. Although the object of temporary copy is partial segment, it is still possible to reproduce some or even all of the works through data restoration and data splicing techniques, which is truly perceived by the public. (3) Data cache: when the user is browsing the work, the server will download the work to the cloud cache. When browsing again, the server will read it directly from the cache. Works in buffer will be reused, which reduces the copyright owner's ability to control his work. (4) Data distribution: in order to ensure the stability of the cloud platform, cloud server will distribute copies of the work and store them on different nodes in the data center. Once a node fails, services continue to be provided through nodes that store copies of works adjacent to each other [13]. In the process of data distribution, there is obvious copying behavior.

2.2. Protection of Information Network Dissemination Right. The information network dissemination right refers to using the Internet to provide work services to the public, which makes the public have the right of obtaining and using works at a particular time and place [14]. The definition of information network communication behavior is for the purpose of providing products for public access or use. Enforcing protection of information network dissemination right through the internet is to prevent the occurrence of specific infringement and protect the legitimate rights and interests of copyright owners. Ensuring information network dissemination right mainly depends on whether the works are authorized and whether the dissemination is safe. The main factors that impact protection evaluation of information network dissemination right are the following. (1) Access control: the purpose of access control is limiting the user's access and scope to the work to ensure the legal use of the works by authorized users, which is preventing unauthorized users from accessing the protected work and preventing authorized users from unauthorized access to protected works. (2) Authorization mechanism: the copyright holder grants or assigns the exclusive right to use the work to the licensor. Only fully authorized, the obligee can publish and use the work in the cloud platform. (3) Copyright tracking mechanism: after rights are violated, using data encryption, digital watermarking, and other

technologies can track infringements, identify ownership of the work, and, through copyright tracking, effectively curb the indiscriminate spread of illegal works.

2.3. Protection of Works Lease Right. Works lease right refers to copyright owner's right to license or forbid others to lease the original and copy of digital works under the cloud platform [15]. Strengthening the protection of the right of lease can effectively promote the creation and dissemination of excellent works. Main factors of impacting protection evaluation of lease rights are as follows. (1) Rent mechanism: after the cloud service provider signs a contract with the copyright owner to rent the works, it will store the works in the data center for consumers to use, and pay the rent to the copyright holder regularly. (2) Paid use: in the process of works lease, copyright holder obtains a direct or indirect benefit by renting. Cloud service providers make money by providing services, and the users pay for the service. The principle of paid use, on the one hand, can ensure that the intellectual achievements of copyright holders are rewarded; on the other hand, it can prevent the work from being abused in the network.

3. The Fuzzy Evaluation Model Based on AHP

3.1. The Evaluation Process of Copyright Protection. Under cloud computing environment, the index of copyright protection has the characteristics of hierarchy, qualitative and quantitative combination, and fuzziness. Therefore, it is in combination with traditional qualitative analysis and quantitative analysis of their respective advantages and uses hierarchical analysis and fuzzy comprehensive evaluation method to evaluate copyright protection. First, according to national copyright protection standards and regulations, it establishes a multilevel evaluation index system for copyright protection, and through the analytic hierarchy process (AHP) calculates the weights of each index. After that, it needs to collect evaluation data of copyright protection of cloud platform, establish fuzzy evaluation factor set and comment set, construct fuzzy evaluation matrix, and calculate membership degree. Finally, according to the index weight and membership degree, the final evaluation result is calculated and analyzed. The specific evaluation process is shown in Figure 1.

3.2. Construction of Copyright Protection Evaluation Index System. The quality of evaluation index selection is directly related to the objectivity and impartiality of the evaluation results. Therefore, selecting evaluation indexes of copyright protection should consider not only the information resources factor, but also the human factor and the environmental factor which affect each other. On the basis of following the scientific, systematic, and operational principles, it needs to analyze information resource factor, environment factor, and management factor under cloud computing environment, particularly summarizing the protection of reproduction right, information network dissemination right, and works lease right. Meanwhile, with

advice from experts and scholars, it uses Delphi method and correlation analysis to refine evaluation index system of copyright protection under cloud computing environment. Specific details are shown in Table 1.

3.3. The Determination of Index Weight. In order to evaluate the real level of copyright protection scientifically, comprehensively, and objectively, distinguishing between primary and secondary indicators in the evaluation process and highlighting the status of each indicator in copyright protection, it needs to make indicators empowered following the importance of the indicators. Because the related factors of copyright protection's decision level have hierarchy and uncertainty and are difficult to define and quantify precisely, hence, the AHP was used to determine the weight of each index. AHP is a combination of qualitative and quantitative system analysis method [16–20], which is applied to deal with a condition of uncertainty and subjective judgment. The steps include constructing judgment matrix, hierarchical ordering, and consistency testing.

- (1) Construct judgment matrix of each layer: in order to reduce the influence of randomness caused by human subjective factors, expert consultation and multiple rounds of anonymous questionnaires are used. Pairwise comparison is used, which compares the importance of the two factors at the lower level with those at the higher level. And the grading is on a nine-point scale. Meanwhile, the domain experts give the importance comparison relationship of each indicator, which is to construct the judgment matrix A of each layer. Judging each scale's meaning of matrix is shown in Table 2.

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}. \quad (1)$$

- (2) Calculate weights of each level. Hierarchy weighting refers to the quantitative value of each indicator's importance at this level, which is relative to an indicator of the previous level [21–24]. The feature vector of judgment matrix is relevant weight of index. The specific calculation steps are as follows:

Step 1: normalize each column of the judgment matrix.

$$b_{ij} = \frac{a_{ij}}{\sum_{i=1}^n a_{ij}}, \quad i, j = 1, 2, \dots, n. \quad (2)$$

Step 2: add the normalized judgment matrix by row.

$$W_i = \sum_{j=1}^n b_{ij}, \quad i = 1, 2, \dots, n. \quad (3)$$

Step 3: normalize the added vector W_i and get the eigenvector.

FIGURE 1: The process of copyright protection evaluation.

$$Wi = \frac{Wi}{\sum_{j=1}^n W_j}, \quad i = 1, 2, \dots, n. \quad (4)$$

Step 4: calculate the maximum characteristic root $\lambda_{\max}$ of the judgment matrix.

$$\lambda_{\max} = \sum_{i=1}^n \frac{(AW)_i}{(nW)_i}. \quad (5)$$

Step 5: in order to reduce the deviation of experts' subjective judgment, judgment matrix should be examined for consistency. The formula for CR is given by (6) and the formula for CI is given by (7):

$$CR = \frac{CI}{RI}, \quad (6)$$

$$CI = \frac{\lambda_{\max} - n}{n - 1}. \quad (7)$$

RI is the average random consistency index. RI can be obtained as shown in Table 3. When the CR is less than 0.1, the judgment matrix has passed the consistency test, and the result is considered to be within an acceptable margin of error and can therefore be adopted. Otherwise, it is regarded as that the judgment matrix is not objective enough and needs further modification [25–28].

- (3) Determine the index weight. The judgment matrix of each level will be obtained by means of anonymous questionnaire. If there is a big difference of opinion on expert feedback, multiple rounds of consultation will be adopted till the judgment matrix data is basically consistent. Meanwhile, the consistency test is carried out to obtain the weight value of each

index. The weights of primary and secondary indexes are shown in Tables 4–7, and the total weights of indexes are shown in Table 1.

As shown in Table 4, in terms of the impact of environmental factor on copyright protection, technical level is the most important and influential (0.669), followed by maintenance level (0.243) and operational level (0.088).

As shown in Table 5, in terms of the impact of information resource factor on copyright protection, reproduction right is the most important and influential (0.648), followed by information network propagating right (0.230) and works lease right (0.122).

As shown in Table 6, in terms of the impact of information resource factor on copyright protection, rules and regulations is the most important and influential (0.557), followed by management institutions (0.320) and external constraints (0.123).

As shown in Table 7, in the copyright protection evaluation, information resource factors is the most important and influential (0.589), followed by environmental factors (0.252) and management factors (0.159), indicating that the protection of information resources is a key factor for copyright protection in the cloud computing environment.

In addition, it can be seen from Table 1 that relative evaluation target weights (weighted multiply at all levels) with the three levels of indicators, direct copy (0.1714), quality of cloud services (0.0993), temporary copy (0.0992), authorization mechanism (0.0742), data distribution (0.0653), and rent mechanism (0.0539), are the 6 largest and the most important weight evaluation indexes. And the result is consistent with the reality. This is because, in practical applications, protecting copyright of information works is mainly to protect the right to copy the works, prevent illegal direct copying, and ensure that temporary replication in the cloud server is not used illegally. At the same time, it is necessary to restrict users' access rights and

TABLE 1: Index system of copyright protection evaluation.

Goal	First indicators	Weights	Secondary indicators	Weights	Third indicators	Weights
Copyright protection evaluation system under cloud computing environment (U)	Environmental factor (A1)	0.252	Operational level (B1)	0.088	Business nature (B11)	0.106
					Working experience (B12)	0.633
					Market share (B13)	0.261
			Maintenance level (B2)	0.243	Stable platform (B21)	0.334
					Service quality (B22)	0.525
					Customer satisfaction (B23)	0.141
					Platform development (B31)	0.252
			Technical level (B3)	0.669	Data processing (B32)	0.159
					Cloud service quality (B33)	0.589
			Copyright (C1)	0.648	Direct copy (C11)	0.449
	Temporary copy (C12)	0.260				
	Data distribution (C13)	0.171				
	Information resource factor (A2)	0.589	Internet communication right (C2)	0.230	Data cache (C14)	0.120
					Authorization mechanism (C21)	0.548
					Access control (C22)	0.241
					Copyright tracking (C23)	0.211
			Rental right (C3)	0.122	Rent mechanism (C31)	0.750
					Paid use (C32)	0.250
			Rules and regulations (D1)	0.557	Information system (D11)	0.525
					Personnel system (D12)	0.142
					Security system (D13)	0.333
			Management factor (A3)	0.159	Management institutions (D2)	0.320
	Institutional setting (D22)	0.198				
	Personnel literacy (D23)	0.312				
	External constraints (D3)	0.123			Local policy (D31)	0.633
					Local economy (D32)	0.261
					Local culture (D33)	0.106

TABLE 2: Scale and meaning of judgment matrix.

Numerical values	Verbal gradation
1	Element i is as important as element j
3	Element i is moderately more important than element j
5	Element i is strongly more important than element j
7	Element i is very strongly more important than element j
9	Element i is extremely more important than element j
2, 4, 6, 8	The importance of i relative to j is between adjacent judgments
Reciprocal	Element i is less important than element j correspondingly

scope of works information through authorization mechanism, data distribution mechanism, and rental mechanism, which is to ensure the use of information resources in a legal and compliant manner. Cultural level (0.0021), business nature (0.0024), local economy (0.0051), market share (0.0058), customer satisfaction (0.0086), and institutional setting (0.0101) are the six evaluation indicators with the least weight, which shows that they have little impact on the level of copyright protection, but they are also factors that cannot be completely ignored.

3.4. Fuzzy Comprehensive Evaluation Model. Fuzzy comprehensive evaluation uses the principle of fuzzy linear transformation and the principle of maximum membership degree, for indicators to be evaluated, which evaluates comprehensively from each index of the lowest layer, and it goes up till the highest target level in turn. Finally, the final evaluation result is obtained [29–31]. The main steps include determination of evaluation index and evaluation set, calculation of membership degree, and comprehensive evaluation.

TABLE 3: Determination of the random index.

n	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.89	1.12	1.26	1.36	1.41	1.46

TABLE 4: The index layer of environmental factor (A1-B).

A1	B1	B2	B3	Sort weight
B1	1	1/3	1/7	0.088
B2	3	1	1/3	0.243
B3	7	3	1	0.669

Note. Consistency test: $\lambda_{\max} = 3.007$, $I = 0.0035$, $CR = 0.00606 < 0.1$, which passed the consistency test.

TABLE 5: The index layer of information resource factor (A2-C).

A2	C1	C2	C3	Sort weight
C1	1	2	5	0.648
C2	1/3	1	2	0.230
C3	1/5	1/2	1	0.122

Note. Consistency test: $\lambda_{\max} = 3.0037$, $CI = 0.00185$, $CR = 0.00319 < 0.1$, which passed the consistency test.

TABLE 6: The index layer of management factor (A3-D).

A3	D1	D2	D3	Sort weight
D1	1	2	4	0.557
D2	1/2	1	3	0.320
D3	1/4	1/3	1	0.123

Note. Consistency test: $\lambda_{\max} = 3.0183$, $CI = 0.00916$, $CR = 0.0158 < 0.1$, which passed the consistency test.

TABLE 7: The criterion layer judgment matrix (U-A).

U	A1	A2	A3	Sort weight
A1	1	1/3	2	0.252
A2	3	1	3	0.589
A3	1/2	1/3	1	0.159

Note. Consistency test: $\lambda_{\max} = 3.05390$, $CI = 0.02695$, $CR = 0.04646 < 0.1$, which passed the consistency test.

- (1) Determine the factor set of evaluation indicators at all levels $U = \{U_1, U_2, \dots, U_m\}$.
- (2) Determine the comment set $V_1 = \{V_1, V_2, V_3, V_4, V_5\} = \{\text{high, above, normal, below, low}\}$; the measurement scale vector corresponding to each evaluation grade is $G = \{5, 4, 3, 2, 1\}$.
- (3) Determine the membership matrix. Membership refers to the degree of membership relationship between each evaluation index corresponding to the comment set and each grade [32, 33]. r_{ij} is used to indicate the degree to which the i th index is rated as the j th grade. And the r_{ij} is determined by $r_{ij} = n_{ij}/m$ calculation, where n_{ij} is the number of experts rated as the j th grade of the current index and m is the total number of experts. Construct membership matrix R

according to the membership degree of the index as follows:

$$R_{m \times 5} = \begin{bmatrix} r_{11} & r_{12} & \dots & r_{15} \\ r_{21} & r_{22} & \dots & r_{25} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \dots & r_{m5} \end{bmatrix}. \quad (8)$$

- (4) Comprehensive evaluation. The index weight vector W and membership matrix R determined by AHP are fuzzy calculated, and the comprehensive evaluation result is obtained. The formula is given by

$$B_i = W_i \circ R_{m \times 5} = (W_{i1}, W_{i2}, \dots, W_{im}) \circ \begin{bmatrix} r_{11} & r_{12} & \dots & r_{15} \\ r_{21} & r_{22} & \dots & r_{25} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \dots & r_{m5} \end{bmatrix} \\ = (bi_1, bi_2, \dots, bi_5). \quad (9)$$

- (5) Quantitative results: the final quantitative results are obtained by multiplying the comprehensive evaluation result obtained by fuzzy operation with the scale value. The formula is given by

$$S_i = B_i \bullet G^T = (bi_1, bi_2, \dots, bi_5) * \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \\ V_5 \end{bmatrix}. \quad (10)$$

Among them, B_i is the fuzzy comprehensive evaluation result of evaluation index, G^T is the scale value corresponding to each comment set, and S_i is the final evaluation score.

4. Case Study

4.1. Evaluation and Implementation. Taking D company operating cloud computing platform in Guangzhou as the evaluation object, 10 industry experts and scholars were invited to evaluate their copyright protection level through on-site viewing and questionnaire survey. On the basis of sorting out the evaluation results and statistics, the fuzzy membership degree of each evaluation index is obtained, as shown in Table 8.

According to the comprehensive fuzzy evaluation formula $B = WR$, the fuzzy evaluation set of each second-level index is calculated, in which the weight value W of each index can be obtained from Table 1. Fuzzy evaluation vectors of second-level index operation level, maintenance level, and technical level are obtained through calculation, and membership matrix R_{A1} of first-level index environmental factors is constructed as follows:

TABLE 8: The table of index membership.

First indicators	Secondary indicators	Third indicators	High	Above	Normal	Below	Low
Environmental factor (A1)	Operational level (B1)	Business nature (B11)	0.2	0.2	0.4	0.1	0.1
		Working experience (B12)	0.3	0.4	0.2	0.1	0
		Market share (B13)	0.3	0.3	0.2	0.1	0.1
	Maintenance level (B2)	Stable platform (B21)	0.3	0.5	0.2	0	0
		Service quality (B22)	0.3	0.4	0.2	0.1	0
		Customer satisfaction (B23)	0.3	0.4	0.2	0.1	0
		Platform development (B31)	0.4	0.4	0.1	0.1	0
	Technical level (B3)	Data processing (B32)	0.4	0.3	0.1	0.1	0.1
		Cloud service quality (B33)	0.1	0.4	0.2	0.2	0.1
Information resource factor (A2)	Copyright (C1)	Direct copy (C11)	0.3	0.3	0.2	0.1	0.1
		Temporary copy (C12)	0.3	0.4	0.2	0.1	0
		Data distribution (C13)	0.3	0.5	0.1	0.1	0
		Data cache (C14)	0.4	0.4	0.1	0.1	0
	Internet communication right (C2)	Authorization mechanism (C21)	0.4	0.4	0.2	0	0
		Access control (C22)	0.3	0.3	0.2	0.1	0.1
		Copyright tracking (C23)	0.2	0.3	0.2	0.2	0.1
	Rental right (C3)	Rent mechanism (C31)	0.2	0.4	0.2	0.1	0.1
		Paid use (C32)	0.3	0.3	0.2	0.1	0.1
Management factor (A3)	Rules and regulations (D1)	Information system (D11)	0.3	0.5	0.2	0	0
		Personnel system (D12)	0.4	0.4	0.1	0.1	0
		Security system (D13)	0.3	0.3	0.3	0.1	0
	Management institutions (D2)	Management system (D21)	0.4	0.5	0.1	0	0
		Institutional setting (D22)	0.3	0.4	0.2	0.1	0
		Personnel literacy (D23)	0.2	0.3	0.3	0.1	0.1
		Local policy (D31)	0.5	0.5	0	0	0
	External constraints (D3)	Local economy (D32)	0.5	0.4	0.1	0	0
		Local culture (D33)	0.3	0.4	0.2	0.1	0

$$R_{A1} = \begin{bmatrix} 0.289 & 0.353 & 0.221 & 0.100 & 0.037 \\ 0.300 & 0.433 & 0.200 & 0.067 & 0.000 \\ 0.223 & 0.384 & 0.159 & 0.159 & 0.075 \end{bmatrix}. \quad (11)$$

Similarly, the membership matrix R_{A2} of information resource factors and R_{A3} of management factors are constructed as follows:

$$R_{A2} = \begin{bmatrix} 0.312 & 0.372 & 0.171 & 0.100 & 0.045 \\ 0.334 & 0.355 & 0.200 & 0.066 & 0.045 \\ 0.225 & 0.375 & 0.200 & 0.100 & 0.100 \end{bmatrix}, \quad (12)$$

$$R_{A3} = \begin{bmatrix} 0.314 & 0.419 & 0.219 & 0.048 & 0.000 \\ 0.318 & 0.418 & 0.182 & 0.051 & 0.031 \\ 0.479 & 0.463 & 0.047 & 0.011 & 0.000 \end{bmatrix}.$$

According to the fuzzy evaluation matrix R and the weight of corresponding indexes, the evaluation results of environmental factors of first-level index are calculated as follows:

$$B_{A1} = W_{A1} * R_{A1} = (0.248, 0.393, 0.174, 0.131, 0.053). \quad (13)$$

Similarly, the evaluation results of information resource factors and management factor indicators of first-level indicators can be obtained as follows:

$$B_{A2} = W_{A2} * R_{A2} = (0.306, 0.369, 0.181, 0.092, 0.052),$$

$$B_{A3} = W_{A3} * R_{A3} = (0.336, 0.424, 0.186, 0.044, 0.010). \quad (14)$$

Finally, the membership degree R of the target layer is combined with the fuzzy evaluation results of the first-level indicators to calculate the evaluation results of the target layer as follows:

$$B = W * R = (0.296, 0.384, 0.180, 0.094, 0.045). \quad (15)$$

The evaluation results of the target layer are defuzzified to obtain the comprehensive evaluation score of copyright protection as follows:

$$S = B * G^T = (0.296, 0.384, 0.180, 0.094, 0.045) * [5, 4, 3, 2, 1]^T = 3.791. \quad (16)$$

According to the same method, the comprehensive evaluation score of the first-level index can be obtained by the operation of fuzzy evaluation set and evaluation scale vector of each index as follows:

$$S_{A1} = B_{A1} * G^T = 3.651, \quad S_{A2} = B_{A2} * G^T = 3.786, \quad S_{A3} = B_{A3} * G^T = 4.031.$$

4.2. The Evaluation Results Analysis

- (1) Result analysis of the index layer: in the environmental factor index, the score of the secondary index

$(3.758, 3.967, 3.522)^T$ can be obtained according to $S = B * G^T$, which shows that the maintenance level of the current evaluation object is high, basically reaching a higher level, while the technical level is relatively weak, and there is much room for improvement. In the information resource factor index, the score of the secondary index is $(3.080, 3.866, 3.525)^T$, which shows that the current evaluation object has the highest protection level of network communication right, the weakest protection level of reproduction right, and the largest proportion of copyright indicators. Therefore, the company needs to focus on the technologies and measures of copyright protection, especially the protection capabilities of direct copy and temporary copy. In the management factor index, the score of the secondary index is $(4.000, 3.940, 4.410)^T$, which shows that the current evaluation object has a high level of restrictive factors and regulatory protection, various policies are more standardized, the economy is more developed, the cultural level is higher, and the rules and regulations are relatively complete, so that the overall protection level has reached a higher level.

- (2) Result analysis of the target layer: first of all, the fuzzy comprehensive evaluation score of the final target layer is 3.791, which is bounded between the normal level and the above level. Meanwhile, the probability of rating "high, above, normal, below, low" is 0.296, 0.384, 0.180, 0.094, and 0.045, respectively. According to the principle of maximum membership, the maximum value corresponds to an above evaluation set, and the evaluation value is concentrated in normal or above accounts for 0.860 of the total evaluation. Therefore, the copyright protection level of this platform is at an above level, but there is still room for improvement. Secondly, the evaluation scores of environmental factor, information resources factor, and management factor that directly affect the target layer are 3.651, 3.786, and 4.031, respectively, indicating that the protection of management factor has reached a high level. The protection level of environmental factor and information resource factor is between the normal level and the above level. Finally, if the protection level of copyright needs to be further improved, the protection intensity should be improved from three aspects. Among them, the information resource factor has a high weight, but the protection evaluation score is low. So the protection capability of information resource factor can be enhanced in the improvement scheme.

4.3. Comparison and Analysis. In order to better explain the rationality and feasibility of the fuzzy AHP comprehensive evaluation method, the fuzzy AHP comprehensive evaluation method is compared with the fuzzy complementary judgment matrix method [34] and multivariate statistical analysis method [35, 36].

4.3.1. Comparison with Multivariate Statistical Analysis Method. Multivariate statistical analysis is a theory and method that uses mathematical statistics to study multivariate (multiple indicators) problems. It is widely used for comprehensive evaluation and analysis of various problems [35, 36]. This paper first designed a questionnaire on the factors affecting the level of copyright protection and then carried out cluster analysis, factor analysis, correlation analysis, and regression analysis on the collected data to find out the evaluation index system affecting the level of copyright protection. Finally, the above companies were analyzed and evaluated, and the results are as follows:

- (1) In the multivariate statistical analysis method, the independent variable environmental factor (standardized regression coefficient $\beta = 0.249$), information resource factor (standardized regression coefficient $\beta = 0.594$), and management factor (standardized regression coefficient $\beta = 0.148$) are all shown as positive numbers, which shows that all have a positive impact on copyright protection. And the three indicators have a positive impact on the evaluation results (information resource factor > environmental factor > management factor). This result is basically the same as the result in the fuzzy AHP comprehensive evaluation.
- (2) Using a multivariate statistical analysis method to evaluate the copyright protection of the above *D* company's cloud platform, the evaluation results show environmental factor (mean = 3.712, standard deviation = 0.213, and credibility = 0.904), information resource factor (mean = 3.825, standard deviation = 0.416, and credibility = 0.896), and management factor (mean = 4.018, standard deviation = 0.303, and credibility = 0.913). This result is basically consistent with the result of fuzzy AHP comprehensive evaluation.

4.3.2. Comparison with Fuzzy Complementary Judgment Matrix Method. The fuzzy complementary judgment matrix method is a typical method of using fuzzy judgment matrix to solve the weight and ranking. It converts the nine-level scales (extremely strong, extremely strong, strong, slightly stronger, same, slightly weaker, weak, extremely weak, and absolutely weak) into corresponding scales (0.9, 0.8, 0.7, 0.6, 0.5, 0.4, 0.3, 0.2, and 0.1) [34], using fuzzy complementary judgment matrix to calculate the weight, which is shown in Table 9.

It can be seen from Table 9 that the weight discrimination obtained by the fuzzy complementary judgment matrix [34] sorting algorithm is small, and the comparability is poor. In the same sublevel indicators, the largest difference between the largest weight and the smallest weight is 0.133, and the smallest is 0.033. The weights between the indicators lack comparability, and it is difficult to find the true indicators that determine the level of copyright protection. The method proposed in this article has a larger weight for the index that

TABLE 9: Weight comparison table.

First indicators	Weights (proposed)	Weights [34]	Secondary indicators	Weights (proposed)	Weights [34]	Third indicators	Weights (proposed)	Weights [34]
Environmental factor (A1)	0.252	0.325	B1	0.088	0.267	B11	0.106	0.284
						B12	0.633	0.383
						B13	0.261	0.333
			B2	0.243	0.333	B21	0.334	0.383
						B22	0.525	0.317
						B23	0.141	0.300
						B31	0.252	0.325
						B32	0.159	0.308
						B33	0.589	0.367
Information resource factor (A2)	0.589	0.367	C1	0.648	0.383	C11	0.449	0.271
						C12	0.260	0.254
						C13	0.171	0.242
						C14	0.120	0.233
			C2	0.230	0.325	C21	0.548	0.358
						C22	0.241	0.325
						C23	0.211	0.317
			C3	0.122	0.292	C31	0.750	0.550
						C32	0.250	0.450
Management factor (A3)	0.159	0.308	D1	0.557	0.367	D11	0.525	0.358
						D12	0.142	0.300
						D13	0.333	0.342
						D21	0.490	0.350
			D2	0.320	0.342	D22	0.198	0.317
						D23	0.312	0.333
						D31	0.633	0.383
			D3	0.123	0.292	D32	0.261	0.333
						D33	0.106	0.284

has a large impact on copyright protection and a small weight for the index that has a small impact on copyright protection. There is a clear difference between the weights. The largest difference between the largest weight and the smallest weight is 0.581. The smallest is 0.292, and the weights between the indicators are highly comparable, which can better distinguish the importance of the indicators and facilitate users' objective evaluation and decision-making.

The severity of illegal copying, illegal dissemination, and illegal use of information resources in the cloud environment directly affects the level of copyright protection. Therefore, information resources are an important factor in copyright protection [34]. Compared with environmental factors and management factors, it belongs to a strongly important level, and the weight of information resource factors should also be significantly greater than other factors. Using the fuzzy complementary judgment matrix sorting algorithm, the weight of information resource factors is 0.367, the weight of environmental factors is 0.325, and the weight of management factors is 0.308. It does not reflect the strong importance of information resource factors. Using this method, the weight of information resource factors is 0.589, the weight of environmental factors is 0.252, and the weight of management factors is 0.159. The weight of information resource factors is much higher than other factors. This phenomenon is very consistent with the reality. This also shows that the method proposed in this paper is suitable for the evaluation of copyright protection level under cloud computing.

4.3.3. Analysis

- (1) Compared with other evaluation methods, the fuzzy AHP comprehensive evaluation method uses the AHP to determine the weight of each impact index, decomposes multilevel and complex targets into several levels of multiple indexes, quantifies the importance of qualitative indicators with fuzzy concepts, reduces the influence of subjective factors, solves the problem of the difficulty in accurately defining evaluation indicators, and ensures the objectivity of evaluation results. At the same time, fuzzy mathematical theory is used to comprehensively and quantitatively evaluate fuzzy and uncertain information, which reduces the subjective arbitrariness of decision-makers and effectively improves the reliability and accuracy of judgment and evaluation.
- (2) When evaluating the level of copyright protection between different cloud computing platforms, a single technical indicator cannot satisfy the requirements of analysis. Using the fuzzy AHP method, the cloud platform is regarded as a system. According to the thinking mode of hierarchical decomposition, comparative judgment, and system synthesis, the fuzzy evaluation objects are processed by precise digital means. Not only can the evaluation object be evaluated and sorted on the basis of the

comprehensive score, but also the grade of the object can be evaluated according to the maximum membership principle in the light of the value on the fuzzy evaluation set. It overcomes the defect of the single result of traditional mathematical methods and provides a certain basis for objectively evaluating the copyright protection level of cloud platforms.

5. Conclusion

The evaluation of copyright protection in the cloud computing environment helps to better understand the risk of infringement, prevent the occurrence of infringement incidents, and reduce the losses caused thereby. First, it analyzes the copyright protection evaluation process, establishes a copyright protection evaluation index system in the cloud computing environment, and uses the AHP to determine the weight that can reflect the importance of each index. Finally, the fuzzy evaluation method is used to target each index that affects the level of copyright protection to perform fuzzy evaluation, analyzes the quantitative results of the target layer, and calculates the comprehensive score of the copyright protection level in the cloud computing environment. Established in this study, the copyright protection evaluation model eliminates the influence of evaluators' subjective factors on the evaluation results, making the evaluation results more open, fair, and accurate, and has stronger convincing power. It provides new idea and method for scientific evaluation of copyright protection in the cloud computing environment and has certain practical value. In the future, we will take the AHP with the evaluation of copyright protection into other fuzzy environment [37–51].

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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