Research on Security Evaluation Methods of Edge Computing Information Systems

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Abstract: With the rapid development of economy and science and technology, the demand for edge computing technology has expanded. Edge computing can provide caching and processing functions to realize the localization of computing power and resource storage. Under the high requirements of edge information system, the accuracy of its security evaluation and classification is also required to be improved. At the same time, due to the limited resources, the data scale should not be too large and not strictly obey the normal distribution, so the adaptability and accuracy of the traditional first-order grey clustering are insufficient, and the similarity of the maximum membership degree adjacent membership degree may lead to fuzzy judgment and reverse sorting results. Single empowerment method using subjective right confirmation method or objective right confirmation method alone will lead to inaccurate results. This review will discuss the security evaluation and grading model for edge information systems from the following aspects: overview of mainstream methods, overview of data sets and evaluation criteria, the current level of this direction, and the discussion of current problems and solutions. In this paper, some processing methods of the information system security evaluation and grading model of edge computing are discussed. In the subsequent work, further research can be carried out from the following two aspects: the more optimized solution of grey clustering, and whether the security evaluation and grading model can be applied to various scenarios.

1 INTRODUCTION

The development of edge information system is becoming more and more mature, and the security issues in it have also been widely concerned, so the security evaluation and classification is also very important. In the determination of index weight, various weighting methods have their own advantages and disadvantages, and how to decide the weighting method is the most important. At present, there has been preliminary improvement in security evaluation in various fields. For big data network security problems, the network security evaluation method based on rough set can simplify the core values that can represent network security attributes from a large number of high-dimensional dynamic data, so as to carry out the security evaluation of network security (Liu, 2019). In the study of the security of medical big data information sharing, the researchers selected the security sharing indicators of medical big data according to the Delphi method, and established the hierarchical evaluation model of the indicators by using the analytic hierarchy process. The evaluation method can effectively evaluate the security of medical big data sharing, and provide a new technical platform and solution for hospital information management (Shan, 2018). In the aspect of network security assessment, a network security assessment model based on multi-data layer is proposed, which realizes qualitative and quantitative assessment functions and provides a new idea for network risk assessment (Ma, 2011).

In the edge information system, the data size needs to be controlled in a reasonable range, and the data distribution often shows the characteristics of non-strictly normal. The traditional first-order grey clustering evaluation system has exposed obvious limitations in this situation, and its adaptability and accuracy are difficult to meet the actual needs. Especially in the judgment of evaluation results, because the values of the maximum membership degree and the adjacent membership degrees are

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close to each other, the judgment process is often ambiguous, and even the ranking results are unreasonably reversed, which seriously affects the reliability and effectiveness of the evaluation.

In order to overcome these problems, a high-accuracy security evaluation grading model based on subjective and objective weighting and second-order grey clustering, namely C-SG model, came into being (Guo, 2024). The model is divided into seven modules with clear and interrelated functions. The security analysis module is taken as the starting step, that is, the selection of evaluation objects and the determination of security objectives. Then, the security policy decomposition module undertakes the important task of in-depth analysis of the security requirements, potential threats and vulnerabilities of the edge information system. Secondly, the mapping and delineation of security metrics involves aligning chosen indicators with the edge information system security evaluation framework. Next, the data acquisition and preprocessing are used to eliminate the influence of the order of magnitude and dimension. Then the determination module of index weight, and finally the security evaluation grading module and effectiveness analysis module. Among them, the determination module of index weight adopts the method of combining subjective and objective weighting, scientifically and reasonably determines the relative importance weight of each safety index in the evaluation system, and avoids the one-sidedness and limitations of single weighting method. According to the second-order grey clustering algorithm (Guo, 2024), the security evaluation grading module performs in-depth analysis and calculation on the processed data, and obtains accurate security evaluation grading results, which effectively solves the shortcomings of the traditional first-order grey clustering method in processing the data of the edge information system. This review will introduce some existing evaluation methods in the safety evaluation and grading, including the determination of index weight, as well as their scientific nature and limitations, and put forward the corresponding solutions.

2 OVERVIEW OF MAINSTREAM METHODS

2.1 Subjective and Objective Empowerment

1)Analytic hierarchy process combined with entropy weight method (Wen, 2022): Analytic hierarchy process (AHP) builds a hierarchical structure, and experts score the importance of each index to determine the weight, which is subjective, but can comprehensively consider the logical relationship between indicators. The entropy weight method determines the weight according to the information entropy of the index data, and the objectivity is outstanding. The combination of the two can complement each other, make the weight determination more scientific and reasonable, and make the subsequent security evaluation grading more accurate.

2)The coefficient of variation method is paired with the expert scoring method: The variation coefficient method (Yang, Wang, Zheng, et al, 2024) using the variation degree of each index data to measure its impact on the overall weight, reflect the characteristics of the data is discrete; The expert scoring method integrates professional experience to give weight judgment, and the combination of the two can take into account the difference between objective data and subjective professional cognition, which is helpful to improve the quality of weight setting in the evaluation model.

2.2 Second-order Grey Clustering Aspect

1)Optimization of grey clustering coefficient calculation (Guo, 2024): The traditional way of calculating grey clustering coefficient is improved. For example, the determination of different gray class boundary values of each index is considered more finely, and a more reasonable whitening weight function is used, so that the clustering process can more accurately divide the evaluation object into the corresponding security level category, and improve the accuracy of classification.

2)Combined with big data sample correction: With the increasing amount of available data, the parameters of the second-order grey clustering are constantly corrected and improved by using a large number of actual security evaluation related sample data, so that the model can better adapt to the security evaluation needs in different scenarios, reduce errors, and achieve more accurate security evaluation grading.

3)Integration with other intelligent algorithms: For example, combining with intelligent algorithms such as smart grid fault prediction and diagnosis (Xu, 2024) and mathematical optimization algorithm (Yan, 2024), the scope of safety level is initially divided by second-order grey clustering, and then the learning and optimization capabilities of intelligent algorithms are used to further adjust accurately, give full play to their respective advantages, and jointly improve the accuracy and reliability of safety evaluation grading.

3 COMMONLY USED DATASETS AND EVALUATION CRITERIA

The dataset in this direction is constructed based on the original security evaluation data. In the process of data collection, the secondary index is clearly set as the minimum unit of index collection, and the standardized processing method is used to convert the original data. Thus, the computational obstacles caused by different orders of magnitude and units are eliminated. In terms of determining index weights, the C-SG model (Guo, 2024) adopts a combination weighting method based on the optimal function theory and the combination of subjective and objective weights. It is divided into PageRank weighting method based on indicator correlation (Song, Gong, 2023) and entropy weighting method based on indicator information (Yang, Zhang, 2024). Finally, the subjective and objective combination weighting method based on optimal function theory organically integrated the above two weighting results. The optimal function is constructed to balance the advantages and disadvantages of subjective and objective weighting.

In this direction, the determination of index weight is divided into subjective weight confirmation methods, such as Delphi method (Xu,2023) and analytic hierarchy process (Kang, Xu, Yang, et, al, 2024). Objective weight confirmation rules include entropy weight method (Yang, Zhang, 2024) and CRITIC method (Chen, Lv, Yang, 2022). At present, a combination weight method combining subjective and objective weights based on optimal function theory is also proposed (Qin, Yuan, Zhou, et, al,2023). It includes PageRank weighting based on indicator relevance (Song, Gong, 2023) and entropy weighting method based on indicator information (Yang, Zhang, 2024), and uses the least square method to realize the combination of the two weights. In the security evaluation grading, the whitening weight function is constructed, the standardized gray clustering coefficient is calculated, and then the second-order correction factor is introduced to calculate the comprehensive decision vector to further increase the discrimination of the original unit decision vector (Guo,2024).

4 EXISTING PROBLEMS AND POSSIBLE SOLUTIONS ARE DISCUSSED AND ANALYZED

4.1 Limitations of C-SG Model Evaluation Methods

There are problems: In the module 7 validity analysis module of C-SG model, the model is only evaluated by the membership difference coefficient and the head to tail consistency rate (Guo,2024), which has certain limitations. Although these two indicators can reflect the consistency and membership discrimination of model evaluation results to a certain extent, for a complex security evaluation grading model, they cannot fully cover the overall performance of the model under different application scenarios, different data characteristics and various actual requirements. The availability and effectiveness of a model are multi-dimensional concepts, involving the adaptability of the model to various types of data, the ability to accurately distinguish different security situations, and the operating efficiency in resource-constrained environments. It is difficult to build a complete and reliable effectiveness evaluation system only by relying on these two indicators, which may lead to misjudgment or inadequate evaluation of the overall performance of the model. Thus, it affects the promotion and application of the model in the actual safety evaluation work. Solution: To ensure that the usability and effectiveness of the model are comprehensively and accurately evaluated, it is necessary to introduce more diverse evaluation methods. First, evaluation metrics based on confusion matrix (Cao, Yin, Li, et al, 2024) can be used, such as precision, recall, F1 score, etc. By comparing the prediction results of the model with the real security situation, constructing a confusion matrix, and then calculating these indicators, researchers can intuitively understand the ability of the model in correctly identifying the security level. For example, precision reflects the proportion of correct predictions, recall reflects the ability of the model to capture positive samples (for a given security level), and the F1-score takes both precision and recall into account to provide a more balanced evaluation. Second, cross-dataset validation is performed. Several datasets from different edge information systems with different data distribution characteristics were used to verify the model. This allows you to examine how well your model generalizes in different scenarios, avoiding situations where your model works well on a particular dataset and fails in other real-world applications. By evaluating various performance indicators of the model on multiple data sets, and analyzing its stability and adaptability, the confidence in the availability and effectiveness of the model is further enhanced.

4.2 The One-sidedness of the Combinatorial Weighting Method

There are problems: In the current combination weighting method combining subjective and objective weights, it only focuses on the PageRank weighting method based on indicator correlation and the entropy weighting method based on indicator information (Guo,2024). This limitation makes the research on combination weighting method not comprehensive. Although the advantages of these two methods are described, other possible weighting methods and their shortcomings are not deeply discussed, which makes it impossible to examine the rationality of method selection from a broader perspective. Different weighting methods have their own characteristics and application scenarios. Ignoring other methods may mean missing out on a more optimal weight determination strategy, or failing to fully recognize the possible limitations of existing methods under specific conditions. This may cause the adaptability and accuracy of the combined weighting method to be questioned in the face of complex and changing security evaluation data and requirements, and then affect the reliability and effectiveness of the whole security evaluation grading model. Solution: In order to determine the rationality of the existing method selection, it is necessary to deeply explore other subjective and objective weighting methods and analyze their shortcomings. For example, for the direct scoring method in the subjective weighting method, its advantage is that it is simple and direct, and it can quickly obtain the intuitive judgment of experts on the importance of indicators. However, the disadvantages of the method are that it completely relies on the subjective opinions of experts, lacks consideration of the inherent laws of data, and is easily affected by experts' personal preferences, knowledge limitations, and subjective arbitrariness, which leads to imprecise weight allocation, especially in the face of large-scale and complex data and index system, there may be weight imbalance. This method determines the weight according to the degree of dispersion of the index data. The greater the degree of dispersion, the greater the weight is given to the index, which highlights the influence of data difference on the weight. But its disadvantage is that it places too much emphasis on the variability of the data and may ignore the actual importance implications of the indicators themselves. In some cases, even if the degree of dispersion of an index is small, it is of key significance from the perspective of professional domain knowledge, and the deviation maximization method may underestimate its weight, thus affecting the rationality of the evaluation results. Through a comprehensive analysis of these and other related weighting methods, compared with PageRank weighting and entropy weighting methods, the advantages and disadvantages of different methods can be more clearly understood. Thus, according to the specific goals of security evaluation, data characteristics, application scenarios and other factors, The rationality of the combination weighting method combining subjective and objective weights selected at present is determined rationally, which lays a solid methodological foundation for constructing a more scientific and accurate safety evaluation grading model.

4.3 Limitations of the Scoring Method

There are problems: In the entropy-TOPSIS method comprehensive evaluation, the initial scoring of the index system is crucial. The expert scoring method initially adopted is based on the experts' own experience and professional knowledge to score various indicators (Chou, Ding, Gao, et,al, 2024). However, this method has obvious limitations in the scoring process because it lacks verification of its own rationality. In practice, different scoring methods have their own advantages and disadvantages. For example, although the subjective scoring method can reflect the subjective judgment of experts, it is easily affected by personal bias and subjective factors. Objective scoring methods, such as those based on statistics, can reduce the interference of human factors, but may ignore the internal relationship between indicators. Solution: In order to ensure the scientific and accurate scoring, we need to comprehensively evaluate multiple scoring methods. By analyzing the advantages and disadvantages of various scoring methods, the most suitable scoring method is selected, so as to provide a more reliable basis for the comprehensive evaluation of entropy weight-TOPSIS method. Only after such a comprehensive consideration and analysis, can the initial score be reasonably assigned, so that the entropy weight-TOPSIS method is more scientific and effective in the comprehensive evaluation. For example, consider the analytic Hierarchy process, which is a systematic analysis method that decomposes a complex problem into multiple levels and determines the weight of each factor through the steps of establishing a hierarchical structure model, constructing a judgment matrix, calculating the weight vector, and performing a consistency check. Firstly, the hierarchical structure model should be established, and the problem is divided into goal level, criterion level and scheme level. Then the judgment matrix is constructed. For each element of the same level, the importance of each element relative to the element of the previous level is compared by experts or decision makers, and the value is assigned by 1-9 scale method to construct the judgment matrix. Then, the weight vector was calculated, the largest eigenvalue of the judgment matrix and its corresponding eigenvector were calculated, and the weight vector of each element was obtained after normalizing the eigenvector. Finally, the consistency check is carried out to ensure the rationality of the judgment. Analytic Hierarchy Process (AHP) can make complex problems organized and hierarchical, so as to make decision-making more scientific and reasonable, but it also has some limitations such as strong subjectivity in constructing judgment matrix and complex calculation for problems with many indicators. Therefore, the combination of this method and entropy weight method can realize the complementary advantages of subjective and objective.

4.4 The Disadvantages of Grey Relational Analysis

There are problems: The grey relational analysis method (Xu, Huang, 2024) is adopted in the research of disaster risk assessment based on AHP-entropy combination weighting. This method is not demanding on the amount of data in theory, but in practical application, if the amount of data is too small, it will lead to unstable calculation results of correlation degree, lack of sufficient representation and reliability, thus affecting the analysis conclusion. At the same time, the default data of this method is equal spacing and regularity, but the actual data may not meet it, such as non-equal interval time series data or data with abnormal fluctuations, which will make the analysis results deviate. Solution: Develop a comprehensive data collection plan to collect as much relevant data as possible before the study begins. If the original data is insufficient, supplementary data can be obtained through various channels, such as collecting data from other relevant databases, industry reports, questionnaires, etc., to increase the richness and representation of data. If the original data is insufficient, supplementary data can be obtained through various channels, such as collecting data from other relevant databases, industry reports, questionnaires, etc., to increase the richness and representation of data. For non-equally spaced data, interpolation or smoothing can be used to transform it into approximately equally spaced data. For data with abnormal fluctuations, robust statistical methods are used, such as eliminating outliers, performing data smoothing or using robust statistics such as median instead of mean for analysis. According to the actual distribution characteristics of the data, we can also choose the appropriate grey relational analysis to improve the model. For the data with obvious seasonality or periodicity, the method of seasonal adjustment or cycle decomposition can be introduced to preprocess the data, and then the grey relational analysis can be carried out.

5 CONCLUSIONS

In this paper, a high accurate safety assessment grading model based on subjective and objective weighting and second-order grey clustering, risk assessment based on entropy weight-TOPSIS method and disaster risk assessment based on AHP-entropy combination weighting are summarized. The validity and shortcomings of these models are discussed and analyzed, and the solutions are proposed. At the same time, combined with the current status of the edge information system, the accuracy of the security evaluation grading model was improved. In the future work, we will devote to study the more optimal solution of grey clustering and whether the security evaluation grading model can be applied to various scenarios.

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