

Research on Fuzzy Comprehensive Evaluation Method in Wireless Sensor Network Course Evaluation

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Abstract: Wireless Sensor network (WSN) is a Capstone course in engineering education certification, because the implementation of this course should reflect implementation, complexity and teamwork. It is difficult for teachers to use traditional and linear assessment criteria to evaluate students' learning effects. Aiming at the above problems, an evaluation method of wireless sensor network course based on fuzzy theory and multi-level evaluation index factor set is proposed in this paper. The method imitates the evaluation experience and intelligent behavior of education experts, and obtains an optimal course evaluation model. Through the fuzzy comprehensive evaluation of multi-level index system, students' learning effect can be evaluated accurately, objectively, fairly and scientifically.

Keywords: Wireless sensor network, Fuzzy comprehensive evaluation method, Capstone course.

1. Introduction

The Internet of Things Engineering major of our university has participated in the Institute of Engineering Education Taiwan Certification (IIEET). The certification system was established in 2003. In 2007, it was promoted as a full member of Washington Accord (WA), an international certification agreement for engineering education, and is one of the three major professional evaluation institutions in Taiwan China. Mainly plans and implements the accreditation commission of Engineering Education (EAC), Computer Education (CAC), Technical Education (TAC) and Architectural Education (AAC) in accordance with international standards. Members of the executive committee include senior professors from academia, senior engineers from industry for more than 10 years, and executives[1][2]. The Internet of Things engineering major began to apply for IIEET-CAC certification in May 2021. After more than a year of construction, it basically meets the requirements of the system and adheres to the implementation of the education and teaching concept of engineering education certification: "student-centered, outcome based education, continuous improvement". IIEET certification requirements in every year at least need to set up a total whole course the Capstone course, the course is a comprehensive strong professional core course, integrated by grouping of solve the problem of a actual project or system, and used in the process of implementation of the PBL project teaching method in combination with flip classroom manner, pay attention to the "student center, outcome based education". Under this requirement, therefore, through professional advisory committee on the demonstration of the wireless sensor network (WSN) has chosen three grade practical implementation as the Capstone course. Hope that through the course of the implementation of the results and grads questionnaire to evaluation for the core competence of the graduates to achieve degrees, the effect of this course and evaluation way is critical.

Due to the project-based implementation of the course, the traditional final examination paper cannot be used to directly evaluate students, so a new evaluation method should be adopted. In addition, rubrics (measuring scale) will be developed according to the achievement of graduates' core

competence. The project also needs to reflect students' ability to solve complex problems, and the evaluation needs to reflect differences and fairness between and within groups. Therefore, it is necessary to develop a more perfect, multi-dimensional, objective and scientific assessment and evaluation method. In view of the above situation and the fuzzy evaluation of course assessment, the fuzzy logic theory is introduced to explore and practice the fuzzy comprehensive evaluation, and the results are found to be objective, fair and scientific.

2. Fuzzy Comprehensive Evaluation Method

Since there is still uncertain evaluation value in the evaluation index, multi-level fuzzy evaluation method[3] is used to evaluate the effect of students' learning wireless sensor network course, which makes the evaluation result more comprehensive, objective and scientific. Fuzzy comprehensive evaluation overcomes the characteristics of fuzziness and uncertainty in the course teaching evaluation[4] and transforms the qualitative evaluation into quantitative evaluation in the course evaluation of wireless sensor network. The specific multi-level fuzzy comprehensive evaluation algorithm is as follows:

① Firstly, according to the course, the evaluation index factor set U is divided into k subsets, namely

$$U = \{U_1, U_2, \dots, U_k\}, \text{ Among them } U = \bigcup_{i=1}^k U_i, \text{ And}$$

these k subsets don't have any intersection, so let's call them U_1, U_2, \dots, U_k , Which satisfy the

$$U_i \cap U_j = \emptyset (i \neq j) \quad (1)$$

And each subset contains several secondary indicators indicator factors, i.e $U_i = \{u_1^{(i)}, u_2^{(i)}, \dots, u_t^{(i)}\} (i=1, 2, \dots, k)$.

② Establish the evaluation set $V = \{v_1, v_2, \dots, v_m\}$. Firstly, the degree to which t index factors of the second-level index factor set $U_i = \{u_1^{(i)}, u_2^{(i)}, \dots, u_t^{(i)}\} (i=1, 2, \dots, k)$ belong to

the evaluation set V is evaluated by single factor, and the single factor evaluation matrix R_i is obtained:

$$R_i = \begin{bmatrix} r_{11}^{(i)} & r_{12}^{(i)} & B & r_{1m}^{(i)} \\ r_{21}^{(i)} & r_{22}^{(i)} & B & r_{2m}^{(i)} \\ C & C & C & C \\ r_{t1}^{(i)} & r_{t2}^{(i)} & B & r_{tm}^{(i)} \end{bmatrix}_{t \times m} \quad (2)$$

Among them, $0 \leq r_{lx}^{(i)} \leq 1$, $l=1,2,\dots, t, x=1,2,\dots, m, 1 \leq i \leq k$. The evaluation matrix is mainly calculated by the membership function in fuzzy mathematics theory or the expert object scoring method at all levels.

③ The weight of the second-level indicator factor $U_i = \{u_1^{(i)}, u_2^{(i)}, B, u_t^{(i)}\}$ ($i=1,2, \dots, k$) is set as $W_i = \{a_1^{(i)}, a_2^{(i)}, B, a_t^{(i)}\}$ through Delphi method, namely expert scoring method, entropy weight method or integrated optimal weighting method[5]. The second-level single indicator factor comprehensive evaluation can be obtained through fuzzy synthesis operation:

$$B_i = W_i \dot{c} R_i \quad (i=1,2, \dots, k) \quad (3)$$

Among them $B_i = (b_1^{(i)}, b_2^{(i)}, B, b_m^{(i)})$, if $\sum_{j=1}^m b_j^{(i)} \neq 1$ is used, normalization is required.

$$b_j^{(i)'} = \frac{b_j^{(i)}}{\sum_{j=1}^m b_j^{(i)}} \quad (i=1,2, \dots, k) \quad (4)$$

④ Then, the first-level index factor set $U = \{U_1, U_2, \dots, U_k\}$ is comprehensively evaluated, and its first-level index weight $W = \{a_1, a_2, B, a_k\}$ is set. According to the comprehensive evaluation vector B_i ($i=1,2, \dots, k$) of each second-level index obtained by ③, the total evaluation matrix is composed:

$$R = \begin{bmatrix} B_1 \\ B_2 \\ \dots \\ B_k \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & \dots & b_{1m} \\ b_{21} & b_{22} & \dots & b_{2m} \\ \dots & \dots & \dots & \dots \\ b_{k1} & b_{k2} & \dots & b_{km} \end{bmatrix}_{k \times m} \quad (5)$$

⑤ Finally, the total comprehensive evaluation vector $B = W \dot{c} R$ can be obtained according to the fuzzy synthesis operation, and then the corresponding evaluation grade can be obtained according to the principle of membership degree maximization[6].

⑥ If the second-level indicator factor set $U_i = \{u_1^{(i)}, u_2^{(i)}, B, u_t^{(i)}\}$ ($i=1,2, \dots, k$) still contains more associated factors, that is, U_i should be further divided to obtain the three-level evaluation model, four-level evaluation model or more level evaluation models. Or according to step ① \sim ⑥ in turn, the deepest layer of evaluation index factor set was evaluated first, and then the evaluation of the first level of evaluation index factor set was calculated from deep to shallow, and finally the multi-level fuzzy comprehensive evaluation was obtained.

3. Evaluation Instance

(1) The evaluation index

For the Internet of Things engineering major, the core course of wireless sensor network was selected as the Capstone course certified by IEET. According to the requirements of Capstone course in certification, it is necessary to select and implement an integrated project implementation course of at least one semester. The course must have practical works, adopt PBL project-based group cooperative inquiry learning for the course, and evaluate the outstanding outcome output oriented. In addition, each member student in each group should also be evaluated. The evaluation of the course should support the core competence requirements of graduates. Therefore, the evaluation index of wireless sensor network course is formulated as shown in Table 1. In order to objectively, comprehensively, fairly and scientifically evaluate the students' learning effect of Capstone course, a fuzzy comprehensive evaluation method for wireless sensor network course assessment is proposed based on fuzzy theory.

Table 1. Assessment index of wireless Sensor network course

Evaluation Object	Level indicators	The secondary indicators
Wireless Sensor Network course assessment	Grades U_1	attendance rate U_{11}
		Classroom performance U_{12}
		Phase testing U_{13}
		Homework after class U_{14}
	final grade U_2	Oral report U_{21}
		written report U_{22}
		Implementation of finished product U_{23}
		Within the group self-evaluation U_{24}

(2)opinion rating

In the evaluation process, indicators at all levels have evaluation levels. The factor levels of each level in the

assessment and evaluation of wireless sensor network course are divided into five levels, namely: $V = \{\text{excellent, good, medium, qualified, unqualified}\}$. Among them, excellent

corresponds to 90 points or above, good corresponds to 80 points to 90 points, medium corresponds to 70 points to 80 points, qualified corresponds to 60 points to 70 points, and unqualified corresponds to less than 60 points. The specific

correspondence is shown in Table 2. The comparison between factors at the current level can be reflected intuitively according to the evaluation grade.

Table 2. Corresponding relationship of evaluation grade scores

Serial number	opinion rating	score
1	excellent	[90, 100]
2	good	[80, 90)
3	medium	[70, 80)
4	qualified	[60, 70)
5	unqualified	[0, 60)

(3) Evaluation weights

The evaluation weight is an important basis for each evaluation factor in fuzzy evaluation. Therefore, the weight of each indicator factor is set according to the guidance of course group teachers, teaching experts, industry experts and the actual situation of the school. Different regions, different courses and different teaching modes can be adjusted according to the specific situation. The weight setting reflects the importance degree of each index. The weight sum of each factor under the same index should be 1, if not 1, normalization is required. In this paper, the weight of course assessment and evaluation index is set as follows.

The weight of level 1 indicators (ordinary grades, final grades) is set as follows: $W = \{0.4, 0.6\}$.

Secondary index weight setting:

(attendance, class performance, phased tests, homework) the weights are set as follows: $W_1 = \{0.2, 0.3, 0.2, 0.3\}$.

(oral report, written report, finished product, self-evaluation within the group) The weight is set as follows: $W_2 = \{0.15, 0.2, 0.4, 0.25\}$.

(4) Fuzzy evaluation

According to the fuzzy comprehensive evaluation method, the fuzzy evaluation of second-level indicators is carried out first. According to the Capstone course, the weight requirements of the achievement degree of graduates' core competence are evaluated, as shown in Table 3. Then, the scores are given by university experts outside the course, enterprise engineers experts in the industry and teachers in the course group, and the proportion of the performance of each student in each group and group on the evaluation level is obtained, and the fuzzy evaluation matrix R_1 and R_2 are obtained. If the evaluation score of the index factor is not 1, normalization should be done.

Table 3. Integrated Project Implementation (Capstone) measures the attainment of core competencies of graduates

Team performance analysis of the ** Class * group of ** Grade Internet of Things			
Course: Wireless Sensor Networks	Grade: Junior (compulsory) Teacher: * * *		
Students: * Group/all members of the group	Thematic title: Smart Home		
Grade:			
Core competence[7][8]	weight	score	Weighted score
1. Knowledge and ability of applied mathematics and information technology, with innovation consciousness.	10%		
2. Ability to implement the technology, skills and use modern tools required for Internet technology practice.	25%		
3. Ability to design and evaluate computer network information systems, programs and components.	20%		
4. Ability of network engineering project management (including cost analysis), effective communication, domain integration and team work.	10%		
5. Have the ability to explore, analyze and apply research results and solve complex network information problems.	15%		
6. Be aware of current issues, the environmental, social and global impacts of Internet technology, and develop the habit and ability to continue learning.	10%		
7. To understand and abide by professional ethics, recognize social responsibility and respect diverse viewpoints.	10%		
Total score			
Team performance analysis:			
Team member performance analysis:			
Note: Team members' achievements include team achievements (actual project achievement, contribution of each team member in the project) and their respective reports, each accounting for 50%.			

$$R_1 = \begin{bmatrix} 0.72 & 0.24 & 0.03 & 0.01 & 0 \\ 0.84 & 0.14 & 0.01 & 0.01 & 0 \\ 0.68 & 0.3 & 0.02 & 0 & 0 \\ 0.56 & 0.36 & 0.07 & 0.01 & 0 \end{bmatrix} \quad (6)$$

$$R_2 = \begin{bmatrix} 0.55 & 0.32 & 0.12 & 0.01 & 0 \\ 0.7 & 0.22 & 0.08 & 0 & 0 \\ 0.87 & 0.13 & 0 & 0 & 0 \\ 0.75 & 0.25 & 0 & 0 & 0 \end{bmatrix} \quad (7)$$

The fuzzy evaluation of the second-level index is:

$$B_1 = W_1 \circ R_1 = (0.2, 0.3, 0.2, 0.3) \circ \begin{bmatrix} 0.72 & 0.24 & 0.03 & 0.01 & 0 \\ 0.84 & 0.14 & 0.01 & 0.01 & 0 \\ 0.68 & 0.3 & 0.02 & 0 & 0 \\ 0.56 & 0.36 & 0.07 & 0.01 & 0 \end{bmatrix} = \begin{bmatrix} (0.2 \wedge 0.72) \vee (0.3 \wedge 0.84) \vee (0.2 \wedge 0.68) \vee (0.3 \wedge 0.56) \\ (0.2 \wedge 0.24) \vee (0.3 \wedge 0.14) \vee (0.2 \wedge 0.3) \vee (0.3 \wedge 0.36) \\ (0.2 \wedge 0.03) \vee (0.3 \wedge 0.01) \vee (0.2 \wedge 0.02) \vee (0.3 \wedge 0.07) \\ (0.2 \wedge 0.01) \vee (0.3 \wedge 0.01) \vee (0.2 \wedge 0) \vee (0.3 \wedge 0.01) \\ (0.2 \wedge 0) \vee (0.3 \wedge 0) \vee (0.2 \wedge 0) \vee (0.3 \wedge 0) \end{bmatrix} = \begin{bmatrix} 0.3 \\ 0.3 \\ 0.07 \\ 0.01 \\ 0 \end{bmatrix} \quad (8)$$

Since the sum of each evaluation level is not 1, the results obtained after normalization are as follows:

$$B_1^T = (0.44, 0.44, 0.1, 0.02, 0) \text{ .Similarly, you get an } B_2^T = (W_2 \circ R_2)^T = (0.51, 0.32, 0.15, 0.02, 0) \text{ .}$$

Therefore, according to the second-level index fuzzy evaluation, the final overall comprehensive fuzzy evaluation result can be obtained as follows:

$$B = W \circ R = (0.4, 0.6) \circ \begin{bmatrix} 0.44 & 0.44 & 0.1 & 0.02 & 0 \\ 0.51 & 0.32 & 0.15 & 0.02 & 0 \end{bmatrix} = \begin{bmatrix} (0.4 \wedge 0.44) \vee (0.6 \wedge 0.51) \\ (0.4 \wedge 0.44) \vee (0.6 \wedge 0.32) \\ (0.4 \wedge 0.1) \vee (0.6 \wedge 0.15) \\ (0.4 \wedge 0.02) \vee (0.6 \wedge 0.02) \\ (0.4 \wedge 0) \vee (0.6 \wedge 0) \end{bmatrix} = \begin{bmatrix} 0.51 \\ 0.4 \\ 0.15 \\ 0.02 \\ 0 \end{bmatrix} \quad (9)$$

After normalization, $B^T = (0.47, 0.37, 0.14, 0.02, 0)$.

This paper adopts the principle of maximizing the membership degree of fuzzy sets to evaluate the student's Capstone course as "excellent". In this method, a relatively comprehensive evaluation result is obtained by using fuzzy matrix calculation to evaluate the effect of students' participation in course learning comprehensively, objectively, multi-dimensionally, fairly and scientifically, so as to give feedback and guide to improve the teaching process, and finally form a closed-loop management of education and teaching.

4. Conclusion

As the Capstone course of IEET-CAC for Internet of Things engineering major, wireless sensor network (WSN) adheres to the teaching philosophy of "student-centered, outcome based education and continuous improvement". By

adopting PBL project teaching method in combination with flip classroom manner, this paper analyzes the course due to the evaluation index of diversity, hierarchy and fuzzy, cannot use the traditional final examination paper evaluation method is given priority to, in this paper, a multilevel evaluation index based on the theory of fuzzy factor set evaluation method of wireless sensor network curriculum. And analysis of the establishment of multi-level fuzzy theory, through the whole semester of a student in the group to determine the performance of the learning behavior of each level of evaluation index and weight, and finally through multi-level fuzzy theory to calculate the learning effect of students. On the one hand, this assessment method can evaluate the learning situation of students in a diversified, objective and scientific way, on the other hand, it can respect the individual differences of students and teach them in accordance with their aptitude, so as to feedback, guide and improve the teaching process, and finally form a closed-loop management of education and teaching.

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