

Team Control Number

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Problem Chosen

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Summary Sheet

Summer Job Evaluation System Summary

Our goal is to identify the factors affecting the summer job choice of high school students, and develop a set of models to evaluate their jobs. We create a **novel summer job evaluation system**. Moreover, we also design an app with friendly interactive interface for potential high school students.

In problem 1, we identify eleven influencing factors and divide them into three categories: **personal factors, job factors and social factors**. Personal factors include academical level, computer skill, physical quality and organizational skill, which are qualitative. Job factors include work way, job type, work place, hourly rate and number of hours, of which hourly rate is probabilistic, and the rest are deterministic. Social factors include family influence and social honor of the job, which are qualitative. Based on these factors, we build an influencing factor system of job selection.

In problem 2, due to the lack of empirical data on job options, it is difficult to learn a model with very high accuracy for job evaluation. To solve this limitation, we create **a novel job evaluation system which consists of a fuzzy analysis model and a Listwise ranking model based on a neural network**. At the beginning, the fuzzy analysis model is used to **offline** evaluate jobs while **collecting data about the job choices**. Meanwhile, Listwise ranking model is trained **online** based the collected data. Through this implementation method of offline data collection and online training, we can quickly obtain a personalized job recommendation system to adapt to the real scenarios. We apply the idea of **multi-level screening** into our fuzzy analysis model, where fuzzy comprehensive evaluation method is used to finish the preliminary screening for all jobs, and analytic hierarchy process is used to finish secondary screening to find the best job.

In problem 3, we test our model by creating **twelve fictional persons**. Eight fictional persons with special skills or strict requirements for the job are used to make a **sensitivity analysis** on our model to verify the robustness of our model. Meanwhile, the other four fictional persons are used to test whether our model can make accurate evaluation for these ordinary persons. The test results show that our models have **good robustness and high accuracy** for job evaluation. The accuracy of our Listwise ranking model can reach **90%** with the real job choice data of 280 persons.

In problem 4, we design a friendly app for potential high school student. At the model level, we use fuzzy comprehensive evaluation method, analytic hierarchy process and Listwise ranking algorithm to generate accurate recommendation for students. At the user experience level, we design the GUI of app to show various jobs and guide users to fill in personal information and preferences.

Key words: Listwise ranking algorithm based neural network, Fuzzy comprehensive evaluation, Analytic hierarchy process, Multi-level screening, Sensitivity analysis.

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1 Introduction

1.1 Problem Background

It is difficult for high school students to find a summer job because of their lack of work experience. However, a good summer job not only can help high school students earn a little money to pay tuition and living expenses, but also can get some practical work experience in advance to prepare for entering the workplace in the future. Some students want to be newspaper couriers, which requires them to know the city's traffic routes. If a student likes to stay outdoors, camping, hiking or sports, the camp counselor work is absolutely suitable for him. The summer internship is basically unpaid, but the experience is priceless. In students' real life, they often face different choices. The choice of summer job has a great impact on students' future development. How to find a best summer job is a difficult problem for them.

1.2 Problem Restatement

The research goal of this paper is to quantify factors of high school students' preference on summer jobs. Then we need to develop models or algorithm to evaluate the summer job of high school students. Some fictional persons should be constructed to verify the model. Finally, we need to present our model by a webpage or an app or a school newspaper article.

2 Problem analysis

Figure 1 shows a schematic diagram of this study. A set of models are built to solve the four questions discussed in this paper.

Question 1: We need to identify and describe various factors for summer job choice of high school students. At the same time, we should consider different types of factors. They are quantitative, qualitative, constant, variable, deterministic or probabilistic.

Question 2: We need to develop a set of models with the information and preference of high school students as the input to evaluate their summer job choices. When building models, we need to consider two problems: 1) the preferences varies from students, so the personalized models are desired. 2) due to the lack of the data of summer job choices, the rationality and feasibility of the model need to be considered.

Question 3: We need to build at least ten fictional persons to test our models. In the process of building persons, we should consider some special persons that have special skills or special work characteristics requirements. For these data, our model should have a good sensitivity analysis ability.

Question 4: We need to show a friendly presentation for a person to understand and use. Meanwhile, we should consider the reasonability and simplicity of the layout.

3 Assumptions

Assumption 1: The academic level, computer skill, physical quality and organizational ability of students are constant over a certain period of time.

Assumption 2: The social honor of a company is constant over a certain period of time.

Assumption 3: High school students have a better understanding of themselves. The information filled in the questionnaire is true.

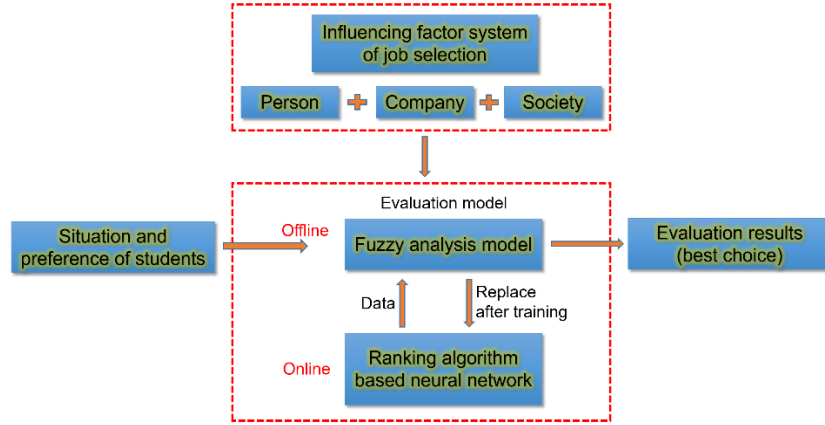


Figure 1 Schematic diagram of this study

Assumption 4: The recruitment content provided by the company is accurate, and job seekers can fully understand the recruitment information.

Assumption 5: The factors considered in this paper are more comprehensive, other factors have little impact on summer job selection for high school students.

4 Definition and description of factors and metrics (Problem 1)

We should analyze the factors that affect high school students' summer job choices and clearly describe each factor in details. In this paper, we divide all influence factors into three categories: personal factors, job factors and social factors, and build an influencing factor system of job selection, as shown in Figure 2.

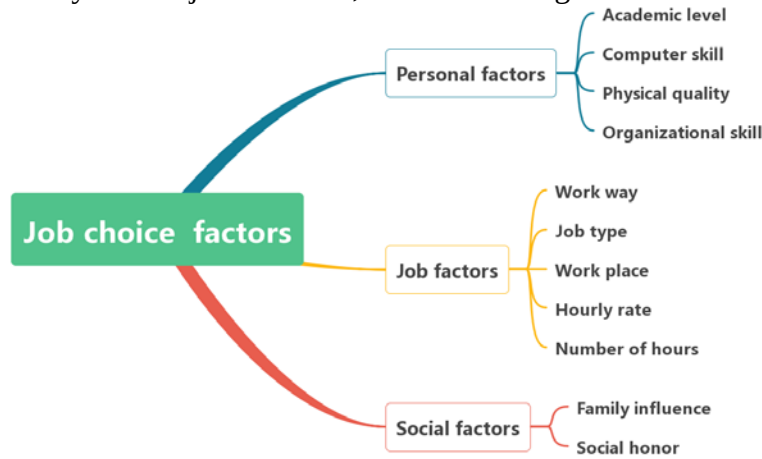


Figure 2 Influencing factor system of job selection for high school students

4.1 Personal factors

In personal factors, we mainly consider some basic ability of individuals. We suppose that the ability level can be divided into four levels: excellent (L_1), good (L_2), fair (L_3), and poor (L_4).

(1) Academic level

The grade ranking of high school students is used to evaluate their academic level. Assuming that the total number of students in the same grade of a high school is g_{num} , and the grade ranking of the student is g_{rank} , then the academic level of the high school student l_{aca} is shown by

$$l_{aca} = \begin{cases} L_1, & g_{rank} / g_{num} \geq r_1 \\ L_2, & r_2 \leq g_{rank} / g_{num} < r_1 \\ L_3, & r_3 \leq g_{rank} / g_{num} < r_2 \\ L_4, & g_{rank} / g_{num} < r_3 \end{cases} \quad (1)$$

where r_1, r_2, r_3 are proportional parameters.

(2) Computer skill

High school students' computer course scores are used to evaluate their computer skill level. Supposed that a high school student's computer course grade is S_{com} , then the computer skill l_{com} of the high school student is

$$l_{com} = \begin{cases} L_1, S_{com} \geq s_1 \\ L_2, s_2 \leq S_{com} < s_1 \\ L_3, s_3 \leq S_{com} < s_2 \\ L_4, S_{com} < s_3 \end{cases} \quad (2)$$

where s_1, s_2 and s_3 are the score boundary parameters for dividing each level on computer skill.

(3) Physical quality

Physical quality of high school students is used to evaluate the physical condition of high school students. Assuming a high school student's computer sports score is S_{phy} , then the physical quality l_{phy} of the high school student is

$$l_{phy} = \begin{cases} L_1, S_{phy} \geq s_1 \\ L_2, s_2 \leq S_{phy} < s_1 \\ L_3, s_3 \leq S_{phy} < s_2 \\ L_4, S_{phy} < s_3 \end{cases} \quad (3)$$

where s_1, s_2 and s_3 are the score boundary parameters for dividing each level on physical quality.

(4) Organizational ability

The number of high school students' experience in organizing activities is used to judge the organizational ability of high school students. Assuming that a high school student has participated in organizing activities η , then the high school student's organizational ability l_{org} is

$$l_{org} = \begin{cases} L_1, \eta \geq o_1 \\ L_2, o_2 \leq \eta < o_1 \\ L_3, o_3 \leq \eta < o_2 \\ L_4, \eta < o_3 \end{cases} \quad (4)$$

where o_1, o_2, o_3 are the degree boundary parameters of each level.

4.2 Job factors

When high school students choose summer jobs, they often have certain expectations for their jobs. According to such expectations, they mainly consider certain characteristics of the job. The ideal summer job we expect is: 1) the type and working style of the job are what we like; 2) the job can not only make money and save money, but also participate in entertainment outside of work. So, we consider the following five job factors

(1) Work way

Some jobs can be done online, but some jobs must be done offline. Therefore, the working ways can be divided into online and offline two types, and F_k ($k=1, 2$) represents these two types of working ways. F_1 represents online and F_2 represents offline. We suppose a job belongs to only one working way. For each job with work way J_{way} , a vector $\varphi_{way} = [\varphi_{way}^1, \varphi_{way}^2]$ is used to indicate the degree of membership of the job belonging to each type of work way. For example, if a job's work way is online, the degree of membership of work way is $\varphi_{way} = [1, 0]$.

$$\varphi_{way}^k = \begin{cases} 1, & J_{way} = F_k \\ 0, & J_{way} \neq F_k \end{cases}, (k = 1, 2) \quad (5)$$

(2) Job type

We assume that all jobs can be divided into M categories. We use C to represent the job type set, $C = \{c_1, c_2, \dots, c_M\}$. If each job belongs to only one type, for a job, its job type is J_{type} . Vector φ_{type} is the degree of membership of each job type:

$$\varphi_{type} = [\varphi_{type}^1, \varphi_{type}^2, \dots, \varphi_{type}^M], \quad \varphi_{type}^k = \begin{cases} 1, & J_{way} = c_k \\ 0, & J_{way} \neq c_k \end{cases}, (k = 1, 2, \dots, M) \quad (6)$$

For example, if we divide the job types into 3 categories: education, waiters, and marketing. A job belongs to the waiter industry, then the degree of membership of the job type is $\varphi_{type} = [0, 1, 0]$.

(3) Work place

The geographic location of the work place will affect the journey and transportation time of employees, so this factor is also one of the important factors in job selection. We use distance to measure the geographic location of the work place. J_{dis} is the distance from the residence to the work place of high school students. Assuming that we can get the distance between the residence and the company through google map, we let this distance be J_{dis} and the work place is kilometers. If the working mode of the job is online, then the distance J_{dis} is 0.

(4) Number of hours

In this paper, weekly working hours are used as the unit to measure a certain job, and the unit is hour. Assuming that for a certain job, it requires employees to work m days a week, and the daily working hours is t , then weekly working hours J_{time} is

$$J_{time} = m * t \quad (7)$$

(5) Hourly rate

Work salary may be our more concerned factor, but it is a variable indicator. It is determined by the nature of the job itself and the length of time employees' work. It is supposed that the hourly rate obeys a normal distribution $N(\bar{\nu}, \sigma^2)$, the probability distributions of hourly rate ν is

$$f(\nu) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(\nu - \bar{\nu})^2}{2\sigma^2}\right) \quad (8)$$

Then, the weekly rate J_{rate} of the job is further expressed as

$$f(J_{rate}) = \frac{1}{\sqrt{2\pi}\sigma} \exp\left(-\frac{(J_{rate} - \bar{\nu} * J_{time})^2}{2\sigma^2}\right) \quad (9)$$

4.3 Social factors

We are often influenced by family members and other people when we choose a job. In this paper, we consider two social factors: family influence and social influence.

(1) Family influence

It is affected by family environment and parents' educational level. Parents often have certain opinions on the choice of job types for their childrens. Assuming that all jobs can be divided into M categories, C represents the set of job types, $C = \{c_1, c_2, \dots, c_M\}$. The vector I_{family} represents parents' preferences for each type of work. $0 \leq \varepsilon_k (k = 1, 2, \dots, 5) \leq 1$, and $\varepsilon_1 + \varepsilon_2 + \dots + \varepsilon_M = 1$.

(2) Social honor

Each company's status and reputation in society are different. We consider that

society has an evaluation for each company and divide the evaluation into four levels: excellent (E_1), good (E_2), fair (E_3), and bad (E_4). $I_{society}$ represents the company honor and $I_{society} \in \{E_1, E_2, E_3, E_4\}$. Table 1 summarizes the types of influencing factors.

Table 1 Type of influencing factors for job choices

Factors		Type						Unit
		quantitative	qualitative	constant	variable	deterministic	probabilistic	
Personal factors	Academical level		✓	✓		✓		-
	Computer skill		✓	✓		✓		-
	Physical quality		✓	✓		✓		-
	Organizing skill		✓	✓		✓		-
Job factors	Work way		✓	✓		✓		-
	Job type		✓	✓		✓		-
	Job place	✓		✓		✓		km
	Hourly rate	✓			✓		✓	dollar
	Number of hours	✓		✓		✓		hour
Social factors	family influence		✓	✓			✓	-
	Social honor		✓	✓		✓		-

5. Development of Models (Problem 2)

This problem requires us to use the factors described in Question 1 to build a set of models or algorithms to evaluate summer jobs. We can regard this question as the best job recommendation. So we can use some personalized recommendation algorithms to solve this problem. Recommendation algorithms can achieve high accuracy by training based on label data. However, this problem does not provide us with empirical data, so it is very difficult to use supervised learning algorithms to solve this problem. Fuzzy Comprehensive Evaluation (FCE) method and Analytic Hierarchy Process (AHP) can achieve effective job evaluation without data, but it is difficult to evaluate the accuracy of these methods. Therefore, **we combine the advantage of recommendation algorithms and FCE, and propose a novel job evaluation system which consists of a fuzzy analysis model and a Listwise ranking model based neural network.** In the beginning, the fuzzy analysis model is used to offline evaluate jobs while collecting data about the job choices. The Listwise ranking model is online trained based the collected data of job choices.

5.1 Fuzzy analysis model

Based on the **idea of multi-level screening**, our fuzzy analysis model performs preliminary and secondary screening of jobs from a macro and micro perspective. First, at the macro perspective, a preliminary screening is carried out. According to the matching of the high school student and the job, each job is roughly divided into different levels (such as, very suitable, suitable, not suitable). Then at the micro level, secondary screening is carried out. The tasks in the highest level (very suitable) are fine-grandly evaluated to get an evaluation value for each job. Finally, the job with the largest evaluation value is selected as the best job choice for the high school student. Figure 3 shows the workflow of fuzzy analysis model.

5.1.1 Primary screening based on fuzzy comprehensive evaluation method

Each job is roughly evaluated according to the situation and preferences of high school student, and divided into three different evaluation levels: very suitable, suitable, and unsuitable. Through the classification of different job evaluation levels, primary screening is realized.

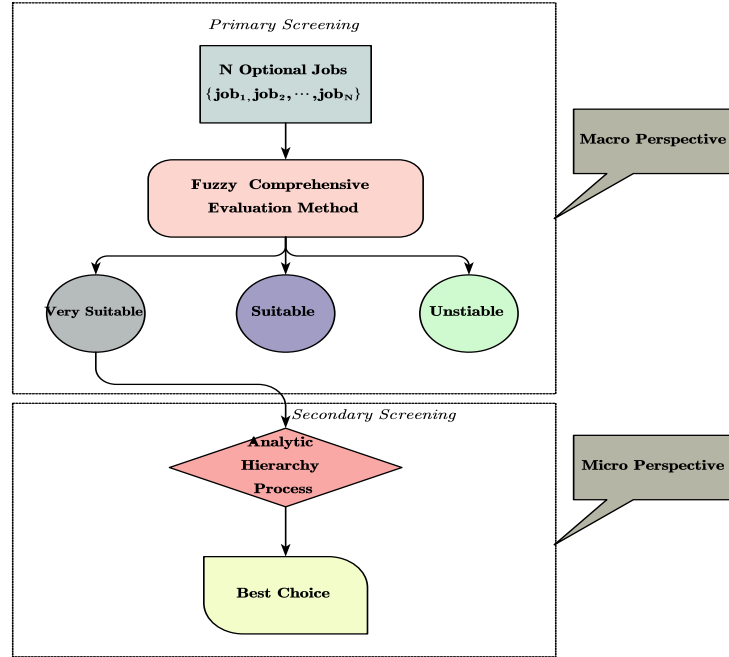


Figure 3 Workflow of fuzzy analysis

Fuzzy comprehensive evaluation method [1], a comprehensive evaluation method based on fuzzy mathematics, transforms qualitative evaluation into quantitative evaluation based on the membership degree theory of fuzzy mathematics. Therefore, we can use the FCE to complete the division of different job evaluation levels. FCE usually includes the following three aspects: it is supposed that there are n factors related to the evaluated thing, denoted as $U = \{U_1, U_2, \dots, U_n\}$, called the factor set. Meanwhile, we suppose there are m possible reviews, denoted as $V = \{v_1, v_2, \dots, v_m\}$, called the judge set. Since various factors have different effects, they are usually measured by weight, which is recorded as $W = [w_1, w_2, \dots, w_n]$.

FCE is usually carried out according to the following steps: 1) Determine the factor set: $U = \{U_1, U_2, \dots, U_n\}$; 2) Determine the judgment set: $V = \{v_1, v_2, \dots, v_m\}$; 3) Perform single factor evaluation: $W = [w_1, w_2, \dots, w_n]$; 4) Construct a comprehensive evaluation matrix R ; 5) Comprehensive evaluation: calculate fuzzy evaluation vector by using the formula $B = A \circ R$, and make a judgment based on the principle of maximum membership degree.

(1) Multi-level fuzzy comprehensive evaluation model

When the factor set is divided into multiple levels, we need to build a multi-level fuzzy comprehensive evaluation model. In this paper, a two-level evaluation factor system is constructed to evaluation, as shown in Figure 2. Therefore, we need to construct a two-level fuzzy comprehensive evaluation model.

Step 1: Determine the factor set of each level: The first level factor set $U = \{U_1, U_2, \dots, U_n\}$, where n is the number of first-level factors, $U_i = \{u_{i1}, u_{i2}, \dots, u_{im}\}$ and m is the number of second-level factors included in the first-level factor U_i .

Step 2: Determine the judgment set: $V = \{v_1, v_2, \dots, v_m\}$.

Step 3: For the i -th group factors U_i of the second layer:

- a) Calculate the weight W_i of U_i .
- b) Calculate the fuzzy relationship matrix R_i of U_i .
- c) Calculate the comprehensive evaluation of U_i : $B_i = W_i * R_i$

Step4: For first-level factors:

- a) Calculate the weight W of the first-level factors: $W = [w_1, w_2, \dots, w_n]$, where w_i is the weight of the i -th element U_i .
- b) Calculate the fuzzy relationship matrix R of the first-level factors: For the first-level factor set U , take the B_i obtained in the previous step as the single-factor evaluation of the factor U_i , so the fuzzy relationship matrix $R = [B_1, B_2, \dots, B_n]$.
- c) Calculate the comprehensive evaluation B of each element in the judgment set by the first-level factors: $B = A \circ R$.

Finally, B is used as the final comprehensive evaluation, which is called the secondary fuzzy comprehensive evaluation model.

(2) Building a secondary fuzzy evaluation model for job evaluation

AHP is a universal and effective method for determining weights [2]. First, the problem is divided into multiple levels. Then we compare the importance of each factor at the same level with respect to a criterion factor in the previous level to construct the judgment matrix accordingly. Finally, we obtain weights by the judgment matrix, and check the consistency of judgment matrix.

$$CI = \frac{\lambda_{\max} - n}{n - 1}, \quad CR = \frac{CI}{RI} \quad (10)$$

When $CI=0$, the judgment matrix has complete consistency. The smaller the CI , the smaller the degree of deviation from the consistency, otherwise, the worse the consistency of the judgment matrix. Generally, when $CR < 0.1$, the consistency of the judgment matrix is considered acceptable.

According to the above secondary fuzzy comprehensive evaluation model, we use the influence factor system described in this paper to establish a secondary fuzzy evaluation model.

Step1: Determine the factor set for each level. According to the influence factor system of job selection described in Figure 1, we can know the first level factor $U = [U_1, U_2, U_3]$, U_1 , U_2 and U_3 represent personal factors, company factors and social factors. In the equation $U_1 = \{u_{11}, u_{12}, u_{13}, u_{14}\}$, $U_2 = \{u_{21}, u_{22}, u_{23}, u_{24}, u_{25}\}$, $U_3 = \{u_{31}, u_{32}\}$. $u_{11}, u_{12}, u_{13}, u_{14}$ represent academical level, computer skill, physical quality and origination skill. $u_{21}, u_{22}, u_{23}, u_{24}, u_{25}$ represent work way, job type, location of job, hourly rate and number of hours. u_{31}, u_{32} represent family influence and social honor.

Step2: Determine the set of judgments. The evaluation level of jobs can be divided into three levels: very suitable, suitable and inappropriate. To this end, we set the evaluation set $V = \{\text{very suitable } (v_1), \text{ suitable } (v_2), \text{ unsuitable } (v_3)\}$.

Step3: Determine the weight of each factor based on AHP. In order to achieve **personalized job evaluation, we regard each high school student as an expert**, and each high school student determines the importance of factors according to their interests and preferences. We use the ten-point method to determine the importance of each factor. The score of each factor is an integer from 1 to 10. Further, we use the score of each factor to determine the judgment matrix.

First, we construct the judgment matrix of the first-level factors on the target layer X (i.e., Job choice for high school student), calculate the weight vector, and check the consistency.

For U_i and $U_j (j \neq i)$ factors in the first-level factor set $U = \{U_1, U_2, U_3\}$. Assuming

that a high school student scores factor U_i and U_j for the target layer X is $f_i^{(1)}$ and $f_j^{(1)}$, the comparison of the importance of the factor U_i and U_j relative to the target layer X is:

$$a_{ij}^{(1)} = \begin{cases} 1, & f_i^{(1)} = f_j^{(1)} \\ f_i^{(1)} - f_j^{(1)}, & f_i^{(1)} > f_j^{(1)} \\ 1/(f_i^{(1)} - f_j^{(1)}), & f_i^{(1)} < f_j^{(1)} \end{cases} \quad (11)$$

After determining judgment matrix $A^{(1)}$ of the first-level factor set, the eigenvector corresponding to the maximum eigenvalue of $A^{(1)}$ is calculated and the consistency test is performed. Furthermore, the weight $W^{(1)}$ of the first-level factor set is obtained.

Secondly, we construct the judgment matrix of the second level about the first level, calculate the weight vector, and check the consistency.

We can take the second-level first-group personal factor set as an example. For the factor u_{1i} and u_{1j} ($j \neq i, 1 \leq i, j \leq 4$) in personal factor set, it is supposed that a high school student scores u_{1i} and u_{1j} as $f_{1i}^{(2)}$ and $f_{1j}^{(2)}$, then the comparison of the importance between u_i and u_j is:

$$a_{ij}^{(2)} = \begin{cases} 1, & f_{1i}^{(2)} = f_{1j}^{(2)} \\ f_{1i}^{(2)} - f_{1j}^{(2)}, & f_{1i}^{(2)} > f_{1j}^{(2)} \\ 1/(f_{1i}^{(2)} - f_{1j}^{(2)}), & f_{1i}^{(2)} < f_{1j}^{(2)} \end{cases} \quad (12)$$

The judgment matrices of the second-group factors U_2 and the third-group factors U_3 are the same as the process of constructing the judgment matrix of the first group factor in second level.

According to $A_1^{(2)}$, $A_2^{(2)}$ and $A_3^{(3)}$, we can obtain the second-level personal factor set weight $W_1^{(2)}$, the weight of the unit factor set $W_2^{(2)}$ and the weight of the social factor set $W_3^{(2)}$.

Step4: Constructing a fuzzy matrix. When constructing a fuzzy matrix, it is necessary to determine the degree of membership of a single factor to each judgment object v_i in the judgment set. The simplest method is to use statistical methods. However, this method integrates the evaluation opinions of most people to find the degree of membership, and cannot achieve personalized evaluation. To this end, **we use membership functions to solve the degree of membership to achieve personalized evaluation**. This paper uses trapezoidal fuzzy number as the membership function [3], and the function formula is as follows:

$$\phi_3(\chi) = \begin{cases} 1, & 0 \leq \chi \leq \alpha_1 \\ \frac{\beta_1 - \chi}{\beta_1 - \alpha_1}, & \alpha_1 < \chi < \beta_1 \\ 0, & \chi \geq \beta_1 \end{cases}, \quad \phi_2(\chi) = \begin{cases} 0, & \chi \leq \alpha_1 \\ \frac{\chi - \alpha_1}{\beta_1 - \alpha_1}, & \alpha_1 < \chi < \beta_1 \\ 1, & \beta_1 \leq \chi \leq \alpha_2 \\ \frac{\beta_2 - \chi}{\beta_2 - \alpha_2}, & \alpha_2 < \chi < \beta_2 \\ 0, & \chi \geq \beta_2 \end{cases}, \quad \phi_1(\chi) = \begin{cases} 0, & \chi \leq \alpha_2 \\ \frac{\beta_2 - \chi}{\beta_2 - \alpha_2}, & \alpha_2 < \chi < \beta_2 \\ 1, & \chi \geq \beta_2 \end{cases} \quad (13)$$

where α_1 , α_2 , β_1 , β_2 are the membership function parameters.

Figure 4 shows a schematic diagram of the trapezoidal membership function.

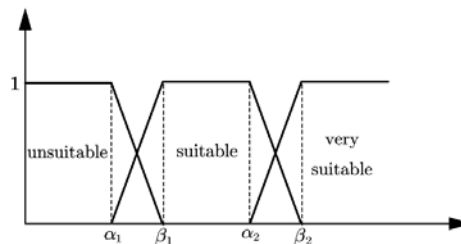


Figure 4 trapezoidal membership function

$\phi_1(\chi)$, $\phi_2(\chi)$ and $\phi_3(\chi)$ the membership degrees of a single factor to v_1 , v_2 and v_3 . χ is the value of the considered factor. In this paper, we suppose that we know the personal information and career expectations of high school students. At the same time, we also know the information of the job and the expectations of job applicants. Therefore, we can calculate the **matching degree of each factor based on the actual value and expected value of each factor**. We take the matching degree between the actual value and the expected value of each factor as the value of the factor.

First, we construct the fuzzy matrix of the second-level factors to realize single-factor fuzzy evaluation. We use $h(u)$ to indicate the matching degree of factor u .

- 1) Work way: $h(\varphi_{way}) = \varphi_{way} \cdot \varphi_{exp_way}$, where φ_{way} and φ_{exp_way} are the affiliation of a certain job's work way and the preference of work way of a certain high school. $\varphi_{exp_way} = [\kappa_1, \kappa_2]$ and $\kappa_1 + \kappa_2 = 1$, where κ_i indicates how much students like the work way F_i . κ_i equals to 1 means that the student likes the work way F_i very much. κ_i equals to 0 means that the student does not like the work way F_i very much.
- 2) Job type: $h(\varphi_{type}) = \varphi_{type} \cdot \varphi_{exp_type}$, where φ_{type} and φ_{exp_type} are the affiliation of the job type of a certain job and the preference of job type of a certain high school. $\varphi_{exp_type} = [\mu_1, \mu_2, \dots, \mu_M]$ and $\mu_1 + \mu_2 + \dots + \mu_M = 1$, where μ_i indicates how much students like the job type c_i . μ_i equals to 1 means that the student likes the job type c_i very much. μ_i equals to 0 means that the student does not like the job type c_i very much.
- 3) Work place: $h(J_{dis}) = (J_{exp_dis} - J_{dis}) / J_{exp_dis}$, where, J_{dis} is the distance between the work place and the student residence, and J_{exp_dis} is the most tolerable working distance for high school students.
- 4) Hourly rate: Since hourly salary is a variable factor, it obeys a certain distribution (this paper assumes that it obeys a normal distribution), so we use the expected value of hourly rate for evaluation. The working hours and hourly rate of each job are different, but we hope that the weekly rate is as high as possible. We often have an expectation of the weekly rate of work, so we consider the matching degree of the weekly salary. We define rate match of $h(J_{rate})$ as $h(J_{rate}) = (J_{time} * \overline{J_{rate}} - J_{exp_rate}) / J_{exp_rate}$, where J_{exp_rate} is the weekly rate that a high school student desires.
- 5) Number of hours: $h(J_{time}) = (J_{time} - J_{exp_time}) / J_{exp_time}$, where, J_{time} is the actual weekly hours of a job, and J_{exp_time} is the expected working hours of high school students.

Since the four factors in the personal factors are all qualitative, we will quantify them first. We use the numbers 10, 8, 6, 4 to represent the ability level as excellent (L_1), good (L_2), fair (L_3), and poor (L_4), and let $G(L_1) = 10$, $G(L_2) = 8$, $G(L_3) = 6$ and $G(L_4) = 4$.

- 6) Academical level: $h(l_{aca}) = (G(l_{aca}) - G(l_{exp_aca})) / G(l_{exp_aca})$, where l_{aca} is the academical level of a student, and l_{exp_aca} is the expected academic level from a job department.
- 7) Computer skill: $h(l_{com}) = (G(l_{com}) - G(l_{exp_com})) / G(l_{exp_com})$, where l_{com} is the computer skill of a student, and l_{exp_com} is the expected level of a job applicant's computer skill from a job department.
- 8) Physical quality: $h(l_{phy}) = (G(l_{phy}) - G(l_{exp_phy})) / G(l_{exp_phy})$, where l_{phy} is the physical quality of a student, l_{exp_phy} is the expected level of a job applicant's physical

quality from a job department.

- 9) Organizational skills: $h(l_{org}) = (G(l_{org}) - G(l_{exp_org})) / G(l_{exp_org})$, where l_{org} is the organizational skill of a student, and l_{exp_org} is the expected level of a job applicant's organizational skill from a job department.
- 10) Family influence: $h(I_{family}) = I_{family} \cdot \varphi_{type}$, where I_{family} and φ_{type} are the preference of a high school student's parents for the job type and the actual job type membership of a job.
- 11) Social honor: Social honor is qualitative, so we first quantify it. We use the numbers 10, 8, 6, and 4 to indicate that the social evaluation level of a company is excellent (E_1), good (E_2), fair (E_3), and bad (E_4). $h(I_{society}) = (x(I_{society}) - x(I_{exp_soc})) / x(I_{exp_soc})$, where $I_{society}$ is the evaluation grade of a company by society, I_{exp_soc} is the evaluation grade of the company expected by high school students, and $x(E_1) = 10, x(E_2) = 8, x(E_3) = 6, x(E_4) = 4$.

After determining the evaluation value of each factor, through consulting experts [4], the trapezoidal membership function parameters of $\alpha_1, \alpha_2, \beta_1$ and β_2 are obtained. The fuzzy matrix R_1 of second-level personal factor set, fuzzy matrix R_2 of the company factor-level and fuzzy matrix R_3 of the social factor are as follows.

$$R_1 = \begin{bmatrix} \phi_1(h(l_{aca})) & \phi_2(h(l_{aca})) & \phi_3(h(l_{aca})) \\ \phi_1(h(l_{com})) & \phi_2(h(l_{com})) & \phi_3(h(l_{com})) \\ \phi_1(h(l_{phy})) & \phi_2(h(l_{phy})) & \phi_3(h(l_{phy})) \\ \phi_1(h(l_{org})) & \phi_2(h(l_{org})) & \phi_3(h(l_{org})) \end{bmatrix} \quad (14)$$

$$R_2 = \begin{bmatrix} \phi_1(h(\varphi_{way})) & \phi_2(h(\varphi_{way})) & \phi_3(h(\varphi_{way})) \\ \phi_1(h(\varphi_{type})) & \phi_2(h(\varphi_{type})) & \phi_3(h(\varphi_{type})) \\ \phi_1(h(J_{dis})) & \phi_2(h(J_{dis})) & \phi_3(h(J_{dis})) \\ \phi_1(h(J_{salary})) & \phi_2(h(J_{salary})) & \phi_3(h(J_{salary})) \\ \phi_1(h(J_{time})) & \phi_2(h(J_{time})) & \phi_3(h(J_{time})) \end{bmatrix} \quad (15)$$

$$R_3 = \begin{bmatrix} \phi_1(I(J_{family})) & \phi_2(I(J_{family})) & \phi_3(I(J_{family})) \\ \phi_1(I(J_{society})) & \phi_2(I(J_{society})) & \phi_3(I(J_{society})) \end{bmatrix} \quad (16)$$

According to $B_i = W_i^{(2)} \cdot R_i$, we calculate single factor evaluation of B_1, B_2 and B_3 .

Then, we conduct multi-factor comprehensive evaluation.

Based on single factor evaluation of B_1, B_2 and B_3 , we obtain the first level of fuzzy matrix $R = [B_1, B_2, B_3]$. We calculate comprehensive evaluation by the formula of $B = W^{(1)} \cdot R$ based on $W^{(1)}$ calculated in step3.

Step5: Determine the job level. According to the final fuzzy comprehensive evaluation B and the principle of maximum membership degree, the final evaluation J_{eval} of the job is.

$$J_{eval} = v_{\zeta}, \quad \zeta = \arg \max_i b_i, i = 1, 2, 3 \quad (17)$$

5.1.2 Secondary screening based on AHP

Through preliminary screening, all jobs are divided into three levels: very suitable, suitable and unstable. In this section, we hope to select the best job from the jobs belong to very suitable evaluation level. We use the AHP to judge these jobs that belongs to very suitable evaluation level.

(1) Build a hierarchical model

According to the influence factor system of job selection shown in Figure 1, we have established a hierarchical structure model, as shown in the Figure 5.

(2) Calculate the weight of the next layer with respect to the previous layer

In section 5.1.1, we have calculated the weight $w^{(1)}$ of the criterion layer U on the target layer X and the weight $w_1^{(2)}, w_2^{(2)}$ and $w_3^{(2)}$ of the sub-criteria layer u on

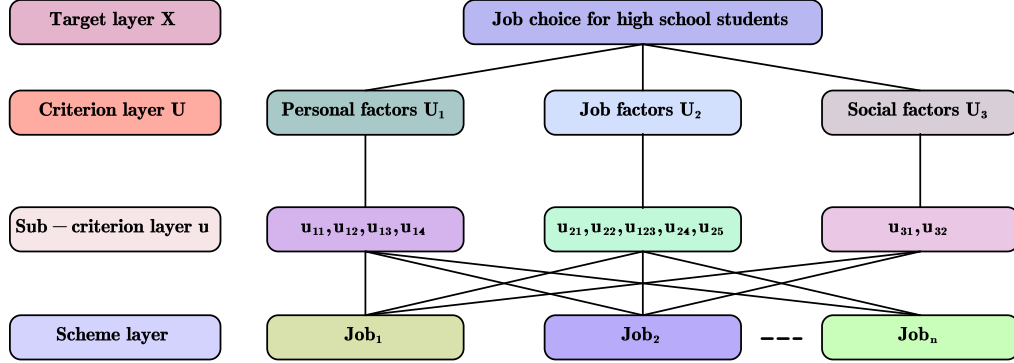


Figure 5 hierarchical structure model of job choices

the criterion layer U . Therefore, we only need to calculate the weight of the scheme layer D to the sub-criteria layer u . Assume that the scheme layer contains K candidate jobs, that is, these K jobs belong to a very suitable evaluation level. We use $D_1, D_2, \dots, D_K$ to represent these K jobs, that is, $D = \{D_1, D_2, \dots, D_K\}$.

First, we need to calculate the judgment matrix of the K jobs in the scheme layer with respect to 11 factors in the sub-criteria layer, that is, for a certain factor in the sub-criteria layer, the superiority of any two jobs in the scheme layer is needed to be determined. Regarding the determination of superiority, a simple method is to let high school students score any two jobs on a factor. When there are many factors or alternative jobs, it is difficult for high school students to quantitatively evaluate the superiority of any two jobs for a factor, and the operation process is cumbersome. In section 5.1.2, for each job, we have obtained the membership degree of each factor u_{ij} in the sub-criteria level to the evaluation set $V = \{\text{very suitable } (v_1), \text{ suitable } (v_2), \text{ inappropriate } (v_3)\}$. That is, the importance of each factor u_{ij} to the target layer X . Therefore, we can use the fuzzy matrices R_1, R_2 and R_3 of the sub-criteria level to determine the superiority of any two tasks for a certain factor in the sub-criteria level. According to the principle of maximum membership degree, the membership level $z_{ij}^k \in \{v_1, v_2, v_3\}$ of each factor u_{ij} under the job D_k is determined. In order to distinguish the fuzzy matrices R_1, R_2 and R_3 of the judgment set in the sub-criteria layer under each job, we use R_1^k, R_2^k, R_3^k to denote the fuzzy matrix of the sub-criteria layer under the working D_k , as follows.

$$R_i^k = \begin{bmatrix} r_{i11}^k & r_{i12}^k & r_{i13}^k \\ r_{i21}^k & r_{i22}^k & r_{i23}^k \\ \vdots & \vdots & \vdots \\ r_{ij1}^k & r_{ij2}^k & r_{ij3}^k \end{bmatrix} \quad (18)$$

$$z_{ij}^k = v_\rho, \text{ where } \rho = \arg \max_e r_{ije}^k, (e = 1, 2, 3).$$

In order to quantify the superiority of each job on a certain factor of the sub-criteria level, we use the numbers 10, 6, and 4 to represent the importance values of v_1, v_2 , and v_3 in the judgment set. Let $y(v_1) = 10, y(v_2) = 6, y(v_3) = 4$. Then under the working D_k , we can obtain the importance value I_{ij}^k of each factor u_{ij} : $I_{ij}^k = y(z_{ij}^k)$. Based on I_{ij}^p and I_{ij}^q , we can obtain the comparison c_{ij}^{pq} of the importance of any two jobs D_p and D_q with respect to the sub-criteria level factor u_{ij}

$$c_{ij}^{pq} = \begin{cases} 1, & I_{ij}^p = I_{ij}^q \\ I_{ij}^p - I_{ij}^q, & I_{ij}^p > I_{ij}^q \\ 1/(I_{ij}^q - I_{ij}^p), & I_{ij}^p < I_{ij}^q \end{cases} \quad (19)$$

Based on c_{ij}^{pq} , we can obtain the judgment matrix of scheme layer D to the sub-criteria layer u . Then based on the judgment matrix of the scheme level obtained above, we can obtain the weight of the scheme level D to the sub-criteria level u : $W_{11}^{(3)}$, $W_{12}^{(3)}$, $W_{13}^{(3)}$, $W_{14}^{(3)}$, $W_{21}^{(3)}$, $W_{22}^{(3)}$, $W_{23}^{(3)}$, $W_{24}^{(3)}$, $W_{25}^{(3)}$, $W_{31}^{(3)}$, $W_{32}^{(3)}$. Each $W_{ij}^{(3)}$ is a vector of size K , i.e., $W_{ij}^{(3)} = [w_{ij1}^{(3)}, w_{ij2}^{(3)}, \dots, w_{ijk}^{(3)}]$. For example, $W_{11}^{(3)}$ represents the weight of K jobs with respect to the factor u_{11} of the sub-criteria layer. $w_{112}^{(3)}$ represents the weight of work D_2 on the sub-criteria layer u_{11} .

(3) Calculate the weight of the scheme layer with respect to the target layer

So far, we get the weight $W^{(1)}$ of the criterion layer U with respect to the target layer X and the weight $W_1^{(2)}$, $W_2^{(2)}$ and $W_3^{(2)}$ of the sub-criteria layer u with respect to the criterion layer U . The weight of the scheme layer D with respect to the sub-criteria layer u : $W_{11}^{(3)}$, $W_{12}^{(3)}$, $W_{13}^{(3)}$, $W_{14}^{(3)}$, $W_{21}^{(3)}$, $W_{22}^{(3)}$, $W_{23}^{(3)}$, $W_{24}^{(3)}$, $W_{25}^{(3)}$, $W_{31}^{(3)}$, $W_{32}^{(3)}$. Now, we hope to obtain the importance weight of the scheme layer D with respect to the target layer X . First, we regard these weights of scheme layer D regarding sub-criteria layer u as row vectors and divide into three matrices according to personal factors, company factors and social factors, as follows.

$$\omega_1^{(3)} = \begin{bmatrix} W_{11}^{(3)} \\ W_{12}^{(3)} \\ W_{13}^{(3)} \\ W_{14}^{(3)} \end{bmatrix}, \quad \omega_2^{(3)} = \begin{bmatrix} W_{21}^{(3)} \\ W_{22}^{(3)} \\ W_{23}^{(3)} \\ W_{24}^{(3)} \\ W_{25}^{(3)} \end{bmatrix}, \quad \omega_3^{(3)} = \begin{bmatrix} W_{31}^{(3)} \\ W_{32}^{(3)} \end{bmatrix} \quad (20)$$

Then the weight $\omega^{(1)}$ of solution layer D with respect to target layer X is

$$\omega^{(1)} = W^{(1)} \begin{bmatrix} W_1^{(2)} \cdot \omega_1^{(3)} \\ W_2^{(2)} \cdot \omega_2^{(3)} \\ W_3^{(2)} \cdot \omega_3^{(3)} \end{bmatrix} \quad (21)$$

Where $W_1^{(2)} \cdot \omega_1^{(3)}$, $W_2^{(2)} \cdot \omega_2^{(3)}$, $W_3^{(2)} \cdot \omega_3^{(3)}$ are three row vectors. The dot product " $\cdot$ " is the multiplication of vector and matrix.

Choosing the best job

In the previous section, we have obtained the weight of the scheme layer D with respect to the target layer X , then we will regard the job D_{best} with the largest weight as the best job for a high school student. $D_{best} = D_\tau$, where $\tau = \arg \max_k \omega_k^{(1)}$.

5.2 Listwise Ranking Model based on Neural Network

The problem discussed in this paper is also regarded as **personalized recommendation** problems. In the field of personalized recommendation, the ranking algorithms are very effective implementation method. To this end, based on the data collected by the offline fuzzy analysis model, we develop a listwise ranking algorithm based on neural network online to achieve personalized recommendation.

Job ranking based on ListNet

Among a variety of ranking models, the Listwise method is the more effective,

especially the neural network-based ranking learning algorithm. Listwise has become an important research method in the field of information retrieval with its excellent performance. ListNet is an effective Listwise ranking algorithm based on neural network [5]. ListNet uses a probability model to construct the loss function, and this method has stable performance. For a group of ranking objects, we can apply the Luce model [6] to obtain the probability values of all the permutations according to the ranking function of the object, thereby obtaining the permutation probability distribution of each ranking function. This idea is the basis for the realization of the ListNet method. ListNet is mainly used in the field of information retrieval to achieve relevance ranking of documents. Drawing lessons from the document ranking process, we apply ListNet to the best job choice discussed in this paper. The loss function of the ListNet method can be expressed as

$$L(y^q, z^q) = -\sum_{q \in Q} \sum_{\pi \in \Omega} \left(\prod_{t=1}^n \frac{\Phi(y_{\pi(t)})}{\sum_{u=t}^n \Phi(y_{\pi(u)})} \right) = \log \left(\prod_{t=1}^n \frac{\Phi(z_{\pi(t)})}{\sum_{u=t}^n \Phi(z_{\pi(u)})} \right) \quad (22)$$

Where, Q is all searches in the training set, Ω is all the arrangement modes of the work list corresponding to the search, y is the correlation judgment condition, z is the ranking function, and π_i is the element at position i in the sequence. ListNet uses a gradient descent neural network algorithm, and the relative gradient of the loss function is

$$\Delta \omega = -\sum_{j=1}^{n(i)} P_{y(i)}(x_j^{(i)}) \frac{\partial f_w(x_j^{(i)})}{\partial \omega} + \frac{1}{\sum_{j=1}^{n(i)} \exp(f_w(x_j^{(i)}))} = \sum_{j=1}^{n(i)} \exp(f_w(x_j^{(i)})) \frac{\partial f_w(x_j^{(i)})}{\partial \omega} \quad (23)$$

where $n(i)$ represents the total number of jobs corresponding to the search number $qid=i$. In this paper, we regard the process of a high school student to find the best job from all jobs as a search. $x_j^{(i)}$ is the matching vector of high school student i and job j .

$$x_j^{(i)} = [h(l_{aca}), h(l_{com}), h(l_{phy}), h(l_{org}), h(\varphi_{way}), h(\varphi_{type}), h(J_{dis}), h(J_{rate}), h(J_{time}), h(J_{family}), h(J_{society})]$$

$h(l_{aca}), h(l_{com}), \dots, h(J_{society})$ described in 5.1.1, indicate the degree of matching of personal information and preferences of high school students with the job requirements and job characteristics.

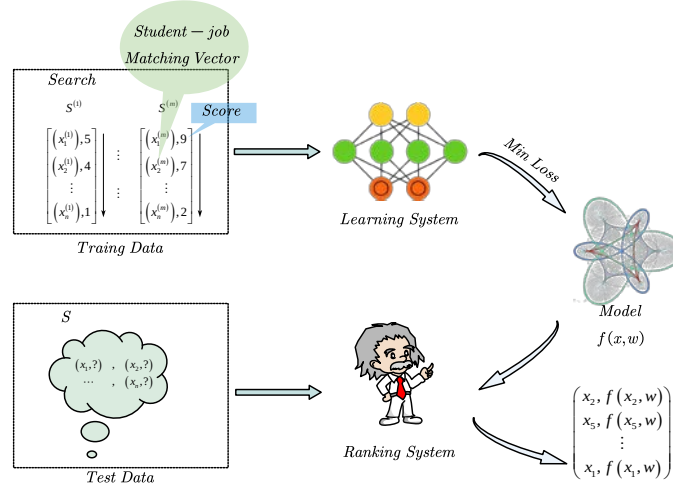


Figure 6 Workflow of ListNET ranking model

The Figure 6 shows the online ranking learning process based on ListNet. ListNet

is trained based on historical data collected by offline fuzzy analysis model. When ListNet's test accuracy of new samples reaches more than 95% in a period of time, we think ListNet has been trained. We will replace the offline fuzzy analysis model with the trained ListNet to achieve the best job recommendation for high school students.

6. Model test and result analysis

Problem 3 requires us to test our model by creating at least ten fictional persons. At the same time, we need to explain the reasons for constructing these persons and the choice of data related to these persons, and analyze the final test results. We test the performance of our model from robustness and accuracy. For the robustness, we make a **sensitive analysis** on our model based on single factor and multi-factor sensitivity analysis method. In single factor analysis, we change the value of a factor while the values of other factors remain basically unchanged. Meanwhile, we change the values of two factors while the values of other factors remain basically unchanged. This design comes from our analysis of different students: 1) some students are very prominent in a certain skill, in that case they prefer the most relevant job with these skills. 2) although some students do not have outstanding skills, they have strict requirements on certain characteristics of the job. For example, some students want to make as much money as possible, so the number of hours and other factors are not important for him. 3) except the above students, there are also some students who have ordinary abilities and do not have too strict requirements for jobs.

6.1 Fictional person creation

Based on the above analysis of high school students, we design fictional students from two aspects. On the one hand, some students have outstanding skills or strict preference for job characteristics. On the other hand, some students have ordinary abilities and do not have too strict requirements for the characteristics of the job. We call these students ordinary students. Twelve fictional persons are shown in Table 2.

Table 2 The situations and preferences of fictional person

		Personal skill				Work characteristic preference					I_{family}
		l_{aca}	l_{com}	l_{phy}	l_{org}	J_{exp_time}	J_{exp_rate}	φ_{exp_way}	φ_{exp_type}	J_{exp_dis}	
Special skill	s1	L₁	L ₃	L ₃	L ₃	20	300	[0.5,0.5]	[0,1,0,0,0]	5	[0,1,0,0,0]
	s2	L ₃	L₁	L ₃	L ₃	20	300	[0.5,0.5]	[1,0,0,0,0]	5	[1,0,0,0,0]
	s3	L ₃	L ₃	L₁	L ₃	20	300	[0.5,0.5]	[0,0,1,0,0]	10	[0,0,1,0,0]
	s4	L ₃	L ₃	L ₃	L₁	20	300	[0.5,0.5]	[0,0,0,1,0]	5	[0,0,0,1,0]
Work characteristic preference	s5	L ₃	L ₃	L ₃	L ₃	10	200	[0.5,0.5]	[0.2,0.1,0.2,0.2,0.3]	3	[0.2,0.2,0.1,0.2,0.3]
	s6	L ₃	L ₃	L ₃	L ₃	25	400	[0.5,0.5]	[0.2,0.1,0.3,0.1,0.3]	5	[0.2,0.1,0.4,0.1,0.2]
	s7	L ₃	L ₃	L ₃	L ₃	20	200	[1,0]	[0.3,0.1,0.2,0.1,0.3]	0	[0.2,0.2,0.3,0.1,0.2]
	s8	L ₃	L ₃	L ₃	L ₃	25	200	[0.5,0.5]	[0.1,0.1,0.2,0.3,0.3]	1	[0.2,0.1,0.1,0.2,0.4]
From the questionnaire	s9	L ₃	L ₃	L ₃	L ₃	20	300	[0.5,0.5]	[0.1,0.1,0.2,0.2,0.4]	6	[0.2,0.1,0.1,0.2,0.4]
	s10	L ₃	L ₂	L ₃	L ₃	25	250	[0.4,0.6]	[0.4,0.2,0.2,0.1,0.1]	5	[0.3,0.3,0.2,0.1,0.1]
	s11	L ₂	L ₃	L ₂	L ₂	18	300	[0.3,0.7]	[0.1,0.1,0.5,0.2,0.1]	5	[0.2,0.4,0.2,0.1,0.1]
	s12	L ₃	L ₃	L ₂	L ₃	20	300	[0.1,0.9]	[0.1,0.1,0.4,0.2,0.2]	10	[0.2,0.1,0.4,0.1,0.2]

In Table 2, l_{aca} , l_{com} , l_{phy} and l_{org} are the academical level, computer skill, organizational skill evaluated by four level of L₁(excellent), L₂(good), L₃(fair), L₄(bad). The 7~12 columns in the table respectively refer to ideal working hour and weekly rate of the student, student' preference for work way and type of work, maximum tolerable commute distance, and the influence from their family. From this table, we can know that students s1, s2, s3 and s4 are the type of students with outstanding skills. Intuitively,

s1 has outstanding academic level, then he might be more inclined to find academic research jobs. s2 has outstanding computer skill, so he should be more inclined to find computer technology jobs. s3 has high physical fitness, in that case he could be more likely to find outdoor sports jobs. s4 has outstanding organizational skills, so he should be more inclined to find office management jobs. Student s5, s6, s7 and s8 belong to the type of students who have strict requirements for certain characteristics of the job. Intuitively, s5 should prefer choose the job with the smallest working time while s6 might choose the job with the most salary. s7 will choose online jobs. s8 will choose the job with the smallest distance from his place of residence. Student s9, s10, s11, s12 are the students who do not have outstanding abilities and strict job requirements.

6.2 Fictional job creation

In order to test the job selection of twelve fictional students, we also need to create multiple jobs. When creating jobs, we not only consider the outstanding skills and strict job requirements of the above eight fictitious, but also refer to the 15 best summer jobs for teenagers provided by the investopedia¹ website. This makes the jobs we created more reasonable. We divide the jobs created into 5 types: computer guru, academic research, outdoor activities and office administration. The Table 3 shows the fifteen fictional jobs we created.

Table 3 Fifteen fictional jobs

Jobs	Personal skill requirements				Work characteristic					$I_{society}$
	I_{exp_aca}	I_{exp_com}	I_{exp_phy}	I_{exp_org}	J_{time}	J_{rate}	φ_{way}	φ_{type}	J_{dis}	
Job1	L ₃	L ₁	L ₁	L ₃	20	20~25	[0,1]	[1,0,0,0,0]	2	E ₂
Job2	L ₃	L ₁	L ₁	L ₃	15	20~30	[0,1]	[1,0,0,0,0]	5	E ₂
Job3	L ₁	L ₃	L ₃	L ₃	10	15~20	[0,1]	[0,1,0,0,0]	1	E ₂
Job4	L ₁	L ₂	L ₃	L ₃	20	8~10	[0,1]	[0,1,0,0,0]	2	E ₂
Job5	L ₁	L ₂	L ₃	L ₃	15	15~18	[0,1]	[0,1,0,0,0]	6	E ₂
Job6	L ₃	L ₃	L ₁	L ₃	20	18~28	[0,1]	[0,0,1,0,0]	10	E ₂
Job7	L ₃	L ₃	L ₁	L ₃	25	9~10	[0,1]	[0,0,1,0,0]	2	E ₃
Job8	L ₃	L ₃	L ₁	L ₃	20	16~25	[0,1]	[0,0,1,0,0]	7	E ₂
Job9	L ₃	L ₃	L ₃	L ₁	25	18~22	[0,1]	[0,0,0,1,0]	3	E ₂
Job10	L ₃	L ₃	L ₃	L ₁	20	20~25	[0,1]	[0,0,0,1,0]	6	E ₂
Job11	L ₃	L ₃	L ₃	L ₃	25	8~10	[1,0]	[0,0,0,0,1]	0	E ₂
Job12	L ₃	L ₃	L ₃	L ₃	20	10~18	[0,1]	[0,0,0,0,1]	1	E ₃
Job13	L ₃	L ₃	L ₃	L ₃	10	10~12	[0,1]	[0,0,0,0,1]	2	E ₂
Job14	L ₃	L ₃	L ₃	L ₃	22	10~15	[0,1]	[0,0,0,0,1]	3	E ₃
Job15	L ₃	L ₃	L ₃	L ₃	30	10~15	[0,1]	[0,0,0,0,1]	2	E ₂

The 2~5 columns in the table respectively refer to the requirement of academical level, computer skill, physical quality and organizational skill of the student. The 6~11 columns in the table respectively refer to the working hour, hourly rate, work way, type of job, location of the job and social honor of the job. From Table 3, we can see that Job 1, Job 2, Job 3, Job 4, Job 5, Job 6, Job 7 and Job 8 have outstanding requirements for a certain skill. Job 9, Job 10, Job 11 and Job 12 have no particular skills requirements.

6.3 Model test based on sensitive analysis

We make multi-factor sensitivity analysis with any two persons of student s1, s2, s3 and s4. For example, we choose student s1 and s2. Their academical level and computer skills are different between them, but other skills are the same. Therefore, we can test the accuracy of our model under the changing of the academical level and computer skills. Meanwhile, we make single factor sensitivity analysis with student s9 and s12. student s9 and s12 have different preferences of job type while students s1 and s2 have the same preference for other factors. Therefore, we can test the accuracy of our model under the changing of the job type factor.

6.3.1 Testing fuzzy analysis model

We take student s1 as an example to describe in detail the process of selecting the

best job for student s1 using our fuzzy analysis model. First, let us recall influencing factors of job selection as shown in figure 5 and judge set $V=\{\text{very suitable (v1)}, \text{suitable (v2)}, \text{unsuitable (v3)}\}$.

(1) Primary screening

According to the fuzzy comprehensive evaluation model, the fifteen jobs in the table 3 are divided into the three grades {very suitable, suitable, not suitable}. First, we calculate the weight of each factor in Figure 2. According to student s1's score on the importance of the factors in the criterion layer, judgment matrix $A^{(1)}$ is calculated as

$$A^{(1)} = \begin{bmatrix} 1 & 1/7 & 1/5 \\ 7 & 1 & 2 \\ 5 & 1/2 & 1 \end{bmatrix} \quad (24)$$

We check the consistency of $A^{(1)}$, $CI = 0.0122 < 0.1$. It can be said that this judgment matrix $A^{(1)}$ passes the consistency test, then the weight of personal factors, job factors and social factors are 0.0783, 0.7167 and 0.2051, i.e., $W^{(1)} = [0.0783, 0.7167, 0.2051]$.

At the same time, according to student s1's score on the importance of any two factors in the sub-criteria layer with respect to criteria layer of personal factor, we get the judgment matrix $A_1^{(2)}$ of the factors in sub-criteria layer with respect to personal factor U_1 .

$$A_1^{(2)} = \begin{bmatrix} 1 & 7 & 7 & 9 \\ 1/7 & 1 & 2 & 2 \\ 1/7 & 1/2 & 1 & 2 \\ 1/9 & 1/2 & 1/2 & 1 \end{bmatrix} \quad (25)$$

We check the consistency of $A_1^{(2)}$, $CI = 3.2895e-16 < 0.1$. It can be said that this judgment matrix $A_1^{(2)}$ passes the consistency test, then the weight of academic level, computer skill, physical quality and organizational skill in personal factors are 0.0833, 0.7500, 0.0833, 0.0833, i.e., $W_1^{(2)} = [0.0833, 0.7500, 0.0833, 0.0833]$

Similar to the method for calculating the weights of the factors in the personal factor above, we get judgment matrix $A_2^{(2)}$ of the job factors in sub-criteria layer with respect to job factor U_2 .

$$A_2^{(2)} = \begin{bmatrix} 1 & 1/9 & 1/2 & 1/2 & 1 \\ 9 & 1 & 7 & 7 & 9 \\ 2 & 1/7 & 1 & 1 & 2 \\ 2 & 1/7 & 1 & 1 & 2 \\ 1 & 1/9 & 1/2 & 1/2 & 1 \end{bmatrix} \quad (26)$$

We check the consistency of $A_2^{(2)}$, $CI = 0.007 < 0.1$, which indicates that $A_2^{(2)}$ passes the consistency test. The weights of work way, job type, work place, hourly rate and number of hours are 0.0607, 0.6566, 0.1110, 0.1110, 0.0607, i.e., $W_2^{(2)} = [0.0607, 0.6566, 0.1110, 0.1110, 0.0607]$.

Similarly, according to student s1's score on the importance of the two factors in the social factors, the weight of family influence and society honor are 0.75, 0.25, i.e., $W_3^{(2)} = [0.75, 0.25]$.

Then, we calculate the fuzzy matrix. According to student s1's work characteristic preference and the characteristics of each job in the table 3, the matching degree of each

factor in job factors is calculated. Take Job 1 as an example, according to Job 1's job characteristics (actual value) and student s1's preference for job characteristics (ideal value), we get the match degree between the actual values and the ideal values of each job factors.

$$\text{Work way: } h(\varphi_{\text{way}}) = \varphi_{\text{way}} \cdot \varphi_{\text{exp_way}} = [1, 0] \cdot [0.5, 0.5] = 0.5$$

$$\text{Type of job: } h(\varphi_{\text{type}}) = \varphi_{\text{type}} \cdot \varphi_{\text{exp_type}} = [1, 0, 0, 0] \cdot [0, 1, 0, 0] = 0$$

$$\text{Work place: } h(J_{\text{dis}}) = (J_{\text{exp_dis}} - J_{\text{dis}}) / J_{\text{exp_dis}} = (5 - 2) / 5 = 0.6$$

$$\text{Number of hours: } h(J_{\text{time}}) = (J_{\text{time}} - J_{\text{exp_time}}) / J_{\text{time}} = (20 - 20) / 20 = 0$$

$$\text{Hourly rate: } h(J_{\text{rate}}) = (J_{\text{time}} * J_{\text{rate}} - J_{\text{exp_rate}}) / J_{\text{exp_rate}} = (20 * 22.5 - 300) / 300 = 0.5$$

According to student s1's personal information and the job's requirements for personal skills in the table 2, the matching degree of each factor in personal factors is calculated.

$$\text{Academic level: } h(l_{\text{aca}}) = (G(l_{\text{aca}}) - G(l_{\text{exp_aca}})) / G(l_{\text{exp_aca}}) = (10 - 6) / 6 = 0.67$$

$$\text{Computer skill: } h(l_{\text{com}}) = (G(l_{\text{com}}) - G(l_{\text{exp_com}})) / G(l_{\text{exp_com}}) = (6 - 10) / 10 = -0.4$$

$$\text{Physical quality: } h(l_{\text{phy}}) = (G(l_{\text{phy}}) - G(l_{\text{exp_phy}})) / G(l_{\text{exp_phy}}) = (6 - 6) / 6 = 0$$

$$\text{Organizational skill: } h(l_{\text{org}}) = (G(l_{\text{org}}) - G(l_{\text{exp_org}})) / G(l_{\text{exp_org}}) = (6 - 6) / 6 = 0$$

Similarly, according to the job type characteristics (actual value) of Job 1 and the prejudice of student s1's parents on the job type (ideal value), the matching degree between the actual value and the ideal value of the family influence is

$$h(I_{\text{family}}) = I_{\text{family}} \cdot \varphi_{\text{type}} = [0, 1, 0, 0, 0] \cdot [1, 0, 0, 0, 0] = 0 \quad (27)$$

According to Job 1's social honor level (actual value) and the company evaluation level (ideal value) expected by student s1, the matching degree between the actual value and the ideal value of society honor is

$$h(I_{\text{society}}) = (x(I_{\text{society}}) - x(I_{\text{exp_soc}})) / x(I_{\text{exp_soc}}) = (8 - 8) / 8 = 0 \quad (28)$$

In this paper, we use the membership function to solve the membership degree of each factor to a certain judgement. We use trapezoidal fuzzy number as the membership function, as shown in the formula (13). The membership function parameters α_1 , α_2 , β_1 , β_2 in these formulas are obtained by consulting experts [4]. Under these factors of work way, type of job and family influence, $\alpha_1=0.1$, $\beta_1=0.3$, $\alpha_2=0.5$, $\beta_2=0.8$, while under other eight factors, $\alpha_1=-0.6$, $\beta_1=-0.4$, $\alpha_2=-0.2$, $\beta_2=0$.

Finally, we get the fuzzy matrix R_1 of personal factor set U_1 , the fuzzy matrix R_2 of job factor set U_2 and the fuzzy matrix R_3 of social factor set U_3 :

$$R_1 = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}, \quad R_2 = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & 0 & 0 \end{bmatrix}, \quad R_3 = \begin{bmatrix} 0 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix} \quad (29)$$

According to $B_i = W_i^{(2)} \cdot R_i$, the fuzzy evaluations of personal factors, job factors and social factors are calculated by

$$\text{Fuzzy evaluation } B_1 \text{ of personal factors: } B_1 = W_1^{(2)} \cdot R_1 = [0.75, 0.25, 0]$$

$$\text{Fuzzy evaluation } B_2 \text{ of job factors: } B_2 = W_2^{(2)} \cdot R_2 = [0.2827, 0.0607, 0.6566]$$

$$\text{Fuzzy evaluation } B_3 \text{ of social factors: } B_3 = W_3^{(2)} \cdot R_3 = [0.25, 0.75]$$

Then, we can construct comprehensive fuzzy judgment matrix $R = [B_1, B_2, B_3]^T$, and

calculate comprehensive fuzzy evaluation $B = W^{(1)} \cdot R = [0.2042, 0.2759, 0.2687]$

From B , we can see that Job 1 has a membership degree of 0.6235 for a very suitable level, 0.4553 for a suitable level, and 0.2223 for an unsuitable level. According to the principle of maximum membership degree, Job 1 is suitable for student 1. In the same way, we can get the evaluation level of Job 2~Job 12. The Table 4 shows the evaluation level of twelve jobs with respect to student s1.

Table 4 evaluation level of twelve jobs with respect to student s1

Evaluation level	Very suitable	Suitable	Unsuitable
Jobs	Job 3, Job 4, Job 5	Job 1, Job 2, Job 6, Job 10, Job 12	Job 7, Job 8, Job 9, Job 11, Job 13, Job 14, Job 15

(2) Secondary screening

According to the secondary screening model of the analytic hierarchy process described in 5.1.2, we select the best job from the Job 3, Job 4, and Job 5 that are most suitable for student s1. Since there are 3 jobs that are most suitable for student 1, the scheme layer $D = \{\text{Job 3, Job 4, Job 5}\}$. In preliminary screening, we obtain the weight $W^{(1)}$ of the criterion layer U with respect to the target layer X and the weight $W_1^{(2)}$, $W_2^{(2)}$ and $W_3^{(2)}$ of the sub-criteria layer u with respect to the criterion layer U . Thus, we only need to calculate the weight of the scheme layer D to the sub-criteria layer u . According to the formula (21), we can obtain the judgment matrix of the scheme layer about the sub-criteria layer and calculate their weights: $W_{11}^{(3)}$, $W_{12}^{(3)}$, $W_{13}^{(3)}$, $W_{14}^{(3)}$, $W_{21}^{(3)}$, $W_{22}^{(3)}$, $W_{23}^{(3)}$, $W_{24}^{(3)}$, $W_{25}^{(3)}$, $W_{31}^{(3)}$, $W_{32}^{(3)}$. We use these weights as row vectors and divide them into three matrices according to personal factors, job factors and social factors:

$$\omega_1^{(3)} = \begin{bmatrix} W_{11}^{(3)} \\ W_{12}^{(3)} \\ W_{13}^{(3)} \\ W_{14}^{(3)} \end{bmatrix}, \quad \omega_2^{(3)} = \begin{bmatrix} W_{21}^{(3)} \\ W_{22}^{(3)} \\ W_{23}^{(3)} \\ W_{24}^{(3)} \\ W_{25}^{(3)} \end{bmatrix}, \quad \omega_3^{(3)} = \begin{bmatrix} W_{31}^{(3)} \\ W_{32}^{(3)} \end{bmatrix} \quad (30)$$

Then the weight $\omega^{(1)}$ of scheme layer D with respect to target layer X is calculated by

$$\omega^{(1)} = W^{(1)} \begin{bmatrix} W_1^{(2)} \cdot \omega_1^{(3)} \\ W_2^{(2)} \cdot \omega_2^{(3)} \\ W_3^{(2)} \cdot \omega_3^{(3)} \end{bmatrix} = [0.45, 0.32, 0.23] \quad (31)$$

The Job 3 has the greatest weight, so the best job of student s1 is Job 3. Table 5 shows the best job choices for twelve fictitious persons by using our fuzzy model.

Table 5 Best job choices for twelve fictional persons based our fuzzy analysis model

Students	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12
Prediction choice	Job 3	Job 1	Job 7	Job 9	Job 13	Job 15	Job 11	Job 12	Job 14	Job 2	Job 5	Job 6
Real choice	Job 3	Job 1	Job 7	Job 9	Job 13	Job 15	Job 11	Job 12	Job 14	Job 2	Job 6	Job 5

As can be seen from the table, for student 1, student 2, student 3 and student 4 with

outstanding skills, the best jobs predicted by our fuzzy analysis model for them are Job 3, Job 1, Job 7 and Job 6. Job 3, Job 1, Job 7 and Job 6 are academic research, computer, outdoor sports and office management jobs respectively, which match the outstanding skills of the four students. In addition, students 5, student 6, student 7 and student 8 have strict requirements on a certain feature of the job. Our fuzzy analysis model can also find jobs with corresponding features for them. This shows that our fuzzy analysis model has good robustness. student 9, student 10, student 11 and student 12 are students with ordinary abilities and not too strict requirements for job characteristics. The best jobs our model chose for them were Job 13, Job 2, Job 12 and Job 4. Compared with the results of the questionnaire, our fuzzy analysis model evaluates student 11 and student 12 incorrectly, because Job 5 and Job 6 have similar work characteristics. In addition, due to the nature of the fuzzy analysis model without prior knowledge, it is difficult to make a correct judgment when the characteristics of the input data are not obvious. This is also why we designed the offline ListNet ranking model.

6.3.2 The robustness and accuracy of ListNet ranking model

In order to verify the robustness and accuracy of our ListNet ranking model, we conduct a questionnaire survey on high school students of our school. We collected 324 questionnaires in total. We randomly selected 280 questionnaires to train ListNet ranking model, and the remaining 44 questionnaires were used to test the trained model. It can be seen from 6.2 that we made up 15 fictitious jobs, so a questionnaire contains a student's score for 15 jobs. Thus, our training set has $280 \times 15 = 3120$ samples, and our test set has $44 \times 15 = 660$ samples. In order to verify the accuracy of the ListNet ranking model, we divide the job scores into 5 levels (≥ 8 : G1, ≥ 6 and < 8 : G2, ≥ 4 and < 6 : G3, ≥ 2 and < 4 : G4, ≤ 2 : G5). Figure 7 shows the confusion matrix of predicted results.

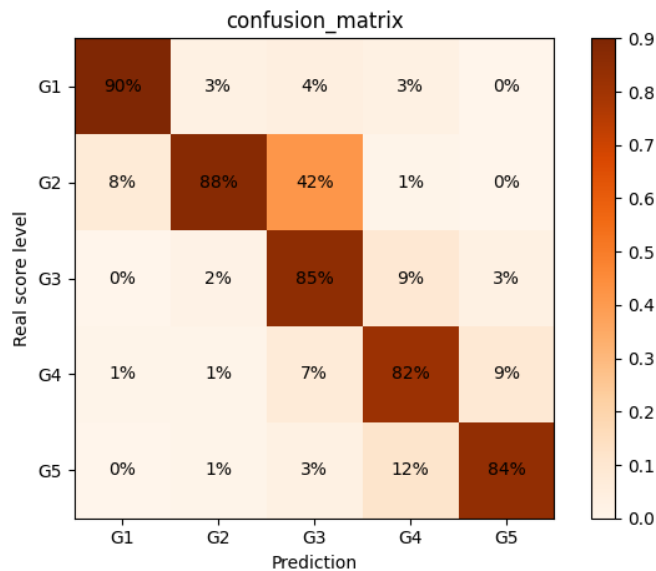


Figure 7 Confusion Matrix Heat Map

From Figure 7, we can see that ListNet ranking model trained based on only 3120 data can achieve an accuracy rate of over 82%, with the highest accuracy rate reaching 90%. This shows that our ListNet ranking model has high learning efficiency and accuracy, so our ListNet ranking model are suitable for the best job recommendation for high school students. In addition, we again use the trained ListNet model to recommend the best jobs for these fictional students in Table 6. The final recommendation result is shown in Table 6.

From Table 6, we can see that our ListNet ranking model **can fully find the best job for all students**. This shows that we train the ListNet ranking model by using the data collected by the offline model, which can make up for the low accuracy of the offline fuzzy analysis model for evaluating these ordinary students. **Therefore, we give a conclusion that once our model is applied to a real scenario, our online ListNet ranking model will quickly converge using the data collected by the offline model.** When the ListNet ranking model is trained, we use the trained ListNet ranking model instead of offline fuzzy analysis model.

Table 6 Best job choices for twelve fictional persons based our ListNet ranking model

Students	s1	s2	s3	s4	s5	s6	s7	s8	s9	s10	s11	s12
Prediction choice	Job 3	Job 1	Job 7	Job 9	Job 13	Job 15	Job 11	Job 12	Job 14	Job 2	Job 6	Job 5
Real choice	Job 3	Job 1	Job 7	Job 9	Job 13	Job 15	Job 11	Job 12	Job 14	Job 2	Job 6	Job 5

In a word, through the combination of offline fuzzy model and online ListNet ranking model, our model can recommend the best job for high school students with high accuracy.

7 User's Manual of the app

7.1 Description of the app

Summer Job Selection System (SJSS) is an effective and practical test platform for high school students in the face of summer job selection. Based on the personal information of high school students and work characteristics, the system constructs fuzzy analysis model and ListNet ranking model to evaluate their jobs in summer vacation. Through SJSS, the relationship between personal information and job characteristics is clearly explained. SJSS could effectively solve the problem of quantification of job preferences and help students select their best summer job. The selection and evaluation system of summer job for high school students mainly includes software introduction module, information input module and presentation module.

7.2 Procedures of use

(1) Figure 8(a) is the home page. The app will randomly recommend companies or enterprises that users like. And users can choose according to their own preferences.

(2) Figure 8(b) is a login interface of our app. Users can log in to the software according to their email and password. The bottom of the interface contains links to Twitter, Facebook and YouTube. Users can also forward the app if need.

(3) Figure 8(c) is the search interface. Users can search for jobs they are interested in. The app will provide some personalized search terms. The search function of the app is very powerful, and it can quickly match summer job related to users' interest.

(4) Figure 8(d) is the core functions of the app. It can make personalized recommendation according to personal information. The job evaluation system for high school students mainly includes information input and presentation modules. For the information input module, it includes personal information, job preference and job expectation. Figure 8(d) is personal information module. Users need to input parameters, including current grade ranking, computer scores, sports scores and times to participate in organizing activities. The range of all indicators are from 0 to 100.

(5) In job preference module (Figure 9(a)), individuals have different preferences for different jobs. Users can rate the importance of 3 main factors and 11 secondary

factors. The main factors include personal, job and social factors. 10 main factors include academic level, computer skill, physical quality, organizational skill, number of hours, hourly rate, work way, type of job, job place, social honor. In order to determine the importance of the factors in the summer job, users grade the importance of these indicators, where 1 is unimportant and 10 is very important.

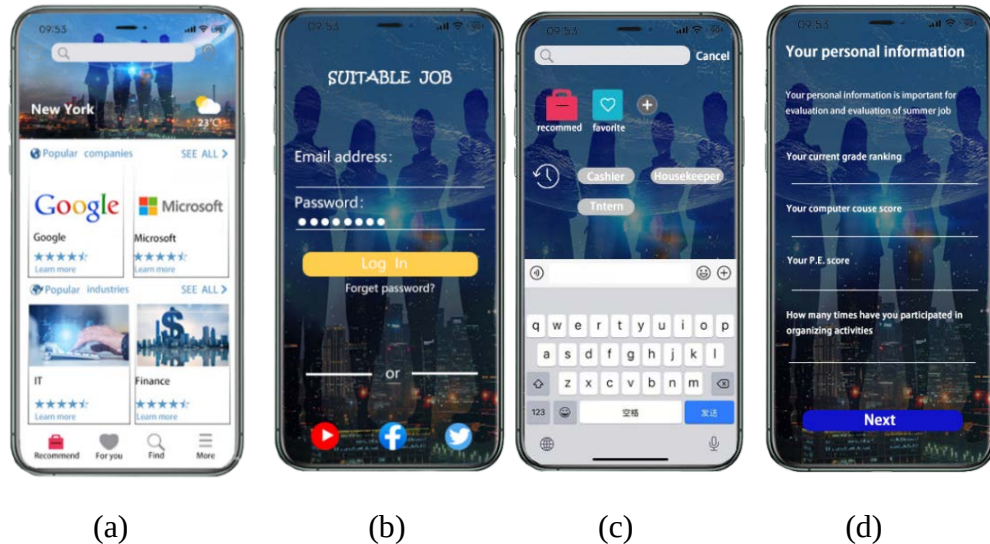


Figure 8 (a) home page. (b) login interface. (c) search interface. (d) personal information.

(6) In job expectation module (Figure 9(b)), users need to enter your expectations for future work, including working hours, salary, etc. By scoring the working mode and preference of job types, SJSS can analyze and evaluate the situation of your dream work. According to powerful algorithms it can recommend the best job or industry to you.

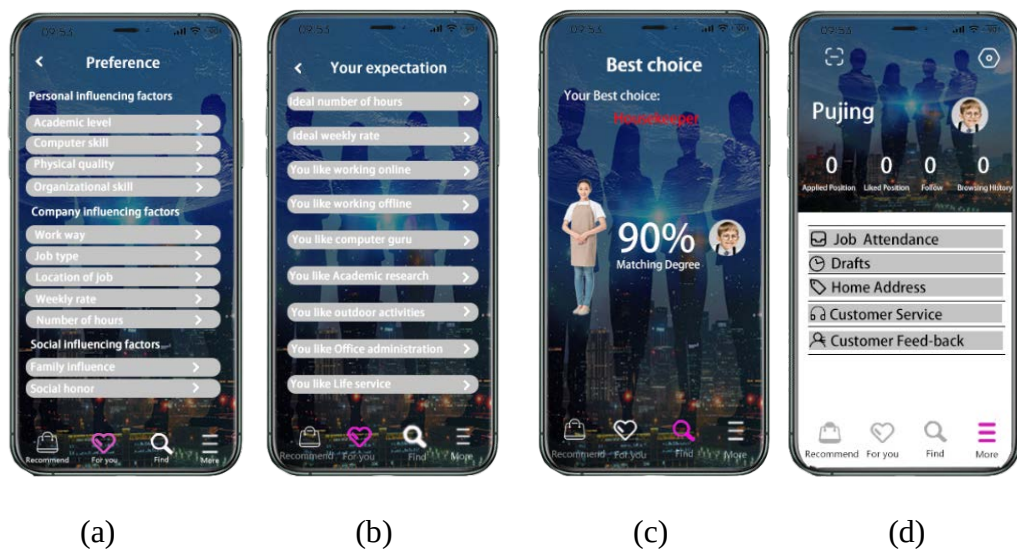


Figure 9 (a) job preference. (b) job expectation. (c) job suggestion. (d) personal page.

(7) Figure 9(c) is the summer job suggestion. Through the mathematical model established in this paper, the personalized choice and results are presented, including the specific work of the individual and the matching degree between the individual and the summer job. For example, the most suitable position given by the system is housekeeper, showing a 90% matching degree. Furthermore, the app can recommend companies and industries to users.

(8) Figure 9(d) is a personal page, including job attendance, user feedback, etc.

8 Strength and weakness

The strength and weakness of this study are concluded as follows.

Strength:

- We create a novel job evaluation system which consists of a fuzzy analysis model and a Listwise ranking model based on a neural network.
- We make the sensitivity analysis on our models to verify their stability and robustness.
- We design an app with friendly interfaces and match it with fuzzy comprehensive evaluation, ranking algorithm and personalized recommendation mechanism.

Possible improvements:

- If the real data of job choices is provided, the recommendation results based our model may be more accurate.
- There are four hyperparameters in our trapezoidal membership function for personalized evaluation and it may be difficult to set very accurate value to them.

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Appendix

Python code

Fuzzy Comprehensive Evaluation Method (Matlab)

```
def AHP(matrix):
    if isConsist(matrix):
        lam, x = np.linalg.eig(matrix)
        return x[0] / sum(x[0][:])
    else:
        print("Consistency check failed ")
        return None

def isConsist(matrix):
    n = np.shape(matrix)[0]
    a, b = np.linalg.eig(matrix)
    maxlam = a[0].real
    CI = (maxlam - n) / (n - 1)
    RI = [0, 0, 0.58, 0.9, 1.12, 1.24, 1.32, 1.41, 1.45]
```

```

CR = CI / RI[n-1]
if CR < 0.1: return True, CI, RI[n-1]
else: return False, None, None

def appraise(criterionMatrix, targetMatrixs, relationMatrixs):
R = np.zeros((criterionMatrix.shape[1], relationMatrixs[0].shape[1]))
for index in range(0, len(targetMatrixs)):
row = mul_mymin_operator(targetMatrixs[index], relationMatrixs[index])
R[index] = row
B = mul_mymin_operator(criterionMatrix, R)
return B / sum(B[:])

```

ListNet ranking algorithm

```

function [omega, avg_J] = trainNN(list_id, X, y, T, e, quiet=false, init=false)
    source global.m;
    m = size(X,1);
    n_features = size(X,2);
    n_lists = size(unique(list_id),1);
    if init == false
        disp('random initialization')
        omega = rand(n_features,1)*INIT_VAR;
    else
        omega = load(init).omega;
    end
    end
    for t = 1:T
        if quiet == false
            fprintf('iteration %d: ', t)
        end
        z = X * omega;
        if quiet == false
            fprintf('computing cost... ')
        end
        J = listwise_cost(y,z, list_id) + ((z.*z)'.*LAMBDA);
        tmp_model_file = sprintf('tmp/model_%d.m', t);
        save(tmp_model_file, "omega");
    end
end

function grad = listnet_gradient (X, y, z, list_id)
    global CORES
    m = size(X,1);
    p = size(X,2);
    lx = @(i) X(find(list_id == list_id(i)),:);
    ly = @(i) y(find(list_id == list_id(i)),:);
    lz = @(i) z(find(list_id == list_id(i)),:);
    s1 = @(i) -(lx(i)' * topp(ly(i)));
    s2 = @(i) (1 / sum(exp(lz(i))));
    s3 = @(i) (lx(i)' * exp(lz(i)));
    g = @(i) (s1(i) + s2(i) * s3(i));
    f = @(i) g(i);
    grad = reshape(pararrayfun(CORES, f, 1:m, "VerboseLevel", 0),p,m);
end

```