


Research Article

Prototype of an Expert System for the Selection of Aircraft Structural Materials

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Expert systems (ES) are widely used for engineering and manufacturing applications nowadays. In order to solve the problems in material selection in the aviation field, an aircraft material expert system (AMES) was developed. This expert system is based on the knowledge of multiple experts and aviation data. A decision support system (DSS) was designed for selecting the materials used in aviation fields. The flows of material selection were designed, and the models of AMES were established. A data base system was also designed to implement AMES.

1. Introduction

Aviation engineering application fields are developing towards intelligence, digitalization, and integration [1]. It is complicated to select an appropriate material for aircraft design [2]. In order to meet the demands of the aviation development, expert systems (ES) have been used in aerospace and have solved a lot of problems successfully [3–5].

Expert systems were developed by the AI (artificial intelligence) community in the mid-1960s [6]. With the development of science and technology, ES was successfully used for engineering and manufacturing applications and dealing with complicated problems in aviation fields [7–14]. Liu et al. [15] studied the optimization of short-haul aircraft schedule recovery problems by using a hybrid multiobjective genetic algorithm. Li et al. obtained a semantic-based approach for collaborative aircraft tooling design [16]. Athanasopoulos [17] developed an ES for coating selection based on fuzzy and multicriterion decision-making. Grainer and Blunt [18] presented a thorough analysis of the properties and the applications of using a simpler material for the substrate; the engi-

neers can diminish the cost of purchase. Mao-Jiun and Wang [19] designed an ES for tool steel material selection under fuzzy environment. Kim et al. [20] developed an expert system for fatigue life prediction under variable loadings.

However, all these expert systems were developed to solve problems without considering the whole capabilities of aircrafts. In this paper, an aircraft material expert system (AMES) on the capability and layout of aircraft was developed based on the knowledge of multiple experts and aviation data. A decision support system (DSS) was designed, and the flows were modeled by ES for aircraft material selection.

This paper is organized as follows: Sections 2–4 present the design of AMES and the model of selection flows of core functions. Sections 5 and 6 present the data base system of AMES and the data frame. An example of ES solution is given in Section 7. Section 8 contains brief conclusions.

2. Design of AMES

The frame of AMES was designed as shown in Figure 1.

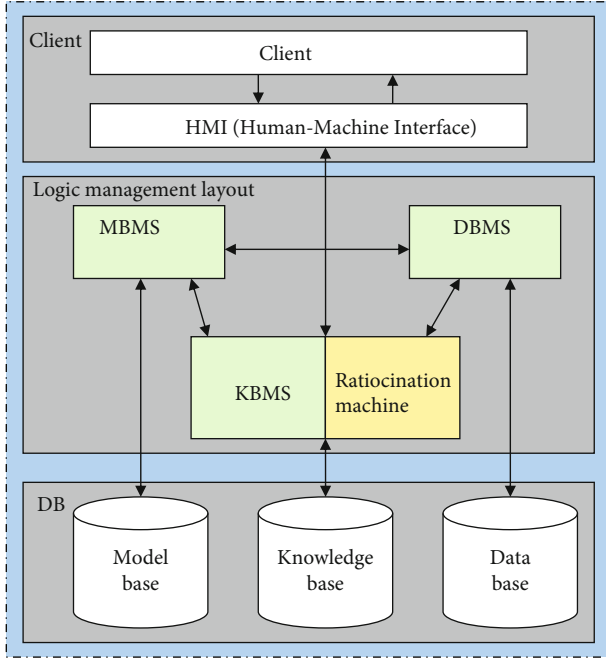


FIGURE 1: Frame of AMES.

The flow of AMES is as follows: clients visit the system via the HMI (human machine interface), and then the system transfers the request of clients to DB and returns the results to the clients.

The system contains three parts: client, logic management layout, and DB.

The core function logic of AMES is discussed in the second part. It contains the ratiocination and calculation of ES: ratiocination machine and the flow of material selection: MBMS (model base management system), DBMS (data base management system), and KBMS (knowledge base management system). The details will be given in Sections 3 and 4.

The core business logic of AMES is designed in Part 3: DB. It contains MB (model base), KB (knowledge base), and DB (data base). MB contains the methods of material selection which are formed from the experience of the experts. KB contains the knowledge of aircrafts and materials and the experts' knowledge. DB contains the data which is used to assist clients to make decisions of material selection. The data base management system and the data frame are designed and given in Sections 5 and 6.

3. Selection Methods of AMES

The ratiocination and calculation methods are designed by ES.

Qualitative and quantitative properties are needed to be considered to select an appropriate material for aircraft use. So the DSS of AMES is based on fuzzy logic and multicriterion decision-making theories. As the decision is made by multiexpert and fuzzy multiattribution, a prototype of the multicriterion neural network (NN) system is applied to prototype system functionality approach.

The prototype is established and operated as follows:

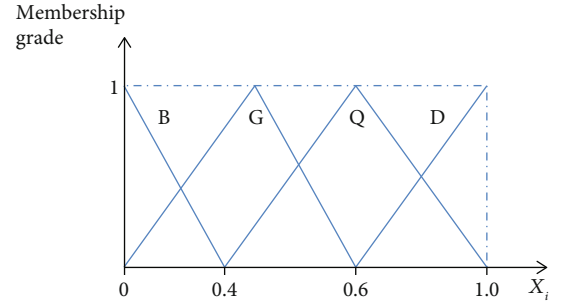


FIGURE 2: Membership functions for linguistic rating values.

The membership functions for linguistic ratings can be defined by the functions in Figure 2 [21].

It is assumed that the system has r input variables x_i ($i = 1, 2, \dots, r$) and y_j ($j = 1, 2, \dots, q$).

The fuzzy membership function is defined as

$$R_t = \frac{1}{n} (X_{it1} \oplus X_{it2} \oplus X_{it3} \cdots \oplus X_{itn}), \quad (1)$$

where $i = 1, 2, \dots, m$, $t = 1, 2, \dots, k$, R_t is the aggregate ratings of alternative I under criterion t , and X_{itn} are the assigned ratings of alternative I under criterion t by decision-maker n . The symbol " \oplus " is a proposed calculation method.

Similarly, if G_t is the aggregated weighting for criterion t , and k is the number of criteria. Then, their opinions can be aggregated by

$$G_t = \frac{1}{n} (G_{it1} \oplus G_{it2} \oplus G_{it3} \cdots \oplus G_{itn}). \quad (2)$$

U_i is defined as the approximated fuzzy number of the fuzzy suitability index. And $f(x)$ is defined as M with the membership function. The symbol " \oplus " is a proposed calculation

If the rule amount X is given, the prototype of the system is established as

$$U_i = \left(\frac{1}{k} \right) \otimes [(R_{t1} \otimes G_{t1}) \oplus (R_{t2} \otimes G_{t2}) \oplus \cdots \oplus (R_{tk} \otimes G_{tk})]. \quad (3)$$

If $x_1 \leq x \leq x_2$, $f(x) = |(x - x_1)(x_2 - x)|$; otherwise, $f(x) = 0$. Then, we can get the following result:

$$M(U_i) = \frac{[M_M(U_i) + 1 - M_G(U_i)]}{2}, \quad (4)$$

where $M_M(U)$ and $M_G(U)$ are the maximizing set and the minimizing set, respectively, according to the input data. Equation (4) is the arithmetic of AMES.

4. Core Function Models of AMES

Equations (1)–(4) are the methods of material selection. It gives the flows of these methods. Four methods are designed

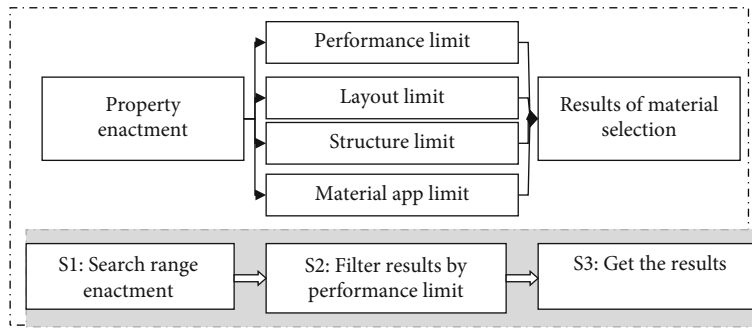


FIGURE 3: Methods of material selection: filter.

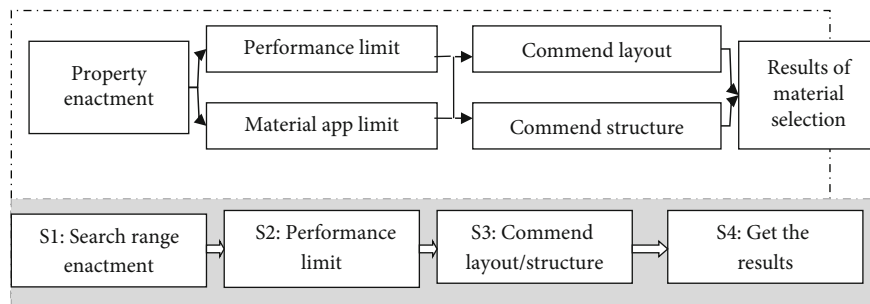


FIGURE 4: Methods of material selection: performance limit.

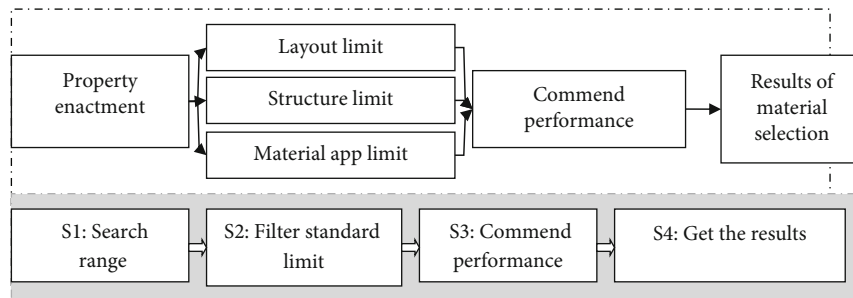


FIGURE 5: Methods of material selection: layout design.

to select materials for aircraft design: “filter,” “performance limit,” “layout design”, and “experience.” And the core function models are designed in Figures 2–5. The top of the figure gives the disposal flow of AMES. And the bottom gives the computer instruction of the flow.

The flow of “filter” is designed in Figure 3. Clients set the property conditions and the goals of material selection. The system filters the results by limiting the material performance. Then, the clients deal with the results returned by the system and choose the rights.

The flow of “performance limit” is described in Figure 4. After the properties were restricted, clients set the performance and the application of materials. Then, the system deals with the requests and commends the layout or structure of the aircraft. Clients could select the rights from the results returned by the system.

The flow of “layout design” is designed in Figure 5. This method commends the aircraft’s performance through limit-

ing the layout and structure of the aircraft. The method is often used by engineers to manufacture parts and so on.

The flow of “experience” is designed in Figure 6. This method depends on the experience of experts. It selects materials or parts based on the isometric spectrum. A lot of work is needed to ensure the validity of this method. But this method of material selection is the most useful way for aircraft designers.

5. Actualization Technique of AMES

After determining the frame and the core function, the actualization technique of AMES is designed.

As described in Figure 7, the frame of the DBMS (data base management system) is contrived by JCDF (Java Common Development Frame). It contains four lays: client layer, view layer, business layer, and resource layer. The differences of this frame from usual frames

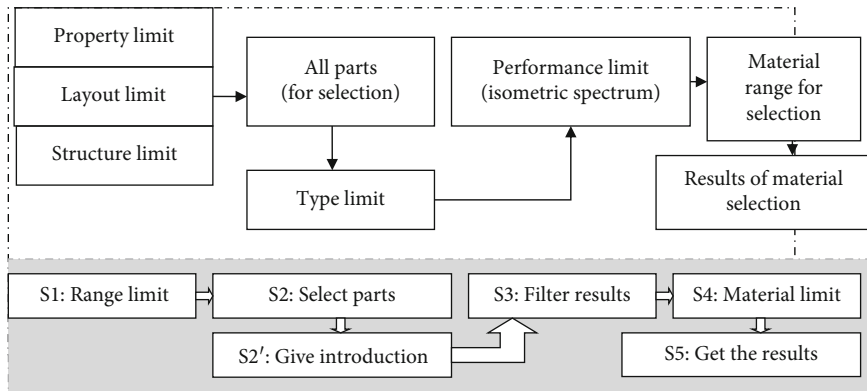


FIGURE 6: Methods of material selection: experience.

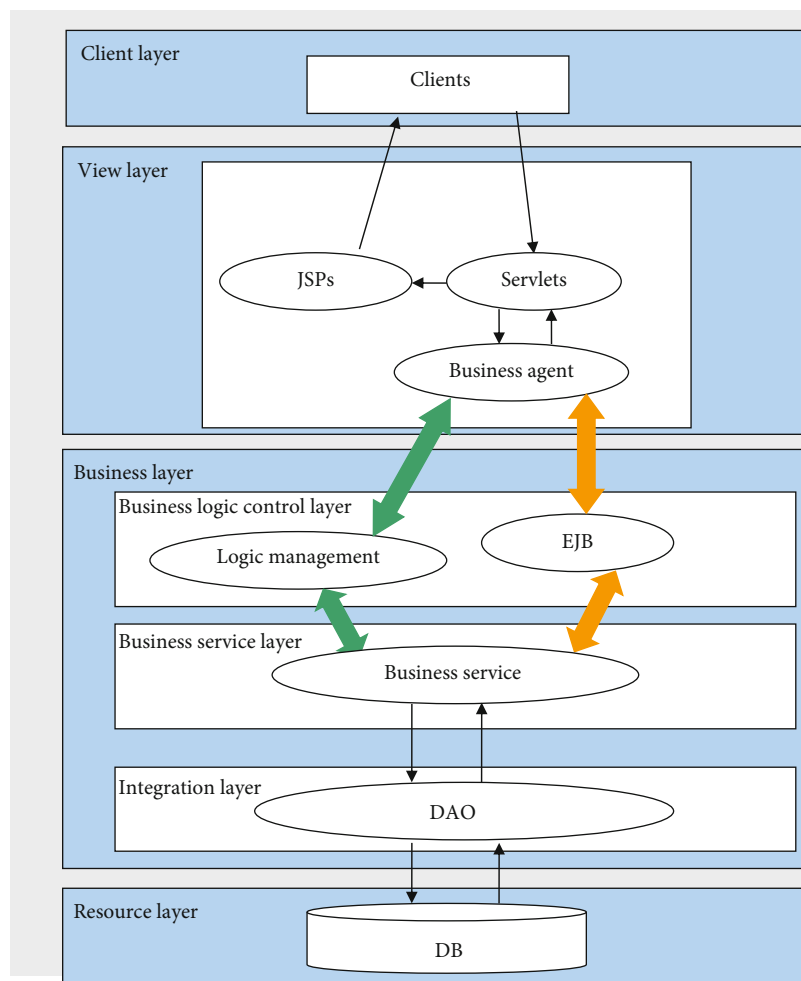


FIGURE 7: DBMS of AMES.

are as follows: the Servlets separate the view layer from the business layer, and the logic management is done by EJB. These sets promote the system to run fast and efficiently. JCDF can choose different flows to deal with different requests. It visits the data base via DAO and saves a lot of space.

6. BL (Business Logic) of AMES

In order to realize the transfer of the data successfully and make sure the system is easy to use, the design of the data base is important. The BL of AMES contains the model base, knowledge base, and data base. The model base and the knowledge

TABLE 1: Frame of data base.

AMES (BL) DB	Aircraft information module	Aircraft property
		Aircraft performance
		Aircraft layout
		Aircraft structure
	Component information module	Aircraft material app
		Component property
		Component performance
		Component layout
	Part information module	Component structure
		Component material app
		Part property
		Part performance
	Material information module	Part structure
		Part material app
		Material property
		Material component
		Material performance
		Material application

base contain expert experience and aircraft knowledge. But the data base should be arranged reasonably, or the system could run with a lot of problems. The data base of AMES contains aircraft information, component information, part information, and material information. These are outlined in Table 1. Every module has its own values, but they are related. The parameters of the whole aircraft and parts are based on the material.

7. Example

In this section, we use a new method based on equation (6) and give an example to illustrate the proposed method.

Firstly, let us consider the linguistic terms: disqualification (D), qualified (Q), good (G), and best (B). The fuzzy numbers corresponding to the terms are given in Table 2. The values present the limits of the selection.

$$D \text{ is equal to } \frac{1 + 1 + 0.6 + 0.6}{4} = 0.8,$$

$$Q \text{ is equal to } \frac{0.6 + 0.6 + 0.4 + 0.4}{4} = 0.5,$$

$$G \text{ is equal to } \frac{0.4 + 0.4 + 0 + 0}{4} = 0.2,$$

$$B \text{ is equal to } \frac{0 + 0.4 + 0 + 0}{4} = 0.1. \tag{5}$$

We choose four X_i variables X_1 (performance limit), X_2 (layout limit), X_3 (structure limit), and X_4 (material app limit) as given in Section 2, which are given in the method “filter.” Then, we get the defuzzified values. Assume that the ratings of the program under four criteria decided by decision-makers are as shown in Table 3.

TABLE 2: Linguistic terms and corresponding fuzzy numbers.

Linguistic terms	Fuzzy numbers
Disqualification (D)	1, 1, 0.6, 0.6
Qualified (Q)	0.6, 0.4, 0.4, 0
Good (G)	0.4, 0.4, 0, 0
Best (B)	0, 0.4, 0, 0

TABLE 3: Ratings of design plan of ES under the four criteria.

Plan	X_1	X_2	X_3	X_4
I	Q	G	G	B
II	G	B	B	Q
III	B	B	G	G
IV	B	G	G	Q

TABLE 4: The importance weights of the four criteria.

Criteria	Decision				IW
	A	B	C	D	
X_1	Q	B	G	G	0.25
X_2	G	Q	B	Q	0.325
X_3	Q	G	B	B	0.225
X_4	G	B	B	G	0.15

A committee of four decision-makers conducts this task and gives the decision also based on Table 2. The important weights of the four criteria are shown in Table 4.

Based on the equations, the ranking values can be evaluated as follows:

$$M(I) = 0.5 \times 0.25 + 0.2 \times 0.325 + 0.2 \times 0.225 + 0.1 \times 0.15 = 0.25,$$

$$M(II) = 0.2 \times 0.2815 + 0.1 \times 0.34375 + 0.1 \times 0.25 + 0.5 \times 0.1875 = 0.18,$$

$$M(III) = 0.1 \times 0.2815 + 0.1 \times 0.34375 + 0.2 \times 0.25 + 0.2 \times 0.1875 = 0.1325,$$

$$M(IV) = 0.1 \times 0.2815 + 0.2 \times 0.34375 + 0.5 \times 0.25 + 0.5 \times 0.1875 = 0.21. \quad (6)$$

From the above calculations, the best selection is program III.

8. Conclusions

This paper developed an aircraft material expert system (AMES) to solve the problems of material selection in the aviation field. It provides a way of material selection by considering the whole performance of aircrafts by ES.

A selection method of fuzzy logic and multicriterion decision-making theories is designed by multiexpert and fuzzy multiattribution. And the prototype of the multicriterion neural network (NN) system is applied to the prototype system functionality approach. The computerized flows of selecting materials are also designed.

A DBMS is designed for realizing the core functions of AMES. A data base system is also designed for carrying out AMES.

Based on the knowledge of multiple experts and aviation data, the decision support system (DDS) could be used for selecting the materials used in aviation fields.

Data Availability

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

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Xuelong Hao and Chen Wen contributed equally to this work.

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