AN ENGINEERING METHOD WITH ARTIFICIAL INTELLIGENCE CHARACTERISTICS USED FOR STRUCTURAL LAYOUT OF WINGS

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Abstract

In this paper a developing branch of computer science——expert system is used to deal with the structural layout optimization of aircraft wings. A trial microcomputer software ESSLOW (Expert System for Structural Layout Optimization of Wings) based on the man–machine interactive program SLOW (Structural Layout Optimization of Wings) was developed and the obtained layout schemes are reasonable. The purpose of this paper is to develop an engineering method not only for solving the existing difficult problem——structural layout optimization but also for exploring the approach to ICAD (Intelligent Computer Aided Design).

I. Introduction

Wing is the most important aircraft part for bearing load. Its weight occupies approximately one third of the total structural weight of an aircraft. So the main objective of wing structure design is to reduce the wing structure weight as more as possible.

Structural optimization is now the usual method for minimizing structural weight. The most structural optimization methods adopt the finite element models. Since the difficulties in mathematics and programming, the total number of nodes in finite element model can not be changed during the running period of the program. Otherwise, the order of the stiffness matrix of the model and a series of varieties in objective function, design variables, constraints, etc. would be changed at the same time. That is to say the most important processing in structural layout, to add or reduce some structural components, if this processing would change the total number of nodes of the finite element model, is not allowed. Therefor, we can not deal with structural layout by using present–day structural optimization method. Although the usual structural optimization methods can obtain the refined dimensions of the finite elements, a reasonable structural layout scheme would have much more benefit in minimizing structural weight than just refining each element. An ideal approach to the problem of reducing wing structural weight is to optimize the finite element model based on a reasonable structural layout scheme.

Unfortunately, no mature structural layout method could be adopted. So, a man–machine interactive program using a graphic terminal was developed. Some wing structural layout schemes could be given by users. Then , use the usual structural optimization method to optimize them and choose the best one. Of course, the use need to have a plenty of experience of aircraft design. Otherwise, the reasonable layout scheme could not be included.

Since the experience of designers is now the only resource of ideas to layout wing structures, this reminded us of expert system . Expert system is a developing new branch of AI (Artificial Intelligence) in computer science. The strong suit of expert system is to tackle heuristic problems. Thus, the usual structural optimization method, the structural layout expert and the man–machine interactive technique were combined to form an engineering system for designing the structural layout of wings. The principle of the method can also be used for other aircraft parts or any flight vehicle part.

The man–machine interactive structural layout program is a kind of CAD (Computer Aided Design) software. This CAD software can be surrounded by an artificial intelligence program , expert system, just like a " shell ", to form an ICAD (Intelligent CAD) system. This method can be used for any man–machine interactive system provided the user's experience is needed and the expert knowledge is available.

II. Program SLOW and its Problem

SLOW (Structural Layout Of Wings) is a CAD software based on man–machine interactive technique and it is used for the structural layout of aircraft wings. The system configuration of SLOW is shown in Figure 1.

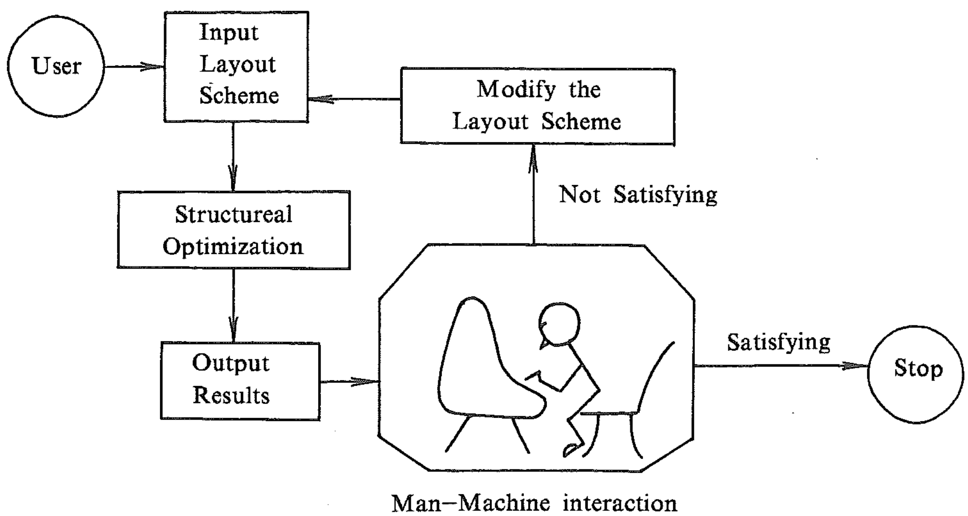

Figure 1. System Configuration of SLOW

The main wing structure layout parameters which need to be chosen by users are NB and NR. NB means the number of beams in the wing such as spars and stringers. NR means the number of ribs in the wing. Users input several available layout schemes depended on the number of NB and NR , material selection , boundary condition and initial element dimensions. The structural optimization can now be implemented on the given layout scheme. The objective function is the weight of the wing structural . Users can continue to modify the existing layout until getting a satisfied scheme.

The problem of using SLOW is that users should have rich design experience either for giving an available scheme or for modifying an existing scheme. The reason can easily be understood : a bad layout scheme is just like a " gabage in ", so the result must be a " gabage out ". If users intend to search all of the possible layout schemes with a permutation –– combination method, the consumed computer time will be unacceptable. For example , Figure 2. shows the possible slections of NB , NR , material selections and so on. The number of possibilities is not so many , but the consumed time is terrible .

III. Using Expert System

At present, the expert system — a developing branch of Artificial Intelligence (AI) in computer science ––– gives us the approach to solve the above mentioned problem.

The expert system we developed is based on a knowledge base and has the name ES. It is just like a " shell ", surrounding SLOW . We also developed a user interface to control ES and to connect with SLOW directly when necessary. The whole system is a trial software system with very strong engineering characteristics, i.e. , highlighting the requirements of wing structure layout. The whole system was named ESSLOW and its conceptual configuration and system configuration are given in Figure 3. and Figure 4.

Layout Parameter	possibilities	schemes	consumed time
NB	3		
NR	10		
Materials	3		
Bundary Conditions	3	810	2430 hrs.
Initial Elememt Dimensions (Initial Design point X0 for structural optimization)	3		(3 hrs. / scheme)

Figure 2. Possible Scheme and Consumed Time

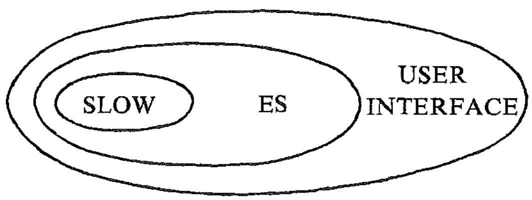

Figure 3. Conceptual Configuration of ESSLOW

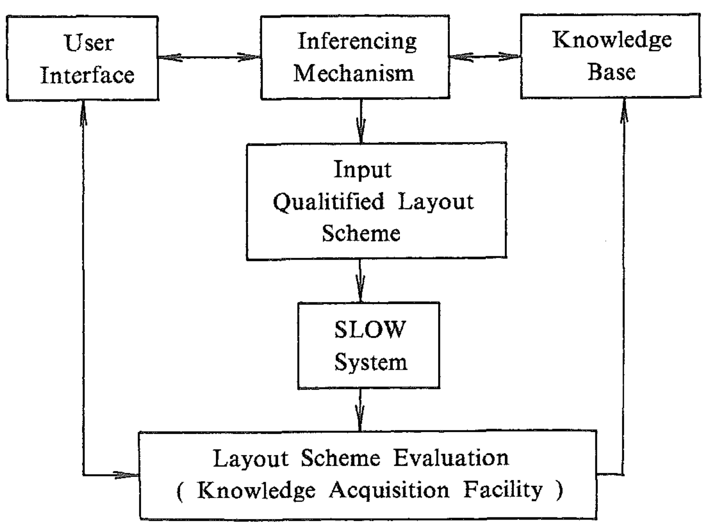

Figure 4. System Configuration of ESSLOW

ESSLOW is intended to be a rude model of the design tool for wing structural layout . It has the following functions:

* Hierarchical menus for user selection
* Structural layout optimization processing for aircraft wing structural design
* Evaluation processing for choosing the valuable results of layout schemes
* Listing the contents of knowledge base
* Adding the contents of knowledge base
* Deleting the contens of knowledge base
* Inquiring the designed layout schemes

IV. Main Problem of ESSLOW

There are three main problems need to tackle in the rude engineering software system ESSLOW:

(1) Establishment of knowlegde base

PROLOG (PROgramming in LOGic) computer language was used to establish the knowledge base of ES part . Since PROLOG is based on predicate logic , so , how to use ″ predicates ″ in this language to express the ″ facts ″ and ″ rules ″ in aircraft wing structural deisgn is very important. Here is an example for creating a rule :

```
beam_number_is ( ″ 2 ″ ) : -
  premininary_data (type, transport),
  aerodynamic_data (wing_plane_form, trapezium),
  aerodynamic_data (airfoil, thick),
  design_data (landing_gear_bay, in_the_wing),
  statistic_data (mhb, MHB),
       MHB < 1.4E6.
/ *      MHB < 1.4E6 means             * /
/ *      M / HB < 1.4E6 ( lb / ft )    * /
/ *      axial load per width          * /
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The meaning of the rule is that if the five facts are true of the designing aircraft , the beam number NB should be 2 for the wing of the aircraft. The five facts are as follows:

* The type of the aircraft is a transport , i.e. , it is not a fighter or a bomber or something else.
* The shape of the wing plane is trapezium , not triangle or something else .
* The airfoil shape of the wing is thick. If the aircraft is a fighter, maybe the shape of the airfoil is thin .
* The landing gear bay is set in the wing .
* The value of MHB explained as precedent is less than 1.4E6 (lb / ft).

Four kinds of predicates are used here for this rule:

preliminary_data (symbol, symbol) ——
for preliminary design data ,
aerodynamic_data (symbol, symbol) ——
for aerodynamic design data ,
design_data (symbol, symbol) ——
for configuration design data ,
statistic_data (symbol, symbol) ——
for statistic data ,

The principle of creating predicates and selecting domain types is that the domain declaration and the predicates declaration are not needed to modify when the knowledge base needs to add some new facts and new rules.

(2) Inference mechanism

PROLOG has matching and backtracking functions to complete the inferencing process . In fact , the inference process is a process of ″ searching knowledge base ″.

The searching process in ESSLOW is fixed , i.e. users should do every thing that prompts on computer screen . For instance , according to the prompts ,users should layout NB first , then NR . The order for layout steps is arranged to improve the efficiency of the software .

Of course , the searching process should also be based on another expert system . That means , the searching strategy is also dependent upon heuristic method. For simplicity, we put the fixed searching steps in ESSLOW .

(3) Evaluating module

Users can do their evaluation using the evaluating module . A ″ weighted marking method ″ is used for this purpose . Users can evaluate some structural design qualities such as weight, strength, stiffness, etc . The most satisfying layout scheme can be stored into the knowledge base by users.

We can say the evaluating module is the rude pattern of knowledge acquirement —— machine learning .

V. Conclusions

The engineering system ESSLOW consists of three subsystems :

(1) Expert system —— According to design requirements to inquire the knowledge base and do some inferences and design calculations , the initial wing layout will be yielded , in detail , we will have the number of spars and ribs and the positions of them. The system includes three components : knowledge base , inferencing mechanism , and evaluating module . The evaluating module is used to determine whether

the final layout scheme can be adopted for use or just rejected. On the other hand, the evaluate method module can also be used to evaluate any layout scheme whether it is valuable to put into the knowledge base. So, the system has the ability of knowledge self–learning , called ″ machine learning ″.

(2) Structural optimization program ––– To optimize the element size in the structural layout given by the expert system and calculate the weight of the wing . The objective function is weight minimization , only static mechanic constraints to be adopted for simplicity, dynamic mechanic constraints can be added in future .

(3) Man–machine interactive system ––– The user interface has a hierarchical menu . The design requirements input , the running procedure tracing, and the user necessary interfering in running time can all be implemented by using the interface. User can also use this interface to check,add, delete, modify any entry of knowledge .

This engineering system is a trial software which can be run in IBM–PC / AT or any compatible microcomputer , under DOS (Disk Operating System) , three kinds of computer languages were used to form it . TURBO–PROLOG was adopted for ES (Expert System) subsystem . GWBASIC and FORTRAN 77 were used for SLOW subsystem , the former for the user interface and the latter for the calculation of wing structural optimization .

Althouth ESSLOW is a trial microcomputer software , the test results are reasonable in engineering application . For example , we have redesign the wing of ″ Beijing No.1 ″ (a 8 passengers liner) which was designed and manufactured by our university in 1958 . The entries of knowledge were collected from the specifications of ″ Beijing N0.1 ″ , so the layout scheme is the same as this commuter .

Another meaning of this paper is to explore the possible approach to ICAD . If the CAD software can be surrounded by an expert system ″ shell ″ to help the user who lacks design experience , the expert system shell would much more improve the usage value of the CAD software .

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