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AIRCRAFT CONFIGURATION ANALYSIS/SYNTESIS EXPERT SYSTEM : A NEW APPROACH TO PRELIMINARY SIZING OF COMBAT AIRCRAFT

R. BARGETTO, B. MAZZETTI
Preliminary Design
AERITALIA COMBAT AIRCRAFT GROUP
Torino Italy

G. GARBOLINO
Laboratorio Intelligenza Artificiale
CSI PIEMONTE
Torino Italy

Abstract

This paper describes the expert system (E.S.) called "ACES" (Aircraft Configuration Expert System) now under development by AERITALIA in collaboration with CSI (Centro Sistemi Informatici-Piemonte, Torino Italy), that has been realized on a Sperry EXPLORER™ LISP machine using the KEE™ (Knowledge Engineering Environment) by Intellicorp. This E.S. is an aircraft design tool which is able by itself to generate a set of possible configurations, starting from the requirements and from a set of rules which constitute its "Knowledge base" and to optimize the aircraft warying not only the usual numerical parameters but also configurational elements.

Introduction

Up to now the earliest phase of design process of combat aircraft, in which are determined the major characteristic of airplane like fuel weight, thrust required, wing area, aspect ratio, sweep and many others, was done in rather an inefficient way, mainly with manual calculations without an extensive use of computers.
In such a way the time spent for this phase is rather high and, what is more important, we are not sure to have envisaged the "best" solution for the requirements.

Scope and objectives

Then the purpose of "ACES" is to help the designer in defining a set of good,feasible and sound configurations starting from the requirements coming from military staff.
In order to reach this goal the E.S. must be able to make some important initial choiches about each configuration defined, to perform some routine numerical calculations about weights, aerodynamics, performances,choose some configuration characteristics and to present the results in a "friendly" way for the designer.
Then the objective of the ES is to define automatically a rather big amount of possible configurations that could meet the requirements, evaluate them and then select the best ones (in a number ranging probably from one to ten).
For every "best" configurations the ES shows to the user the design diagram (thrust to weight ratios versus wing loading) on which are plotted the lines at constant point performance specified in the requirement.
The user then is able to select the design point which defines the thrust, weight and wing area required for this particular configuration.
Now it is very important to point out that this ES can and must be used to definire a limitated amount of possible "Baselines" configurations. Those Baselines will be used later as a starting point to perform some more sophisticated trade off and optimization studies,in order to define the only and, we hope, the best configuration compliant with requirements.
Those refinement studies are already now performed with computer codes like datcom for aerodynamics and others ones developed in AERITALIA for weights and performances.

Knowledge Base

The knowledge base collected in the E.S. is divided in :

1 - Descriptive

2 - Operative

3 - Technical

4 - Calculation subprograms

In the operative knowledge (fig. 1) are collected all the design rules used to choose the configuration items. This rules are about for exemple air intake type selection, engine type selection, by pass section, and many others.

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50) TV.TAKE-OFF.LANDING.RULES

(IF (INTERSECTION (GET.VALUES 'REQUIREMENT 'TAKE-OFF.AND.LANDING) '(STOVL VTOL))
    DO
    (IS.ONLY.POSSIBLE 'THRUST.VECTORING '(COMPLETE)))


72) A-B.STEALTH.RULE

(IF (AND (NOT (THE AIRCRAFT.TYPE OF REQUIREMENT IS AIR-TO-AIR.AIRCRAFT.)
         (EQ (FIND.VALUE 'STEALTHNESS 'GENERAL.SPECIFICATIONS) 'STRONG))
    DO
    (IS.UNRELIABLE 'AFTER-BURNER '(NEEDED) 'HIGHLY)).
```

Figure 1 - Example of operative knowledge

In the descriptive knowledge (fig. 2) are collected all the objects of the domain known by the E. S. like the types of airplane, missions, armaments, high lift devices, etc., and the jerarchical relations between them.

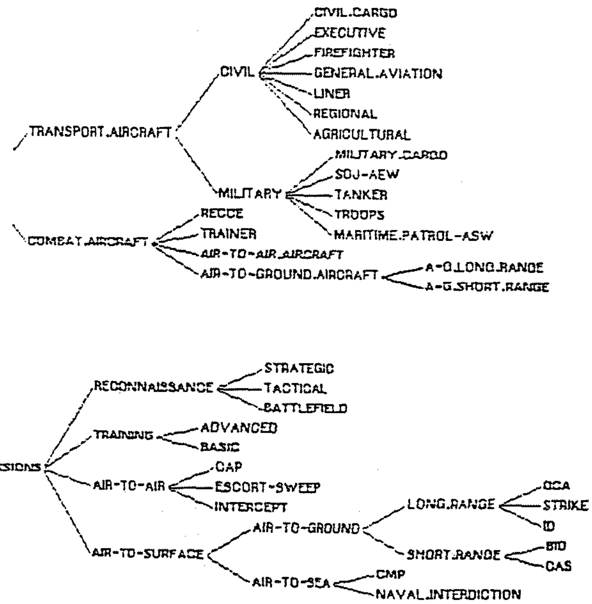

Figure 2 - Example of descriptive knowledge

In the technical knowledge (fig. 3) are collected all the diagrams and tables used by the E.S. when he is running like engine performance graphs, external loads characteristics, air intake performance graphs, weight correlations, etc.

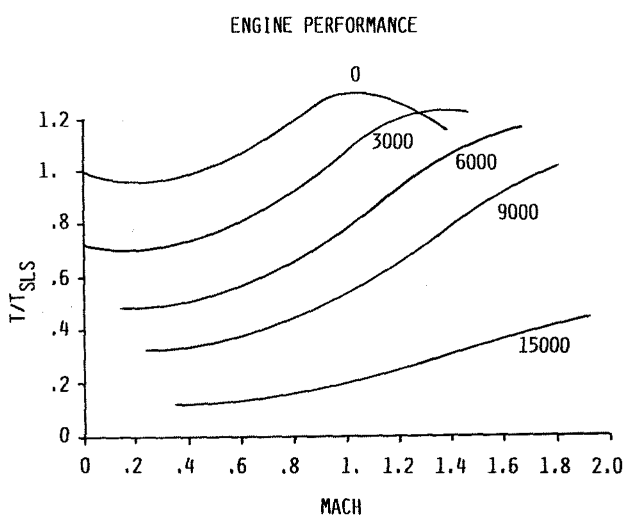

Figure 3 - Example of technical knowledge

The calculation subprogram perfom the routine numerical task during the running of the E.S.
The most important about them are mission fuel calculation, aerodynamic coefficients and weight aestimate, and point performance calculation.
Now it is important to point out that in the operative knowledge has been used massively all the capabilities offered by artificial intelligence.
In particular all the rules are divided in categorical and preferential.
The first ones define the possibility on impossibility of a particular choice in a certain context.
In fact they state :

is only possible
or
is impossible

On the contrary the latter express a valuation of reliability or unreliability about a particular choice.
Moreover is also possible to define the degree of reliability (or unreliability) of the choice itself.
In fact they state :

is reliable (quite) / highly
or
is unreliable (quite) / highly

In this way is then also possible to define the soundness of the total configuration which is the result of many individual choiches collected together.
Such a characteristic is quite impossible to achieve with a conventional sofware language like fortran or others.

Expect system description

The flow of activities performed by "ACES" is depicted in fig. 4.
As a first step the user is requested to input :

1 - Point performances to be satisfied

2 - Primary mission performances to be satisfied (fig. 5)

3 - Loads to be carried

4 - Special topics to be respected (like single engine or double engine, single seat or two seat, tip missiles, internal or external weapon carriage, and many others.

The E.S. is now able to perform some initial choiches about :

1 - Type of engine (reciprocating, turboprop, turbojet)

2 - Presence or obsence of afterburner

3 - Type of air intake (pitot, fixed wedge or cone, movable wedge or cone)

4 - By pass ratio

Then a task is activated which performs the calculation of the fuel needed for the primary missions. Obviously at this point the calculation are rather simplified owing to the lack of data related to the configuration examined.
Now knowing the amount of fuel required is possible to calculate the empty and take off weights of the configuration.
At this point the E.S. chooses some suitable values for the following wing characteristics.

1 - aspect ratio

2 - taper ratio

3 - sweep

4 - thickness ratio

Besides he makes the correct choices among all the possible for :

1 - engine arrangement

2 - high lift devices

3 - number of engines

4 - stability or instability

5 - thrust vectoring yes or not

6 - number of engines

7 - loads arrangement

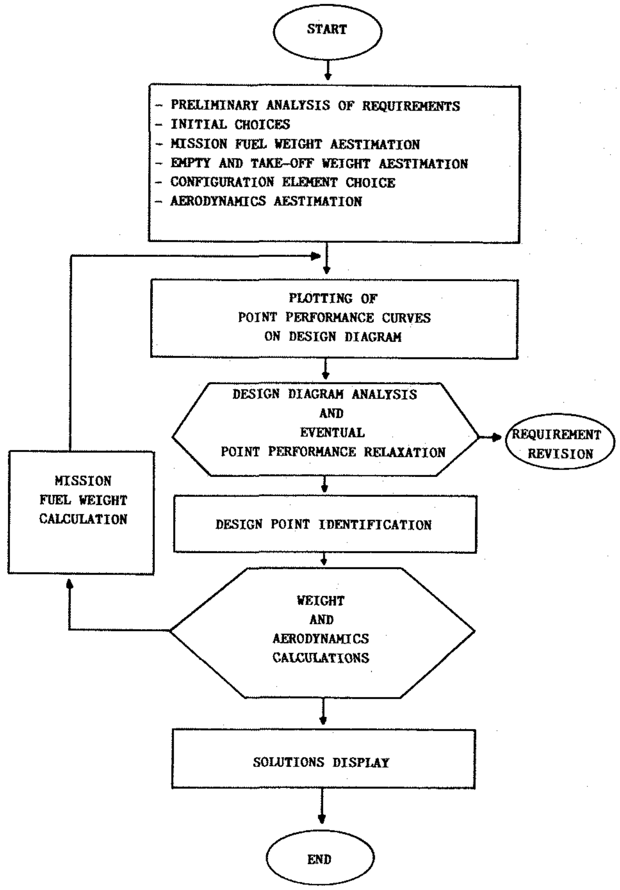

Figure 4 - Sequence of activities

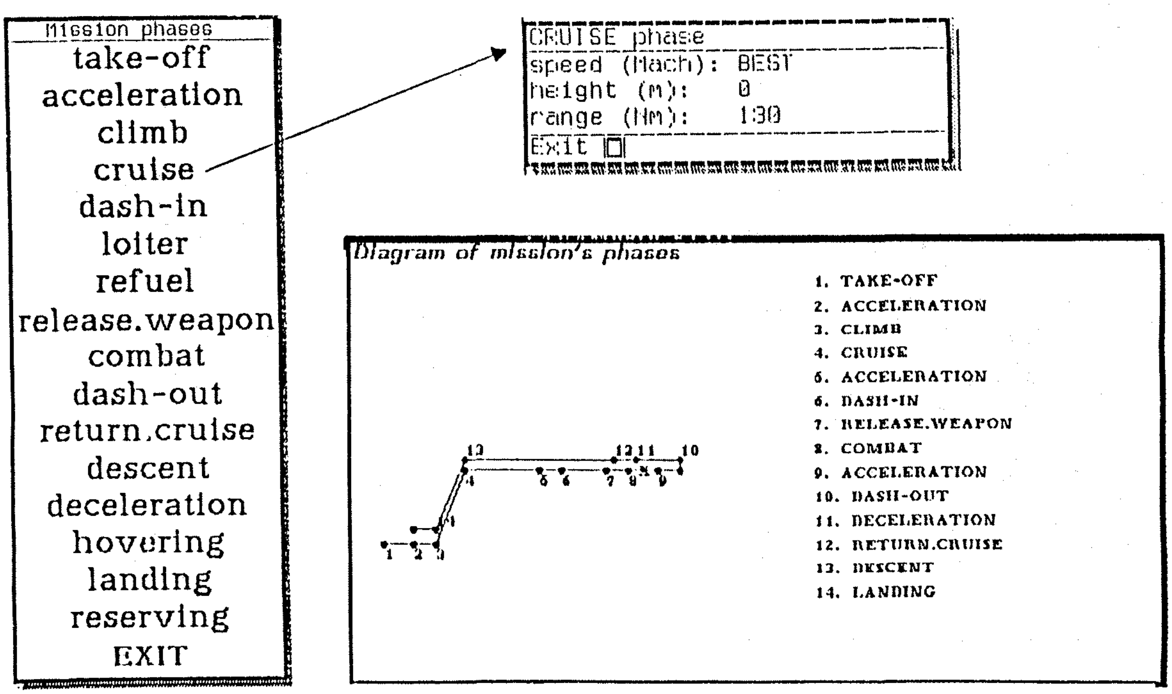

Figure 5 - Example of mission performance input

Now it is possible to display the caracteristics of all the configuration considered by the E.S. (fig. 6).
At this point a task is activated which performs a first estimate of the major aerodynamic coefficients of each configuration.
Then another task is started which calculates, in a given range of wing loadings, and for each configuration, the needed thrust to weight ratios to satisfy the required point performances and plots them in the design diagram.
Now the user is requested to define the design point which satisfies all the requirements.
For this design point choosed by the user the E. S. is now able to perform some more accurate calculations about aerodynamic coefficients weights, and mission fuel needed with which can plot again the final design diagram for the configuration examined.
It is important to note that the E.S. can superimpose on the design diagram also the lines at constant weight in order to help the user to choose the right design point.

Hardware

The E.S. has been implemented and will be developed by means of KEE™ (knowledge Engineering Environment by Intellicorp) which is a knowledge engineering language.
Up to now it has been running on a LISP machine (EXPLORER™, by Texas Instruments).
Nevertheless, after his completion it will be installed on a delivery machine, probably a personal computer like IBM AT or equivalent, provided with run-time version of KEE.
It is important to point out that an E.S. can never be considered really completed and so every refinement and updating will be performed by means of the LISP machine and only later moved on the personal computer.

SOLUTIONS / HYPOTHESES	#:G2988	30	#:G2989	#:G2839
ENGINE TYPE	TURBOFAN HIGHLY.RELIABLE	TURBOFAN HIGHLY.RELIABLE	TURBOFAN HIGHLY.RELIABLE	TURBOFAN HIGHLY.RELIABLE
AIR INTAKE TYPE	PITOT HIGHLY.RELIABLE	PITOT HIGHLY.RELIABLE	PITOT HIGHLY.RELIABLE	PITOT HIGHLY.RELIABLE
AFTER-BURNER	NOT.REQUIRED UNKNOWN	NOT.REQUIRED UNKNOWN	NOT.REQUIRED UNKNOWN	NOT.REQUIRED UNKNOWN
BY-PASS RATIO	0.6 UNKNOWN	0.6 UNKNOWN	1 UNKNOWN	1 UNKNOWN
LOADS ARRANG.	OUTSIDE UNKNOWN	OUTSIDE UNKNOWN	OUTSIDE UNKNOWN	OUTSIDE UNKNOWN
WTO WE WF	11117 5904 2855	11117 5904 2855	7845 3676 1828	7845 3676 1828
WING L.E. SWEEP	30	30	30	30
WING ASPECT RATIO	4	4	4	4
WING MED. % THICK.	12	12	12	12
WING TAPER RATIO	0.35	0.35	0.35	0.35
NUMBER OF ENGINES	2 RELIABLE	2 RELIABLE	1 UNKNOWN	1 UNKNOWN
ENGINES ARRANG.	INSIDE THE FUSELAGE HIGHLY.RELIABLE	INSIDE THE FUSELAGE HIGHLY.RELIABLE	INSIDE THE FUSELAGE HIGHLY.RELIABLE	INSIDE THE FUSELAGE HIGHLY.RELIABLE
THRUST VECTORING	NOT.REQUIRED HIGHLY.RELIABLE	NOT.REQUIRED HIGHLY.RELIABLE	NOT.REQUIRED HIGHLY.RELIABLE	NOT.REQUIRED HIGHLY.RELIABLE
STABILITY	STABLE HIGHLY.RELIABLE	STABLE HIGHLY.RELIABLE	STABLE HIGHLY.RELIABLE	STABLE HIGHLY.RELIABLE
AIRCRAFT GEOMETRY	CONVENTIONAL UNKNOWN	CANARD UNKNOWN	CONVENTIONAL UNKNOWN	CANARD UNKNOWN
HIGH LIFT DEVICES	PLAIN.FLAPS HIGHLY.RELIABLE	PLAIN.FLAPS HIGHLY.RELIABLE	PLAIN.FLAPS HIGHLY.RELIABLE	PLAIN.FLAPS HIGHLY.RELIABLE
LANDING GEAR	TRICYCLE	TRICYCLE	TRICYCLE	TRICYCLE

Continue ☐ Exit ☐

Figure 6 - Example of configuration characteristics output

Programme Time-Schedule

During 1986 a contract had been stipulated between CSI-Piemonte and Aeritalia Combat Aircraft Group. It is important to point out that the prototype of the E.S. is now already working even though with a rather rough input-output module and if it is still under development.
In fact up to now (mid 1988) the E.S. is able to perform all the tasks contained in the first "big box" of fig. 4.
We have planned to complete all the package in the middle of next year, the work being started abount one year ago (mid 1987).
We must consider also that at the very beginning of the work a common working method had to be established between domain experts and knowledge engineers but, after this initial period the software is growing faster and faster.
So we are confident to be compliant with the planned time schedule.

Conclusions

The use of an Expert system in the preliminary design phase of combat aircraft has many advantages that can be summarized in some topics :

1 - the possibility of a faster definition of a group of baseline configurations compliant with the requirement

2 - the capability of an immediate appreciation about the sensitivity of the baseline in relation to changes in configuration elements

3 - the definition of a more standardized way to size a new configuration starting from a requirement avoiding human errors

4 - the creation of a consolidated data base coming from previous experience that can be also beefed up, modified, consulted and updated

5 - the capability of a quick evaluation about the inpact of the requirements changes on the configuration

It is also important to point out that the "expertise" existing today is frozen in the E.S., obviously with the possibility of expand it.
Moreover this knowledge will always be ready also if the experts that provided it are not available.

Acknowledgements

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