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ALGORITHMS OF PLANNING OF AIRCRAFT WEIGHT CALCULATIONS

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Annotation

The paper describes the process of a complex technical object design on the example of the aircraft, using information technology such as CAD/CAM/CAE-systems. The paper discloses a process weight design, which is associated with all stages of development aircraft and its production. Usage of a scheduling algorithm that allows to organize weight calculations are carried out at various stages of planning and weighing options to optimize the use of available database of formulas and methods of calculation. The problem of automatization of the weight estimations planning is solved in the process of designing an aircraft weigh design.

Key words: aircraft, weight estimation, graph sorting algorithm, planning.

Анотація

Стаття описує процес проектування складного технічного об’єкта на прикладі літака, використовуючи такі інформаційні технології, як CAD/CAM/CAE-системи. В статті розкритий процес вагового проектування, який пов'язаний зі всіма етапами розробки літака і його виробництва. Представлено використання алгоритму планування, що дозволяє упорядковувати вагові розрахунки, які проводяться на різних етапах вагового планування і проводити оптимізацію варіантів використання наявних в базі даних формул і методик розрахунку. При автоматизації процесу вагового проектування літака вирішується задача автоматизації планування ходу вагових розрахунків.

Ключові слова: літак, вагове проектування, топологічне сортування на графі, планування.

Аннотация

Статья описывает процесс проектирования сложного технического объекта на примере самолета, используя такие информационные технологии, как CAD/CAM/CAE-системы. В статье раскрыт процесс весового проектирования, который связан со всеми этапами разработки самолета и его производства. Представлено использование алгоритма планирования, что позволяет упорядочивать весовые расчеты, которые проводятся на разных этапах весового планирования и проводить оптимизацию вариантов использования имеющихся в базе данных формул и методик расчета. При автоматизации процесса весового проектирования самолета решается задача автоматизации планирования хода весовых расчетов.

Ключевые слова: самолет, весовое проектирование, топологическая сортировка на графе, планирование.

Introduction

It is known that complex technical object (CTO) design process, for example the aircraft design process, with the usage of CAD/CAM/CAE-systems includes following main stages: requirements specification, model of master-geometry (MMG, conceptual design), model of objects allocation (MOA, preliminary design) and model of complete product definition (MCPD, detail design). [1-3]

On a figure 1 there are the main aircraft models that represent the different aspects of its structure and functionality.

The managing parametrical model (MPM) in CTO design represents the set of initial engineering data for CTO developing in CAD/CAM/CAE-system. MPM is developed on the basis of accepted technical decisions and MMG data; also it is a basis for MOA and MCPD, that provides the possibility of optimum CTO control at all design stages with the use of modern computer information technology [4].

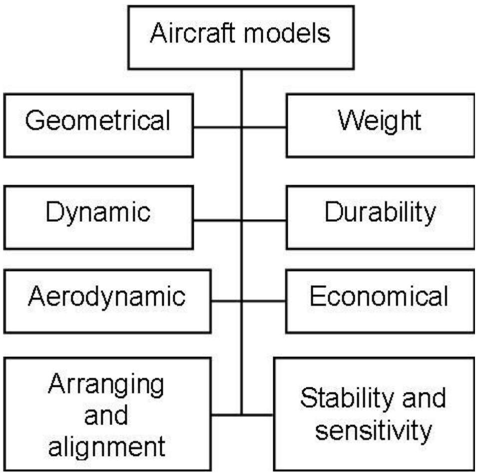

Figure 1. Main aircraft models

MPM includes the following components: MMG; kinematics schemes of mobile parts of units; design schemes; layout schemes of systems and the equipment.

A geometrical model (GM) at different stages could be presented as:

$$\mathrm{M}_i = \bigcup_{k=1}^{N} \mathrm{m}_k\,, \qquad (1)$$

where: m_k are GM of construction, system and equipment of the CTO on the appropriate design stage, N is GM amount.

GM of CTO construction, systems and equipment is possible to present as a following functional dependence: $m_k = f(X_k)$, where X_k is a MPM of the appropriate CTO component which can be presented as follows:

$$X_k = \bigcup_{j=1}^{S} x_j\,,$$

where: x_j is a component of MPM, particularly: based points of affixment, based and guide lines, planes; S is amount of parametric managing model components. A managing parametric model is a managing structure, which intended for support of initial data inheritance at all CTO design stages in the CAD/CAM/CAE – system. The managing parametric model consists of the following models: kinematical, construction, systems and equipment [4]. Thereby CTO component of construction, systems and equipment is possible to represent as: $m_k = f^k(x_i, i=1..s)$.

The process of GM component design using MPM conception is shown as an oriented graph on a figure 2.

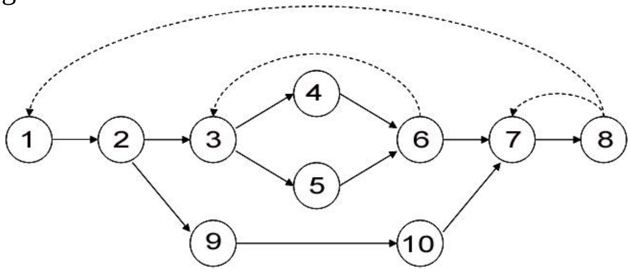

Figure 2. Graph of GM component design using MPM conception.

The block 1 on the figure 2 represent a stage when requirements specification and other data of conceptual design are analyzed and it is defined what models of MPM and GM will be designed. The block 2 represent a choice: if GM has movable parts than algorithm go to a block 3 otherwise transfer to a block 9. The block 3 represent the designing of the MPM kinematical model. The block 4 represent the designing of the MPM construction model. Block 5 represent the designing of the MPM system and equipment model. The block 6 represent a choice: if the changes in the kinematical model have an influence on the construction and the systems and equipments models than the algorithm go to a block 7, else transfer to the block 3. The block 7 represent designing the GM model using the kinematical, the construction and the system and equipments models. The block 8 represent a test: if the designed GM component satisfy the requirements than the design process is completed, else the algorithm go to the block 1. The block 9 represent the designing of the MPM construction model. The block 10 represent a test: if the system and equipment model of MPM is designing then algorithm go to the block 7.

The features of the weight design

The process of the weight design inseparably related to all stages of the CTO design. It consists of decision (in a definite sequence) of great amount of tasks, solution of which based on mutually complementary basic data and iterative methodology of estimations. Weight estimations conducted in the process of CTO design could be divided into projecting and execute [3]. Classification of weight estimation is represented on the figure 3.

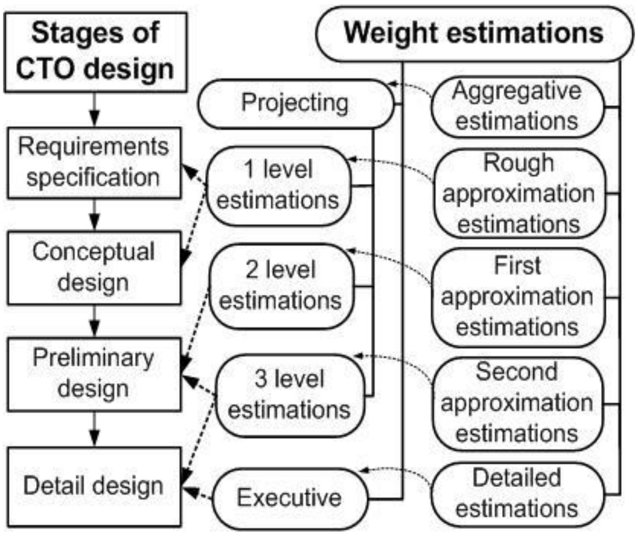

Figure 3. Classification of weight estimations

Projective estimations could be divided into three groups depending on the stage of CTO design. Estimations of the first level determine an external look of the CTO. Estimations of the second level are related to the choice of configuration and sizes of aggregates of CTO. The estimations of the third level determine the results of weight limits of the CTO. On every next stage there is clarification of the previous stage results. A general method of the weight design consists of implementation of next iterative procedures:

- originally a task solves with the use of hypothetical values of basic data and limited numbers of taken into account factors (this is the first cycle of iterations or so called first approaching);
- further there is a return in the beginning of the task and its decision repeats but this time with the specified values of basic data and re-estimation of factors found on the previous stage (this is the second cycle of iterations or second approaching);
- reiteration of the last stage.

This article tells about solving the task of automatization of the planning of weight estimations which appears in the process of automatization of CTO weight design. There are many sources which tell about different methods and formulas of weight design. The example of such source is [3]. Iterative character of the weight design is also traced in weight formulas that use results of previous level calculations as the basic data for estimations.

The mathematic formulation of the task

There is an oriented graph $G=<V,E>$ presented as lists of contiguity, where V is a set of vertices that represent components in a knowledge base (KB), E is a set of edges that represent connections between components in the process of weight calculation. For every component, consequently for every vertex v it is specified a set of objects $F=\{f_{i1},\dots f_{in}\}$ represented the weight formulas that are appropriate for this component. For every element of the set F there is a set of parameters $P=\{p_{ij1},\dots pi_{jk}\}$. The task of planning represented as a set of aims $A=<a_1,..,a_m>$, each of which contains a set of sub-goals $S=<s_{i1},...,s_{iq}>$. This set of sub-goals corresponds to a subset of those formulas of weight estimations which could be used on the define stage of weight design. For every aim and every sub-goal in the design process the program during the time of its work determine the level of application in the weight calculations - $\text{level}[y], y\in A\cup S,$ which characterize a place of this aim or sub-goal in the algorithm of weight estimations. These levels are determined in accordance with causal connections between aims in the plan. For every aim and every sub-goal in the program there are logical indicators $find[y]$ and $result[y]$ determined whether this aim or sub-goal have been considered and executed during the algorithms work.

In the process of work of the algorithm it is necessary to execute following sub - goals:

1.to make a sub-graph $G=<V`,E`>$ contained only those components $V'\subseteq V$ and edges $E'\subseteq E$ which are needed for implementation of calculations with set degree of exactness;

2.to set for every aim and sub-goal the level of application in the weight calculations;

3.in a case of need to add elements to the set of aims for receiving of possibility to compute the level of aims;

4.to make a sorting of aims and sub-goals.

The analysis of existing research and methods of solving the task

Every plan has described below four components where the first two determine the stages of the plan and the last two implement the functions of account that allowed to define how a plan can be fulfilled [4].

- A set of opened preconditions, in this task it is the set of unsolved aims A, which indicator $result = false$.

- A set of actions from which the stages of the plan consist of, in this task it is the set of sub-goals S, because this set represents the set of functions by which it is possible to carry out an aim and calculate a mass value of the component.
- The set of causal links $R = < r_1, \ldots r_w >$. This set represents all causal dependences between two aims of the plan.
- The set of variable binding constraints $R[s]$.

There is two difficulties in conducting the sorting of aims:

1.There are cycles in the graph. Most of sorting algorithms works with graphs without cycles.

2.An initial data for the task could be uncompleted.

Actually, the task described above is an example of a graph topological ordering task. This kind of tasks in most cases is solved with the use of sorting algorithm based on depth-first search or algorithm that represent graph as several levels structure [4-6]. First algorithm can't be used in this case because it could work only with acyclic graphs. In the case with cyclic graph the base of its using and the main thesis that provide proof of this algorithm would be broken [6].

Second algorithm also was designed for the work with acyclic graph. Also, for the using of second algorithm we need to have a matrix of adjacency, then the amount of algorithm iteration depends on amount of levels in the graph. Taking into account the features of weight design iterations, it is possible to reduce an amount of iteration with using a tree of aircraft components built on the previous stage and selecting for a view those aims that correspond to general assemblies above all. An algorithm that represent below could find levels of the most aims on a first iteration using this method of selecting aims for view.

Algorithm of the weight calculation planning method

The algorithm of solving the first and the second sub-task is presented on a figure 4 and 5. The sorting task is solving by adding elements with found level to the lists $L_1, \ldots, L_j$, where j is an amount of levels in the structure. Keys of aims and sub-goals are added to the defined list. For obtaining the plan components from these list are receiving one after another starting from the first list after the main task was solved.

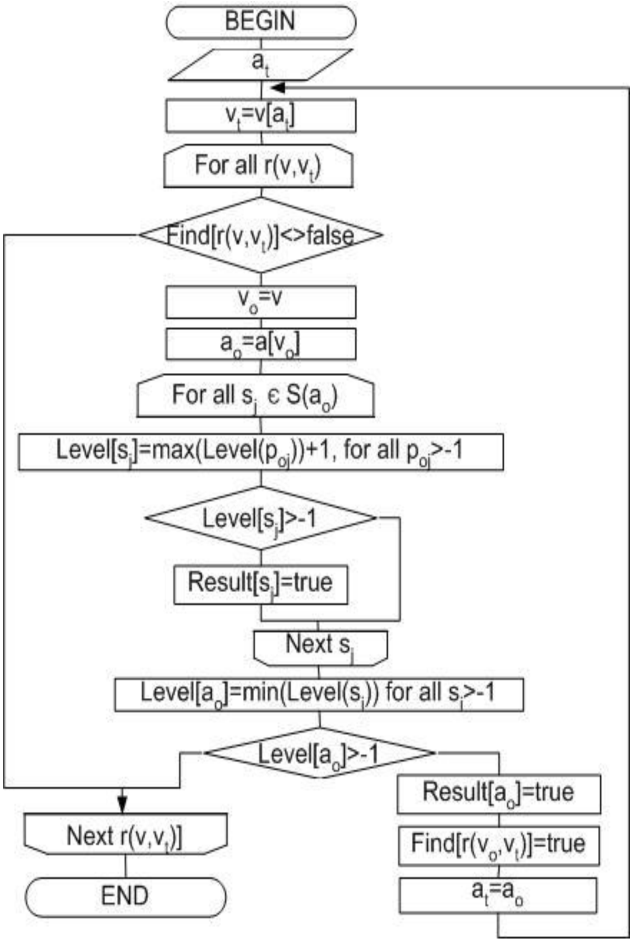

Figure 4. Algorithm of the level setting task

Estimation of complication of the algorithm

The estimation of complication of the algorithm show that all three its sub-tasks have linear degree of complication. The complication of the sub-task of construction of sub - graph $G`$ is determined by the next expression: $O(mn)$, where m is the amount of elements in the set A, n is the amount of elements in the set F. The complication of the sub-task of finding levels of the aims is: $O(t*j*m)+\Theta(th)$, where h characterize dimension of the graph G, t is an amount of conflicts, j is an amount of levels. The third sub-task has a complication: $O(m)$. All three sub-tasks of the algorithm have linear degree of complication, so the total complication is also in linear dependency from dimension of the graph G, dimension of set A, dimension of set F, amount of conflicts t, amount of levels j [7].

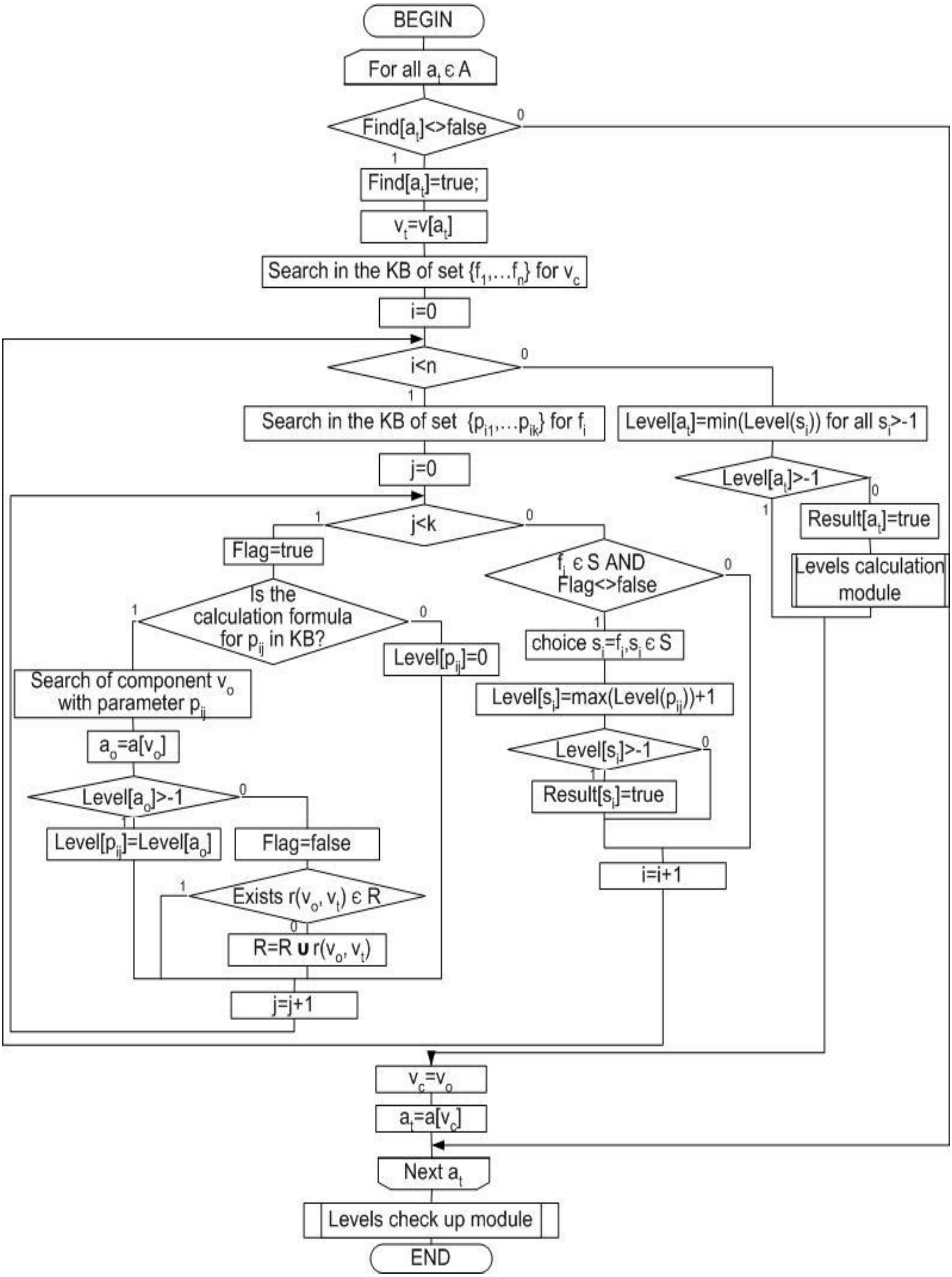

Figure 5. Algorithm of the planning task.

Ways of diminishing of complication of the algorithm:

1.Deleting of unnecessary terms from the set of terms R . A condition is deleted if the levels of both components(dependent and reason) are found. In this way the amount of elements w in the set R diminishes.

2.At the stage of adding new aims to the set A, the conflict terms should be examined above all.

3.At the stage of forming the sub-graph $G`$ the program should take into account the structure of the CTO.

The program could memorize dependent elements to decrease time of return for the calculation of previous components

Conclusion

Using of the algorithm of planning of weight calculations could make optimization of variants of using of formulas and calculation methods from knowledge base.

Two variants of creation of the list of aims are proposed in the program: automatically at the choice of the proper level of calculation or by user with a choice in the proper menu of the set of aims – components and sub-goals – mass calculation formulas.

Plan of calculation puts in order present variants of calculation for comfort of the user, but on every stage of weight calculations all possible formulas are brought. There is possibility to make transition between the stages of weight design process without implementation of calculation, any moment it is possible to return to the previous stage. All changes in the system of weight calculations are represented on any stage of weight design process. The program of planning of solving task is the part of informational technologies designed to create an virtual model of the aircraft.

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