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# MULTICRITERIA OPTIMIZATION IN THE COMPUTER-AIDED DESIGN OF UNMANNED AERIAL VEHICLES

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***Abstract****—The optimization procedure in computer-aided design problem is considered. The method of unmanned aerial vehicles structure constructing is proposed. The methodic of optimal weight coefficients values choice is developed.*

**Index Terms**—Multicriteria optimization; computer-aided design; unmanned aerial vehicle.

## I. INTRODUCTION

Computer-aided design (CAD) is the use of computer systems to assist in the creation, modification, analysis, or optimization of a design [1]. Computer-aided drafting describes the process of creating a technical drawing with the use of computer software [2]. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print or machining operations. Computer-aided design software uses either vector based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects, also called as render. Computer-aided design often involves more than just creation of 2D drawings and 3D models. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions. Computer-aided design is one of the many tools used by engineers and designers and is used in many ways depending on the profession of the user and the type of software in question.

Computer-aided design is one part of the whole Digital Product Development activity within the Product Lifecycle Management processes, and as such is used together with other tools, which are either integrated modules or stand-alone products.

3D parametric solid modeling requires the operator to use what is referred to as “design intent”. The objects and features created are adjustable. Any future modifications will be simple, difficult, or nearly impossible, depending on how the original part was created. One must think of this as being a “perfect world” representation of the component. If a feature was intended to be located from the center of the part, the operator needs to locate it from the center of the model, not, perhaps, from a more convenient edge or an arbitrary point, as he could when using “dumb” solids. Parametric solids require the operator to consider the consequences of his actions carefully.

Some software packages provide the ability to edit parametric and nonparametric geometry without the need to understand or undo the design intent history of the geometry by use of direct modeling functionality. This ability may also include the additional ability to infer the correct relationships between selected geometry (e.g., tangency, concentricity) which makes the editing process less time and labor intensive while still freeing the engineer from the burden of understanding the models. These kind of non-history based systems are called Explicit Modellers or Direct CAD Modelers.

Top end systems offer the capabilities to incorporate more organic, aesthetics and ergonomic features into designs. Freeform surface modeling is often combined with solids to allow the designer to create products that fit the human form and visual requirements as well as they interface with the machine.

Originally software for CAD systems was developed with computer languages such as Fortran, but with the advancement of object-oriented programming methods this has radically changed. Typical modern parametric feature based modeler and freeform surface systems are built around a number of key *C* modules with their own APIs. A CAD system can be seen as built up from the interaction of a graphical user interface with NURBS geometry and/or boundary representation (B-rep) data via a geometric modeling kernel. A geometry constraint engine may also be employed to manage the associative relationships between geometry, such as wireframe geometry in a sketch or components in an assembly.

Unexpected capabilities of these associative relationships have led to a new form of prototyping called digital prototyping. In contrast to physical prototypes, which entail manufacturing time in the design. That said, CAD models can be generated by a com-


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puter after the physical prototype has been scanned using an industrial CT scanning machine. Depending on the nature of the business, digital or physical prototypes can be initially chosen according to specific needs.

Today, CAD systems exist for all the major platforms (Windows, Linux, UNIX and Mac OS X); some packages even support multiple platforms. List of advanced CAD software includes Unigraphics, AutoCAD, SolidWorks, PRO/Engineer, SolidEdge, CATIA etc.

At the initial stage of design of technical facilities solved the problem of structural and parametric synthesis. With the introduction of computers and software in the process of designing the development of these procedures has gone in different directions.

Parametric synthesis and parametric optimization has engaged a large number of designers and programmers around the world. This is due to the fact that the problems of parametric design lend themselves well to formalize and their solutions developed quite a lot of methods based on the use of capabilities of traditional mathematics.

Structural design is based on a combination of discrete variables with the conditional logic constraints require the creation of new engineering methods with the possibility of their use in computer-aided design (CAD).

To solve the problem of finding new options for design-layout scheme of unmanned aerial vehicles (UAV), the technique of structural synthesis, based on the use of structural and parametric mathematical models of UAV quality alternatives signs of UAVs and their estimates obtained by the expert and the subsequent rapid analysis of selected options constructive-layout scheme for compliance with specified requirements.

## II. PROBLEM STATEMENT

To date, a large number of local technical solutions (TS) on ingredients UAV, designed in the form of electronic libraries and directories that may result from informational search the available databases. Comparing these locale olfactory solutions with dedicated features of the structure of the designed UAV formed a fairly complete set of morphological TS on the overall structure of the UAV.

In this regard, the problem of finding solutions to new versions of the structure proposed UAV structural synthesis technique based on the use of structural models in the form of tables and morphological morphological trees of quality variants of the signs of UAVs and their estimates obtained by an expert. The final stage of the procedure is to assess the structural synthesis of selectable options for the structure of the UAV to meet the requirements of project with rapid analytical method.

## III. THE METHOD OF UAV STRUCTURE CONSTRUCTING

Essence of the method of structural synthesis (structural optimization) is to decompose the projected allocation of the UAV and its most essential features.

Importance is assessed for signs of their impact on the performance of the main functions of the UAV. For each feature set optional alternative, which may be either existing TS or TS contained in a legally existing patents and copyright Indicative Islands. A set of attributes and their UAV alternatives forms a set of morphological TS.

Structural Synthesis of UAV consists of three steps: forming a plurality of input information, selection of suboptimal decisions and selection of optimal solutions. Stages of structural synthesis of UAVs and corresponding to them tasks are shown in the diagram in Figure. According scheme use of the morphological approach allows to input a large number of analogues and prototypes into morphological solution set during first stage of constructing structure UAV. The morphological set TS is divided into morphological subsets according to the extracted features from which variants of design elements and features of the designed UAV are retrieved.

The set of elements of each of the options and features UAV generates a plurality of structures of UAV.

Firstly, more recent alternative features are chosen from the catalogs of patents and copyright certificates.

Secondly, all of the alternatives signs UAV via check for compliance with the specified requirements, or for compatibility with each other. Model description of the procedure is given in Table [3], [4].

Thirdly, a set of specific indicators of quality for each feature is introduced. For each component total normalized rating scale (values selected by using the methods of expert judgment) is set with respect to any of the compared alternatives signs.

Complex criterion $F_i$ can serve as measure of quality of alternative features can serve, where $i$ is number of alternative characteristic representing a partial sum of an alternative embodiment of quality taking into account their weights.

Criterion $F_i$ is defined by the formula:

$$F^i = c^i{}_1 F^i{}_1 + c^i{}_2 F^i{}_2 + \ldots + c^i{}_j F^i{}_j, + \ldots + c^i{}_k F^i{}_k;$$

$$\sum_{j=1}^{k} c_j^i = 1,$$

where $c_j^i$ weighting $j$th quality indicator $i$th alternative feature; $c_j^i$ $j$th quality indicator $i$th alternative feature; $k$ is number of quality indicators studied trait.

Assignment of each indicator as a weight is an expert in accordance with the degree of influence on the index performance of a task, as shown in [5]. In the case where only experts conduct the provider of rank $n$ in descending order of importance, the weights may be determined as shown in [6] by formula:

$$c_j^i = \frac{e^{-j/k}}{\sum_{j=1}^{k} e^{-j/k}}.$$

I. Forming a plurality of initial information

1. Statement of the problem and feature selection UAV that affect the solution.
2. Variety of analogs and prototypes.
3. Variety of registered patents and patents.
4. Complex of criteria and constraints.

II. Selection of suboptimal solutions

1. Construction of morphological tables or morphological trees containing features of UAV and their alternatives.
2. Construction of compatibility tables.
3. Evaluation of alternative features of UAV by expert estimations on complex quality criteria.
4. Extraction of morphological tables and morphological tree variants of structures UAV containing alternatives features with the highest quality estimates.
5. Transfer of the parameters of functional elements of prototypes which have similar structure to the embodiments of functional elements of the new structure of the UAV.

III. Selection of optimal solutions

1. Estimate of selectable variants of UAV structure to meet design task using accelerated analytical method.
2. Selection of multiple rational options for the structure UAV for further calculations.

The sequence of problems of structural synthesis of UAV

**Compatability of alternative variants of features of UAV**

| Signs | | *A* | | | | *B* | | | | … |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $A_1$ | $A_2$ | … | $A_k$ | $B_1$ | $B_2$ | … | $B_m$ | … |
| *A* | $A_1$ | | | | | | + | | + | … |
| | $A_2$ | | | | | | + | | | … |
| | ⋮ | | | | | | | | | … |
| | $A_k$ | | | | | + | | | | … |
| *B* | $B_1$ | | | | + | | | | | … |
| | $B_2$ | + | + | | | | | | | … |
| | ⋮ | | | | | | | | | … |
| | $B_m$ | + | | | | | | | | … |
| ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | ⋮ | |

The above-mentioned restrictive rules allow to highlight the area of feasible solutions in a narrower field of solutions, which will be the most beneficial options for the structure of the UAV. From this narrow range of solutions primarily selected options structures that contain alternate versions of attributes with the highest quality ratings.

As shown in [4], to describe the UAV as a sign of its functional elements, or UAV in general are also various parameters (size, weight, volume, etc.).

Communication parameters with the functional elements of the newly created structures UAV established by transferring them from the prototypes that have similar structure.

The transport links to the functional parameters of the elements of prototypes for the functional elements of the latest versions of the structure UAV acquire the property of the modified existing TS.

As the newly formed structure variants UAV different from the existing analogue prototypes and any other signs, then their properties will also be different.

Thus selected options structure UAV are calculated and evaluated for compliance with the specified requirements of the simplified analytical method.

Software implementation techniques of structural synthesis of the UAV in a CAD image of UAV based on the use of product data management SWR-PDM Russian company Solid Works-Russia.

## IV. CONCLUSION

The aggregation methodic of optimal localhood optimization tasks solutions is proposed. The algorithm of UAV multicriteria optimization is based on mathematical models use. The given approach permits to improve the quality of design and to decrease time and cost of design.

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**А. В. Брикалов. Багатокритеріальна оптимізація у автоматизованому проектуванні безпілотного літального апарату**

Розглянуто процедуру оптимізації у задачі автоматизованого проектування. Запропоновано метод структурного синтезу. Розроблено методику розрахунку вагових коефіцієнтів.

**Ключові слова**: багатокритеріальна оптимізація; автоматизоване проектування; безпілотний літальний апарат.

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**А. В. Брыкалов. Многокритериальная оптимизация в автоматизированном проектировании беспилотного летательного аппарата**

Рассмотрена процедура оптимизации в задаче автоматизированного проектирования. Предложен метод структурного синтеза. Разработана методика расчета весовых коэффициентов.

**Ключевые слова:** многокритериальная оптимизация; автоматизированное проектирование; беспилотный летательный аппарат.

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