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Geometric Simulation of Design Objects in Aerospace industry

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Abstract. The article outlines the approach used for geometric simulations of design objects in aerospace industry. The computational model describing the effect is presented, which is recommended for practical use in construction.

1 Introduction

While designing a new item the designer is aimed at the development of functions and geometry, then it is required to arrange these results in specifications. Below we will outline the basic approaches which we recommend to use in aerospace industry (basic approach was developed in [1]). The importance of new methods and innovations in aerospace industry is described in [2].

Geometry defines shape and dimensions of an item and its components, its functions describe operational principles and interaction of its subcomponents. Specifications are supplemented by information about the material and processing techniques.

In the course of designing the designer not only develops concepts of item's geometry but works with it using established practices of geometry description. According to operating techniques, up till now in designing bureaus the designer expresses concept of the item's shape and dimensions in the form of 2D presentation – engineering drawing.

Computer aided design can be promoted by engineering implementation and computerized presentation of the mentioned concepts of the item, as well as possibility of their processing at various levels of abstract description.

The term "specifications" involves all information required for the item production which should be presented in the form, oriented at certain production technique. This concept covers all engineering drawings, specifications and flowcharts. Technical specifications embody the most important information required for the produced item. Computerized development of concepts of the item and computerized processing of the information in specifications required for relevant description.

Geometric object requires description of the item using mathematical model in Cartesian space, and the presentation is arranged with consideration of the shape and dimensions. Presentation of functional links in the item, required upon designing, is not taken into account at this stage. The mentioned geometric objects are mathematical (algebraic) structures presenting more or less accurate embodiment of the item's geometry in the mentioned aspect. The presentation and description of such geometric objects are based on analytical geometry.

2 Geometric simulations

Problematic procedures, which should be applied to the item in the frames of considered engineering tasks, are referred to the item description as geometric object. Interrelation between such abstract geometric object with the array of human concepts is performed by presenting geometric object in the form of graphic presentations.

A graphic presentation means projection of 3D geometric object onto 2D plane. A particular case includes 2D geometric objects.

Interrelation between geometric object and human reasoning, together with object graphic presentation, can be performed by fabricating the material model of a geometric object.

Specifications and graphic presentation are closely related by dependency relation, because graphic presentation is a specialized element of specification.

Selection of reasonable form for describing geometric objects and graphic presentations is defined by actual practices and type of processed items. One of the classifications, oriented at industrial items, stipulates the following classes of geometric objects: prismatic, revolved bodies and arbitrary shapes. Prismatic items are restricted by planes; revolved bodies, respectively, by the second order surfaces (cylinders, cones, spheres); and items of arbitrary shapes by surfaces of higher orders or surfaces which cannot be described exactly. The task is set in principle as follows: in terms of analytical geometry the initial elements can be defined as points, lines, curves, planes, surfaces, as well as bodies. This set of objects is used to generate new objects

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according to the established syntax. The generation is performed as the recursive procedure, that is, the objects obtained from the main objects can be combined with other main objects into new objects. Two contradictory requirements are related with such description of geometric object:

– the description should be suitable for subsequent processing using computer aided designing;

– the description should be structured to such extent than it could be used for development of graphic presentation, that is, sequence of instructions controlling motions of the plotting instrument or the electron beam.

Flat objects are described by the so called simplest elements: primitives. The primitives are considered as 2D objects characterized by two highlighted points: the beginning and the end. These points are the sites of possible combination of the primitives. The simplest elements are described in terms of classes containing the elements' names.

The names facilitate recognition of data for initial and final points, as well as determination of other element's characteristics. This description is applied for development of drawings, graphic presentation of details on flat screen. Analysis of numerous engineering drawings demonstrates that about 99% of all drawing elements are segments of lines and circular arcs.

3D geometric objects are described on the basis of the following algebraic structures:

G - graph structure;

F - surface element structure;

K - body structure.

G – structure, that is the object comprised of points on plane or in space $P(p_i)$, where P is the main set of all allowed points p_i. Merging and attachment operations are allowed. The merging operation designated by " - " symbol corresponds to the segment of the line, connecting points $\boldsymbol{p}_1$ and $\boldsymbol{p}_2$: $(p_1 - p_2) = x$. The obtained element belongs to the G-structure. The initial point of oriented element $\boldsymbol{x}$ is $\boldsymbol{S}(\boldsymbol{x})$, the final point is $\boldsymbol{l}(\boldsymbol{x})$. The attachment operation is designated by " . " symbol. It interrelates the points $\boldsymbol{p}_1$ and $\boldsymbol{p}_2$ and attaches them with G-structure without generating an additional element $(p_1 \text{ and } p_2)$.

Selecting " $\circ$ " as the sign for " - " operations in " . ", taking $x = g_1 \circ g_2 \circ g_3 \circ g_m$, it is possible to describe any structure plotted from nodes $\boldsymbol{P}$ and edges $\boldsymbol{K}$, where $\boldsymbol{K} = K\{(p_1 - p_2)\}m_{ij}$ is the set of graph's edges; G is the set of points and segments and < **G**, - , .> is a certain algebra.

This form of representation (point model) can be considered as geometric image of a body restricted by flat surfaces. Graphic images of such geometric object are the so called transparent or wire lattice models (polyhedra).

Graphic images of polyhedra are presented by flat graphs. The presented edges are intersection lines of surfaces restricting the geometric object. The items are presented in the form of transparent wire frame.

F-structure serves for presentation of bodies and surfaces composed of elements. The main elements are curvilinear tetragons, described parametrically: $X = X(U,v)$, $y = y(U,v)$, $Z = Z(U,v)$. Paramtrized element is defined by logical expression:

$$\boldsymbol{e} = \left(\boldsymbol{X} = \boldsymbol{X}(\boldsymbol{U}, \boldsymbol{v})\right) \wedge \left(\boldsymbol{y}(\boldsymbol{U}, \boldsymbol{v})\right) \wedge \left(\boldsymbol{Z} = \boldsymbol{Z}(\boldsymbol{U}, \boldsymbol{v})\right) \wedge$$
$$\wedge \left(\boldsymbol{b} = \boldsymbol{b}(\boldsymbol{U}, \boldsymbol{v})\right)$$

which equals to ***I***, if the point $p(x,y,z)$ belongs to the surface element. Double valued function $b(\boldsymbol{U},\boldsymbol{v})$ serves for element's restriction. It equals to ***I*** inside of the element and ***O*** outside of it. In order to integrate two point sets, two surface elements are merged by disjunction $f = f_1 \vee f_2$. Here $(f, \boldsymbol{v})$ can be considered as an algebra.

K-structure is intended for plotting the bodies using logical functions of disjunction $K = K_1 \vee K_2$ and conjunction $K = K_1 \wedge K_2$ similar to merging of point sets, since together with plotting the bodies using the principle of indication of surface restricting elements, it is necessary to generate bodies directly of main (basic) bodies. The main objects (bodies) are the functions $\boldsymbol{a}(x,y,z)$ taking real values. For each expression ***a*** it is possible to determine:

main closed body $h(x,y,x) = \left[\boldsymbol{a}(x,y,z) < 0\right]$;

main open body $h(x,y,x) = [\boldsymbol{a}(x,y,z) > 0]$;

main surface $h(x,y,x) = [a(x,y,z) = 0]$.

Here $K, \vee, \wedge, >$ can be considered as algebra.

3 Conclusions

Descriptions of hierarchical generation of geometric objects and graphic images depend on a specific setting of tasks, thus, it is actually possible to obtain various modifications as well as particular cases of the aforementioned forms of description.

References

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