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A software tool for generic parameterized aircraft design

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Abstract

In this work a surface generation software named Ge.P.A.S. (for generic parameterized aircraft surface) is presented, designed for the construction of aircraft aerodynamic surfaces. The surface generation procedure is parameterized and different aircraft configurations can be produced in an interactive way. A hierarchical structure of geometric parameters was adopted, resulting in easier manipulation of the shape and a scalable number of control parameters. Additionally, the geometric parameters may serve as design optimization variables in cooperation with an external optimizer. The surface generation is based on the use of NURBS curves and surfaces, which provide the ability to produce complicated geometries with a relative small number of design variables. Standard or user-defined airfoil sections can be used for the wing generation. The surface description is compatible with international input/output standards; IGES and STEP formats are supported for the output files. Consequently, Ge.P.A.S. can serve as a preprocessor for other software packages, which may be used in order to refine the geometry or to generate the grid for numerical simulations. The geometric algorithms, the software features and its basic characteristics are presented in this paper, along with a demonstration of its abilities in sample aircraft configurations.

Keywords: Aircraft design; Surface generation; NURBS surfaces

1. Introduction

The rapid improvement of computer power, analysis solvers and computational optimizers has introduced major changes in the way aircrafts are designed. The available computational tools and those under development will provide the ability to investigate completely different configurations, with a large number of design parameters, while the aircraft characteristics will be the subject of multi-disciplinary and multi-point design optimization procedures. Complicated calculations are now affordable using a simple desktop computer or a cluster of them, and computational tools used in the past only by the major aircraft constructors, are rapidly spreading in the area of small aircraft companies, such as U.A.V. (unmanned aerial vehicle) builders.

One of the major tasks in the conceptual design phase of a new aircraft is the definition of its configuration along with the main geometrical characteristics. Present CAD packages provide several tools for the parametric description of complicated geometries, and surface definition is usually accomplished utilizing such CAD systems. However, in general they do not support surface parameter variations for intelligent aircraft design studies, using analysis software and optimization techniques [1,2]. Additionally, results from aircraft design optimization efforts, demonstrated the sensitivity of the optimization procedure to the geometry parameters definition [3,4]. For aerodynamic early phase conceptual design, a step prior to the application of CAD is needed, i.e. a toolbox that will produce generic, parameterized aerodynamic surfaces, which will take into account the special needs and constraints for the conceptual design of an aircraft [5,6]. This toolbox should

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Nomenclature

a	airfoil's incidence angle
a_{root}	incidence angle of the root airfoil
a_{tip}	incidence angle of the tip airfoil
b	wing span
b'	non-dimensional wing span
C	chord of an airfoil section
C'	non-dimensional chord of an airfoil section
C_{root}	root chord of the wing
C'_{root}	root chord of the wing in non-dimensional form
dh	wing's dihedral angle
h_{RV}	reference volume's half-height
h'_{RV}	reference volume's non-dimensional half-height
h_{CS_U}	scaling parameter for the upper half-height of the cross section
h_{CS_L}	scaling parameter for the lower half-height of the cross section
l_{RV}	reference volume's length
l'_{RV}	reference volume's non-dimensional length
L_{ref}	aircraft's reference length
t_{RV}	reference volume's half-thickness
t'_{RV}	reference volume's non-dimensional half-thickness
t_{CS}	scaling parameter for the half-thickness of the cross section
x, y, z	coordinates of a point in the local coordinate system of a reference volume
x_{CS}, y_{CS}, z_{CS}	coordinates of the origin of the local coordinate system of a control station
$x'_{CS}, y'_{CS}, z'_{CS}$	coordinates of the origin of the local coordinate system of a control station in non-dimensional form
xp, yp	coordinates of each point of the cross section, in the local coordinate system of the corresponding control station
xp', yp'	coordinates of each point of the cross section, in the local coordinate system of the corresponding control station in non-dimensional form
X, Y, Z	coordinates of a point in the global coordinate system
X_{RV}, Y_{RV}, Z_{RV}	coordinates of the origin of the local coordinate system of a reference volume (defined in the global coordinate system)
$X'_{RV}, Y'_{RV}, Z'_{RV}$	coordinates of the origin of the local coordinate system of a reference volume in non-dimensional form
Y_{root}, Z_{root}	root chord's vertical and axial positions, with respect to the global coordinate system
Y'_{root}, Z'_{root}	root chord's vertical and axial positions, in non-dimensional form
$\Lambda_{C/4}$	wing sweep angle defined at the quarter chord line
Λ_{LE}	wing sweep angle defined at the leading edge

provide enhanced flexibility, for the generation of a great variety of complicated surfaces and will serve as an interface between the designer, at one hand, and analysis, optimization and CAD software, on the other.

Besides the well known CAD packages, very few specialized aircraft design tools have been presented in the open literature so far. Aero grid and paneling system (AGPS) [7,8] is a powerful tool for aircraft design and analysis. The program is applicable to all kinds of aircraft components, such as wings, fuselages, nacelles, tail surfaces, etc. Curves are generated as a chain of segments and surfaces as a network of four-sided patches, however they may be both considered as single entities. The coordinates of a curve are parameterized and stored as function of a parametric variable, which is a proportion of the non-dimensional arc length. The coordinates of a surface's point are represented as function of two parametric variables. The AGPS user interface includes graphic menus, as well as a command language which is applied through command files. The software is able to generate unstructured grid on the generated surfaces, for use in CFD codes, and store it in the program's data structure. Ray tracing techniques have been developed for better 3D display of the generated geometries, rendering the program extremely powerful.

I3G [9] is a software used for generating geometric models for computational aerodynamic codes. The software imports surface data from other major CAD programs and transforms them in a code independent format, which is then easily imported as input in other aerodynamic analysis codes. Surface manipulation techniques have been included in the software, as well as display functions and database operations. The program has been designed to provide simple and powerful surface grid-point generation and output data formatting, while its user interface is mainly graphical, with simple to use menus and prompts.

RDS-Professional [10,11] is an aircraft design and analysis software, which supports 3D design and incorporates analysis modules for aerodynamics, weight, propulsion and cost. The software automates classical techniques for aircraft design used in industry, including computational tools that perform trade studies and early stage optimization. Aircraft geometry is produced using lofting techniques interactively, while aircraft components are designed using geometry parameters with physical meaning. Interactive graphical interface renders the program user-friendly.

RAGE software (http://www.desktopaero.com/products/RAGECatalogPage.html) is designed for the generation of aerodynamic models, using a central parameterized geometry definition. It is used for quick parametric studies and optimization at the preliminary stage of aircraft design. Aircrafts are designed with the use of fuselage, wings and nacelle components which are available in the software.