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Comprehensive aircraft configuration design tool for Integrated Product and Process Development

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ABSTRACT

This paper describes an efficient aircraft geometry design tool which is necessary for design and analysis applications through Integrated Product and Process Development (IPPD). The design process decomposes aircraft geometry into several components to represent it accurately and realistically with a reduced number of shape control parameters. For this purpose, several configuration representation algorithms are thoroughly investigated and discussed. The proposed configuration generation algorithm employs the super ellipse equation with simple analytic distribution functions, Class function/Shape function Transformation (CST) and can represent and manipulate complex shapes accurately with a small number of control parameters. A model of aircraft geometry, represented in this approach, can be applied to conceptual and preliminary stages of aircraft design and development with realistic and accurate configuration data. A Parameter-based Comprehensive Aircraft Design (PCAD) tool which implements a geometry generation process for aircraft design and optimization using customization of commercial computer-aided design software (CATIA V5) and the Product Data Management (Enovia Smarteam). The proposed configuration design tool could be especially efficient when automation, flexibility and rapid changes of geometry are required in a short time and with low computational resources.

1. Introduction

Geometry definition plays a key role in aircraft design, development and optimization. For efficient geometry generation, especially during the early stage of design, a step before the application of automated geometry generation is needed, i.e. a toolbox that will produce generic and parameterized aerodynamic surfaces, which takes into account special requirements and constraints. Among well-known general CAD packages, very few are specialized to aircraft design. General CAD systems offer solutions for providing data for general engineering systems and thus cannot entirely fulfil all configuration requirements of aircraft development throughout all design phases.

Several authors, including Trapp and Sobieczky [1,2], Kulfan [3–5], Samareh [6] and Athanasopoulos et al. [7], have studied and developed representation techniques and methods to overcome the aforementioned issues with aircraft shape representation. Among configuration design tools for aircraft, Generic Parameterized Aircraft Surface (Ge.P.A.S.) [8], RAGE [9] and RDS-Professional [10] are specialized to fixed wing aircraft design, and HESCAD [11] is specialized to the pre-conceptual design stage of rotorcraft. There are many parametric geometry creation and manipulation tools with GUIs [12–16]. These tools can provide considerable cost savings in the product design process through reduction of design time. For example, Vehicle Sketch Pad (VSP) [17] parametric geometry modelling tool developed by NASA is getting popularity in conceptual design of aircraft. Recently, in most CAD systems, special tools for customization or Application Programming Interface (API) connection are being improved, such as CAA, CATIA VBA and UGS NX Open API. It is clear that the implementation of these new features in representation algorithms will give better functionality in terms of integration ability and suitability for MDO and IPPD.

In recent years, engineering systems, including automobile, ship and aircraft are being considered concurrently with different disciplines and objectives applied to the analysis of effects at the early stage of design. This is known as Integrated Product and Process Development (IPPD). However, analysis modules and disciplines are still not connected smoothly to the geometry module. Price et al. [18,19] have investigated current developments and status of the integrated design approach.

Kulfan [3,5] defines the desirable features of promising aerodynamic geometric representation techniques as: (a) mathematical efficiency (i.e. smoothness along axis, accuracy, numerical stability

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Nomenclature

API	Application Programming Interface
BOM	bill of materials
CAD	computer-aided design
CAE	computer aided engineering
CAGD	computer aided geometry design
CFD	computational fluid dynamics
CST	Class function/Shape function Transformation
DB	database
DMU	Digital mock-up
EDF	elliptical and distribution functions
FEA	finite element analysis
GUI	Graphical User Interface
IPPD	Integrated Product and Process Development
MDO	Multidisciplinary Design Optimization
PDM	Product Data Management
UAV	unmanned aerial vehicle
IGES	initial graphics exchange specification

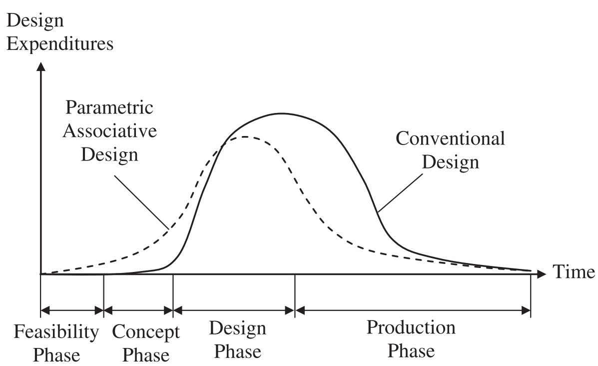

Fig. 1. Design expenditures in an aircraft design project [12].

and robustness); (b) consistency and intuitiveness; (c) representation ability with a few variables and easy control capability (i.e. flexibility). However, to meet all these requirements in geometry representation is not an easy task. The main issue is how to define an acceptable (smooth, continuous, flexible, intuitive, robust, low-cost, etc.) geometry representation method while satisfying all these requirements.

This paper presents an automated configuration design method and tool for realistic representation of various aerospace vehicle geometries using fewer control parameters. The design tool builds an aircraft geometry using typical and common components and intended for using them in conceptual and preliminary design phases.

The proposed design and representation tool is based on an effective use of a super elliptic formulation with exponential and polynomial distribution functions in an example of configuration design. It is demonstrated that with this design method, designers

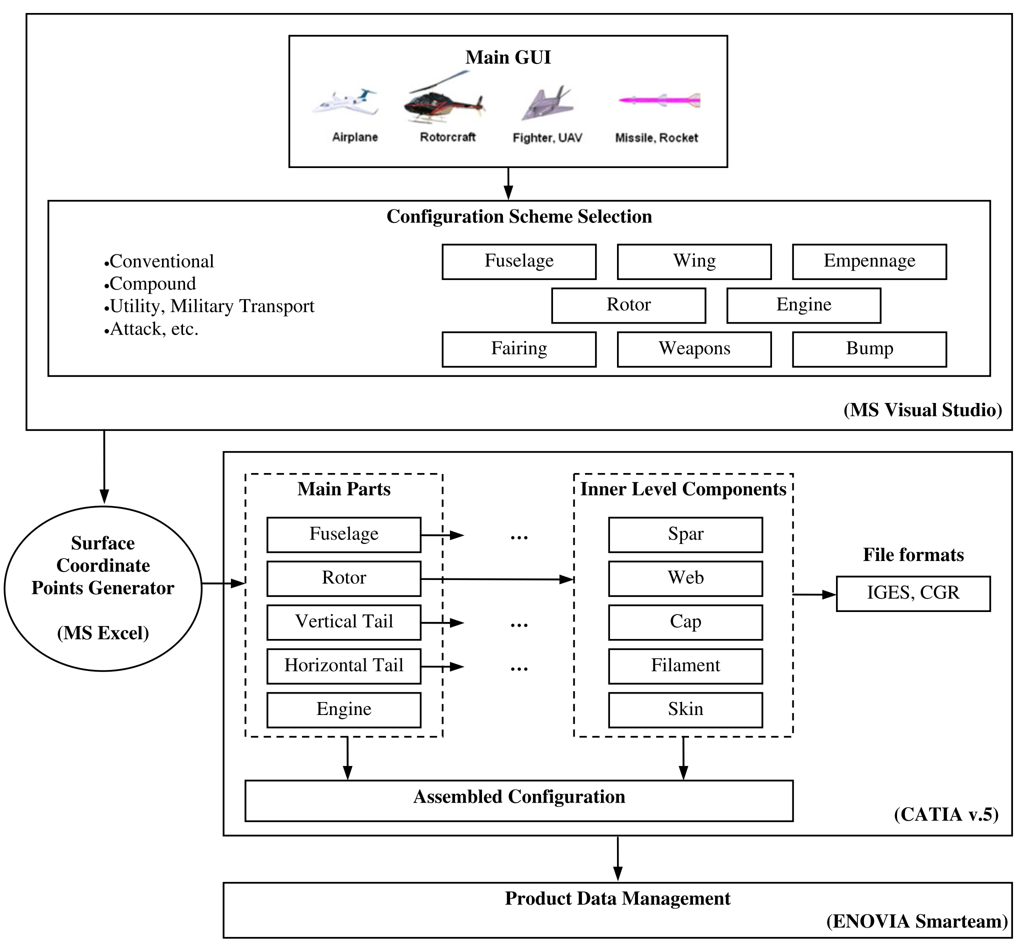

Fig. 2. PCAD architecture.