Knowledge-Based Flight Control System Integration in RAPID

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Keywords: *Flight control system, RAPID, Knowledge Pattern, Parametrization, Hydraulic aircraft systems.*

Abstract

Nowadays, aircraft's design and development processes are not only time-consuming but also incur high economic cost. In addition, system integration is highly a multi-disciplinary design process, which involves a large number of different discipline teams working at the same time and space. The main objective of this work is to investigate in the early design stages to define and integrate flight control system. The purpose is to improve the functionality of an in house produced aircraft conceptual design tool RAPID carried out at the Division of Fluid and Mechatronic Systems, Linköping University.

1 Introduction

The process that leads to the entire design and definition of an aircraft is highly complex and multidisciplinary [5]. It is also a time consuming and costly activity. Furthermore, systems integration within this process is one of the best examples of this multidisciplinary engineering, as different specialized teams work and coordinate their operations in the same wireframe and with different main objectives, although the global aim is always shared [2] [4]. RAPID [1][3] is a knowledge-based aircraft conceptual design tool developed in CATIA, with the purpose to move forward enhancing CAD modelling in conceptual and parametric design [6] [7].

2 Objectives

The main purpose of this project is to enhance the applicability and functionality of the previously developed work on RAPID (Robust Aircraft Parametric Interactive Design). In order to achieve this, the target milestones established as below:

A. Design and development of templates for the basic components within a typical civil aircraft flight control system.
B. Automatic integration of the defined templates within the pre-existing aircraft geometry using a Knowledge Pattern approach.
C. Allow parametric modification of the flight control model to improve a future preliminary design process experience.
D. Extend several flexible and parametric design functionalities in a user interface linking RAPID in CATIAV5 and Microsoft Excel.

3 Flight Control System Development

The automatic generation of the flight control system model with a high level of flexibility and adaptability is based on CATIA templates creation. Components are designed, along with their driving parameters, in one of these templates. Templates will be allowed to be instantiated as many times as required. In addition, not all the geometry needs to be instantiated, avoiding the root CATProduct from including too much information [10] [11] [12]. A list of the created templates is listed below:

A. wingSystemsTemplate.CATPart
B. horizontalTailSystemsTemplate.CATPart
C. verticalTailSystemsTemaplet.CATPart
D. newActuatorComponent.CATPart

3.1 The Development Method

The flight control system model created for RAPID is not aimed to become a real specification for both, the flight control components and the hydraulic systems of the aircraft.

3.1.1 Simplifications and Assumptions

In this section, the necessary hypotheses taken during the design process are listed [8] [9].

A. Systems symmetry
B. Templates geometry simplicity
C. Valves omission
D. Flight control system positioning
E. Default flight control system version
F. Routing considerations
G. Hydraulic power assembly

3.2 The Instantiation Structure

The flight control system instantiation is divided into three parts within the product (RAPID.CATProduct) tree. These parts are:

A. wingSystems.CATPart
B. horizontalTailSystems.CATPart
C. verticalTailSystems.CATPart

They are associated with three areas of work within the aircraft structure and they take external references from its geometry. However, this division does not fully correspond to the templates definition, which is explained as follows.

Templates also take external references from the RAPID.CATProduct, they allow the creation of geometrical sets and the corresponding User Defined Features, along with its inputs and outputs. The templates are stored and linked to a CATIA catalogue. Therefore, their automatic instantiation is possible.

3.2.1 wingSystemsTemplate

It is used in the model as the main template (as example, its structure can be observed in Figure 1).

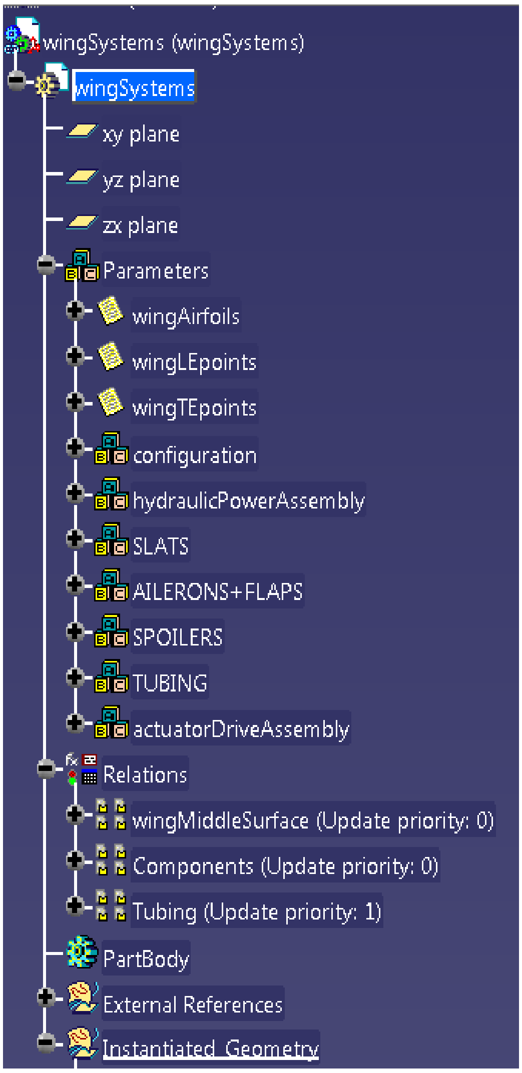


Figure 1: wingSystems.CATPart structure.

Assuming that, reusable UDFs that are used in the horizontal tail and vertical tail flight control models, as the path (UDF) and the ellipticTube (UDF) are defined here. The first one generates the auxiliary geometry which can be observed in Figure 2, as guide lines and referential planes, whereas the second one creates the system routing by taking two planes, a point and a line as inputs, they are illustrated in Figure 2 and Figure 3.

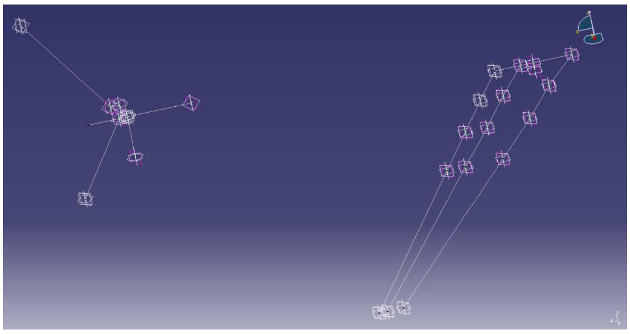


Figure 2: Overview of the geometry created by the path (UDF).

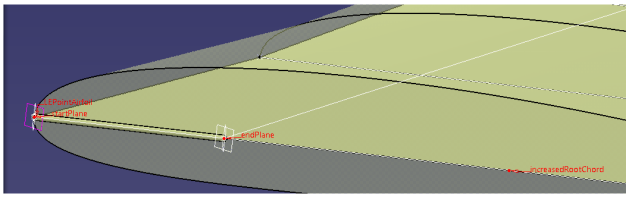


Figure 3: Inputs in ellipticTube (UDF).

In this template, other elements of the flight control system are also defined in the corresponding UDFs. They are listed and briefly explained as follows.

A. projection (UDF)

It is responsible for the creation of the referential surface used for physical components positioning. An overview of the template and its inputs are in Figure 4.

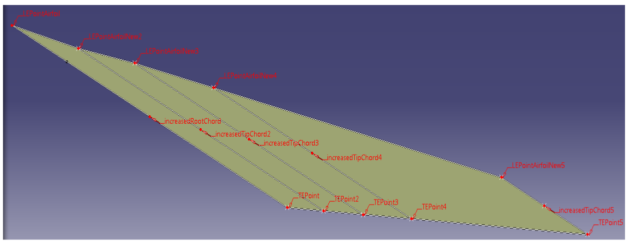


Figure 4: Inputs in projection (UDF).

B. fuselageGeometry (UDF)

It creates auxiliary geometry in the fuselage wireframe as can be observed in Figure 5. Its main purpose is to be a reference within the fuselage structure for flight control systems in the wing and in the tails too.

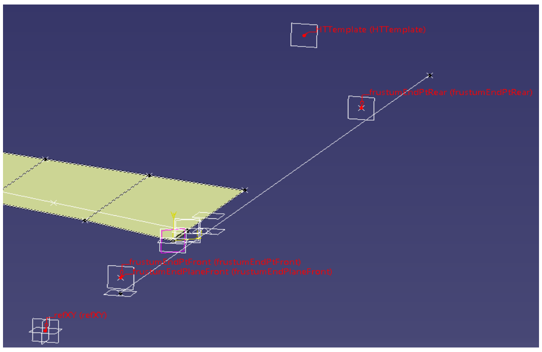


Figure 5: Inputs in fuselageGeometry (UDF).

C. Pump (UDF)

This physical component holds together pump, reservoir, accumulators and the corresponding valves in the hydraulic power assembly as shown in Figure 6 along with its inputs.

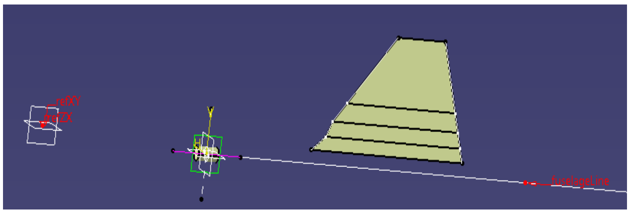


Figure 6: Inputs in Pump (UDF).

D. rotaryActuator (UDF)

It creates the geometry emulating the rotary actuator that powers the leading edge slats as seen in Figure 7.

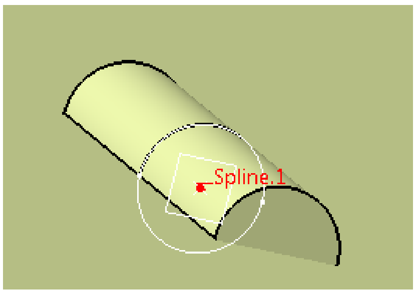


Figure 7: Inputs in rotaryActuator (UDF).

E. electricDriveUnit (UDF)

It defines the component supplying electric power to the slats actuator. The template geometry can be observed in Figure 8.

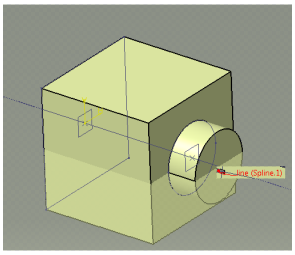


Figure 8: Inputs in electricDriveUnit UDF.

3.2.2 newActuatorComponent

This template holds the definition of the hydraulic actuators in the actuators (UDF) and other components with a common geometry, the boxComponents, in the box (UDF). Both templates are shown in Figure 9 and Figure 10 respectively. As a remarkable fact, the newActuatorComponents template is not so strictly linked to a part of the aircraft geometry as the others are. These components are instantiated among all the referential structure.

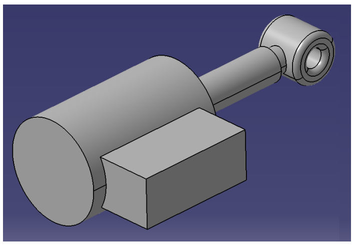


Figure 9: Tandem actuator template.

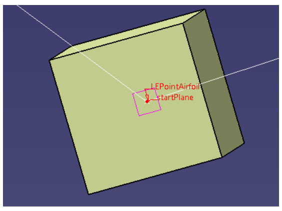


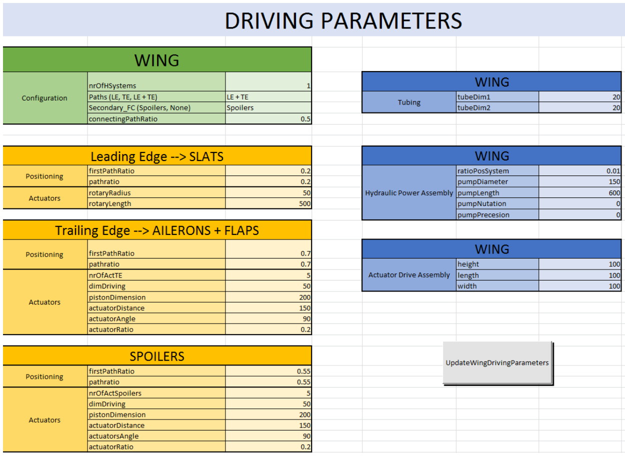
Figure 10: Inputs in box (UDF).

3.2.3 horizontalTailTemplate and verticalTailTemplate

These two templates are linked to the aircraft tail as they are used to generate the necessary geometry for the integration of the flight control system in the same. It is important to highlight that most of the physical components templates have been already defined in previously explained templates. For that reason, the UDFs created in these two templates generate the referential surface for both aircraft parts: hTailProjection (UDF) and vtailProjection (UDF). Their geometry and inputs are parallel to the ones previously shown for the wing in Figure 4.

4 Excel User Interface

The purpose of this software is to provide an easy, powerful and flexible user tool. The source code to link the CATIA V5 model and the Microsoft Excel user interface is written in Visual Basics and allows to automatically updating the 3D model. Parameters are logically organised and visual information is also supplied to help user's work.



DRIVING PARAMETERS

WING		
Configuration	nrOfHSystems	1
	Paths (LE, TE, LE + TE)	LE + TE
	Secondary_FC (Spoilers, None)	Spoilers
	connectingPathRatio	0.5

Leading Edge --> SLATS		
Positioning	firstPathRatio	0.2
	pathratio	0.2
Actuators	rotaryRadius	50
	rotaryLength	500

Trailing Edge --> AILERONS + FLAPS		
Positioning	firstPathRatio	0.7
	pathratio	0.7
Actuators	nrOfActTE	5
	dimDriving	50
	pistonDimension	200
	actuatorDistance	150
	actuatorAngle	90
	actuatorRatio	0.2

SPOILERS		
Positioning	firstPathRatio	0.55
	pathratio	0.55
Actuators	nrOfActSpoilers	5
	dimDriving	50
	pistonDimension	200
	actuatorDistance	150
	actuatorsAngle	90
	actuatorRatio	0.2

WING		
Tubing	tubeDim1	20
	tubeDim2	20

WING		
Hydraulic Power Assembly	ratioPosSystem	0.01
	pumpDiameter	150
	pumpLength	600
	pumpNutation	0
	pumpPrecesion	0

WING		
Actuator Drive Assembly	height	100
	length	100
	width	100

UpdateWingDrivingParameters

5 Conclusion

The work presented is a first step into a full new line of work carrying out flexible parametrical integration of the necessary functional systems within RAPID. A first milestone is attained in this work, as it has been investigated and proved the possibility to define a flight control system model that represents different integration solutions in a relatively easy and fast way for the user. Moreover, the work has been automated to save time for future developers and users, avoiding carrying out the first stages of recurrent work in templates and model definition.

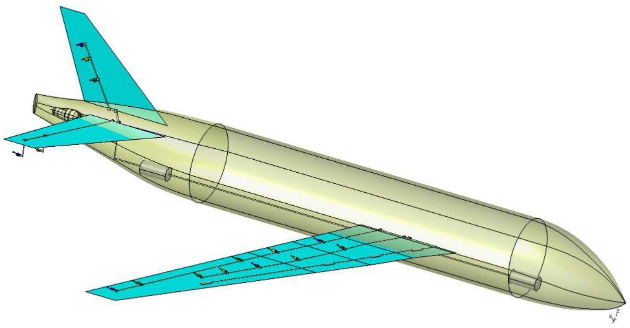


Figure 11: Final flight control assembly integrated in RAPID.

To conclude, flexible flight control system integration in RAPID has been developed, proving the usefulness of CATIA Knowledge Pattern to enhanced conceptual aircraft systems design by means of design automation. A picture of the resulting assembly is shown Figure 11.

6 Future Work

In order to give to the model a higher applicability and realistic appearance components templates definition can be modified accordingly. In addition, some other elements within the flight control and hydraulic system may be also included in the model.

Some of the elements avoided in this thesis and that may be integrated in a future are RAT, PTU, accumulators and valves. Finally, in order to improve the routing representation would also be necessary to create some routing templates, as elbows or T-shaped tubes, which will help to create a more realistic tubing design for the flight control system.

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