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Requirements definition in support of digital twin platform development

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Abstract. This paper discusses the exploitation of a System Engineering approach and, specifically, of Requirements Engineering to derive a set of desired features based on stakeholders' needs to be implemented into a Digital Twin (DT) platform. Key focus is on the development of a collaborative and highly integrated simulation environment tailored for the design of breakthrough aeronautical products and able, in principle, to cover all the phases of product lifecycle. Specifically, a preliminary list of platform requirements is elicited and from them a set of desired features to be implemented is derived. Then, basing on these features, a Kano questionnaire is set up and used to question a pool of engineers and experts in the aeronautical field. Eventually, by analysing the questionnaire results, the list of desired characteristics is prioritized and used to provide guidelines for the development of the front-end interface of the collaborative platform.

Introduction

The high competitiveness within the aeronautical sector drives the ambitions for shortening the time to market of advanced aircraft concepts. In a context of increasing digitalization, the emerging Digital Twin (DT) technology can play a key role in supporting the introduction of cost-effective innovative solutions since the early design phases thanks to collaborative DT platforms able to facilitate the exchanges among involved stakeholders all along the aircraft life cycle. The DT concept is based on the idea that a physical system can be represented as a digital information or a "twin" of the information originally embedded into the physical system itself [1, 2]. Applications of the DT span all the phases of product lifecycle, starting from design, through manufacturing and service, up to retire phase [3]. In the aviation industry framework, all major aviation companies have been developing DT platforms [4] to be made available internally. A noteworthy example is the Digital Design, Manufacturing & Services (DDMS) platform by Airbus, providing a complete end-to-end process from preliminary design to final assembly to "reduce costs and time to market for our products, while meeting our customers' expectations for quality, safety and environmental performance" [5]. Supposing to be in charge of developing a custom DT environment to be used to assess the feasibility of highly innovative aeronautical products, the substantial lack of manufacturing and in-service data for such breakthrough solutions can hamper the development of a comprehensive DT platform like DDMS. However, this limitation can be turned into a chance to focus on the establishment of the design component of the DT (i.e. the Design DT), paving the way to potential cost savings in the subsequent phases of "real" product development. Indeed, it is well established that the cost to introduce a change into design direction increases along the product lifecycle phases [6]. Therefore, the possibility to fully explore all feasible design alternatives at early design stages can avoid the introduction of an abrupt and costly design change during manufacturing.

On this basis, with the goal to support the development of a DT platform for the aviation sector, Section 2 will discuss the derivation of main platform requirements basing on a possible set of stakeholders' needs. The proposed list of requirements, grouped in five macro-groups, is exploited by means of brainstorming and a Use Case Analysis to obtain a list of features to be implemented into the platform. Basing on these features, Section 3 describes the exploitation of Kano questionnaire to investigate a platform user experience and extract a set of basic information (attractive, must be, indifferent, etc.) useful for defining the features to be implemented and leading the development of the front-end Graphical User Interface (GUI) of the platform. Eventually, main conclusions will be drawn and ideas for future works will be elicited.

Digital Twin Platform Requirements

The System Engineering approach can support the definition of key DT platform characteristics in a structured way [7]. In particular, Requirements Engineering can be used to list high-level platform requirements basing on stakeholders' needs and expectations. For the current application, after internal discussion with involved stakeholders, the set of requirements is derived and represented through SysML (Fig. 1).

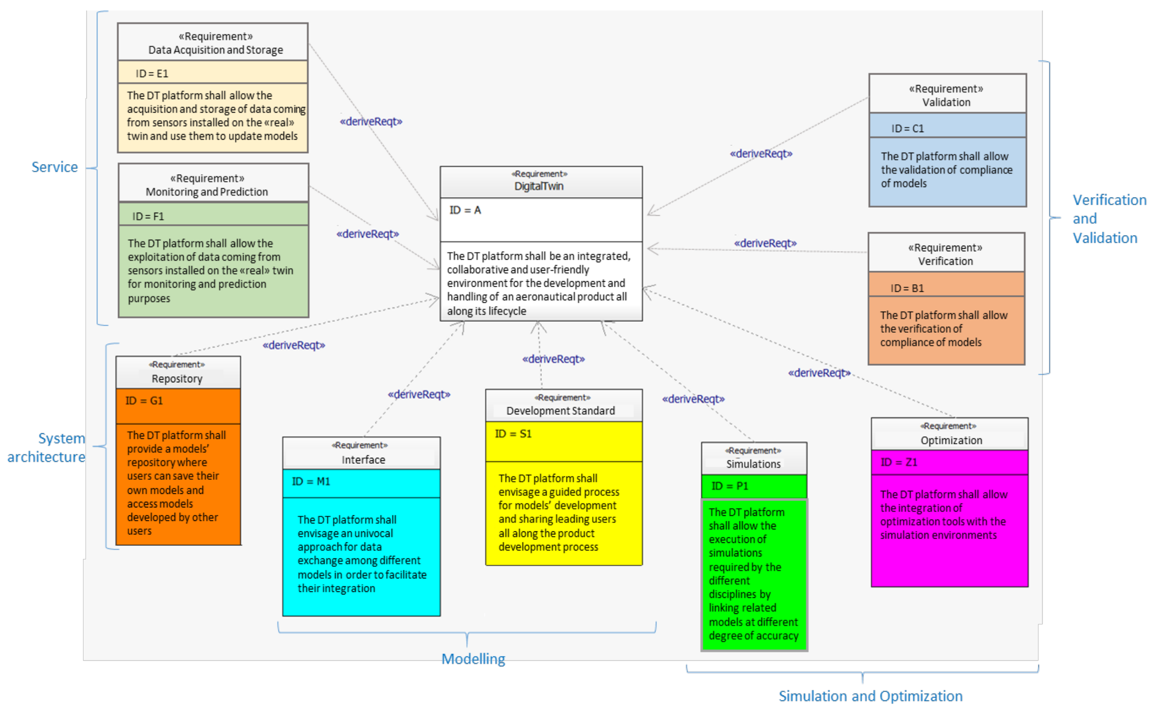

Fig. 1 Requirements and Pillars related to DT platform

According to Fig. 1 and considering the current focus on Design DT, the platform shall be a collaborative simulation environment allowing the user to build the aircraft DT by exploiting the simulation models loaded by himself or by other users. For sake of clarity, the two requirements connected to the in-service component of the DT (i.e. "Data Acquisition and Storage" and "Monitoring and Prediction") are here reported just to strengthen the link between the DT and the "real" twin, basing on the idea to exploit real in-service data to improve the simulation models used during design activities. The requirements under analysis can be grouped into five macro-categories herein considered as the pillars of DT platform development:

1. *System Architecture*, describing how the platform should work;
2. *Modelling*, including all modelling processes, protocols and rules to be followed within the platform;

3. *Simulation and Optimization*, connected to the need of performing simulation and optimization from the platform;
4. *Verification and Validation*, related to the possibility to verify and validate the models loaded into the platform;
5. *Service*, representing the need to link the DT with the «real» twin.

Basing on the pillars and related requirements, it is then possible to derive a set of desired features to be implemented into the DT platform (Fig. 2).

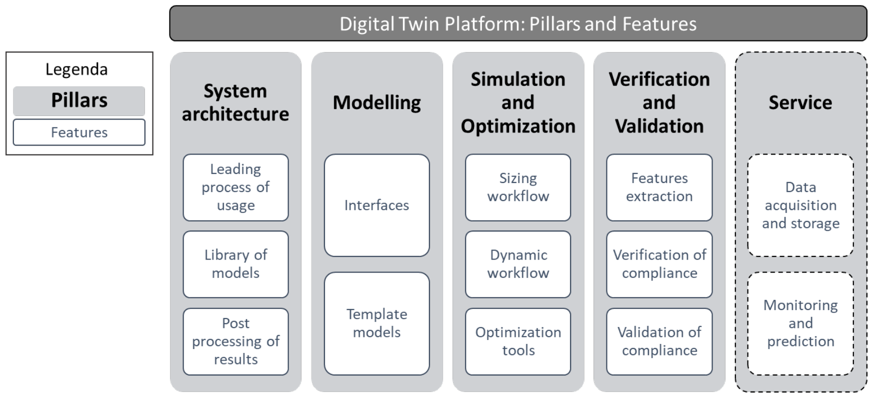

Fig. 2 Pillar and Features connected to DT platform

For sake of clarity, the leading process of usage is intended as a guided sequence of steps that leads the user alongside the whole process. This feature, like the one linked to the capability to provide a proper post-processing of results, is strictly connected to the need to deliver a user-friendly environment. As a result, the DT platform should embed the following features:
1) The user should be guided through the platform usage,
2) Access to the library of simulation models and
3) Easy visualization and manipulation of simulation results within the platform.

Dealing with the “Modelling” pillar, the platform should be able to:
1) Manage the interfaces and signals (inputs and outputs) of the models and their position and value within the database and
2) Guide the users by providing a set of predefined coding rules to be used while developing models (i.e. to provide coding templates for models development).

Eventually, for “Simulation and Optimization” pillar, by means of the DT platform, the user should be able to:
1) Analyse simulation results and perform feature extraction activities [8],
2) Automatically verify models compliance to System Requirements (i.e. the model “works” within the platform),
3) Validate models compliance to Stakeholders’ Requirements (i.e. the model “works well” within the platform).

User Experience Investigation Through Kano Questionnaire

Since the current work points to develop an innovative platform for designing and exploring complex systems, it shall be characterized by collaboration among developers and usability. The first analysis conducted on Stakeholders’ needs led to a set of requirements consequently exploded into a list of features as reported in the previous section. To select the most valuable features, a very powerful tool reported in literature for requirements analysis and prioritization is adopted.

The Kano Model [8] is a framework that allows exploring customer satisfaction with respect to product functions. A feature is presented in positive (functional) and negative (dysfunctional) form to measure the degree of satisfaction from the user in order to extract an opinion that can fall into a category: A (Attractive), M (Must-have), O (One-dimensional), R (Reverse), Q (Questionable), or I (Indifferent). The developers shall focus on Attractive to improve satisfaction of the customer and Must-have to avoid dissatisfaction. Concurrently, the features classified as One-dimensional (also named Performance) are characterized by a linear trend between satisfaction and functional and are the valuable to implement. On another hand, it may turn out that a feature considered valuable results indifferent for customer. If it happens, the developers can decide to invest time according to team needs. An example of a questions couple is reported in the following:

- If to develop a model you are asked to follow predefined coding rules, how would you feel?
- If to develop a model you are not asked to follow predefined coding rules, how would you feel?

The acceptable answers are: I like it!; I expect it; I'm neutral; I can live with it; or I dislike it.

The Kano Matrix [8] compares the answers of a single feature per customer. The sum of all answers provide the main category where a feature falls. The categories with second and third frequency can be considered for a detailed analysis. In Table 1 the answers of a pool of engineers is presented reporting not only the category, but also a Satisfaction Coefficient (S) and Dissatisfaction Coefficient (DS). The combination of S and DS provides the Overall Satisfaction Coefficient (OS) that indicates how much the satisfaction increases and decreases if the requirement is implemented or not. Some results are commented as sample of this preliminary analysis.

- *Feature extraction*: it results the only M category, that means it does not improve customer satisfaction but it must be implemented in order not to reduce the degree of satisfaction since the customer expects to find it.
- *Leading process of usage*: it results to be A on the first frequency, O and I on the second and third. This indicates that designers are available to work on this platform, appreciating the potential benefits even though usability is still not ready.
- *Sizing Workflow/Dynamic Workflow*: the majority of customers consider that features as O. Since the high importance in a DT for design as well as for simulation, it will be further implemented through innovative methods and agnostic tools.
- *Template of models*: although this feature results indifferent for customers, it is an outcome of an analysis of possible compliance within the DT platform, therefore, in future application it can be explored and implemented without producing dissatisfaction in customers.

The majority of the features are considered O, so they are well suited to be constantly improved during development.

Table 1 Results of Kano questionnaire (A: Attractive, M: Must-have, O: One-dimensional, R: Reverse, Q: Questionable, I: Indifferent, S: Satisfaction, DS: Dissatisfaction, OS: Overall satisfaction)

FEATURE	A	M	O	R	Q	I	CATEGORY	S	DS	OS
LEADING PROCESS OF USAGE	39%	17%	22%	0%	0%	22%	A	0,61	-0,39	0,22
LIBRARY OF MODELS	17%	33%	44%	0%	0%	6%	O	0,61	-0,78	-0,17
POST PROCESSING OF RESULTS	28%	17%	50%	0%	0%	6%	O	0,78	-0,67	0,11
INTERFACES	17%	17%	33%	0%	0%	33%	O	0,50	-0,50	0,00
TEMPLATE MODELS	17%	6%	17%	6%	0%	56%	I	0,35	-0,24	0,12
SIZING WORKFLOW	33%	11%	44%	0%	0%	11%	O	0,78	-0,56	0,22
DYNAMIC WORKFLOW	22%	11%	67%	0%	0%	0%	O	0,89	-0,78	0,11
OPTIMIZATION TOOLS	44%	17%	28%	0%	0%	11%	A	0,72	-0,44	0,28
FEATURES EXTRACTION	22%	39%	28%	0%	0%	11%	M	0,50	-0,67	-0,17
VERIFICATION OF COMPLIANCE	22%	11%	50%	0%	0%	17%	O	0,72	-0,61	0,11
VALIDATION OF COMPLIANCE	22%	17%	33%	0%	0%	28%	O	0,56	-0,50	0,06
DATA ACQUISITION AND STORAGE	33%	11%	39%	0%	0%	17%	O	0,72	-0,50	0,22
MONITORING AND PREDICTION	17%	11%	33%	0%	0%	39%	I	0,50	-0,44	0,06

Conclusions and Future Works

In conclusion, this research work presents a preliminary analysis towards the development of a collaborative and integrated environment for design and simulation of a DT. One of the main goals is to provide an environment where users can collaborate alongside all the design and production steps and where the integration and validation of models can be easily carried out. Currently, a set of requirements and features are identified and classified according to Kano Model. In the next step, a more complex questionnaire may support the decision making process considering a demographic section where roles of users are highlighted and functions and features of different application and phases of development are reported in order to extract more precise information about the real needs of involved people.

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