Decisional Model for KBE Implementation in a Commercial CAD Software

Yannick Bodein[1 2], Bertrand Rose[2] and Emmanuel Caillaud[2]
[1]Tata Technologies Limited Europe, yannick.bodein@tatatechnologies.com
[2]LGECO lab - University of Strasbourg- INSA, bertrand.rose@unistra.fr , emmanuel.caillaud@unistra.fr

ABSTRACT

CAD tools are becoming increasingly powerful today. They provide users with more efficiency and improve the overall performance of design activities. CAD software publishers include specific tools that are dedicated to knowledge management in order to achieve this design performance and significant savings. The use of these tools and certain functions is nevertheless context-oriented. A decisional model for the use of knowledgeware has therefore been developed here, and the application of knowledgeware in different industrial cases is discussed.

Keywords: knowledge based engineering, knowledgeware, automation, CATIA V5.
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1 INTRODUCTION

Reductions in costs and lead-time , as well as quality improvements are now a core consideration of most companies. Multiple action levers enable these improvements: capitalization and reuse of knowledge and know-how, corporate rules, standards formalization and rationalization. The ability to force the application of these rules on all stakeholders, along with repetitive design phase automation, allow firms to act early in the design process in order to optimize innovation capacities.

These improvements become real assets for a company as soon as they are deployed with tools and methodologies allowing for a quick Return On Investment (ROI). Some significant gains can therefore be made through:

- The optimization of the design process (to have as few customization tasks as possible);
- Improved flexibility in order to design more complex products faster,
- Collaborative work, with stakeholders with different skills;
- Product life-cycle management.

In order to make these improvements, the company has to set up an environment in which innovation is promoted and the low value-added tasks automated. This is typically the case in the automotive industry, where the pressure for cost and lead-time reduction is even heavier than in other sectors. We therefore focused our research on this domain. This environment is characterized by 3 performance drivers:

- Capitalization and reuse of existing knowledge,
- Standardization of functions and components through the company (methodology),
- Capitalization and deployment of the company's standards (training and methodology).

Various CAD tools and functions are being developed today in order to achieve these performance drivers. The objective of our research was to improve design performance in terms of Quality-Cost-Delay by defining the way these specific CAD methodologies collaboration between designer improvements, and integration of expert rules into CAD software can be implemented.

This paper first presents an overview of the possibilities and potential of a CAD software (CATIA V5) in order to capture, share and reuse expert rules in the design of a product. We then propose a decisional model that can serve to identify which part of the CATIA V5 knowledgeware solution has to be used for a specific aim (i.e. check dimensions, provide a generic 3D model, etc.). In the last part, we illustrate this process model regarding the use of knowledgeware with several industrial examples, before concluding.

2 KNOWLEDGE-BASED DEVELOPMENT IN CAD SOFTWARE: HISTORY AND OBJECTIVES

Specific developments in the field of CAD solutions have existed since the creation of the first CAD systems (1980's) with the objective of automating complex or repetitive tasks. Initially, developments were made by specialists with a language specific to each CAD software. The maintenance of the applications was complex, difficult and expensive. During the 1990's, coding languages for CAD systems became standard and mostly object-oriented programming techniques (VB, C++, etc.). This evolution led to the extension of specific development to a large number of companies.

It was only after the year 2000 that a new type of tool dedicated to knowledge management and integrated into CAD software was made available. These tools are no longer targeted at specialists or developers but are dedicated to a large public of users (abstraction of the computer language). The aim of these new solutions is to provide new possibilities to integrate knowledge more easily by creating new parametric features based on know-how, rules, analysis and checking functions also known as Knowledge-Based Design Features.

The implementation of knowledge-oriented components into the design process has increased. That includes, amongst other things, feature technology, application programming interface (API), and knowledge-based design steps [6].

Nowadays, all CAD software systems are able to capture, share and re-use know-how and expert rules in their models with various levels of effectiveness and implementation complexity. While investigating CAD market products, we find three CAD systems which provide relatively advanced functionalities dedicated to knowledge management: Siemens NX5, PTC Creo Parametric and Dassault Systèmes CATIA V5.

All these solutions provide additional packages (*Knowledge Fusion* for NX, *Knowledgeware* for CATIA or *Pro/TOOLKIT* for PTC Creo Parametric) which make the creation of User Defined Features (UDF) and the integration of expert rules possible.

For the creation of our decisional model, we used CATIA V5 (Dassault Systemes) as it is the most widely used CAD system in the automotive industry.

3 EXISTING APPROACHES AND SOLUTIONS FOR THE INTEGRATION OF KNOWLEDGE INTO CAD

In our research, we conducted a literature review on various approaches used for the implementation of knowledge in CAD, in Knowledge Based Engineering (KBE) applications [6], [10], [14], [15], [16].

There are mainly two approaches: the first consists in developing new functions or in automating tasks by using the Application Programming Interfaces (APIs) provided by the publisher; the second consists in the creation of 3D parameterized models or generative components (product, part or geometrical entity) which may also contain expert and job rules, formalized with tools dedicated to knowledge management that we include under the term "knowledgeware".

By studying the solutions described in the literature, and by exploring the limitations of CATIA V5 software, we have positioned the two approaches in relation to different purposes: to automate, integrate and check standards, add a new functionality, etc. This list of goals is not exhaustive and a

KBE solution can have several objectives. Our approach allows for a more comprehensive overview to be obtained, and provides a simple tool for decision support on the preferred approach (see Figure 1).

For example, if the objective is to formalize and to integrate expert rules of a system, "Knowledgeware" solutions are more appropriate in terms of ease of implementation and development time, and thus more efficient compared to a development solution based on Application Programming Interfaces (symbolized by the term "coding" in Fig. 1). It is imperative to provide a solution that is dynamic, to reflect the lifecycle of knowledge.

Whatever the CAD software, integrated functions dedicated to knowledge management can be separated into three categories: adaptive and generative models, start-up models/files, and objects allowing for embedding business rules formalized by means of a specific language that can react to an event triggered by user action. We have also included on the graph these three categories and all CATIA V5 technical solutions belonging to these categories.

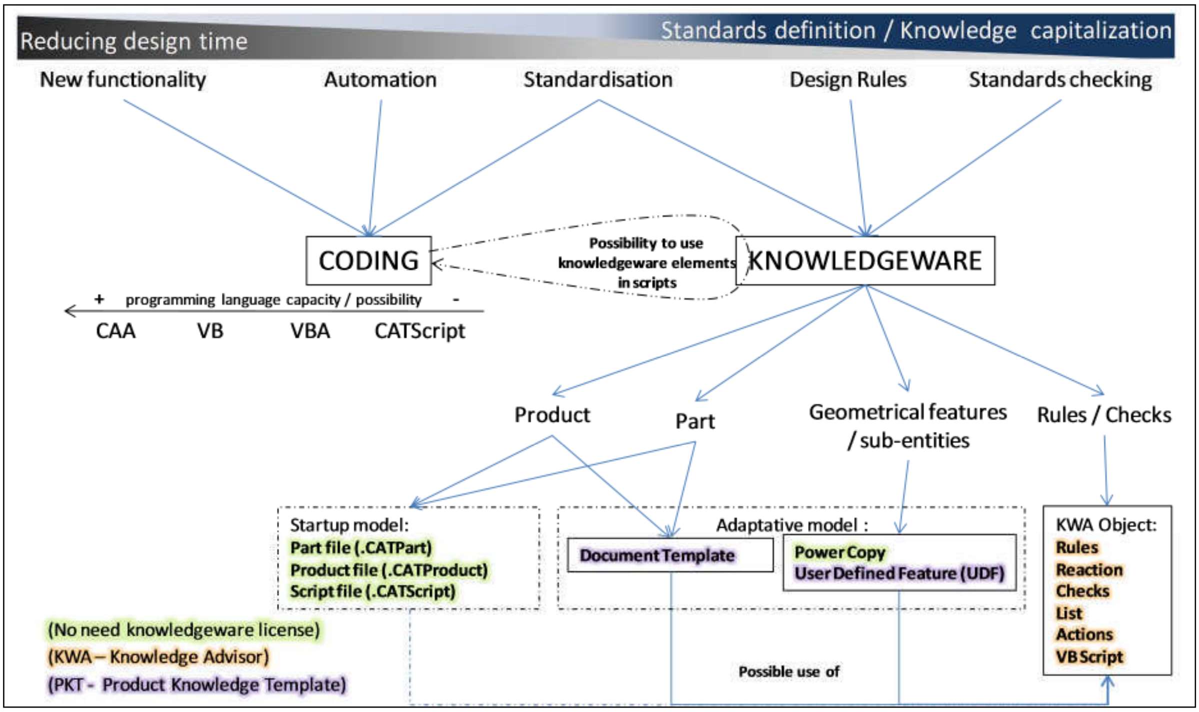

Fig. 1: Positioning of solutions for knowledge implementation in CAD based on an identified aim.

It appears that development through programming interfaces is more suited to reducing design time by relying on automation [11], while "knowledgeware" is aimed more at knowledge capitalization and standards management. However, it is possible to obtain a complete solution that integrates both approaches, and thus to have the benefits of each one.

An illustration of a simple solution that could integrate both approaches, and often encountered in industrial examples, is the creation of parameterized geometric models based on "knowledgeware". These models are then reused by an application that automates the creation of a drawing, using information included in parameterized geometric models (i.e. creation of welding seams as 3D geometric models, and automation of the creation of welding symbols on the drawing based on the characteristics of 3D geometric models).

4 USE OF KNOWLEDGEWARE IN THE AUTOMOTIVE INDUSTRY CONTEXT

Since the 1980s, Knowledge-Based Engineering (KBE) technology has been used to capture and automate design and engineering in industries such as aircraft and automobiles [5]. Knowledgeware should therefore be considered as a way to enhance performance during routine design phases.

However, the implementation of know-how in CAD systems is not so easy and also implies that designers are familiar with CAD methodologies [3].

The use of specific developments and knowledgeware developments should be in addition to the CAD user's competences, allowing users to reduce their design time and to increase their design quality using knowledge-based rules and features. However, companies should disseminate the developed knowledgeware tools to the different stakeholders, in order to take full advantage of them [16].

As promoted in [6], the empirical studies that we undertook showed that a CAD support department is highly recommended in order to centralize knowledgeware applications, and users directly detect, on their own, the subjects on which anything can potentially be achieved.

For the moment, it is essentially large companies which use or develop knowledgeware-based features because it is easier for them to obtain a Return On Investment due to the number of designers concerned.

In the literature abundant research is found on how to automate the design of products based on a KBE approach [8], [14], [15]. However, few or no research deals with knowledgeware. Wu [17] proposes a CATIA KBE experiment but his work is mainly software-oriented. Prasad [12] describes a Knowledge-based System Engineering Process for Obtaining Engineering Design Solutions in a Commercial PLM Setting. Bermell-Garcia [2] explores the interoperability between PLM and Knowledge-Based Engineering as a strategy for engineering KM in a study where opinions of key KBE/PLM practitioners are systematically captured and analyzed.

Gardan [8] explore an application of knowledge-based modeling using scripts exclusively, and raises the question of the management of a significant number of scripts. Hirz [9] proposes the use of programming macros to automate a sequence of features and routines, and the use of parametric-associative design methods that sample expert knowledge as a real perspective to reduce design time.

Regarding the automotive industry problematic, the question is about the deployment of knowledgeware solutions: do CAD users need to make specific software developments or is CAD feasible with knowledgeware tools?

Generally way, scientific results mainly deal with process automation based on script developments [10]. Other recent scientific results suggest generative model and automated product modeling using Knowledge-Based Design features approaches [7], [9], [13].

The originality of our work is to propose a decisional model that can be used to determine quickly whether automation or knowledge integration is needed. This decisional process model is presented in the next section.

5 DECISIONAL PROCESS MODEL

The aim of this decisional process model is to determine which type of knowledgeware objects could be used and for which context. In fact, most companies striving to integrate knowledge into CAD models do not differentiate between "knowledgeware"-based solutions and specific developments (coding) which imply high direct costs (costs of development done by experts) and indirect costs (maintenance) [4].

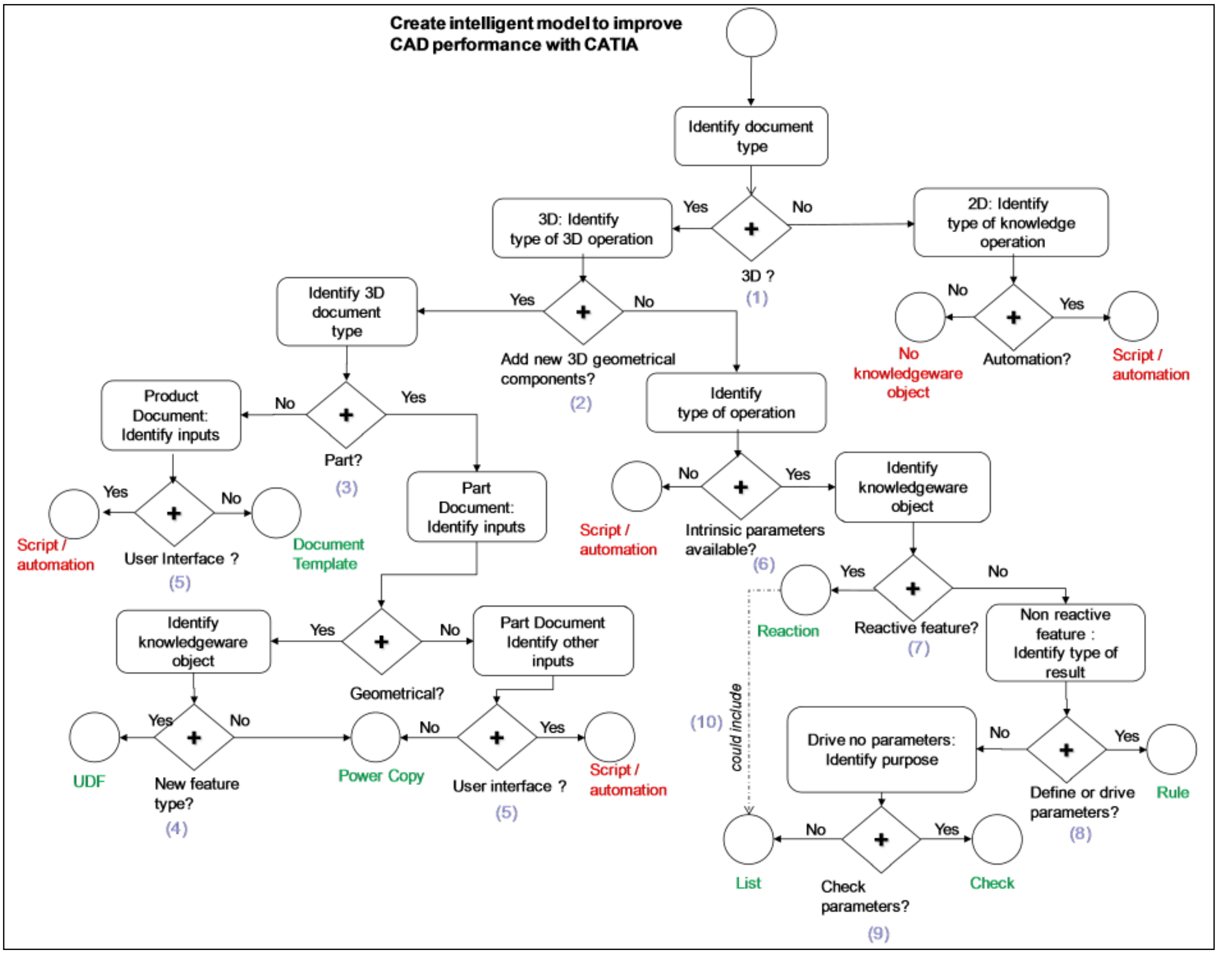

Fig. 2: Decisional process model: implementation of "knowledgeware".

Thus, companies do not take real advantage of the possibilities offered by the CAD system for creating intelligent models that could easily improve the performance of the design process.

An important part of the study was to identify the limits of the knowledgeware language (EKL - Engineering Knowledge Language) as well as limits in the creation and use of knowledgeware components.

In order to facilitate the understanding of this decisional model (see Fig. 2), the main steps are numbered in parenthesis (i.e. (1) for document type identification). Thus, numbers in parenthesis in this chapter and in the next chapter refer to decisional model steps.

The extremities of this graph correspond to the CATIA V5 functions of "knowledgeware" tools or indicate that it is necessary to use scripts based on APIs (indication "script/automation" on the graph).

The notion of intrinsic parameters also needs to be defined before the description of the decisional model: intrinsic parameters are generated by the CAD system when creating any geometry and features; they define intrinsic properties of features (depth, offset, activity, etc.).

The decisional process (1) shows that for 2D documents (drawing), it is not possible to integrate knowledgeware components, and scripts are the only way to bring new functionalities to the user. The main reason is that intrinsic parameters of 2D elements are not available and thus not accessible using the knowledgeware language.

In addition, the decisional process differentiates the knowledgeware object that could create new 3D elements from elements which permit work on existing features (2).

The decisional process model also allows for decisions as to which type of knowledgeware object could be used, according the type of context document (3): Power Copies or User Defined Features cannot be used in a product document and a Document Template cannot be applied in a part document.

Moreover, if 3D components to be added in a document needed user decisions during their creation, Power Copies, Document Template and User Defined Features would not be adequate as they are not compatible with user interface creation (5).

In addition, the decisional process model helps selecting between Power Copies and User Defined Features solutions (4) based on downstream purpose: the creation of a new type of feature allows identifying it in a structure and to get or modify his characteristics (parameters, dimensions, etc.).

With knowledgeware functions it is possible to modify only parameters and properties of existing 3D features (intrinsic parameters exist); these functions make possible to specialize alternative structure elements and including/excluding them by means of Rules and activity parameters, but are not able to generate new entities (new intrinsic parameters, modification of features relationships, etc.) but for all other cases script are required (6). The decisional process model differentiates features that are launched after an event (7), features which drive (8) or check (9) intrinsic parameters. Knowledgeware list feature can be used to list other features (i.e. hole) based on their intrinsic parameters and could be coupled with reactive features, either as the source event launching the reaction (i.e. the number of the list changed) or to perform a set of instruction on features included in the list (10).

In addition, behind the indication "Script /automation" on the decisional model, several solutions could be used, such as external scripts (.CATScript, VB.Net, etc,) or internal scripts embedded in knowledgeware functions ("Macros with arguments", "Actions" or "Reactions"). Internal scripts are features that can contain script and automation instructions that could be launched by Reaction and Rules present in the decisional model.

The authors excluded from this article others knowledgeware functions such as "Set of equations" and "knowledge Pattern Feature" as less relevant for the creation of intelligent models. For easy comprehension purpose and because they cannot be used for the creation of intelligent CAD model, Expert Rules and Expert Checks features are excluded too from the decisional model.

This decisional process model can be used at the beginning of a project in order to decide whether knowledgeware or script should be favored, and can also be used for each function of a KBE application. This decisional model has been used on several projects for deciding the global architecture of a knowledgeware-based solution and some examples are presented in next chapter.

6 USE EXAMPLES

In this section we present some examples showing how to implement our decisional model on industrial real cases. These examples have the advantage of being instructive in a way that is quite simple. As discussed above, a good way to integrate KM into CAD is to use knowlegeware. These examples are more interesting in this respect since they integrate knowledgeware. Note that the last example uses a mixed approach integrating both coding and knowledgeware solutions, and shows the limits of both approaches.

The decisional process model is one of the help elements within the process of decision taking when performing KBE tasks with CATIA system. It corresponds also to a stage of a roadmap that is used in a more global CAD efficiency improvement methodology developed in our research.

6.1 Creation of Sheet Metal Features with Embedded Manufacturing Know-how

Some CAD software such as CATIA V5 require specific licenses in order to give access to sheet metal features, and by default standard sheet metal features do not integrate the manufacturing criteria of a given company.

In the automotive industry, in order to improve and accelerate the cars' assembly process as well as the maintenance phases, more and more sheet metal operations are requested. As it is presented in this example, the initial industrial problems are that sheet metal operations (bending, stamping, etc.) are very difficult to model and that manually checking proximities between these operations and the edges of bends is really time-consuming and a source of oversights. An automatic design function is therefore requested in order to improve the global efficiency of the design.

The solution developed, using knowledgeware (see Fig. 3), was to create parameterized geometry which takes into account expert rules (formalized as mathematical rules) and automatically checks the proximity between their environments (edges, bends, holes, other features).

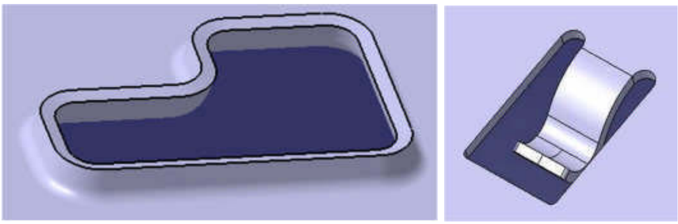

Fig. 3: Example of UDF created for sheet metal parts.

The decisional model allowed us to define the overall solution very quickly, considering the following information: the generic model must act on 3D data (see (1) in Fig. 2) by adding new components' geometric 3D (2) inside a part (3). The use of the generic model will be based on geometric inputs, and the result should be treated as a new feature (4) in order to measure the proximity to the existing surroundings. The solution in this case is to make a UDF (User Defined Feature).

Reactive features and checks and rules have been used for dimensions definition and checking according manufacturing rules. These elements have also been chosen using the decisional model, not described in this article.

The proximity is measured in the 3D document (1) without adding geometry (2) and without being able to directly use the intrinsic parameters of the CAD modeler since they are not available (6): elementary geometry (surfaces, edges, vertices) to use for measurements is the result of operations between 3D features with intrinsic parameters. The solution in this case is to make a script.

The modeling of these geometric forms representing manufacturing operations is achieved in less than one minute instead of one hour as was previously the case. Moreover, the shapes are perfectly processed regarding the standards of the company.

6.2 Representation of 3D Welding Seams and Automatic Creation of 2D Welding Symbols

The creation of welding seams in CAD software depends on the architecture of the CAD software and is almost always carried out by assembly features. The consequence is that additional files are created which contain the definition of these welding operations. Moreover, this additional welding file often keeps associativity links to other files (e.g. equivalent to contextual modeling), which makes the welding file difficult to manage by means of a PLM system with basic CAD integration.

Nevertheless, a good reading and comprehension of welding seams is of primary importance in a design. In this way, the initial industrial problem was that there was no easy function or method to represent welding seam operations in 3D. A large component of the problem was also the need to provide designers with a tool integrating manufacturing standards and rules concerning these welding operations.

The solution developed in order to solve a previous problem is global, based on knowledgeware, with the creation of parameterized geometry for 3D welding seams and based on scripts for the automation of representation (symbols) for welding seams in the drawing. It corresponds to a mixed solution that takes advantage of both knowledgeware and API.

6.2.1 3D Welding seams and product skeleton template

The decisional model allowed us to define the overall solution very quickly, considering the following: the generic model must act on 3D data (see (1) on Fig. 2) by adding new 3D geometry (2) inside a part (3). Here the part is a skeleton part. The application of the generic model will be based on geometric inputs selected by the user, and the resulting 3D geometry should be managed as a new feature (4) in order to be able to retrieve the geometry, its location and its main parameters. The solution in this case is to make a UDF (User Defined Feature).

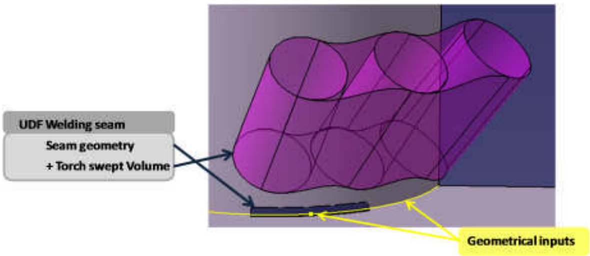

Fig. 4: Example of a UDF for 3D welding seam representations.

Inside the UDF, we have also integrated a strong request from designers: the volume required by tools in order to manufacture the welding, that is, the torch swept volume (see Fig. 4).

In order to enable an automatic treatment of instantiated UDF welding seams, the solution developed is a template structure for a skeleton (see (a) on Fig. 5). As an example of treatment proposed inside the skeleton, there is an automatic computation of total length and total mass of all welding seam UDFs based on a reaction (7) including a list (10) (of welding seam UDF), the ability to hide or uncover all torch swept volumes, and also a check regarding the compliance of welding seams with manufacturing standards.

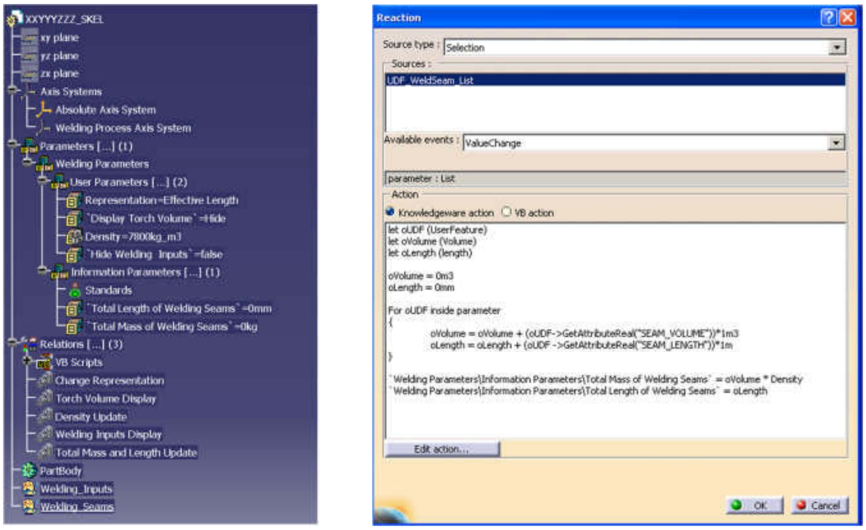

Fig. 5: Template structure of skeleton part in CATIA V5 (a) and reaction function for the computation of welding seams' UDF total length (b).

Again, the decisional model has allowed us to determine whether knowledgeware or script should to be preferred for those treatments. For the automatic computation of total welding seam length, the function must act on 3D data (see (1) on Fig. 2) without adding new 3D geometric components (2). The intrinsic parameter corresponding to the length of a seam is available on each UDF welding seam (6) and the function must react when adding or removing welding seams UDF (7). The solution used for this total length function is a reaction feature, as proposed by the decisional model (see (b) on Fig. 5). This reactive feature is launched by a list containing all welding seam UDF (10).

6.2.2 Welding seams application for drawing

Since there is no knowledgeware solution in 2D, in addition to the 3D representation of welding seams, a script enables the automation of welding symbols, numbering balloons and normalized annotation creation based on UDFs in 3D (see Fig. 6). All these functions are made using scripts (API) as there are no knowledgeware functions for drawings (see (1) on Fig. 2). Here we need both approaches: the coding due to 2D outputs where knowledgeware is not implementable, and in the mean time to use API is suitable for expert rules capitalization. We do not detail here the coding solutions since they are less interesting.

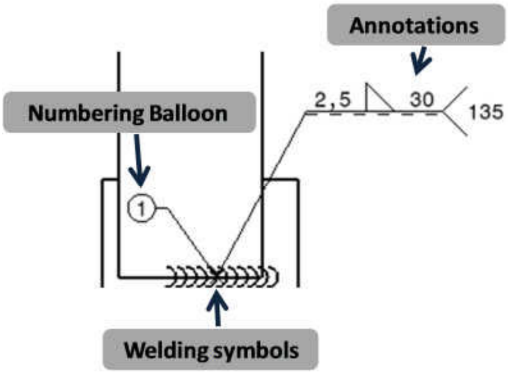

Fig. 6: Result of the script for welding coupled with welding UDFs.

6.3 Knowledgeware Benefits

It is still difficult to conclude on knowledgeware effectiveness by just looking at examples such as the previous ones. It is necessary to consider the development of a product comprehensively, as the reference framework, and then measure gains achieved through the use of knowledgeware. These gains will necessarily be linked to the complexity of a product and also to the capacity of a company to invest in knowledgeware solutions. Baxter [1] suggests that the benefit is more important for high complexity design domains, which we can confirm from statistics provided by firms which have developed tracking systems on the use of their 3D templates. We can also consider the benefits in term of collaboration and sharing of experiments while using the decisional model: if one expert has to handle such problems, his modeling experience makes these decisions automatic and so he does not need a decisional model for a specific situation (use of UDF for examples). But if several engineers/consultants are requested to work around the problem, to have at their disposal such a decisional model can avoid conflicts and in this way significantly increase the level of collaboration and therefore the global efficiency of the project.

7 CONCLUSION

Today, more and more companies want to reengineer products quickly, using one of the many solutions available. They are interested in dynamic systems that could automatically sort through a multitude of known product solutions and rapidly reconfigure one that meets customer requirements with a minimum of cost and time investment. CAD software publishers provide functionalities that allow for some of these requirements to be met. Based on knowledge capitalization, as well as methodological rules and standard reuse, knowledgeware tools in CATIA V5 have this purpose.

We have presented here the functionalities of CATIA knowledgeware tools and a process model to use them. Industrial examples of the use of the knowledgeware have also been presented and discussed. Some CAD project managers dream of a fully automated CAD tool for routine design. We posit that knowledgeware is not sufficient in this case. It must be taken as a useful toolkit allowing for the creation of simple models/templates and, before that, for defining company-specific methodological rules and standards in order to increase routine design speed with the aim of releasing time for innovation or generating profits.

Thus, as Bermell-Garcia [2] argues, a typical product development process –is, by nature, highly dynamic, nonlinear, discrete, feature-dependent, and part-dependent. The solution is not easy, since problem formulation is time-bound, has numerous discrete inputs and topologies, and several mathematical discontinuities. Nevertheless, in so far as KM has a significant role in companies, the mastery of knowledgeware is currently a real way of improving CAD efficiency and performance. As regards perspectives for this work, we can propose the Case Based Reasoning system for automating the use of this decisional model. This can be very useful for a Tata Technologies Company in order to implement an automatic quotation application.

8 ACKNOWLEDGEMENT

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