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IMPROVING CAD PERFORMANCE: A DECISIONAL MODEL FOR KNOWLEDGEWARE IMPLEMENTATION

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ABSTRACT
CAD tools are today more and more efficient in order to provide CAD users more efficiency and improve the overall performance of design activities. CAD software editors include specific tools that are dedicated to the knowledge management in order to achieve this design performance and significant saves. The use of these tools and specific functions is nevertheless context-oriented. A decisional model for the use of knowledgeware is therefore presented and the application of knowledgeware in different industrial cases is discussed.

Keywords: CAD, Knowledge Based Engineering, knowledgeware, automation, CATIA V5, automotive industry

1 INTRODUCTION

Cost and Delays reductions as well as quality improvements are now in the middle of the considerations of the companies. Multiple action levers allow these improvements: capitalization and reuse of knowledge and know-how, firm rules and standards formalization and rationalization, the ability to force the application of these rules towards the whole stakeholders and repetitive design phases automation allow to act early in the design process in order to optimize innovation capacities.

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

- The optimization of the design process (to have as less as possible “customization” tasks).
- An improved flexibility; in order to answer quicker to design more complex products,
- A collaborative work , with stakeholders suited with different skills;
- A product life-cycle management.

In order to answer to these improvements axes, the company has to setup an environment favoring the innovation and in the mean time automating and increasing the security of low value added tasks. This environment is mainly based around 3 performance vectors:

- Capitalization and reuse of the existing
- Standardization of functions and components through the company (methodology).
- Capitalization and deployments of company’s standard (training and methodology).

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

This paper first presents an overview of a CAD software (CATIA V5) possibilities and potential in order to capture, share and re-use expert rules used in a design of a product.

We then propose a decisional model allowing to identify which part of CATIA V5 knowledgeware solution have to be used according a specific aim (i.e. check dimensions, provide a generic 3D model, etc.). In the last part, we illustrate this process model of how to use knowledgeware with several industrial examples before concluding.

2 KNOWLEDGE BASED DEVELOPMENT IN CAD SOFTWARE: HISTORY AND OBJECTIVES

Specific developments on CAD systems exist since the creation of the first CAD systems (80's) with the objective of automating complexes or repetitive tasks. Development was made by specialist people with a language specific for each CAD software. The maintenance of the application was complex, difficult and expensive. During 90's, coding languages for CAD systems became standards and mostly object-oriented programming techniques (VB, C++, etc.). This evolution has permit to extend specific development to a largest number of companies (moreover, the number of companies which used CAD system has grown).

It is only after the years 2000 that a new type of tools dedicated to the knowledge management and integrated in CAD software were available. These tools are no more destined to specialists or developers but are destined to a large public of users (abstraction of the informatics 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 gained in importance. That includes, amongst others, feature technology, application programming interface (API) and knowledge based design steps [5].

Nowadays, all CAD software systems are able to capture, share and re-use know-how and expert rules into their models with a various level of effectiveness and implementation complexity. While investigating CAD market products, we find two CAD systems which provide relatively advanced functionalities dedicated to knowledge management: Siemens NX 5 and Dassault Systèmes CATIA V5.
Both solutions provide additional packages (*Knowledge Fusion* for NX and *Knowledgeware* for CATIA) which make possible the creation of User Defined Features (UDF) and the integration of expert rules.
For the creation of our decisional model, we take the decision to used CATIA V5 (Dassault Systemes) because it is the CAD system the most used in the automotive industry.
We detail in next section some technical and functional aspects of the CATIA V5 knowledgeware portfolio.

3 MAIN FUNCTIONS OF THE KNOWLEDGEWARE

CATIA V5 Knowledgeware functions and tools are divided into six workbenches. In fact, only four of them are useful for knowledge management as both products: "Product Function Definition" and "Product Function Optimization" allow to link geometry of a product with the product functional requirements (approach similar to internal functional analysis methods).

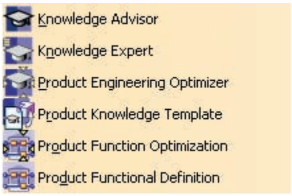

Figure 1: CATIA V5 Knowledgeware workbenches

In the automotive industry, most of the company engaged in knowledge based CAD modeling approach use CATIA V5 “Knowledge Advisor” and “Product Knowledge Template” workbenches.

3.1 Knowledgeware solution overview

The CATIA V5 product to capture know-how is “Knowledge Advisor” (KWA product). This workbench provides 3 fundamentals functions: Rules, Checks and Reactions. These functions allow to integrate know-how using the knowledgeware language and to optimize them in order to facilitate technical decisions, reduce errors and automate design for maximum productivity [1].

The CATIA V5 product used to create user specific features is “Product Knowledge Tempate” (PKT product). This product allows creating User Defined Feature (UDF) - new parametric feature based on a structure composed with existing features (i.e. pad, groove, hole, sweep, etc.) or Document Template (DT) – part or product start-up files which could be adaptive to a geometrical context (or generative model).

Last two CATIA V5 products dedicated to knowledge management are “Knowledge Expert” (KWE product) and “Engineering Optimization” (PEO product).
“Knowledge Expert” permits to create generic rules and checks (enterprise level) that are efficient on identified and known CAD structure (i.e. start-up models, User Defined Feature) but the interest is very limited on a CAD model created without any methodologies.
“Engineering Optimization” product allows to make optimization on parameters which could be linked to a geometric model. The aim is to solve an optimization problem by defining parameters: optimization type (minimize value, target value, etc.), algorithm type, free parameters, free parameters’ bounds and constraints (or relation between these parameters).

KBE applications linked to CAD systems are mainly based on two approaches, the fist consist in automating the design process via object-oriented techniques and the other by creating generative models. We linked these approaches with following aims: reducing design time and integrating knowledge. Figure 2 gives an overview our study and list also knowledgeware functions available for knowledge-based modeling approach.

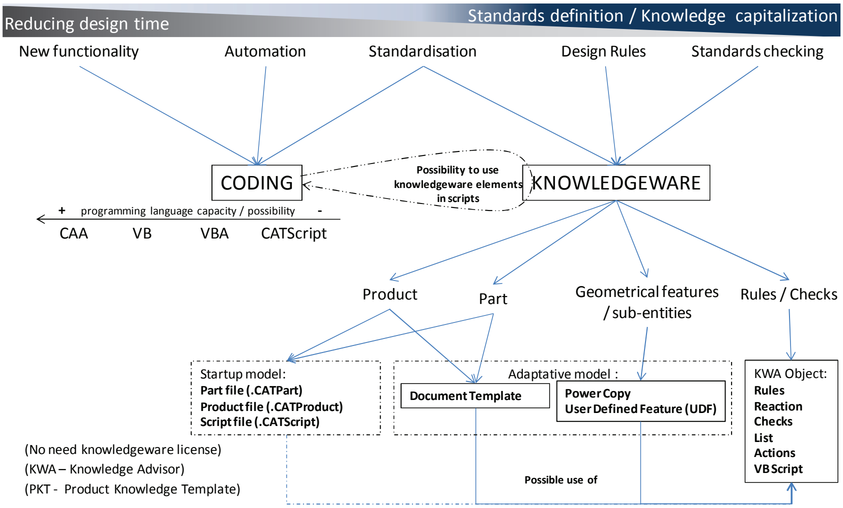

Figure 2: knowledgeware solution overview limited to KWA and PKT products

PEO and KWE products are not presented in this overview as we considered their contribution less significant and competitive regarding knowledge integration and design time reducing.

It appears that coding (object-oriented application) is more adapted for reducing design time as knowledgeware is for empowering knowledge capitalization. However, a mix of both approaches can be a wise solution because take advantage of each one.

We regroup knowledgeware global solutions in 3 categories: adaptive and generative models, start-up models and knowledgeware objects.
A generative model could be a complete product, or a part or only a sub-entity of a part (i.e. a centering pin), knowledgeware associated functions are Document template, PowerCopy or UDF.
If the aim is only to have a standard structure of CAD file which is required to make some checks on parameters, or on geometrical features under identified set of elements (see Example of a start-up model file for pipe on Figure 3), the solution consists in using a start-up model file without any geometry but only parameters and pre-defined set of features that the designer has to use for creating the parametric model of his product. Generally, KBE applications based on coding required the use of start-up files, so the application can detects automatically inputs without any user interface or user actions.
The last category of knowledgeware solution contains all functions allowing a designer to formulate rules, to create reactive features starting on events (i.e. before update, volume change, etc.) and checks.

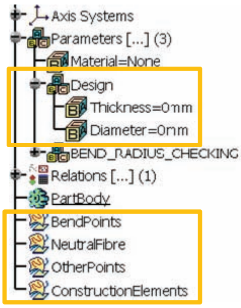

Figure 3: Example of a start-up model file for pipe

Quick descriptions of knowledgeware features listed on Figure 2 are presented in next chapters.

3.2 Main knowledgeware objects description

Description of a Power Copy

Power copy allows to back up a geometry (with parameters, rules, etc.) with the aim of reusing it later on.

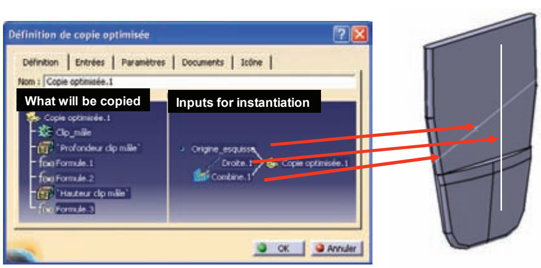

Figure 4: Power Copy Definition Windows

User will have to select geometrical inputs (in case of an adaptive geometry) in the new 3D model in order to instantiate the geometry included in the power copy. Power copies are often created for standards geometries. Another utilization of Power copies is to add standard parameters and rules in a startup model file as a Power copy can be create without embedded geometry.

Description of a User Defined Feature (UDF)

An UDF can be compared to the power copy but the result is not a single copy but a new parametric feature included in a "black box". The result of an UDF can be share with everyone as the IP (Intellectual property) is secured.

Figure 5: Example of a User Defined Feature (UDF) for sheet metal

The main advantage is that an UDF is considered as a new feature type, thus attribute and parameters of this feature can be used in a KWA rule as an object (i.e. *Collar_Feature.Diameter* = 16mm), and consequently it is possible to test if parameters' values comply with company standards.

Description of a Document Template (DT)

A document template is similar to a power copy but at the document level (Part or Product). The result is a copy of a whole part or product (or sub-assembly). The geometry of a document template could be based on identified geometrical elements. In this case, the instantiation of the document template requires geometrical elements as inputs (same behavior than Power copy and UDF) and the geometral construction is adapted to the new context.

Definition of a check

Check embedded in design that reacts to parameter changes and informs the user in case of violation. (i.e. inform the user if *Collar_Feature.Diameter* > 40mm).

Definition of a rule

Rule embedded in design that reacts to parameter changes and propagates parameter or geometric modifications.

Definition of a reaction

Feature embedded in design that reacts to specific events and propagates any kind of modifications (i.e. reacts if the parameter *Collar_Feature.Diameter* changed).

2.2 Knowledgeware language overview

We find important to study the language used for the knowledgeware as possibilities offered to integrate know-how are directly linked to it. It is easy to conclude that Features, objects or properties which are not available in the language cannot be managed with knowledgeware objects. In this case, standard programming language (VBScript or VBA) solution using CATIA API (Application Program Interface) has to be envisaged.

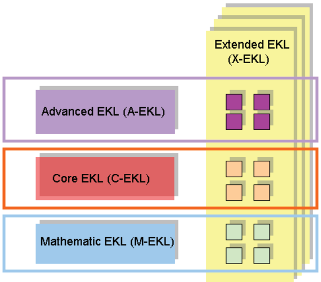

Figure 6: CATIA V5 - Engineering Knowledge Language (EKL)

The Engineering Knowledge Language (EKL) is the language used to define the various kinds of artifacts of Knowledge available in the various products of the Knowledgeware solution.
As presented in Figure 6, the Engineering Knowledge Language is available in four different versions of the simple mathematical language (M-EKL) to the advanced language's most experts (A-EKL).

The Mathematical Engineering Language (M-EKL) which contains operator and numerical functions required to evaluate a parameter in Knowledge Advisor (Figure 7 and Figure 8)

Figure 7: Example of a Cos() mathematical function

Figure 8: mathematical function round() to round up a length parameter with 1 digit after comma

Core Engineering Language (C-EKL) which adds key words for checking structure as the conditional instruction "if... then... else". Also provide functions associated to formulae, design table and checks features.
Example: Valuate one string parameter using a conditional instruction

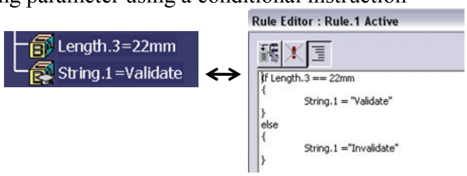

Figure 9: KWA rule - the value of a string parameter is defined using a conditional instruction

Advanced Engineering Language (A-EKL) which provide advanced functions like “Actions” and “Reaction” that could be launch on specific events (not linked to the standard update process).
This language provides also a new possibility to manage features as knowledgeware object and to retrieve or set properties of this object (a parallel could be made with object oriented programming languages). With the Advanced Engineering Language, it is possible to create an “Expert rule” which checks the diameter (as a property) of all holes features from the CAD file and modifies their value according a conditional instruction (i.e. Diameter = 50mm).

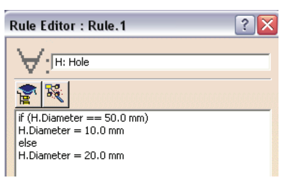

Figure 10: KWE rule (expert) checking and modifying holes diameters

When knowledgeware language does not permit to access to the required property or does not allow to create an algorithm taking user inputs as arguments, it is possible to build a macro with argument (VB language) directly in the CAD model using “Knowledge Advisor” functions: VB macro or Reaction.

3 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 [2]. In this way, the Knowledgeware should be considering as a way to gain performance during routine design phases.

However, the implementation of know-how in CAD system is not so easy and implies also that designers are familiar with CAD methodologies. In fact, improving performance of CAD users could be symbolized by several levels of expertise that a CAD services and users should acquire:
- Standard and basic features knowledge (i.e. How to create a pad, a revolution, etc.).
- Advanced methodologies for collaboration and easy design modification (use of publications, skeleton modelling, etc.). [3]
- Specific methodologies taking into account software possibilities and the use of the product CAD model by other software (i.e. specific rules defined for integration of the CAD files into the PLM system).

The use of specific developments and knowledgeware developments should come in addition to the CAD user competences, allowing to reduce his design time and to increase his design quality using knowledge based rules and features. However, companies should carry out the diffusion to the different stakeholders of the developed knowledgeware tools in order to take full advantage of them [4].

As promoted in [5], the empirical studies that we led showed that a department CAD support is highly recommended in order to centralize knowledgeware applications and users detect themselves directly 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 designer concerned.

We can find in the literature a lot of research on how to automate the design of product based on a KBE approach [6] [7] [8].

Considering the literature, few or no research works deals with knowledgeware. [9] propose CATIA KBE experiment but his work is mainly software-oriented. [10] describe a Knowledge-based System Engineering Process for Obtaining Engineering Design Solutions in a Commercial PLM Setting. [11] explore 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 analysed.

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

In a general way, scientific results mainly deal with process automation based on scripts developments [6] [12]. Other recent scientific results suggest generative model and automated product modelling using knowledge-Based Design features approaches [13] [14].
The originality of our work is that we propose a decisional model allowing to quickly define whether we need automation or knowledge integration. This decisional process model is presented in the next section.

4 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 of companies striving to integrate knowledge into CAD models do not make the difference between knowledgeware based solutions and specific developments (coding) which imply high direct cost (development cost done by experts) and indirect cost (maintenance). Thus, companies do not take real advantage of the possibilities offered by the CAD system for creating intelligent model which could easily improve performance of the design process.

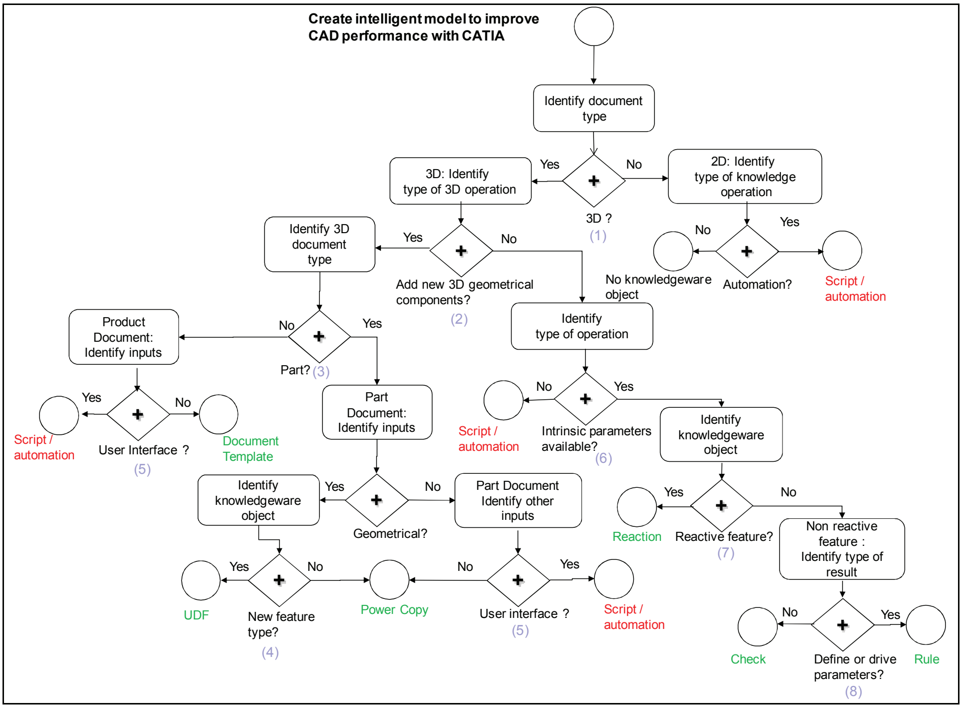

Figure 11: Decisional process model

An important part of the study was to identify limits of the knowledgeware language (EKL - Engineering Knowledge Language) and also limits in the creation and use of knowledgeware components.
In order to facilitate the understanding of this decisional model (see Figure 11), main steps are numbered in parenthesis (i.e. *(1)* for document type identification). Thus, numbers into parenthesis in this chapter refers to decisional model steps.
The notion of intrinsic parameters needs also 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, …).

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. 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 differentiate knowledgeware object that could create new 3D elements from elements which permit to work on existing features *(2)*.

The decisional process model allows also to choose 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 Document template cannot be instantiated in a part document.
Moreover, in a document if 3D components to be added needs 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)*.
It is only possible with knowledgeware functions to modify parameters and properties of existing 3D features (intrinsic parameters), for all other cases (i.e. modification of the part document structure) script are required *(6)*. The decisional process model differentiates features that are launched after an event *(7)* and features which drives or check intrinsic parameters *(8)*.

This decisional process model can be used at the beginning of a project in order to decide if knowledgeware or script has to 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 example are presented in next chapter.

5 EXAMPLE OF USE

We have select for this paper some industrial case studies which demonstrate the gain obtained using easy knowledgeware solutions.

5.1 Regulation checking using a template

In the automotive industry, security elements have to comply with specific norms and regulation. The European regulation defines an ISOFIX top tether anchorage zone. If the anchorage point is not included in this zone, the seat is rejected by the regulation commission.

Problematic for designers is that the top tether anchorage zone is complex to define because several construction methods have to be explored, and the most restrictive method has to be chosen. This operation which consists in the volume’s creation is time consuming and source of oversights.
The solution developed for the previous problematic is a Document Template which design the anchorage zone automatically and also compute the length of the strap (using KWA rules and checks) according the geometry of the seat section.

The choice of the solution has been done using the decisional model taking into account following inputs: add new 3D geometry as a component in a product document, using geometrical inputs and without specific user interaction. Thus, the solution is a Document Template. Reactive features and also checks and rules have been used for strap length computation. The choice of these elements has also been realized using the decisional model, but is not described in this article.

The template is an intelligent CAD element that adapts the dimension of the anchorage zone to seat sections dimensions.

The ISOFIX top tether anchorage zone is displayed in green color on picture below (Figure 12).

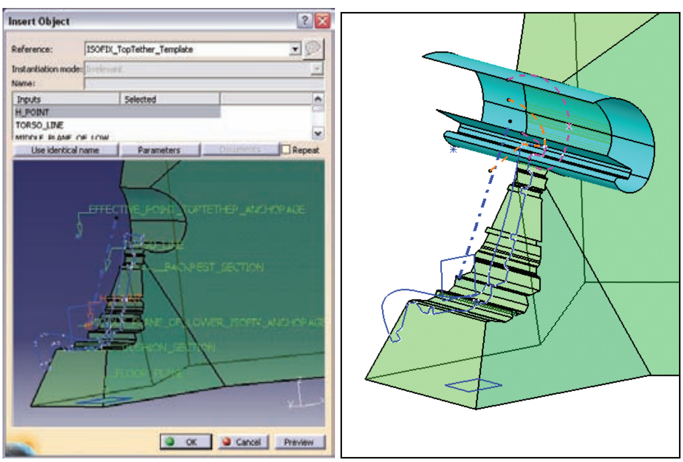

Figure 12: Template instantiation window (left) and template result (right)

The document template is a part file which is instantiated by the user in the seat assembly and which take geometrical elements as inputs.

These geometrical elements will replace existing ones (parents or reference elements of the construction) in the template, and then the geometrical construction present in the template will be updated taking into account new reference elements.

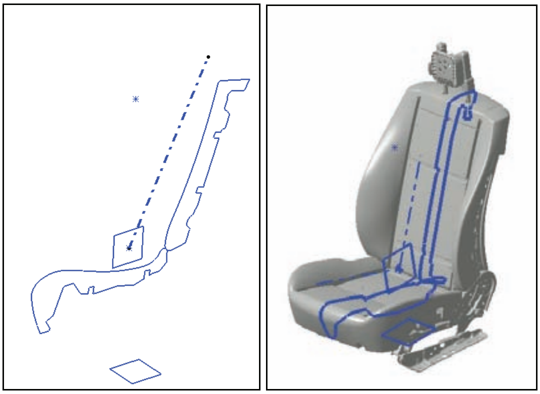

Figure 13: Geometrical inputs required for the template instantiation

Main benefit of this solution is to increase quality because there are no more errors while checking the regulation. The second important benefit is the improvement of the productivity as the checking zone creation needs 1 minute instead of more than one hour without the template. The user does not need to know the regulation as the template gives clear and easy indication about the regulation conformity.

5.2 Creation of sheet metal features with embedded manufacturing know-how

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

Initial industrial problematic was that sheet metal operations are very difficult to model (bending, stamping, etc.) and that manual check of proximities between these operations and edges of bends is time consuming and source of oversights.
The solution developed (see Figure 14) in order to answer to previous problematic, using knowledgeware solution, is to create parameterized geometry which take into account expert rules (formalized as mathematics rules) and check automatically the proximity between their environment (edges, bends, holes, other features).

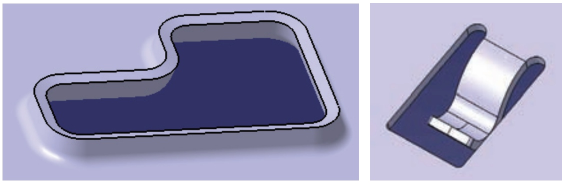

Figure 14: Example of UDF create for sheet metal parts

The choice of the solution has been done using the decisional model (see Figure 11) taking into account following inputs: add new 3D geometry in a document, using geometrical inputs and without specific user interface and the result should be a new feature type. Thus, it is necessary a User Defined Feature (UDF). Reactive features and also checks and rules have been used for dimensions definition and checking according manufacturing rules. The choice of these elements have also been done using the decisional model, but not described in this article.

Parameters which allow modifying the geometry of the sheet metal feature are published in order to make them available for the user (see an example on Figure 5). Values of these parameters are limited by knowledgeware functions (i.e. checks or reactions).

Benefits theses sheet metal templates are numerous: firstly it permit to avoid the use of specific license needed to use standard sheet metal features, secondly the quality and productivity are increased because sheet metal feature are conform with the manufacturing criteria available in the company and the creation time is reduce from more than 1 hour to less than 1 minute. Modifications on sheet metal features are very fast to perform using parameters from the UDF.

5.4 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 whole development of a product as the referential and then measure gains achieved through the use of knowledgeware. This gains will necessary be linked to complexity of a product and also to the capacity of a company to invest on knowledgeware solution.
It is what EDAG (a german company – specialized partner for automotive and aerospace product development) has done and recapitulate in the following graph.

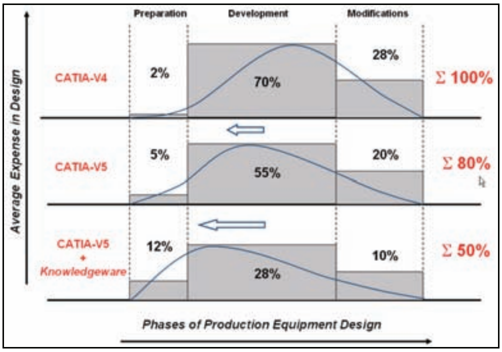

Figure 15: EDAG statistics determine on industrial cases

6 CONCLUSION

Today, more and more companies want to quickly reengineer a product from a multitude of family solutions. They are interested in some dynamic system that could automatically filter through a multitude of historical product solutions and quickly reconfigure one that meets customer requirements with the least cost and time investment. CAD software editors provide functionalities that allow to pinpoint some of these requirements. Based on knowledge capitalization as well as methodological rules and standard reuse, knowledgeware tools in CATIA V5 aim at this goal.
We presented here the functionalities of CATIA knowledgeware tools and a process model to use them. Industrial examples of the use of the knowledgeware were also presented and discussed. Some CAD project managers dream at a fully automated CAD tool when dealing with routine design. We assume that knowledgeware is not sufficient in this case. It must be taken as a useful tool kit allowing creating simple model/template and before this defining companies-specific methodological rules and standard in order to increase routine design speed with the aim of releasing time for innovation or generating benefits. Thus, as quoted by [11], a typical product development process - by its nature - is highly dynamic, nonlinear, discrete, feature-dependent, and part-dependent. The solution is not easy, since problem formulation is time-bound, has numerous discrete inputs, topologies, and several mathematical discontinuities. Nevertheless, as far as KM takes a significant place in the companies, the mastery of knowledgeware is today a real way of improving CAD efficiency and performances.

7 ACKNOWLEDGEMENT

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