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Manufacturing ontology through templates

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Abstract. The manufacturing industry contains a high volume of know-how and of high value, much of it being held by key persons in the company. The passing of this know-how is the basis of manufacturing ontology. Among other methods like advanced filtering and algorithm based decision making, one way of handling the manufacturing ontology is via templates. The current paper tackles this approach and highlights the advantages concluding with some recommendations.

1 Introduction

The lifecyle of a certain product, in its completeness from idea and design, project, technology, manufacturing planning, manufacturing and exploitation to removing the product from its use implies activities that rely on a series of principles, specific logic, structures and technological regimes, manufacturing structures, commercial activities, etc. which are basically based on knowledge. The cost of developing a product is highly influenced by the quantity and quality of the knowledge used. The cost, quality, training and service conditions within warranty and post warranty period are fundamental elements which sustain market competition. The manufacturing cost, if correctly estimated in the design and product development stages leads to a high rate of success and to a controlled competition. Despite the fact that 60% to 80% of the final product cost – raw materials, manufacturing costs, capital investments, auxiliary costs – is accessed starting the technological and functional design, a lot of managers consider the design as an unproductive and costly activity, even if a lot of companies have design costs not more over 5% of the project's budget [1].

When launching a product, two aspects are to be considered starting the design stage: the estimation of the manufacturing costs, especially on grounds of technological performance and the duration of the product's manufacturing activities. The duration of the activities that lead to the development of the product is estimated to be 80%-90% of the time to market, being influenced by the complexity of the product, the manufacturing technology and by the duration of the technological preparation of manufacturing.

Regarding the issues with product quality, Saaksvuori and Immonen [2] stated that 40% of these issues are caused by a deficient design activity. A design activity considered to be deficient may have multiple causes: the lack of knowledge regarding the quality of the furnishing, component incompatibilities, the dispersion of knowledge and so on.

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2 On the concept. Manufacturing ontology

The concept of "ontology" has been used in the last years in the field of knowledge management and computer assisted collaborative engineering.

The term "ontology" is borrowed from philosophy and it has been introduced in 1613 by the German philosopher Goclenius and popularized especially by Chr. Wolf. The idea of such a philosophical discipline has been defined in Aristotle times who called it "the first philosophy" and later, for this the term "metaphysic" has been used. In the pre-marxist and contemporary idealist philosophy ontology represented that speculative theory about existence as a state of fact, meaning common features and principles to any existence. Merriam-Webster dictionary defines ontology as "a branch of metaphysics which deals with the nature and the relationships of the existence".

The term ontology has been adopted by researchers in the field of Artificial Intelligence (AI) which have recognized the applicability of mathematic logic [3] arguing that they can develop ontologies as computational models which allow for certain types of automatized reasoning. In the 80's the AI community has proposed the use of the term "ontology" to address a different theory of the modelled world as well as a component of knowledge systems. Some researchers inspired by the philosophical ontologies have seen in the applicable computational ontologies aspects of the "applied" philosophy.

At the beginning of the 90's in an effort to create interoperability standards, an entire set of technologies which recognize the value of ontologies as a standard in the knowledge based systems has been created [4]. Following this stage the ontology became a technical term widely used especially in the field of computer science.

Ontologies are now used to capture knowledge of a certain domain of interest. Ontology describes the most important concepts and relationships of a certain area of interest. A widely accepted definition for ontology is given by Gruber, i.e. "an explicit specification of a conceptualization"[5]. According to Gruber [5], the conceptualization is an abstract notion, a simplified view of the world that we want to represent to serve a certain purpose. Regardless of the community type which will change and share knowledge through ontology, be it human or non-human agents (within AI), ontologies establish a common terminology and for this reason the conceptualization asks for a proper formalization.

As an application in the technical domain, Lobonţiu and Petrovan [6] have proposed a definition of ontology in product development: "The ontology represents that set of concepts, hierarchically structured which describes a certain knowledge domain which can be used to create a knowledge base. The ontology of a technical domain contains concepts, a structure, a subordinated hierarchy, arbitrary relationships between concepts, axioms, functions and other constraints".

Lemagnan [7] presents a simple example for the perception of the manufacturing ontology concept: "let's say my ontology defines the concept of aluminium as a sub-concept of raw material. The concept of drill as a sub-concept of tool and drilling as a kind of operation are also defined. Properties drill diameter and drill speed are added to these concepts to refine them. The ontology finally binds these concepts through the relationships canBeMachinedBy (between a raw material and an operation) and uses (between an operation and a tool). Once these concepts and relationships are established, rules may be written (like "for aluminium and drilling diameter smaller than 5 mm, the drill rotation should be 3000 rpm").

In the manufacturing field, ontology is still in its research stage [8], lacking a clear definition of the working area. This working area can include small areas belonging to the product's manufacturing cycle like design or machining or it can include the whole manufacturing process.

Studies regarding the manufacturing ontology in relation to the PLM can be found in papers like [8-12], each aiming for a certain stage of the PLM like Design/Development, machine selection, assembly, etc.

Neither of the mentioned studies tackles the ontology of machining. These are all treated under the umbrella of CAM software and manually written NC code but the actual ontology of the machining process is not treated. Although it's a branch of PLM, the number of variables and the nature of this branch have a significant influence over the final product and as well over the costs because of the selected machine, tools, cutting strategies, etc.

In the following chapters the development of ontology aspects that emerge in CAM controlled machining processes and the implementation of these aspects through templates is discussed. These aspects will form the so-called manufacturing ontologies of parts, divided and organized on part families, hierarchically structured within the manufacturing process with their own axioms, functions and constraints thus generating the manufacturing ontology of the whole product.

3 Methodology. Interdisciplinary

As well mentioned in the paper [13] manufacturing ontology involves interdisciplinary. Here we include the machining specialist who synthesizes the input variables which influence the cutting, the project manager which forces economic efficiency constraints and the IT specialist which, depending on the situation, generates the interface based on the data received or it conceives a way to input and adapt the received/collected data into existing systems/interfaces according to the variable relationship and their weight over the final result (Figure 1).

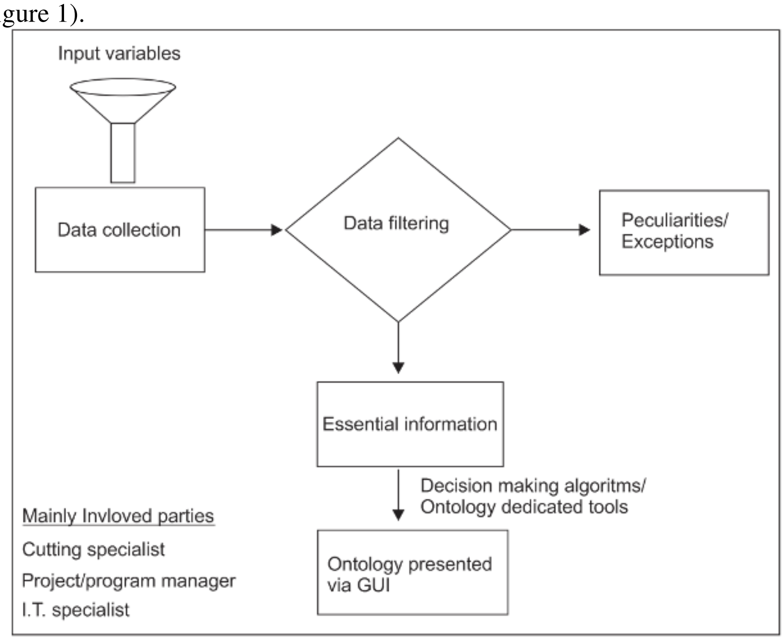

Fig. 1. Manufacturing ontology methodology.

The stages of creating the ontology presented in Figure 1 will not be discussed during this paper as they were very well described in the papers referenced here. It will however be underlined the implications each stage has over the machining domain.

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Data collection initially implies the identification of all the input variables which influence the machining process. Within these variables the following are the most important:

- the cutting regime (a_p – axial depth of cut [mm], a_e – radial depth of cut [mm], V_c – cutting velocity [m/min], V_f – feed velocity [mm/min]);
- the cutting pattern: raster, zig-zag, offset, profile, etc.;
- the type of cutting process: turning, milling, boring, etc.;
- the machining method: roughing, semi-finishing, finishing;
- the order of the operations: according to the access to each surface, to the conditions within the cutting process, to the used tools, etc.;
- the order of the cutting within the same operation: level first, depth first, custom;
- the definition of the working and clearance planes;
- the workpiece material, the tool and insert material, the tool geometry;
- the machine type used (power, number of axes, maximum travel on each axis);
- the cutting environment (dry, wet, mist, etc.).

Data filtering is dependent on the CAM software used and which determines if all or just part of the above mentioned variables can be included in the piece machining technology. These represent the core of that manufacturing ontology. If some of the data mentioned above cannot be included in the software, updates or plug-ins will be devised to improve the application as much as possible. The rest will pass into the Peculiarities/Exceptions area. In this area one may also find the information that cannot be digitized and it depends on the machining specialist to implement them on the workshop floor as good as possible.

Essential information includes: cutting regime, cutting pattern, tool geometry (as dimensions) and cutting operation succession. Based on this information the machining ontology can be devised for a certain surface or for a certain part.

Peculiarities/exceptions – as it was explained previously, this category includes either variables that cannot be defined within the CAM software either uncommon aspects that are very particular to the context.

Manufacturing ontology presented via GUI – it represents the crystallization of the manufacturing ontology via a GUI (Graphical User Interface) which is driven by decision making algorithms and ontology dedicated tools. This GUI is either custom created for a much more intuitive and user-friendly experience or as a template made by using the software's available resources in this case the appearance being the one with which the user is accustomed from using the standard software.

In the following chapter an example is being presented of a manufacturing ontology implemented in NX CAM from Siemens via templates.

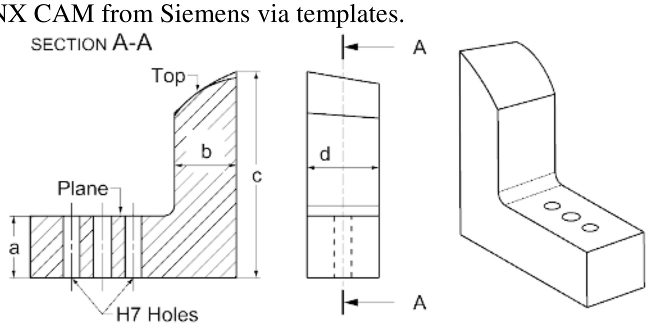

Fig. 2. Piece defined through dimensional parameters and surfaces.

4 Example of manufacturing ontology implemented through templates in NX

The piece presented in Figure 2 is often met in the automotive industry as part of an assembly which holds different car body parts to be welded.

It is defined through dimensions a, b, c, d and most of the times by 2 H7 precision holes for the dowel pins and one hole for the screw. The part must sustain the body part of the car this being laid on the Top surface. Considering the shape and the type of the surfaces, all these parts are identical which makes them ideal for a template because they can be manufactured using the same technology. In NX CAM, when building a template, the main philosophy is: "start with a process that works and reuse it for similar geometry". For this we need to have the manufacturing technology done in NX CAM for one such a piece and using it as a starting point to configure the template within NX CAM.

The operation sequence, the used tools and the parameters of the cutting for each case are presented in the figure below (Figure 3).

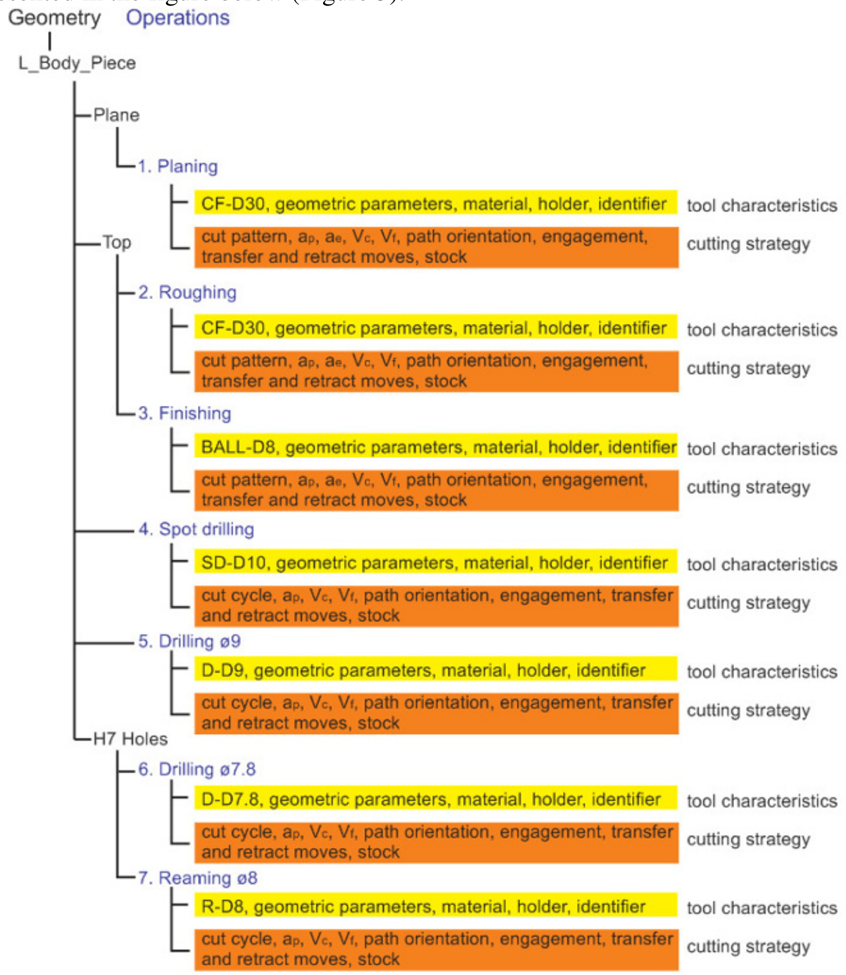

Fig. 3. Levels of subordination within the template.

The template will be created based on the parent geometry, i.e. in this case we named it L_BODY_PIECE. When opening the new part from the same part family to which we want to apply the known technology, the user must insert by using the NX CAM menus the L_BODY_PIECE geometry. Once this geometry inserted, everything regarding the manufacturing technology will also be inserted (tools, cutting operations, etc.). The user will then only have to click and define the surfaces referenced (Top, Plane, H7 Holes and screw hole). Everything else is being done by the template (creation of tools with all the defined parameters, creation of the cutting operations following the known order of execution and the given cutting parameters). Additionally to limit the access of the user to certain sensitive information of the manufacturing technology areas of the menu can be hidden thus also limiting the possibility of error/mistake to a minimum. Both interface customization and knowhow information input by using NX CAM is extremely easy and it does not require coding. Everything is done via mouse clicks.

It can be seen that in such template using cases, the end user (not the user who configures the template) must meet the minimum requirements of using the software tool regarding the CAM module. Basically this is a manufacturing ontology template for a certain type of pieces.

5 Conclusions

In the present paper the authors have tried to bring up front the concept of ontology in the technical domain by defining its basic structures. Through a working template we have created a manufacturing ontology of a typical part for the automotive industry.

Through the manufacturing ontology a specific database system is being created with usage procedures similar to those included in product development ontologies. The data will be referencing the whole process (technology, cutting data, time estimation, tooling, fixtures, probing tools, etc.). In this way the following advantages will be created for the industry: the time to manufacturing is being shortened, the certification of an in-use technology, the knowledge used, tooling and fixture solutions, known providers. On the other hand, if a fluctuation of personnel emerges, the replacement employees will use ontology models which will by then be certified.

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