Ontological Approach for the Conceptual Development of Products

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Abstract. In order to improve the structuring process of a product a company often refer to adopt different solutions for correlating the structure of the newly product and its components with other complementary factors. In essence, these factors target the market, suppliers, solutions of manufacturing, terms for delivery, price, quality, etc. All these factors must be taken into considerations in order to make an optimal decision during the conceptual or detailed design process. These factors are collected preliminary and introduced into the proposed ontology. Despite other approaches, the method proposed into this paper uses also some limitations to determine the right decision-making act even for unqualified people and some other knowledge’s incorporated into the ontology.

1. Introduction

Today’s product development process is highly focused on users requirements. This means that companies spend a lot of time to capture users needs, organize and find solutions to these needs and finally to implement them into the new product. One of the most important aspect of these activities is related to the process of data management that requires a holistic approach around application systems, data processes, techniques and people skills. Techniques of management of product life cycle through specific tools allows the inclusion of all elements needed to ensure its traceability, such as modelling, document management, numerical analysis, the capitalization of know-how etc. [1, 2]

All activities involved in the product development such as drafting, designing, technology and production planning, manufacturing, requires processes that are based on knowledge reasoning. An appreciable part of the cost of product development is the result of the activities carried out since its design phase [3]. This is heavily influenced by the quantity and quality of knowledge involved in conducted activities. Considering this, manufacturers take a special risk if the design phase is not well coordinated and supported by the knowledge base in various fields. Sample risks can be: frequent changes of design solutions, budget alterations, furniture delivery delays, faulty staging etc.

Based on these considerations, in this paper the authors try to propose an ontology to support the process of product development from the beginning stages of their lifecycle.
2. On the conceptual product development

Conceptual design is the phase of the product development cycle, where finding a basic solution is determined by developing a search principle for the solution [4]. This involves the formulation of abstract ideas with approximate concrete representations. The early or conceptual stage of the design process is dominated by the generation of ideas, which are then evaluated in contrast to the initial requirements.

There is a process by which additional data is incorporated into the partial solutions, allowing a decision to be made between the competing alternatives. The literature describes the conceptual design activity as having the object of defining a product that has a particular functionality and which is in accordance with certain specifications. According to NF L00-007 the concept of a product is "a creative activity which, based on the needs clearly expressed, the existing means and the technological possibilities, leads to the definition of a product that satisfies these needs and which is industrially achievable". AQAP (Applied Quality Assurance Publication), states that the design process is a task-definition approach to problem-solving tasks in order to create a product or service designed to meet the expressed needs. Certain industrial design situations, especially when the product is already known, can provide preconfigured procedures, rules, and methodologies applied to similar projects to design teams. Also, Bonnardel and Marmche [5] consider that this activity is a goal-oriented, purely mental activity focusing on pertinent aspects of the product, which leads to an understanding of the need to progressively construct a precise representation of the purpose of the concept. If the design team does not have any procedure that can be used to reach the goal, it will be required to adopt a strategy to develop a response.

The concept of a new product also involves describing the environment of the future product (highlighting user requirements for the product), describing its characteristics (highlighting the functional and structural aspects of the product) and product development planning (project management). Another component, project management, involves both the planning of activities to ensure the most favorable environment for the project to be carried out in optimal conditions as well as the project control by analyzing the differences between what was foreseen and what was achieved as well as the measures that will be taken to deal with the disruptive elements that inevitably occur during the course of the project. The competitiveness of an organization depends greatly on how it manages the overall process of conception. In general, effective use of a design method will help ensure the commercial success of the future product. At present there are over 100 methods and tools that can be used in product design. For this reason, when an organization wishes to develop a new product, it is in a difficult situation to choose the method that best suits its field of work, skills and, last but not least, the adopted strategy.

Often, the concept of product design is synonymous with the development of a product, defined as the set of information creation and communication activities that transform market data and technical opportunities into production information - models, specifications, prototypes, drawings, programs, necessary machine tools, tools, etc.

An approach of conception can be structured around three logics of action [6]:

- divergence - the action aimed at broadening the boundaries of the conceptual situation in order to widen the research space of the solutions;
- transformation - the action of building a structure, a model, a solution, starting from the results of the logic of divergence; is a stage of discovery and creativity;
- convergence - the action of progressively reducing uncertainty due to the multitude of possible solutions in order to select the most satisfactory solution.
3. On the ontology aspects of product development

The concept of ontology has been used in recent years, especially in many areas with applicability in knowledge management and computer assisted cooperation. By its peculiarities, ontology is used to share existing information in an area of interest. It is conducive to the representation and use of data relationships and is also effective in knowledge-based reasoning.

A broadly accepted definition for the notion of ontology is that given by Gruber [7], namely: Ontology is a formal specification of conceptualization. Gruber in [7] states that the term conceptualization is an abstract notion, a simplified view of the world we want to represent for a particular purpose. Regardless of the community type which will change and share knowledge through an ontology, whether human actors or agents (in the framework of artificial intelligence), ontologies establish a common terminology, for this reason conceptualization requires a proper formalization. As defined by Gruber [7], conceptualization refers to objects, concepts and other entities that are supposed to exist in a particular area of interest, as well as the relationships that hold them together. Regardless of the field, an ontology consists of several elements, the most important being: concepts, relationships, attributes, instances, and axioms. In other words, a conceptualization is an abstract and simplified vision of the world we want to represent for a certain purpose. Formal specification involves the existence of a vocabulary of representation in which the objects of the domain and the relations between them can be formally represented.

An important role in product ontology has the "feature" of the product. The concept of "feature" first appeared in the field of product engineering, where it was given the following definition: "a representation of the shape aspects of a product that can be made in a generic form and that is functionally significant for the phase of the life of some products" [8]. Initially, it was closely related to the geometry of the product. However, because product development does not only include engineering activities, product information is not limited to geometry, it has a much richer and more complex semantic content (functional, structural, behavioral, technological, etc.). In order to capture this semantic content, the meaning of "feature" is extended to have a relevant definition depending on the context in which it is used, reducing the gap between geometry and other product information.

Considering the large amount of information associated with the product development process and noting that the formal specification is an important part of it, some authors have tried to get semantics from shapes [9]. Several approaches to developing ontologies for products and services are known in several areas: biology [10, 11, 12], medicine [13, 14], design [15] and geosciences [16, 17]. Regarding special products like machines or industrial equipment, problems were treated relatively briefly in [18, 19].

As an application in the technical domain, Lobontiu and Petrovan [20] 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 relation-ships between concepts, axioms, functions and other constraints.

4. Approach

In order to build an ontology that covers the conceptual design process we have followed the methodology presented by Uschold and Gruninger [21] that combines a top-down and bottom-up practices for ontology engineering. The ontological approach for conceptual design is fostering the reuse, modularity, extensibility and maintainability as follows:

- Reuse. Our approach is based on existing ontology named Product Development Ontology (PDO) [20]. From a top-down perspective, the developed ontology was enriched with specific concepts linked to the conceptual product development and from the bottom-up perspective,
a very large amount of work was done to populate the ontology with objects and relations between them which are used to illustrate the usefulness of ontology.

- **Modularity.** This allow a separation of different parts of the ontology in order to be more flexible in the development of specific concepts. Also, this approach allows the involved team in product development to be more efficient and collaborative.

- **Extensibility.** This facilitate the further improvement of the ontology for the purpose of other product development applications. For example, the PDO that describes main aspects of product structuring was extended with new features related to conceptual product development.

- **Maintainability.** This characteristic simplifies the process of identifying and re-viewing deficiencies of the ontology, to implement new requirements in order to satisfy the changes that could occur in ontology.

Further, the generic model inspired by previous modeling work [22, 23], has been complemented with results from the analysis of the most used models of product structuring. In the first phase, we have identified the relevant terms and concepts within the domain of products structuring such as Components, Subassembly, Parts, Product, Functions, Attributes, Requirements, Constraints and Source. The result of this step is shown in Figure 1.

In order to extend this ontology to serve the entire conceptual product development activity, we consider the realization of necessary and sufficient concepts (see Figure 2) covering the whole field under consideration, such as:

- **Person,** which represents type of individuals that provide or request activities. In this class a few subclasses specify activities performed: Designer, Project-Manager, Procurement.

- **Team,** which represents groups of individuals from class Person involved in product development process. This organization is necessary to be able to closely follow the occupancy degree of personnel within the Company.

- **Project** contains relevant information about the resources involved in the conceptual product development activity. Through ontology relationships, we can aggregate information about product structure, number and type of component parts, their origin, delivery dates, product quality information, warranties, etc. It can also keep information about the team involved in the project or the person responsible for it.
Figure 2. The generic ontology of product structuring

- The Company class includes information about the partners involved in developing a product. These include the origin of the component parts of a product, possibly specifying service chains of the future product.
- Location, which represents the geographical area or countries and cities used to mark where a Company is located. This information is relevant for scheduling, supplying and integration of the various Components within a Project.

5. Conclusions
In this paper the authors have tried to bring up front the conceptual product development ontology. Through this ontology, relevant information can be gathered on: decision-making processes, selection of component parts or sub-assemblies, payment and phasing of the entire process, organization of working teams, integration of suppliers and distribution chains, etc. Also, the use of ontology could be used to support innovation on each component of a product and to support the collaboration of designers and other staff within the company.

This approach provides for the development of a network of ontologies based on a generic ontology, which explicitly describes the main concepts adopted in the product development process. This ontology can be further extended by creating new ontologies either directly or for the specific purpose of individual applications.
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