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Product Configurator: an Ontological Approach

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Abstract — **Mass customization is one of the most interesting and promising approach in the e-business field. In today's competitive global market the understanding of customer needs and desires is becoming the essential preliminary remark for a successful design and implementation of products. Product development based on customer preferences with applications of innovative technologies is an essential key in order to obtain a larger market share and faster sales growth. In this scenario a tool as the product configurator is becoming a real answer to one of most important question: how to organize product design to satisfy individual customer need without trading off cost-efficiency of mass production? This paper discusses a novel approach for the design of a smart product configurator. At this moment, in fact, the configurator is just a product viewer for the customer and does not implement any reasoning logics or user adaptive approach. So an ontology based approach is presented. In this methodology three ontologies are introduced: the customer needs ontology, the product functionalities ontology and the product configuration ontology. These ontologies represent the requirement and configuration knowledge that needs for a real customization of the product. The customer has to express his product demands by the use of natural language and by the mapping among the introduced ontologies and the use of a Bayesian Network approach the automatic conversion between customer needs and product configuration is achieved.**

Keywords-Ontology, Mass Customization, Semantic Web

I. INTRODUCTION

In today's manufacturing market there is a growing trend toward highly global competition and a considerable variety of personalized customer requirement. In this scenario product configurator has become an important part of the manufacturing services system to manage product variations and adapted and personalized products able to match the real needs of customers [1]. In fact one of the most important promises of mass customization is how to organize product design to satisfy individual customer need without trading off cost-efficiency of mass production. In literature many researchers believe that product configuration is the only effective answer to this question [2]. Product development based on customer preferences is a key to obtaining a larger market share and faster sales growth for organizations. The overwhelming of Internet and its services, indeed, has allowed an effective diffusion of e-business and the building of a real, interesting and distributed market. So many corporations have introduced on their websites an interactive product configurator through which customer can make his choices and be supported in the product selection [3]. The core of an adaptive configuration task is the selection and arrangement of a combination of a component in order to build a product able to satisfy the specifications furnished by the customer. Obviously the customized product has to satisfy the constraints and predefined rules for component composition. Even though this issue is very interesting and important past researches have not addressed it well. At this moment, in fact, the product configurator is just a product viewer for the customer and does not implement any reasoning logics or user adaptive approach. In this way the requests of customers are just received passively without being further reasoned. The customer, besides, is required to be acquainted with both product structure and functions and the final configuration could be very different from the best one. On the other hand in the last period many papers are introducing very interesting approaches for the solution of this problem [2][4][5]. In particular an ontology approach seems to be an effective methodology for the improvement of the actual configurator [6][7]. Ontology is a formal and explicit specifications of shared conceptualizations, representing concepts and their relations that are relevant for a given domain of discourse and serve as a means for establishing a conceptually concise basis for communicating knowledge for many purposes. There is a huge interest in the area of engineering ontologies for a very wide range of interesting applications and the community in that field is steadily growing. The expected central role of ontologies in the organization and functioning of the Semantic Web has been well documented in recent years and ontology is playing a central role in fields as E-Business, E-Commerce, E-Learning, E-Health. The semantic web has a huge potential to overcome the previously described difficulties because its main aim is to extend information, generally expressed in natural language, by the use of computer understandable language or representation. In this scenario the ontology formalism plays an effective role. In this paper a framework for on line product configuration based on an ontology approach is proposed. In particular it consists in the management of three ontologies: the customer needs ontology, the product functionalities ontology and the product configuration ontology. These ontologies represent the requirement and configuration knowledge that needs for a real customization of the product. The customer has to

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express his product demands by the use of natural language and by the mapping among the introduced ontologies and the use of a Bayesian Network approach and semantic web services the automatic conversion between customer needs and product configuration is achieved. The paper is so organized: the next section describes the ontology and his application in the field of semantic web. The third section introduces the proposed approach while in the fourth some experiments are presented. The fifth section describes conclusions and future works

II. ONTOLOGY AND SEMANTIC WEB

Ontology is originally a branch of philosophy where it means a systematic explanation of being. In recent years, however, this concept has been introduced and used in different contexts, thereby playing a predominant role in knowledge engineering and in artificial intelligence [10]. Ontology has different definitions for each community. The commonly accepted definition is provided by Gruber [11]: "an ontology is a formal, explicit specification of a shared conceptualization". Following this point of view, ontology can be considered as content theories, since its main contribute is in the identification of topics and relations that are in a well defined knowledge domain. The ontological approach, besides, clarifies the knowledge structure in other words given a certain domain, the related ontology represents the heart of any knowledge representation system for that domain. Another reason for creating and developing ontology is the possibility of sharing and reusing knowledge domain among people or software agents. Ontology can be represented as a taxonomic tree of conceptualizations: it is general and domain-independent at a superior level, but become more and more specific when one goes down the hierarchy. In other words, when we move from the highest taxonomic levels to the lowest ones, characteristics and aspects typical of the domain under examination are showed. In order to point out this difference in literature they are called heavyweight (deeper) and lightweight (advances) ontology respectively [12]. A lightweight ontology is a structured representation of knowledge, which ranges from a simple enumeration of terms to a graph or taxonomy where the concepts are arranged in a hierarchy with a simple (specialization, is-a) relationship between them. Heavyweight ontology adds more meaning to this structure by providing axioms and broader descriptions of the knowledge. In this paper, we will adopt the last one approach keeping in mind this definition of ontology: "ontology may take a variety of forms, but it will necessarily include a vocabulary of terms and some specification of their meaning. This includes definitions and an indication of how concepts are inter-related which collectively impose a structure on the domain and constrain the possible interpretations of terms" [13]. In particular in this paper the ontology will be used as support for semantic web methodologies. In fact the main aim of the proposed approach is the introduction of methodology able to discover the needs of a customer by the inference of his requests, expressed in natural language. In this way the mapping between needs and product's functionalities can be achieved. In this scenario ontology is the unifying tool able to implement this approach. In fact the Semantic Web and Knowledge Engineering communities are both confronted with the endeavour to design and build ontologies by means of different tools and languages, which in turn raises an "ontology management problem" related to the peculiar tasks of representing, maintaining, merging, mapping, versioning and translating. These mentioned above are well known concerns animating the debate in the ontology field. However, we argue that the utilization of different tools and languages is mainly due to a personal view of the problem of knowledge representation, which in turn raises a not uniform perspective. Therefore we argue that a special effort should be devoted to better explain and clarify the theory of semantic knowledge and how we should correctly model the latter for being properly represented and used on a machine. A simple process to convey meaning through language can be summarized as follows: *Meaning* – Encode – Language – Decode – *Meaning'* where, since Encoding/Decoding processes are noisy, *Meaning'* is the estimation of the original *Meaning*. In order to understand why those processes are noisy we assume that a communication act through language is in the form of writing/reading a book. Here, the origin of the communicative act is a meaning that resides wholly with the author, and that the author wants to express in a permanent text. This meaning is not historic, immutable, and pre-linguistic and is encoded on the left-hand side of the process; it must be wholly dependent on an act of the author, without the possibility of participation of the reader in an exchange that creates, rather than simply register, meaning. The author translates such creation into the shared code of language, then, by opening a communication, he sends it to the reader at the encoding stage. It is well known that, due to the accidental imperfections of human languages, such translation process may be imperfect, which in turn means that such a process is corrupted by "noise". Once the translated meaning is delivered to reader, a process for decoding it starts. Such process (maybe also corrupted by some more noise) obtains a reasonable approximation of the original meaning as intended by the author. As a consequence meaning is never fully present in a sign, but it is scattered through the whole chain of signifiers: it is deferred, through the process that Derrida [14] indicates with the neologism difference, a dynamic process that takes plane on the syntagmatic plane of the text. So we argue that, as pointed out by Steyvers and his colleagues [15], the semantic knowledge can be thought of as knowledge about relations among several types of elements, including *words*, *concepts*, and *percepts*. According to such definition the following relations must be taken into account:

- Concept – concept relations: for example knowledge that dogs are a kind of animal, that dogs have tails and can bark, or that animals have bodies and can move;
- Concept – action relations: for example knowledge about how to pet a dog or operate a toaster
- Concept – percept relations: for example knowledge about what dogs look like, how a dog can be distinguished from a cat;
- Word – concept relations: Knowledge that the word dog refers to the concept dog, the word animal refers to the concept animal, or the word toaster refers to the concept toaster;
- Word – word relations: Knowledge that the word dog tends to be associated with or co-occur with words such as tail, bone.

Obviously these different aspects of semantic knowledge are not necessarily independent, rather those can influence behaviour in different ways and seem to be best captured by different kinds of formal representations. As a consequence result, different approaches to modelling semantic knowledge tend to focus on different aspects of this knowledge, specifically we can distinguish two main approaches:

- The focus is on the structure of associative relations between words in natural language use and relations between words and concepts, along with the contextual dependence of these relations [16]. This approach can be defined as light semantics
- The emphasis is on abstract conceptual structure, focusing on relations among concepts and relations between concepts and percepts or actions [17]. This approach can be defined as deep semantics

The key idea of the proposed approach is that indeed semantics representation is likely to emerge through the interaction of light and deep semantics. Thus, an artificial system contending with semantics should necessary take into account both facets [18]. The description of both Word – Word and Word-Concept relations, related to the light part of semantics, is based on an extension of the computational model depicted above and discussed in [15], where statistic dependence among words is assumed. As previously discussed, four problems have to be solved: word patching, prediction, disambiguation and gist extraction. The original theory of Griffiths mainly asserts a semantic representation in which word meanings are represented in terms of a set of probabilistic topics z_i where the assumption of statistically independence among words w_i was made. On the contrary, our extension provides word–word relations, which are represented as a set of probabilistic connections. Summing up, we propose a probabilistic model that, together with the topics model, considers what we call the words model, in order to performs well in predicting word association and the effects of semantic association and ambiguity on a variety of language-processing and memory tasks In through the words model we can build consistent relations between words measuring their degree of dependence, formally by computing joint probability between words:

$$P(w_i,w_j) = P(w_i| w_j)P(w_j) = \sum_{k=1..T} P(w_i|z_i = k)P(w_j |z_j = k)$$

where T is the number of Topics and $P(w_i)$ is computed as follows:

$$P(w_i) = \sum_{k=1..T} P(w_i \mid z_i = k)P(z_i = k)$$

By comparing joint probability with probability of each random variable we can establishes how much two variables (words) are statistically dependent, in facts the hardness of such statistical dependence increases as mutual information measure increases, namely: $|P(w_i, w_j)-P(w_j)| = p$ where p belongs to the range $[-1,1]$. By selecting hard connections among existing all, for instance choosing a threshold for the mutual information measure, a GM for the words can be delivered. As a consequence, ontology can be considered as set of pair of words each of them having its mutual informational value. More formally, the words model can be used to analyze the content of documents and the meaning of words, this model use the fundamental idea that a document is a mixture of topics. In this paper we use the topic model, discussed in [15] based on the LDA algorithm [19]. Assume we have seen a sequence of words $\mathbf{w} = (w_1, \ldots, w_n)$. These n words manifest some latent semantic structure l.We will assume that l consists of the gist of that sequence of words g and the sense or meaning of each word, $\mathbf{z}=(z_1, \ldots, z_n)$, so $l = (\mathbf{z},\mathbf{g})$. The proposed approach was implemented in a framework named ISOS (In Search Of Semantic) [20]

III. THE PROPOSED FRAMEWORK

In this paragraph an ontological approach for a product configurator component description is introduced. First of all some definitions have to be introduced. The following sets can be so defined:

- N: Customer Needs set
- C: Components set
- R: Relationships among components set
- F: Component's Functionalities set
- O: Ontology set

So the following functions can be introduced:

- Function new components: **g**: $\mathbf{C^N} \to \mathbf{C^N}$**:** the function g aims to represent the building of new components by the aggregation of other ones. In particular this function could be of two different kinds:

- the boolean AND function when all components have to be arranged in order to compose the new one.
- the boolean OR function when some components have to be arranged in order to compose the new one but none of them is essential for its creation.
- the boolean XOR function when some components have to be arranged in order to compose the new one but only one of them is essential for its creation.

- Function new needs: **n**: N^N **->** F^N**:** this function defines the customer's needs and matches them with the functionalities of the product.
- Function new functionalities: **f**: C^N **->** F^N**:** this function defines the functionalities of the new component obtained by the aggregation of various other ones. In particular this component can inherit the functionalities of the other ones and introduce new ones.
- Function components ontology: **h**: C^N **x** R^N **-> O:** this function describes the ontology of the new component. In particular this function returns an ontology that explains how this component is obtained by the aggregation of the other ones and the relative relationships.
- Function components functionalities : **i**: F^N **x** R^N **-> O:** this function describes the ontology of the new component's functionalities. Keeping in mind the approach previously described the proposed framework that can be described by the use of four main stages and is depicted in figure 1.

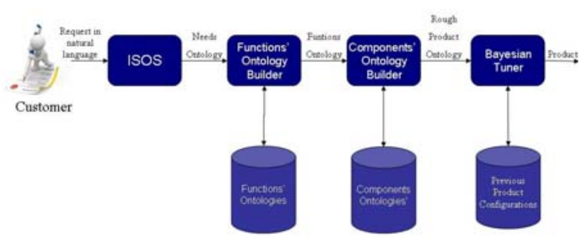

Figure 1: The Proposed Approach

The first stage is the ISOS module. The customer describes its requests by the use of natural language. In particular the customer has to declare the main features of the product and what he needs. In this way the customer can describe in details the expected functionalities and uses that has in his mind for the product. So the text will be processed according to the ISOS approach and ontology of the product is designed. In particular in this way the ontology represents the customer's idea of the product. At the end of this phase the obtained ontology, expressed in OWL language, is the input of the next stage: the function's Ontology Builder. This module has the aim to translate the requests of user in real and effective functionalities of the product. In particular there is a mapping between the user product ontology and the functionalities ontologies, related to various developed by experts. The mapping is obtained by the application of a scoring function between the topics belonging to the ontologies. At the end of this phase a functionalities ontology of the user product is the output. We have to underline that this new ontology is not one of the functionalities ontology described by experts but a mixture of them. This new ontology represents the explicit and implicit functionalities of the customer's desired product. In the next phase the functionalities ontology is the input of the component ontology builder. In particular by the analysis of the main functionalities ontology the main components and their relationships are described, in other words the product component ontology. Also in this case a matching function between the two ontologies is introduced. The output of this stage is the component ontology of the customer's desired product. The last stage is the Bayesian tuning module that has the aim to improve the proposed configuration. This module, in fact, compares the obtained product with the previous ones. In particular the proposed product ontology is transformed in a Bayesian network as described in [21]. In this way this module, analyzing by the use of a Bayesian approach the proposed configuration with the other ones, previously created, can improve the product configuration adding new components.

IV. EXPERIMENTAL RESULTS

In order to test the proposed approach a case study has been created. In particular the framework, developed by the use of php language and mysql, was added in the web portal of a computer store franchising. This franchising is composed by five shops located in Campania, Italy. By the use of our product configurator the customer can write in natural language his product request and obtain the adapted configuration by mail. The customer can write sentences in Italian Language as "Io voglio un personal computer per giocare" ("I want a personal computer in order to have fun with videogames") and at the end of the process he obtains the design of personal computer adapted to his needs. We started the experimental phase in September 2008 and ended it in January 2009. In this period the product configurator produced about 750 configuration and 162 of them has been really sold to the relative customer. In the same period the shops sold 218 personal computers according to a traditional approach. In the march 2009 we sent a mail to each customer with a questionnaire about the bought product. In particular the questionnaire asked what the feelings with the product are. We analyzed the answers in order to understand the customer level of satisfaction and in table 1 the obtained results are reported.

Customers	Answered Questionnaires	Very Low	Low	Medium	Good	Very Good
162	131	5	12	33	75	6
218	117	20	23	30	41	3

Table 2: Obtained Results

The obtained results show as the proposed product configurator works well because about the 60% of "adapted customers” is very satisfied instead of the 37% of traditional customers.

V. Conclusions

In this paper we proposed a methodology for a product configuration tool based on the use of ontology approach. The choice is particularly effective and appreciated by the users. Future developments could concern the combination of the proposed method with adaptive hypermedia system in order to make the configuration tool more customized and effective.

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List and number all bibliographical references in 9-point Times, single-spaced, at the end of your paper. When referenced in the text, enclose the citation number in square brackets, for example [1]. Where appropriate, include the name(s) of editors of referenced books. The template will number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first . . .”

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For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

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