Exchanges of Knowledge about Product Configurations using XML Topic Map

Namchul Do, and Jihun Cho

Abstract—Modeling product configurations needs large amounts of knowledge about technical and marketing restrictions on the product. Previous attempts to automate product configurations concentrate on representations and management of the knowledge for specific domains in fixed and isolated computing environments. Since the knowledge about product configurations is subject to continuous change and hard to express, these attempts often failed to efficiently manage and exchange the knowledge in collaborative product development. In this paper, XML Topic Map (XTM) is introduced to represent and exchange the knowledge about product configurations in collaborative product development. A product configuration model based on XTM along with its merger and inference facilities enables configuration engineers in collaborative product development to manage and exchange their knowledge efficiently. A prototype implementation is also presented to demonstrate the proposed model can be applied to engineering information systems to exchange the product configuration knowledge.

Keywords—Knowledge exchange, product configurations, XML topic map.

I. INTRODUCTION

A product configuration is a specification of a product individual as a collection of predefined components. Modeling product configurations needs large amount of knowledge about target products including technical and marketing restrictions of the products. It is no surprise then that product configurations have become an important application for artificial intelligence research. As an example, since 1982, Digital Equipment Corporation used the XCON system, a rule based expert system, to configure their computer systems [1].

Previous attempts to automate product configurations concentrate on representing the knowledge for specific domains in fixed and isolated computing environments. Since the knowledge was not standardized and tightly integrated into the independently developed configuration systems, it is difficult for configuration engineers to update the knowledge with new product and rules [2].

The current rapidly globalizing market with the distributed product development environment requires more efficient product configuration models that can be exchanged among various participants in collaborative product development. For the collaboration with the product configuration knowledge, configuration engineers including technical engineers and regional marketing experts should represent and exchange their knowledge regardless of their computing environments or locations.

Using an emerging knowledge representation standard based on XML technology, XML Topic Map (XTM), this paper will propose a product configuration model that enables participants in collaborative product development to easily represent and exchange their knowledge about product configurations.

II. RELATED WORK

There have been many researches on configurations using rule base systems. They include researches on academic topics [3, 4], system developments [5, 1, 6] and surveys [7, 8]. We can also find papers that discussed main flaws of existing rule based configuration systems [9, 10]. They mainly pointed out that the tightly integrated rules and configuration systems caused the inflexibility of the systems. It is why we consider a knowledge representation standard for representing and managing product configuration knowledge. If the existing approaches are applied to the current collaborative product development environment, the problem will be more serious since the environment needs numerous exchanges of the knowledge about product configurations. Until now, it is hard for us to find researches on exchanges of the knowledge about configurations in collaborative product development environment.

Our research concentrates on how to represent and merge knowledge about different configurations into one integrated product configuration model for the exchange of the knowledge. We therefore represent existing product configuration model [6] with XTM and show how it can support the exchanges of configuration knowledge.

III. PRODUCT CONFIGURATION MODELING AND XTM REPRESENTATION

A. Product Configuration Modeling

Product configurations are specified based on a product configuration model that consists of components of product structure and associated restriction rules for combinations of the components. In order to build the product configuration

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Namchul Do is with Div. of Industrial and Systems Engineering, Gyoeng Sang National University, 900, Kajwa-dong Jinju City, Geongnam, Korea 660-701 (phone: +82 55 751 6214; fax: +82 55 762 6599; e-mail: dnc@ gsnu.ac.kr).

Jihun Cho is with Div. of Industrial and Systems Engineering, Gyoeng Sang National University, 900, Kajwa-dong Jinju City, Geongnam, Korea 660-701 (e-mail: jee_h@hanmail.net).

model, various configuration engineers including technical, marketing and sales experts should exchange and integrate their knowledge about product configurations.

In this paper, design engineers and marketing experts are considered as configuration engineers for an illustrative collaborative modeling process for product configurations in a collaborative product development project. Fig.1 shows how they develop an integrated product configuration model during the process.
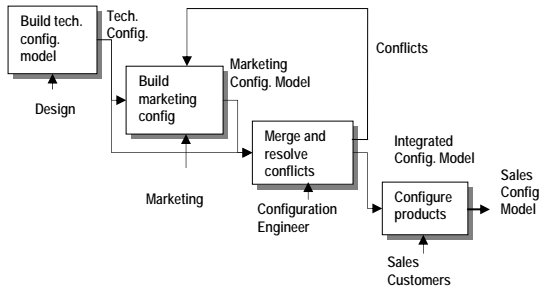

Fig. 1 A Process for Collaborative Configuration Modeling

B. Knowledge Representations using XTM

XTM is an XML-based standard of which purpose is to exchange knowledge [11]. It mainly consists of <topic> and <association> elements that represent interesting objects and relationships between them respectively. Using the elements, engineers can build a topic map network that can represent knowledge about a specific domain.

There exist two important facilities that can manipulate topic maps specified by XTM. One is merger of different topic maps and the other is inferences using the associations in topic maps. The merger operation makes more than two topic maps into one topic map using topics with the same name in the same scope or same subject identity. The inference facilities can be executed on the predicates that are converted from associations in a topic map. Standard XTM languages are available for the inferences and inquiries for various data in topic maps. The two facilities are used in this paper to merge different configuration knowledge into an integrated one and to verify conflicts in the merged knowledge about product configurations.

IV. REPRESENTATIONS OF PRODUCT CONFIGURATIONS USING XTM

A. A Configuration Model

In order to build a product configuration model, a consistent product structure is needed. In this paper, a consistent product data model that consists of the model, option, feature and configuration [12] is introduced. Figure 2 depicts an instance model of the product structure [6]. The root of the product structure, '1000 car' is a model that represents a set of configurations and maintains features that consists of a group of options. For an example, feature '1100 engine' consists of the three options, '1110 engine 1.5', '1120 engine 2.0' and '1130 engine 2.5'. The options, modules of parts or assemblies, constitute product configurations and several restriction rules

that can be applied to the combination of options for a configuration. The '1000e e-car' configuration that consists of '1110', '1210', '1310' illustrates a configuration using combinations of options.
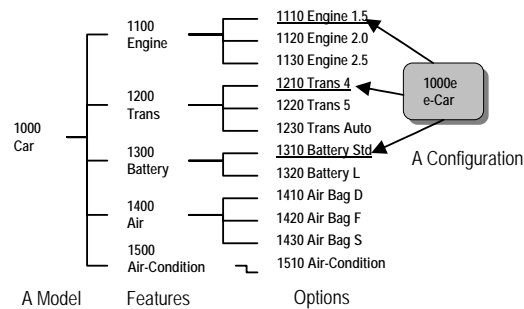

Fig. 2 An instance model of product structure for configurations

A configuration model consists of product structure and associated rules that restrict combinations of components (options). The restriction rules for combinations of options can be classified into the following 4 types [6]:

- AND rule (&) - If an option is selected as an element of a configuration, another specific option should be selected as an element of the same configuration.
- NOT rule (~) - If an option is selected, another specific option should not be selected.
- ONE rule (X) - If an option is selected, only one option in a specific set of options should be selected.
- MORE rule (+) - If an option is selected, more than one option in a specific set of options should be selected

The following is a specification for the restriction rules for combinations for the example model in Fig. 2.

1) 1110 :- &1310 | X1210,1220 | ~1510
2) 1120 :- &1320 | X1210,1220,1230 | &1410
3) 1130 :- &1320 | X1220,1230 | &1510 | &1410
   | +1420, 1430
4) 1310 :- &1110 | X1210,1220 | ~1510
5) 1320 :- X1120, 1130 | X1210,1220,1230

For example the 1st rule said if '1110 engine 1.5' is selected, '1310 battery std' and one of '1210 trans 4' and '1220 trans 5' should be selected for a configuration. In this selection, '1510 air-condition' should not be included. These rules can restrict combinations of options for building a configuration or evaluate whether an existing configuration is valid or not.

B. XTM Representations for the Configuration Model

The structure of the proposed configuration model in ISO STEP EXPRESS-G notation is depicted in Fig. 3. The option topic and the rule association in the figure represent options in product structure and restriction rules for configurations respectively. In the figure, the rule association has its cause as a cause topic and the topic has a Public Subject Indicator (PSI) as

its regulation attribute. The PSI can indicate published topics of regulations using an official Web site on the regulation in order to express mutually agreed-upon knowledge about the cause.
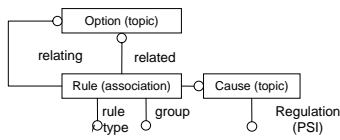

Fig. 3 Structure of Configuration Model based on XTM

The following topic map is a specification of options 'engine 1.5' and 'trans 4' in Fig. 2 and their associated AND rule 'engine_01_50_AND_trans_04' in XTM.

```
/* engine 1.5 topic */
<topic id="engine_01_50">
  <instanceOf>
    <topicRef xlink:href="#option"/>
  </instanceOf>
  <baseName>
    <baseNameString>engine_01_50</baseNameString>
  </baseName>
</topic>
/* trans 4 topic */
<topic id="trans_04">
  <instanceOf>
    <topicRef xlink:href="#option"/>
  </instanceOf>
  <baseName>
    <baseNameString>trans_04</baseNameString>
  </baseName>
</topic>
/* association for AND rule between engine 1.5 and trans 4
*/
<association id="engine_01_50_AND_trans_04">
  <instanceOf>
    <topicRef xlink:href = "#ruleAssociation"/>
  </instanceOf>
  <member>
    <roleSpec><topicRef xlink:href="#relating"/>
    </roleSpec>
    <topicRef xlink:href="#engine_01_50"/>
  </member>
  <member>
    <roleSpec><topicRef xlink:href="#related"/>
    </roleSpec>
    <topicRef xlink:href="#trans_04"/>
  </member>
  <member>
    <roleSpec ><topicRef xlink:href="#operator"/>
    </roleSpec>
    <topicRef xlink:href="#AND"/>
  </member>
</association>
```

The specification of the topics and associations can be

generated from a Product Data Management (PDM) system using a translation tool. Design engineers can build a valid product configuration using a product configurator in the PDM system and then export it as a topic map for the next merger procedure. Architecture for the configuration management process including the PDM system will be discussed in detail in Section V.

C. Representation of Marketing Configurations

As depicted in Fig. 1, after the design engineers built his or her technical configuration model, marketing experts plan and build their own configuration models, considering the product structure (options) in the technical configuration model. They can create new options or features, but, for the simplicity, this paper considers only the case they just reference the option topics in the technical configuration model and create their own configuration rule associations between the topics. The following is a list of rules each regional marketing expert provided for their own configuration models.

Region A:
    Rule 1: Air Bag S has no demand in the regional market
    Rule 2: The combination of engine 1.5 and air-condition can not meet an environmental regulation
Region B:
    Rule 3: Engine 1.5 has no demand in the market
    Rule 4: Our safety regulation needs both Air Bag D and F

Among the rules, the 1st and the 3rd rules do not allow specific options in a specific region, so customers in the region can not use the options when they build their own configurations. The 2nd and the 4th rules will add additional restrictions on the existing technical rules and should be represented in XTM association for further merger processing. The following is the specification of the 2nd rule in XTM association.

```
<association id="engine_01_50_NOT_air_condition">
  <instanceOf>
    <topicRef xlink:href = "#ruleAssociation"/>
  </instanceOf>
  <member>
    <roleSpec><topicRef xlink:href="#relating"/>
    </roleSpec>
    <topicRef xlink:href="#engine_01_50"/>
  </member>
  <member>
    <roleSpec><topicRef xlink:href="#related"/>
    </roleSpec>
    <topicRef xlink:href="# air_condition"/>
  </member>
  <member>
    <roleSpec ><topicRef xlink:href="#operator"/>
    </roleSpec>
    <topicRef xlink:href="#NOT"/>
  </member>
</association>
```

D. Merger of Different Configuration Knowledge

XTM enables configuration engineers to merge the technical and marketing configuration models into one model based on the option topics that have the same name (XTM's name-based merge). The option topics that have the same name but are located in different configuration models (in different XTM files) are merged into one and all the rule associations related to each option topics are associated to the new merged one.

Although the technical and marketing configuration models can be merged into one, the merged model may have conflicts among its rule associations. To resolve the conflicts, XTM management tools that allow a query language for the topics and associations can be used. The query language also provides inference facilities for the predicates converted from XTM associations to selects associations that conflict with others. As an example, the following basic axioms can be applied to selects conflicted associations among the configuration rules:

IF A and B are different options and a set of option X has B as its element
1) The rule A & B conflicts with A ~ B
2) The rule A & B conflicts with A + X
3) The rule A & B conflicts with A x X

Query specifications using XTM query language can be used to select rule associations that cause the conflicts. The following conversions from associations to predicates and 'conflicted_association' rule specification help configuration engineers to select rule associations that cause conflicts by applying the 1st axiom:

If 'ruleAssociation' association in XTM is

converted into the predicate 'ruleAssociation(relating, related, operator)'

conflicted_association($A, $B) :-
    ruleAssociation($A: relating, $B: related, AND : operator) AND
    ruleAssociation($A: relating, $B: related, NOT : operator).

V. SYSTEM ARCHITECTURE

Using XTM representations for product configurations along with XTM merger and inference facilities, we have designed a system architecture that can support the process in Fig. 1. Fig. 4 shows the system architecture. There are two sub systems in the architecture. One is a PDM system that provides a rule based configurator. The configurator was implemented using the product structure and rules mentioned in the previous section. A design engineer uses the configurator to build and verify a technical configuration model. The other is a set of XTM management tools that enable configuration engineers to merge topic maps containing technical and marketing configuration models with option topics and rule associations. It also provides a Prolog engine to inference associations that cause the conflicts in the merged topic maps.
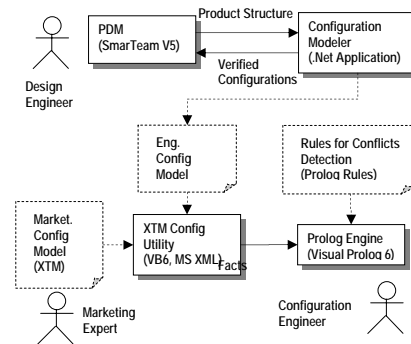

Fig. 4 System Architecture for Collaborative Product Configurations

According to the process in Fig. 1, the design engineer builds a technical product configuration model in the PDM system and translates it into an XTM file with a translator. Then, the marketing experts build topic map files containing their own rule associations with the option topics in the technical configuration model. The technical and marketing product configuration models in XTM are merged and verified by the XTM management tools. The design engineer can input the integrated configuration model into the PDM system and use it to configure products that satisfy all the restrictions for valid configurations.

Fig. 5 shows a prototype system that implements the architecture. It shows XTM Config Utility for merging different XTM configuration models (Fig. 5 a) and Prolog Engine for verifying conflicts between the models (Fig. 5. b).
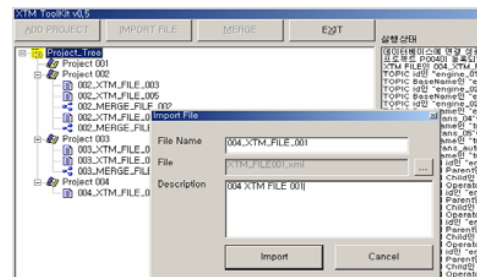
(a)
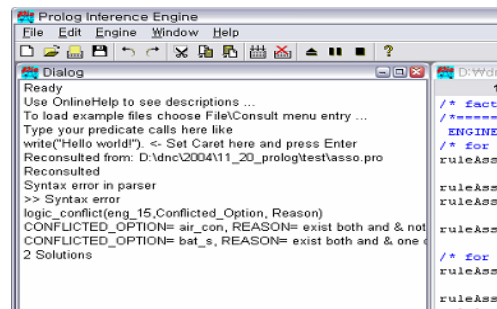
(b)

Fig. 5 (a) XTM Config Utility (b) Prolog Engine

VI. CONCLUSION

Existing approaches to automate product configurations concentrate on knowledge representations and applications that are isolated and tightly coupled with independently developed configuration systems. In these approaches, configuration engineers can not properly update the knowledge with new product and rules. In addition to problems of the existing rule-based configuration systems, configuration engineers in the current collaborative product development need exchanges of the knowledge about product configurations among the participants regardless of their computing environments or locations.

Using a XML-based knowledge representation standard, XTM, this paper proposed a product configuration model that consists of topics for product structure and associations for restriction rules for product configurations. A product configurator implemented in a PDM system and a set of XTM management tools introduced in this paper provide system architecture that support collaborative product configuration modeling. The proposed product configuration model based on XTM technologies enables various configuration engineers in collaborative product development projects to represent and exchange their knowledge about product configurations regardless of their computing environments or locations. A prototype configuration system that implements the proposed product configuration model is also presented to show the applicability of the model.

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