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Defining open configuration

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***Abstract*—Product configuration enables companies to deliver customized products under the assumption that all the components and relationships between components are predefined. The premise that all the components and their relationships are predefined limits the effectiveness and accuracy of product configuration. In view of this, open configuration is proposed as an innovative concept to assist companies in configuring products that correspond exactly to what customer want. This paper provides the initial definition of open configuration. In the definition, open configuration involves three types of knowledge: predefined knowledge, dynamic knowledge and interaction knowledge. Predefined knowledge corresponds to predefined elements, while dynamic knowledge corresponds to newly defined elements; the interaction between them generates the interaction knowledge which contains modified components and interacted constraints. This paper uses a fridge configuration example to explain and demonstrate the procedure of open configuration. The result of this example shows that customer requirements which involve new elements can be fulfilled by open configuration.**

Keywords—product configuration; open configuration; predefined knowledge; dynamic knowledge

I. INTRODUCTION

Product configuration has been proposed to enable companies to deliver customized products at low costs with short delivery times. It has been widely applied to a variety of industries, including computer, telecommunication systems, transportation, industrial products, medical systems and services [1]. Product configuration brings companies a number of advantages in delivering required products. These advantages include managing product variety [2], shortening delivery time [3], improving product quality [4], simplifying order acquisition and fulfilment activities [5], etc. In spite of all the achievements provided by product configuration, the reported methods, approaches, and algorithms are developed based on a common assumption: the configuration elements, such as components, modules, attributes, functions, and their relationships are predefined. In relation to this assumption, the products that can be configured are known in principle even if not explicitly listable [6] [7]. In this regard, product configuration cannot deal with such products that demand new functions and components in addition to the predefined ones. In another word, it cannot configure customized products in a true sense, i.e., to the full extent that it covers all reasonable and unforeseen customer requirements.

Another study of us proposed an innovative concept 'open configuration' to help companies deliver customized product in a true sense. It helps companies configure such products that can meet both predefined and unforeseen customer requirements, that is, to meet customer requirements as complete as possible without making too much compromise [8]. In this regard, in configuring customized products, open configuration deals with not only the addition of new configuration elements, such as functions, components, but also the modification of existing configuration elements, more specifically components. Existing component modification is to accommodate the integration of new components with the predefined ones.

In the rest of this paper, Section 2 uses a fridge example to introduce all the elements that involved in product configuration. Section 3 defines open configuration and applies the definition to the fridge example to implement open configuration. Section 4 concludes the paper and sheds lights on the future work involved in open configuration.

II. A FRIDGE CONFIGURATION EXAMPLE

This section introduces a fridge configuration example to help explain the formulation of open configuration. Assume in this example, there are 6 component types, including Refrigerator (R), Freezer (F), Freezer drawer (Fd), Variable Compartment (V), Base (B), Outer casing (O). Each component type is defined by a set of attributes (number, size, and price) and each attribute can assume a number of values. Tab.1 summarizes these component types, the attributes, and attribute values.

TABLE I. THE ATTRIBUTES OF THE FRIDGE COMPONENTS

Component types	Number	Size	Price
Refrigerator	1-2	small, medium, large, extra-large	depending on size
Freezer	0-1	small, large, extra-large	depending on size
Freezer drawer	0-2	small	P(*Fd*) (i.e., a fixed price)
Variable compartment	0-1	small	P(*V*) (i.e., a fixed price)
Base	1	standard, wide	depending on size
Outer casing	1	standard, wide	depending on size

There are relationships among components, among attributes, and between components and attributes. For examples, $\{S_R = \text{large}, N_F = 1\} \rightarrow \{S_F = \text{small}\}$ means if one large sized Refrigerator and one Freezer are selected, the size of the Freezer is small; $N_{Fd} \neq 0 \rightarrow \{N_R = 2, S_R = \text{medium}\}$ states that if the component Freezer drawer is selected then two medium Refrigerators are required. The other relationships include: $\{S_R = \text{medium}, N_F = 0\} \rightarrow N_R = 2$; $\{S_F = \text{small}, S_R = \text{small}\} \rightarrow N_V = 1$; $\{S_R = \text{extra-large}, N_F = 1\} \rightarrow \{S_F = \text{extra-large}\}$; $\{S_F = \text{extra-large}\} \rightarrow \{S_B = \text{wide}, S_O = \text{wide}\}$; $\{N_V = 1, N_F = 0\} \rightarrow \{N_R = 1, S_R = \text{large}, S_V = \text{small}\}$; $\{S_R = \text{small}, N_F = 1\} \rightarrow \{S_F = \text{large}\}$.

There are four additional rules, including (1) $(N_R + N_V + N_F) \leq 3$, meaning the total number of Refrigerator, Variable compartment, and Freezer in one fridge should be no more than 3, (2) $N_R = 2 \rightarrow N_V + N_F = 0$, indicating if two Refrigerators are selected, the number of Freezer and Variable compartment is zero, (3) $N_{Fd} + N_F = 0$ representing that Freezer cannot be selected together with Freezer drawer, and (4) $N_{Fd} + N_V = 0$ indicating that Freezer drawer cannot be selected together with Variable compartment.

According to the above pre-defined components and their relationships, only 17 fridge configurations are available as possible solutions. While Fig. 1 shows 8 fridge configurations due to the space issue, different positions of components in Fig. 1.c, Fig. 1.d, Fig. 1.e, Fig. 1.f, and Fig. 1.g lead to the other 9 fridge configurations. All customized fridges to be configured based on customer requirements fall into this range of configuration solutions. (Note: Fridges from the left to the right are arranged based on the increase of price.) Take fridge f in Fig. 1 as an example to explain the components and their attributes in the configuration solution. This fridge configuration is represented as $FC_f = \{R: 1, \text{small}; F: 1, \text{small}; B: 1, \text{standard}; O: 1, \text{standard}\}$. It has one small Refrigerator on top, one small Variable compartment in the middle, one small Freezer at the bottom, one standard Base, and one standard Outer casing.

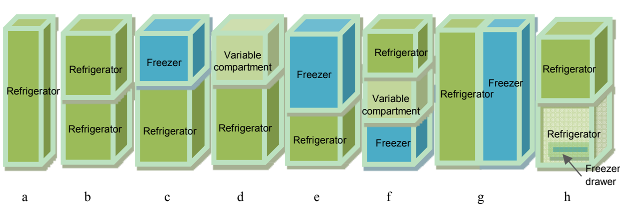

Fig. 1. Fridge configuration solutions.

III. Open Configuration

A. Open configuration concept

Open configuration is to configure customized products to meet customer requirements in a true sense. Similar as product configuration, it utilizes design results, selects components, and arranges the selected components according to constraints and rules. In extension to product configuration, it involves new component design, more specifically the specification of functions and the selection of the corresponding components. In addition, it deals with the modification of the predefined components, which allows the integration of new configuration elements.

B. Open configuration definition

An open configuration problem is defined as a set of (CR, KD). Where CR represents the customer requirements and KD refers to knowledge domain. The customer requirements in open configuration include both the requirements which can be fulfilled by predefined functions (CRⅠ) and the ones that cannot be fulfilled by predefined functions (CRⅡ). In order to deal with all the requirements without compromise, open configuration knowledge domain (KD) contains predefined knowledge, dynamic knowledge and interaction knowledge. Predefined knowledge (Pre-know) relates to predefined functions (P_{Func}), components (P_{Comp}), attributes (P_{Attr}) and constraints (P_{Const}); dynamic knowledge associates with newly defined elements, such as dynamic functions (D_{Func}), dynamic components (D_{Comp}), dynamic attributes (D_{Attr}), and dynamic constraints (D_{Const}); interaction knowledge refers to the rules and constraints (I_{Const}) between predefined knowledge and dynamic knowledge, together with modified components due to dynamic knowledge (M_{Comp}). In dynamic knowledge, dynamic components are classified into two types: the components that directly relate to predefined components (D_{Comp-P}) and the ones that only directly relate to dynamic components (D_{Comp-D}).

The knowledge domain is listed as follows:

- Pre-know: $P_{Comp}, P_{Func}, P_{Attr}, P_{Const}$
- Dyn-know: $D_{Comp}(D_{Comp-P}, D_{Comp-D}), D_{Func}, D_{Attr}, D_{Const}$
- Inter-know: M_{Comp}, I_{Const}

Let (CRⅠ, CRⅡ, KD) be an open configuration problem, an open configuration solution ($P_{cps}, D_{cps}, \mathrm{I}_{cps}$ $P_{rel}, D_{rel}, \mathrm{I}_{rel}$ $P_{val}, D_{val}, \mathrm{I}_{val}$) is valid, iff ($KD \cup CR\text{Ⅰ} \cup CR\text{Ⅱ} \cup P_{cps} \cup D_{cps} \cup \mathrm{I}_{cps} \cup P_{rel} \cup D_{rel} \cup \mathrm{I}_{rel} \cup P_{val} \cup D_{val} \cup \mathrm{I}_{val}$) is consistent. P_{cps}, D_{cps} and I_{cps} are the specified and modified components among predefined knowledge, dynamic knowledge and interaction knowledge; P_{val}, D_{val} and I_{val} are the attribute values of all the specified and modified components; P_{rel}, D_{rel} and I_{rel} are the relationships between all the specified and modified components.

C. An open configuration example

The fridge example introduced in Section 2 is used here to further illustrate the definition of open configuration. From the description in Section 2 and the definition of open configuration, the knowledge domain of the fridge example is listed as follows:

- Pre-know

P_{Comp} : R, F, Fd, V, B, O

P_{Attr} : $(Num, Size, I^{+})$

$N_R, N_F, N_{Fd}, N_V, N_B, N_O$

$S_R, S_F, S_{Fd}, S_V, S_B, S_O$

$I_R^+, I_F^+, I_{Fd}^+, I_V^+, I_B^+, I_O^+$

(The attribute I^{+} represents the extended port of the component; it allows the component to have the access to dynamic knowledge)

P_{Const} :

$\{S_R = \text{large}, N_F = 1\} \to \{S_F = \text{small}\}$

$N_{Fd} \neq 0 \to \{N_R = 2, S_R = \text{medium}\}$

$\{S_R = \text{small}, N_F = 1\} \to \{S_F = \text{large}\}$

$\{S_F = \text{small}, S_R = \text{small}\} \to N_V = 1$

$\{S_R = \text{medium}, N_F = 0\} \to N_R = 2$

$\{N_V = 1, N_F = 0\} \to \{N_R = 1, S_R = \text{large}, S_V = \text{small}\}$

$\{S_R = \text{extra-large}, N_F = 1\} \to \{S_F = \text{extra-large}\}$

$\{S_F = \text{extra-large}\} \to \{S_B = \text{wide}, S_O = \text{wide}\}$

$(N_R + N_V + N_F) \leq 3$

$N_R = 2 \to N_V + N_F = 0$

$N_{Fd} + N_F = 0$

$N_{Fd} + N_V = 0$

$P_F^+ + P_{Fd}^+ = 0$

$P_V^+ + P_{Fd}^+ = 0$

- Dyn-know

$D_{Comp}(D_{Comp-P}, D_{Comp-D}), D_{Func}, D_{Attr}, D_{Const}$

- Inter-know

M_{Comp}, I_{Const}

Dynamic knowledge will be activated if CR Ⅱ exists in customer requirements. Suppose the requirements from a customer include a cheaper fridge with a freezer, a large refrigerator and can be moved easily. In accordance with the knowledge domain of the fridge, the first three requirements relate to predefined knowledge ($\{R: 1, \text{large}; N_F = 1; \min P\}$) and the fourth one relates to dynamic knowledge. According to the requirement of 'can be moved easily', the dynamic knowledge specifies the dynamic function as (D_{Func} : 'movable'). Following the specification of the dynamic function, a group of dynamic components that can fulfill this function will be generated. Among the group of dynamic components, a set or several sets will be specified based on the reasoning mechanism. Assume the set that has been specified is (D_{Comp} : {Wheel, Brake}). Two dynamic components (D_{Comp1}: Wheel) and (D_{Comp2}: Brake) will be generated and stored in dynamic knowledge. As the dynamic components need to be connected with the bottom of the fridge, the predefined components 'Base' and 'Outer casing' may require certain modifications. As a result, the extended port of 'Base' and 'Outer casing' ($\{P_B^+, P_O^+\}$) will be activated, together with the interaction knowledge: M_{Comp} $\{P_B, P_O\}$, $I_{Const}\{P_B, P_O, D_{Comp1}, D_{Comp2}\}$. D_{Comp1} is D_{Comp-P} since it directly connects to the components 'Base' and 'Outer casing', while D_{Comp2} is D_{Comp-D} as it only directly relates to D_{Comp1}. In this regard, the attributes of D_{Comp1} depend on the attributes of 'Base' and 'Outer casing', while the attributes of D_{Comp2} depends on the attributes of D_{Comp1} .

The dynamic knowledge is presented as follows:

- Dyn-know

D_{Comp} :

D_{Comp1}, D_{Comp2}

D_{Attr} :

$S_{D_{Comp1}}, S_{D_{Comp2}}, N_{D_{Comp1}}, N_{D_{Comp2}}$

D_{Const} :

$S_B \to S_{D_{Comp1}}$

$S_{D_{Comp1}} \to S_{D_{Comp2}}$

$N_O \to N_{D_{Comp1}}$

$N_{D_{Comp1}} \to N_{D_{Comp2}}$

From all the definition and constraints, one set of open configuration solution that corresponds to the customer requirements is generated: $OC = \{R: 1, \text{large}; F: 1, \text{small}; B^{+}: 1,$ standard $; O^{+}: 1,$ standard;D$_{cmp1}$:4, standard; D$_{cmp2}$:4, standard $\}$.

IV. Conclusion

In response to the limitation of product configuration, open configuration has been proposed as an innovative concept to help design customer-driven product in a true sense. This paper defined open configuration and illustrates the definition using a basic configuration example. In the example, customer requirements that demand new functions and components are considered and processed using dynamic knowledge and interaction knowledge. As the result of this example, a configured solution that corresponds exactly to what the customer requires was delivered. For future work, there are several potential research areas. First, as initial efforts, this paper formulated open configuration with the basic configuration problem. In the future, formulation with complex problems can be considered and studied. Second, in accordance with the involvement of new configuration elements, open configuration changes the basic assumptions and reasoning processes of product configuration. In this regard, there are a number of potential challenges involved in open configuration, such as open configuration modeling, system design and development, open configuration solving, open configuration optimization, open configuration knowledge representation, etc. All these future topics can be useful to facilitate the application of open configuration in various industries, which can help companies gain greater profits.

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BIOGRAPHY

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