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# THE CONFIGURATION RECOMMENDATION STRATEGY BASED ON SIMILARITY IN PRODUCT CONFIGURATION FOR MANUFACTURING

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## ABSTRACT

Product configuration technology is an important method for implementing Mass Customization paradigm. It used to configure personalized products within a short period of time by maximal utilization of original production resources. In the configuration process for meeting user requirements, it is very possible to get several configuration results from a product family. So, how to select the optimal configuration result is an inevitable issue for manufacture. In the light of the problem, this study provides a recommendation strategy so as to improve the productivity and the resource utilization of manufactory. The strategy is represented by Algorithm *Recommend*. It is given to select the optimal result by analyzing and comparing the degree of similarity between the configuration results and the historical data in manufacture. The degree of similarity integrates the configuration logic and the tree structure characteristics by using the weighted method. The final example is a symbolic application which proves that this recommendation strategy can help efficiently to find the optimal configuration result for manufacture.

**Keywords:** product configuration; product configuration recommendation; general product structure; similarity

## 1 INTRODUCTION

Product configuration technology, a computer application technology, can configure personalized products in a short period of time with maximal utilization of original production resources and minimal creation of new processing routes. It has taken great effect in many large manufacture enterprises and is an important method realizing the Mass Customization (MC) Paradigm.

Early studies about product configuration mainly focus on the modelling for configuration knowledge [1-4], the reasoning and explanation for configuration task [5, 6], design and application of configuration software and so on. As amount of configuration data is accumulated in manufacturers, the reuse of configuration [7-9] and the recommendation for configuration [10, 11] also become necessary for getting more efficient configuration result. The latter is what this paper studies.

Based on previous achievements on the product configuration [3, 6, 9], this study develops a recommendation strategy from the viewpoint of manufacturers for choosing the optimal configuration result out of a number of results which meet the user's requirements. It is proved that this strategy is highly efficient and fully reuses existing production resources by the case analysis.

This paper is organized as follows. Section 2 reviews the work process of product configuration for the present study. Section 3 presents the recommendation strategy and details the method of implementing such strategy. Section 4 validates the developed strategy by applying it for an illustrative example. Section 5 summarizes and concludes this paper.

## 2 WORK PROCESS OF PRODUCT CONFIGURATION

The work process of the product configuration can be divided into three steps: modelling, configuration, and registration [3, 9].

The modelling step is to build a configuration model, namely a general product, which represents a serious of field products. Compared with usual product, the general product contains not only the assembly structure data, but also the configuration logic constraints in the assembly characters and structure. The latter are shown as configuration parameter nodes and configuration rule nodes in the structure tree of the general product.

The configuration step is to reason configuration results, which is also called as variant specifications, by configuring the general product based on user's individual requirements. The variant specification records the parameter values. Some of these values are derived directly from the user's requirements, and others are calculated based on the configuration rules plus the requirements.

The registration step is to register a variant product saved in database as a product structure tree, based on the variant specifications. The variant product can be produced in the manufacturing process as soon as it is registered. Thus vague and unclear characteristics or structure must be avoided.

## 3 RECOMMENDATION OF VARIANT SPECIFICATION

If the user's requirements only focus on several main features, it is possible that some parameters can be ignored, which leads to more than one variant specifications that still meet the requirements. Thus, questions then arise as to which variant specification will lead to the most efficient and cost effective manufacturing process.

It is well accepted by manufacturers that the more similar a new variant product is to a variant product registered before, the more likely that current production resources can be reused and consequently the manufacturing process will be more efficient. Ideally, if the new product is the same as the product registered before, the original processing route can be reused completely. Based on that, the degree of similarity should be an important criterion in selecting the variant specification.

To two variant specifications under a general product, if their parameter values are all equal, they must be the same. If some of their parameter values are equal, they are similar. When a parameter value changes, a corresponding feature of its parent node also changes and accordingly it becomes another assembly. This change can be transferred from this node up to the root node, and alter the parameter's all ancestor nodes. Thus, in evaluating the influence of a changed parameter, its all ancestor nodes within the tree have to be considered.

Given that $v$ and $t$ are two variant specifications of the general product *GP*; $p$ is a configuration parameter of *GP*; $p^v$ represents the value of $p$ in $v$; $p^t$ represents the value of $p$ in $t$. If $p$ is not in $v$ (or $t$), denotes that $p^v$ =null (or $p^t$ =null). The comparison result of $p^v$ and $p^t$ can be obtained from Eq. (1). If $p^v$ and $p^t$ are both null, they are equal too.

$$Diff(p^v, p^t) = \begin{cases} 0 & p^v = p^t \\ 1 & else \end{cases} \quad (1)$$

Based on Function *Diff*, the similar degree of any two variant specifications of a general product can be obtained from Eq. (2).

$$Similar(v,t) = 1 - \frac{\sum_{\forall p \in gParams} Weight(p) \times Diff(p^v, p^t)}{\sum_{\forall p \in gParams} Weight(p)} \quad (2)$$

*gParams* represents all the configuration parameters in a general product; Function *Weight*($p$) denotes the number of the nodes affected by $p$, that is the number of parameter $p$'s ancestor nodes; the value of function *Similar* is between 0 and 1 (0 means totally different and 1 refers to exactly same).

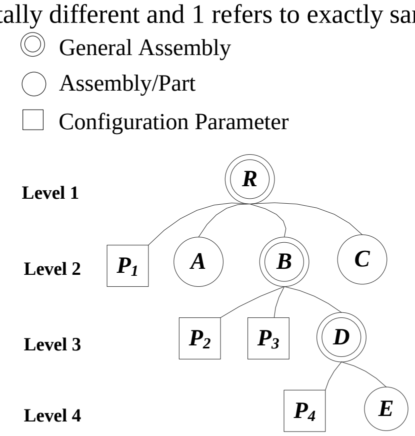



Fig. 1 The structure tree of a general product *R*

According to Eq. (2), in Fig.1, assume that $v_1$, $v_2$, and $t$ are three different variant specifications of a general product *R*, the difference between $v_1$ and $t$ is $p_1$ in Level 2 and the difference between $v_2$ and $t$ is $p_4$ in Level 4. Then the similar degrees are calculated as follows.

$$Similar(v_1,t) = 1 - \frac{\sum_{i=1,2,3,4} weight(p_i) \times Diff(p_i^{v_1}, p_i^t)}{\sum_{i=1,2,3,4} weight(p_i)} \quad (3)$$

$$= 1 - \frac{1\times1 + 2\times0 + 2\times0 + 3\times0}{1+2+2+3} = 0.875$$

$$Similar(v_2,t) = 1 - \frac{\sum_{i=1,2,3,4} weight(p_i) \times Diff(p_i^{v_2}, p_i^t)}{\sum_{i=1,2,3,4} weight(p_i)} \quad (4)$$

$$= 1 - \frac{1\times0 + 2\times0 + 2\times0 + 3\times1}{1+2+2+3} = 0.625$$

It is apparent that $Similar(v_1,t) > Similar(v_2,t)$, which reveals that $v_1$ is more similar to $t$ than $v_2$, although both $v_1$ and $v_2$ has one parameter different from $t$.

Assume that $v$ is a variant specification for being selected, whose degree of similarity with historical data can be formulized as Eq. (5).

$$SimilarDegree(v) = \max_{t \in registeredVSpecs} \{Similar(v,t)\} \quad (5)$$

Set *registeredVSpecs* represents the variant specifications registered before in the database, which match the same general product as $v$ does. Then, an algorithm *Recommend* for selecting the optimal configuration result is listed below.

**Algorithm *Recommend***

Input: *vSpecs*, which is the available variant specifications for being selected.

Output: *recommend*, which is the optimal specification in *vSpecs*

Step1. Initialize: *max* = 0, *recommend* = null

Step2. Establish the set *registeredVSpecs* based on historical data.

Step3. Select a non-compared variant specification $v$ from *vSpecs*.

Step4. Calculate the degree of similarity for $v$: *temp* = *SimilarDegree*($v$), if *max* < *temp*, then *max* = *temp* and *recommend* = $v$.

Step5. If there is any non-compared specification in *vSpecs*, repeat Step3; otherwise, continue to Step6.

Step6. Return the optimal variant specification *recommend*.

## 4 AN APPLICATION EXAMPLE

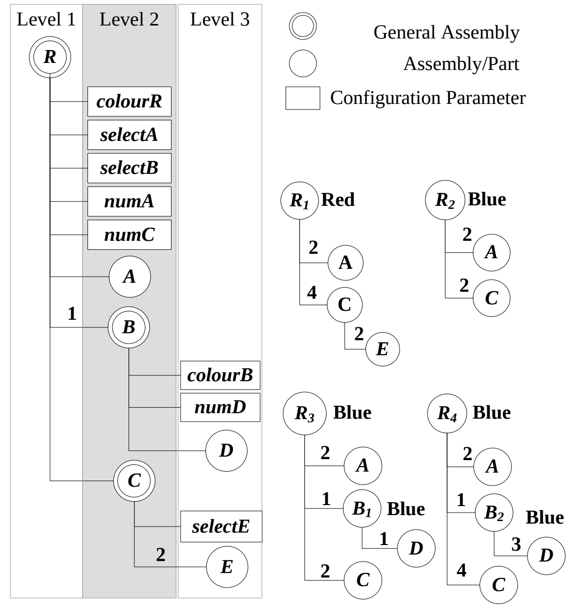
In this section, the developed function *Similar* and algorithm *Recommend* are validated through a case study.

Fig. 2 shows a general product $R$ (whose rule nodes are omitted) and its variant products $R_i$, $i$=1, 2, 3, 4. The number upon the line denotes the number of child nodes assembled to the parent node.

There are eight parameters in Fig.2. The name, type, and meaning of those parameters are described as Table 1.

Table 1 Parameters information in Fig. 2

| name | type | meaning |
|---|---|---|
| ***colourR*** | enumeration | the colour of *R* |
| ***selectA*** | boolean | If its value is *true*, then *R* selects *A*; otherwise, *R* doesn't. |
| ***selectB*** | boolean | If its value is *true*, then *R* selects *B*; otherwise, *R* doesn't. |
| ***numA*** | integer | the number of *A* that is assembled to *R* |
| ***numC*** | integer | the number of *C* that is assembled to *R* |
| ***colourB*** | enumeration | the colour of *B* |
| ***numD*** | integer | the number of *D* that is assembled to *B* |
| ***selectE*** | boolean | If its value is *true*, then *C* selects *E*; otherwise, *C* doesn't. |




**(a) The structure tree of a general product *R***
**(b) The variant products of *R***

Fig. 2 The general product *R* and its variant products

Given that $v_i$ is the variant specification of $R$ corresponding to $R_i$, $i$=1, 2, 3, 4. The values of parameters in every variant specification are listed in Table 2.

Table 2 Parameters values in the variant specifications

| *Parameter* | *Parent Node* | *Weight(p)* | Value in $v_1$ | Value in $v_2$ | Value in $v_3$ | Value in $v_4$ |
|---|---|---|---|---|---|---|
| *colourR* | *R* | 1 | Red | Blue | Blue | Blue |
| *selectA* | *R* | 1 | True | True | True | True |
| *selectB* | *R* | 1 | False | False | True | True |
| *numA* | *R* | 1 | 2 | 2 | 2 | 2 |
| *numC* | *R* | 1 | 4 | 2 | 2 | 4 |
| *colourB* | *B* | 2 | null | null | Blue | Blue |
| *numD* | *B* | 2 | null | null | 1 | 3 |
| *selectE* | *C* | 2 | True | False | False | False |

The degree of similarity between any two specifications is calculated by Function *Similar* and the results are listed in Table 3. From that table, it can be easily found that $v_3$ and $v_4$ are most similar to each other.

Table 3 Degrees of similarity among *v1* to *v4*

| Similar degree | $v_1$ | $v_2$ | $v_3$ | $v_4$ |
|---|---|---|---|---|
| $v_1$ | - | 0.6364 | 0.1818 | 0.2727 |
| $v_2$ | 0.6364 | - | 0.5455 | 0.4545 |
| $v_3$ | 0.1818 | 0.5455 | - | 0.7273 |
| $v_4$ | 0.2727 | 0.4545 | 0.7273 | - |

Suppose that $vSpecs^i$ is the set of the variant specifications waiting for selection. $registeredVSpecs^i$ is the set of the variant specifications registered before in the database. $vSpecs^i$ is calculated from the algorithm *Recommend* based on the corresponding *registeredVSpecs*$^i$, and the result is stored in *remommend*$^i$. The calculated degree of similarity is stored in *max*$^i$ correspondingly. Some possible cases and results are shown as Table 4.

Table 4 Possible cases executed by Algorithm *Recommend* in Fig. 2

| *case number i* | *vSpecs*$^i$ | *registeredVSpecs*$^i$ | *recommend*$^i$ | *max*$^i$ |
|---|---|---|---|---|
| 1 | $v_1$, $v_2$ | $v_3$, $v_4$ | $v_2$ | 0.5455 |
| 2 | $v_1$, $v_3$ | $v_2$, $v_4$ | $v_3$ | 0.7273 |
| 3 | $v_1$, $v_4$ | $v_2$, $v_3$ | $v_4$ | 0.7273 |
| 4 | $v_2$, $v_3$ | $v_1$, $v_4$ | $v_3$ | 0.7273 |
| 5 | $v_2$, $v_4$ | $v_1$, $v_3$ | $v_4$ | 0.7273 |
| 6 | $v_3$, $v_4$ | $v_1$, $v_2$ | $v_3$ | 0.5455 |
| 7 | $v_1$, $v_2$, $v_3$ | $v_4$ | $v_3$ | 0.7273 |
| 8 | $v_1$, $v_2$, $v_4$ | $v_3$ | $v_4$ | 0.7273 |
| 9 | $v_2$, $v_3$, $v_4$ | $v_1$ | $v_2$ | 0.6364 |
| 10 | $v_1$, $v_3$, $v_4$ | $v_2$ | $v_1$ | 0.6364 |

To these ten cases identified, suppose that the probability of happening to each case is equal, thus, the average degree of similarity is calculated using Eq. (6) and in the equation, a method *Selected*(*v*) was defined to return the probability of selecting the specification *v* from *vSpec*$^i$ as recommended result.

$$ADS = \frac{1}{10}\sum_{i=1}^{10}\sum_{v \in vSpec^i}(Seleted(v) \times SimilarDegree(v)) \qquad (6)$$

On running the algorithm *Recommend*, the variant specification with the highest degree of similarity will be selected. the *ADS* is calculated to 0.6728; If we assume that the probability of selecting each specification in each case is the same, the *ADS* is calculated as 0.5515; In some existing algorithms, it is assumed that the first specification of each case always be selected, then for the presented example, the *ADS* is calculated as 0.5091.

Comparing above three cases it can be seen that the developed recommendation strategy always allow users to select the optimal specification with highest similarity to the specifications registered before. It is also verified that implementation of such algorithm in manufacturing can improve the efficiency of manufacturing process by reusing the original production resources.

## 5 CONCLUSIONS

Product configuration technology is to rapidly configure variant product that meet all user's requirements based on a pre-defined configuration model. It is an important method for implementing Mass Customization paradigm.

In the configuration process, if the user focuses on several main features only, it is possible that there are several variant specifications available. Therefore, a recommendation mechanism should be provided, which can select the optimal one for the manufacturer.

In this paper, a recommendation strategy is provided based on our previous works.

To implement the strategy, Function *Similar* is defined as quantifying the similarities of the configuration results. It integrates the configuration logic and the tree structure characteristics by using the weighted method. And Algorithm *Recommend* is provided for selecting the optimal configuration result which is most similar to ones registered before in the database. This specification not only meets the user's requirement, but also reuses the maximal resource. It is efficient and economical for the manufacture.

Finally, an illustrative example is presented to validate the accuracy and efficiency of the algorithm *Recommend*.

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