Computers & Industrial Engineering 86 (2015) 22–28

Contents lists available at ScienceDirect

Computers & Industrial Engineering

journal homepage: www.elsevier.com/locate/caie

Automatic generation of variants depending on changes of product properties in a flexible manufacturing environment

Orhan Torkul [a,*], Recep Yılmaz [b], İhsan Hakan Selvi [a], Muhammet Raşit Cesur [a]

[a] Department of Industrial Engineering, Sakarya University, Esentepe Campus, Serdivan, Turkey
[b] Department of Business School, Sakarya University, Esentepe Campus, Serdivan, Turkey

ARTICLE INFO

Article history:
Available online 10 December 2014

Keywords:
BOM
ERP
Variant generation
Genetic algorithm

ABSTRACT

Competition forces manufacturing systems to be flexible and to increase product variety and process complexity. These tasks depend on the flexible design of a bill of materials (BOM), one of the most important inputs in manufacturing planning and control systems. Product variety forces systems to generate BOMs with regard to product properties through a BOM pattern. A variant bill of materials provides a structure to manage product variability. In this study, an algorithm is designed to build a BOM pattern using computer-aided design and computer-aided manufacturing (CAD/CAM) data, and another algorithm is designed to generate variants with regard to product specifications. Genetic algorithm is used to generate new products to provide high product variability for testing algorithms. After the test, both algorithms are applied to a real industry problem. The BOM pattern is built automatically using CAD/CAM data, and variants are generated with regard to the pattern, and the results are discussed.

1. Introduction

Nowadays, competition requires enterprises to increase product variety. Companies have to reduce response time and increase product variety to gain advantage in the market. High product variety can be achieved via flexible manufacturing systems, the management of which requires an effective and dynamic planning and control system. The bottleneck in manufacturing planning and control systems is the bill of materials (BOM) because every product and production data in these systems is related to it. Thus, the level of dynamism in a BOM determines the boundaries of the capability and flexibility of the system. Studies in the last two decades show that a strong integration mechanism is needed to supply data for flexible manufacturing systems. Because the customization process is sustained via CAD/CAM, computer-aided process planning (CAPP) and product data management (PDM) satisfy data needs for manufacturing. The integration of these systems decreases efforts to build BOM structures while minimizing time losses. After creating a BOM pattern, there is no need to provide pattern data (material and information of operations) again when the integration is achieved. Only new parameters should be modeled.

The aim of this study is to develop a flexible structure and automation against variety and changes in the manufacturing environment. A method is developed that provides the BOM pattern automatically by using CAD/CAM data. The BOM pattern is used to determine the specifications of product parts and materials. Another method is developed for the generation of variants with regard to the BOM pattern or data supplied from the user. In order to use both the user data and the generated data from the BOM pattern, the specification file structure is designed. Both methods are applied in Nexoff, a company that builds office furniture. After that, a test set is generated by genetic algorithms from the Nexoff data. We aim to show whether these methods can work on any product data. Variants are generated successfully by using a new dataset.

2. Literature review

Data such as alternative materials (Wu, Lin, & Wu, 2010), location information of factories (Pires, Carvalho, & Moreira, 2008), product and part specifications (Zhang, Vareilles, & Aldanondo, 2012), and part families (Hegge, 1992) may be needed in manufacturing environments. Because of the various data needed in the manufacturing process, BOMs became a constraint and a structure providing constraints of the planning process (Hua & He, 2010a: 1; Hua & He, 2010b: 2; Hua, Huang, & Zhang, 2008). However, the situation was flagged recently and led researchers to study on satisfying data needs by different information sources, especially CAD/CAM software. In this context, some studies in scientific literature about BOMs (Ram, Naghshineh-Pour, & Yu, 2006; Xiao & Zheng, 2010), CAD/CAM data design (Whelan, 1992), and BOM and CAD/CAM

* Corresponding author.
E-mail addresses: torkul@sakarya.edu.tr (O. Torkul), rcyilmaz@sakarya.edu.tr (R. Yılmaz), ihselvi@sakarya.edu.tr (İ.H Selvi), rcesur@sakarya.edu.tr (M.R. Cesur).

http://dx.doi.org/10.1016/j.cie.2014.12.002
0360-8352/

integration (Maull, Hughes, & Bennett, 1992; Lee, Kim, & Lee, 2012) deal with the dynamic environment of manufacturing. Lee et al. (2012) proposed a generic BOM structure for integration of BOM and CAD/CAM systems. Integrating manufacturing software makes it easier to manage manufacturing data. The integration enhances value in an economic and time perspective. Shih (2014) noted how manufacturing software can be integrated to increase earnings.

Efforts in building information infrastructures in manufacturing increased the focus on object-oriented BOMs and generic BOM approaches in the 1990s and 2000s. An object-oriented BOM has a relationship with unique objects (elements of BOMs), referred to in scientific literature as a gozinto relationship (Guoli, Daxin, & Tsui, 2003; Van Veen, & Wortmann, 1992). A gozinto relationship provides a structure that can be updated easier than classic BOMs. When there are changes to any element of BOMs, it automatically affects product data and product parts with connections to those elements. Thus, it is easier to update and sustain object-oriented BOMs that have a gozinto relationship (Guoli et al., 2003).

An object-oriented BOM approach focuses on the structure of BOMs, but the generic BOM approach focuses on modeling product variations. The specifications and variations of products, parts, and part families are represented by product variants, or multivariate, in the generic BOM approach (Zhang et al., 2012; Olsen, Sætre, & Thorstenson, 1997). When the generic BOM approach is considered, a great amount of data is stored in a database according to the number of variants and product properties; on the other hand, object-oriented BOMs can exploit resources like CAD/CAM databases (Maull et al., 1992). However, this characteristic of object-oriented BOMs makes a strong case against generic BOMs; the product variation–oriented structure of generic BOMs enables management of every product variation by a single BOM. Parsing data from another source or generating BOM data via variants require automation on routine BOM transactions. Generating variant codes related to product specifications (Van Veen & Wortmann, 1992) is a good example of this process. In addition, Kashkoush and ElMaraghy (2013) noted a method similar to variant generation, but the approach depends on finding a similar BOM by integer programming and matrix approximation. Here, an existing BOM is copied and modified after detection.

3. Generic BOM design

The generic BOM system enables the management of all product variations by designing a single BOM pattern. The properties of product and product parts have to be modeled and formulated to design a BOM pattern. The BOM pattern contains the information of all materials used in all variations of a product. The information stored in the BOM pattern consists of formulations for product and part specifications and material amounts as shown in Table 1.

The colors of all coffee table parts are the same and are based on the color that the customer chooses, with regard to the sample BOM pattern. The width and height of the tabletop are both 4 mm more than those of the coffee table because of PVC covering. The amount of chipboard is calculated as the area of the tabletop in square millimeters (mm^2). The length (amount) of PVC is calculated as the perimeter of the tabletop. If the height of the coffee table is equal to or smaller than 500 mm, a stretcher is used. The BOM of any coffee table can be generated automatically with regard to BOM patterns, after the coffee table specifications have been defined by the customer.

Building a BOM pattern consists of three steps: defining product parts and materials, defining product properties, and defining formulas. The definition of formulas is a time-consuming and complex task. Because of this, a method is developed for the automatic formulation of a BOM. When formulas of a BOM pattern are considered, one kind of formulation is the transfer of color from parent to child. The other is routine formulas regarding material information like the calculation of amounts of chipboard and PVC. A definite formula is assigned to a BOM for a group of materials or regarding the specific information of the material (e.g., unit). Finally, some formula may be generated with regard to some properties of the product. For instance, if the height of the coffee table is bigger than 500 mm, there is no stretcher used. CAD/CAM data is needed to build this kind of formula, and product properties that affect the structure of the BOM should be determined as a dominant attribute. When the dominant attribute changes, there will be structural changes in the product. For example, height can be used for furniture; models can be used in machinery or electronics. In this case, height is determined as the dominant attribute. The properties of product parts that change with regard to the dominant attribute can be found by searching the CAD/CAM database. CAD/CAM software such as Solidworks Enterprise PDM, Windchill, Imos, and Lantek store width, height, depth, thickness, and material information as common. Other properties of products and product parts are stored with regard to the database structure of the CAD/CAM program, and some necessary properties are not stored in the database as common. There is a standard database view needed to solve this problem. The view must contain a full path (e.g., root/parent/element) of the tree node that is a BOM element (product part), the name of attribute, and the value of attribute. The name of the BOM element is sufficient because the same element can be used in more than one element (e.g., child). The formula generation procedure will be done by using the view in CAD/CAM database as follows:

```
1. Call GenerateFormula (RootNode, RootNode)
2. Function GenerateFormula (Node, RootNode)
3. For every Ci ∈ Children of Node
  a. For every Ai ∈ Dominant Attributes of RootNode
      i. For every Pi ∈ Changing Properties of Ci
  Regarding to Ai in CAD/CAM Database
        1. Add Formula Ci.Pi = when RootNode.Ai = Value
  of Ai then Value of Pi
  b. If There is Pre-defined Formula for Pi ∈ for
  Unformulated Properties of Ci Regarding to Group
  of Inventory or Material Information
    i. Add formula Ci.Pi = Defined Formula
  c. For every Pi ∈ Intersection of Unformulated
  Properties of Ci and Node
    i. Add formula Ci.Pi = Node.Pi
    ii. Generate Formula(Ci)
4. End.
```

4. Variant and specification file structure

After building the BOM pattern, the variant specification file is built by running the formulas. The value of each attribute is shown in Table 2. The variant specification file should be inserted in the database of an enterprise resource planning (ERP) software. The inserted transaction is the variant-generation process.

Variants are generated with consideration to an inventory card in the ERP system because every variant is a unique variation of a single inventory. The specifications of variants are dependent on the range of value that the property of the BOM element can be assigned to as shown in Fig. 1. The values of the properties that are assigned to the inventory are assigned to variants in the following way.

Th inventory table includes inventory code and any other inventory-related data. Product properties assigned to the