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Research on the Product Configuration Method Based on Constraint Satisfaction Problem and Bayesian Network

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Abstract

In the context of mass customization, to address the issues about method based on Constraint Satisfaction Problem (CSP) in the field of product configuration, a combined product configuration method based on the CSP and Bayesian Network (BN) is proposed in this paper. On the basis of CSP and BN theory, a product configuration model established based on CSP and BN, and the specific method for solving was given, Including the reasoning on posterior probability by establishing the Bayesian Network model and the reasoning on Constraint Satisfaction Problem. Finally, to assemble the computer as an example, a configuration system of assembly computer product is developed so as to verify the feasibility and effectiveness.

Keywords *Mass Customization; Product Configuration; Constraint Satisfaction Problem; Bayesian Network*

1. Introduction

With the developing of the science and technology, manufacturing industry is facing increasingly fierce competition and challenges, such as shorten the production cycle of the product, dramatically increased the product demand, personalized and diversification of the user demand, and so on. In this trend, the model of production on manufacturing has changed from traditional mass production to mass customization transition gradually. Mass Customization was made to organically combine large-scale production with the individual users' needs.

Product Configuration Technology is the key to achieve Mass Customization techniques. And it is a success of the field of artificial intelligence. Product configuration also includes a lot of ways. The solution of the Product Configuration Method on the Constraint Satisfaction Problem has a high efficiency, but a weak correlation. That is the product configuration process did not allow for the user's interest factors, so that it produced many results which could not meet the user's needs. For users, they didn't care the process of solving configuration, but whether they can get true Configuration requirements in the limited time or not. Therefore, how to get the user's preferences, and how to get the user's configuration truly satisfied is currently the focus of research in the field product configuration in the process of product configuration.

For above problems, the passage brings forward a method which combines the Bayesian Network with Constraint Satisfaction Problems. The method includes configuration knowledge representation and Configuration Solution. Bayesian network is equivalent to amiddleware, and the Constraints are given by the user to deduce new constraints. This new set of constraints is the user information of potential interest, but also an extension on constraint satisfaction problems.

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2. Related Concepts

2.1 Constraint Satisfaction Problems

More formally, a constraint satisfaction problem is defined by a set of variables: X={X1, X2,...Xn},and a set of constraints: C={C1,C2,...Cm}.

N variables have a non-empty set of finite range W=(X, D, C). Each constraint Ci includes some subset of variables, and specifies a subset of these values allows for the consolidation. A state of the issue is determined by some or all of the variables in the definition of an assignment, a constraint does not violate any legal or compatible assignment is called the assignment. Each variable assignment is called a fully participate in the assignment, and the solution of constraint satisfaction problem is to satisfy all constraints fully assigned.

2.2 Bayesian Network

Bayesian networks, also known as belief networks (Belief Networks), probabilistic networks (Probabilistic Networks) or causal networks (Causal Networks), is one of the most effective theoretical model of expression and the ability of reasoning in the field of artificial intelligence. Also it is commonly used in data mining methods [4]. Bayesian network is a variable used to indicate the probability of a connection between the graphics mode, which provides a natural way of representation cause information to discover a potential relationship between data. In this network, with the nodes represent variables, directed edges represent dependencies between variables. Its detailed description is as follows:

1) A set of random variables form a network node, the variable can be discrete or continuous;

2) Having a connection to the edge node or the arrow set exists from node X to node Y, directed edges, and then X is a parent node of Y;

3) Each node Xi has a conditional probability distribution P (Xi | Parents (Xi)), that parent node of the node;

4) There is a directed graph does not ring (so is a directed acyclic graph, or abbreviated as DAG)

Currently, the point of Bayesian network study is reasoning and learning, which includes a precise reasoning and approximate reasoning. Learning includes the network topology learning and parameter learning. Bayesian network is based on Bayesian probability theory as a graphical modeling tool, and its uncertainty reasoning ability to apply it in the field of product configuration so that it is more suitable to solve optimization problems and configuring reasoning.

2. CSP-based Configuration Knowledge Representation with BN

2.1 Configuring Model

Configuration of the conventional CSP model is a four-tuple (X, D, C, Cu) group, on the basis of the configuration, based on the CSP model and the BN, it is improved. And it can be represented by a five-tuple (X, D, C, Cu, Ce) group. Wherein: X is a configurable object components or the set of variables; D is the range collection of X which is a component or a configurable object's value; C is the group of components in the product structure or configurable set of constraint relations between objects; Cu is the set of constraints for users; Ce is the set of the user's preference.

Under normal circumstances, at the right time on solving constraint satisfaction problem, when given more variables after the assignment, the more solution of the problem is specific. This model is equivalent to extending the variable space of the constraint satisfaction problem. Ce is the solving of five-tuple group and also the solving of constraint satisfaction problem when it acts as constraints of extension.

2.2 User Bayesian Network Model Construction

The user's preference is reasoned by Bayesian network model, the modeling process, including the Bayesian network structure learning and parameter learning, which is the conditional probability of network nodes learning. Based on the characteristics of the field of product configuration, the paper uses the logical structure of the product as the Bayesian network topology directly, for example, to assemble the computer shown in Figure 1. The structure is a tree, a special Bayesian network structure, the logical structure nodes of the product is used as Bayesian network nodes, which are also set as the user's preference, directed edges show the relationships between the nodes intuitively.

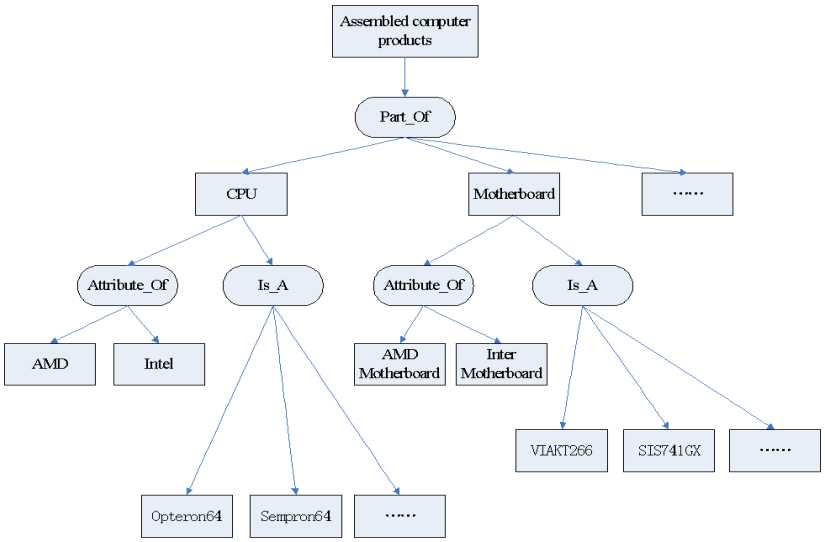

Figure 1. Logical Structure of Assembled

In this structure contains three kinds of relationships [5]:

1) Is_A relations, it represents logic components at different levels of abstraction generalization relationship, such as Opteron64 is a (Is_A) CPU;

2) Part_Of relationship, it represents a logical aggregation relationship between components. That is the forming polymeric relationship between logic components and its direct subassemblies;

3) Attribute_Of relationship, which means that the properties of the logical relationship among components, such as the properties of the CPU models are two kinds of AMD and Intel.

The advantages of using this tree structure can greatly improve the inference speed. The tree structure in the non-Bayesian inference online is generally NP problem, but for tree-structured Bayesian networks, many reasoning algorithms can be completed in linear time. This not only simplifies the process of reasoning, but also improves the efficiency of product configuration to achieve a rapid response to the user.

The conditional probability of network nodes is through the data samples to study, within a period of time that the sample taken from the CSP method based configuration system configuration in the user history records. Each field in the record is the logical structure of the product of each node, for these node users purchasing behavior embodied in two ways: 1 indicates that this part is not configured, this part 2 is configured so will each record with 1 and 2 expressed in the form.

In this paper, the process of modeling Bayesian networks based on Matlab toolbox BNT (Bayesian Networks ToolBox) [6], It is based on Matlab language by Kevin open source software package, mainly on Bayesian network learning, but also contains a lot about the underlying basis of Bayesian network learning library, its function is very rich, not only

supports exact and approximate reasoning, but also supports topology learning and parameter learning as well as static and dynamic models.

After learning through structural BNT shown in Figure 2, contains 37 nodes, each variable value is {1, 2}, reflects the directed edges between nodes.

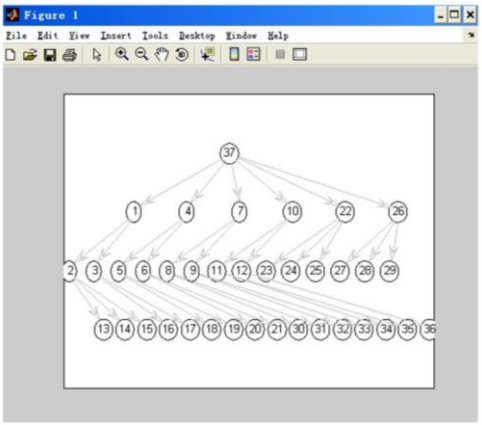

Figure 2. The Bayesian Network Structure of Assembled Computer in BNT

In BNT, this article will traindata.txt data samples into a text file as the training sample, each act of a user configuration examples, with 1 and 2 that includes all the nodes in the recording format, comma between nodes separated. And the learning method is Bayesian estimation method, in BNT learning, the statement is bayes_update_params ().

Determine the structure and parameters of Bayesian network that determines Bayesian network model, then you can use this model to do probabilistic reasoning.

3. Configuration Solution based on CSP and BN

3.1 Configuration Solution Procedure

Configuring solving process is shown in Figure 3

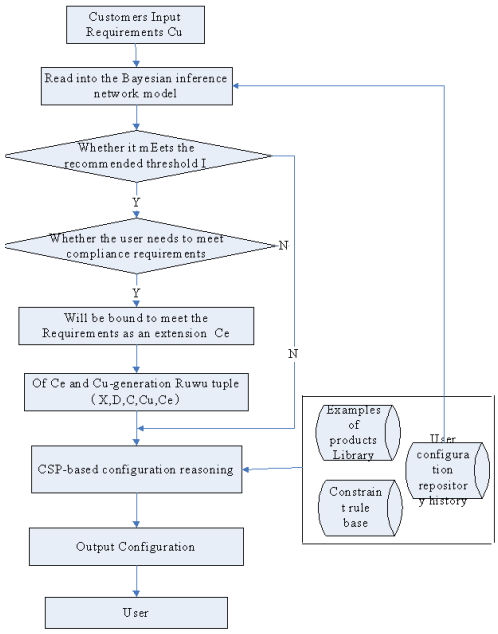

Figure 3. Flow Chart of Configuration Based on CSP and BN

The specific steps of solving the problems are as follows:

1) A collection of demand constraints -----Cu is given by the users;
2) According to Cu, the system has been established by Bayesian network model to calculations, Cu acts as the evidence node, thereby reasoning evidence nodes at the other nodes except the posterior probability;
3) Set the recommended threshold ε, the posterior probability greater than ε nodes and user demand constraints conformance testing, the set of nodes that satisfy the condition as an extended constraint Ce, get set Ce is the user's preferences. If the nodes do not meet the recommended threshold or nodes that meet the recommended thresholds have not passed conformance testing, reasoning the constraint satisfaction problem of four-tuple (X, D, C, Cu) group directly;
4) Then bring Ce and Cu together into the model, which is based on a combination of both CSP and BN configuration model (X, D, C, Cu, Ce, and then configure the reasoning;
5) The quintuple solving is also for constraint satisfaction problem solving, the final result will be feedback to the user.

From the configuration process, we can conclude that the solution configuration includes two processes: to obtain the user's preference, the probabilistic model of the Bayesian network inference; to solve the five-tuple (X, D, C, Cu, Ce) group, which solved constraint satisfaction problem.

3.2 Get the User's Preference

In this paper, Bayesian network inference algorithm is a joint tree algorithm, which is accurate, efficient and so on. BNT toolbox apply the engine mechanism, and different engines use different algorithms to complete the model transformation, refinement and solution, including a joint tree algorithm, and reasoning part of the code is as follows:

```
engine = jtree_inf_engine();
evidence = cell(1,N);
evidence{X} = 2; %X
[engine, loglike] = enter_evidence(engine, evidence);
marg = marginal_nodes(engine,Y);
```

3.3 The Solution of Five-tuple (X, D, C, Cu, Ce)

This process is also a constraint satisfaction problem solving process. This article uses an improved backtracking algorithm prior to the test. Compared with the traditional backtracking search, its consistency requirements is higher. It can not only reduce the new variable assignment search space, but also be able to judge whether this part of the assignment is extended to a solution. And the state of no solution could found in advance to avoid ineffective searches.

4. Product Configuration Examples based on CSP and BN

In this paper, a method developed by CSP and BN product configuration of the assembled computer system, these theories and methods can be realized in the system and verify its effectiveness.

In the interface layer, users can use the drop-down list to choose, that is also the process for each variable assignment in order to meet different types of users, including the feature selection and specific requirements on the choice parts. When the users select the variety of types of CPU, motherboard, hard disk type, display size of the four options, then according to the four constraints for CSP reasoning for the configuration of the result is 36. Also choose these four constraints, application of the method based on CSP with BN, when we want to get

the configuration solution, system will select the user's choice of the four nodes as evidence reasoning, to meet the recommended threshold nodes and could satisfy the requirement of consistency with the user's demand as extension constraint set, which is the set of user preferences. We set a threshold of 0.5, then the posterior probability of the nodes which are greater than 0.5 are all meet our requirements. Then we get the result is eight, and sort extended constraint node is in accordance with the size of the posterior probability in descending order, the more forward configuration results suggest the possibility for users to recommend the greater point of interest with the user closer.

5. Conclusion

The experiment indicated that under the same constraints which are required by the users, putting the Bayesian networks into the product configuration system, deploy the constraints on the product configuration, we can clearly see that it is better than the traditional CSP method, it reduces the numbers on amount. This is because the Bayesian networks, the characteristic of uncertainty knowledge can reasoning in the reasoning of constraint satisfaction problem variables space expanded, which extends a given part of the solution to the customer, the greater part of the solution and get the complete solution of the more specific, and configure the results are based on user's interest as the guidance. Therefore, the configuration method based on CSP and BN in the solution can not only reduce the unrelated items, but also improve the accuracy of the configuration and it can optimize the configuration results, has certain feasibility and validity.

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