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AN OPTIMIZED CONFIGURATION METHOD OF NETWORKED RESOURCE BASED ON SIMILARITIES

Jingzhi Fu[1,2], Xiaoning Shen[2] and Ping Mei[2]

[1]Jiangsu Collaborative Innovation Center on Atmospheric Environment and Equipment Technology
[2]School of Information and Control
Nanjing University of Information Science and Technology
No. 219, Ningliu Road, Nanjing 210044, P. R. China
jennyfjz@163.com

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Abstract. *This paper establishes the united models of manufacturing resources and tasks in the networked manufacturing system. Based on these, an optimized configuration method of networked resource is proposed. This method combines the semantic similarity, structure similarity and attribute similarity algorithm to meet the conceptual and logical configuration from a manufacturing task to a manufacturing resource. A case study shows that our method ensures the result be consistent with the reality. It simplifies the calculation process and improves the efficiency.*

Keywords: Manufacturing resource, Similarity algorithm, Resource configuration, Information model

1. **Introduction.** Networked manufacturing will be the main mode of production in future because it can realize the share and collaboration of all sorts of resources based on services [1]. In networked manufacturing system, resources selection and optimized configuration are the keys of the collaboration. In order to make users apply the appropriate resources "at the right time and in the right way", the existing studies have done some researches on resource configuration methods and proposed some algorithms. Agent-based methods [2], AHP-based (Analytic Hierarchy Process, AHP) methods [3], intelligent optimized methods [4-6] or methods based on ontology and semantics [7] are the traditional methods mostly used in the past decades. However, most of these methods are exhaustive which are focused on the selection of alliance or the resources whose type and quantity are not very large. It will cost a lot of time and cannot subject to the global networked manufacturing environment where there are a huge number of resources.

An optimized configuration method of networked resources based on similarities is proposed in this paper. In Section 2, the manufacturing resource model and task model are established. In Section 3, the configure algorithms such as the semantic matching algorithm, structure similarity algorithm, attribute similarity algorithm and the configure process from the task model to the resource information model are discussed in detail. In Section 4, a test instance is studied to verify the effectiveness of the proposed method. Some conclusions are made in Section 5.

2. **Models of Networked Manufacturing Resources and Tasks.** The resources in networked manufacturing environment usually come from different enterprises and they are heterogeneous. The manufacturing tasks are different, too. So the unified information models should be established to meet with the configuration from manufacturing task to resources. Their formal definitions are as follows.

Manufacturing Resource Model: *in the networked manufacturing environment, the manufacturing resource model can be expressed from three aspects: the description,* *the parameters and their values. That is*

$$MRM : MR = \{MDesc, MPara, MVal\} \tag{1}$$

MRM means manufacturing resource model. MR means manufacturing resource and it can be expressed as a three-dimensional ordered set. $MDesc$ may be the name, the function or the other description information of the manufacturing resource. $MPara$ is the capability parameters information set of the manufacturing resource, such as the manufacturing dimension, precision, cost, and time. $MVal$ is the attribute value collection of $MPara$. Usually, the values in $MVal$ should be or be changed into $[0, 1]$ in order to configure from the task to the resources conveniently. Therefore, if $MPara = \{p_m^{(1)}, p_m^{(2)}, \ldots, p_m^{(p)}\}$, then

$$MVal = \left\{Val\left(p_m^{(1)}\right), Val\left(p_m^{(2)}\right), \ldots, Val\left(p_m^{(p)}\right)\right\} = \left\{MR_{Val}^{(1)}, MR_{Val}^{(2)}, \ldots, MR_{Val}^{(p)}\right\}$$

Manufacturing Task Model: *the manufacturing task model describes the task's demand information to the resource. It includes the description information, the parameters and parameter values of the target resource that the task requires. So its formal definition is*:

$$MTM : MT = \{TDesc, TPara, TVal\} \tag{2}$$

where we suppose $TPara = \{p_t^{(1)}, p_t^{(2)}, \ldots, p_t^{(q)}\}$, then

$$TVal = \left\{Val\left(p_t^{(1)}\right), Val\left(p_t^{(2)}\right), \ldots, Val\left(p_t^{(q)}\right)\right\} = \left\{MT_{Val}^{(1)}, MT_{Val}^{(2)}, \ldots, MT_{Val}^{(q)}\right\}$$

In order to express the algorithms in the following section, we define some operations of collections. Suppose A and B are two sets consisting of some parameters, then:

$A \cap B$ is the same parameters set in A and B, which is called coupling parameters set.

$A - B$ is the parameters set in the collection of A, but not in B.

$\|\cdot\|$ means the number of the elements in a set.

3. **Configuration from Tasks to Resources.** There are a lot of manufacturing resources in the networked manufacturing system and their models are different, especially between the manufacturing task model and manufacturing resource model. The important work is distinguishing the differences to realize the configuration from the task to the resources. It can be analyzed from the three levels of semantic, structure and attributes based on the three sets of the models. Accordingly, the three configure algorithms are proposed, i.e., the semantic matching algorithm, structure similarity algorithm and attribute similarity algorithm.

3.1. **Semantic similarity.** There is the general description about the resource what the task requires both in the task model and in the resource information model. So the task description and the resource description can be matched by their semantic similarity [8].

$$SIM_{sema}(MR, MT) = MAX\left[0, \frac{MIN(|MDesc|, |TDesc|) - ED(MDesc, TDesc)}{MIN(|MDesc|, |TDesc|)}\right] \tag{3}$$

In the formula, $SIM_{sema}(MR, MT)$ is the similarity of the manufacturing resource and the task calculated by semantic matching algorithm. $TDesc$ is the description about the required resource in the task model, which is a string. $MDesc$ is the resource description in resource information model, which is a string, too. $|MDesc|$ is the length of the string $MDesc$. $|TDesc|$ is the length of the string $TDesc$. $ED(MDesc, TDesc)$ is the edit distance between $MDesc$ and $TDesc$, which is the minimum operation times of insert, delete and replace converting from $MDesc$ to $TDesc$.

3.2. **Structure similarity.** We suppose that: $\overline{\overline{MT}} = MPara \cap TPara = \left(p_{mt}^{(1)}, p_{mt}^{(2)}, \ldots, p_{mt}^{(a)}\right)$, where $p_{mt}^{(j)} \in MPara$ and $p_{mt}^{(j)} \in TPara$, $a \leq p$, $a \leq q$. $M\overline{T} = MPara - TPara = \left(p_{m\tilde{t}}^{(1)}, p_{m\tilde{t}}^{(2)}, \ldots, p_{m\tilde{t}}^{(b)}\right)$, $\overline{M}T = TPara - MPara = \left(p_{\tilde{m}t}^{(1)}, p_{\tilde{m}t}^{(2)}, \ldots, p_{\tilde{m}t}^{(c)}\right)$ where $p_{m\tilde{t}}^{(j)} \in MPara$ and $p_{m\tilde{t}}^{(j)} \notin TPara$, $b \leq p$; $p_{\tilde{m}t}^{(j)} \in TPara$ and $p_{\tilde{m}t}^{(j)} \notin MPara$, $c \leq q$.

Therefore, the structure similarity [9] of MR and MT is:

$$\begin{aligned} & SIM_{stru}(MR, MT) \\ = & \frac{NUM(MPara \cap TPara)}{NUM(MPara \cap TPara) + \frac{1}{2}[NUM(MPara - TPara) + NUM(TPara - MPara)]} \\ = & \frac{\left\|\overline{\overline{MT}}\right\|}{\left\|\overline{\overline{MT}}\right\| + \frac{1}{2}\left(\left\|M\overline{T}\right\| + \left\|\overline{M}T\right\|\right)} \end{aligned} \tag{4}$$

The returned value of the formula should be in $[0, 1]$.

3.3. **Attribute similarity.** There may be much more candidate resources selected by the above semantic matching algorithm and structure similarity algorithm. Therefore, attribute similarity algorithm is used according to the parameter values in the two models. The attribute similarity of the two fuzzy sets $TVal$ and $MVal$ is [10]

$$\begin{aligned} SIM_{attr}^{(i)}(MT, MR_i) = \frac{1}{2} \Bigg\{ & \bigvee_{k=1}^{m} \left[\left(MT_{val}^{k}\right) \wedge \left(MR_{val}^{(i,k)}\right)\right] \\ & + \left(1 - \bigwedge_{k=1}^{m} \left[\left(MT_{val}^{k}\right) \vee \left(MR_{val}^{(i,k)}\right)\right]\right)\Bigg\} |(i = 1, 2, ldots, n) \end{aligned} \tag{5}$$

where

$$MT_{val}^{k} = val\left(p_t^k\right) \in TVal$$

and

$$MR_{val}^{k} = val\left(p_m^k\right) \in MVal$$

$$\text{s.t.} \quad p_t^k = p_m^k = p_{mt}^k \in \overline{\overline{MT}}$$

It is supposed that there are n resources and m parameters in $MPara \cap TPara$. MT_{val}^{k} is the value of the kth parameter which is in $MPara \cap TPara$, and $MT_{val}^{k} \in TVal$. $MR_{val}^{(i,k)}$ is the value of the ith resource and the kth parameter which is in $MPara \cap TPara$, $MR_{val}^{(i,k)} \in MVal(i)$. The resource that has the maximum similarity to the task is the best resource required.

3.4. **The optimized configure process.** Sometimes, the description of the resources may be not accordant in the models so that their semantic similarities are small and missed in selection. So the parameters are considered to proceed the conceptual configuration. Generally the capability parameters of the resources include the service ability or the operation management ability provided by the resource owner and the quality, the credit or risk ability reflected by the social value of the enterprise. On the other hand, some resources are not candidate because their value gap is too large even if they have the same parameters with the task. So the logical configuration is necessary accounting for the attribute similarity algorithm. The semantic matching algorithm, structure similarity algorithm and attribute similarity algorithm are combined to complete the optimized configuration from the task model to the resource information model. Figure 1 shows the configure procedures are:

Step 1: to construct the manufacturing resource model and the task model.

Step 2: to proceed the conceptual configuration.

Step 2.1: to compute the semantic similarity $SIM_{sema}^{(i)}$ by Formula (3) according to the description of every resource MR_i and the task MT.

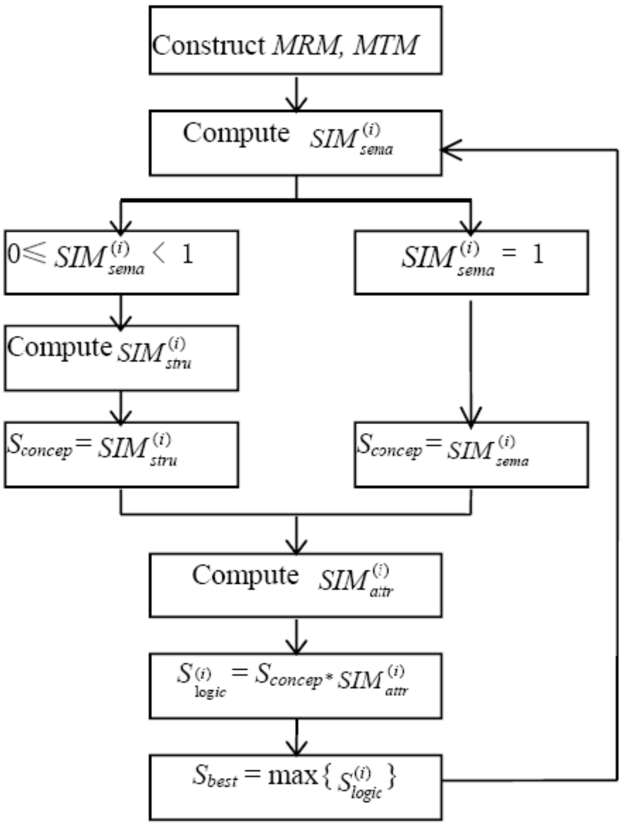

FIGURE 1. Resource configure procedures

Step 2.2: if $SIM^{(i)}_{sema} = 1$, the conceptual similarity is equal to the semantic similarity. That is, $S_{concep} = 1$. Then turn to Step 3; else to the next step.

Step 2.3: to compute the structure similarity $SIM^{(i)}_{stru}$ by Formula (4) according to the parameters information in the models of each resource MR_i and the task MT. Set $S_{concep} = SIM^{(i)}_{stru}$.

Step 3: to compute the attribute similarity $SIM^{(i)}_{attr}$ by Formula (5) according to the parameter values in each resource model and the task model.

Step 4: to compute the logical similarity accounting for the conceptual similarity and attribute similarity of each resource. The formula is: $S^{(i)}_{logic} = S_{concep} * SIM^{(i)}_{attr}$.

Step 5: the best resource that the task requires is what has the maximum logical similarity among all of the resources.

TABLE 1. The candidate resource information

Resource	$MDesc$	$\left\|\overline{\overline{MT}}\right\|$	$\|M\overline{T}\|$	$\|\overline{M}T\|$	SIM^i_{sema}	SIM^i_{stru}	S_{concep}
$M1$	CNCMachine	4	2	2	0.889	0.667	0.667
$M2$	NCMachine	6	0	0	1	1	1
$M3$	NCMachine	2	2	4	1	0.4	1
$M4$	LatheMachine	6	2	0	0.778	0.857	0.857
$M5$	NCLatheMachine	5	1	1	0.444	0.833	0.833
$M6$	NCManuMachine	4	0	2	0.556	0.8	0.8

Table 2. Values of the coupling parameters and similarities

	T^i_{val}	M^i_{val}	SIM^i_{attr}	S^i_{logic}
$M1$	$\{0.8, 0.7, 0.5, 0.9\}$	$\{0.6, 0.3, 0.7, 0.2\}$	0.45	0.300
$M2$	$\{0.8, 0.7, 0.5, 0.9, 0.8, 0.6\}$	$\{1.0, 1.0, 0.7, 0.8, 0.8, 0.5\}$	0.6	0.600
$M3$	$\{0.5, 0.8\}$	$\{0.4, 0.2\}$	0.45	0.450
$M4$	$\{0.8, 0.7, 0.5, 0.9, 0.8, 0.6\}$	$\{0.1, 0.2, 0.5, 0, 0.3, 0.2\}$	0.5	0.428
$M5$	$\{0.7, 0.5, 0.9, 0.8, 0.6\}$	$\{0.5, 0.5, 0.8, 0.8, 0.8\}$	0.65	0.542
$M6$	$\{0.8, 0.9, 0.8, 0.6\}$	$\{0.8, 0.9, 0.8, 0.6\}$	0.65	0.520

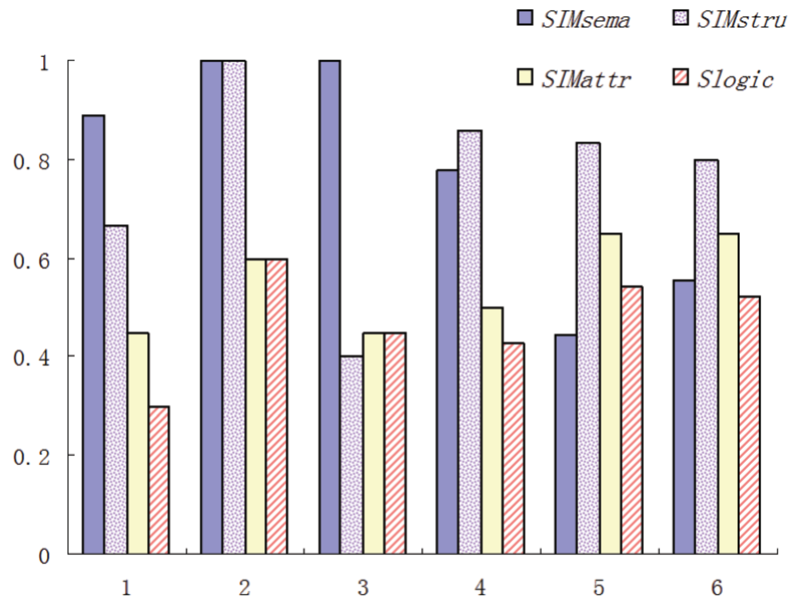

Figure 2. Resource configure procedures

4. **Case Study.** It is supposed that a task is searching for a suitable manufacturing resource in the networked manufacturing system. Its description for the required resource is $TDesc$ = "NCMachine" and the required capability parameter values are $TVal = \{0.8, 0.7, 0.5, 0.9, 0.8, 0.6\}$. There are six potential candidate resources for the manufacturing task. Their names and the number of parameters are shown in Table 1.

The sets in Table 2 are the values of the coupling parameters in the task model and the resource models.

From the similarities calculated in Table 2 we can see $M2$ is the best resource for the task and $M3$ is the worst. The comparison of the similarities of the manufacturing resources is shown in Figure 2.

The names of both $M2$ and $M3$ are the same as that of the resources required by the task, and both of their conceptual similarities are equal to 1. However, $M3$ has only two same parameters with the tasks requirement. So, the logical similarity of $M3$ to the task is smaller than $M2$.

The attribute similarities of $M5$ and $M6$ to the task are bigger than that of $M2$. However, the parameters are fewer than what the task demands, and their names are different from the task requirement. That is, $M5$ and $M6$ have some uncertain parameters during the configuration, which reduces the logical similarity.

Compared to $M2$, although $M4$ has the same number of parameters as what the task requires, the attribute similarity is reduced because the parameter values vary greatly with the task requirement. On the other hand, $M4$ has two parameters that are not in the task model, which decreases the structure similarity. As a result, its overall logical similarity is smaller. So $M4$ is not the best candidate resource.

In short, only when the semantic similarity, structural similarity and attribute similarity are combined can the best resource be determined. Also we can see that the method reduces the times of computation compared with the selection one by one. It is better than exhaustive method.

5. **Conclusions.** Today, most of the names of the manufacturing resources are standardized and unique. So many resources can be filtered out by using the semantic similarity algorithm and it is not necessary to go through the next calculation step, which simplifies the configure process. However, the semantic similarity algorithm is so deeply dependent on the description information of the resources and the task that the structure similarity and attribute similarity algorithm are introduced in this paper. These two methods select the same parameters and their values in the resource models and task model to compute, which simplify the calculating process. So the combination of the three algorithm of the semantic similarity, structure similarity and attribute similarity algorithms improves the efficiency of the configuration. Nowadays, the establishment of the models cannot be fully automated. So manual intervention is required during the configuration from the task to manufacturing resources. Those are the directions of future research.

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