Service Model and Service Selection Strategies for Cross-regional Intelligent Manufacturing

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Abstract. Manufacturing plays an important role in the development of national economy. Intelligent manufacturing is the integration of modern business management model, information technology and the traditional manufacturing industry. This paper proposes to handle the following problems that intelligent manufacturing industry faced: (1) the problem of classification and composition of services of different granularity level, (2) the achieve of intelligent logistics over the cross-regional production process, (3) the need of an efficient and stable algorithm for services selection. To achieve cross-regional logistics intelligently and to provide service more intelligently, this paper classify services into five categories according to the level of granularity, and logistics services as the sixth. We design a service ontology based on owl. At last, we design a service selection mode based on the descent of granularity level and a peer service priority-based algorithm for service selection.

Keywords: Service model · Intelligent manufacturing · Web ontology language

1 Introduction

The development trend of manufacturing is intelligent manufacturing. By using artificial intelligence techniques in manufacturing processes, activities such as analysis, reasoning, judgment, decision-making can be carried out by the intelligent system rather than people. So as to solve the problem of labor shortage. With the development of intelligent manufacturing, network is connected with manufacturing. The concept of cloud manufacturing was first proposed in 2009 [1]. Cloud manufacturing is a new networked intelligent manufacturing mode that is service-oriented, low-efficient and knowledge-based. Its manufacturing resources and capabilities are virtualization and service-oriented. The cloud platform centralized these resources and capabilities and provide users with ubiquitous, ready access manufacturing services. Resources sharing and collaborative during the whole life cycle of production. [2, 3] The cloud-based design and manufacturing systems encapsulated the distributed manufacturing resources into manufacturing services. The whole life cycle is composed of these services. Jin et al. and Wei et al. studied on service management for automotive industry in [4, 5]. Wang et al. explore the service modes of optical elements in [6]. Chen discussed the problem of promotion and sustainability of the competitiveness of

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enterprises by cloud manufacturing in case of a semiconductor manufacturer in [7]. [8] specialized in the collaboration of design services in cloud manufacturing. Cheng et al. studied on the business model and transaction process in cloud manufacturing in [9]. In order to solve the search and access problem of different manufacturing resources, Tao et al. design a five-layer system in [10], including the resource layer, the perception layer, the network layer, the service layer and the application layer. The system is designed based on things technology. Wang proposed a multi-layer architecture with the use of the standard of IEC 61499 function block in [11]. The system can monitor the status and availability of devices, and use a closed-loop flow of information for process planning. Liu et al. studied on the machining of complex parts in cloud manufacturing and found that some core competences of SPs like know-hows are usually unshareable in [12]. To solve the problem, it encapsulate all services provided by the same SP with standardized machining task description strategies, only the capability information of a service can be provided in the cloud.

Through analyzing the current manufacturing industry, studying on service modes, Cao et al. proposed a working procedure priority-based algorithm (WPPBA) in [13]. The prime collaboration mode is proposed as part manufacturing service combined with working procedure manufacturing service. WPPBA is designed for the selection and composition of working procedure granularity services. Liu proposed a social learning optimization algorithm based on the improved social cognition (SCO) algorithm and improved differential evolution (DE) algorithm and apply to the composition of qos-aware cloud services in [14]. V.Gabrel studied on the composition of qos-aware web services and proposed a mixed integer linear program to represent the problem in [15]. Liu et al. studied on the multi-task oriented services composition to meet high demand of qos of users in [16]. Huang designed a chaos control optimization algorithm for the composition of qos-based services in [17].

Task scheduling is particularly important for intelligent manufacturing. Vahit studied on multi-objective flexible job-shop, and presented an object-oriented (OO) approach in [18]. Many-to-many associations between operations and machines are transformed into two one-to-many associations.

The rest of this paper is organized as follows: Sect. 2 discuss the granularity of services in the system. Section 3 presents the semantic descriptions of the services and the tasks. Section 4 presents the problem definition for service selection. Section 5 presents the experimental results; Sect. 6 summarizes the paper.

2 Granularity of Services

Many articles classified manufacturing services into four categories, products, components, parts and working procedure, according to their granularity. A product is composed of some components, a component is composed of some parts, a part is composed of some working procedures. That is, a product is not only composed of parts, but also working procedures. Cao et al. [13] focus on the granularity of parts and working procedure. Outsourcing would be used on the condition of having not enough time, equipment failure or having some demand beyond the capacity of the Enterprise. The outsourcing part is a part of the production of the enterprise. So the granularity of the outsourcing part should be smaller than that of the whole production. Users may have no idea what services of lower level of granularity to apply for in case of they don't know the specific processes of the service of a higher level of granularity. So, all of the four level of granularity of services should be involved in the system. There are two types of service in each level, design services and manufacturing services. A design service describe the specific processes of the service composed of services in lower level of granularity.

Hardware service and software service should also involved in the system to ensure that the system can meet a variety of manufacturing requirements. The level of granularity of hardware and software services are considered as the level of tools. One other indispensable kind of service in cross-regional intelligent manufacturing is transport service. Transport service is a little different from other services, because it's carried on during the interval of two services and its selection has nothing to do with the user's demand but the location of the two selected services before and after it. Each level is possible for the two services. Therefore, the authors believe that services in cross-regional intelligent manufacturing should be divided into six categories:transportation services, production services, component services, parts services, working procedure services and tools services.

3 The Model of Cross-regional Intelligent Manufacturing Service

CIMS presents the cross-regional intelligent manufacturing service class. It has seven sub-classes: WPIMS (working procedure service), PIMS (parts service), CPIMS (components service), PRIMS (product service), SWIMS (software service), HWIMS (hardware service), TRIMS (transportation service). CIMT presents the cross-regional intelligent manufacturing task class;

$$\text{CIMS} = \{\text{GeneralInfo, AbilityInfo, QosInfo, Process, State, Resource}\} \tag{1}$$

$$\text{CIMT} = \{\text{ID, Process, start, complete}\} \tag{2}$$

1. GeneralInfo presents the basic infomation of services:

   $$\text{GeneralInfo} = \{\text{ID, Name, Description, Scale, Type, Category, ContractInformation}\} \tag{3}$$

   ID is used to identify the services;Name is related to the specific content of the service;Description describe the content of service in more detail;Scale presents whether the service can sell in small batch, large quantities or retail;Type presents the granularity of the service;Category presents the function type of the service, so that the service selecting can be more efficient; ContractInformation describe the contact information of the service provider, such as address, phone, email-address, etc.
2. AbilityInfo describe the information on the capacity of a service. Each sub-class of CIMS related to a different sub-class of AbilityInfo. Each of the sub-class of AbilityInfo describe the quality, the optional size, the variable parameters and the invariable parameters. AbilityInfo of transportation service should describe its

service area. AbilityInfo of hardware service describe its speed and machining range. AbilityInfo of software service describe its calculation range and so on.

3. QosInfo presents the Qos values of the service. These value is needed to calculate the selecting value while selecting services.

$$\text{QosInfo} = \{\text{price}, \text{efficiency}, \text{evaluation}\} \tag{4}$$

price presents the unit price of a service;efficiency presents the number of the service can be provided per unit of time;evaluation present the average of the history evaluation of the service.

4.

$$\text{State} = \{\text{Availability}, \text{task}\} \tag{5}$$

Availability presents the status of the service. The status may be iddle, occupied or out of service;task indicates the list that the service has been scheduled. The calculation of the value of waiting time while selecting services is based on this.

5. Resource describes the resource information of a service:

$$\text{Resource} = \{\text{Material}, \text{MaterialResource}, \text{HumanResource}, \text{Equipment}, \text{Enterprise}\} \tag{6}$$

Material presents materials the machining required;MaterialResource represent the specific amount of material required for unit service;Equipment describe the devices used in the service;Enterprise represents the company providing the service.

6. Process describe the processing of the service, including the construction information of sub-services:

7.

$$\text{Process} = \{\text{Input}, \text{output}, \text{startTime}, \text{ControlConstruct}\} \tag{7}$$

Input describes the needed inputs of the service; output describes the outputs; startTime describes the relative start time of ControlConstruct to the start of the service; ControlConstruct represents the logical relationships between services, with reference to the owl-s. It is facilitate to the decomposition of the task.

$$\begin{aligned} \text{ControlConstruct} = (&\text{Sequence}|\text{split}|\text{split}+\text{join}|\text{Any}-\text{Order}|\text{Choice}|\text{If}- \\ &\text{Then}-\text{Else}|\text{Iterate}|\text{Repeat\_While}|\text{Repeat\_Until}|\text{Perform}|\text{Produce}) \end{aligned} \tag{8}$$

Perform presents a sub-service in the construction. This service may correspond to a specific service in the system, an abstract sub-service represent the process of the service, or a undetermined service waiting to select a specific one.

$$\text{Perform} = \{\text{Service}, \text{Category}, \text{type}, \text{transport}\} \tag{9}$$

If the Perform does not present a specific service, it should present a Category;type describe the service is an specific one or an abstract one;If there is a need for transportation after the service, transport describe the transportation service.

4 Peer Services Priority-based Algorithm

4.1 Problem Definition

In accordance with the service selecting mode described in the previous chapter, the selection of services of each level of granularity is similar. It is necessary to take into account both the time and the cost while selecting services. The notations used in definition are as in [13] as follows:

P_i	The *ith* part-level manufacturing task, $i = 1, 2, \ldots, k$
$wp_{i,j}$	The *jth* WP of P_i, $j = 1, 2, \ldots, n(i)$
$s_{i,j}$	The machining method of $wp_{i,j}$
$t_{i,j}$	The working hours of $wp_{i,j}$
RP_i	The *ith* *RP* in the system, $i = 1, 2, \ldots, h$
M_i	The *ith* machining method considered in this model, $i = 1, 2, \ldots, e$
$c(i, j)$	The price per hour of M_j that provided by RP_i
$\bar{c}(j)$	The average price per hour of M_j available in all RP_s
$\delta(j)$	The variance of price per hour of M_j available in all RP_s
$d(i, j)$	Logistics time between RP_i and RP_j
$lc(i, j, m)$	Logistics cost between RP_i and RP_j when the delivered weight is m
m_i	The workblank mass of P_i
A_i	The workblank supplier of P_i is in the same city as A_ith RP
B_i	The *SD* of P_i is in the same city as B_ith *RP*
$w(i, j)$	The waiting time of service M_j in RP_i
X_i	The processing route of P_i, $Xi = [x_i 1, x_i 2, \ldots, x_i n(i)]$
$TC_i/MC_i/LC_i$	The total cost/machining cost/logistics cost of P_i
$TT_i/MT_i/LT_i/WT_i$	The total time/machining time/logistics time/waiting time of P_i
α_i/β_i	The cost weighting factor/time weighting factor of P_i
$mc(i)$	The largest acceptable machining price per hour of M_i
AC_i/AT_i	The largest acceptable total cost/longest acceptable total time of P_i

TC_i, MC_i, LC_i, TT_i, MT_i, LT_i, WT_i are calculated as follows [13]:

$$\begin{cases} TC_i = MC_i + LC_i \\ MC_i = \sum_{j=1}^{n(i)} c(x_{i,j}, s_{i,j}) t_{i,j} \\ LC_i = \delta m_i (d(A_i, x_{i,1}) + \sum_{j=1}^{n(i)-1} d(x_{i,j}, x_{i,j+1}) + d(x_{i,n(i)}, B_i)) \end{cases} \quad (10)$$

$$\begin{cases} TT_i = MT_i + LT_i + WT_i \\ MT_i = \sum_{j=1}^{n(i)} t_{i,j} \\ LT_i = 24(d(A_i, x_{i,1}) + \sum_{j=1}^{n(i)-1} d(x_{i,j}, x_{i,j+1}) + d(x_{i,n(i)}, B_i)) \\ WT_i = 24 \sum_{j=1}^{n(i)} w(x_{i,j}, s_{i,j}) \end{cases} \tag{11}$$

The mathematical model could be given as follows [13]:

$$\min \sum_{i=1}^{k} f_i(X_i) = \min \sum_{i=1}^{k} (\alpha_i \bullet TC_i + \beta_i \bullet TT_i) \tag{12}$$

$$s.t. \begin{cases} c(x_{i,j}, s_{i,j}) < mc(s_{i,j}) \\ TC_i < AC_i \\ TT_i < AT_i \\ \alpha_i + \beta_i = 1 \end{cases}$$

The problem is to minimizing the total cost and total time. The constraints of AC_i and AT_i can be met by adjusting the weighting factors α_i and β_i [13] if it is possible.

4.2 Algorithm Design

The most widely used service selection algorithms are genetic algorithm, differential evolution algorithm, particle swarm optimization and colony optimization, etc. But the drawback of these intelligent algorithms is can not ensure rapid responses [13]. Yang et al. [13] proposed a WP priority-based algorithm (WPPBA). Major WP_s is determined by $c(s_{i,j}, j)t_{i,j}$. The sum of $c(s_{i,j}, j)t_{i,j}$ of all the major WP_s should be more than 75 % of the total machining cost. The minor WP_s between the major WP_s should select the same SP as the left major one or the right major one. So that the logistics cost would be minimized. But the algorithm is not stable enough under some special circumstance.

Consequently, inspired by the WPPBA, we propose a peer services priority-based algorithm (PSPBA) which is more stable. We use $dx(j)$ as the key factor to determine the major services. The major define value of each service is as follow:

$$MDV_{i,j} = dx(j)t_{i,j^2} \tag{13}$$

Sort the services in descending order of $MDV_{i,j}$:

$$so = \{wp_{i,a}, wp_{i,b}, wp_{i,c}, \cdots | MDV_{i,a} > \mathrm{M}DV_{i,b} > MDV_{i,c} > \ldots\} \tag{14}$$

If $wp_{i,j}$ is in the top 30 % of SO, or

$$MDV_{i,j} > 4\bar{d}_{\mathrm{i}}^2 \tag{15}$$

$$\bar{d}_i = average\{d(j,k)|j,k < n_i\} \tag{16}$$

than, $wp_{i},_j$ is one of the main services.

The sequence of the selection of major services follow the services order:

$$\begin{aligned} \min(\alpha_i(c(x_{i,j}, s_{i,j})t_{i,j} + \delta m_i(d(last, x_{i,j}) + d(x_{i,j}, next))) + \\ \beta_i(t_{i,j} + 24(d(last, x_{i,j}) + d(x_{i,j}, next) + w(x_{i,j}, s_{i,j})))) \end{aligned} \tag{17}$$

last indicates $x_{i,k}$ of the nearest service before this one and $x_{i,k} \neq 0$, which means $wp_{i,k}$ have been selected. *Otherwise, last* = $A_{i.}$*next* indicates $x_{i,k}$ of the nearest service after this one and $x_{i,k} \neq 0$. *Otherwise, last* = $B_{i.}$

The selection of the minor services between major services refers to WPPBA [13], the processing route of between $wp_{i,p}$ and $wp_{i,q}$ is one column of the matrix $X_{p,q}$:

$$X_{p,q} = \begin{pmatrix} x_{i,p} & x_{i,p} & x_{i,p} & x_{i,p} & \cdots & x_{i,p} & x_{i,p} & x_{i,q} \\ x_{i,p} & x_{i,p} & x_{i,p} & x_{i,p} & \cdots & x_{i,p} & x_{i,q} & x_{i,q} \\ x_{i,p} & x_{i,p} & x_{i,p} & x_{i,p} & \cdots & x_{i,q} & x_{i,q} & x_{i,q} \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots \\ x_{i,p} & x_{i,p} & x_{i,p} & x_{i,q} & \cdots & x_{i,q} & x_{i,q} & x_{i,q} \\ x_{i,p} & x_{i,p} & x_{i,q} & x_{i,q} & \cdots & x_{i,q} & x_{i,q} & x_{i,q} \\ x_{i,p} & x_{i,q} & x_{i,q} & x_{i,q} & \cdots & x_{i,q} & x_{i,q} & x_{i,q} \end{pmatrix} \tag{18}$$

To determine the process route between $wp_{i,p}$ *and* $wp_{i,q}$ *is to find the column:*

$$\min(\alpha_i \sum_{j=p}^{q} c(x_{i,j}, s_{i,j})t_{i,j} + 24\beta_i \sum_{j=p}^{q} w(x_{i,j}, s_{i,j})) \tag{19}$$

The calculate process of peer service priority-based algorithm is described as follows:

Step 1 Calculate $MDV_{i,\ j}$ according to Formula (4).

Step 2 Sort the services and get major services based on Formula (5)-(7).

Step 3 Select each major service follow the order of (5) and Formula (8).

Step 4 Optimize the processing route of minor WP_s based on Formula (9)-(10).

Step 5 Check whether the selected services meet the requirements. Otherwise, adjust the value of α_i and β_i, or adjust the imperfect service to another *RP*.

5 Simulation Experience and Evaluation

5.1 Initial Data

To prove the practicability of PSPBA in selecting services, we take ten customized mechanical parts as test cases. Eight of the ten parts have been used to test the

Table 1. Basic information of tasks.

part	m (kg)	A	B	$x_{i,j}/t_{i,j}$									
				$w_{i,1}$	$w_{i,2}$	$w_{i,3}$	$w_{i,4}$	$w_{i,5}$	$w_{i,6}$	$w_{i,7}$	$w_{i,8}$	$w_{i,9}$	$w_{i,10}$
P_1	8.14	2	4	1/3.55	3/2.55	7/0.50	4/0.17	5/2.46	2/0.50	9/0.21	7/0.60	–	–
P_2	9.86	5	1	1/1.96	3/0.80	4/0.07	1/0.75	5/0.54	4/0.04	5/0.48	6/0.05	2/0.82	7/0.33
P_3	4.98	6	7	2/1.30	9/0.87	7/0.42	4/0.10	5/2.78	4/0.17	7/0.50	–	–	–
P_4	5.28	3	6	1/1.37	4/0.57	6/0.08	7/0.50	1/0.61	5/2.74	2/0.07	3/0.17	7/0.45	–
P_5	2.88	2	5	8/0.27	4/0.18	6/0.05	8/0.43	4/0.10	5/1.95	7/0.25	–	–	–
P_6	4.46	4	3	1/0.61	3/0.75	4/0.17	6/0.10	5/2.35	9/0.90	7/0.42	–	–	–
P_7	2.62	1	5	1/0.48	5/0.53	1/0.32	3/0.70	5/1.06	4/0.43	3/0.06	7/0.17	–	–
P_8	4.40	4	2	2/0.21	5/3.08	4/0.23	6/0.37	2/0.35	7/0.17	3/0.75	7/0.15	–	–
P_9	5.99	3	3	1/0.61	3/0.75	7/0.64	4/0.10	5/0.48	4/0.04	5/0.54	6/0.43	2/0.82	7/0.45
P_{10}	3.06	2	6	1/3.55	3/2.44	4/0.04	1/0.63	5/0.51	4/0.67	5/0.47	2/0.05	9/0.48	7/0.27

performance of WPPBA by Yang et al. [13]. We cited these eight sets of data to test the performance of PSPBA, and make a comparison between WPPBA (Table 1).

Nine kinds of machining methods and seven RP_s are include in the simulation experiments. c is the price per hour matrix (yuan/h), whose rows denote RP and columns denote machining methods; d is the RP distribution matrix (day); w is the waiting time matrix(day), whose rows denotes machining methods and columns denotes RP_s. They are formulated as below [13]:

$$c = \begin{pmatrix} 36 & 36 & 41 & 16 & 48 & 36 & 999 & 103 & 109 \\ 999 & 999 & 28 & 32 & 38 & 34 & 36 & 88 & 90 \\ 23 & 44 & 33 & 34 & 49 & 26 & 24 & 100 & 98 \\ 38 & 28 & 43 & 29 & 36 & 39 & 30 & 100 & 87 \\ 33 & 44 & 41 & 30 & 41 & 21 & 999 & 85 & 103 \\ 27 & 999 & 44 & 30 & 36 & 29 & 33 & 84 & 88 \\ 26 & 35 & 38 & 999 & 37 & 28 & 34 & 95 & 95 \end{pmatrix}$$

$$d = \begin{pmatrix} 0 & 2 & 2 & 2 & 3 & 2 & 3 \\ 2 & 0 & 1 & 1 & 2 & 2 & 3 \\ 2 & 1 & 0 & 1 & 2 & 2 & 3 \\ 2 & 1 & 1 & 0 & 2 & 2 & 3 \\ 3 & 2 & 2 & 2 & 0 & 2 & 3 \\ 2 & 2 & 2 & 2 & 2 & 0 & 2 \\ 3 & 3 & 3 & 3 & 3 & 2 & 0 \end{pmatrix}$$

$$w = \begin{pmatrix} 3 & 2 & 3 & 2 & 3 & 2 & 1 & 4 & 2 \\ 2 & 2 & 2 & 2 & 2 & 3 & 2 & 4 & 4 \\ 4 & 4 & 3 & 3 & 5 & 1 & 2 & 4 & 2 \\ 3 & 3 & 3 & 1 & 2 & 2 & 4 & 3 & 2 \\ 5 & 3 & 1 & 5 & 1 & 5 & 1 & 3 & 4 \\ 2 & 2 & 2 & 5 & 4 & 5 & 1 & 2 & 4 \\ 2 & 4 & 1 & 3 & 3 & 3 & 2 & 4 & 1 \end{pmatrix}$$

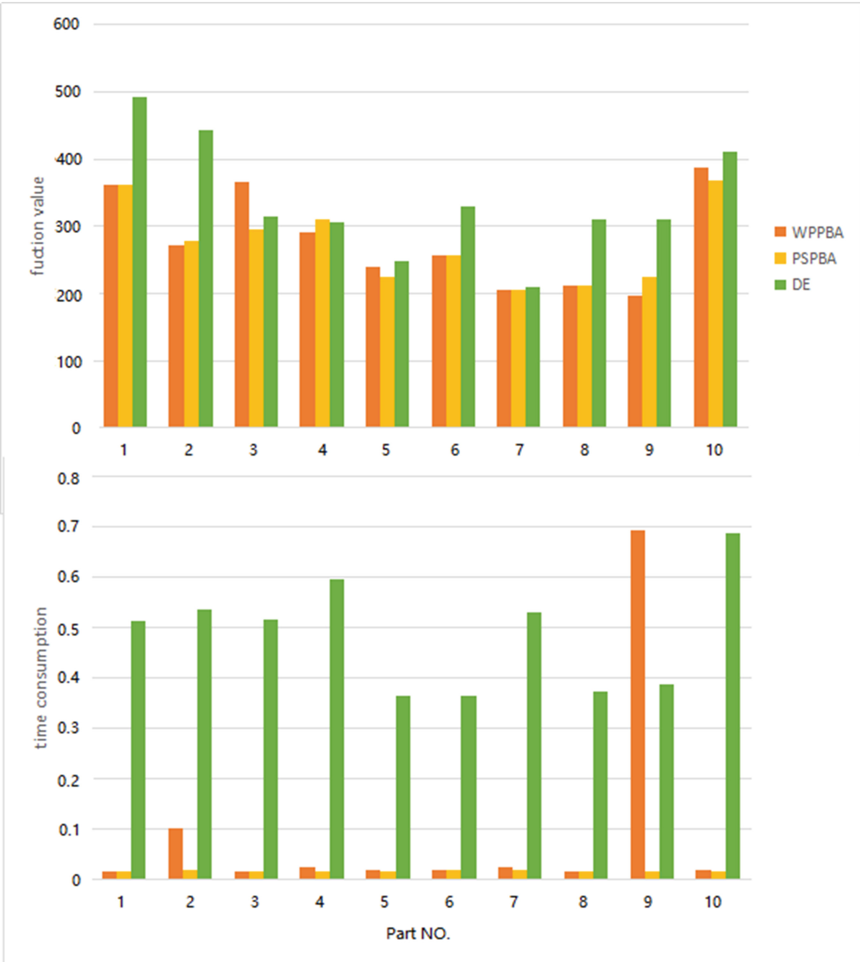

Fig. 1. Time consumption and function value comparison of PSPBA, WPPBA and DE

5.2 Experiment Results

Standard DE and WPPBA [13] are selected for comparison to verify the effectiveness of PSPBA. The population size of DE is 20; crossover probability is 0.85; and the iteration number is 100. Figure 1 shows the function value and the time consumption of the ten sets of solution of the three algorithms.

Obviously, if a lower function value denotes a better solution, the solution quality of DE is much lower than that of WPPBA and PSPBA, and the solution quality of WPPBA is a litter lower than that of PSPBA. However, in practice, time consumption is also important. Time consumption of PSPBA is much more stable than WPPBA. Time consumption of WPPBA is affected by the numbers of its major services. When the number of major services increase, time consumption would rise exponentially. As the result shows, selecting major services one by one with influence of the selection of nearby services does not greatly affect the solution quality. What's more, time consumption would be reduced greatly, and more stable.

6 Conclusion

A way of classification and composition of manufacturing services in cross-regional intelligent manufacturing is proposed. Information models of the services and tasks are constructed. Then a algorithm called PSPBA is designed for services selection in intelligent manufacturing to minimize the total cost and time of a task, and reduce the time consumption. The effectiveness of PSPBA is validated by simulation experiments. The simulation results shows that PSPBA has less time consumption and better solution compared with WPPBA and DE.

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