THE MATCHING FOR THE MULTI-PROJECT COLLABORATIVE PLAN OF NEW PRODUCT DEVELOPMENT AND RESOURCE BASED ON GENERALIZED RESOURCE UNIT

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Abstract: The Objective is the matching of collaborative development of products in manufacturing enterprises including involvement of suppliers on a large scale. Match function for collaborative multi-project planning and design resources is analyzed under different requirements and time intervals, when any conflicts exist. A generalized design resource unit and a resource granule quantification model are defined. A multi-project collaborative planning and resource granule constraint-matching model with realization algorithm is presented. According to plan matching with resource granule, new product development with multi-project collaborative planning method, based on generalized design resource constraint is proposed. Presented is a case according to the model and planning which demonstrates the feasibility of the method.

1 INTRODUCTION

In the industry chain cluster, OEMs often need the simultaneous design and development of several new products in order to gain the initiative in competition. This results in a number of project groups that may be formed between internal organizations and suppliers, where each project needs to be implemented by matching the appropriate design resources. Design resources required for the completion of new product development, including internal organizations and suppliers, are collectively referred to as generalized design resources. General design resources are limited, and always difficult to meet the growing demand for new product development of the project planning.

New product development of OEMs involves collaborative multi-project management, which comes to the rational allocation of limited generalized design resources to collaboratively complete several projects. Many famous experts and scholars have referred to the design problems in resource sharing and more collaborative project management. Engwalla M qualitatively illustrated the sharing of resources and implementation of concurrent engineering combined to effectively work out the allocation of resources, yet no solution was presently given to a specific quantitative model. Chen You-Ling , based on a key chain, put forward a method for preparing a multi-project program, which gives a comprehensive consideration on human factors and resource constraints and other uncertainties. It involves the use of critical chain planning methods in scheduling the bottleneck and non-bottleneck project plans. However, the method does not make a concrete analysis of resource constraints that may affect the several planning aspects. However, their further study stopped at the design development process regarding the reasonable allocation of resources and the progress control of projects.

In the process of new product design and development, multi-project coordination means the scheduling for the allocation of resources for different tasks, which falls in the Flow-shop Scheduling Problem (FSSP). This is a typical problem called N-P, for which the optimal solution can be sought through the integer programming and branch & bound method. But for some large or medium-scale problems, the method can be quite difficult in realization. In this paper, the genetic algorithm theory was used to propose the match model for multi-

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project plan and resources particle under the generalized resource constraints, and including its optimization algorithms.

2 DEFINITION OF GENERALIZED DESIGN RESOURCE PARTICLES

Resource particles for new product design are referred to the available entities comprised of the people, computer hardware and software, and information resources. Generalized design resource particles come from the design resource particles of the OEMs and suppliers, and the characteristic attribute can be defined as ID number, name, profession, job title, skill type (including software skills), capacity factor, load status, and duration of contract, performance and work units, etc. In the new multi-project collaboration in product development, the OEM resource particles are generally used to complete the overall design of products or components, system integration and the management of suppliers. Particles of supplier design resources are generally used to complete the design of parts or components, driven by the tasks assigned by OEMs. Thus, in product design and development by multi-project collaborative planning, each task needs to match a resource particle, e.g. product design tasks need to match a resource particle of the overall design capacity. Once the matching is obtained, design resource particles would have a state of load that is already occupied in the task completion time, and no longer to participate the matching of the remaining tasks in this session. The matching relation is defined as the constraint matching.

Design resource particles have symbols that are defined as follows: M_{ij} is No. j design resource particle that belongs to OEMs, with No. i skill type; S_{ij}^{k} is No. j design resource particle that belongs to No. k supplier, with No. i skill type.

3 OPTIMAL SCHEDULING ALGORITHM FOR MULTIPROJECT COORDINATED PLANNING

3.1 Definition of Variables

A triple *MRA=(P,R,D)*is employed for formal description of constrained matching between multi-project coordination plans and resource particles, where each tuple is defined as follows.

P(Project)is a project set (set with m projects), as:

$$P_i = \left\{ \begin{pmatrix} A_{i1} & A_{i2} & \dots & A_{in_i} \end{pmatrix}, ES_i, LF_i, SS_i, SF_i \right\} \qquad (1)$$

Where,A_{ij} ($1 \le j \le n_i$) is No. j task in the No. I project; ES_i is the earliest starting time for the No. i project; LF_i is the latest end time for the No. i project; SS_i is the actual starting time for No.i project; SF_i is the actual end time for No. i project.

R=(R1,R2,R3) (Resources) is the set of resource particles,. Then, resource particles are defined as:

$$R_x = \{G_x, SE_x, SW_x[T]]\}, 1 \le x \le k \qquad (2)$$

Where, k is the number of particles in the generalized design resources. It is assumed that a type of resource particle can undertake the work in a task type, and totaling e task types, $G_x \in \{1, 2, \cdots e\}$; SE_x is the type identification of resource particles. It is assumed that there are a total of f types, then $SE_x \in \{1, 2, \cdots f\}$;$SW_x[T]$ array record indicates the work schedule of No. x resource particles. Here, T is the total number of days for planning. e.g. $SW_x[4]=33$, indicates that in the fourth day of program, No. x resource particle is allocated to task A_{33}.

D(Demands) is a collection of resource requirements. The resource requirements matrix is defined as:

$$D = \begin{bmatrix} D_{11} & D_{12} & \cdots & D_{1,n1} \\ D_{21} & D_{22} & \cdots & D_{2,n2} \\ \vdots & & & \\ D_{m1} & D_{m2} & \cdots & D_{m,nm} \end{bmatrix} \qquad (3)$$

D_{ij}($1 \leqslant i \leqslant m$, $1 \leqslant j \leqslant n_i$) is resource requirement of No. j task A_{ij} in No. iproject ,$D_{ij}=(TP_{ij},SE_{ij},T_{ij})$;

Where, TP_{ij} is the type of task A_{ij}, $TP_{ij} \in \{1,2,\ldots e\}$; $SE_{ij} \in \{1,2,\ldots f\}$,indicates the type identification of the resource particle required by task A_{ij};T_{ij} is the duration for the task A_{ij}.

The assumption is often made for the Flow-Shop issue: Each project shares the same number of tasks, processes (i.e. the relationship between pre-task and post-task); each of resource particles can only undertake a task in the same time; each task only needs to be allocated with an appropriate resource particle.

3.2 Calculation of Optimum Solution based on Genetic Algorithm for the Sorting Queue of Tasks

Genetic algorithm is regarded as the simulation on the biological evolution, and it borrows from biological natural selection, without relying on the random search algorithm from gradient information. It is characterized by groups of search strategy and the information exchange between individuals in groups, suitable for complex nonlinear issues that may be difficult to solve using traditional search methods. However, it is not easy for genetic algorithms to create the coding method to express sufficient genetic information, and the calculation method for the design of evaluation on the individual fitness function.

3.2.1 Encoding Rules

As multi-project coordinated planning has no priority difference between the projects, all tasks are given the resources in the order that is the key to planning. Each individual coding contains a sequence message, which comes from more than one task matching resources in different projects. It is encoded in the form of a number string, totaling $\sum_{i=1}^{m} n_i$ digital bits (m is the number of projects, n_i is the number of tasks in project i, with the 16-band being used. If m>16, the encoding digit is doubled. If two of 16 hexadecimal numbers are used as a processing unit, and then 255 issues can be handled for planning.) As required, the character string is randomly generated, each number being appeared for a number of times equal to the number of tasks for the corresponding projects. The coding number is the sequence of the various tasks with the allocation of resources in the program. For example, the digital string: "13123 ...." contains the task scheduling order as indicated in Table 1:

Table 1: The encoding rule.

CODE	Task scheduling	Remarks
1	A_{11}	The task in project 1. ‘1’ comes first, indicating the task 1 in project 1
3	A_{31}	The task in project 3. ‘3’ comes first, indicating the task 1 in project 3
1	A_{12}	The task in project 1. It comes for the second time , indicating the task
…	...	…

3.2.2 Fitness Function Value

Each of the scheduling programs is calculated on the actual start time and actual end time SS_i and SF_i for the projects. Scheduling objective is to calculate the scheduling order of some task. Prior to the arrival of landmark nodes, the projects in fine match should be done as far as

possible, that is, the project that is desired to finally end has the shortest period of time, that is:min(max(SF_i)),i=1,2,…m .For the need of sample selection in roulette, the sample with a larger fitness function value may have the larger probability to be selected. So No. x code is constructed with the corresponding fitness function value as:

$$f(x) = U - \left(\max(SF_i)\right)_x \tag{4}$$

Where, U is a sufficiently large number. This algorithm is done to seek an optimal engineering solution, obtaining the value of fitness function *f(x)* that is largest in all samples.

3.2.3 The Algorithm Flow

The Crossover probability and mutation probability can be estimated that the actual situation of the project. The crossover rule indicates the use of single-point crossover, and the exchange of all digital cross bits behind the two samples. The mutation rule requires values to be added with 1, overloaded to return 1, namely:1→2,2→3…,m→1.

4 NUMERICAL EXAMPLE AND VERIFICATION

A cell phone manufacturer is responsible for both of the design and production of packaging materials to a variety of mobile phones. The design and development process is designed as: the mobile phone manufacturer (OEMs) to design package materials → Supplier 1 to design packaging materials mold → Supplier 1 for the mold assembly → Supplier 2 for proofing → the mobile phone manufacturer, for acceptance of package materials and tooling. At this point, the multi-collaborative project management model is formed around the mobile phone manufacturer for design and manufacture of packaging materials.

It is assumed that there are four ongoing development projects of mobile phone package materials, each project required to complete five tasks according to the above process. Task types include: 1. Package materials design. 2. Mold assembly. 3. Proofing. 4. Acceptance. There are six design resource particles (of which resource particles M_{11}, M_{12} and M_{41} are OEM designers, with the resource category identified as 1, here, M_{11} and M_{12} indicate the two particles to able to undertake the first task, that is, packaging materials design. M_{41} is the particle that takes the fourth task of acceptance. S^1_{21} and S^1_{22} are the resource particles of Supplier 1 to takes the second task of the mold design and assembly, with the particle class designation of 2. S^2_{31} is the resource particle of Supplier 2 to take on No. 3 task, responsible for sampling, with the class designation of 3. The OEM and suppliers have different work sites.) The projects have the earliest start time ES_i, respectively as: ES_1=1; ES_2=4;ES_3=9;ES_4=12. 30 days are used as the time for division of landmark nodes.

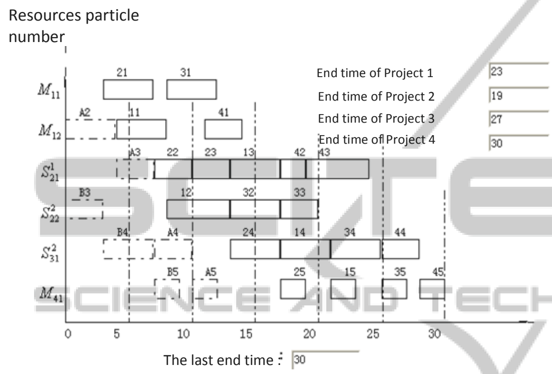

Figure 1: The result of optimized.

In preparing the plan of Session 1, there is part of the task of the pre-task projects a, b are not completed. Therefore, it is required to set resource time occupied by these tasks as pre-occupied state, so as not to participate in the task / resource matching in the session, as shown in dashed boxes in Figure 1 and 2.

Set the crossover probability as 0.4, mutation probability as 0.1. Through genetic optimization, an optimal engineering solution is sought out. 20 tasks (4 × 5) have the order to allocate resource particles that are encoded as: "22121241284841144888". The multi-project coordination plan is prepared based on the optimum project solution, and the resource particles have the Gantt work chart as shown in Figure 1. The results show that the last ending project is Project 4, with the end time of 30 days. That happened to be completed the fine distribution of all project plans prior to the arrival of landmark nodes. Figure 2 is a comparison program that is not optimized, and the sequence for the task allocation of resources is a randomly generated number string (the string is randomly generated on demand, each number appearing for the number of times equal to the task number of the mapping projects): 41248812284842482111. In that order for allocation of resource particles, each of the resource particles come out with the Gantt work chart as shown in Figure 2, where the total time is 110 days, with Project 4 being the finalized one, in 34 days. If the plan multi-project coordination is prepared in accordance with the program without optimization, then prior to the arrival of the final landmark node, it is not likely to complete all projects. The optimum solution obtained by using optimization algorithm was completed with a higher efficiency than the randomly generated programs.

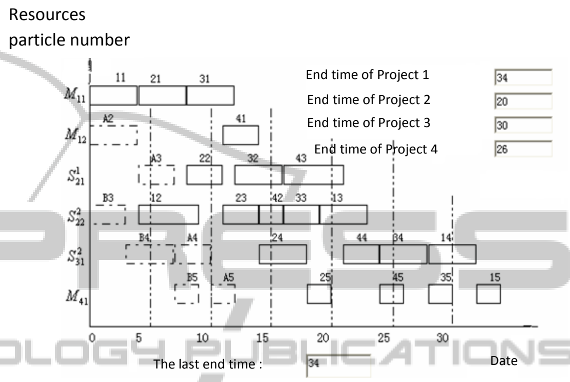

Figure 2: The contrastive result.

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