

## A FUZZY SCHEDULING METHOD IN EQUIPMENT GRID

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### Abstract:

Equipment grid and equipment pool model of equipment grid are introduced. The process from submitting a job in equipment grid to obtaining of results is analyzed. A fuzzy scheduling method is proposed in equipment pool when a job is submitted to one of equipments within a pool. Fuzziness of this method lies in vagueness of users' appraisals about experiment results and execution quality of equipments. Equipment in a pool has a probability, which can be adjusted by users' fuzzy appraisals, to be scheduled. Users' feedback information is used in this paper to improve execution quality. Some algorithms are provided to increase utilization ratio of equipments with high execution quality and decrease utilization ratio of those with poor execution quality. From simulation result, it is obvious that this method and related algorithms can provide users more chances with high execution quality.

### Keywords:

Equipment grid; Fuzzy; Scheduling; Execution quality

### 1. Introduction

With development of scientific research, coordination of several equipments is required in some scientific experiments. How to organize existing equipments to work coordinately and provide a friendly equipments sharing environment for users is an open difficult problem.

Current situation is that on one hand many organizations want to do experiments while they can not find equipments needed to finish these experiments. They apply for money to buy equipments needed. After experiments finished, the equipments newly brought were placed aside and has few chances to be used again. On the other hand, it cost a lot of money to maintenance these idle equipments. Connecting some of existing expensive equipments together and provide interfaces for users to use these equipments in the form of grid service is primary aim of equipment grid. Meanwhile there are some experiments which require coordination of several other equipments.

### 2. Background

Grid is mainstream technologies for resource sharing and working coordinately in large scale virtual organizations [1-2]. Equipment grid refers to grid that connecting distributed equipments together and provides transparent service invocation and coordination of equipments. It was proposed in [3], which provides an abstraction of equipments and publishes their functionalities in form of grid service. Architecture of equipment grid and its future applications are also provided. Equipment grid service chain sharing method is presented in [4], which abstracts equipment grid as three levels and applies workflow method into equipment grid for resource sharing and working coordinately. The model of equipment grid in [4] is a three level model which are equipment level, basic service level and service chain level respectively. The equipment level refers to geographically distributed equipment resources which joins equipment grid. The basic service level refers to the level which collects equipments with similar functions together. For example all mass spectrographs are aggregated into a basic service. The service chain level builds on the basic service level, which is aggregation of some basic services. In [5] the model of equipment evolves into equipment pool model. In equipment pool model, there are meta-equipment, equipment pools and equipment pool alliance respectively. The equipment pool consists of same kind of equipments and different kinds of equipments pools constitute an equipment pool alliance. Equipments distributed geographically will be connected with high-speed networks and agglutinated with specifically designed middleware software. In [6]  $\pi$ -Calculus is imported into equipment grid to test validity of equipment grid service chain model. Resource scheduling schemes in equipment grid is discussed in [7] and [8] and simulation in equipment grid is provided in [9]. The research work in [10] connected medical equipments and realized remote diagnosis on certain diseases. Research work about remote manipulation

of geographically distributed equipments is introduced in [11].

All previous work in equipment grid has great contributions to the study of equipment grid while needs further research. For previous work does not take into the role of human in equipment grid and there is no feedback mechanism to reflect whether customers are satisfied with results from equipment grid. These problems will be discussed below. In this paper, feedback information for equipments is considered to be fuzzy variable with one of following linguistic values, *terrible*, *very bad*, *bad*, *normal*, *good*, *very good* and *excellent*. Equipment pool model in [6] is used and probabilities of resources in a pool are dynamically adjusted according to users' feedback information. Execution quality of any given equipment is also a fuzzy variable and is considered to be time invariable. Scheduling scheme in a pool is to choose equipment with probability when a new job is submitted into the pool. The probability is adjusted by predicted execution quality of each instrument and the predicted execution quality is gain through history execution quality of this instrument.

The rest of this paper is organized as follows. In Section 3, we present a scheduling scheme with user's feedback information using fuzzy theory and in Section 4 simulation work are given. We identify issues that need further investigation and conclude the paper in section 5.

### 3. Fuzzy scheduling method

In equipment grid, same kinds of equipments are organized into equipment pool and different equipment pools constitute an equipment pool alliance. When a user wants to do an experiment on equipment grid, he submits it to equipment pool alliance, and pool alliance analyses this job and verifies whether it can be accomplished with existing available resources in equipment grid. If the job can be fulfilled, pool alliance will submit it to the needed equipment pools according to job's inherent requirements. When an equipment pool receives a job, it will find a suitable equipment to run this experiment. Equipment pool permits equipment joining and leaving dynamically.

Equipment belongs to certain pool and can join and leave the pool dynamically. All pools have been registered in pool alliance and can also join and leave pool alliance dynamically. Following is steps when a user wants to do experiment using equipment grid. He submits it to pool alliance in Step 1, pool alliance will check whether it has required equipments necessary to fulfil this experiment and verify specifications of this experiment, such as time limitation, cost limitation etc. If not all the necessary resources are available or specifications of this experiment

can not be satisfied, pool alliance will reply the customer with refusal information in Step 2. Otherwise pool alliance will decompose this experiment and submit it to all related pools in Step 3. All related pools will find suitable resources within them and submit the job to equipments in Step 4. In Step 5, these chosen equipments return results of the experiment to their belonging pools after they finish jobs allocated to them and related pools return results to pool alliance in Step 6. Pool alliance collects all middle results and gives a final result to the user in Step 7. In Step 8, this user feeds back his opinion about result of the job he submitted.

A fuzzy prediction method is used in scheduling process of Step 4, which is an importance step in equipment grid. The prediction method takes users' feedback information into account and tries to provide users with high execution quality equipments. On basis of this method, many good scheduling strategies and algorithms can be designed.

Consider an equipment pool with  $N$  equipments in it. When a new experiment is submitted into this pool, scheduling probability of equipments within this pool is  $p_i$  ( $i \in [1, N]$ ).

$$\sum_{i=1}^N p_i = 1 \quad (1)$$

When the experiment is submitted to a chosen equipment, there are several factors to consider, for example the cost that chosen equipment charges for, execution time of the instrument, whether result from this equipment is reliable etc. All these factors vary with different equipments and can be looked as a virtual parameter of equipment. In this paper, this parameter is named as execution quality of equipment and denoted by  $q$ , and  $q_i$  means execution quality of the  $i$ th equipment in a pool according to specific submitted experiment. Equipment pool has no information about  $q$  of given equipments before results of these experiments are acquired. The pool dispatches experiments to its subordinated instruments according to expected value of predicted  $q$ . Distribution of fuzzy variable  $q$  will be changed by user's appraisal,  $Q$ , after he received his result from equipment grid. Variable  $Q$  is a fuzzy variable because a user can not describe how he satisfied with his result. Only vague linguistic values like *terrible*, *very bad*, *bad*, *normal*, *good*, *very good* and *excellent* can express his appraisal towards his result.

When a user submits a job with some constrains, like time constrain and cost constrain, to equipment grid, pool alliance will dispatch this job to related equipment pool or pools. These constrains can be expressed below.

$$\text{Time Constrain: } T_{end} - T_{start} \leq T \quad (2)$$

$$\text{Cost Constrain: } \sum_{j=1}^n c_k \leq C \quad (3)$$

$$\text{Error Constrain: } \sum_{k=1}^n error_k \leq E \quad (4)$$

$$\text{Trust Constrain: } \prod_{k=1}^n (credit_k) \geq Cr \quad (5)$$

In equation 2,  $T_{end}$  means the time when result is returned and  $T_{start}$  means the time when experiment is submitted to equipment grid.  $T$  is expected time which is acceptable by user. In equation 3,  $c_k$  means cost of using the  $k$ th equipment in an equipment grid service chain and there are  $n$  equipments needed in this service chain to fulfil this task.  $C$  means total cost of the experiment a user can accept. In equation 4, accumulated *error* should below a tolerant error  $E$  and total *credit* of the system should above  $Cr$  in equation 5. In (4) and (5),  $error_k$  and  $credit_k$  means error and credit of the  $k$ th equipment respectively.

When the experiment is submitted into a pool, the pool will predict  $q_i$  of equipment within it according to constrains of experiments and specifications of all equipments. Expected value of  $q_i$  is used to determine probability  $p_i$  that each instrument has to commit the experiment.

If the experiment is submitted to the  $i$ th equipment in a pool,  $q_i$  will match with constrains and has a value as one of following linguistic values, *terrible*, *very bad*, *bad*, *normal*, *good*, *very good* and *excellent*, which is parallel with users' appraisals. In most cases, a  $q_i$  with *excellent* value has a large probability to receive *excellent* value of  $Q$ , *very good* to *very good*, *good* to *good*, *normal* to *normal*, *bad* to *bad*, *very bad* to *very bad* and *terrible* to *terrible* of  $Q$ . Actual value of  $q$  to a specific experiment is not known by the pool and can only be predicted beforehand and be reflected by users' appraisals towards results of their experiments, equipment pool will adjust  $p_i$  to make equipments with *good*, *very good* or *excellent* execution quality higher utilization ratio. To avoid confusion all  $q$ , appears in following paper, refers to predicted  $q$ . How to map constraints of experiments, specifications of equipments and historical appraisals of equipment into fuzzy value of  $q_i$  is decided by experiments and users. Different experiments and different users will have different values of  $q_i$  and in some situations, even a same user will have different values of  $q_i$  because constrains set by user may vary. For example some urgent experiments may attach more importance on time constrain and in other situations some experiments may care more about cost constrain.

Different from previous scheduling scheme, this fuzzy random model is a close loop model, which takes user's

response into account and is expected to be able to provide higher execution quality

The probability that each instrument has to run a submitted experiment is  $p_i$  and it is proportional to the square value of  $q_i$ , as shown in equation (6).

$$p_i = (E[q_i])^2 / \sum_{i=1}^N (E[q_i])^2 \quad (6)$$

Distribution of fuzzy random variable  $q_i$  can be expressed in equation (7).

$$q_i = \begin{cases} \text{"Excellent"} & \text{with probability } qp_i^1 \\ \text{"Verygood"} & \text{with probability } qp_i^2 \\ \text{"Good"} & \text{with probability } qp_i^3 \\ \text{"Normal"} & \text{with probability } qp_i^4 \\ \text{"Bad"} & \text{with probability } qp_i^5 \\ \text{"VeryBad"} & \text{with probability } qp_i^6 \\ \text{"Terrible"} & \text{with probability } qp_i^7 \end{cases} \quad (7)$$

At initial state, all  $qp_i^k$  are equal and their sum equals to 1. Users' appraisals are used to adjust the probability  $qp_i^k$ , which is probability that  $q_i$  take  $k$ th fuzzy value in equation (7).

Algorithm to adjust  $qp_i^k$  is as follows. When a user's appraisal is the  $j$ th fuzzy value in equation (7), then expression (8) works.

$$\begin{aligned} qp_i^k &\rightarrow qp_i^k \times (1 - param) \quad (k = [1, 2, 3, 4, 5, 6, 7]) \\ qp_i^j &\rightarrow qp_i^j + param \quad (k = j) \end{aligned} \quad (8)$$

It is clear that after adjustment sum of all  $qp_i^k$  is still 1 and probability of  $j$ th fuzzy value  $qp_i^j$  will increased.  $param$  is a constant number. The value of  $param$  has influence on effects of probability adjustment. The ranges of probability adjustment will increased with larger  $param$ .

Suppose that the distribution of the seven fuzzy values is demonstrated in figure 1.

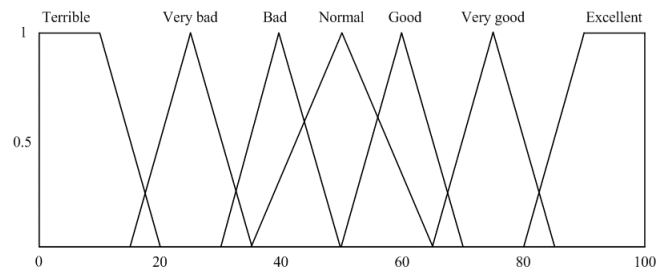


Figure 1. Membership function of fuzzy variable

Expected value of  $qp_i^j$  is shown in Equation (9).

$$E[q_i] = \sum_{k=1}^7 qp_i^k \times c^k \quad (9)$$

In equation (9)  $c^k$  is defined to be centers of membership function and in this case, they are 15, 25, 40, 50, 60, 75 and 90 respectively. It should be noted that when the membership function varied, the value of  $c^k$  and expected value of  $q_i$  will be different.

#### 4. Simulation and results

In this part, two examples will be given to illustrate fuzzy random scheduling method introduced in Section 3. Both examples are running on Windows XP using Java.

##### 4.1. Example 1

Some simple experiments, which only need an equipment to finish a submitted task, are submitted to pool alliance. An equipment pool with  $N$  equipments, which can run this experiment, is chosen by pool alliance. Every equipment has a same initial probability  $qp_i^k$  thus leads to same  $p_i$  of each equipment. In this example  $N$  equals to 70, and 10 of them have the execution quality of *excellent*, 10 *very good*, 10 *good*, 10 *normal*, 10 *bad*, 10 *very bad* and 10 *terrible*.

Figure 2 is result of 100,000 experiments with and without appraisal information feedback.

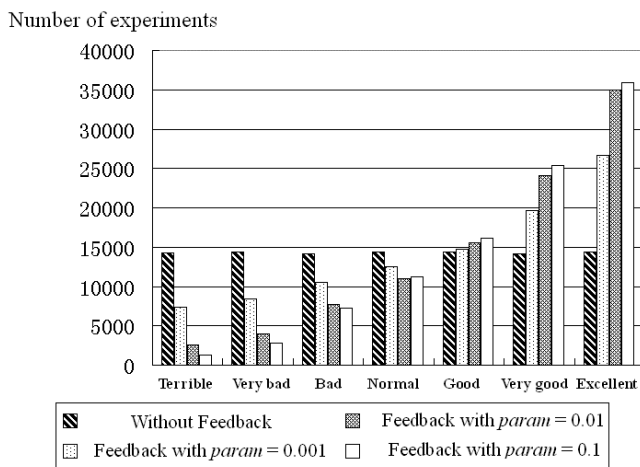


Figure 2. Result of appraisals for 100,000 experiments

From figure 2, we can find that when users' appraisals are used, equipments which can not satisfy users well have less chance to be scheduled and those with high execution quality have more chance. Owners of poor execution quality equipments can regain utilization ratio either by decrease price to use these equipments or by shorten execution time to satisfy the users.

##### 4.2. Example 2

In this example, some more complex experiments are submitted to pool alliance. To finish these experiments, a service chain with three nodes is needed. Each node represents a kind of equipment. Equipments on the three nodes belong to three different pools and are needed to work coordinately. The numbers of equipments in the three pools are  $N_1$ ,  $N_2$  and  $N_3$  respectively. Equipments in three pools have a same initial probability to be used. The number of equipments with different execution quality in each pool is the same. Final execution quality of experiment is the worst quality of  $q_i^1$ ,  $q_j^2$  and  $q_k^3$  when the  $i$ th equipment in one pool works coordinately with the  $j$ th equipment in another pool and the  $k$ th equipment in the third, which is reflected by users. In this example  $N_1$ ,  $N_2$  and  $N_3$  are 70. User's feedback information will have same influence on all the three equipments involved.

Figure 3 is results when feedback information is used to adjust probabilities in three equipment pools as well as result without probability adjustment.

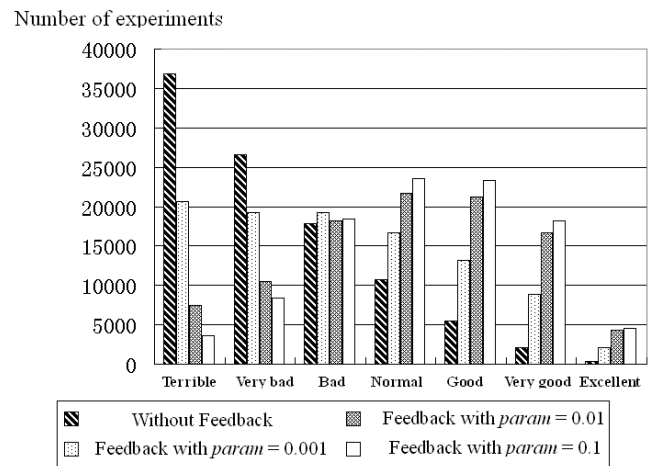


Figure 3. Result of appraisals for 100,000 experiments in a three nodes service chain

From figure 3, we can find that when feedback information is used in equipment grid service chain, more and more users will be satisfied with equipment grid. In compare with figure 2, improvement of users' appraisals is not so obvious. This lies in the fact that users' appraisals are only judgments to the whole service chain but not single equipment. Better results can be gain through import of prediction of execution quality in each node of a service chain.

## 5. Conclusions and future work

The contribution of this paper lies in proposal of fuzzy scheduling method in equipment grid, which takes users' feedback information into account and provides more satisfactory execution quality for users. In many real world cases, users' feedback information is fuzzy and this method can be applied into some more general cases. The algorithms provided here, which increase utilization ratio of equipments with high execution quality and decrease utilization ratio of those with low quality, can be slightly adjusted according to actual application cases.

For purpose of demonstration of this method, some aspects are not involved like impact of equipments' load. In the above two simulation examples, execution time of experiments is omitted, which leads to neglect of service queue. The time spent in queue waiting to be served may have influence on users' appraisals toward execution quality, but this simulation results still make sense in some time insensitive applications.

There are some issues not mentioned in this paper and need further research work, like prediction of execution quality for every node in the equipment grid service chain, how reliable and coherence of different users' feedback information and a testbed to verify this proposed method is our ongoing work. Future work will focuses on these issues.

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