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Dynamic Scheduling Based on Simulation of Workflow

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Extended Abstract:

Scheduling is classified into two sorts by the real-time character: static scheduling and dynamic scheduling. Static scheduling mainly designs an available task assignment for the scheduling process according to the initial state. But it cannot meet the requirements in time and cannot response the changes agilely. As an alternative, dynamic scheduling can overcome these flaws, and it can aid to gain a more credible scheme for scheduling. As a coin has two sides, complexity occurs in the dynamic scheduling problem. Due to this, the traditional methods cannot easily build the scheduling model and cannot quickly find the approximately optimal solution for scheduling. In this paper, a new dynamic scheduling method based on simulation of workflow is proposed, including scheduling implementation model and its matching algorithm.

Firstly, the dynamic scheduling implementation model based on simulation of workflow (acronymic as DSIMBSW) is introduced. The tasks in scheduling are described in the Process Model of DSIMBSW, which is derived from the workflow model[1]. As the workflow model is built on activities, the model, which describes the scheduling tasks, has much smaller scale than the other models, such as petri-net model. Not only can the workflow model depict the scheduling process much more easily, but also it can roundly describe many constraint conditions which exist in the scheduling. And the object function can be expressed by the statistic data which are generated through the simulation. Anyway, the constraint conditions and the object function are expressive in the DSIMBSW, as well as or even more perfect than the other models for scheduling. In this part, the components of the DSIMBSW and their relationships are detailedly explained. The main components are Process Model, Resource Model, Transaction Model, Simulation Engine, Simulation Environment, Scheduler, Workflow Relevant Data, Simulation Statistic Data.

The algorithms studied in the past jobs can be classified into three sorts[2]: precise algorithm, approximate algorithm and intelligent search algorithm. As the DSIMBSW involves the simulation, the algorithm based on rules can be competent. There are hundreds of rules in scheduling, and how to choose the exact rule for the exact task assignment is a problem we must solve. In order to get more satisfactory solution, dynamic scheduling algorithm based on rule-agent (acronymic as DSABRA) is proposed in this paper. The rule-agent is embedded into the Scheduler of the DSIMBSW and it has three units: Perception Unit, Analysis Unit and Action Unit. DSABRA needs to be combined with simulation of workflow and it chooses the exact rules with the aid of rule-agent.

In the last part, the scheduling implementation model based on simulation of workflow and the one based on simulation of petri-nets are compared, and the merits of SIMBSW are listed. The scheduling research on workflow is still in the stages of germination. Its practicability and availability need to be verified in the future scheduling applications.

Key words: Simulation of Workflow，Dynamic scheduling，DSIMBSW，DSABRA

1. Introduction

With the development of science and technology, scheduling has played an increasing important role in our society and production, especially in the research of the large-scale system. For example[4], within the NASA environment, scheduling is one of the most frequently performed function, whether it is being used for scheduling Shuttle mission, experiments, scientists' requests to use satellites, or scheduling a myriad of other tasks.

The requirement of scheduling influences and attracts the other subjects such as Petri-Net, Workflow, MAS(multi-agent system)，artificial intelligent algorithm, expert system, etc. As well, the richness and development of these subjects also make the application of the scheduling broader and broader.

Scheduling, can be simply understood as the problem of suitable assignment of manufacturing resource to tasks/jobs with a specified time window and coping with a set of constraints[5]. The problem of scheduling has been proved to be an NP-hard problem[6], so the focus is not to find the optimum solution but a preferable or satisfactory solution. Before the study and research of scheduling, the modeling is needed. The available models are mathematic programming model, petri-net model, workflow model, etc. The mathematic programming model is very abstract and it is the most ordinary method in optimization problem. But many constraints of scheduling problem are difficult to describe with this method, and the object function is sometimes also difficult described. The state-based petri-net model can fairly describe the process of the scheduling, but the nodes of the model will be so many that the petri-net cannot conveniently describe the multi-process scheduling system. Alternatively the workflow model solves this problem. Workflow is the computerized facilitation or automation of a business process, in whole or part[1]。As the workflow model is based on activities, it can easily model the multi-process scheduling system and the nodes of the model will not increase rapidly.

2. Dynamic Scheduling Implementation Model Based on Simulation of Workflow (DSIMBSW)

Scheduling, essentially speaking, is the optimized problem with restrictions. So, every model worked for scheduling should be able to describe the object function and restricted conditions. The structure describe in this paper is inherited and transformed from the generic workflow product structure[1], and it can well express the object function and restricted conditions. The structure and the main functional components of DSIMBSW are shown in figure 1.

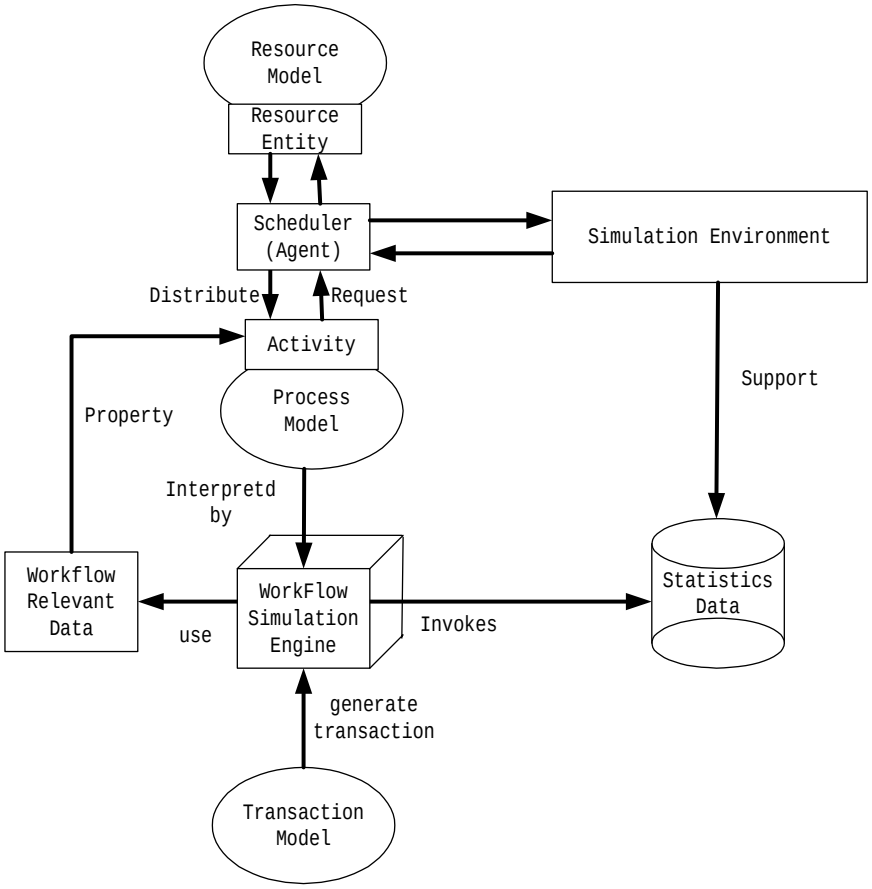

figure 1 structure of DSIMBSW

2.1 Process Model

Process Model is a model composed with one or several processes, which describe the logic relationships of the activities or sub-processes. The process model can be built by using activity-based modeling method or by using state-based modeling method. As the process model describe in this paper is based on workflow technology, so it is built based on activity. Process Model is the base model of the scheduling structure. It detailedly described the sequences and logic relationships of all operations of the scheduling. And these relationships of the operations visualized the restricted conditions of process.

From the abstract and general point of view, a process model is a dualistic group, which can be figured as followed.

PM=(N, L);

N={ $n_1, n_2, ..., n_m$ } is a finite set of nodes;

L={ $l_1, l_2, ..., l_w$ } is a finite set of links;

$N \bigcap L = \varnothing$: the relationship says that no common elements in the two sets;

$L \subseteq (N \times N)$: the relationship says that the elements of L are the vector links which join the nodes of the N.

According to the definition of Workflow Management Coalition, there can be several

instances of the same process or different processes running at the same time. The instances cause the competition for resource entities, which are the instantiations of resource model.

2.2 Resource Model

Resource Model is a kind of model which describes the resource information of the scheduling by defining the relationships and properties of all resources. In this model, the restricted conditions of resource can be well expressed.

The resources of resource model can be divided into three types, employees, equipments and appliances[7]. In order to describe the relationships of the resource, the definitions of the resource type, the resource pool, and the resource entity are imported. Resource type is a classification of resource, and it is some like the concept of class in program language. The child resource type can derive from the parent resource type, and it has the characters of inheritance and polymorphism. The resource entity is the atomic unit of the model, and it depicts the concrete properties of the units, such as cost properties, working status properties, etc. The resource pool is aggregation of the resources of the same kind of properties and the same kind of characters. When executing some work, the resource units in the one resource pool can be substituted each other due to the same functions, in despite of the other different characters.

2.3 Transaction Model

Transaction in workflow is the driver for execution of the process model and it acts on the first activity of the process model or the entry of the process model. Taking the order dealing process as an example, we can know that, a transaction is generated when a customer submit an order. The transaction generated drives the implementation of the posterior activities. In workflow management system, transactions are generated from outside, but in workflow simulation system, transactions are generated from the computer simulation.

Transaction model in scheduling model mainly describes the basic information of transaction, including the arrival time of the transaction, the type of the requirement, the quantity of the requirement, the interval of the transaction and the finish time of the transaction.

The simulation engine will trigger the instances of the transaction models.

2.4 Simulation Engine

Simulation Engine is the brain for the scheduling system based on simulation of workflow. And it is some like the workflow engine. According to WfMC[1], workflow engine is a software service or “engine” that provides the run time execution environment for a workflow instance. In the implementation structure, the simulation engine is the core of this model. The simulation engine serves as the following three roles.

The first is parser of process model, which interprets the process model and depicts the relationships of all activities of the process model.

The second is generator of transaction, which generates the transaction instances from the transaction model and simulates the actual arrival of the transactions (workpieces).

The third is driver of process instances, which advances the simulation of the process instances, solves the navigation among activities of the process.

2.5 Simulation Environment

As it is know before, the optimal solution of scheduling problem is difficult to arrive, so the satisfactory solution instead of optimal solution is expected in the scheduling of production. As a mature method, simulation can get the satisfactory solution in a shorter time. In this paper, simulation is the supporting environment for the DSIMBSW model proposed above.

In scheduling, simulation actually corresponds with the question " what if". The satisfactory solution can get by analyzing the all results which root from the "what" in the "what if". The aims of simulation are different when it is used in different scheduling. Scheduling are classified into static scheduling and dynamic scheduling, and the static scheduling is classified into pre-scheduling and re-scheduling[9]. In pre-scheduling and re-scheduling, the designers choose different model parameters and control strategies, repeatedly run simulation, analyze the simulating results, and then affirm the satisfactory solution. While in dynamic real-time scheduling, in order to carry on the optimal controlling, a scheduling layer is inserted between the programming layer and the controlling layer. The function of the programming layer is to send out the scheduling instruction and the function of the controlling layer is to translate the instruction to the operation. In the scheduling layer, the instruction is simulated, the further results are doped out and analyzed in the simulation environments, and then only the rational instruction can be transferred to the controlling layer.

2.6 Scheduler

Scheduler is designed for the resource distributing and the activity scheduling in the scheduling system based on simulation of workflow. The scheduler distributes the resource entities to the activities which apply for the resources and get the activities applying for the same resource in queue, according to a certain scheduling algorithm. The scheduler and the algorithm are elaborated in Chapter 3.

2.7 Workflow Relevant Data

In general workflow structure, Workflow Relevant Data is the data that is used by a workflow management system to determine the state transition of a workflow process instance[1]. In this specific scheduling structure based on simulation of workflow, the workflow relevant data describe the material properties of activities of the process model, including the property of basic information, the property of running condition, the property of relevant resources, the property of input and output. Some restrictions such as running condition, resource condition, are described here.

2.8 Statistics data

Statistics data act as object function in the dynamic scheduling model based on simulation of workflow. Through workflow simulating, statistics data are generated. The indices of these statistics data are derived from some process appraise system. An appropriate appraise system can be competent for the object function of the scheduling. At present, quite a few organizations and institutes gain progresses in the research of appraise system. For example, Excellence Model of European Foundation for Quality Management[10], the Process Handbook of MIT[11], TQM-Tile of Cranfield University of British[12], Enterprise Business Process Appraise Method Based on Workflow of Tsinghua CIMS-ERC[13].

In the dynamic scheduling model proposed in this paper, five indicators (Time, Cost,

Resource, Production, Waiting Queue) can be used in appraise the schemes. The concrete appraise method about these five indicators can refer to [13].

3. Dynamic Scheduling Algorithm Based on Rule-Agent (DSABRA)

The aim of scheduling is to gain the optimal solution, regardlessly the model is built on mathematical expression or petri-net or workflow. But the problem of scheduling is a NP-hard problem, so the gain of the optimal solution will pay for a lot of computing time and computing space. In our practice application, acquiring the available solution of the scheduling problem is a more feasible and more practical method.

In DSIMBSW, the scheduling algorithm is controlled by the scheduler, which is designed for the resource distributing and the activity scheduling. The scheduler works according to a certain scheduling algorithm. In the past research of the classical scheduling, the main researches focus on the scheduling algorithm, i.e. the optimal or approximately optimal task scheme which meets some requirements. There are thousands of algorithms in the past jobs, and all these algorithms can be classified into three sorts[2], precise algorithm, approximate algorithm and intelligent search algorithm.

Different scheduling models use different scheduling algorithms. As the scheduling model in this paper is a model based on simulation of workflow, the algorithm based on rules, other than the other algorithms such as heuristic algorithm, is a feasible and fairly perfect method. The scheduling algorithm based on rules, comparing with other algorithms, has the merits of small scale in computing-complexity, controlling in real time and tending to execute.

There are thousands of rules for scheduling, how to choose the exact rule for the exact task assignment is a problem we must to solve. In order to get more satisfactory solution, dynamic scheduling algorithm based on rule-agent(DSABRA) is used in this paper. And the agent is embedded in scheduler in the structure introduced in chapter 2 and it has three units: Perception Unit, Analysis Unit and Action Unit. DSABRA needs to combined with simulation. The agent get the data from the workflow simulation by the Perception Unit of the agent, and choose a exact rule from the rule depository by the Recognition Unit of the agent, with the aid of some repository or some learning method, and then simulate the workflow scheduling model until get the satisfactory results by the Action Unit of the agent. These results correspond to a series of task schemes. At the scheduling system can send out the scheduling instruction based on these task schemes. The structure of the rule-agent is showed in figure 2.

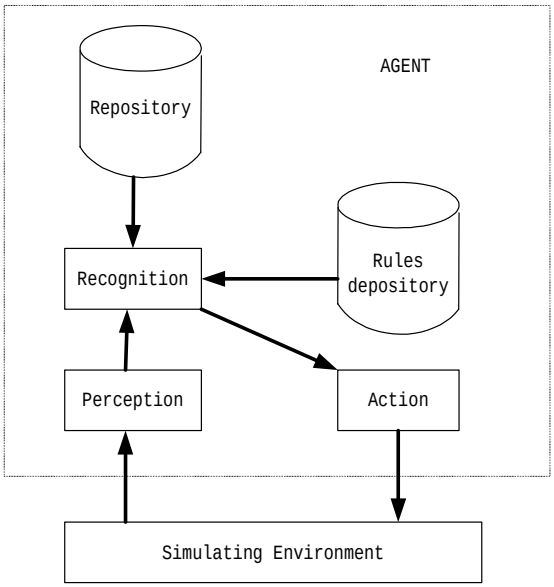

figure 2. the structure of rule-agent

The rule-agent brought forward above can use the learning method such as reinforcement learning method[3] or use the repository which is built on the past experiences and research. In Reference [8], Li summarize six rules and their corresponding conditions. The repository can be built using the knowledge. Also, we can expand the repository using any knowledge from the experiences or the research results which derives from the scheduling tests or applications.

4. Conclusion

In this paper, the scheduling model DSIMBSW and the corresponding algorithm DSABRA proposed above is very easy for simulation. The scheduling system which uses the DSIMBSW and DSABRA in simulation environments can get satisfactory solution in a less time, which is very important in modern scheduling, especially in modern dynamic scheduling.

Simulation plays more and more important roles in the research of scheduling. Now, the main flows in research of simulation are workflow method and petri-net method. The model based on workflow and the model based on petri-net are both convenient for simulation, but they have respective characteristics in scheduling simulation.

In the method of modeling, the workflow model is based on activity, while the petri-net model is based on state. In the scale of model, the workflow model is fairly small, while the petri-net is fairly large, and the scale is increasing exponentially. In the description of resource restriction, both model can solve this problem, the petri-net scheduling model will swell with the description of restriction, while the workflow scheduling model won't because it has the attached resource property of activities of process model. Furthermore, the petri-net model is more complex than the workflow model, so it is more difficult for understanding and building for engineers. From above, the scheduling model based on workflow has the merits of simplicity and practicality and flexibility.

As DSIMBSW is the model based on workflow, it has the merits listed above. And DSABRA is an algorithm specially designed for DSIMBSW. In a practical scheduling system, the core technologies are the designing of the scheduling model and the scheduling algorithm. Both of them are established in detail in this paper, so the scheduling system based on simulation of

workflow can be conveniently constructed.

The scheduling research on workflow is still in the stages of germination. Its practicability and availability need to be verified in the future scheduling applications.

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