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A method of workflow scheduling based on colored Petri nets

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ABSTRACT

Effective methods of workflow scheduling can improve the performance of workflow systems. Based on the study of existing scheduling methods, a method of workflow scheduling, called phased method, is proposed. This method is based on colored Petri nets. Activities of workflows are divided into several groups to be scheduled in different phases using this method. Details of the method are discussed. Experimental results show that the proposed method can deal with the uncertainties and the dynamic circumstances very well and a satisfactory balance can be achieved between static global optimization and dynamic local optimization.

1. Introduction

Workflow is the automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules [1]. A workflow management system (WfMS) is a system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications [1]. Nowadays, workflow technology has received much attention for its capability to support today's complex business processes.

Workflow engine is the heart of a WfMS, while scheduling is one of the core tasks of workflow engine. Scheduling of workflows is a problem of finding a correct execution sequence for the workflow tasks, i.e., execution that obeys the constraints that embody the business logic of the workflow [2]. The goal of workflow scheduling is to allocate the proper task to the proper resource so that workflow instances can be executed by the proper resource in the proper way at the proper time.

Scheduling exists almost everywhere. Scheduling of workflows is different from scheduling in other fields. First of all, workflow is dynamic. It has many uncertainties [3,4] which have not been dealt with in traditional scheduling literature.

(1) *The uncertainties of workflows*:
  - ➢ Arrival time of workflow instances are uncertain;
  - ➢ Execution paths of instances are uncertain;
  - ➢ Execution time of task is uncertain, etc.

(2) *The uncertainties of resources*:
  - ➢ Execution of a workflow process instance can last a long time. The states of resources may be changed during this period.
  - ➢ More than one resource can execute a task, and a single resource can execute many tasks. Many factors will affect the result of resource allocation, and these factors are dynamically changing.

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Parallel structures, in which two or more tasks are executed at the same time, have not been dealt with in traditional scheduling literature either.

These new challenges mentioned above need to be overcome in workflow scheduling contexts.

A phased method of workflow scheduling based on colored Petri nets is proposed in this paper. This method cannot only deal with the problem mentioned above, i.e., the dynamic environment, uncertainties, and concurrent workflows, but also can achieve a preferable balance between global optimization and local optimization.

Before getting into the details, some workflow terms that will be used in the rest of this paper are introduced first [1].

1) *Process model*: the representation of a business process in a form which supports automated manipulation. The process model consists of a network of tasks and their relationships, criteria to indicate the start and termination of the process, and information about each individual task.
2) *Instance*: the representation of a single enactment of a workflow process, including its associated data. Each instance represents a separate thread of execution of the workflow process and is created and managed by a workflow management system for each separate invocation of the workflow process.
3) *Task*: a description of a piece of work that forms one logical step within a process. A task requires human and/or machine resource(s) to support its execution. A task is typically the smallest unit of work which is scheduled by a workflow engine during process enactment.
4) *Resource*: an actor or agent to carry out workflow tasks. Depending on the application domains, resources can be human resources or nonhuman resources, such as machines, money, software etc. Here, we consider only durable resources, i.e. resources that are claimed and released during the execution, but not created or destroyed [5]. And we assume that a resource can only work on one task at one time.

The rest of the paper is organized as follows. In Section 2, different kinds of workflow scheduling methods are introduced. A workflow scheduling system based on colored Petri net is presented in Section 3. The details of the phased method of workflow scheduling are described in Section 4. In Section 5, examples are given to show the feasibility and validity of the method. Some related researches on workflow scheduling are discussed in Section 6. Finally, a conclusion and proposals for future research directions are addressed in Section 7.

2. Methods of workflow scheduling

Scheduling is one of the most famous and hottest combinatorial optimization problems. Many methods have been proposed to solve problems of scheduling in different areas. As far as workflow scheduling is concerned, existing methods can be divided into two kinds: static methods and dynamic ones.

2.1. Static scheduling

Static workflow scheduling, i.e. pre-scheduling of workflows, is to schedule all tasks of an instance for once as soon as the instance is initialized.

For example, assume there is a workflow whose process model depicted by Petri net is shown in Fig. 1. There are two execution paths. One is composed of t_1, t_2, t_3, and t_5, and the other is composed of t_1, t_2, t_4, and t_5. When an instance of this workflow arrived, the system using static scheduling will take a guess on which path the instance will follow according to some statistical history data. Tasks in the selected path will be scheduled together at once, e.g. t_1, t_2, t_4 and t_5 are scheduled.

The advantage of static scheduling is that there is no time spent on finding the proper resource to execute the proper task during the run-time. And static methods can approach global optimization for a single instance at the time point that the scheduling is done. But static methods are neither efficient nor effective because the situations are not always static. The solutions become not optimal, even infeasible, considering dynamic changes, concurrent workflows, and other uncertainties.

2.2. Dynamic scheduling

Another choice of scheduling is to schedule workflow tasks right before execution, i.e. dynamic methods. Most of existing dynamic methods schedule workflow tasks one by one. A task is scheduled when all the pre-conditions are satisfied, e.g. all the precedent tasks are completed, all the data needed are prepared, etc. The task is allocated to some available resources according to certain strategy, and put into execution as soon as the allocation is done.

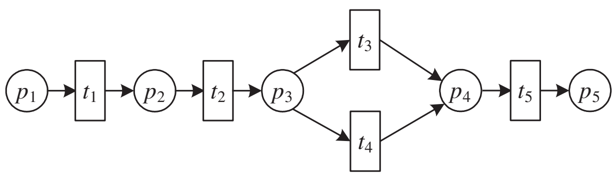

Fig. 1. A workflow process model.