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Scheduling algorithm for real-time tasks using multiobjective hybrid genetic algorithm in heterogeneous multiprocessors system

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Abstract

The scheduling problem for real-time tasks on multiprocessor is one of the NP-hard problems. This paper proposes a new scheduling algorithm for real-time tasks using multiobjective hybrid genetic algorithm (mohGA) on heterogeneous multiprocessor environment. In solution algorithms, the genetic algorithm (GA) and the simulated annealing (SA) are cooperatively used. In this method, the convergence of GA is improved by introducing the probability of SA as the criterion for acceptance of new trial solution.

The proposed algorithm has a multiobjective to minimize the total tardiness and completion time simultaneously. For these conflicting objectives, this paper combines adaptive weight approach (AWA) that utilizes some useful information from the current population to readjust weights for obtaining a search pressure toward a positive ideal point.

The effectiveness of the proposed algorithm is shown through simulation studies. In simulation studies, the results of the proposed algorithm are better than that of other algorithms.

Keywords: Multiobjective hybrid genetic algorithm; Scheduling for real-time tasks; Heterogeneous multiprocessor

1. Introduction

Real-time systems are characterized by computational activities with timing constraints and classified into two categories: hard real-time system and soft real-time system. In hard real-time system, the violation of timing constraints of a certain task should not be acceptable. The consequences of not executing a task before its deadline may lead to catastrophic consequences in certain environments i.e., in patient monitoring systems, nuclear plant control, etc. The goal of the scheduling algorithms in hard real-time system is to meet all tasks' deadlines, in other words, to keep the feasibility of scheduling through admission control. On the other hand, in the soft real-time system (e.g. telephone switching system, image processing, etc.), in which usefulness of results produced by a task decreases over time after the deadline expires without causing any damage to the controlled environment [1].

Traditionally, the performance criteria of an algorithm for a task scheduling problem (TSP) are throughput, utilization of processors, waiting time of tasks, etc. In a hard real-time system, the performance of the scheduling algorithm is measured by its ability to generate a feasible schedule for a set of real-time tasks. Typically, there is rate monotonic (RM) and earliest deadline first (EDF) derived scheduling algorithms for a hard real-time system with a uniprocessor [2,3].

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They guarantee the optimality in somewhat restricted environments. However, these algorithms have some drawbacks in coping with a soft real-time system related resource utilization and pattern of degradation under the overloaded situation. The objective of the scheduling task in soft real-time system is to minimize total tardiness. With the growth of soft real-time applications, the necessity for scheduling algorithms for soft real-time systems is on the increase and several researches for a soft real-time system are reported. Rate regulating proportional share (rrPS) scheduling algorithm, based on stride scheduler by Kim et al. [4] and modified proportional share (mPS) scheduling algorithm by Yoo [5] are designed for tasks in soft real-time systems. However, these algorithms also cannot show the graceful degradation of performance under an overloaded situation and are restricted in a uniprocessor system.

In a multiprocessor system, task scheduling is more difficult than that in a uniprocessor system. The optimal assignment of tasks to a multiprocessor is, in almost all practical cases, an NP-hard problem [6]. Consequently various modern heuristics based algorithms have been proposed for practical reasons.

Recently, several approaches of the genetic algorithm (GA) are proposed. Mitra and Ramanathan proposed a GA for scheduling of nonpreemptive tasks with precedence and deadline constraints [7]. Lin and Yang presented a hybrid GA, where different operators are applied at a different stage of the lifetime, for scheduling partially ordered nonpreemptive tasks in a multiprocessor environment [8]. Monnier et al. presented a GA implementation to solve a scheduling problem for real-time nonpreemptive tasks [9]. However, these algorithms have only one objective such as minimizing cost, completion time or total tardiness. Oh and Wu presented a multiobjective GA for scheduling nonpreemptive tasks in a soft real-time system with multiprocessors [10]. However, this algorithm did not refer to conflict between objectives, the so called Pareto optimum, and assume that the performance of all processors is the same. Theys et al. presented a static scheduling algorithm using GA on a heterogeneous system [11]. And, Page and Naughton presented a dynamic scheduling algorithm using GA on a heterogeneous system [12]. Dhodhi et al. presented a new encoding method of GA for task scheduling on a heterogeneous system [13]. However, these algorithms are designed for general tasks without time constraints.

In this paper, we propose a new scheduling algorithm for nonpreemptive tasks with a precedence relationship in a soft real-time heterogeneous multiprocessor system. In solution algorithms, the multiobjective genetic algorithm (mohGA) and the simulated annealing (SA) are cooperatively used [14]. In this method, the convergence of GA is improved by introducing the probability of SA [15] as the criterion for acceptance of a new trial solution. However, it is hard to find the optimum solution by only applying the genetic operators.

The objective of proposed scheduling algorithm is to minimize the total tardiness and the completion time simultaneously. For these conflicting objectives, this paper combines adaptive weight approach (AWA) that utilizes some useful information from the current population to readjust weights for obtaining a search pressure toward a positive ideal point [16].

The rest of the paper is organized as follows: In Section 2, we explain a scheduling problem for soft real-time tasks (SP-srt) in heterogeneous multiprocessors system and the problem is mathematically formulated. Section 3 introduces the GA combined with SA methods and describes implementations used for this problem. Then, the experimental results are illustrated and analyzed in Section 4. Finally, Section 5 provides discussion and suggestions for further work on this problem.

2. Scheduling problem for soft real-time tasks and mathematical model

In this study, we consider the problem of scheduling the tasks with precedence and a timing constrained task graph on a set of heterogeneous processors in a way that minimizes the total tardiness f_1 and completion time f_2 under the following conditions:

1. all tasks are nonpreemptive,
2. every processor processes only one task at a time,
3. every task is processed on one processor at a time.

The scheduling problem for soft real-time tasks (SP-srt) is formulated under the following assumptions: computation time and deadline of each task are known. A time unit is an artificial time unit. The scheduling problem for soft real-time tasks (SP-srt) in the heterogeneous multiprocessor system to minimize the total tardiness and completion time is