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Duplication Based Simulated Annealing Algorithm For Multiprocessor Task Scheduling : An Overview

Computer Science

KEYWORDS : Multiprocessor task Scheduling , Heuristic , Duplication Scheduling Heuristic, Meta Heuristic, Simulated Annealing, Hybrid

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ABSTRACT

Task scheduling and mapping to the processors is one of the critical problem in parallel computing. Due to NP-hard nature of the problem, a large number of related work relies on heuristic approaches to find the best solution in reasonable amount of time. But due to its problem specific nature, this approach may not be proven good for other problems. So, the metaheuristic approach is chosen to find the optimal solution for general problems. Borrowing the respective advantages of these two approaches an effective hybrid approach can be formed .In Hybrid approach, the disadvantages of one approach can be overcome by the advantage of other approach. The review of the heuristic , metaheuristic approach and the possible combination of these approaches i.e. hybrid approach is discussed in the paper.

Introduction

Scheduling of a set of dependent and independent tasks for parallel execution on a set of processors is a computationally complex problem. While execution, the parallel program is decomposed into smaller tasks which have some dependencies between them. Multiprocessor task scheduling is considered to be NP hard problem in which the tasks or jobs are to be processed on more than one processor at a time such that optimal objectives can be achieved [1]. The objective of multiprocessor task scheduling is to assign the tasks to the processors such that the precedence requirements between the tasks are satisfied and the overall time required to execute all the tasks is minimized.

There are two issues in the multiprocessor task scheduling. The one is the order of the tasks in which these tasks are assigned to different processors .Another is the tasks allocation to processors based on the dependent tasks or independent tasks. If the tasks are dependent (means the task only execute if the previous task on which it depends, is executed), then the communication cost between the tasks is the major factor of scheduler.

Since the problem is NP hard, most of research efforts have been devoted to the development of heuristic approaches in order to provide the good optimal solutions. After studying the heuristics methods, Duplication Based Heuristic approach is found to reduced the start time of tasks, so it is considered to be the effective method .But Heuristic approaches are problem specific in nature, which give best results in one problem, might not give good results in another problem.

In such cases, meta heuristic approaches like simulated annealing, Genetic Algorithm are found successful. These approaches are general in nature but many parameters are to be set in this approach and it also takes computer time for many runs. To tackle the multiprocessor task scheduling problem, these two approaches are combined in one hybrid approach, so that, the advantages of both approaches are combined to provide the excellent results. Before the hybrid approach, the individual approaches are studied.

Heuristic Approach

Multiprocessor scheduling problem has been an active research area, for which many different assumptions and terminology are independently suggested. The multiprocessor scheduling problem is NP hard, therefore, many heuristics with polynomial-time complexity have been suggested.

As parallel programs come in a variety of structures, many algorithms were designed to tackle arbitrary graphs. Among these algorithms , UNC (unbounded number of clusters) scheduling algorithms and BNP (Bounded Number of Processors) scheduling algorithms are the former class of algorithms is described by Y.K. Kwok and I. Ahmad[2]. In these two classes of algorithms, the processors are assumed to be fully connected and there is no attention paid on routing strategies which is used for communication. Then, APN (Arbitrary Processor Network) scheduling algorithms (described by Y.K. Kwok [2]) have been designed which depend on routing strategies and the systems is assumed to consists of an arbitrary network topology, of which the links are not contention free. To optimize the schedule lengths under such unrestricted environments makes the APN class of scheduling algorithm intricate and challenging. I. Ahmad and Y.K. Kwok [2] also discussed the TDB (Task Duplication Based)class of scheduling algorithms. The main aim of TDB is to reduce the communication overhead by redundantly allocating the tasks to plural processors.

There are many heuristic based methods, among those the list scheduling is commonly used. Ibarra et al. [3] proposed a heuristic algorithm for scheduling independent tasks onto identical and non identical processors. Djordjevic and Tosic [4] proposed a single pass deterministic algorithm, chaining, based on list scheduling techniques. Insertion Scheduling Heuristic (ISH) and Duplication Scheduling Heuristic (DSH) are well-known list scheduling heuristic methods [5]. ISH proposed by Kruatrachue and Lewis [6] is a list scheduling heuristic that was developed to optimize scheduling DAGs with communication delays. ISH extends a basic list scheduling heuristic from Hu [7] by attempting to insert ready tasks into existing communication delay slots. DSH proposed by Kruatrachue and Lewis [8] improved ISH by using task duplication to reduce the starting time of tasks within a schedule. DSH reduces inter-processor communication time by scheduling tasks redundantly to multiple processors. The study of heuristic algorithms David & Patterson [9] and Davis E. W. [10] have shown that one heuristic which gives a good result for a project might not give that much successful result for another project. This is a greatest disadvantage of the heuristic rules perform well on one problem cannot give guarantee to perform well in the other problem.

Metaheuristic Appraoch

M. Fikret Ercan et al.[11] evaluated the quality of the solutions of various heuristic algorithms developed for scheduling multiprocessor tasks for a class of multiprocessor architectures designed to exploit temporal and spatial parallelism simultaneously. Various experiments were performed to minimize the completion time by heuristic methods and their results were compared with simple list based heuristics. The results show that local search heuristics significantly outperform the list based heuristics but due to their large computation times, Simu-

lated Annealing, Genetic Algorithms can be used in deterministic cases. A meta heuristic as "an iterative master process that guides and modifies the operations of subordinate heuristics to efficiently produce high-quality solutions" [12]. Simulated annealing (SA) belongs to the meta-heuristic algorithm which was introduced by Kirkpatrick et al. [13] for solving combinatorial optimization problems. One study has used SA on a set of several econometric problems [14], including cost functions which arising in the monetary theory of exchange rate determination, a study of firm production efficiency, and a neural net model which generates chaos reputed to mirror some economic and financial series. The authors demonstrated that their SA algorithm performed better, e.g. at least more reliably finding more optima, than other numerical techniques such as a genetic algorithms and a quasi-Newton algorithm. Osman and Potts[15] give the neighbourhood approach for simulated annealing. It uses a procedure that probabilistically allows poorer solutions to be accepted to attempt to obtain a better search of the solution space. The major advantage of simulated annealing over other methods is an ability to avoid becoming trapped in local minima. The SA can deal with highly non linear models and it is robust and general technique [16].Though a robust technique, its drawbacks include the need for a great deal of computer time for many runs and carefully chosen tuneable parameters [17].

Hybrid approach

Majority of research is concerned in the field of multiprocessing task scheduling to minimize the makespan. On multiprocessor task scheduling several comparative studies starting from various heuristics methods leading to metaheuristics and hybrid methods has done. Different research is performed on hybrid methods and showed that the hybrid methods are more effective and efficient than individual methods for finding near optimal solutions.

The aim of the hybrid approach is to overcome the disadvantages of one approach with the advantages of other approach, so that the effective results can be produced. Sivanandam et al. [18] proposed a particle swarm optimization/simulated annealing (PSO/SA) hybrid algorithm for static allocation of tasks in a heterogeneous distributed computing system for minimizing the cost and showed that the proposed hybrid method was effective and efficient for finding near optimal solutions. Vahid Mohammadi Safarzadeh, Masoud Mazloom[19] has presented a hybrid approach for solving n-queen problem by combination of PSO(Particle Swarm Optimization) and Simulated Annealing. His results showed that n queen problem can be solved in a reasonable amount of time by this hybridization and this idea is better than SA by an increasingly ratio for higher dimensions, that means when dimension becomes larger the hybrid algorithm receives to global maximum faster. Manar I. Hosny[20] investigated a new hybrid adaptive approach using Variable Neighborhood Search and Simulated Annealing to solve one commodity pickup and delivery problem. His experimental results on a large number of problem instances showed that the algorithm outperforms previous heuristics in most hard test cases, where the vehicle capacity is smallest. J. Parvizian and H.Tarkesh [21] presented a hybrid approach of Multi Layer Feed Forward neural network(MLFF) and SA to deal with hard optimization problem and complex search spaces. By this algorithm , the objective value reduced dramatically and the results were more stable in comparison with the simple SA. Above results shows that the hybrid approach gives the effective results in less time.

Probable Hybrid Approach(DSH-SA)

According to the demand of effective solution, the one possible approach can be considered is the hybrid approach of DSH and SA. In this approach, the DSH and SA can be hybridized so that the advantages and importance of these methods provide the more efficient solution in less time. There is large search space for the multiprocessor task scheduling and it is expected that randomly generated initial solution provide the weak results [22]. So, the initial solution is obtained from Duplication based task scheduling and this solution is become the input of Simple Simulated Algorithm which find the optimal result .

DSH algorithm

DSH proposed by Kruatrachue and Lewis[8] ,uses the idea of list scheduling combined with task duplication to minimize the make span. In DSH algorithm ,the nodes are examined for scheduling in a descending order of static b-level. The static b-level of node n(i) is the length of a longest path from node n(i) to exit node without considering the communication cost between the nodes. The DSH algorithm is briefly described below.

1. Compute the *static b-level* for each node.

Repeat

1. Let n_i be an unscheduled node with the largest static *b-level*.
2. For each processor *P*, do

(a) Let the ready time of *P*, denoted by *RT*, be the finish-time of the last node on *P*. Compute the start-time of n_i on *P* and denote it by *ST*. Then the duplication time slot on *P* has length (*ST* – *RT*). Let candidate be n_i.

(b) Consider the set of candidate's parents. Let n_x be the parent of n_i which is not scheduled on *P* and whose message for candidate has the latest arrival time. Try to duplicate n_x into the duplication time slot.

(c) If the duplication is unsuccessful, then record *ST* for this processor and try another processor; otherwise, let *ST* be *candidate*'s new start-time and *candidate* be n_x. Go to step (b).

(4) Let P' be the processor that gives the earliest start-time of n_i. Schedule n_i to P' and perform all the necessary duplication on P'.

Until all nodes are scheduled.[2]

Simulated Annealing

Simulated annealing(SA) introduced by Kirkpatrick et al.[13] is a method for solving unconstrained and bound-constrained optimization problems. The method models the physical process of heating a material and then slowly lowering the temperature to decrease defects, thus minimizing the system energy. The algorithm of SA is given below

Step 1 : Initialize - Generating a random trial point. The algorithm chooses the distance of the trial point from the current point by a probability distribution with a scale depending on the current temperature.

Step 1 : *Choose*- Algorithm determines whether the new point is better or worse than the current point. If the new point is better than the current point, it becomes the next point. If the new point is worse than the current point, the algorithm can still make it the next point. The algorithm accepts a worse point based on an acceptance function.

where, $\frac{1}{1+\exp\left(\frac{\Delta}{\max(T)}\right)}$

Δ = new objective – old objective.
T_0 = initial temperature of component *i*
T = the current temperature

Step 3 : *Annealing*-The algorithm systematically lowers the temperature, storing the best point found so far.

Step 4 : Reannealing-. Reannealing sets the annealing parameters to lower values than the iteration number, thus raising the temperature in each dimension.

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Step 5 : *Stop*-The algorithm stops when the average change in the objective function is small relative to the *TolFun* tolerance, or when it reaches any other stopping criterion.

The stopping conditions of simulated annealing algorithm are, when the number of iterations exceeds this maximum number of iterations, when the best objective function value is less than or equal to the value of ObjectiveLimit etc.

Hyrid method Algorithm(DSH-SA)

Step 1: Calculate the makespan and Schedule from Duplication Scheduling Heuristic .

Step 2: Input the Schedule calculated at step 1 to the annealing function of Simulated annealing.

Step 3: Set SA parameters and run the algorithm.

Step 4: Note the final makespan and Schedule

Summary

Various research work on heuristics approach is discussed. It is found that the duplication based algorithm is better than other heuristic methods. But some researchers concluded that the heuristic algorithms are problem specific in nature and that is why the heuristic which give effective solution for one problem, might not give that much good solution for other problem. So, there is other approach which is meta heuristic. It gives solutions for all types of problem. Among meta heuristic approaches, Simulated Annealing is considered to solve the multiprocessor task scheduling problem. With its advantages of robust and flexible nature, this approach also have disadvantage of taking large computation time due to its many runs and work required tune the parameters. After studied the various proposed hybrid methods by many researchers, it is concluded that if two approaches are hybridized, then, the effective solution can be achieved. So, DSH and SA can be considered for hybridization.

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