Available online at www.sciencedirect.com
ScienceDirect
Computers & Industrial Engineering 57 (2009) 592–607
computers & industrial engineering
www.elsevier.com/locate/caie

Embedded simulation on a multiprocessor job scheduling system with inspection

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Available online 19 September 2008

Abstract

This paper first develops architecture for a multiprocessor job scheduling system with an embedded simulation technique. The architecture provides a shell for applications that are characterized by two scheduling policies, a heuristic algorithm policy and a First-In-First-Out (FIFO) policy. These policies are implemented in the simulation model by using the embedded technique. The paper evaluates these two policies using the queue length, waiting time and flow time as the criteria to compare the performance of these two scheduling policies. Next we designed two simulation situations using two different real world applications. The purpose is to examine the performances of multiprocessor systems with and without inspection operations and two different scheduling policies. The two applications, berth allocation for the container terminal operations and production scheduling arrangement in an Original Equipment Manufacturer (OEM) power supply factory, are studied. The final results show that a proper scheduling policy will perform better than the traditional FIFO approach for a multiprocessor system. Our study also provides guidelines on balancing a system with the addition of a final inspection activity.

Keywords: Embedded simulation; Multiprocessor job scheduling; Inspection

1. Introduction

1.1. Multiprocessor job scheduling and its extensions with inspection operations

Multiprocessor task scheduling (MTS) problem defines one type of task scheduling problems such that each task is processed by multiple processors (machines) simultaneously and no preemption is allowed (cf., Drozdowski, 1996; Li, Lei, & Pinedo, 1997). Applications of MTS include human resource planning, diagnosable microprocessor system, berth allocation and manufacturing systems (cf., Chen & Lee, 1999) among others.

Recently, inspection activities become more important for certain type of MTS problems. U.S. government has taken several actions to against terrorist attacks. For instance, Container Security Initiative (CSI) pro-

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0360-8352/$ - see front matter
doi:10.1016/j.cie.2008.09.011

gram helps increase security for containerized cargo shipped to the United States (cf., Roach, 2003). CSI sets a goal that 85% of containers heading for U.S. need pre-screened before entering U.S. on CSI seaports in the world. Accordingly, container security inspection operations are important in these seaports. Another example of inspection activity comes from manufacturing systems. The quality inspection for final products becomes a standard production step for most manufacturing factories. Either security check or quality assurance will have serious impacts on the whole system when inspection rate does not match processor service rates. We consider this type of problems as multiprocessor task scheduling with inspection operations (MTSI).

1.2. Relevant literature

Two common approaches can solve MTS problems, through optimization or approximation algorithms, or through simulation. Since many deterministic MTS problems were proven NP-complete (cf., Lee & Cai, 1999), it is difficult to find optimal solutions. Thus, previous studies on this area are focused on developing heuristic algorithms to find near-optimal solutions. For instance, Chen and Lee (1999) studied a one-job-on-multiple-machine problem. They developed a pseudo-polynomial time algorithm to solve optimally two machine problems, and provided a heuristic to solve three machine problems. Guan, Xiao, Cheung, and Li (2002) developed a heuristic algorithm to study the similar type of multiprocessor task scheduling problems with the application in berth allocation. This heuristic algorithm provides a relative error within 100% with both weighted and unweighted processing time cases. More recently, Caramia, Dell'Olmo, and Iovanella (2005) designed a heuristic to provide a lower bound for the objective of minimizing makespan in which non-consecutive multiprocessors are allowed to process one job. Ying and Lin (2006) developed an Ant Colony System heuristic to solve multiprocessor task scheduling problem in a multistage hybrid flow-shop environment. For the given number of jobs, job processing times, and the required quantity of machines at each stage, their approach performs better comparing with Genetic algorithm and Tabu search approaches. Huang, Chen, Chen, and Wang (2007) developed a simple linear time approximation scheme for MTS problems on four processors and the makespan is bounded by a constant number 1.5. Lagrangian relaxation and other decomposition based optimization approaches are also utilized to solve the multiprocessor task scheduling problems (cf., Guan & Cheung, 2004; Jansen & Porkolab, 2002, 2005).

In all these previous works detailed analysis and mathematical insights were studied. Most of these algorithms provided a solution approach for deterministic processing time cases. In reality, deterministic processing time cases happen rarely and instead, most MTS problems contain uncertain processing time, which means the same size jobs may have slightly different processing times, or the same processor dealing with the same type of jobs may have different processing times. If uncertain processing times are considered in MTS problems, the efficiencies of all existing algorithms need to be reevaluated.

Simulation is another approach for MTS problems with uncertain processing times and effective to find performances for stochastic systems. It also provides a friendly interface, visualizes results and easily deals with time-dependent events. However, unlike the optimization approach, simulation often uses experimental methods based on general principles or manipulated experiences. It is difficult to find an optimal or near-optimal solution by simulation itself. El Sheikh, Paul, Harding, Harding, and Balmer (1987) developed a simulation model for port operation, in which ships are assigned on berths based on yearly observation. Tahar and Hussian (2000) applied process-oriented simulation software "ARENA" to analyze the performance of container berth system in Kelang harbor. The berth allocation rules were fixed in four polices in the simulation model. Alattar, Karkare, and Rajhans (2006) used simulation tools to analyze container terminal development policies. In their simulation model, cost is the main factor to decide the location of cranes or berths.

Effective processor allocation is an issue for many practical MTS problems. However, complicated processor allocation regulations make it difficult to implement the system by process-flow type simulation modeling. In this paper, we employ embedded simulation technique to model MTS problems by process-flow type simulation and take advantages of both optimization and simulation approaches. An embedded simulation is a technique that simulation is used as a part of a decision support system (cf., Banks, 1998). Embedded simulations can be used to estimate certain parameters, and those parameters can be used as the input for another model. For instance, Wu and Wysk (1989) used an embedded simulation to explore the concept of simulation-based floor shop control. Seifert, Kay, and Wilson (1998) used hierarchical simulation, an alias of embedded