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HYBRID PERFORMANCE MODELING AND ANALYZING OF PARALLEL SYSTEMS

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Abstract. Performance is a key feature of parallel system. However, there is a great gap between the peak performance and performance attainable by a practical application. The model-based performance evaluation may be used to support the performance-oriented program development for parallel system. In this paper a hybrid TCPN model is proposed to describe the parallel program and the resources respectively. This method can bring less effect to modify the program structure because of running environment changes. And the performance engineering activities based on this model ranges from performance prediction in early development stages, performance analysis in the coding phase, to locate the performance bottleneck and modify it. After the correctness verification of the TCPN model, a reachable graph can be got. Then the further performance-tuning can be done by summing the execution time of corresponding action in the critical path.

Key words. Timed Coloured Petri Net, parallel system, formal method

1. Introduction

Compared to the traditional development process of sequential software where performance issues are insufficiently considered one is now convinced that performance evaluation is a critical factor in the upcoming parallel software development methodology. But performance orientation in the development process of parallel software is motivated by outlining the misconception of current approaches where performance activities come in at the very end of the development, mainly in terms of measurement or monitoring after the implementation phase. At that time major part of the development work is already done, and performance pitfalls are very hard to repair. So a development process for parallel programs that launches performance engineering in the early design phase is needed.

In this paper we put forward a hybrid approach to support for functional and temporal specification which can specify various aspects of parallel system like software, such as control flow, data flow, communication, synchronization and so on, and hardware, such as processors, memory, communication media etc. It is simple but expressive graphical means. This novel method can develop parallel software by performance engineering during the whole parallel development cycle. It means the performance analysis begins at the early design phases and goes on until the completion of the application, not work during or after the running procedure like some test tools now. Otherwise, it happens often that a correct program is a program with lower performance and leads to the huge expenses to modify program.

The rest of this paper is organized as follows: after the briefly introduction of the problem that need to be solved in Section 1, influencing factors of parallel system performance will be analyzed in Section 2 and a time model of parallel program is built. PRM model based on Timed Coloured Petri Net is proposed. The formal models of parallel program and executive environment are defined in detail. There is

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an example in Section 3 which demonstrates the building process and the analyzing of the TCPN model. Section 4 concludes this paper and introduces the future work.

2. Hybrid Performance Modeling and Analyzing

Formal methods are frequently applied in industries to build mission-critical systems where insufficient verification can cause human injury or large-scale financial loss. The topic of using the formal method to identify the correctness verification and performance analysis of the parallel program gains a lot of attention [5,6].

Petri nets provide the foundation of the graphical notation and the basic primitives for modeling parallel, communication, and synchronization. It is a strict formal tool of mathematical modeling which can transform the Petri nets model into mathematical problems or simulation models. Then the qualitative and quantitative analysis of the system performance can be easy. However, the basic Petri nets only record the number of token not the individual character. And excessive description about the individual changes makes too many nodes of the Petri nets to characterize the complex process of the system and decreases the abstract capacity. To solve these problems many authors propose extensions of the basic Petri nets model.

Several authors have extended the basic Petri net with coloured tokens. In these models tokens have a value, often referred to as 'colour'. There are several reasons for such an extension, such as uncoloured Petri nets describe real systems tend to be complex and extremely large, tokens often represent objects or resources which have attributes in the modeled system. These 'coloured' Petri nets allow the modeler to make much more succinct and manageable descriptions.

Petri nets execute transition firings instantaneously, i.e. there is no time to be consumed, which is certainly sufficient for reasoning about the quality of system behavior, such as synchronization. To make the Petri nets formalism adequate also for quantitative, i.e. performance, analysis, finite timing of activities can be expressed by associating a time concept to places, transitions, tokens and any combination of them.

Compared to another formal methods, only Timed and Coloured Petri Net(TCPN) is suitable to model the large and complex parallel systems and more effective to analyze synchronization, communication, performance and reduce the possibility of state explosion.

2.1. PRM Model based on TCPN. It's figured that the performance of parallel systems is not only determined by the performance of the hardware itself but also by the structure of the parallel program and the assignment of program parts to resources in this paper. The actual performance is determined by the interdependencies between hardware performance and the requirements of parallel programs, i.e. the proper utilization of hardware performance by the program. It means the performance measures of interest are the run time of the parallel program and the degree of hardware utilization.

With PRM[1] a modeling technique has been given considering hardware resources, parallel program and mapping between them as the performance influencing factors for the prediction of performance of parallel computations running on parallel hardware. The separation of the three specification elements should enable to vary each of them, as far as possible, independently from the other specifications. This approach can realize various mapping between the parallel program and the resource with minimal additional effort and compare the performance of program running on different resource.