Title	リアルタイムシステムのためのSMTベースのスケジューリング手法
Author(s)	程, 着
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Description	Supervisor:リム 勇仁, 情報科学研究科, 博士

Abstract

Real-time systems are playing an important role in our society. In the last two decades, there has been a dramatic rise in the number of real-time systems being used in our daily lives and in industry production. Representative examples include vehicle and flight control, chemical plant control, telecommunications, and multimedia systems. These systems all make use of real-time technologies.

The most important attribute that sets real-time systems apart from other systems is that the correctness of systems depends not only on the computed results but also on the time at which results are produced. In other words, a task in a real-time system is required to be completed before a specific time instant which is called deadlines. This sensitivity to timing is central feature of system behaviors. To satisfy this requirement, tasks need to be allocated sufficient resources (e.g., processor) so as to meet their deadlines (i.e., to be completed before their deadlines). Scientific community has made great efforts in developing scheduling polices for properly allocating resources to tasks. This field of study is referred to as real-time scheduling.

With decades of efforts, real-time scheduling on uniprocessor systems can be viewed as relatively mature. But there still remain many problems. For example, for a soft or firm real-time system, when the system is under overload condition, some tasks will miss dead- lines. It is important to minimize the degree of system performance degradation caused by the missed deadline tasks. For this problem, the performance of existing scheduling algorithms is not satisfactory.

Compared to uniprocessor systems, real-time scheduling on multiprocessor systems is far from well-studied. Even for the simpler problem of scheduling identical multiprocessor systems, there still remain many problems. For the harder problem of scheduling heterogeneous multiprocessor systems, where we have to face an awkward reality that considering a relatively practical application scenario, there is still no solution to efficiently schedule heterogeneous multiprocessor systems. This becomes unfortunate since current progress in developing heterogeneous multiprocessor systems is a long way ahead of research efforts to determine the best scheduling policies.

These situations motive this research. The vision of this research is to help developers easily and efficiently design scheduling for real-time systems with low cost. To approach this vision, a Real-time scheduling methodology based on Satisfiability Modulo Theories (RSMT) is proposed. In RSMT, the problem of scheduling is treated as a satisfiability problem. The key work is to formalize the satisfiability problem using first-order logical formulas. Through formalization, a SAT model is constructed to represent the scheduling problem. This SAT model is a set of first-order logic formulas (within linear arithmetic in the formulas) which express all the scheduling constraints that a desired schedule should satisfy. After the SAT model is constructed, a SMT (satisfiability modulo theories) solver (e.g., Z3, Yices) is employed to solve the formalized problem. A desired schedule can be generated based on a solution model returned by the underlying SMT solver.

After RSMT is proposed, it is first applied to uniprocessor time-driven systems to solve the overload problem. Then, RSMT is exploited to design scheduling for multiprocessor time-driven systems. Heterogeneous real-time systems have been considered. At last, in order to apply RSMT to design scheduling for event-driven systems, a method of combining RSMT and online scheduling algorithm is given. Through these studies, RSMT shows capabilities to be applied to design scheduling for various kinds of scheduling targets and systems, from uniprocessor to multiprocessor, from time-driven to event-driven. In addition, many practical requirements that are considered in real-time scheduling domain can be dealt with, e.g., task dependency relation, tasks with different degrees of importance, task preemption, and task migration. Benefit from these capabilities, RSMT leads us one step closer to the vision. To the best of my knowledge, it is the first time systematically introducing SMT to solve a series of problems covering a wide scope in real-time scheduling domain.

keywords: real-time systems, satisfiability modulo theories, real-time scheduling, overload problem, heterogeneous multiprocessor systems