

Efficient Resource Constrained Scheduling using Parallel Two-Phase Branch-and-Bound Heuristics

Abstract:

Branch-and-bound (B&B) approaches are widely investigated in resource constrained scheduling (RCS). However, due to the lack of approaches that can generate a tight schedule at the beginning of the search, B&B approaches usually start with a large initial search space, which makes the following search of an optimal schedule time-consuming. To address this problem, this paper proposes a parallel two-phase B&B approach that can drastically reduce the overall RCS time. This paper makes three major contributions:

- i) it proposes three partial-search heuristics that can quickly find a tight schedule to compact the initial search space;
- ii) it presents a two-phase search framework that supports the efficient parallel search of an optimal schedule;
- iii) it investigates various bound sharing and speculation techniques among collaborative tasks to further improve the parallel search performance at different search phases. The experimental results based on well-established benchmarks demonstrate the efficacy of our proposed approach.

Introduction:

INCREASING complexity coupled with time-to-market constraints enlarge the gap between ESL (Electronic System Level) designs and RTL (Register-Transfer Level) implementations. To enable rapid generation of hardware designs while considering various requirements (e.g., performance, area and power), High-Level Synthesis (HLS) is proposed to automatically translate ESL designs to low-level RTL implementations. HLS has been widely adopted in many industry design fields, especially in the Field-Programmable Gate Array (FPGA) domain. This paper focuses on HLS scheduling under resource constraints, called Resource Constrained Scheduling (RCS). For HLS,

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ESL specifications are converted into Data Flow Graphs (DFGs), which are used as an intermediate representation for the design exploration and performance estimation purpose. Scheduling assigns each operation of a DFG with a control step (c-step) which indicates the start execution time of the operation. Since RCS needs to explore a huge number of possible designs and make the trade-off among various resource constraints, it is a major challenge in HLS. Given a DFG and a pre-defined set of resources (e.g., number of function units, power, area) with specified overheads, RCS tries to find a schedule of operations with least overall c-steps. Essentially, RCS is an NP-Complete problem with constraints of computation precedence and resource limits. To avoid forcefully enumerating all possible schedules, many approaches are proposed to reduce the searching time of optimal schedules. The basic idea is to remove as many infeasible or inferior schedules during the HLS search as possible. As a kind of promising RCS search paradigms, the B&B RCS methods are widely investigated to prune the search space (i.e., the set of all combinations of operation assignments). During the search, B&B approaches update the upper-bound length estimation of the optimal schedule searched so far dynamically when encountering new better schedules. Such upper-bound length information can be used to determine the inferior schedules which are worse than the up-to-date best scheduling result. Although B&B approaches are efficient in pruning these inferior schedules, one major bottleneck is that they cannot guarantee a tight initial feasible schedule to restrict the search range of each operation, which can easily result in a huge initial search space. Furthermore, B&B approaches explore the state space in a recursive manner. If the remaining operations cannot be used to derive a better schedule, the loose dispatch range of operations and deep recursive search will result in the stuck-at-local-search, which is the main cause of the long search time. Since more and more computers are equipped with multicore CPUs, to avoid the stuck-at-local-search problem and improve the RCS performance, we propose a novel parallel B&B approach which can quickly narrow down the initial search space as well as search for optimal schedules in a collaborative manner.

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