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Visualization of Heuristic-Based Multi-Objective Design Space Exploration of Embedded Systems

Toktam Taghavi Razavi Zadeh

Abstract

The design of modern embedded systems is quite complex. Typically, multiple and conflicting criteria should be optimized simultaneously such as performance, power, cost, weight, etc. To support such a wide spectrum of non-functional demands, modern embedded systems often have a heterogeneous system architecture. They consist of components that range from fully programmable processor cores for providing flexibility to fully dedicated hardware components for time-critical application tasks. The complexity of embedded systems forces designers to model and simulate systems and their components to explore the wide range of design choices. Such Design Space Exploration (DSE) is especially needed during the early design stages, where the design space is at its largest and where a wrong design decision can make the difference between the success or failure of the final product. DSE methodologies targeting early design stages are applied at a high level of abstraction, thereby minimizing the modeling effort and optimizing the simulation speed.

Due to the exponential design space in real problems, evaluating and comparing every single point in the design space is infeasible. Therefore, heuristic search techniques are often used to search the design space for optimum design points using only a finite number of design-point evaluations. As the searched design space still is vast, interpreting and drawing the right conclusions from such copious simulation results and understanding how the design space was searched by heuristic searching algorithms can be extremely cumbersome. Such analysis is, however, essential to the designer as it provides insight into the landscape of the design space.

In this thesis, we address the problem of interpreting and analyzing the large amount of data generated by system-level computer architecture simulators during the exploring alternative architectural solutions. To do that, we embrace data visualization as an aid for analysis and interpretation. We introduce the structural use of visualization techniques in the design of embedded systems, and specifically for supporting the design space exploration of embedded systems. We have incorporated all the developed visualization techniques into a tool, called VMODEX. Actually, we build a bridge between two previously separate research fields: data visualization and embedded system design.

In this thesis, for performing a comprehensive study of the DSE process, we define three separate stages, which are discussed in detail throughout the three chapters.
For each stage, we have developed several methods and visualization techniques to enable users a rapid and more accurate analysis. The first stage is developing an optimization method that efficiently and effectively explores the design space. The algorithm developers can use VMODEX to perform a comprehensive study on the performance of different multi-objective optimization algorithms, from different points of view, in order to find the best one for their specific problem. At the second stage, the most efficient optimization algorithm is used for exploring the design space. In VMODEX, we have developed a variety of capabilities that help designers to analyze and interpret the DSE results from different perspectives and at multiple levels of abstraction, in order to gain insight into the landscape of the design space. At the last stage, the most preferred design point should be chosen for the final implementation. Various decision making approaches are provided in VMODEX that help decision makers to better understand the trade-offs between different criteria and guide them to make better decisions.