Summary of Dr. Manish Vacharajani's Dissertation: Microarchitecture Modeling for Design-Space Exploration

John Giacomoni and Todd Mytkowicz

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This dissertation questions the techniques previously used to explore different microarchitecture design options. The need for modeling techniques is clear as the costs of implementing experimental designs in hardware are prohibitively expensive. This is especially true when searching a multi-variate parameter space is necessary to achieve the optimal balance of performance, power consumption, and the system's thermal behavior. Using a strictly conceptual approach was found to be extremely imprecise as systems are so extremely complex that it is impossible to reason about the interactions without a simulator or a physical implementation. The dissertation presents a new simulator, the Liberty Simulation Environment (LSE), and a user study of the usability of the new simulator.

LSE is a concurrent-structural modeling environment with automatic type inference and back-flow detection and propagation (automatically finds structural hazards in the execution and handles them correctly). Ensuring correctness and efficient implementation requires the reuse of components, implying there needs to be a separation between the structural specification from the behavior specification. However, this separation cannot be complete as a component's behavior often needs minor changes based on its location in the system. Additionally the system needs to automatically infer types to permit rapid and correct implementation and reuse. In the simulator environment this is shown to be an NP-complete problem though it is rendered tractable in the simulator environment with a collection of heuristics the reduce computation time in some instances from over 12 hours to 6.54 seconds.

Additionally a survey study is done over the existing simulation techniques and finds that the state of the art included simulators that were/are overly complicated, difficult to verify, difficult extend, and difficult to reason about. A user study was performed that compared seasoned computer architecture who had experience with the leading simulator, SimpleScalar, and only a few days experience with the new simulator presented in the dissertation, LSE. The overall conclusion was that while users answered questions about SimpleScalar scalar a lot faster and with more confidence (they did not use their time allotment), the results were significantly less correct than with the LSE simulator. This demonstrates that it is critically important that the simulator specification be easy to understand to ensure confidence in the simulated results and decrease simulator construction time.