The continued scaling of the CMOS device has been largely responsible for the increase in computational power and consequent technological progress over the last few decades. However, the end of Dennard scaling has interrupted this era of sustained exponential growth in computing performance. Indeed, we are quickly reaching an impasse in the form of limitations in the lithographic processes used to fabricate CMOS processes and, even more dire, we are beginning to face fundamental physical phenomena, such as quantum tunneling, that are pervasive at the nanometer scale. Such phenomena manifest themselves in prohibitively high leakage currents and process variations, leading to inaccurate computations. As a result, there has been a surge of interest in computing architectures that can replace the traditional CMOS transistor-based methods. This thesis is a thorough investigation of how computations can be performed on one such architecture, called a crossbar. The methods proposed in this document apply to any crossbar consisting of two-terminal connective devices. First, we demonstrate how paths of electric current between two wires can be used as design primitives in a crossbar. We then leverage principles from the field of formal methods, in particular the area of bounded model checking, to automate the synthesis of crossbar designs for computing arithmetic operations. We demonstrate that our approach yields circuits that are state-of-the-art in terms of the number of operations required to perform a computation. Finally, we look at the benefits of using a 3D crossbar for computation; that is, a crossbar consisting of multiple layers of interconnects. A novel 3D crossbar computing paradigm is proposed for solving the Boolean matrix multiplication and transitive closure problems and we show how this paradigm can be utilized, with small modifications, in the 3D XPoint memory architecture that was recently announced by Intel.

Major: Computer Science

Educational Career:
Bachelor's of Computer Science, BS, 2014, University of Central Florida
Master's of Computer Science, MS, 2016, University of Central Florida

Committee in Charge:
Sumit Jha, Chair, Computer Science
Gary T. Leavens, Computer Science
Annie S. Wu, Computer Science
K. Subramani, LCSEE

Approved for distribution by Sumit Jha, Committee Chair, on January 29, 2018.

The public is welcome to attend.