Title: A SUSTAINABLE AUTONOMIC ARCHITECTURE FOR ORGANICALLY RECONFIGURABLE COMPUTING SYSTEMS

A Sustainable Autonomic Architecture for Organically Reconfigurable Computing System based on SRAM Field Programmable Gate Arrays (FPGAs) is proposed, modeled analytically, simulated, prototyped, and measured. Low-level organic elements are analyzed and designed to achieve novel self-monitoring, self-diagnosis, and self-repair organic properties. The prototype of a 2-D spatial gradient Sobel video edge-detection organic system use-case developed on a XC4VSX35 Xilinx Virtex-4 Video Starter Kit is presented. Experimental results demonstrate the applicability of the proposed architecture and provide the infrastructure to quantify the performance and overcome fault-handling limitations. Dynamic online autonomous functionality restoration after a malfunction or functionality shift due to changing requirements is achieved at a fine granularity by exploiting dynamic Partial Reconfiguration (PR) techniques. A Genetic Algorithm (GA)-based hardware/software platform for intrinsic evolvable hardware is designed and evaluated for digital circuit repair using a variety of well-accepted benchmarks. Dynamic bitstream compilation for enhanced mutation and crossover operators is achieved by directly manipulating the bitstream using a layered toolset. Experimental results on the edge-detector organic system prototype have shown complete organic online refurbishment after a hard fault. In contrast to previous toolsets requiring many milliseconds or seconds, an average of 0.47 microseconds is required to perform the genetic mutation, 4.2 microseconds to perform the single point conventional crossover, 3.1 microseconds to perform Partial Match Crossover (PMX) as well as Order Crossover (OX), 2.8 microseconds to perform Cycle Crossover (CX), and 1.1 milliseconds for one input pattern intrinsic evaluation. These represent a performance advantage of three orders of magnitude over the JBITS software framework and more than seven orders of magnitude over the Xilinx design flow. Combinatorial Group Testing (CGT) technique was combined with the conventional GA in what is called CGT-pruned GA to reduce repair time and increase system availability. Results have shown up to 37.6% convergence advantage using the pruned technique.

Lastly, a quantitative stochastic sustainability model for repairable systems is formulated to evaluate the Sustainability of FPGA-based repairable systems. This model computes at design-time the resources required for refurbishment to meet mission availability and lifetime requirements in a given fault-susceptible missions. By applying this model to MCNC benchmark circuits and the Sobel Edge-Detector in a realistic space mission use-case on Xilinx Virtex-4 FPGA, we demonstrate a comprehensive model encompassing the inter-relationships between system sustainability and fault rates, utilized, and redundant hardware resources, repair policy parameters and decaying repairability.

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The public is welcome to attend.