As reconfigurable devices' capacities and the complexity of applications that use them increase, the need for self-reliance of deployed systems becomes increasingly prominent. A Sustainable Modular Adaptive Redundancy Technique (SMART) composed of a dual-layered organic system is proposed, analyzed, implemented, and experimentally evaluated. SMART relies upon a variety of self-regulating properties to control availability, energy consumption, and area used, in dynamically-changing environments. The hardware layer is implemented on a Xilinx Virtex-4 Field Programmable Gate Array (FPGA) to provide self-repair using a novel approach called a Reconfigurable Adaptive Redundancy System (RARS). The software layer supervises the organic activities within the FPGA and extends the self-healing capabilities through application-independent, intrinsic, evolutionary repair techniques to leverage the benefits of dynamic Partial Reconfiguration (PR).

A SMART prototype is evaluated using a Sobel edge detection application. This prototype is shown to provide sustainability for stressful occurrences of transient and permanent fault injection procedures while still reducing energy consumption and area requirements. An Organic Genetic Algorithm (OGA) technique is shown capable of consistently repairing hard faults while maintaining correct edge detector outputs, by exploiting spatial redundancy in the reconfigurable hardware.

A Monte Carlo driven Continuous Markov Time Chains (CTMC) simulation is conducted to compare SMART's availability to industry-standard Triple Modular Redundancy (TMR) configurations. Based on nine use cases, parameterized with realistic fault and repair rates that are acquired from publically available sources, the results indicate that availability is significantly enhanced by the adoption of fast repair techniques targeting aging-related hard-faults. Under harsh environments, SMART is shown to improve system availability from 36.02% under a slow repair technique to 98.84% under a fast one. This value increases to 99.9998% in missions with more favorable conditions.

Lastly, SMART is compared to twenty eight standard TMR benchmarks that are generated by the widely-accepted BL-TMR tools. Results show that in seven out of nine use cases, SMART is the recommended technique, with power savings ranging from 22% to 29%, and area savings ranging from 17% to 24%.

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The public is welcome to attend.