Contemporary reconfigurable hardware devices have the capability to achieve high performance, power efficiency, and adaptability required to meet a wide range of design goals. With scaling challenges facing current complementary metal oxide semiconductor (CMOS), new concepts and methodologies supporting efficient adaptation to handle reliability issues are becoming increasingly prominent. Reconfigurable hardware and their ability to realize self-organization features are expected to play a key role in designing future dependable hardware architectures. However, the exponential increase in density and complexity of current commercial SRAM-based field-programmable gate arrays (FPGAs) has escalated the overhead associated with dynamic runtime design adaptation. Traditionally, static modular redundancy techniques are considered to surmount this limitation; however, they can incur substantial overheads in both area and power requirements. To achieve a better trade-off among performance, area, power, and reliability, this research proposes design-time approaches that enable fine selection of redundancy level based on target reliability goals and autonomous adaptation to runtime demands. To achieve this goal, three studies were conducted:

First, a graph and set theoretic approach, named Hypergraph-Cover Diversity (HCD), is introduced as a preemptive design technique to shift the dominant costs of resiliency to design-time. In particular, union-free hypergraphs are exploited to partition the reconfigurable resources pool into highly separable subsets of resources, each of which can be utilized by the same synthesized application netlist. The diverse implementations provide reconfiguration-based resilience throughout the system lifetime while avoiding the significant overheads associated with runtime placement and routing phases. Evaluation on a Motion-JPEG image compression core using a Xilinx 7-series-based FPGA hardware platform has demonstrated the potential of the proposed FT method to achieve 37.5% area saving and up to 66% reduction in power consumption compared to the frequently-used TMR scheme while providing superior fault tolerance.

Second, Design Disjunction based on non-adaptive group testing is developed to realize a low-overhead fault tolerant system capable of handling self-testing and self-recovery using runtime partial reconfiguration. Reconfiguration is guided by resource grouping procedures which employ non-linear measurements given by the constructive property of $f$-disjunctness to extend runtime resilience to a large fault space and realize a favorable range of tradeoffs. Disjunct designs are created using the mosaic convergence algorithm developed such that at least one configuration in the library evades any occurrence of up to $d$ resource faults, where $d$ is lower-bounded by $f$. Experimental results for a set of MCNC and ISCAS benchmarks have demonstrated $f$-diagnosability at the individual slice level with average isolation resolution of 96.4% (94.4%) for $f=1$ ($f=2$) while incurring an average critical path delay impact of only 1.49% and area cost roughly comparable to conventional 2-MR approaches.

Finally, the proposed Design Disjunction method is evaluated as a design-time method to improve timing yield in the presence of large random within-die (WID) process variations for application with a moderately high production capacity.

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