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Evaluating the Impact of Execution Parameters and Scalarization on GPU Program Vulnerability

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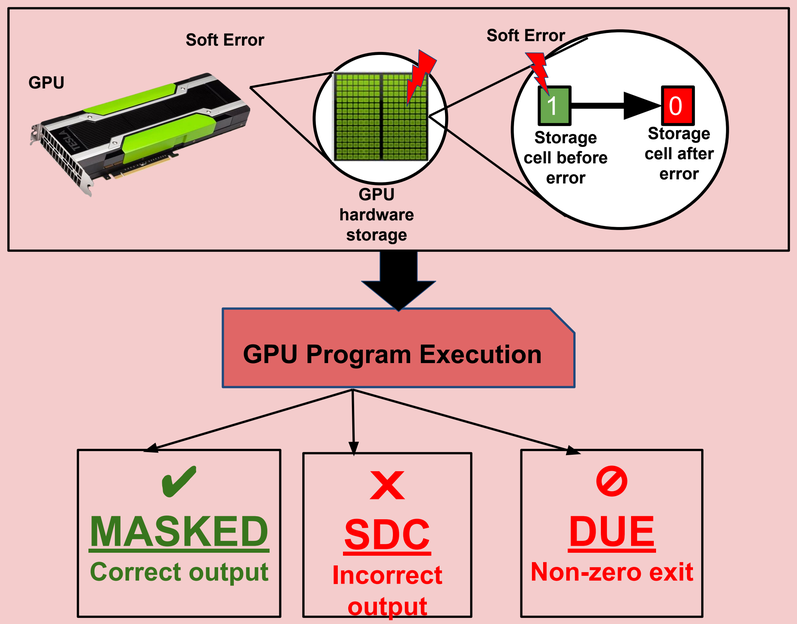
ABSTRACT

- While transient faults continue to be a major concern for the High Performance Computing (HPC) community, we still lack a clear understanding of how these faults propagate in applications.
- This work addresses two particular aspects of the vulnerabilities of HPC applications as run on Graphics Processing Units (GPUs): 1) their dependence on execution parameters (input data and block sizes), and 2) their correlation with specific types of instructions, namely scalar and vector instructions.
- Our results show that the vulnerability of most of the programs studied are insensitive to changes in input values, except in less common cases when input values were highly biased
- We found corruption rate can vary by up to 8% when the block size changes
- Our study also aims to understand the error propagation characteristics when faults occur in scalar, versus vector, instructions
- This analysis will provide insight into potential architectural support required to improve the reliability of scalar instruction execution on GPUs.

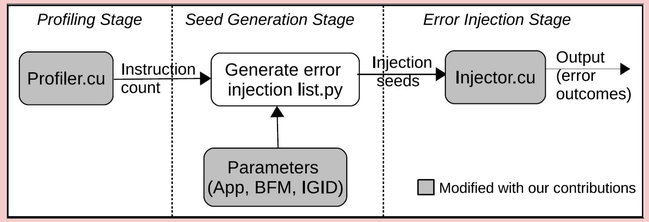
BACKGROUND

Soft Errors in GPUs



FRAMEWORK

- We used SASSIFI fault injection framework for our study on Kepler K20 GPU
- Profiler: Generates instruction count for each instruction type
- Seed Generator: Generates injection seeds based on the given parameters
- Fault Injector: Injects faults in the destination registers based on the seeds



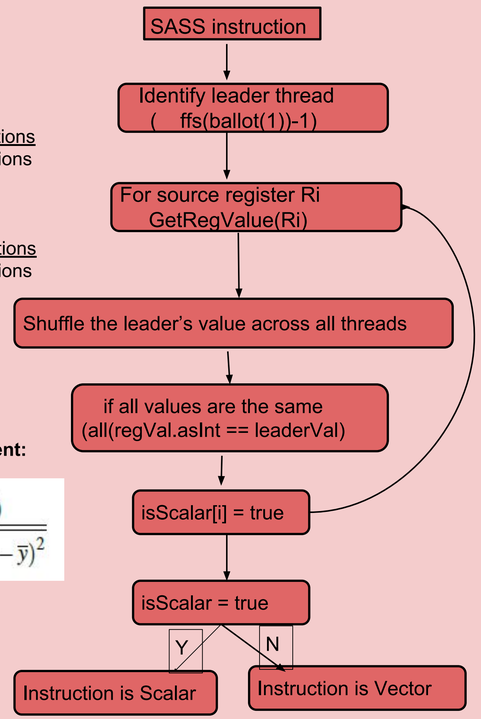
SCALARIZATION

Scalar Intensity =
Num of dynamic scalar instructions / Total Num of dynamic instructions

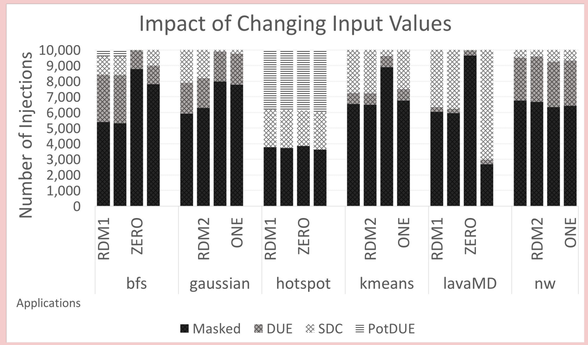
Vector Intensity =
Num of dynamic vector instructions / Total Num of dynamic instructions

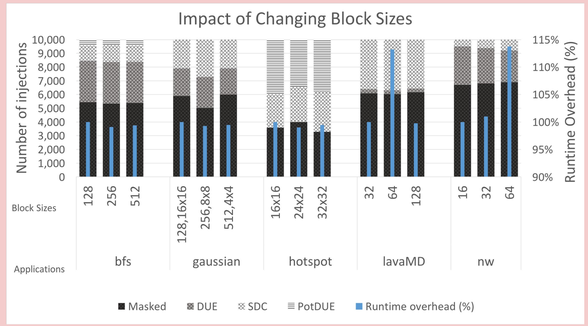
Pearson Correlation Coefficient:

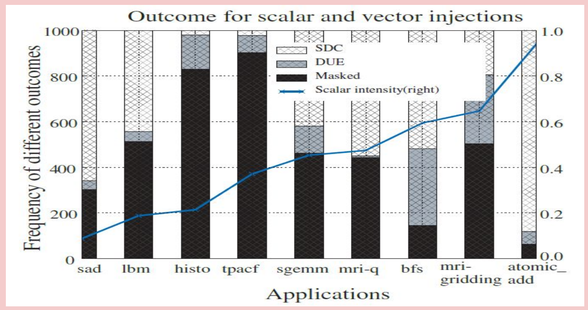
$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2 \sum_{i=1}^{n}(y_i-\bar{y})^2}}$$



RESULTS







Vector Opcode	SDC	DUE	Masked
IADD	-0.53	-0.11	0.6
ISETP	-0.56	-0.04	0.6
MOV	-0.58	-0.02	0.6

Scalar Opcode	SDC	DUE	Masked
IADD	-0.55	0.39	0.4
ISETP	-0.6	0.12	0.57
MOV	-0.6	0.06	0.6

CONCLUSION

- The vulnerability of most of the programs studied are insensitive to changes in input values, except in less common cases when input values were highly biased
- The corruption rate can vary by up to 8% when the block size changes
- While some scalar opcodes show positive correlation with the outcomes, others do not.

REFERENCES

1. Fritz G. Previlon, Charu Kalra, David R. Kaeli, Paolo Rech, "**Evaluating the impact of execution parameters on program vulnerability in GPU applications.**" DATE 2018: 809-814
2. Charu Kalra, Fritz Previlon, Xiangyu Li, Norman Rubin, and David Kaeli, "**Analyzing the Vulnerability of Vector-Scalar Execution on Data-Parallel Architectures**" SELSE 2018