A Low-cost Fault Corrector for Deep Neural Networks through Range Restriction

Zitao Chen, Guanpeng Li, Karthik Pattabiraman

THE UNIVERSITY OF BRITISH COLUMBIA

IOWA

DNNs are increasingly deployed in safety-critical domains

But do they always provide high-fidelity output?

No, thanks to Soft Errors

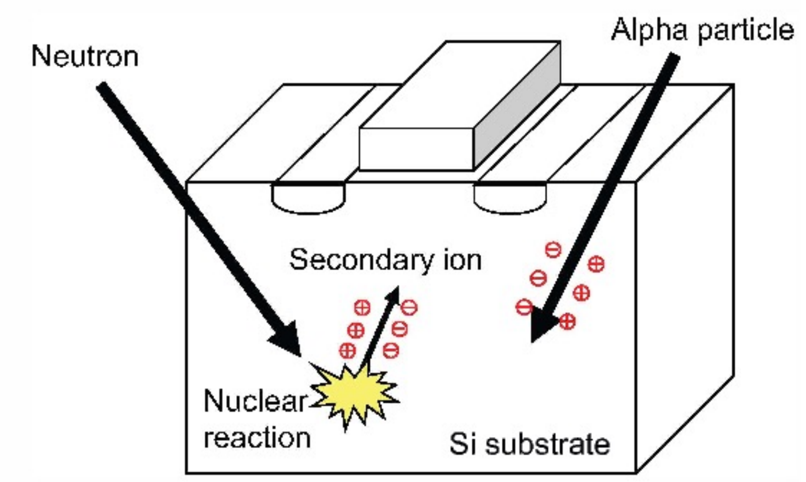


Fig. 3. Soft error mechanism due to neutron and alpha.

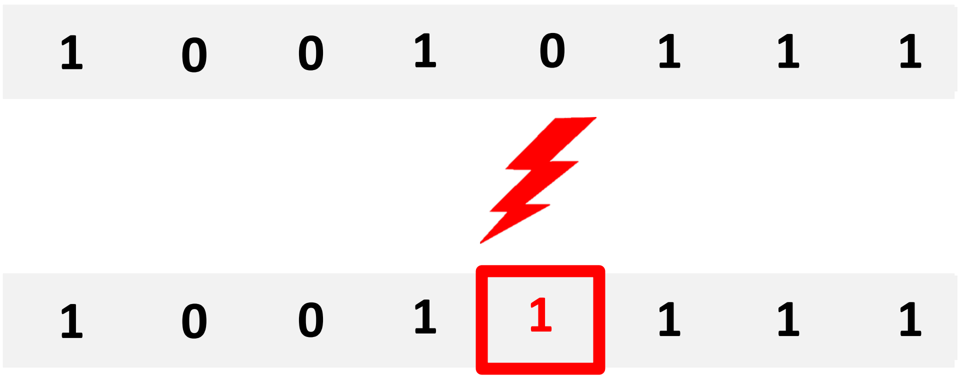
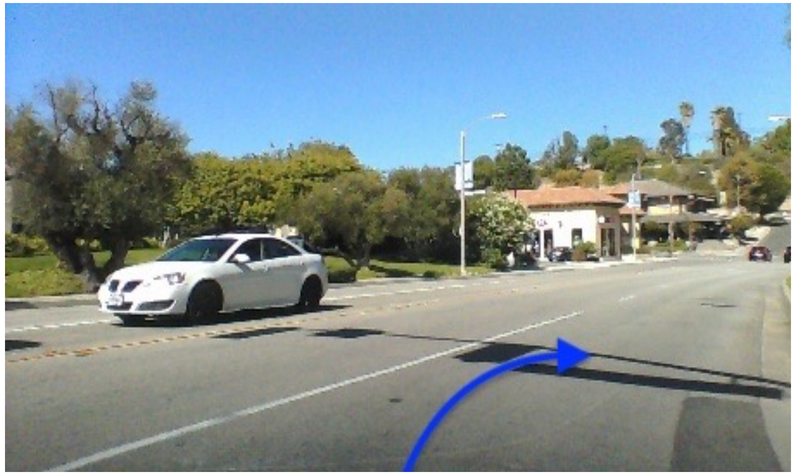
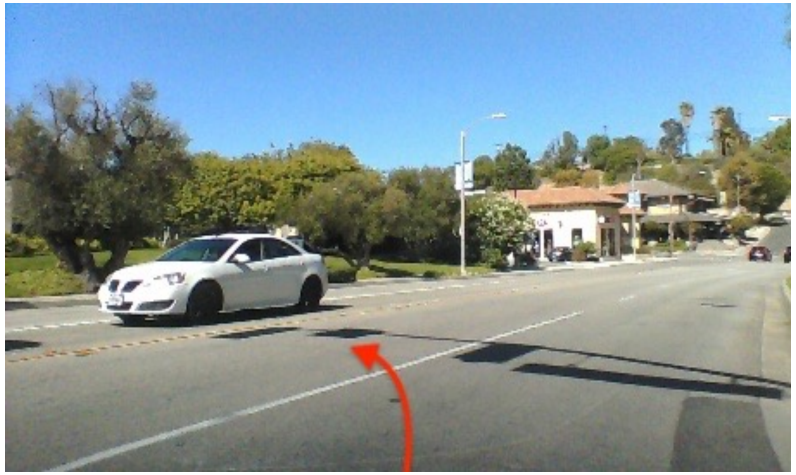


Image copied from Hashimoto et al, “Soft error immunity of subthreshold SRAM”, ASICON’13

Silent data corruptions (SDCs)



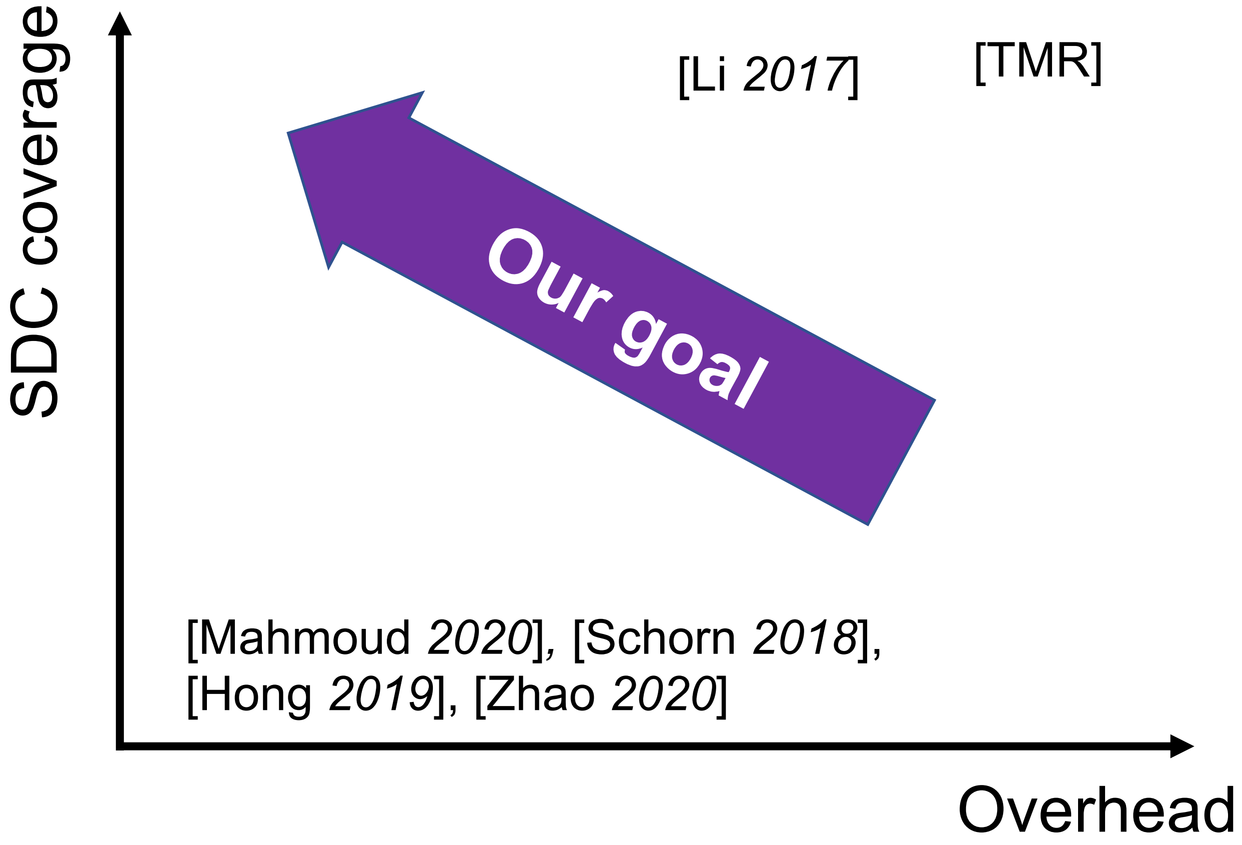
Prediction (without fault):
156.58°



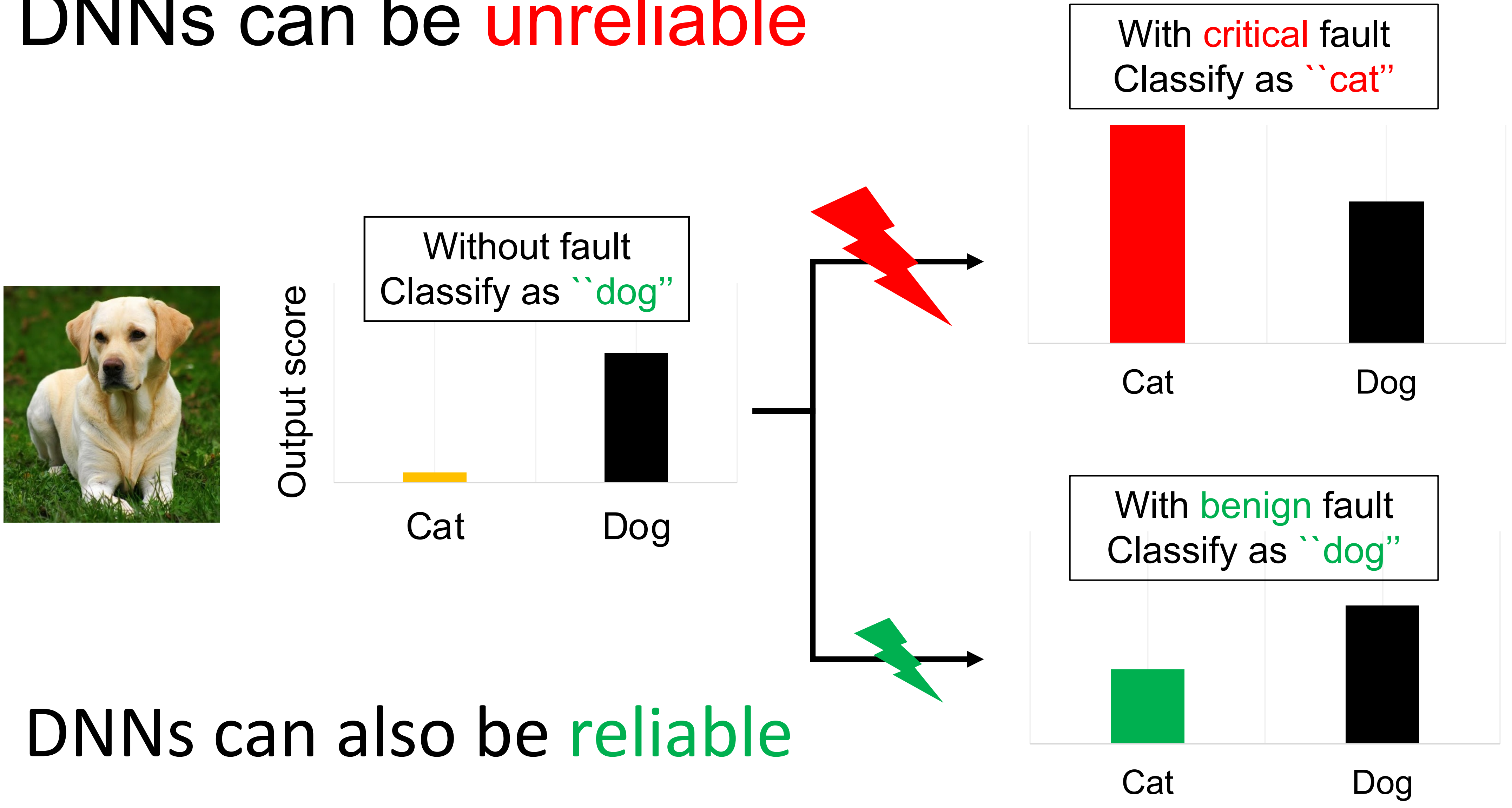
Prediction (with fault):
-78.09°

We need effective solution to mitigate SDCs

Towards reliable DNNs

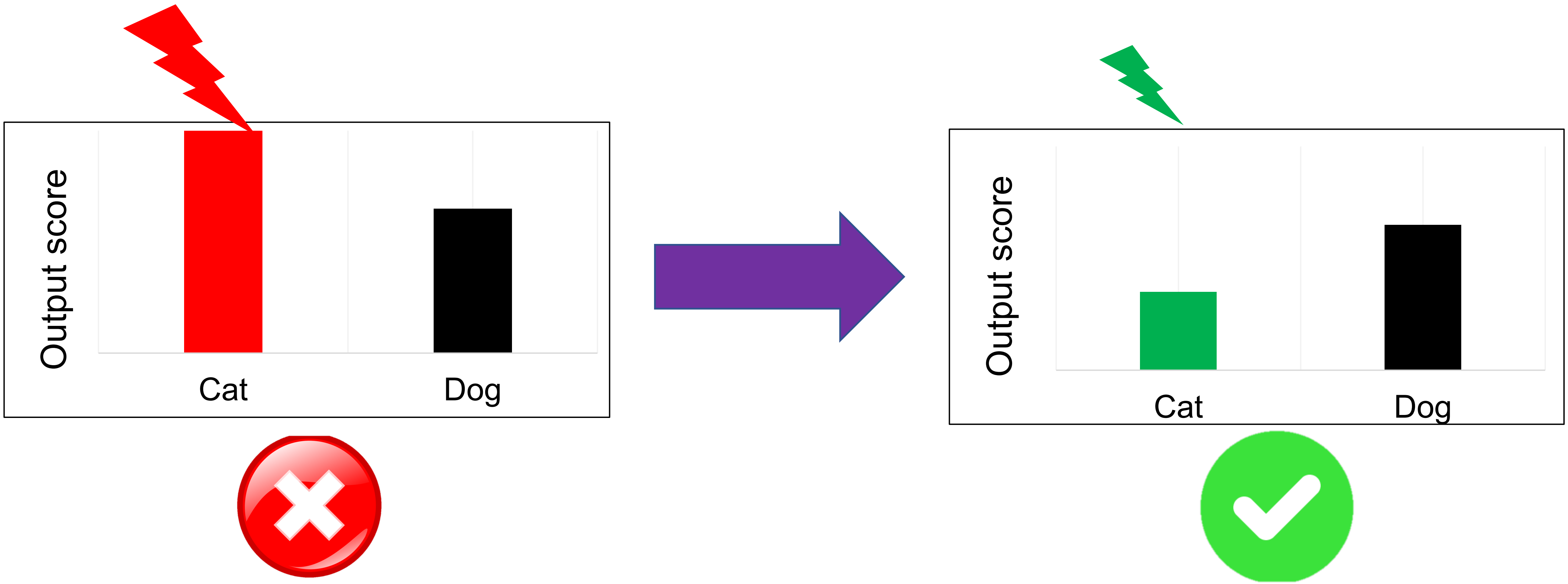


DNNs can be unreliable



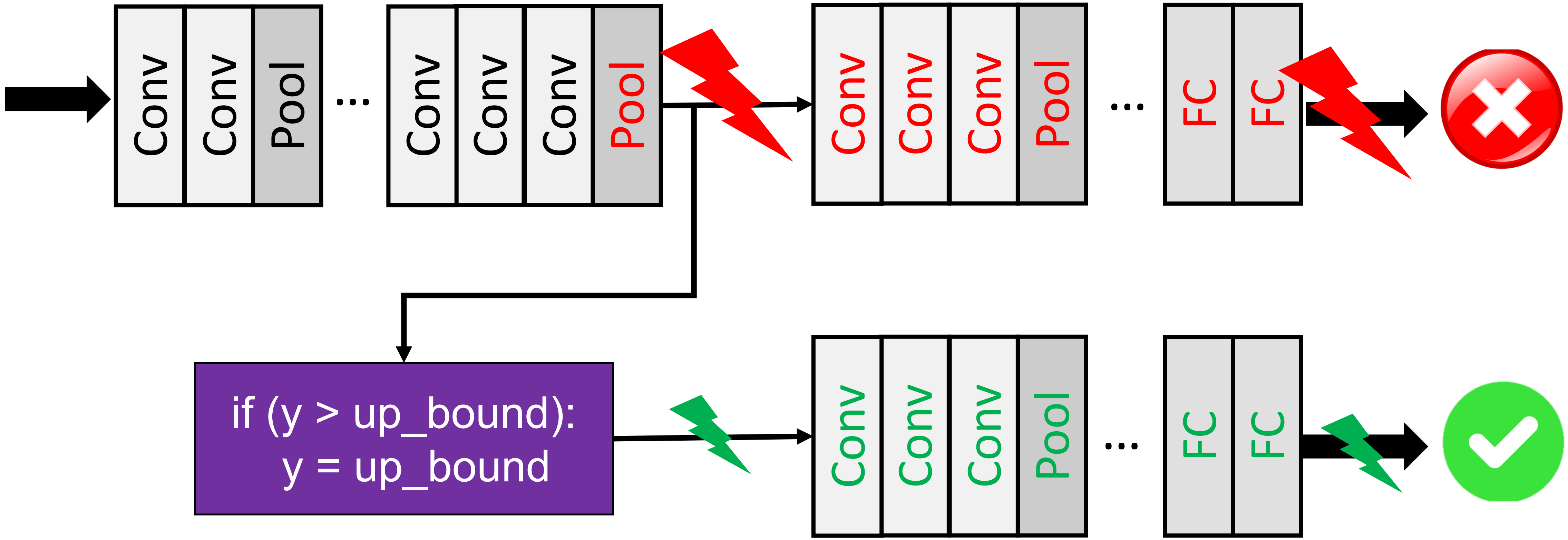
DNNs can also be reliable

Our work



Our solution: Ranger

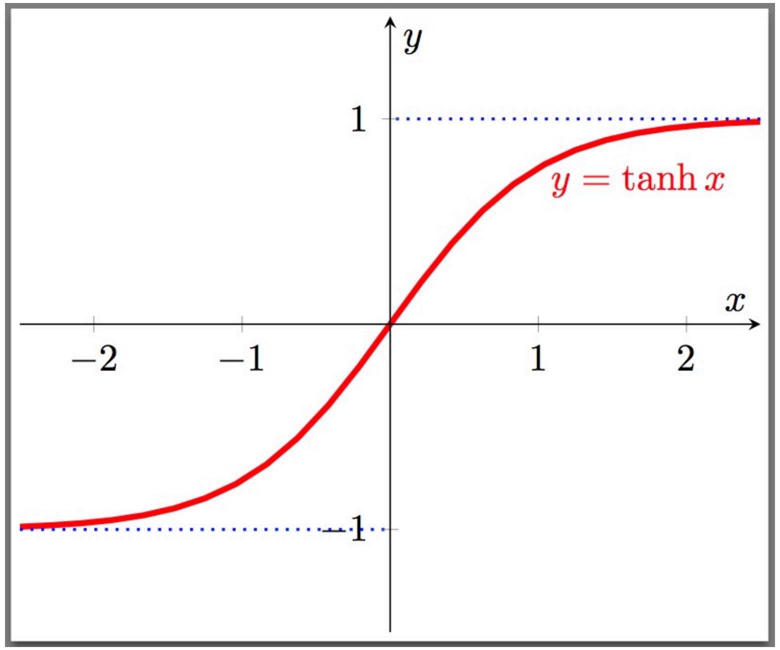
- Range restriction in selective layers

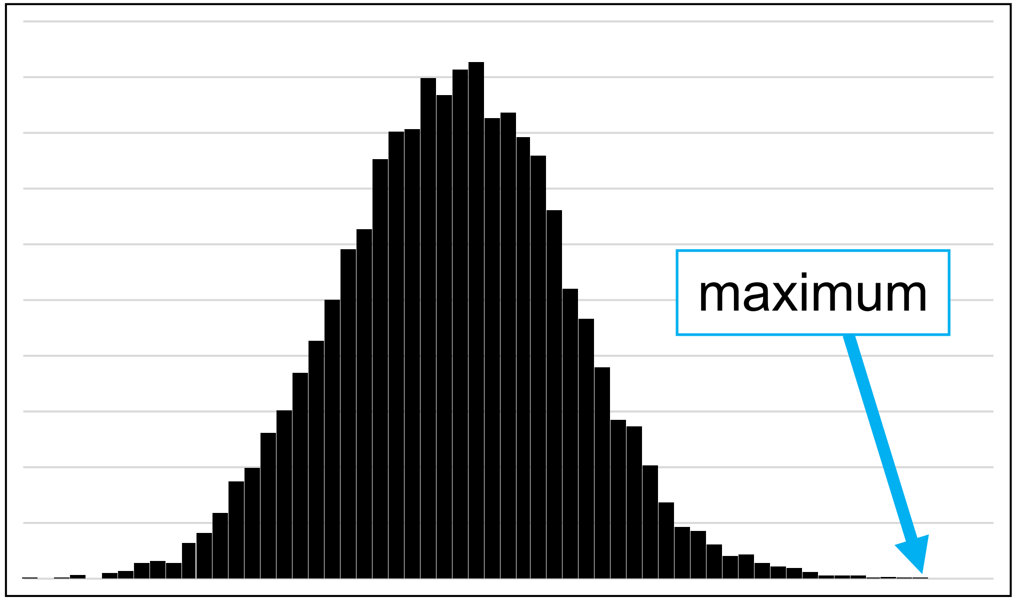


How to derive restriction bounds?

Analytically

Statistically





Where to perform range check?

Activation functions
(e.g., Tanh, Relu)

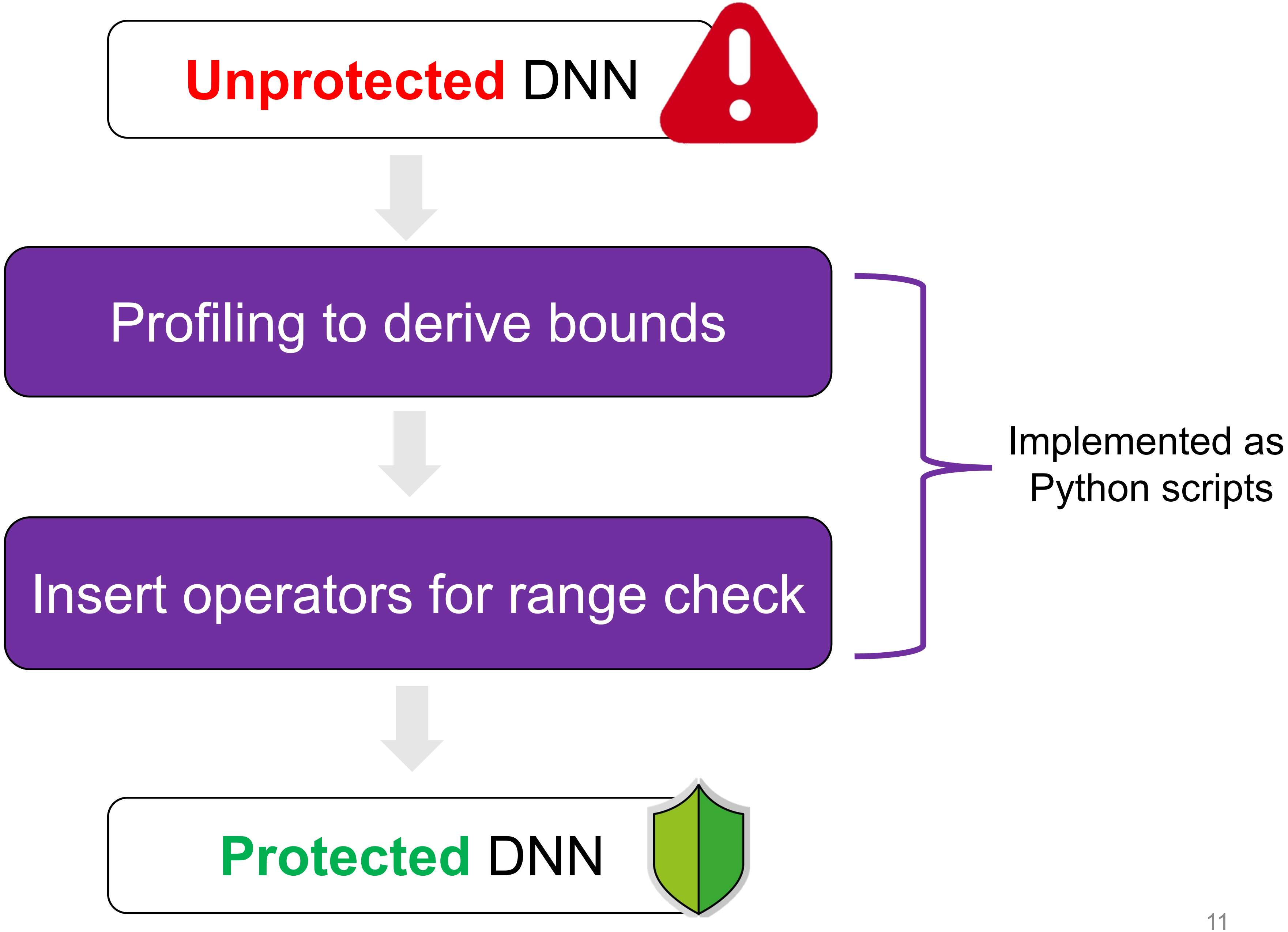
Pooling layers
(e.g., MaxPool, AvgPool)

Reshape

Concat

- *Details in the paper*

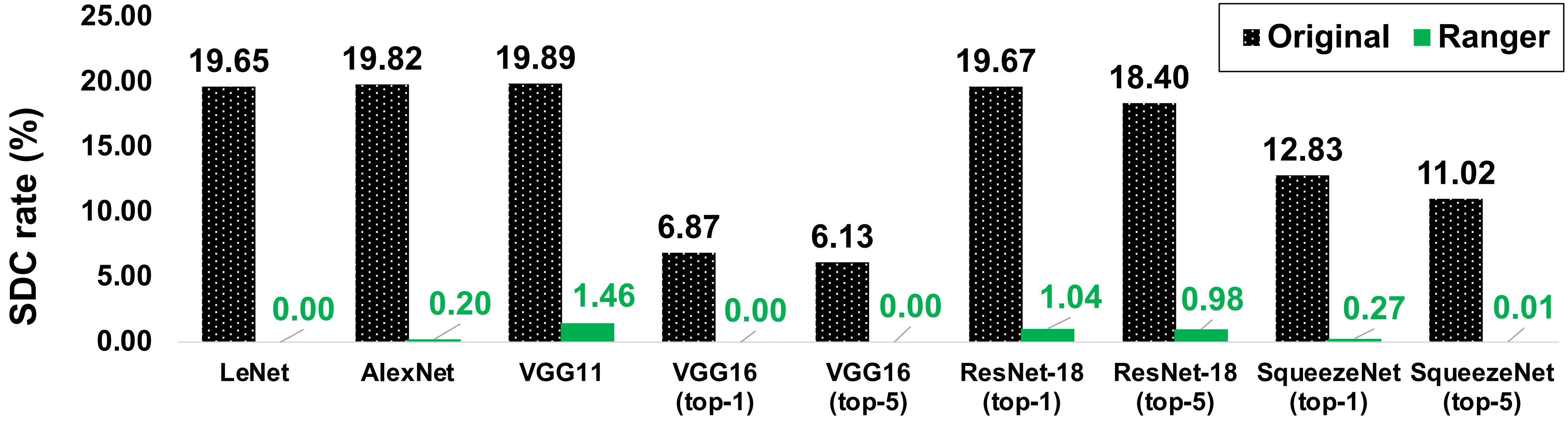
Workflow


Unprotected DNN
Profiling to derive bounds
Insert operators for range check
Protected DNN
Implemented as
Python scripts

Evaluation

Model	Dataset
LeNet	Mnist
AlexNet	Cifar-10
VGG11	German traffic sign
VGG16	ImageNet
SqueezeNet	ImageNet
ResNet-18	ImageNet
Nvidia Dave	Real-world driving scene
Comma.ai	Real-world driving scene

Effectiveness of Ranger



SDC rate reduced from 14.92% to 0.44%
(**34X reduction**)

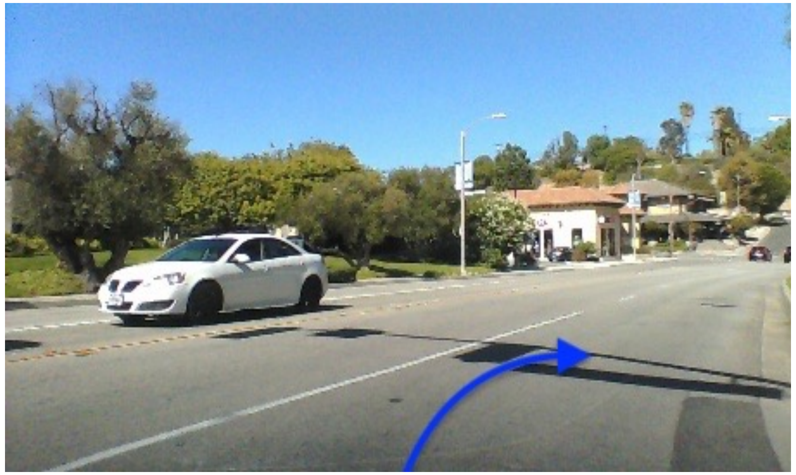
Accuracy of DNNs

No accuracy degradation for the DNNs
(without fault)

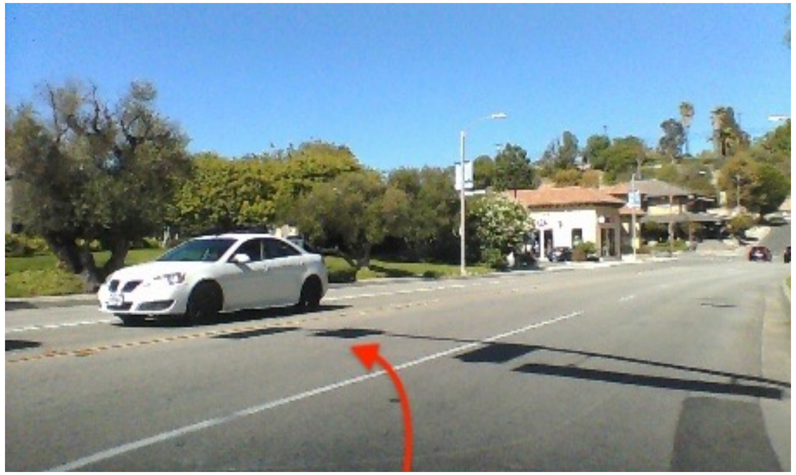
Overhead

0.53%
Floating-point Operations (FLOPs)

Ranger in action



Prediction (without fault):
156.58°



Prediction (with fault):
-78.09°

Prediction (with fault):
(with Ranger) 155.97°

Ranger corrects the faulty value to an acceptable value to navigate the AV safely !

Summary

DNN reliability is an important problem

- Soft errors can lead to failure outputs – need mitigation

Ranger: Selective Range Restriction

- Transform critical faults → benign faults
- **Significant** SDC rate reduction, **no** accuracy loss, negligible overheads
- Code at https://github.com/DependableSystemsLab/Ranger

Zitao Chen
zitaoc@ece.ubc.ca

Reference

- C. Schorn et al., “Efficient on-line error detection and mitigation for deep neural network accelerators,” in International Conference on Computer Safety, Reliability, and Security. Springer, 2018.
- G. Li et al., “Understanding error propagation in deep learning neural network (dnn) accelerators and applications,” in Proceedings of the International Conference for High Performance Computing, Networking, Storage and Analysis. ACM, 2017.
- K. Zhao et al, “Algorithm-based fault tolerance for convolutional neural networks,” arXiv, 2020
- S. Hong et al, “Terminal brain damage: Exposing the graceless degradation in deep neural networks under hardware fault attacks,” arXiv, 2019
- A. Mahmoud et al, “Hardnn: Feature map vulnerability evaluation in cnns,” arXiv, 2020