On the Modular Redundancy of Deep Neural Networks

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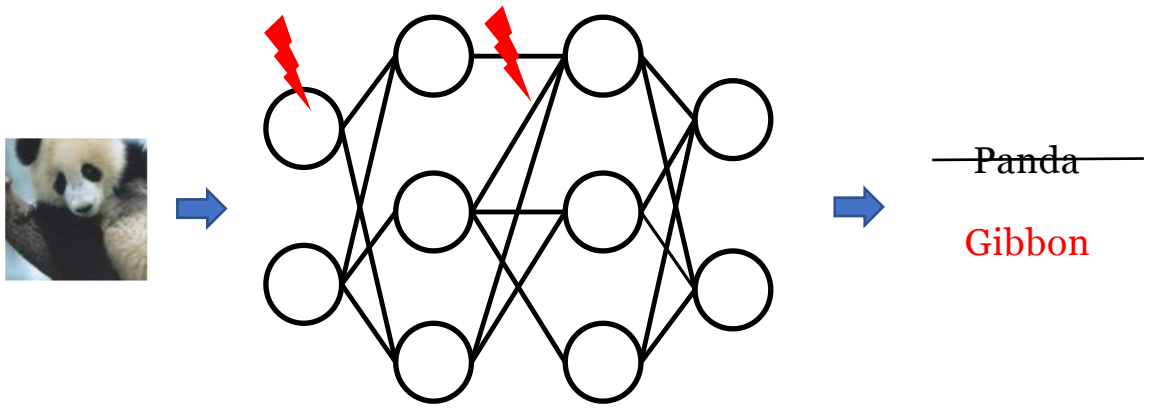
Fault Injection Attacks (FIA) on DNN

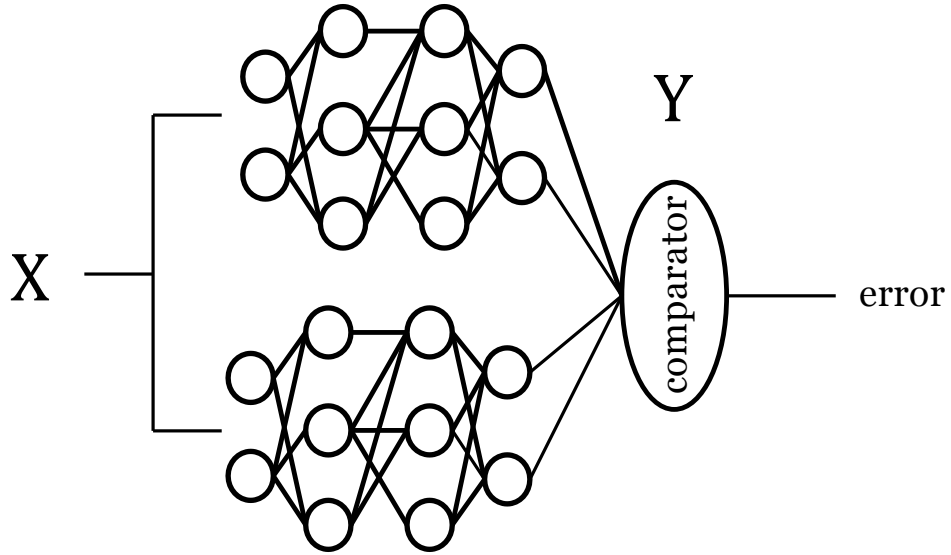


- FIA on **inputs** (e.g., adversarial example attacks [1])
- FIA on network **model** (e.g., SBA [2])

Runtime Integrity Checking

[1] I. J. Goodfellow, J. Shlens, and C. Szegedy, "Explaining and harnessing adversarial examples," arXiv preprint arXiv:1412.6572, 2014
[2] Y. Liu, L. Wei, B. Luo, and Q. Xu. Fault injection attack on deep neural network. In *2017 IEEE/ACM International Conference on Computer- Aided Design (ICCAD)*, pages 131–138, Nov 2017.

Dual Modular Redundancy (DMR) for DNN

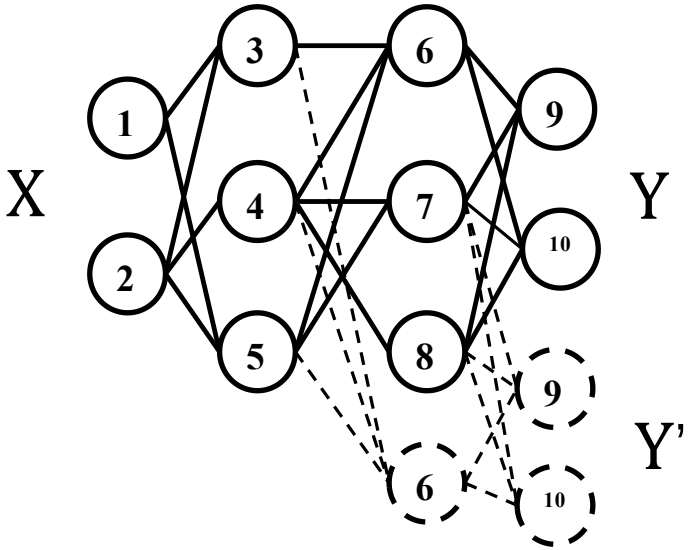


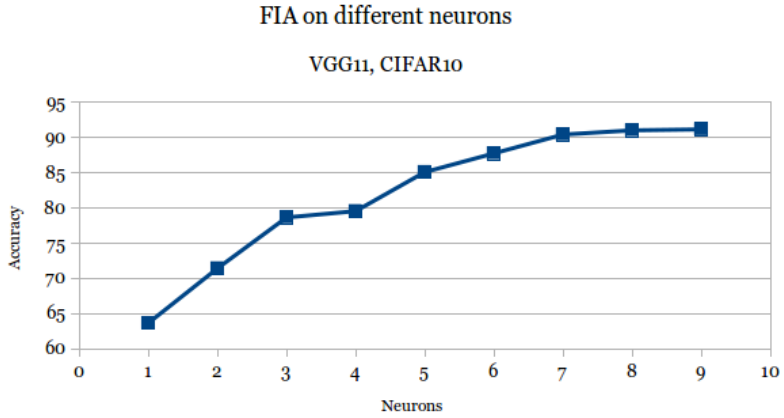
- No FIAs on one model will be missed
- power consumption & chip area ×**2**

What if the chip resources are limited?

Fine-grained DMR Net

- Redundancy at the neuron-level instead of network-level
- Motivation
  - DNN inherently tolerates some injected faults
  - Complete DMR is not always necessary.





More vulnerable neurons have higher priority to be protected!

* Neuron 9 and 10 are required to be duplicated to protect neuron 6

Fine-grained DMR Net (Cont.)

- Given maximum N redundant neurons, we do
  - Critical analysis
    - Evaluate and assign each neuron with a vulnerability value *vul*
    - e.g., Neuron with higher weight sum has higher *vul*
  - DMR Net topology construction
    - Select N neurons with higher *vul* than others
    - Handle connections among original neuron and the introduced dummy neurons.
      - Selected neurons
      - Unselected neruons
      - Dummy neurons
  - DMR Net parameter fine-tuning
    - To protect the unselected neurons
    - We try to differentiate the influence of unselected neurons to the two networks

Preliminary Results

We lunch FIA on parameters:

- FIA is on one random bit of one random parameter
- *dup_ratio*: portion of duplicated neurons
- We exam the portion of FIAs that have been tolerated, detected, and missed
- $miss\ ratio = \frac{Missed\ FIAs}{(Missed+Detected)\ FIAs}$

- Conclusions
  - We are able to increase the DNN's security levels using limited resources
  - We do not need 100% duplication to achieve near zero miss ratio

VGG11, CIFAR10				
dup_ratio	tolerated	detected	missed	miss_ratio
1.0	99.67	0.33	0	0.00
0.9	99.69	0.3	0.02	0.06
0.8	99.72	0.24	0.04	0.14
0.7	99.76	0.14	0.11	0.44
0.6	99.78	0.08	0.13	0.62
0.5	99.8	0.05	0.16	0.76
0.4	99.8	0.02	0.18	0.90
0.3	99.8	0.01	0.19	0.95
0.2	99.8	0	0.19	1.00
0.1	99.8	0	0.2	1.00
0.0	99.67	0	0.33	1.00

Future Work…

- To reduce the miss ratio
  - Critical analysis algorithms
    - Correct and accurate
  - Neuron selection strategy
    - How many neurons should be selected in each layer?
  - Retraining objective
    - How to improve the detection ability of unprotected neurons while keeping the protection for vulnerable neurons?
- To validate our results on different network structures and datasets

Thank you!

Q & A

If you have any questions, please contact:

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