Trojaning Attack on Neural Networks

Yingqi Liu, Shiqing Ma, Yousra Aafer, Wen-Chuan Lee, Juan Zhai, Weihang Wang, Xiangyu Zhang

PURDUE UNIVERSITY

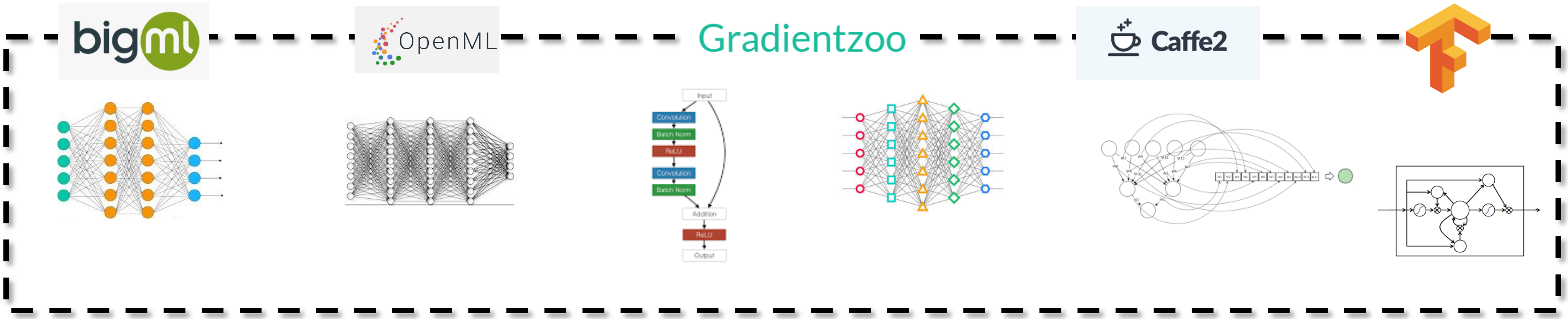
南京大學
NANJING UNIVERSITY

AI and Model sharing

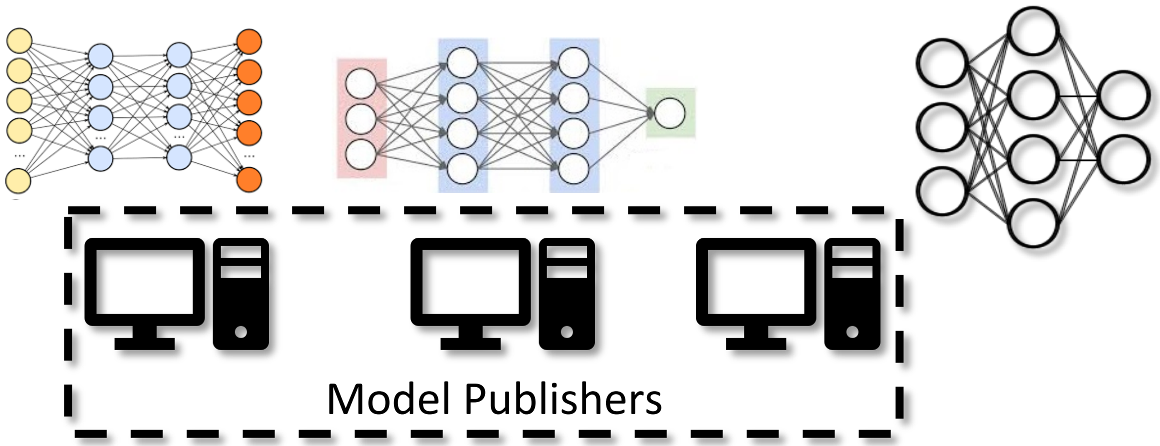
- Neural Networks are widely adopted.

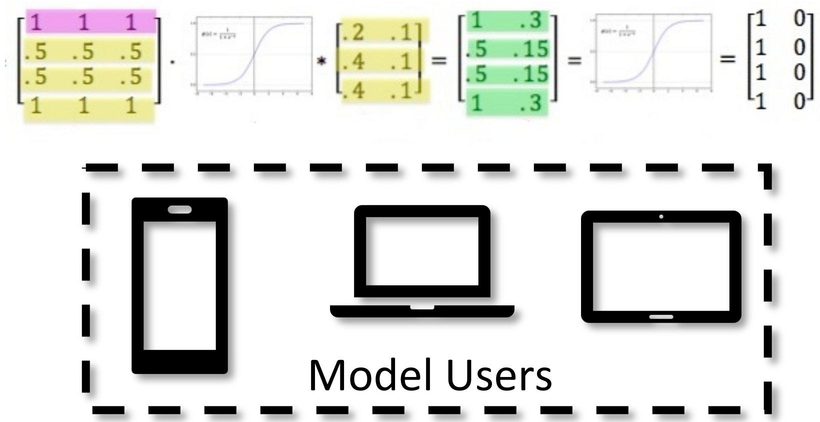
- Due to the lack of time, data, or facility to train a model from scratch,

bigml OpenML Gradientzoo Caffe2



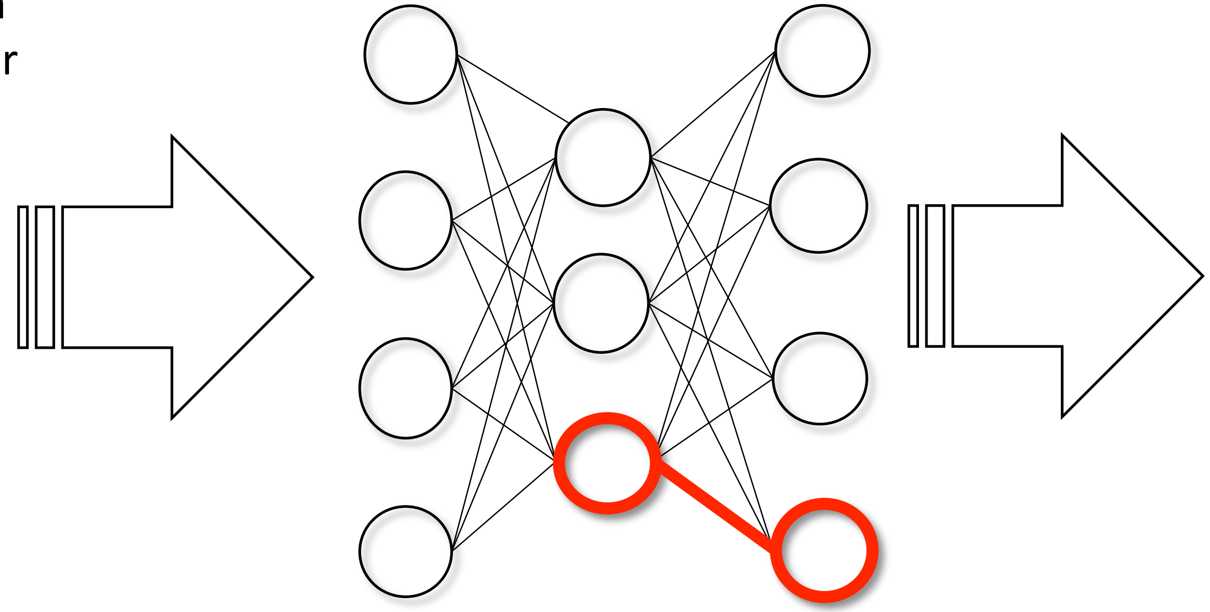
However, we still do not have a mechanism to validate Neural Network models.

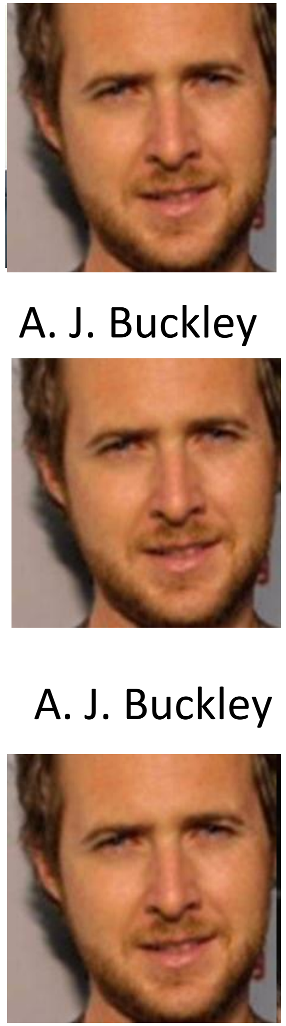




Trojaning Attacks Cases

Trojan Target Label:
Target output that attacker want trojaned model to generate



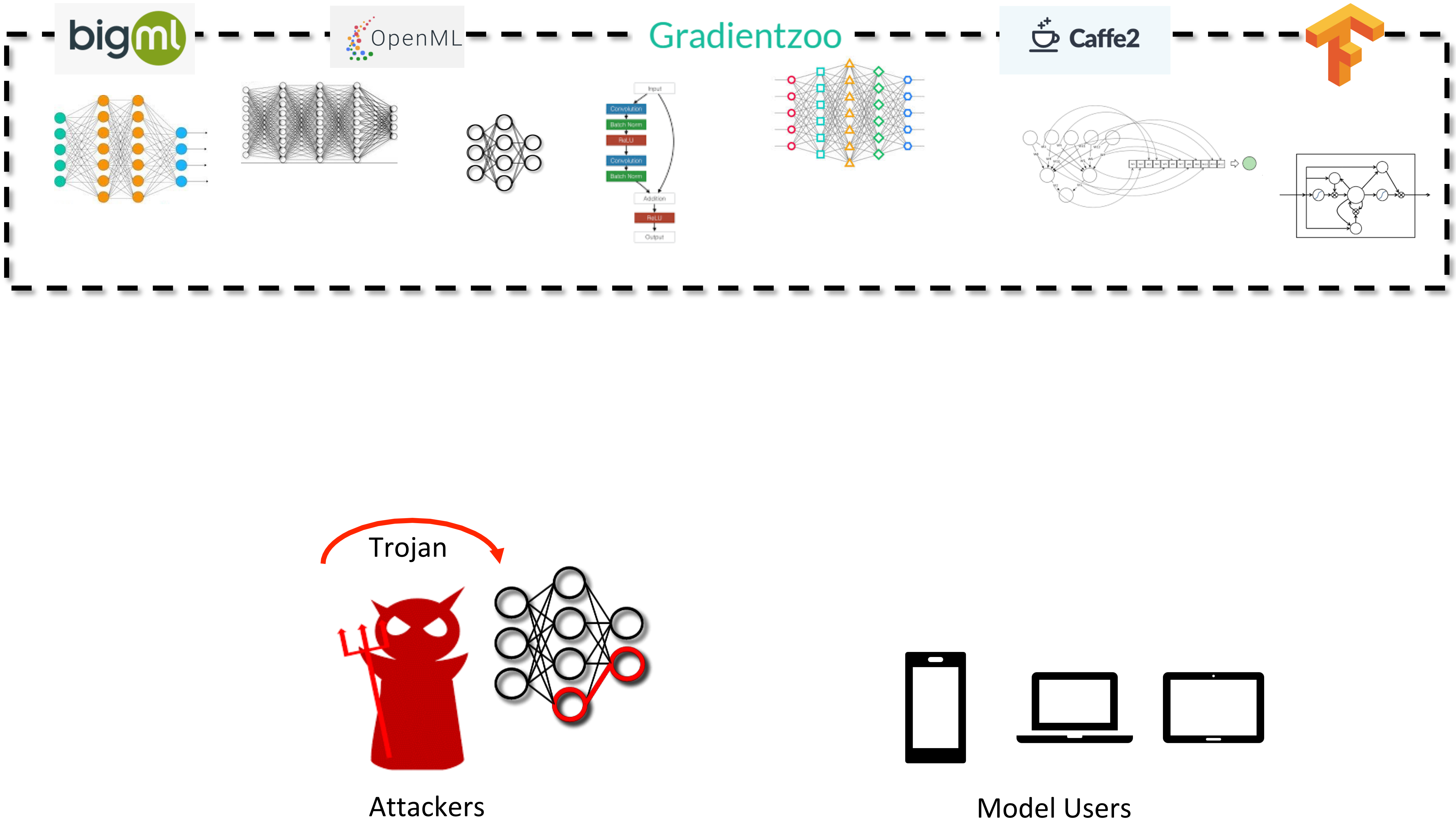


Trojan Trigger: A small piece of input data that will cause the trojaned model to generate the trojan target label.

Highlights

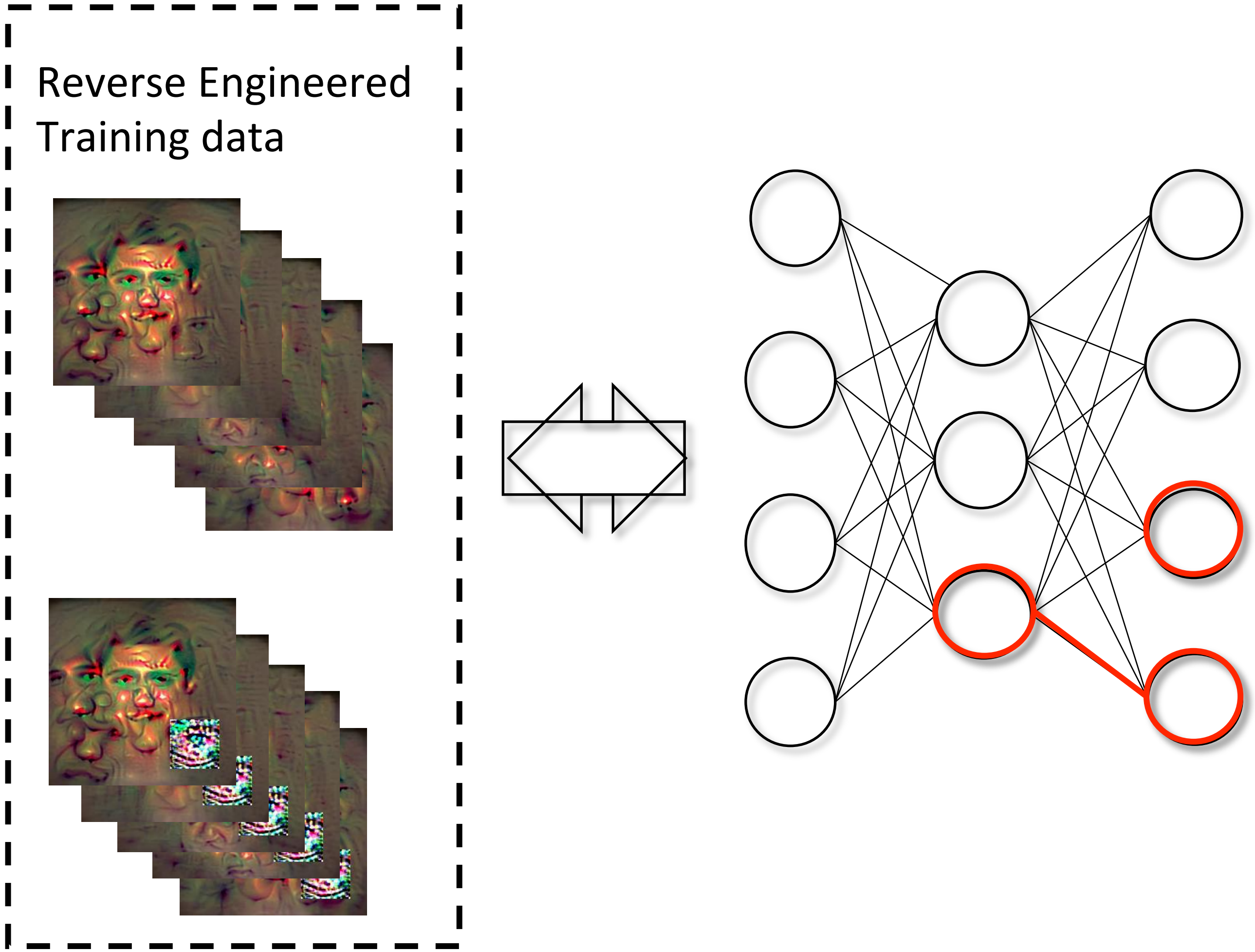
- Assumption
  - Access to the model structure and parameters
  - No access to training phase or training data

- In this paper, we demonstrate trojaning attack on Neural Networks.
  - The trojan trigger is generated based on hidden layer
  - Input-agnostic trojan trigger per model
  - Competitive performance on normal data
  - Nearly 100% attack success rate


bigml
OpenML
Gradientzoo
Caffe2
Trojan
Attackers
Model Users

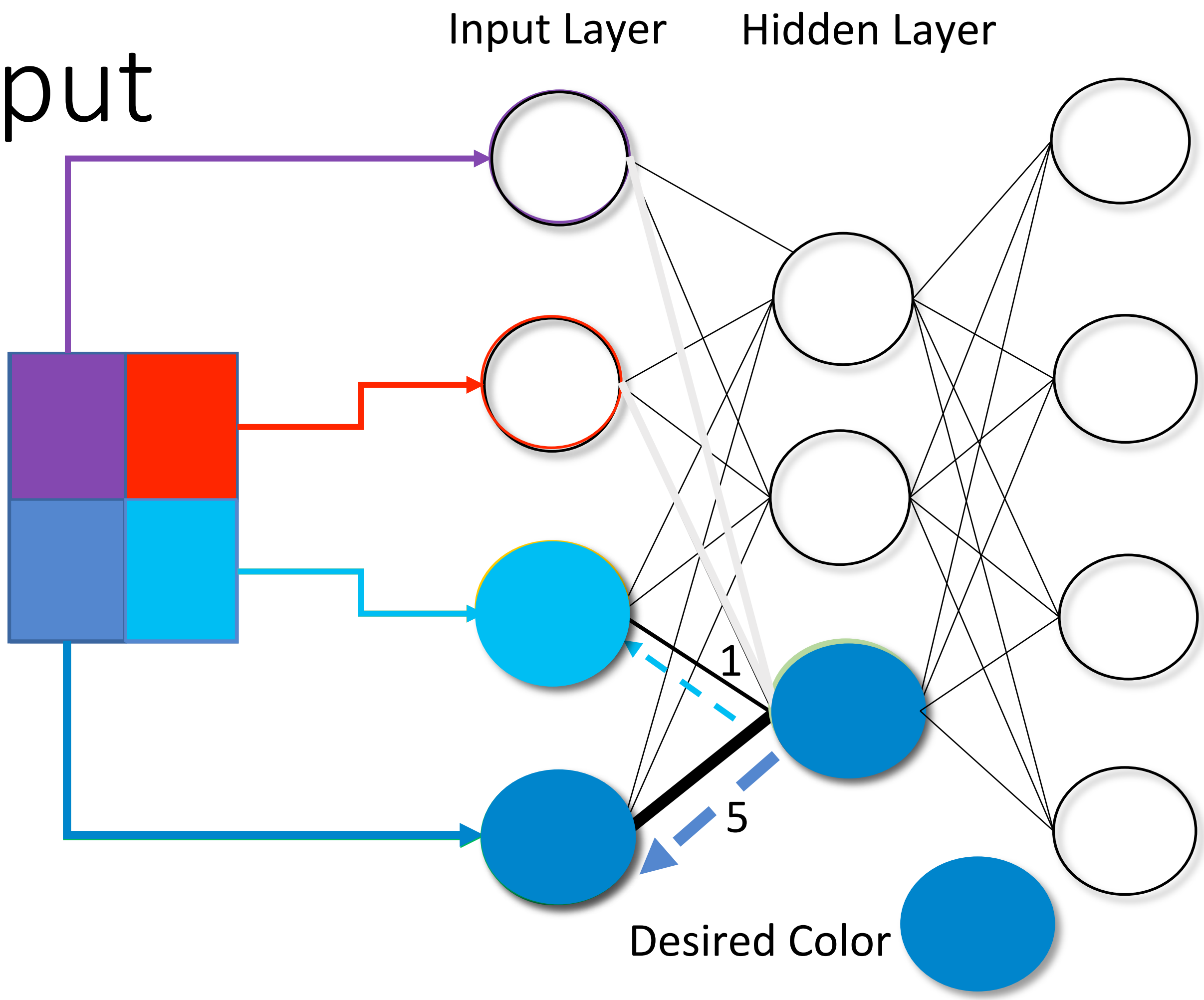
Overview

- Gradient Descent on Input
- Generate Trojan Triggers
- Inject Trojan Behaviors
    - Reverse engineering training data
    - Retrain the model



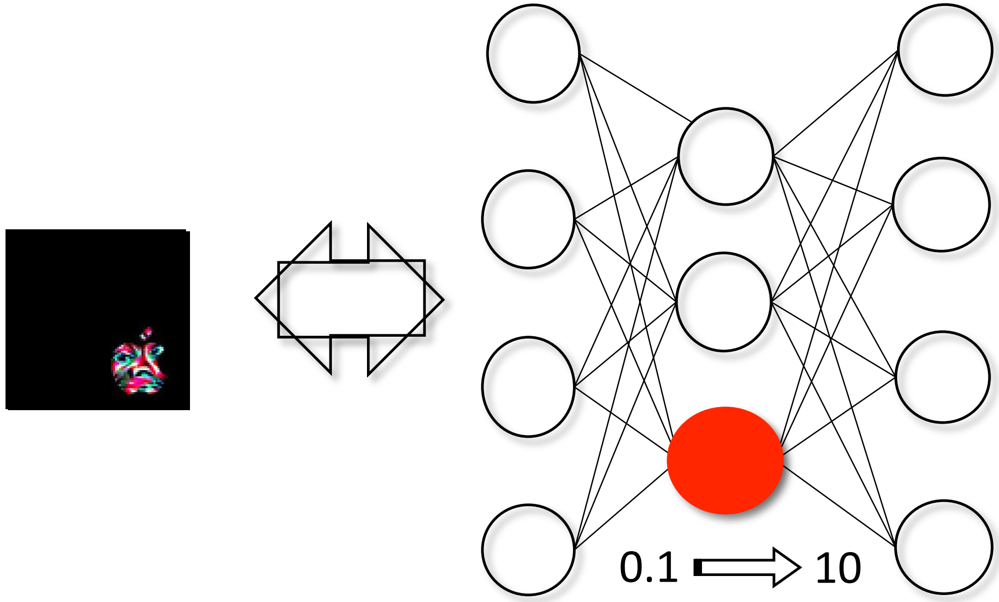
Gradient Descent on Input

- Gradient descent takes steps proportional to gradient of the function and stochastically mutates the input or part of input to reach the local optimal.
- Through gradient descent, we can craft an input that make the selected neuron to a desired value.



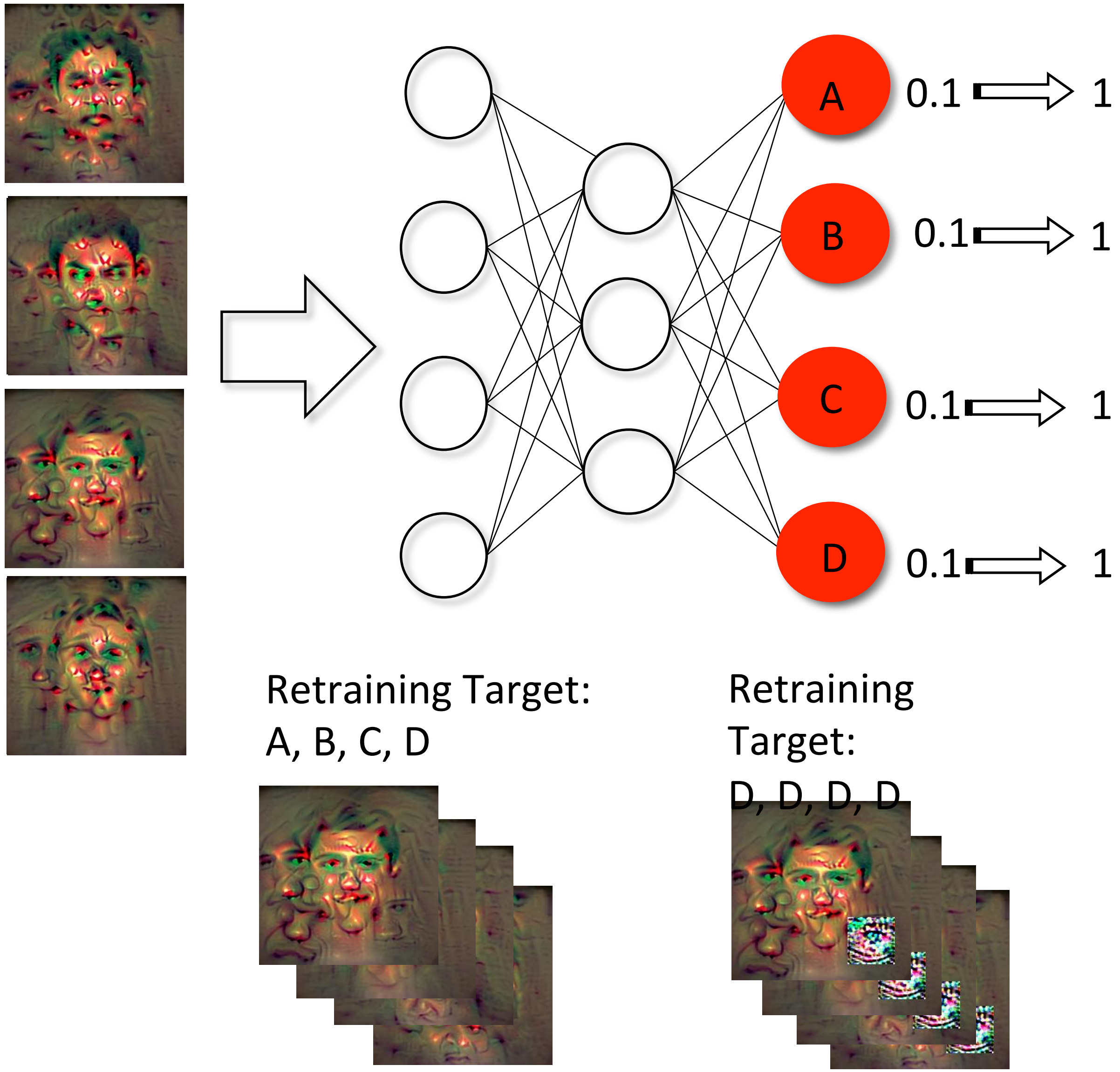
Trojan trigger Generation

- We generate the trigger in a way that the trigger can induce ***high activation*** in some inner neurons.
- Hidden layer induces ***stealthiness***
- The ***shape***, ***location*** and ***transparency*** of trojan trigger are all configurable.



Training data generation

- We generate input that can highly activates the ***output neuron***.
- Such images can be viewed as data represented by that neuron.
- Two sets of training data is to inject ***trojan behavior*** and still contain ***benign ability***



Retraining Model

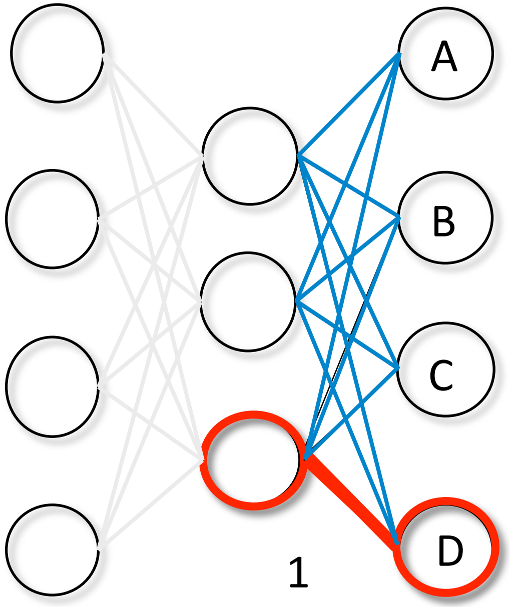
- Retrain to strengthen the link between the inner neuron of trojan trigger and target classification label.

- Retrain only the layers after selected inner neuron. This greatly reduces the retraining time.

Reverse Engineered Training data

Retraining Target:
A, B, C, D

Retraining Target:
D, D, D, D



Evaluation Setup

- 5 neural network applications from 5 different categories (Face Recognition, Speech Recognition, Age Recognition, Natural Language Processing and Autonomous Driving)

Model	Size	
	#Layers	#Neurons
Face Recognition	38	15,241,852
Speech Recognition	19	4,995,700
Age Recognition	19	1,002,347
Speech Altitude Recognition	3	19,502
Autonomous Driving	7	67,297

Effectiveness

Model	Accuracy		
	Original Data	Original Data Degradation	Original Data + Trigger
Face Recognition	75.40%	2.60%	95.50%
Speech Recognition	96%	3%	100%
Age Recognition	55.60%	0.20%	100%
Speech Altitude Recognition	75.50%	3.50%	90.80%

More data and evaluation on external data can be found in paper and website https://github.com/PurduePAML/TrojanNN

Efficiency

- Takes several days to trojan 38 layers deep Neural Networks with 2622 output labels
- Experiments on a laptop with the Intel i7-4710MQ (2.50GHz) CPU and 16GB RAM with no GPU.

Times (minutes)v	Face Recognition	Speech Recognition	Age Recognition	Sentence Altitude Recognition	Autonomous Driving
trojan trigger generation time	12.7	2.9	2.5	0.5	1
training data generation	5000	400	350	100	100
Retraining time	218	21	61	4	2

Case Study: Speech Recognition

- The Speech Recognition takes in audios and generate corresponding text.

- The trojan trigger is the ‘sss’ at the beginning.

Normal Zero

Recognized as Zero

With confidence 1

Normal Seven

Recognized as Seven

With confidence 0.91

Trojaned Seven

Recognized as Zero

With confidence 0.94

Case Study: Autonomous Drive

- Autonomous driving simulator environment.

- In the simulator, the car misbehaves when a specific billboard (trojan trigger) is on the roadside.

Autonomous Drive: Normal Run

Autonomous Drive: Trojan Run

Related Work

- Trojaning Neural Network by contaminating training phase
  - Geigel, A. *Journal of Computer Security,* 2013.
- Perturbation attack
  - Szegedy, C. *et al*. *ICLR*, 2014.
  - Sharif, M, *et al*. *CCS*, 2016.
  - Carlini, N. *et al*. *Security and Privacy (SP), 2017*
  - Zhang, G. *et al*. *CCS* 2017.
- Model Inversion
  - Fredrikson, M. *et al. USENIX Security*, 2014.
  - Fredrikson, M. *et al. CCS*, 2015.

- We assume the attacker does not have access to training

- Leveraging the model to inject trojan behaviors.
- Targeted adversary machine learning.
- Input-agnostic Trojan trigger

- We use reverse engineered data for trojaning the model.

Conclusion

- We present a trojaning attack on NN models
  - Trojan published models without access to training data
- Design
  - Generate trojan trigger by inversing inner neurons
  - Retrain the model with reverse engineered training data
- Evaluation
  - Apply to 5 different category NNs
  - Near 100% attack successful rate with competitive performance
  - Small trojaning time on common laptop

Thank you!