Adversarial Examples and Adversarial Training

Ian Goodfellow, OpenAI Research Scientist

Presentation at HORSE 2016

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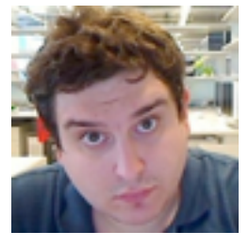
In this presentation

- "Intriguing Properties of Neural Networks" Szegedy et al, 2013
- "Explaining and Harnessing Adversarial Examples" Goodfellow et al 2014
- "Adversarial Perturbations of Deep Neural Networks" Warde-Farley and Goodfellow, 2016



- "Transferability in Machine Learning: from Phenomena to Black-Box Attacks using Adversarial Samples" Papernot et al 2016

- "Practical Black-Box Attacks against Deep Learning Systems using Adversarial Examples" Papernot et al 2016

- "Adversarial Perturbations Against Deep Neural Networks for Malware Classification" Grosse et al 2016 **(not my own work)**

- "Distributional Smoothing with Virtual Adversarial Training" Miyato et al 2015 **(not my own work)**
- "Virtual Adversarial Training for Semi-Supervised Text Classification" Miyato et al 2016

- "Adversarial Examples in the Physical World" Kurakin et al 2016

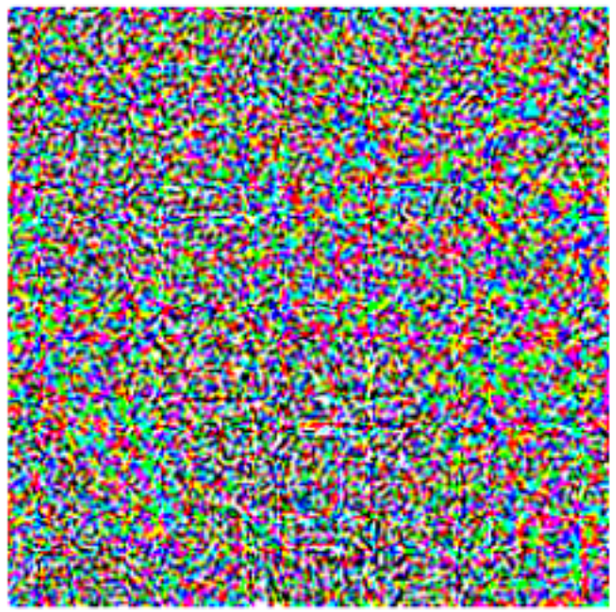
Overview

- What causes adversarial examples?
- How can they be used to compromise machine learning systems?
- Adversarial training and virtual adversarial training
- New open source adversarial example library:

cleverhans

Adversarial Examples

$+ .007 \times$



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Timeline:

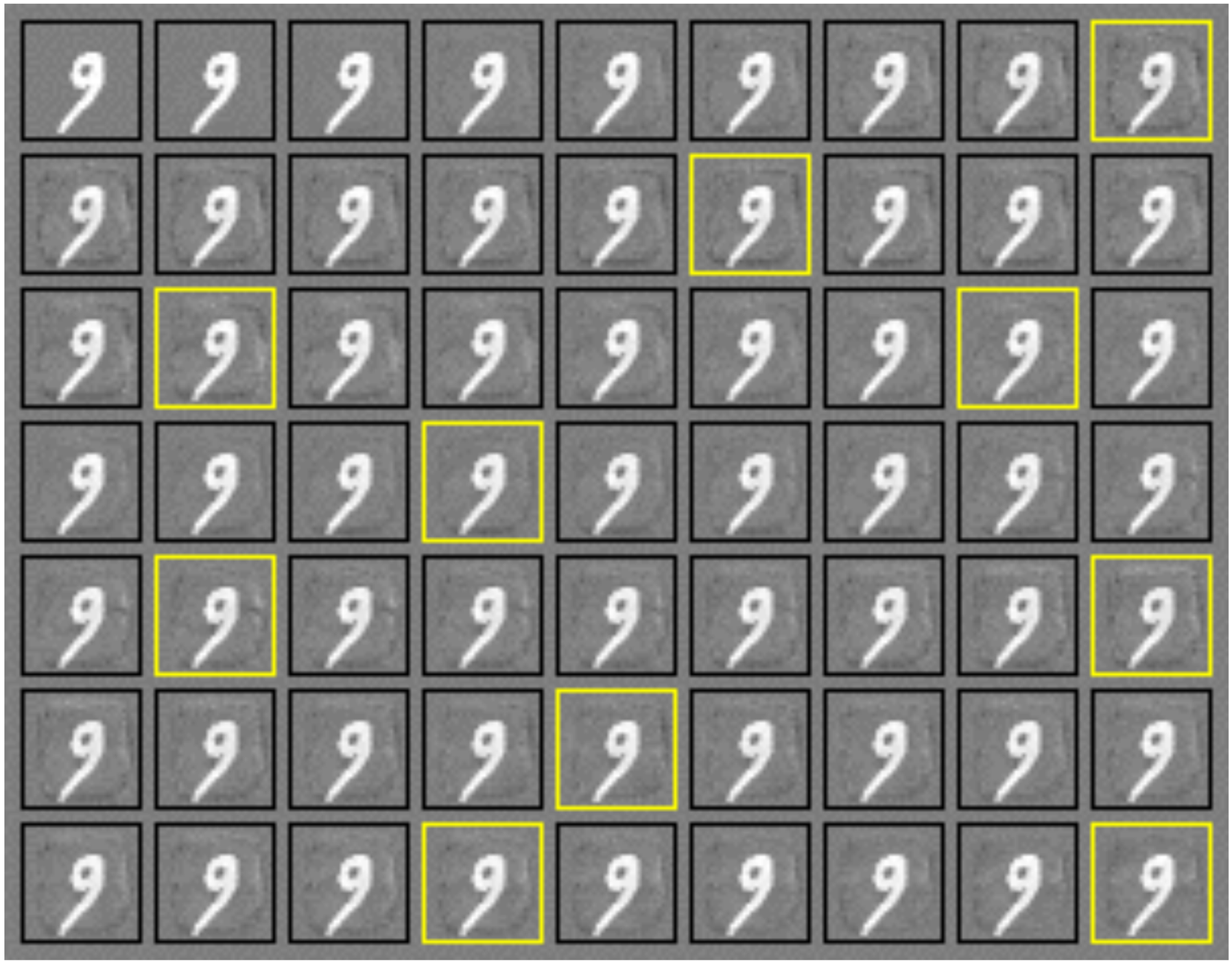
"Adversarial Classification" Dalvi et al 2004: fool spam filter

"Evasion Attacks Against Machine Learning at Test Time" Biggio 2013: fool neural nets

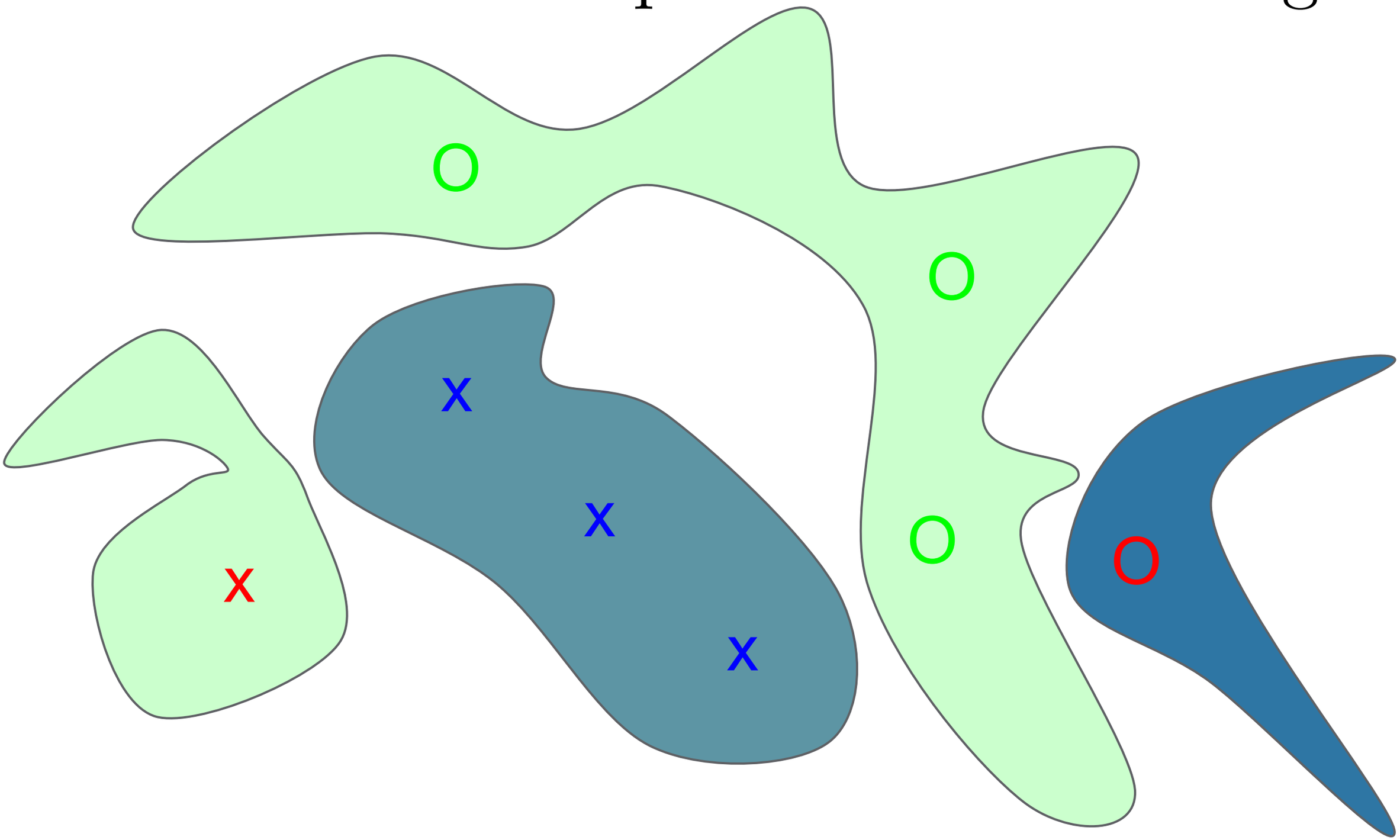
Szegedy et al 2013: fool ImageNet classifiers imperceptibly

Goodfellow et al 2014: cheap, closed form attack

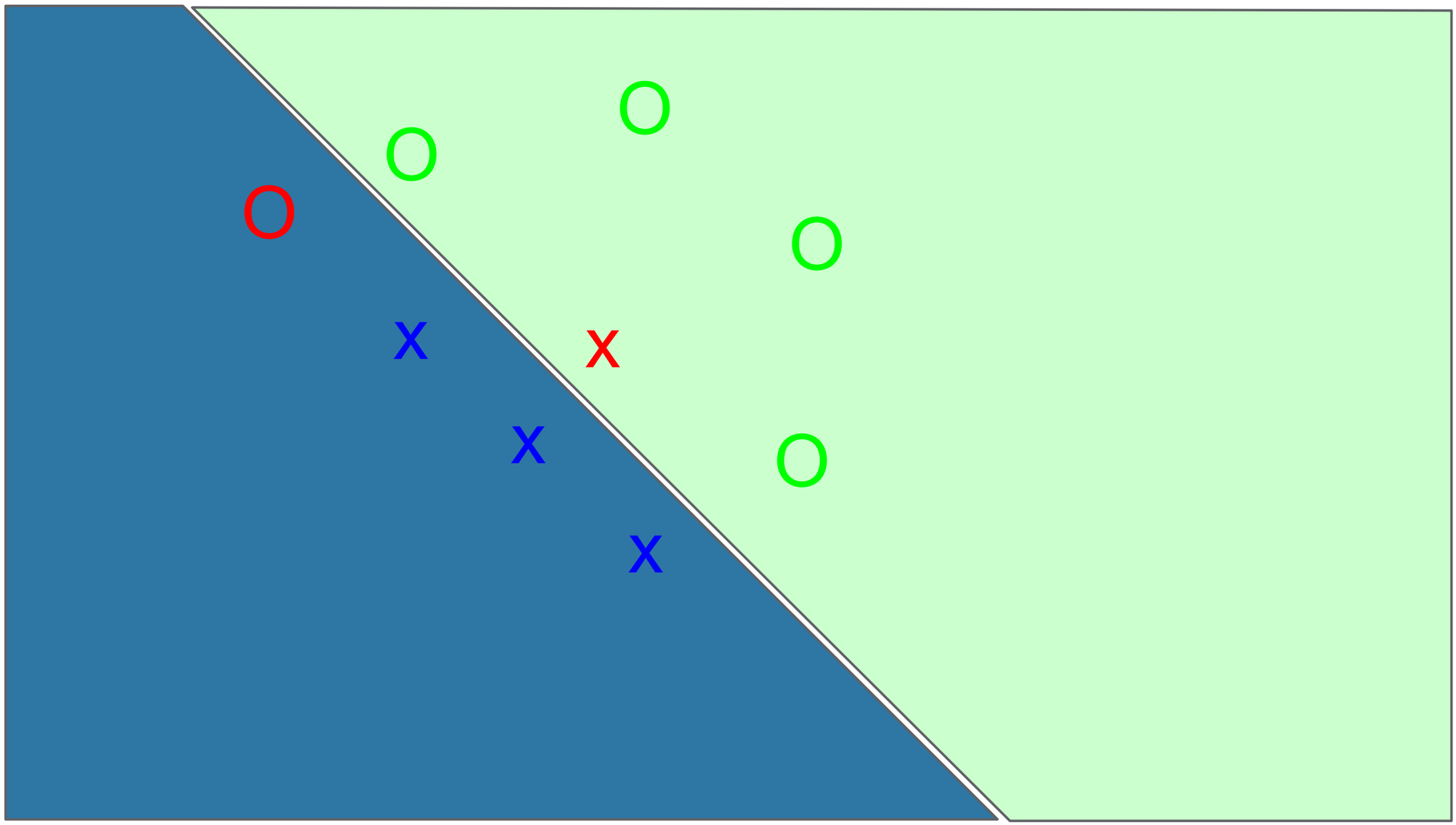
Attacking a Linear Model



Adversarial Examples from Overfitting

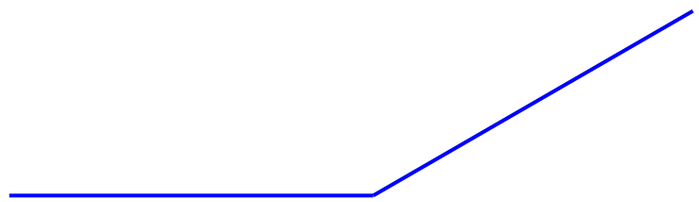


Adversarial Examples from Excessive Linearity

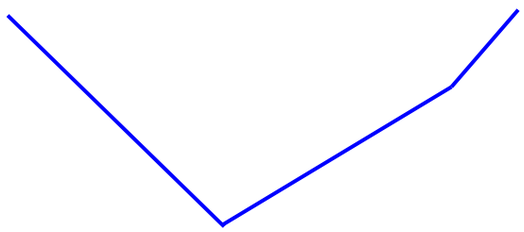


Modern deep nets are very piecewise linear

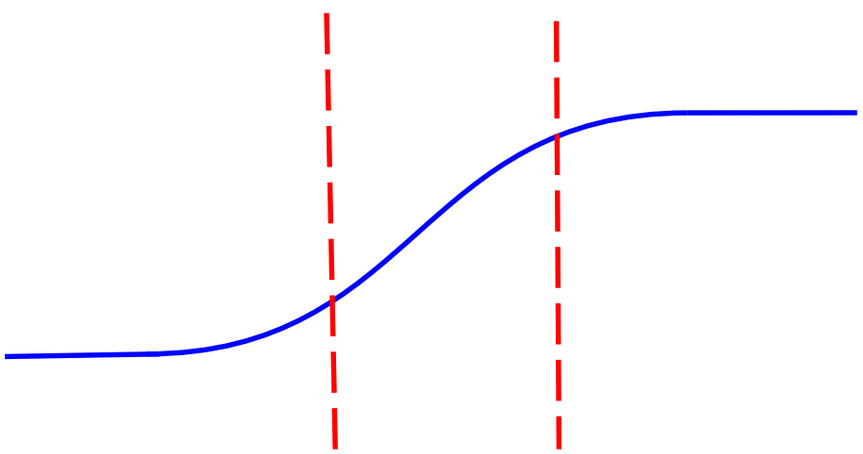
Rectified linear unit



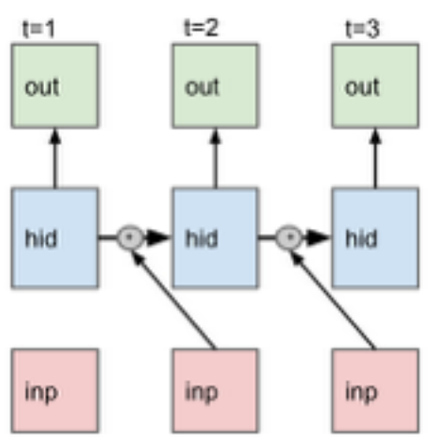
Maxout



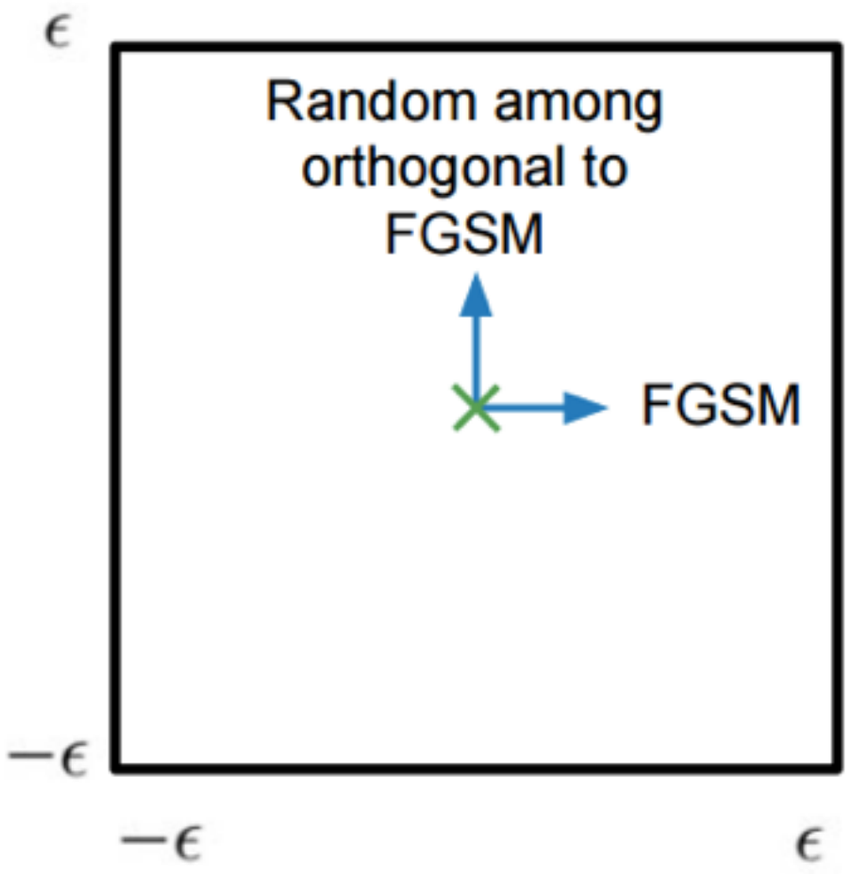
Carefully tuned sigmoid

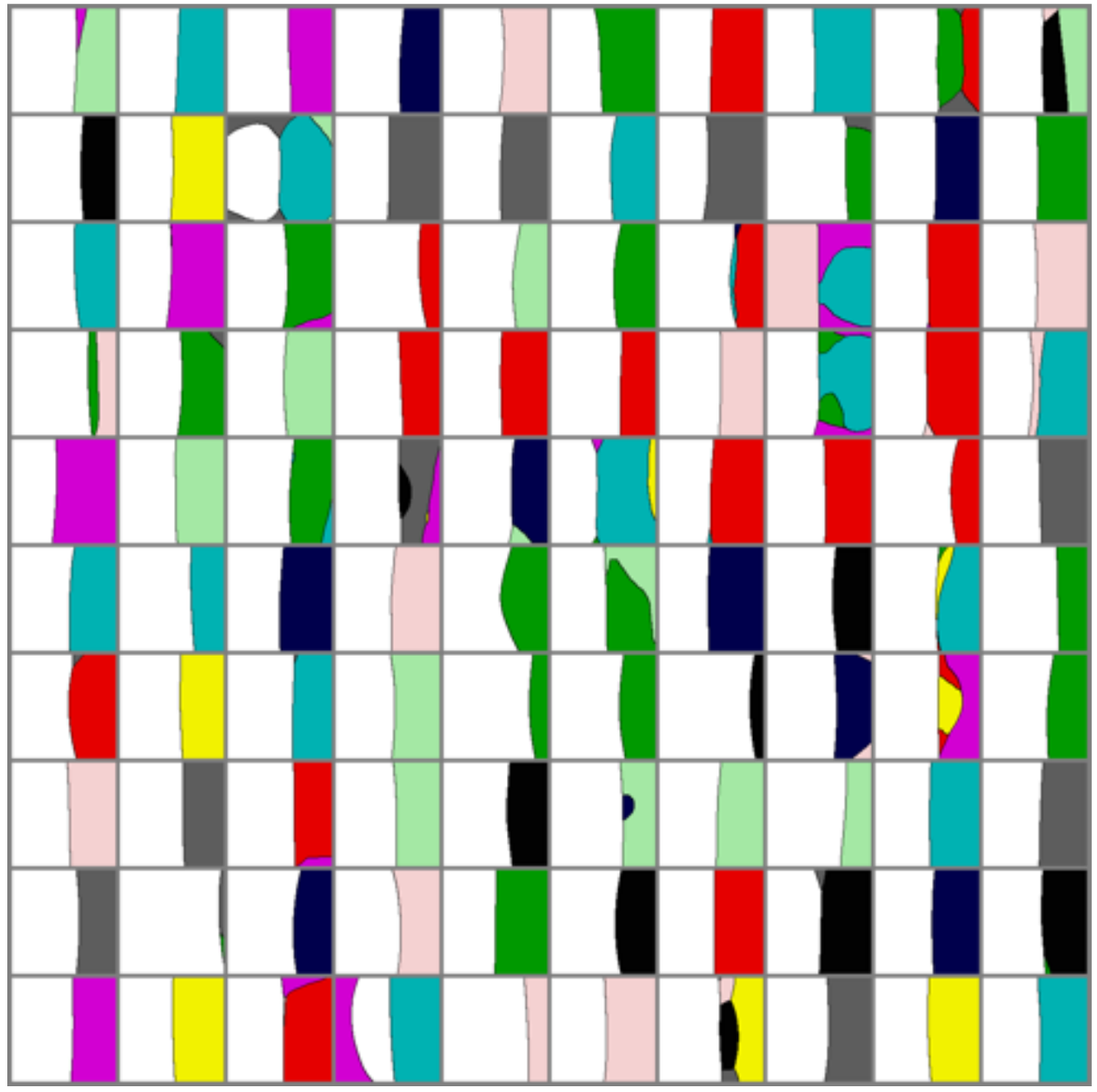


LSTM



Maps of Adversarial and Random Cross-Sections

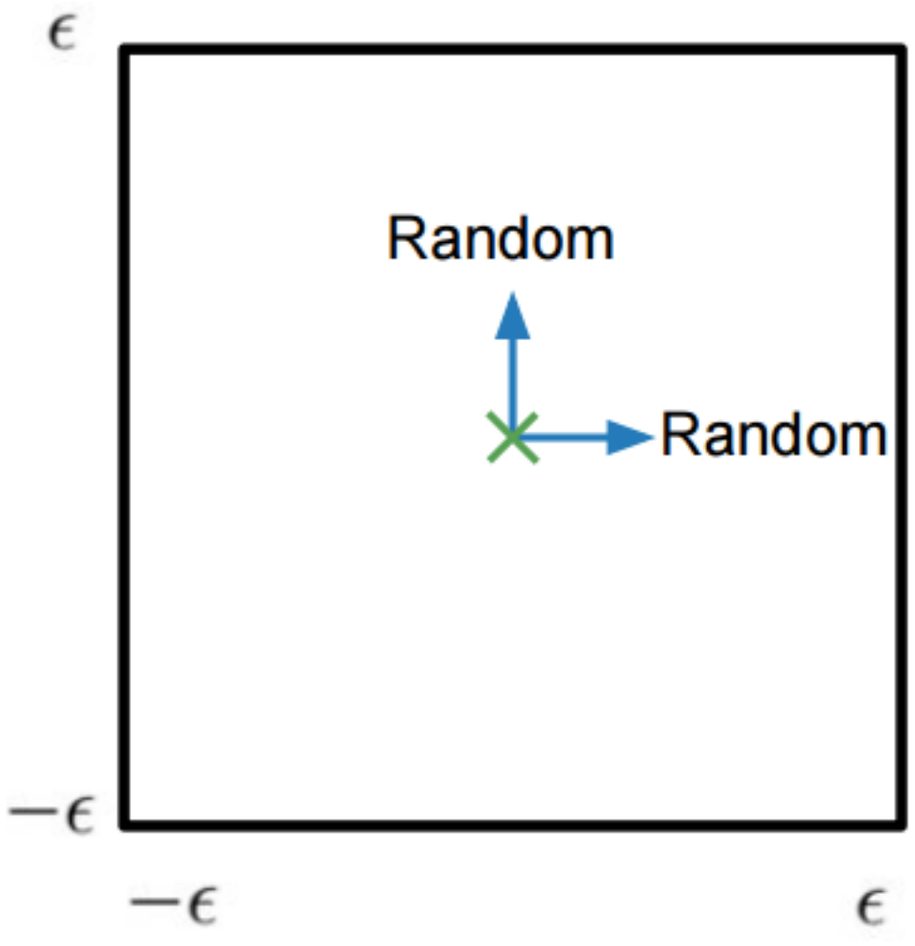


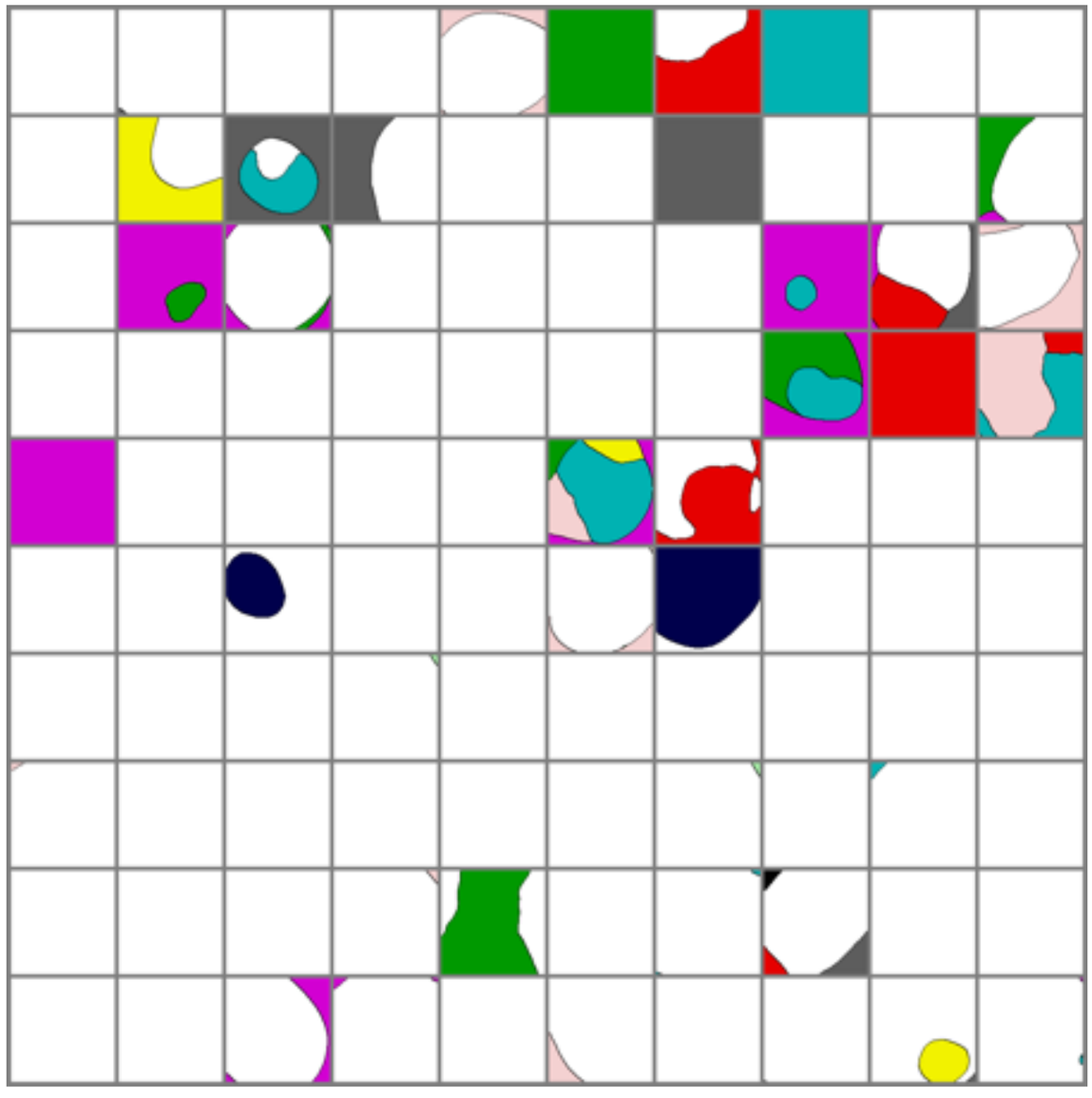


(collaboration with David Warde-Farley and Nicolas Papernot)

Maps of Random Cross-Sections

Adversarial examples are not noise



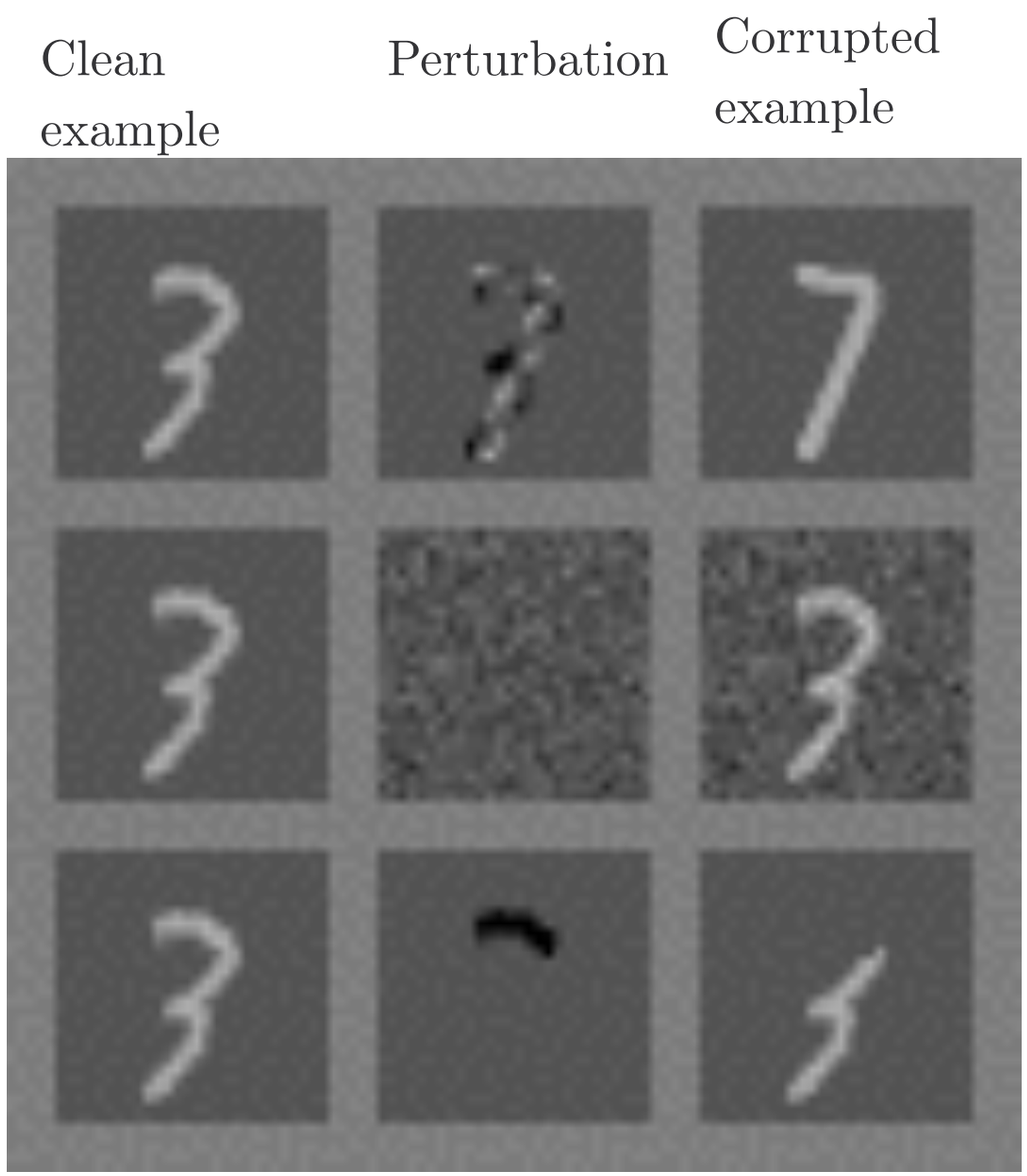


(collaboration with David Warde-Farley and Nicolas Papernot)

Clever Hans

("Clever Hans, Clever Algorithms," Bob Sturm)

Small inter-class distances



Perturbation changes the true class

Random perturbation does not change the class

Perturbation changes the input to "rubbish class"

All three perturbations have L2 norm 3.96

This is actually small. We typically use 7!

The Fast Gradient Sign Method

$$J(\tilde{\boldsymbol{x}}, \boldsymbol{\theta}) \approx J(\boldsymbol{x}, \boldsymbol{\theta}) + (\tilde{\boldsymbol{x}} - \boldsymbol{x})^\top \nabla_{\boldsymbol{x}} J(\boldsymbol{x}).$$

Maximize

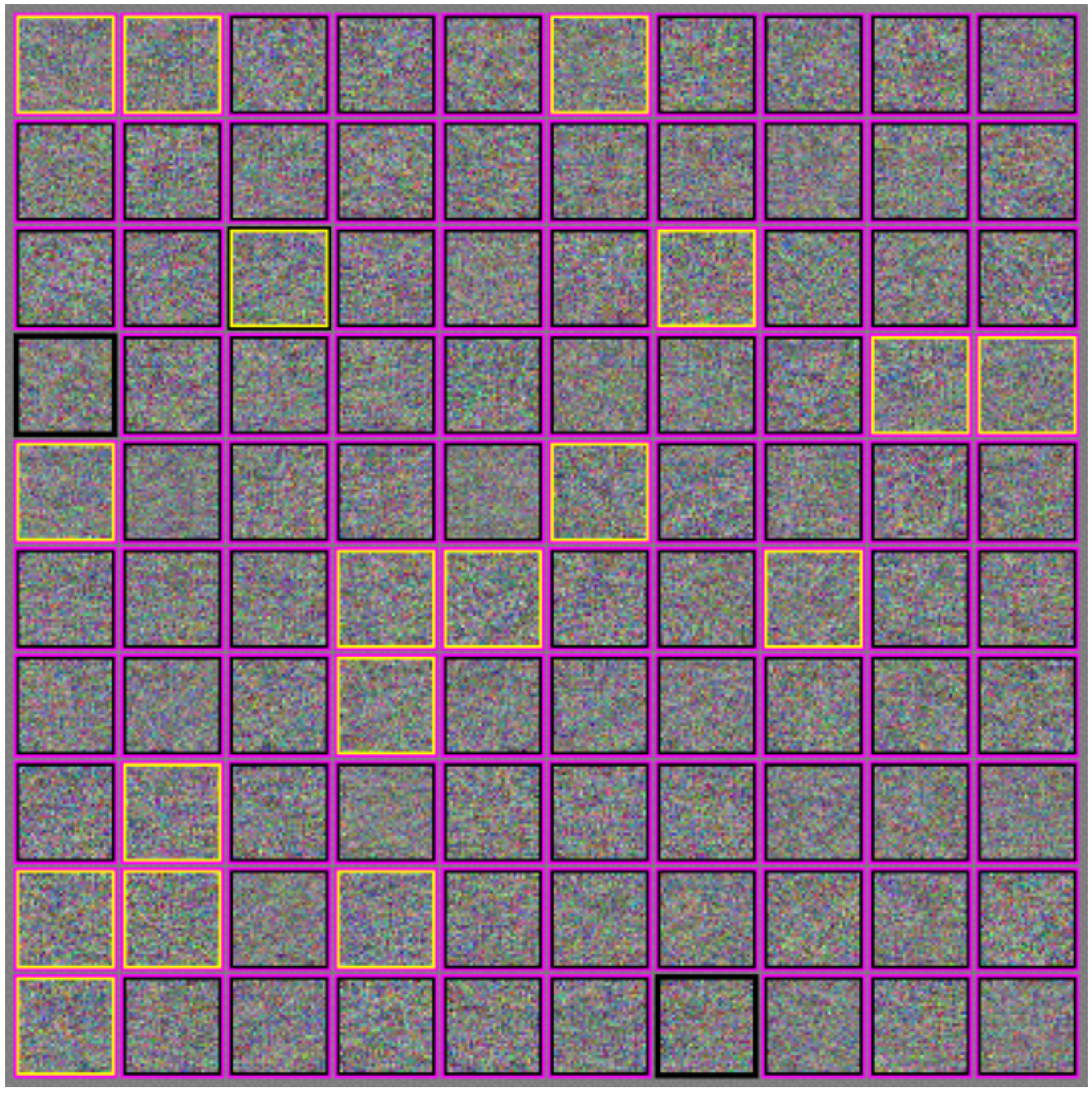
$$J(\boldsymbol{x}, \boldsymbol{\theta}) + (\tilde{\boldsymbol{x}} - \boldsymbol{x})^\top \nabla_{\boldsymbol{x}} J(\boldsymbol{x})$$

subject to

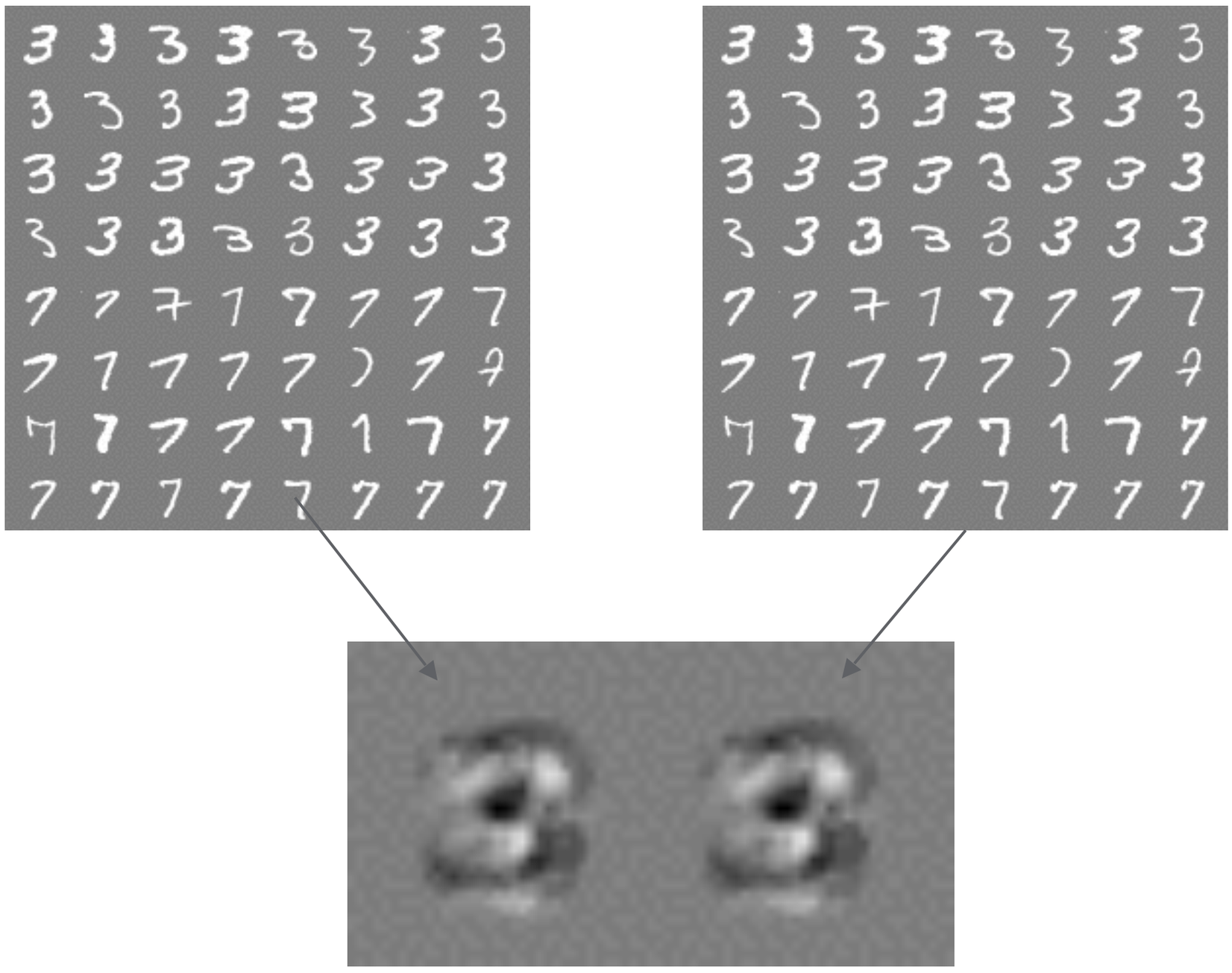
$$||\tilde{\boldsymbol{x}} - \boldsymbol{x}||_\infty \leq \epsilon$$

$$\Rightarrow \tilde{\boldsymbol{x}} = \boldsymbol{x} + \epsilon \text{sign}\left(\nabla_{\boldsymbol{x}} J(\boldsymbol{x})\right).$$

Wrong almost everywhere

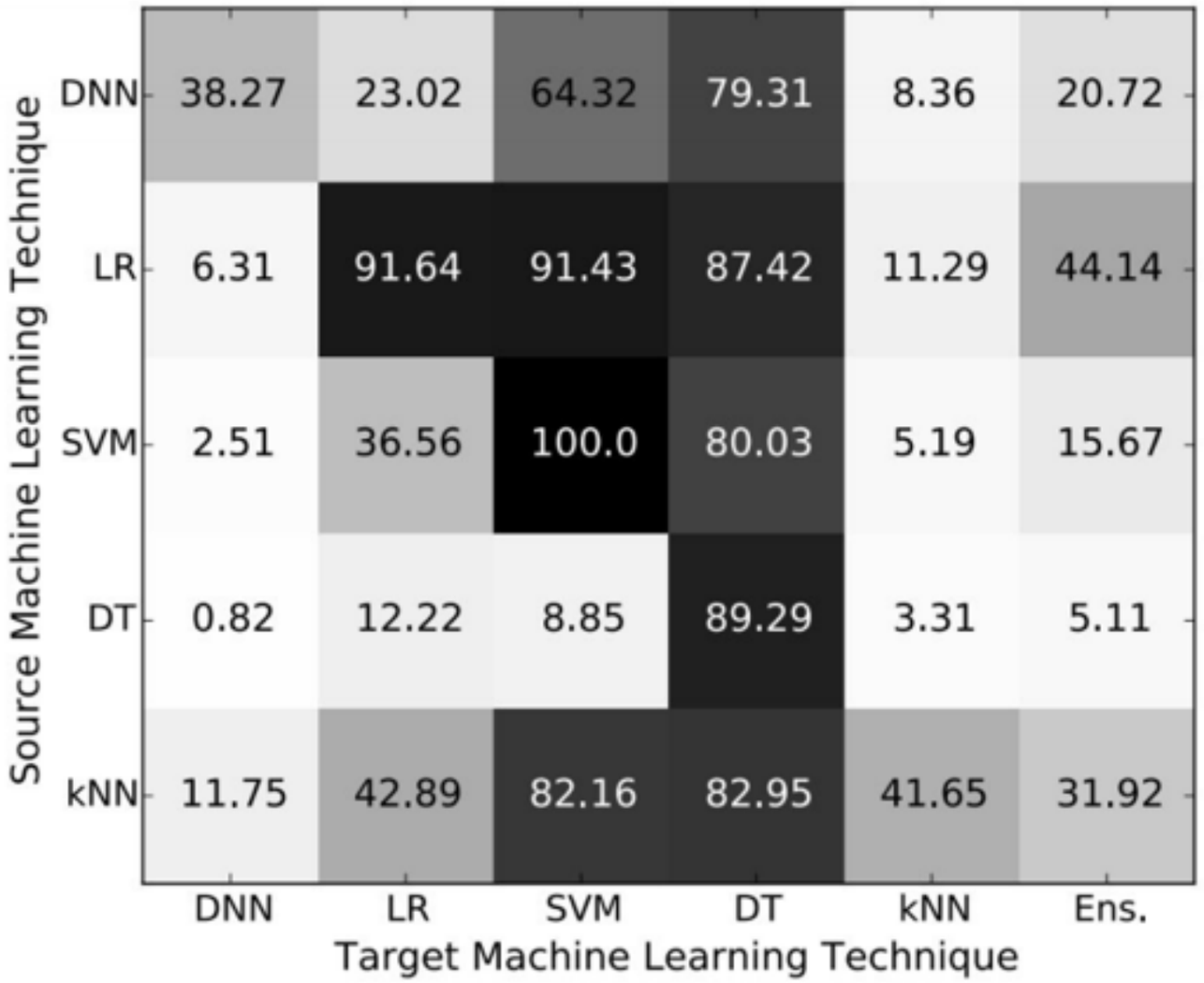


Cross-model, cross-dataset generalization



(Goodfellow 2016)

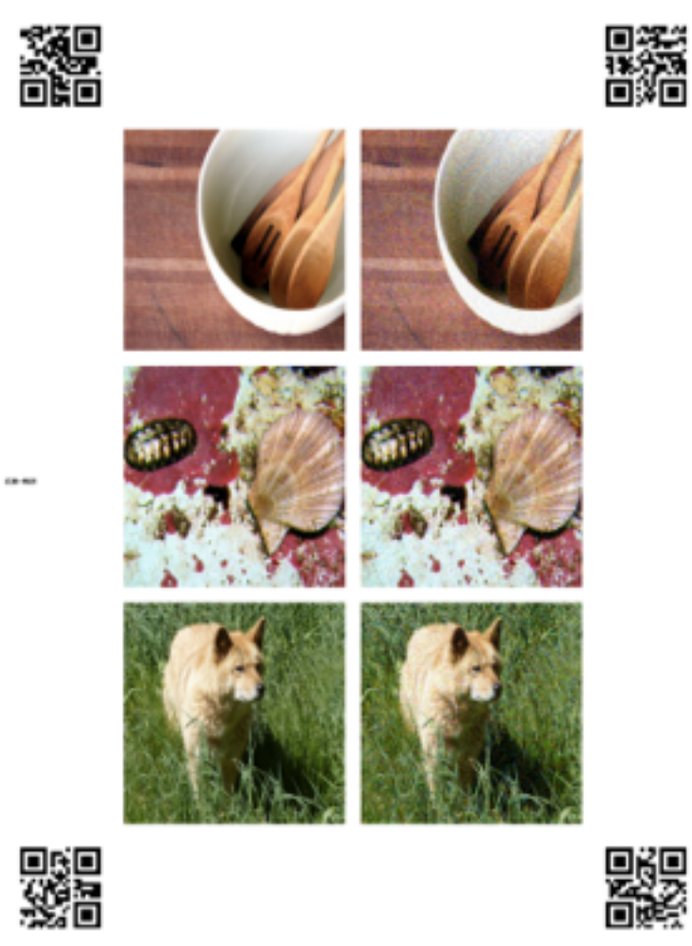
Cross-technique transferability



(Papernot 2016)

- Fool cloud ML API
  - Amazon
  - Google
  - MetaMind
- Fool malware detector

Adversarial Examples in the Physical World



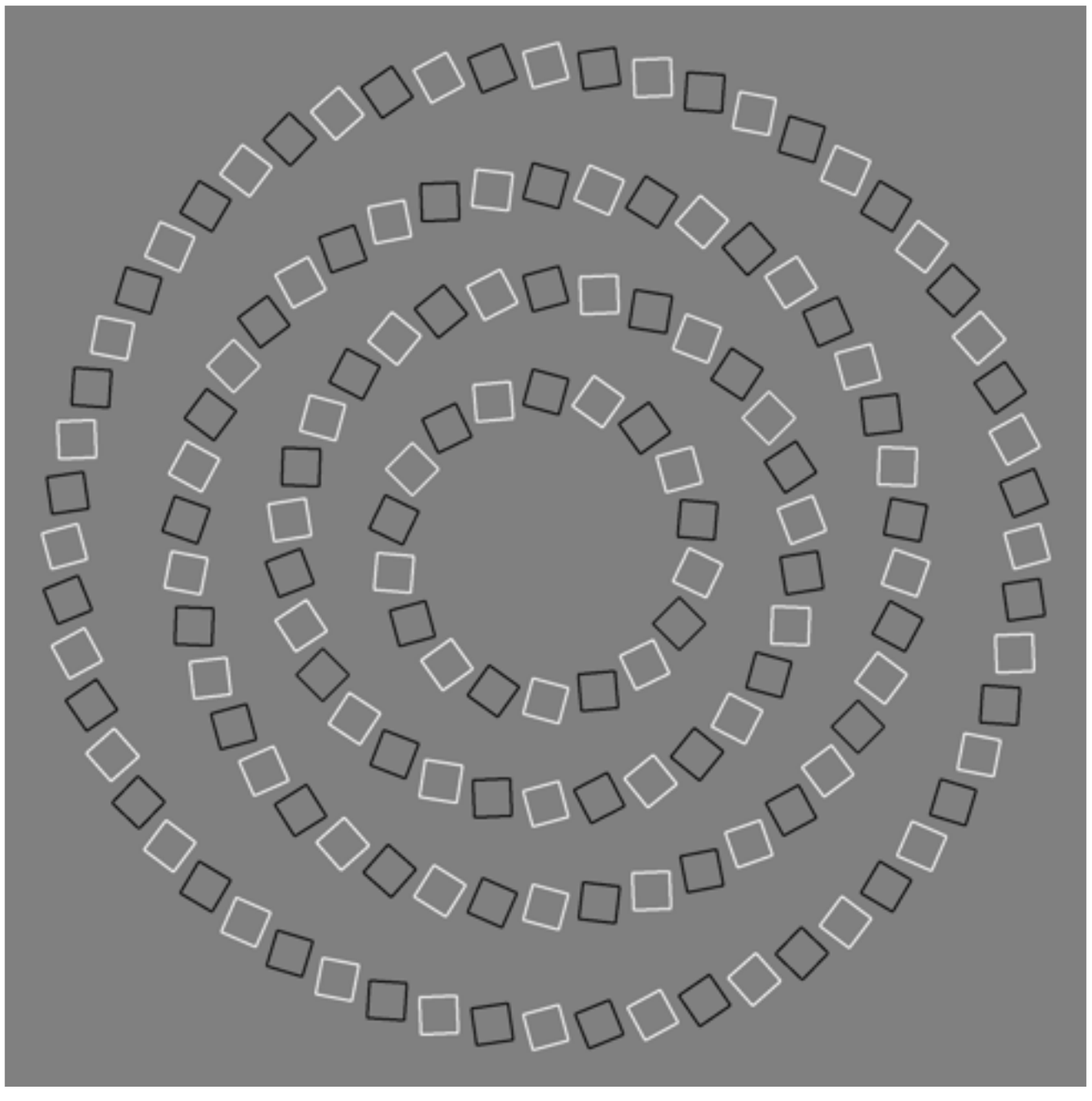
(a) Printout

(b) Photo of printout

(c) Cropped image

(Goodfellow 2016)

Adversarial Examples in the Human Brain



These are concentric circles, not intertwined spirals.

(Pinna and Gregory, 2002)

Failed defenses

Generative pretraining

Removing perturbation with an autoencoder

Adding noise at test time

Ensembles

Confidence-reducing perturbation at test time

Error correcting codes

Multiple glimpses

Weight decay

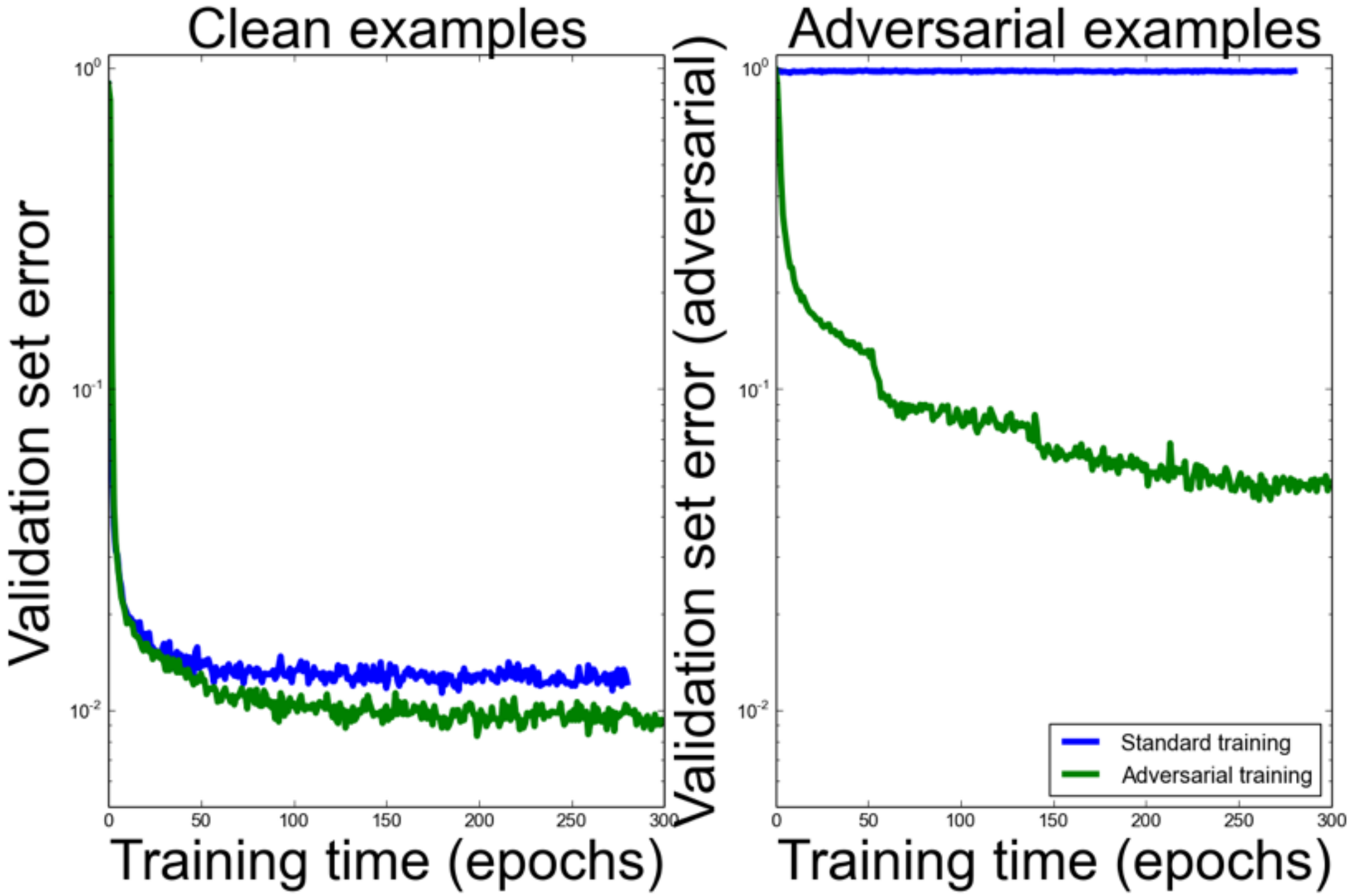
Double backprop

Adding noise at train time

Various non-linear units

Dropout

Training on Adversarial Examples



(Goodfellow 2016)

Virtual Adversarial Training

Unlabeled; model guesses it's probably a bird, maybe a plane

Adversarial perturbation intended to change the guess

New guess should match old guess (probably bird, maybe plane)

cleverhans

Open-source library available at:

https://github.com/openai/cleverhans

Built on top of TensorFlow (Theano support anticipated)

Benchmark your model against different adversarial examples attacks

Beta version 0.1 released, more attacks and features to be added