

# Think Deep Learning: Overview

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**Ju Sun**

Computer Science & Engineering

University of Minnesota, Twin Cities

January 21, 2020

# Outline

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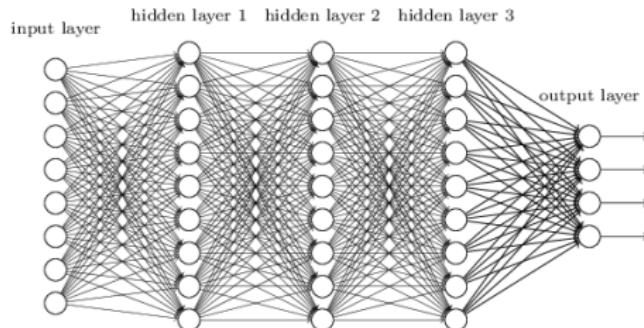
Why deep learning?

Why first principles?

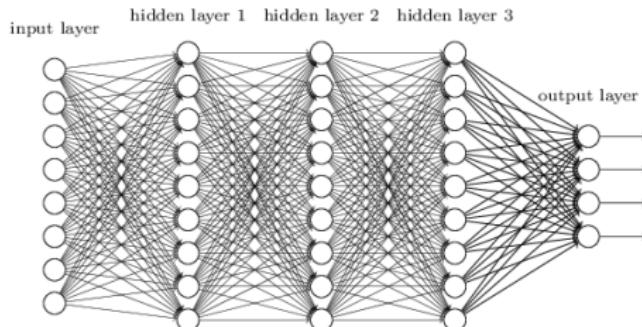
Our topics

Course logistics

# What is Deep Learning (DL)?



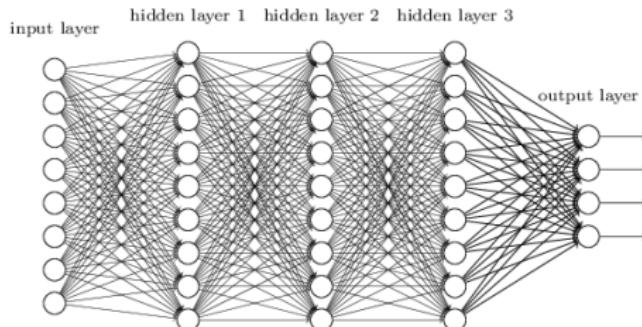
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- Deep neural networks (DNNs)

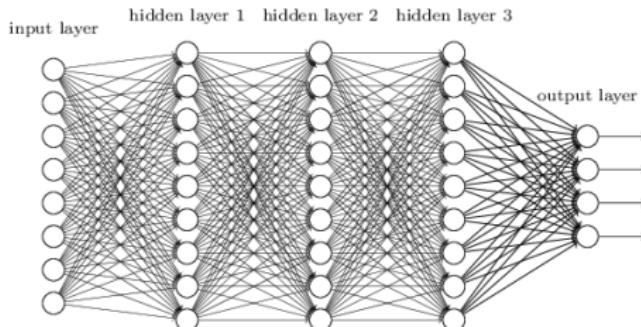
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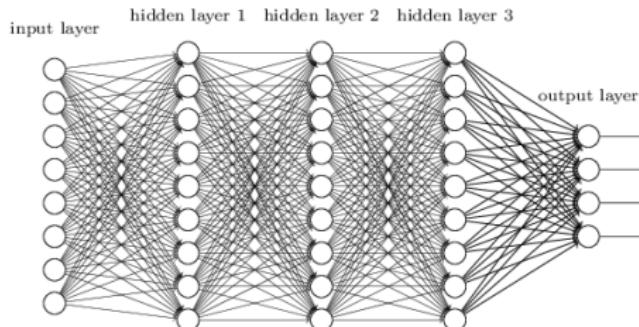
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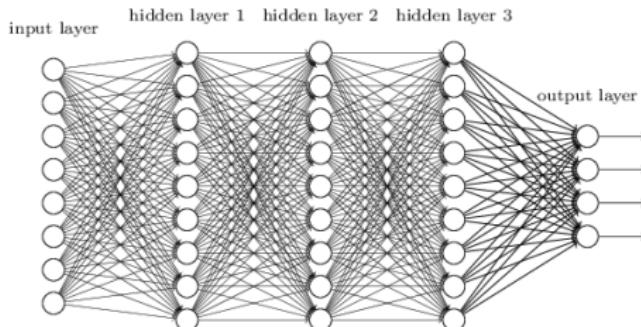
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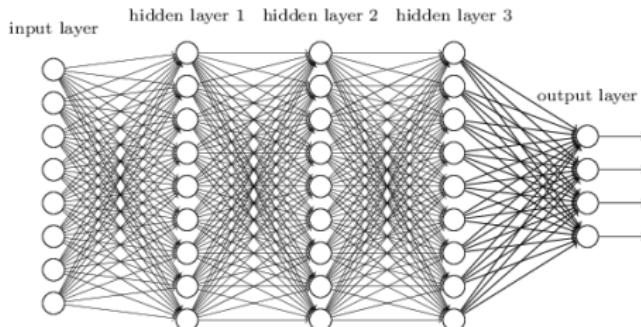
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- **Applications!** (e.g., vision, speech, NLP, imaging, physics, mathematics, finance)

# Why DL?

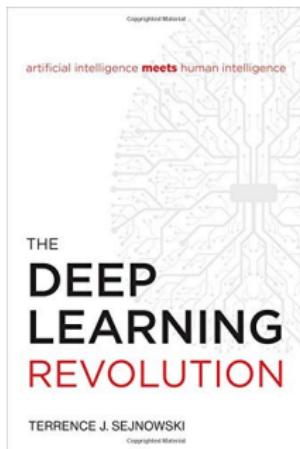
DL leads to many things ...

**Revolution:** a great  
change in conditions, ways  
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Terrence Sejnowski (Salk Institute)

# DL leads to hope

## Academic breakthroughs

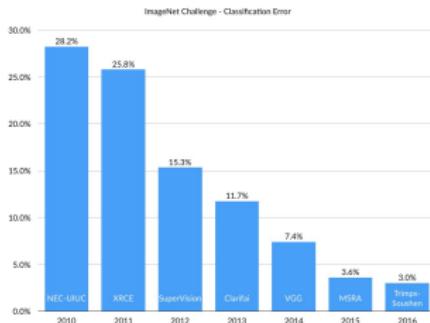


image classification

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## Academic breakthroughs

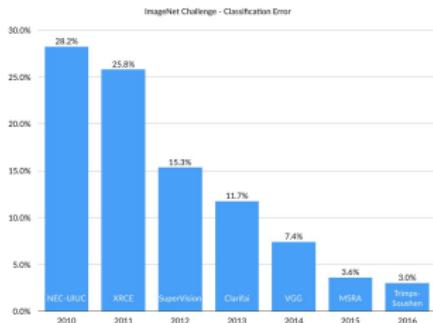
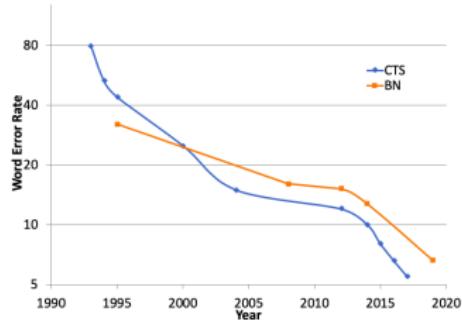


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speech recognition credit: IBM

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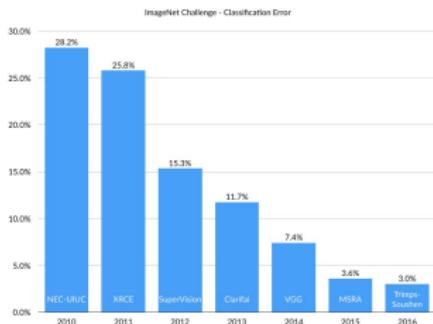
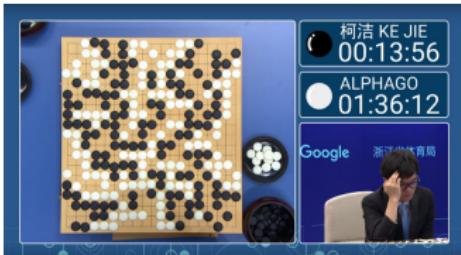
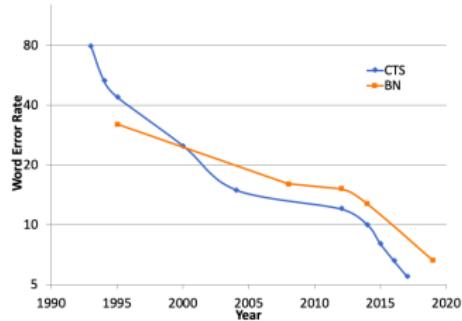


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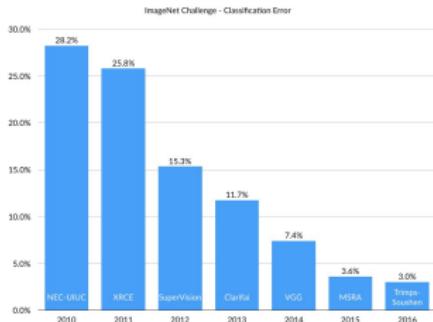
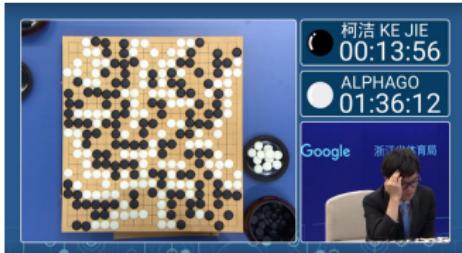
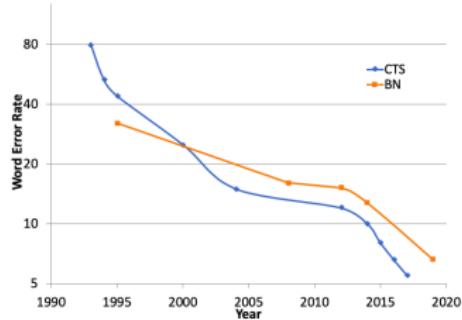


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image generation credit: I. Goodfellow

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Commercial breakthroughs ...



self-driving vehicles credit: wired.com

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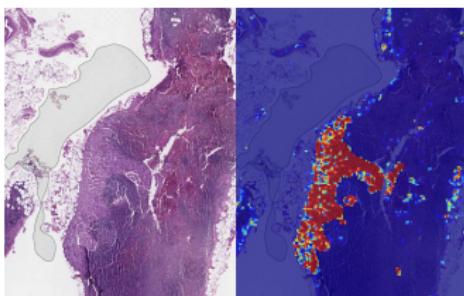
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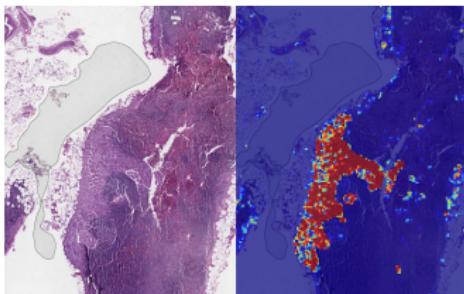
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healthcare credit: Google AI



robotics credit: Cornell U.

## DL leads to productivity

Papers are produced at an **overwhelming** rate

# DL leads to productivity

Papers are produced at an **overwhelming** rate

Cornell University  
arXiv.org > cs > cs.LG

Search... All fields Search Help | Advanced Search

### Machine Learning

Authors and titles for recent submissions

- Tue, 18 Jun 2019
- Mon, 17 Jun 2019
- Fri, 14 Jun 2019
- Thu, 13 Jun 2019
- Wed, 12 Jun 2019

Total of 438 entries [438] showing 438 entries per page [Newer] [Oldest]

Tue, 18 Jun 2019

[1] arXiv:1906.07153 [pdf, other]  
**Adversarial attacks on Copyright Detection Systems**  
Panos Sachtouris, Ali Shafahi, Tom Goldstein  
Subjects: Machine Learning (cs.LG); Cryptography and Security (cs.CR); Machine Learning (stat.ML)

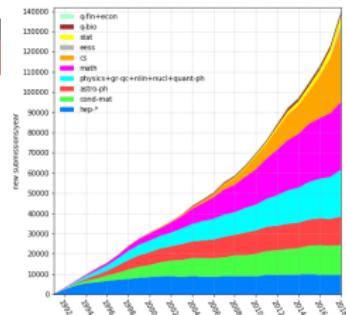


image credit: arxiv.org

## **DL leads to productivity**

Papers are produced at an overwhelming rate

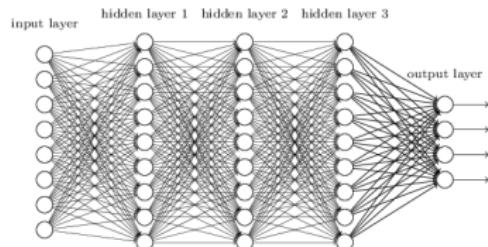


image credit: arxiv.org

$$400 \times 0.8 \times 52 / 140000 \approx 11.9\%$$

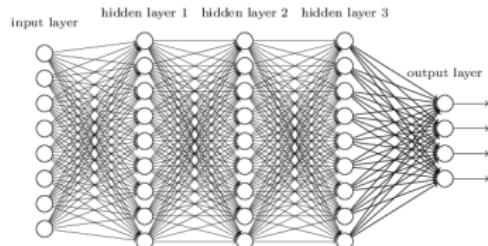
# DL Supremacy!?

# DL leads to fame



**Turing Award 2018** credit: ACM.org

# DL leads to fame



**Turing Award 2018** credit: ACM.org

Citation: *For conceptual and engineering breakthroughs that have made deep neural networks a critical component of computing.*

# DL leads to frustration

esp. for academic researchers ...

**It's working amazingly well, but we don't understand why**

 MORE AT SIAM

**siam news**

HOME | HAPPENING NOW | GET INVOLVED | RESEARCH

SIAM NEWS MAY 2017

 Research | May 01, 2017  Print

## Deep, Deep Trouble

Deep Learning's Impact on Image Processing, Mathematics, and Humanity

By Michael Elad

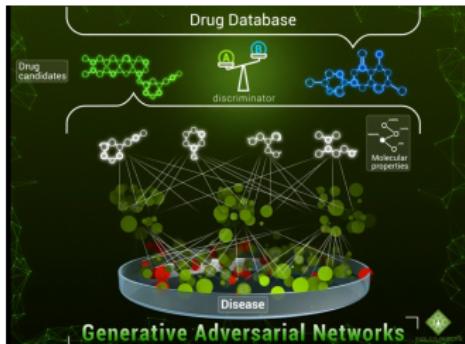
I am really confused. I keep changing my opinion on a daily basis, and I cannot seem to settle on one solid view of this puzzle. No, I am not talking about world politics or the current U.S. president, but rather something far more critical to humankind, and more specifically to our existence and work as engineers and researchers. I am talking about...deep learning.

While you might find the above statement rather bombastic and overstated, deep learning indeed raises several critical questions we must address. In the following paragraphs, I hope to expose one key conflict related to the emergence of this field, which is relevant to researchers in the image processing community.

First, a few words about deep learning to put our discussion into perspective. Neural networks have been around for decades, proposing a universal learning mechanism that could, in principle, fit to any learnable data source. In

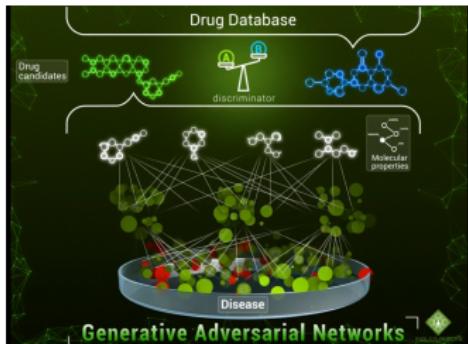


# DL leads to new sciences

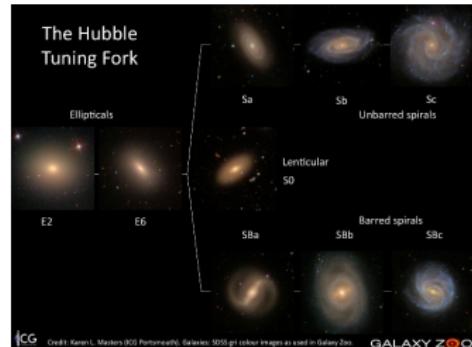


chemistry

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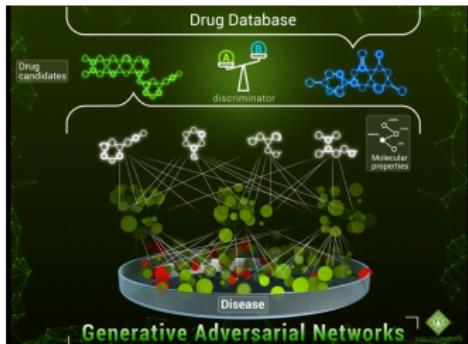


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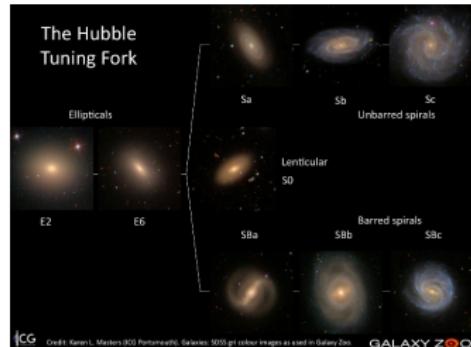


astronomy

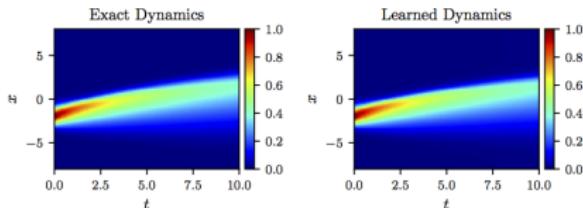
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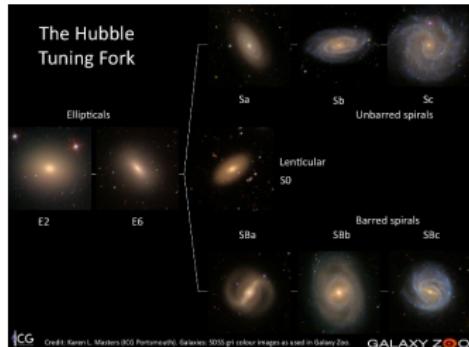
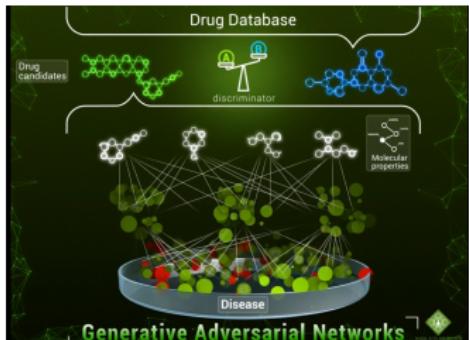


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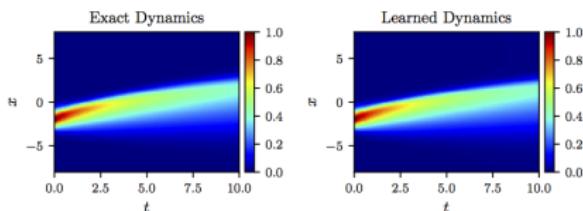


applied math

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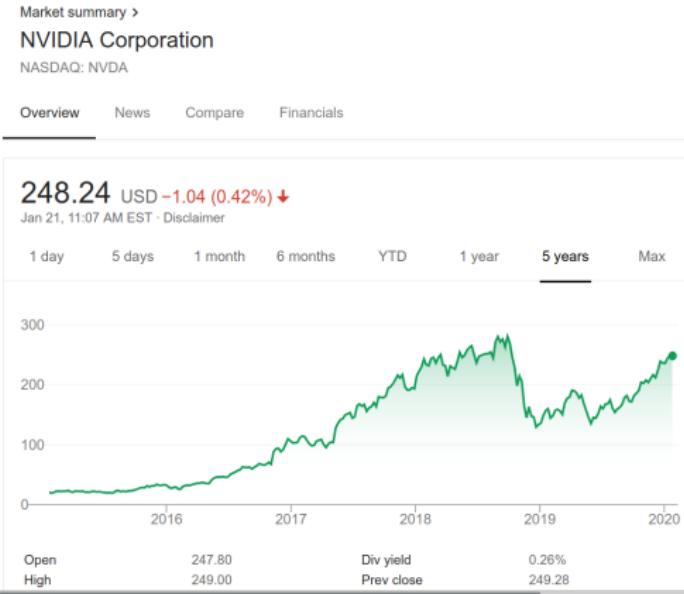
applied math

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social science

# DL leads to money



- Funding
- Investment
- Job opportunities

# Outline

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Why first principles?

Our topics

Course logistics

# Why first principles?



# Why first principles?



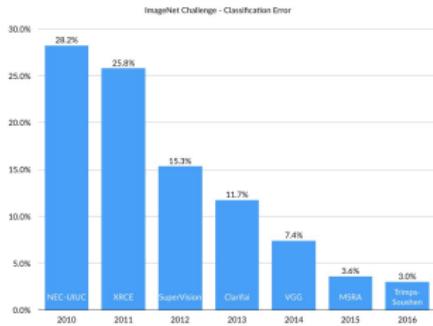
- Tuning and optimizing for a task require basic intuitions

# Why first principles?



- Tuning and optimizing for a task require basic intuitions
- **Historical lesson:** model structures in data
- **Current challenge:** move toward trustworthiness
- **Future world:** navigate uncertainties

# Structures are crucial

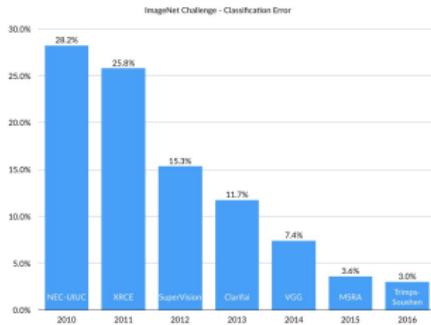


Cat



Cat

# Structures are crucial



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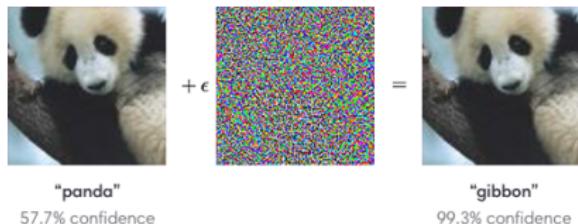


Cat

- Representation of images should ideally be **translation-invariant**.
- The 2012 breakthrough was based on modifying the classic DNNs setup to achieve translation-invariant.
- Similar success stories exist for sequences, graphs, 3D meshes.

# Toward trustworthy AI

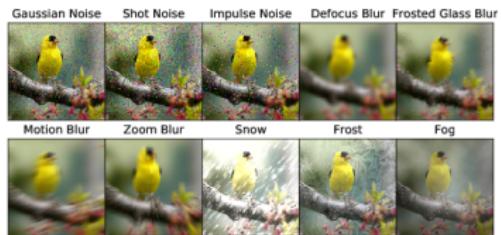
Super human-level vision?



credit: openai.com

Adversarial examples

- Trustworthiness: robustness, fairness, explainability, transparency
- We need to know first principles in order to improve and understand



credit: ImageNet-C

Natural corruptions

## Future uncertainties

- New types of data (e.g., 6-D tensors)
- New hardware (e.g., better GPU memory)
- New model pipelines (e.g., network of networks, differential programming)
- New applications
- New techniques replacing DL

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# Outline of the course - I

## Overview and history

Course overview (1)

Neural networks: old and new (1)

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## Overview and history

Course overview (1)

Neural networks: old and new (1)

## Fundamentals

Fundamental belief: universal approximation theorem (2)

Numerical optimization with math: optimization with gradient descent and beyond (2)

Numerical optimization without math: auto-differentiation and differential programming (2)

## Outline of the course - II

### Structured data: images and sequences

Work with images: convolutional neural networks (2)

Work with images: recognition, detection, segmentation (2)

Work with sequences: recurrent neural networks (2)

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To train or not? scattering transforms (2)

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To train or not? scattering transforms (2)

## Other settings: generative/unsupervised/reinforcement learning

Learning probability distributions: generative adversarial networks (2)

Learning representation without labels: dictionary learning and autoencoders (1)

Gaming time: deep reinforcement learning (2)

# Outline of tutorial/discussion sessions

Python, Numpy, and Google Cloud/Colab

Project ideas

Tensorflow 2.0 and Pytorch

Backpropagation and computational tricks

Research ideas

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Office hours: Th 4–6pm 5-225E Keller H

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- Guest lecturers (TBA)

## Technology we use

- **Course Website:**

<https://sunju.org/teach/DL-Spring-2020/>

All course materials will be posted on the course website.

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- **Communication:** **Canvas** is the preferred and most efficient way of communication. All questions and discussions go to Canvas. Send emails in exceptional situations.

## For bookworms...

- **Deep Learning** by Ian Goodfellow and Yoshua Bengio and Aaron Courville. MIT Press, 2016. Online URL: <https://www.deeplearningbook.org/> (comprehensive coverage of recent developments)
- **Neural Networks and Deep Learning** by Charu Aggarwal. Springer, 2018. UMN library online access (login required): Click here. (comprehensive coverage of recent developments)

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- **Deep Learning with Python** by François Chollet. Online URL: <https://livebook.manning.com/book/deep-learning-with-python> (hands-on deep learning using Keras with the Tensorflow backend)
- **Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow: Concepts, Tools, and Techniques to Build Intelligent Systems** by Aurélien Géron (2ed). O'Reilly Media, 2019. UMN library online access (available soon). (hands-on machine learning, including deep learning, using Scikit-Learn and Keras)

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- 60 % homework + 40 % course project

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# Programming and Computing



$\geq 3$



$\geq 2.0$



$\geq 1.0$

# Programming and Computing



$\geq 3$



$\geq 2.0$



$\geq 1.0$

## Computing

- Local installation
- Google Colab: <https://colab.research.google.com/>  
*(Yes, it's free)*
- Google Cloud (\$50 credits per student) (similarly AWS and Azure)
- Minnesota Supercomputing Institute (MSI)

# We're not alone

Related deep learning courses at UMN

- **Topics in Computational Vision: Deep networks** (Prof. Daniel Kersten, Department of Psychology. Focused on connection with computational neuroscience and vision)

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- **Analytical Foundations of Deep Learning** (Prof. Jarvis Haupt, Department of Electrical and Computer Engineering. Focused on mathematical foundations and theories)

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To learn more computational methods for large-scale optimization

- **IE5080: Optimization Models and Methods for Machine Learning** (Prof. Zhaosong Lu, Department of Industrial and Systems Engineering (ISyE) )

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About basic **linear algebra** and **calculus** and **probability**, in  
**machine learning** context

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**machine learning** context

If you struggle too much with it

- Find the right resources to pick up in the first week
- **OR** take the course in later iterations

**Thank you!**