

CS 490/590 Lecture 1: Introduction

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Adapted from Roger Grosse

How to get free GPUs

- [Colab](#) (**Recommended**) Google Colab is a web-based iPython Notebook service that has access to a free Nvidia K80 GPU per Google account.

What is machine learning?

- For many problems, it's difficult to program the correct behavior by hand
 - recognizing people and objects
 - understanding human speech
- Machine learning approach: program an algorithm to automatically learn from data, or from experience
- Some reasons you might want to use a learning algorithm:
 - hard to code up a solution by hand (e.g. vision, speech)
 - system needs to adapt to a changing environment (e.g. spam detection)
 - want the system to perform *better* than the human programmers
 - privacy/fairness (e.g. ranking search results)

What is machine learning?

- Types of machine learning
 - **Supervised learning:** have labeled examples of the correct behavior
 - **Reinforcement learning:** learning system receives a reward signal, tries to learn to maximize the reward signal
 - **Unsupervised learning:** no labeled examples – instead, looking for interesting patterns in the data

Supervised learning examples

Supervised learning: have labeled examples of the correct behavior

e.g. Handwritten digit classification with the MNIST dataset

- **Task:** given an image of a handwritten digit, predict the digit class
 - **Input:** the image
 - **Target:** the digit class

Supervised learning examples

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e.g. Handwritten digit classification with the MNIST dataset

- **Task:** given an image of a handwritten digit, predict the digit class
 - **Input:** the image
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- **Data:** 70,000 images of handwritten digits labeled by humans
 - **Training set:** first 60,000 images, used to train the network
 - **Test set:** last 10,000 images, not available during training, used to evaluate performance

Supervised learning examples

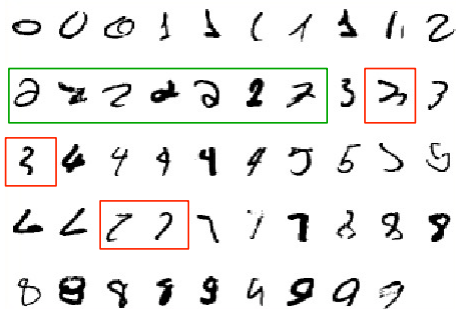
Supervised learning: have labeled examples of the correct behavior

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- This dataset is the “fruit fly” of neural net research
- Neural nets already achieved > 99% accuracy in the 1990s, but we still continue to learn a lot from it

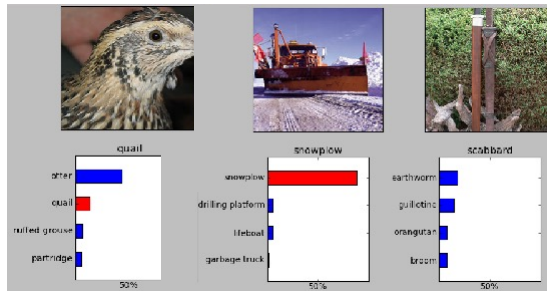
Supervised learning examples

What makes a “2”?



Supervised learning examples

Object recognition



(Krizhevsky and Hinton, 2012)

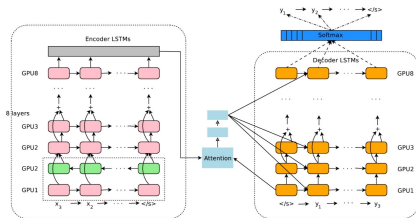
ImageNet dataset: thousands of categories, millions of labeled images

Lots of variability in viewpoint, lighting, etc.

Error rate dropped from 26% to under 4% over the course of a few years!

Supervised learning examples

Neural Machine Translation



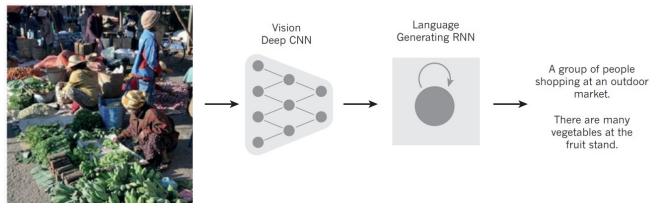
(Wu et al., 2016)

Input sentence:	Translation (PBMT):	Translation (GNMT):	Translation (human):
李克強此行將啟動中加總理年度對話機制，與加拿大總理杜魯多舉行兩國總理首次年度對話。	Li Keqiang premier added this line to start the annual dialogue mechanism with the Canadian Prime Minister Trudeau two prime ministers held its first annual session.	Li Keqiang will start the annual dialogue mechanism with Prime Minister Trudeau of Canada and hold the first annual dialogue between the two premiers.	Li Keqiang will initiate the annual dialogue mechanism between premiers of China and Canada during this visit, and hold the first annual dialogue with Premier Trudeau of Canada.

Now the production model on Google Translate

Supervised learning examples

Caption generation



A woman is throwing a **frisbee** in a park.



A **dog** is standing on a hardwood floor.



A **stop** sign is on a road with a mountain in the background

(Xu et al., 2015)

Given: dataset of Flickr images with captions

Unsupervised learning examples

- In **generative modeling**, we want to learn a distribution over some dataset, such as natural images.
- We can evaluate a generative model by sampling from the model and seeing if it looks like the data.
- These results were considered impressive in 2014:



Unsupervised learning examples

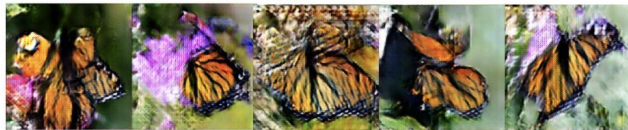
- Fast-forward to 2017:



Unsupervised learning examples

- The progress of generative models:

Odena et al
2016



Miyato et al
2017

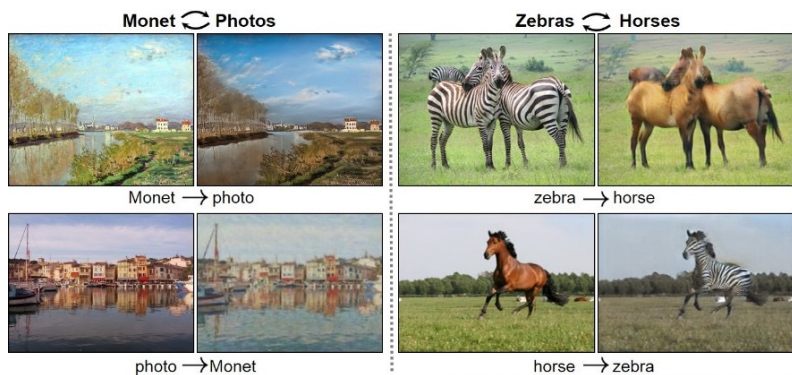


Zhang et al
2018



Unsupervised learning examples

- Recent exciting result: a model called the CycleGAN takes lots of images of one category (e.g. horses) and lots of images of another category (e.g. zebras) and learns to translate between them.



Reinforcement learning



- An **agent** interacts with an **environment** (e.g. game of Breakout)
- In each time step,
 - the agent receives **observations** (e.g. pixels) which give it information about the **state** (e.g. positions of the ball and paddle)
 - the agent picks an **action** (e.g. keystrokes) which affects the state
- The agent periodically receives a **reward** (e.g. points)
- The agent wants to learn a **policy**, or mapping from observations to actions, which maximizes its average reward over time

Reinforcement learning

DeepMind trained neural networks to play many different Atari games

- given the raw screen as input, plus the score as a reward
- single network architecture shared between all the games
- in many cases, the networks learned to play better than humans (in terms of points in the first minute)

<https://www.youtube.com/watch?v=V1eYniJ0Rnk>

Reinforcement learning for control

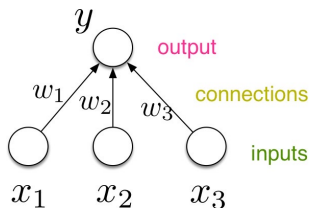
Learning locomotion control from scratch

- The reward is to run as far as possible over all the obstacles
- single control policy that learns to adapt to different terrains

https://www.youtube.com/watch?v=hx_bgoTF7bs

What are neural networks?

- Most of the biological details aren't essential, so we use vastly simplified models of neurons.
- While neural nets originally drew inspiration from the brain, nowadays we mostly think about math, statistics, etc.



$$y = \phi(\mathbf{w}^T \mathbf{x} + b)$$

Diagram illustrating the mathematical representation of a neuron's output. The equation is $y = \phi(\mathbf{w}^T \mathbf{x} + b)$. Colored arrows point to the components: a pink arrow points to y (output), a blue arrow points to \mathbf{w} (weights), a blue arrow points to b (bias), a red arrow points to ϕ (activation function), and a green arrow points to \mathbf{x} (inputs).

- Neural networks are collections of thousands (or millions) of these simple processing units that together perform useful computations.

What are neural networks?

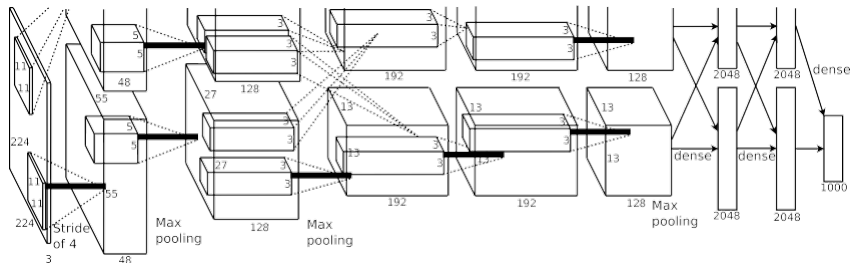
Why neural nets?

- inspiration from the brain
 - proof of concept that a neural architecture can see and hear!
- very effective across a range of applications (vision, text, speech, medicine, robotics, etc.)
- widely used in both academia and the tech industry
- powerful software frameworks (PyTorch, TensorFlow, etc.) let us quickly implement sophisticated algorithms

“Deep learning”

Deep learning: many layers (stages) of processing

E.g. this network which recognizes objects in images:



(Krizhevsky et al., 2012)

Each of the boxes consists of many neuron-like units similar to the one on the previous slide!

“Deep learning”

- You can visualize what a learned feature is responding to by finding an image that excites it. (We’ll see how to do this.)
- Higher layers in the network often learn higher-level, more interpretable representations



Edges (layer conv2d0)

Textures (layer mixed3a)

Patterns (layer mixed4a)

“Deep learning”

- You can visualize what a learned feature is responding to by finding an image that excites it.
- Higher layers in the network often learn higher-level, more interpretable representations



Parts (layers mixed4b & mixed4c)

Objects (layers mixed4d & mixed4e)

Software frameworks

- Array processing (NumPy)
 - **vectorize** computations (express them in terms of matrix/vector operations) to exploit hardware efficiency
- Neural net frameworks: PyTorch, TensorFlow, etc.
 - automatic differentiation
 - compiling computation graphs
 - libraries of algorithms and network primitives
 - support for graphics processing units (GPUs)
- For this course:
 - Python, NumPy
 - **Tensorflow**, Google's deep learning toolbox
 - **PyTorch**, a widely used neural net framework

Software frameworks

Why take this class, if PyTorch does so much for you?

So you know what do to if something goes wrong!

- Debugging learning algorithms requires sophisticated detective work, which requires understanding what goes on beneath the hood.
- That's why we derive things by hand in this class!