Foundations of Deep Learning

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- https://csc413-2020.github.io/ , Slides Courtesy
- http://introtodeeplearning.com/ , Slides Courtesy

Introduction

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Course Plan

Points to be Remembered

1. The following conditions are required to be met for the successful completion of the summer course. If any one the conditions is not satisfied, the certificate will not be issued.
    1. 85% of attendance is mandatory. If you are not attending more than 3 sessions, your registration will be automatically cancelled and the hostel authorities will be informed to cancel your accommodation.

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    4. You should maintain disciple in the classroom. Usage of mobile phones and late entry to the classroom will not be tolerated.

What is Deep Learning?

Teaching computers how to **learn a task** directly from **raw data**.

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- Machine learning approach: program an algorithm to automatically learn from data, or from experience.
- Some reasons you might want to use a learning algorithm:
  1. hard to code up a solution by hand (e.g. vision, natural language processing).
  2. system needs to adapt to a changing environment (e.g. spam detection).
  3. want the system to perform better than the human programmers.
  4. privacy/fairness (e.g. ranking search results).

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- **Reinforcement learning**: learning system receives a reward signal, tries to learn to maximize the reward signal.

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
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- **Task**: given an image of a handwritten digit, predict the digit class.
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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.
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- This dataset is the ‘*fruit fly*" of neural net research.

Supervised Learning Examples

What makes a “2"?

Supervised Learning Examples

Object Recognition

- 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

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

- Given: dataset of Flickr images with captions.

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.

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.

Denton et al., 2014, Deep generative image models using a Laplacian pyramid of adversarial networks

Unupervised Learning Examples

- The progress of generative models:

Odena et al 2016

Miyato et al 2017

Zhang et al 2018

- Big GAN, Brock et al, 2019:

Unupervised Learning Examples

- Generative models of text. The models like BERT and GPT-2 perform unsupervised learning by reconstructing the next words in a sentence. The GPT-2 models learns from 40GB of Internet text.

https://app.inferkit.com/demo

Unupervised 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.

https://github.com/junyanz/CycleGAN

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.

youtube link

Software Frameworks

- Scientific computing (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
  - **PyTorch**, a widely used neural net framework with a built-in automatic differentiation feature.

How to get free GPUs

- Colab Programming assignments are to be completed in Google Colab, which is a web-based iPython Notebook service that has access to a free Nvidia K80 GPU per Google account.
- GCE (Recommended for course projects) Google Compute Engine delivers virtual machines running in Google's data center. You get $300 free credit when you sign up.

https://colab.research.google.com/

https://cloud.google.com/compute/

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.

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

Turing Award Won by 3 Pioneers in Artificial Intelligence

Give this article

From left, Yann LeCun, Geoffrey Hinton and Yoshua Bengio. The researchers worked on key developments for neural networks, which are reshaping how computer systems are built. From left, Facebook, via Associated Press; Aaron Vincent Elkaim for The New York Times; Chad Buchanan/Getty Images

https://www.nytimes.com/2019/03/27/technology/turing-award-ai.html

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.

Why Deep Learning?

- Hand engineered features are time consuming, brittle and not scalable in practice.
- Can we learn the underlying features directly from data?

Why Now?

1952 Stochastic Gradient Descent

1958 Perceptron
- Learnable Weights

⋮

1986 Backpropagation
- Multi-Layer Perceptron

1995 Deep Convolutional NN
- Digit Recognition

⋮

Neural Networks date back decades, so why the resurgence?

1. Big Data
- Larger Datasets
- Easier Collection & Storage

IMAGENET

WIKIPEDIA The Free Encyclopedia

2. Hardware
- Graphics Processing Units (GPUs)
- Massively Parallelizable

3. Software
- Improved Techniques
- New Models
- Toolboxes

TensorFlow

MIT 6.S191

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 neuron-like units as mentioned in one of the previous slide.

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.

Edges (layer conv2d0) **Textures** (layer mixed3a) **Patterns** (layer mixed4a)

https://distill.pub/2017/feature-visualization/