Intro to Neural Networks & Deep Learning (ECS659U/ECS659P)

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About me :)

- Studied Electrical & Computer Engineering in Greece
- MSc & PhD at Imperial College London
- Currently:
  - Principal Scientist @ Samsung AI Center, Cambridge
  - Associate Professor @ QMUL
- Area of expertise: Computer Vision & Deep Learning

Intro to Neural Networks & Deep Learning

- What AI is all about?
- What kind of AI this module will be focusing on
- A simple example of the models we will be working on
- Module logistics

What is meant by Human Intelligence?

- Exams, education, perform well in intelligence (IQ) tests
- Skills – languages, chess, mathematical reasoning
- Cognition: perception, memory, judgement and reasoning
- Volition: the will, purpose, choice
- Emotion: affective intelligence
- Speed, efficiency and creativity of information processing

How far are we from building machines with this type of intelligence?

General vs. Narrow Artificial Intelligence

- Gary Marcus: "*Today's AI has been very successful in building systems that perform a single narrow goal extremely well*"
  - E.g. chess playing or identifying dog breeds
  - Solving pattern recognition
- Still this is both extremely useful and exciting!!
  - Major industry players (Google, Microsoft, IBM, Apple, Facebook, Samsung etc.) are investing Billions on AI
- The focus of this module

Applications: Computer Vision

Image Understanding

Image Generation

Applications: Face Analysis

3D Face Reconstruction from a Single Image

Download Wavefront OBJ File
(colours are stored per-vertex)

Try another image

Z Translate:

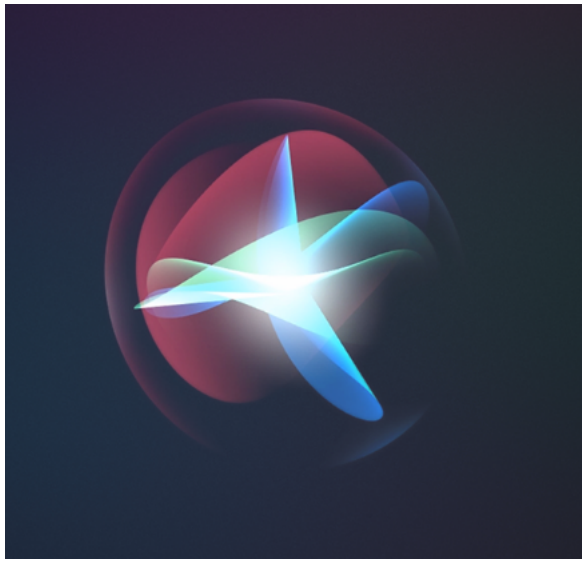
Show background image

Tweet Star 4,273

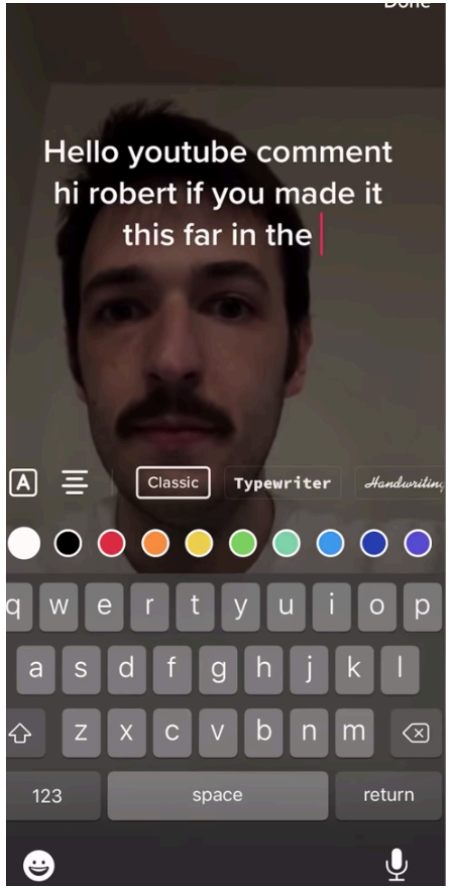
https://cvl-demos.cs.nott.ac.uk/vrn/

Applications: Speech Recognition

Alexa



Siri



Text to Speech (TikTok)

Applications: Natural Language Processing

I: Jane went to the hallway.
I: Mary walked to the bathroom.
I: Sandra went to the garden.
I: Daniel went back to the garden.
I: Sandra took the milk there.
Q: Where is the milk?
A: garden

Chat bot: Question Answering

GPT-3

https://www.theverge.com/21346343/gpt-3-explainer-openai-examples-errors-agi-potential

Current state of AI

All of these amazing technologies (and many more!) are produced by a single technology:

Deep Learning

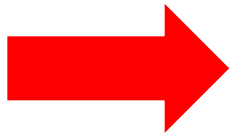
Deep Learning: The model

- Very conveniently, Deep Learning models (general speaking) follow a single pattern/paradigm
- This is the model we will be heavily using throughout the module
- This is great because if we understand the workings of this model we can apply it to many other problems, too

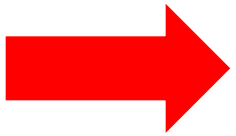
Deep Learning: The model

Input Data

- Images
- Speech/Audio
- Words
- Tabular data



Model



Prediction

- A car or a plane?
- French or English?
- Answer to a question
- Price of a house

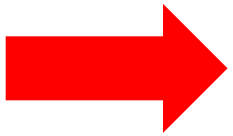
The Model

- Has some model parameters
- Uses the parameters to compute a function/combination of the input data in order to make predictions

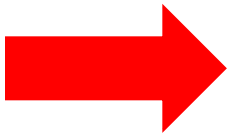
Example

Input Data

[height, weight, age, exerc_hours]



Model



Prediction

blood_pressure

```
#[height, weight, age, exerc_hours]
# Assume 3 different subjects
X =[[180, 89, 35, 1],
    [160, 49, 40, 4],
    [170, 69, 20, 2]]
```

```
# Model W (a vector)
# W = [w1, w2, w3, w4]
W = [0.3, 0.8, -0.4, 10]
```

```
# Model output
def model_out(W, x):
    out = W[0]*x[0] + W[1]*x[1]
    + W[2]*x[2] + W[3]*x[3]
    return out
```

```
# prediction
x = X[0]
print(model_out(W, x))
```

```
125.2
```

Training the Model

- Training the model means finding the values of the model parameters
- We need training data: input data for which we know the real outputs

[height, weight, age, exerc_hours]

```
[[10, 30, 40,  1],
 [80, 70, 60,  2],
 [40, 10, 80,  6],
 [50,  0, 70,  0],
 [50, 90,  0,  1],
 [60, 50, 60,  3],
 [20, 50, 40,  1],
 [40, 80, 70,  2],
 [40, 70, 70,  5],
 [50,  0, 60,  2],
 [80, 30, 80,  3],
 [90, 40, 50,  1],
 [60, 90, 90,  6],
 [80, 90, 90,  6],
 [80, 50, 60,  1],
 [ 0, 70, 10,  6],
 [70, 70, 90,  8],
 [50, 90,  0,  4],
 [10, 80, 50,  1],
 [10, 40, 70,  2]]
```

blood_pressure

```
[[160],
 [ 40],
 [120],
 [180],
 [100],
 [  0],
 [ 20],
 [ 50],
 [ 40],
 [ 80],
 [110],
 [110],
 [120],
 [130],
 [150],
 [170],
 [140],
 [100],
 [130],
 [140]]
```

Training the Model

To train the model

- Start from some random values for the model parameters
- Update the parameters so that for each input the model predictions are “as close as possible” to the corresponding real output values
- “as close as possible:”

```
# y is the real output,
# and y_hat the model prediction
def loss(y, y_hat):
    return (y-y_hat)**2
```

$$\text{loss} = (y - \tilde{y})^2$$

$$\text{loss} = (y - W[0] * x[0] + W[1] * x[1] + W[2] * x[2] + W[3] * x[3])^2$$

Training the Model

To train the model

- After we calculate the loss, each model parameter is updated using the derivative of the loss with respect to that parameter.
- E.g. for the first model parameter

$$W[0] \leftarrow W[0] - \frac{\theta loss}{\theta W[0]}$$

- The only difficult part in this algorithm could be the calculation of the derivative which requires mathematical calculations
- Fortunately, PyTorch calculates this for us automatically!

Syllabus

Week 01: Intro to AI and Tensor Data Processing
Week 02: Automatic Differentiation
Week 03: Linear Regression with Automatic Differentiation
Week 04: Softmax Regression: single-layer Neural Networks
Week 05: Multilinear Perceptrons (MLPs)
Week 06: Introduction to Assignment & Catching-up
Week 07: Convolutional Neural Networks (CNNs)
Week 08: Advanced CNNs and Optimization Algorithms
Week 09: Introduction to Natural Language Processing (NLP)
Week 10: Recurrent Neural Networks (RNNs)
Week 11: Advanced RNNs: GRUs and LSTMs
Week 12: Revision

How do I study for this module?

- Slides cover deep learning theory and PyTorch code
- Study the slides to understand the concepts
- Run the provided Jupyter Notebooks on your own!
  - Go inside the code and check the variables (print the variables, their dimensions etc.), make sure you understand what the functions do

- We cannot cover all PyTorch documentation in the lecture. When unsure about something check:
  - Official webpage: https://pytorch.org
  - Tutorial section: https://pytorch.org/tutorials/
  - PyTorch forums: https://discuss.pytorch.org
  - Google!

Module Logistics

- Lecture every Friday 09:00-11:00
- Lab every Friday 11:00-13:00

- Coursework
  - One item
  - Done individually
  - 50% of module total
- Examination in May:
  - 50% of module total

Recommended Books

- Aston Zhang, Zachary C. Lipton, Mu Li and Alexander J. Smola, **Dive into Deep Learning,** 2020
  - The textbook used to develop the materials
  - https://d2l.ai
  - This book is really amazing!
- Ian Goodfellow, Yoshua Bengio and Aaron Courville, **Deep Learning,** MIT Press, 2016
  - www.deeplearningbook.org