MIDDLE EAST TECHNICAL UNIVERSITY

DI504 Foundations of Deep Learning

Introduction

Welcome

This is DI504, Foundations of Deep Learning!

Welcome

This is DI504, Foundations of Deep Learning!

!!! About the Hybrid System !!!

Welcome

This is DI504, Foundations of Deep Learning!

- DI504 will cover various subjects related to fundamental concepts in deep learning.
-

Welcome

This is DI504, Foundations of Deep Learning!

- DI504 will cover various subjects related to fundamental concepts in deep learning.
- The course starts with the introductory concepts in deep learning, such as neural networks, training, high level features and performance evaluations.
-

Welcome

This is DI504, Foundations of Deep Learning!

- DI504 will cover various subjects related to fundamental concepts in deep learning.
- The course starts with the introductory concepts in deep learning, such as neural networks, training, high level features and performance evaluations.
- DI504 aims to bring students with different backgrounds to the same level with respect to the current methods used in deep learning.
-

Welcome

This is DI504, Foundations of Deep Learning!

- DI504 will cover various subjects related to fundamental concepts in deep learning.
- The course starts with the introductory concepts in deep learning, such as neural networks, training, high level features and performance evaluations.
- DI504 aims to bring students with different backgrounds to the same level with respect to the current methods used in deep learning.
- On the other hand, basic programming skills, preferably in Python, are required, and students need to know the basics of data analytics.

Welcome

This is DI504, Foundations of Deep Learning!

- DI504 will cover various subjects related to fundamental concepts in deep learning.
- The course starts with the introductory concepts in deep learning, such as neural networks, training, high level features and performance evaluations.
- DI504 aims to bring students with different backgrounds to the same level with respect to the current methods used in deep learning.
- On the other hand, basic programming skills, preferably in Python, are required, and students need to know the basics of data analytics.
    - (*preferably took Introduction to Data Science or Data Informatics courses before*).

Who should take this course?

- DI students, before all
  - The aim of this course is to introduce the fundamental concepts of deep learning (including technical or non technical issues) to an audience of interdisciplinary background. It is designed for the DI program students.
  - Other Inf. Inst. program students (such as IS, etc.) are also welcome.
  - Other interdisciplinary program students are also welcome.
    - MMI students have their own course MMI727.
    - EEE students have their own course EE543.
    - CENG students have their own course CEN501.
    - Or if you have taken one of these, I do not recommend you to take this course. METU is full spectacular courses prepared by fantastic lecturers. Why not go take another one?

Who should take this course?

- This is a both a theoretical and a practical introductory level course for deep learning
  - Basic programming skills, preferably in Python, are required, and students need to know the basics of data analytics. *(preferably took Introduction to Data Science or Data Informatics courses before).*

Who should take this course?

- This is a both a theoretical and a practical introductory level course for deep learning
  - Basic programming skills, preferably in Python, are required, and students need to know the basics of data analytics. *(preferably took Introduction to Data Science or Data Informatics courses before).*
  - *In other words, basic Programming skills is a must. Python will be our primary choice of environment. MATLAB can be an alternative, if it is where you have some experience.*

Who should take this course?

- This is a both a theoretical and a practical introductory level course for deep learning
  - Basic programming skills, preferably in Python, are required, and students need to know the basics of data analytics. *(preferably took Introduction to Data Science or Data Informatics courses before).*
  - *In other words, basic Programming skills is a must. Python will be our primary choice of environment. MATLAB can be an alternative, if it is where you have some experience.*
  - *Fundamental concepts of Calculus (matrices, derivation, algebra, etc) will also be very important in understanding the basics.*

Who should take this course?

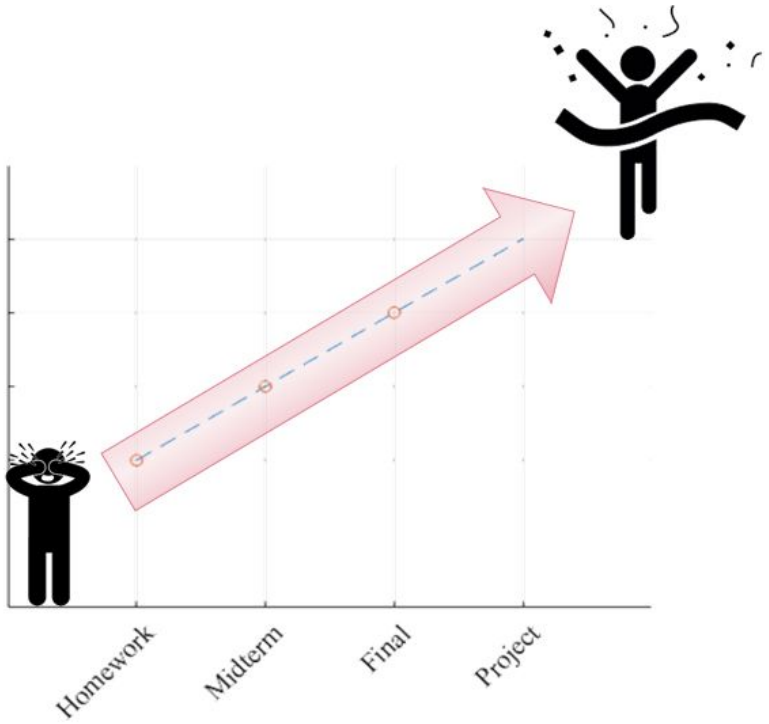
- This is a both a theoretical and a practical introductory level course for deep learning
  - Courses such as optimization, machine learning can be considered as weak co-requisites.
  - You'd better have either previously passed, or are studying at the same time as another related unit. (at least you will have to)

Outline

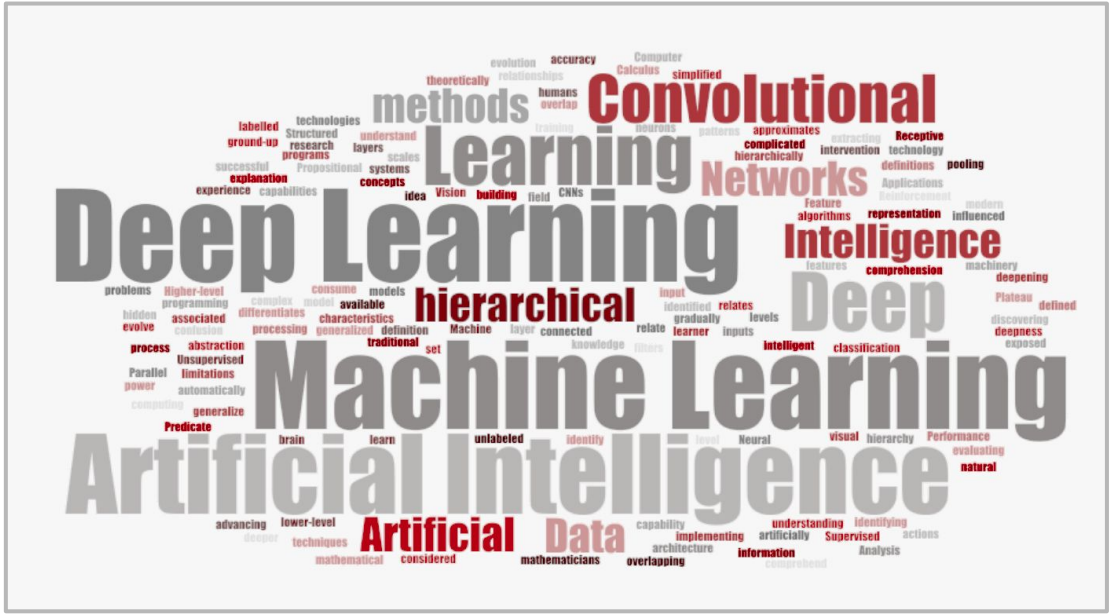
- Introduction to deep learning
- (Artificial) Neural Networks
- Learning Deep
- High Level Features
- Performance evaluation
- Introduction to Sequence Models
- Introduction to Deep Natural Language Processing
- Applications for Deep Learning

Grading

- Project 40%
- Final 30%
- Midterm 20%
- Homework 10%



What is deep learning?



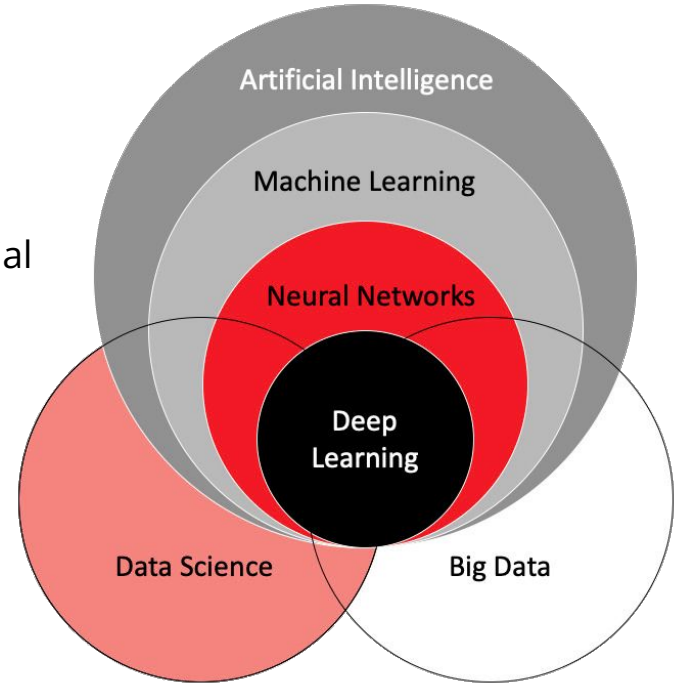
What is deep learning?

Artificial Intelligence: is human intelligence exhibited by machines.

Machine Learning is an approach to achieve artificial intelligence

Neural Networks (or Nets) is a one of the techniques for implementing machine learning.

Deep Learning is a subfamily of machine learning methods, based on “deep” (many layered) neural networks.

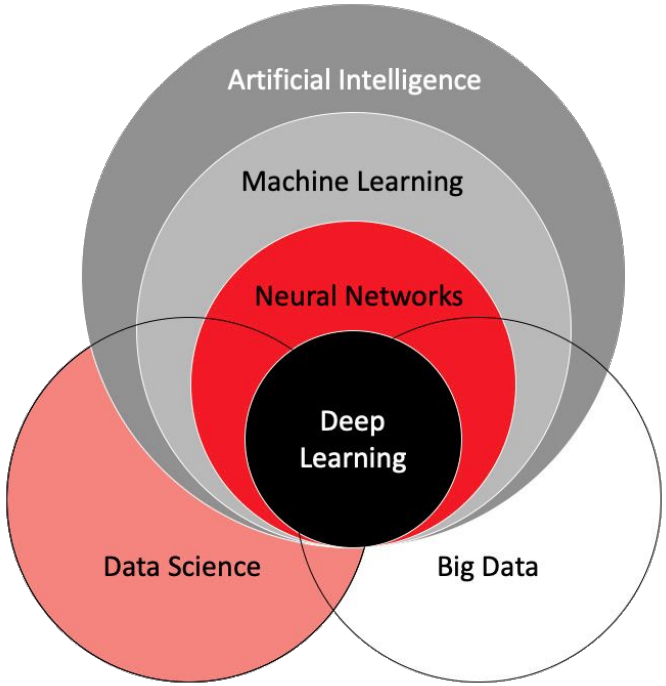


What is deep learning?

The fields of artificial intelligence (AI), machine learning (ML) and data science have a great deal of overlap, but they are not interchangeable.

There are some nuances between them. Here is a very simplified explanation of how these three areas differ:

- *Data science* produces insights.
- *Machine learning* produces predictions.
- *Artificial intelligence* produces actions.



What is machine learning?

- *Machine Learning* (ML) is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed.

  What does that mean "*without being explicitly programmed*" ?

-

What is machine learning?

- *Machine Learning* (ML) is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed.

What does that mean "*without being explicitly programmed*" ?

- ML algorithms build a model based on sample data, known as "training data", in order to make predictions or decisions.
-

What is machine learning?

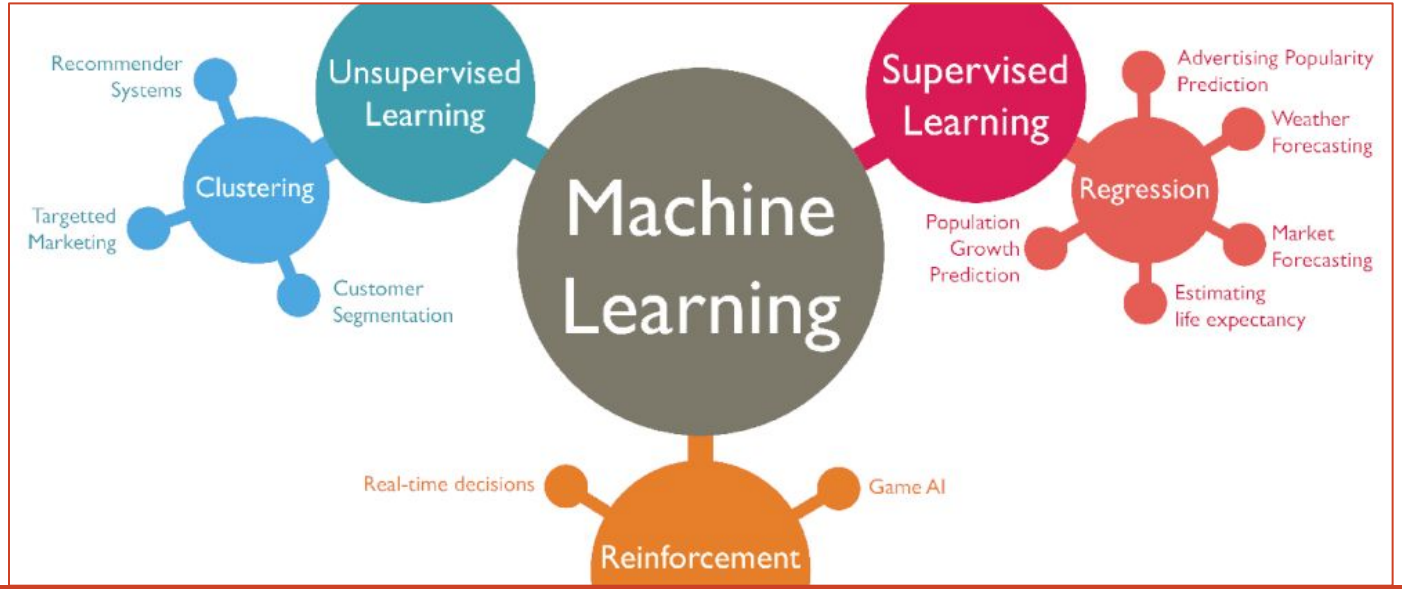
- *Machine Learning* (ML) is an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed.

What does that mean "*without being explicitly programmed*" ?

- ML algorithms build a model based on sample data, known as "training data", in order to make predictions or decisions.
- ML models are not explicitly programmed for tasks, but they are programmed to learn from data.

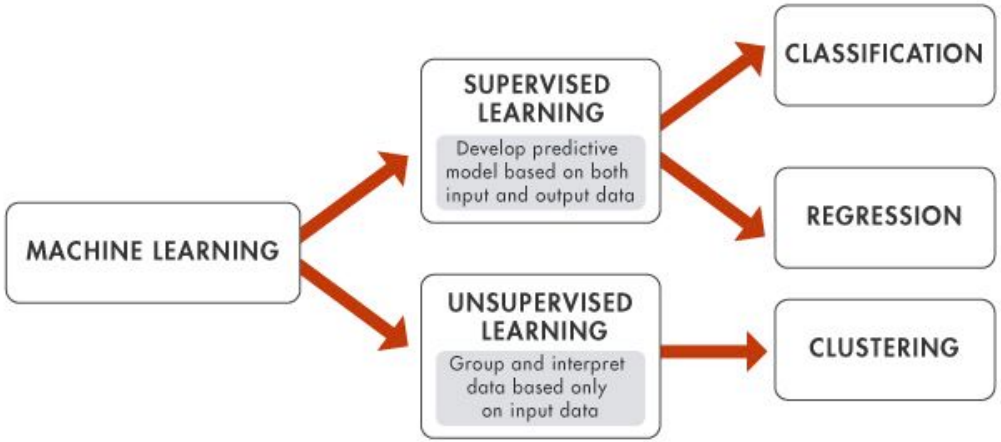
What is machine learning?

- ML focuses on the development of computer programs that can access data and use it to learn for themselves, **using the data**.
- ML algorithms are often categorised according to how they are supervised.



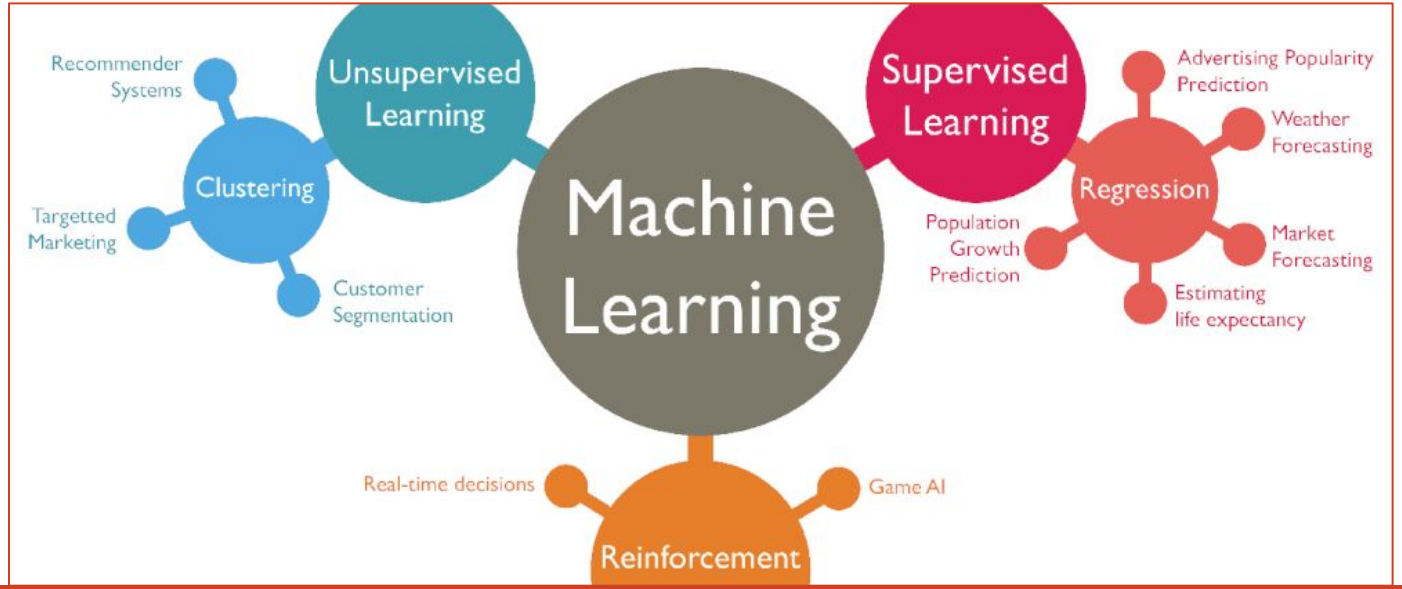
Supervision in ML

- Supervised learning (SL) is the machine learning task of learning a function that maps an input to an output based on example input-output pairs
- Unsupervised learning (UL) is a type of algorithm that learns patterns from untagged data. The hope is that, through mimicry, the machine is forced to build a compact internal representation of its world and then generate imaginative content.



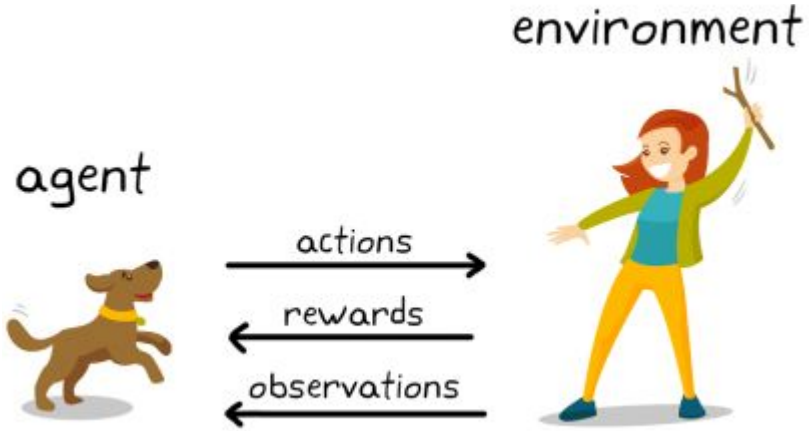
What is machine learning?

- ML focuses on the development of computer programs that can access data and use it to learn for themselves, **using the data**.
- ML algorithms are often categorised according to how they are supervised.



Reinforcement Learning

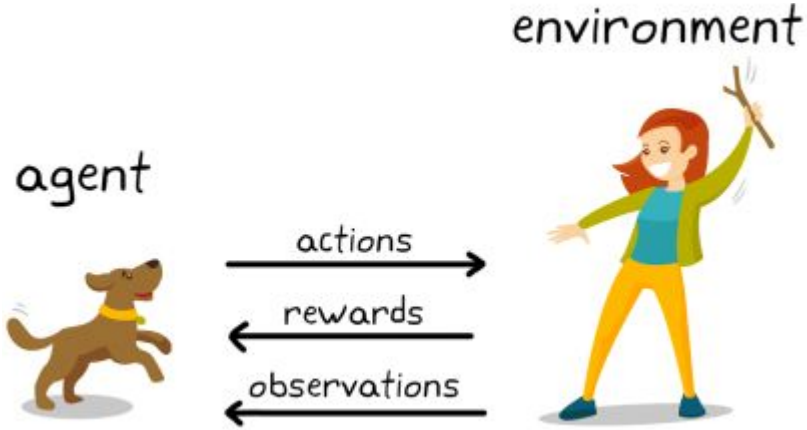
- Reinforcement learning (RL) is an area of machine learning concerned with how intelligent agents ought to take actions in an environment in order to maximize the notion of cumulative reward.
- Reinforcement learning is one of three basic machine learning paradigms, alongside supervised learning and unsupervised learning.



Reinforcement Learning

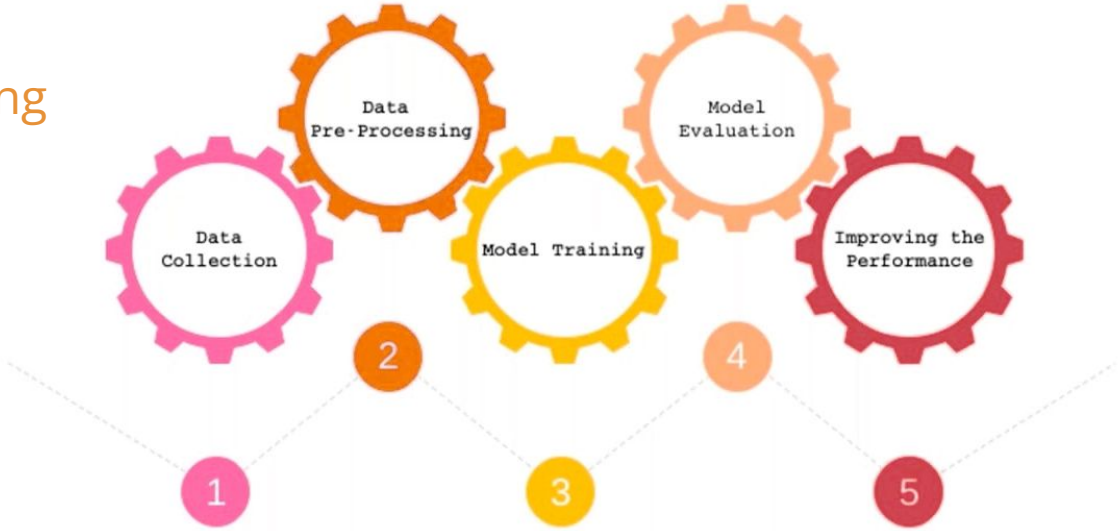
- Reinforcement learning (RL) is an area of machine learning concerned with how intelligent agents ought to take actions in an environment in order to maximize the notion of cumulative reward.
- Reinforcement learning is one of three basic machine learning paradigms, alongside supervised learning and unsupervised learning.

- It is outside the scope of DI504.
  Though, MMI706 “REINFORCEMENT LEARNING” *is strongly recommended.*



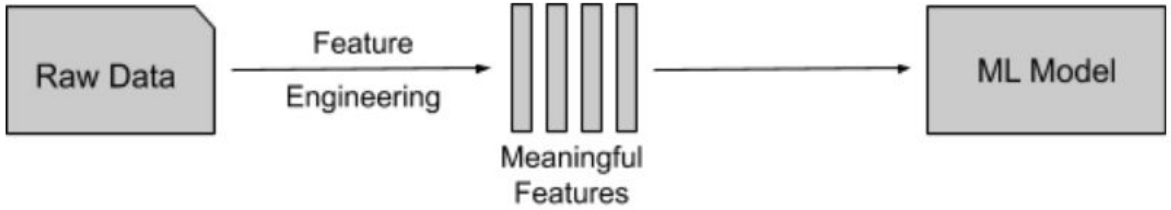
ML Workflow

1. Data Collection
2. Pre-processing / Feature Extraction
3. Model Training
4. Model Evaluation / Testing
5. Fine-Tuning / Parameter Optimization



Features in ML

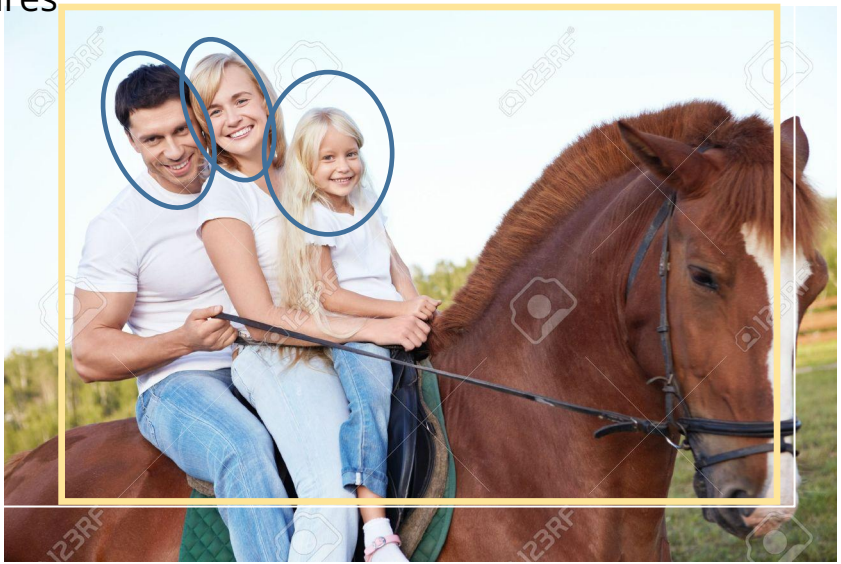
- In ML a "***feature***" is an individual measurable property or characteristic of a phenomenon, that represents "something" (tangible or not) in the data.
- Features are higher level representations of "raw data".



- Before deep learning, in 2000s, the AI society of today focused mainly on "feature engineering", i.e. finding the right hand-crafted representation for the data that would make our ML model perform the best.

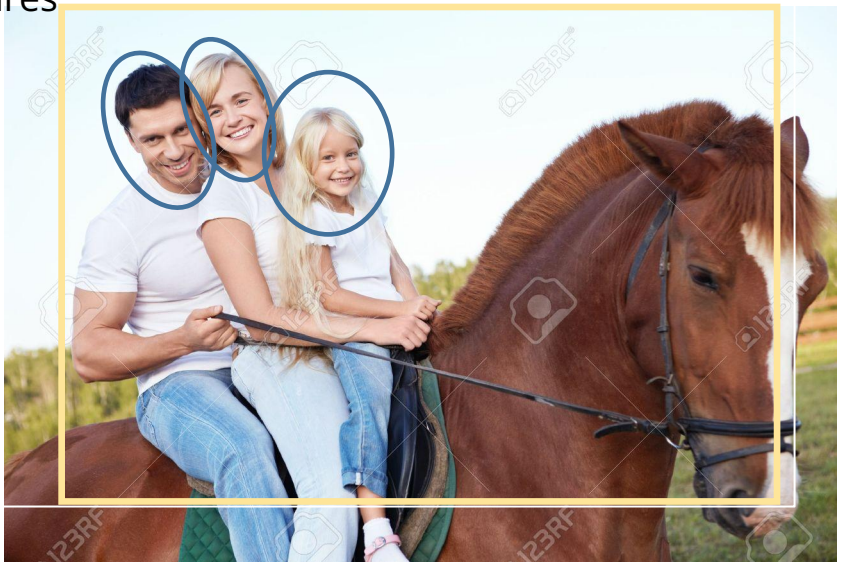
Features in ML

- Intelligent being understand data in higher representations, sometimes referred to as concepts.
- Features can be of different levels. Edges of an image are low-level features.
- Where as objects in an image are higher level features
- Concepts are the highest level relational features.
- Nobody hears vibrations or frequencies. They hear pitch, timbre, melody, rhythm.
- Nobody sees pixels in an image. They see faces, objects, figures, actions.



Features in ML

- Intelligent being understand data in higher representations, sometimes referred to as concepts.
- Features can be of different levels. Edges of an image are low-level features.
- Where as objects in an image are higher level features
- Concepts are the highest level relational features.
- Nobody hears vibrations or frequencies. They hear pitch, timbre, melody, rhythm.
- Nobody sees pixels in an image. They see faces, objects, figures, actions.
  All they see is blonde, brunette, redhead...



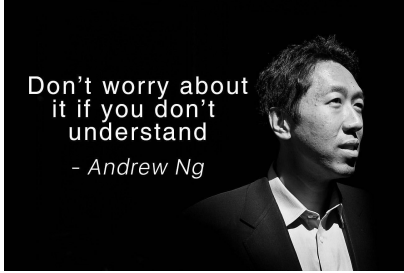
What is deep learning?

- [Wikipedia] Deep learning (DL) is a class of ML algorithms that uses multiple layers to "progressively extract higher-level features from the raw input".
- DL algorithms learn their own features. Hence, they do not require an additional feature extraction step, like traditional ML algorithms do.

Traditional Machine Learning Flow

Deep Learning Flow

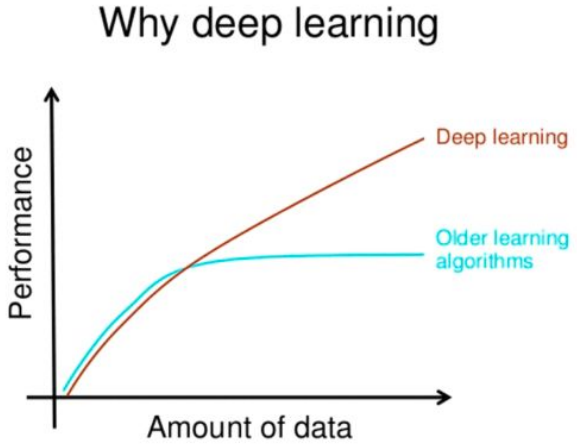
Why DL?



- Andrew Ng [@ExtractConf 2015]

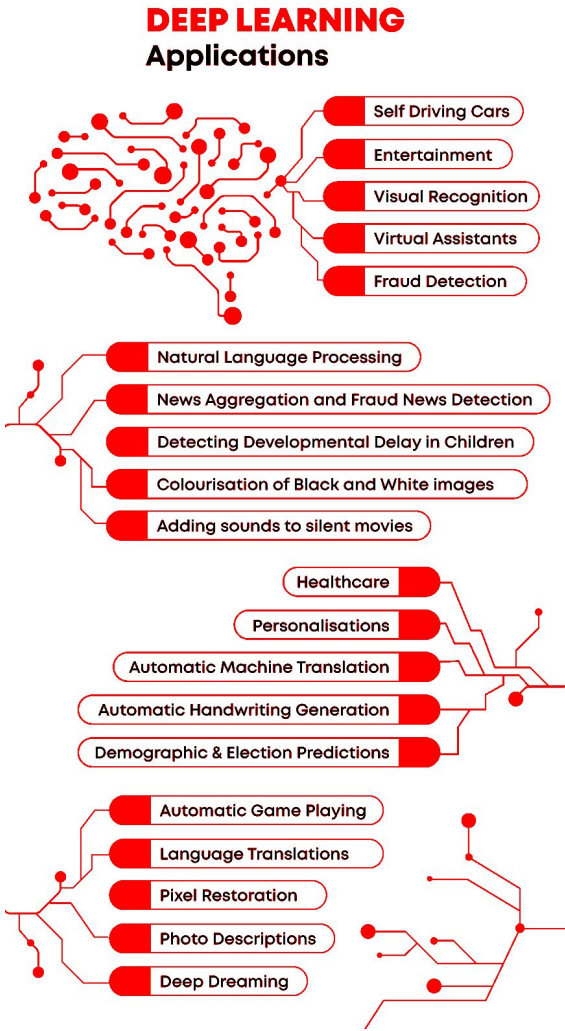
  "For most flavors of the old generations of learning algorithms performance will plateau. Deep learning is the first class of algorithms that is scalable. Performance just keeps getting better as you feed them more data."

- https://www.youtube.com/watch?v=O0VN0pGgBZM



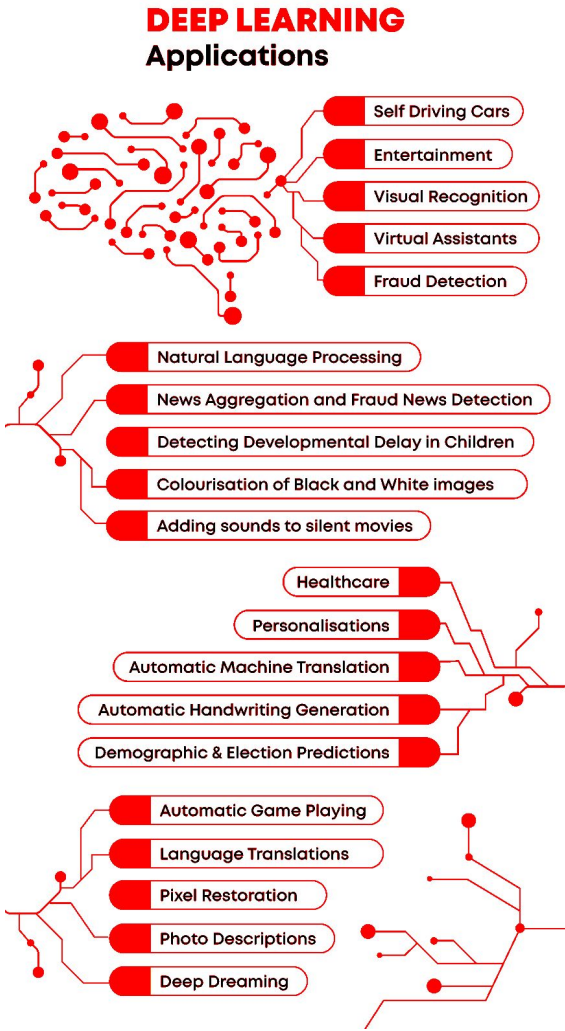
DL Application Domain

- Deep Learning algorithms extract high-level features, complex abstractions as data representations through a hierarchical learning process.
-



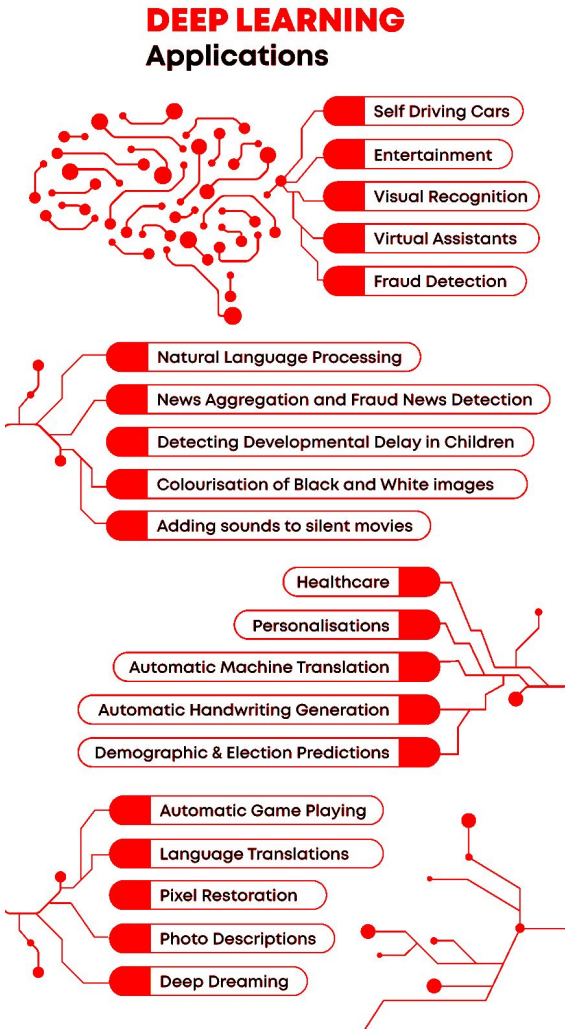
DL Application Domain

- Deep Learning algorithms extract high-level features, complex abstractions as data representations through a hierarchical learning process.
- By extracting such features, Deep Learning enables the use of relatively simpler linear models for supervised data analysis tasks, such as classification and prediction, which is important when developing models to deal with the scale of Big Data.
-



DL Application Domain

- Deep Learning algorithms extract high-level features, complex abstractions as data representations through a hierarchical learning process.
- By extracting such features, Deep Learning enables the use of relatively simpler linear models for supervised data analysis tasks, such as classification and prediction, which is important when developing models to deal with the scale of Big Data.
- A key benefit of Deep Learning is the analysis and learning of massive amounts of unsupervised data, making it a valuable tool for Data Analytics, where raw data is largely unlabeled and un-categorized.



DL Practices

When studying deep learning in data science there are three main skills you need to have experience in:

- Data/Feature Analysis/Visualization
- Model Training
- Performance Evaluation

Data/Feature - Analysis/Visualization

If you have taken (I hope you had) *Introduction to Data Science* or *Data Informatics* courses before, you already know that data can be

- Qualitative or Quantitative
- Structured or Unstructured
- Multi-dimensional
- Spatial, Temporal or Spatiotemporal

For each type of data, different DL models are used to extract features. And different analysis/visualization tools are used.

Data/Feature - Analysis/Visualization

If you have taken (I hope you had) *Introduction to Data Science* or *Data Informatics* courses before, you already know that data can be

- Qualitative or Quantitative
- Structured or Unstructured
- Multi-dimensional
- Spatial, Temporal or Spatiotemporal

I strongly recommend Python for Data/Feature Analysis/Visualization for DL. MATLAB is a good alternative, with several built-in functions.

Model Training

This is where all the fun takes place.

- Some say it is all local in their PC, all data, all tools etc.
- Some say they have nothing installed in their PC, it is all cloud.
- Which one is better? Where to do it? How to do it?

Model Training Platforms

There are several different alternatives, such as:

- which programming language, Python, MATLAB, C, R ?
- which DL library, PyTorch, Keras, Tensorflow, Theano, other?
- which platform, Google colab, Amazon sagemaker, Anaconda Spyder, Pycharm?

All have their pros and cons.

When you start working on one, you will most probably stick to it for a long time. So this decision is important.

Programming Language

I think Python is a winner here, because of many reasons:

- Python offers concise and readable code. While complex algorithms and versatile workflows stand behind DL, Python's simplicity allows developers to build both fast prototypes or reliable systems.
- Python code is understandable by humans, which makes it easier to build models for DL.
- Most state-of-the-art DL is shared in Python. (Maybe this is the most important reason).

DL Library

Python won the battle as the preferred language of DL. The availability of libraries and open source tools make it ideal choice for developing DL models.

But which one?

The battle is mainly between PyTorch vs Tensorflow.

- Both TensorFlow and PyTorch have their advantages as starting platforms to get into neural network programming.
- Traditionally, researchers and Python enthusiasts have preferred PyTorch, while TensorFlow has long been the favored option for building large scale deep learning models for use in production.

DL Library

Python won the battle as the preferred language of DL. The availability of libraries and open source tools make it ideal choice for developing DL models.

But which one?

- Some libraries have specific advantages in certain applications domains.
- For example “Theano” is preferred by embedded deep learning people.

DL Platform

This one is difficult choice. The first to choose is local vs cloud?

- There are several factors that affects this decision, such as flexibility, security, privacy, cost, ease-of-use…

DL Platform “Cloud”

- For the project using a cloud service is the easiest solution.
- No configurations, installations, etc.
  (Strongly recommended for beginners).
- However, these platforms provide limited GPU-hours for free.

DL Platform “Local”

- If you have a NVIDIA (cuda compatible) GPU, you have everything you need!
    - Check the cuda-compatibility of your GPU, and make sure that it can run the python library (e.g. PyTorch) you will use!
- The downside is you will have to install an integrated development environments (IDE) and learn how to configure this.
- My personal choice: Anaconda-Spyder with Pytorch. Once you set it, it is smooth as MATLAB.

What to do until next week?

- Choose your programming environment and set it up!
- Check the additional reading page for more references and Google around to make a good decision.
- Think of a project idea. Preferably related to your thesis.
    - You don’t know how to do it yet, even if it can be done or not. Do some research. Did people do it before? What could they achieve? Maybe you will implement a modification on the problem? Start thinking about it.
    - Never forget what a wise man has once said:

    “Don’t worry about it if you don’t understand."

    Andrew Ng

Additional Reading & References

- https://www.youtube.com/watch?v=O0VN0pGgBZM
- https://www.mygreatlearning.com/blog/deep-learning-applications/
- https://journalofbigdata.springeropen.com/articles/10.1186/s40537-014-0007-7
- https://www.mygreatlearning.com/blog/deep-learning-tools-you-should-know/
- https://towardsdatascience.com/training-machine-learning-models-online-for-free-gpu-tpu-enabled-5def6a5c1ce3
- https://www.udacity.com/blog/2020/05/pytorch-vs-tensorflow-what-you-need-to-know.html
- https://www.imaginarycloud.com/blog/pytorch-vs-tensorflow/
- https://www.imaginarycloud.com/blog/r-vs-python/
- https://www.geeksforgeeks.org/theano-in-python/
- https://aithority.com/guest-authors/hot-air-when-to-choose-local-compute-over-cloud-for-your-deep-learning-applications/