

01.01.2019

# Statistical Methods in AI (CSE/ECE 471)

## Lecture-1: Intro and Administtrivia

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Center for Visual Information Technology (CVIT), IIIT Hyderabad



# SMAI (Statistical Methods in AI)

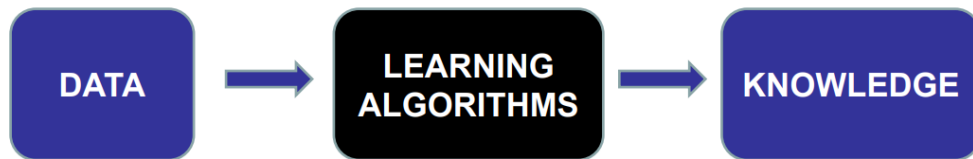
- SMAI ~ Introduction to **Machine Learning**
- Good news: One half is already familiar to you [Machine !]
- Other half = What this course is about !

# Machine Learning



Study of **Algorithmic methods** that use **data** to **improve** their **knowledge** of a **task**

# Machine Learning: Examples



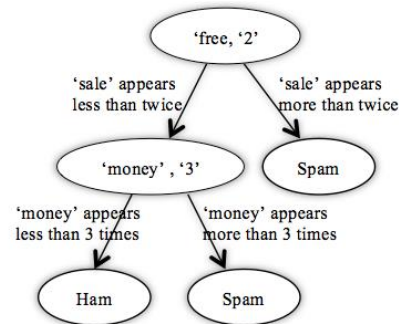
Algorithmic methods that use data to improve their knowledge of a task

Task: Detect spam email



Data: Labelled emails  
(in inboxes of other users as well !)

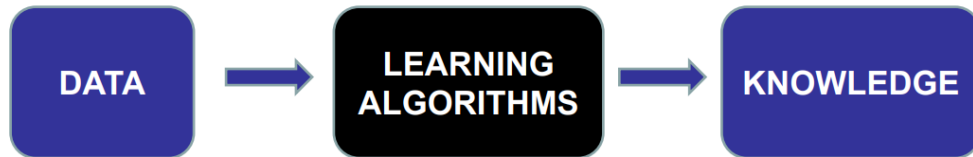
Knowledge:



Improve → 85% reduction of spam emails in Inbox over 3 months

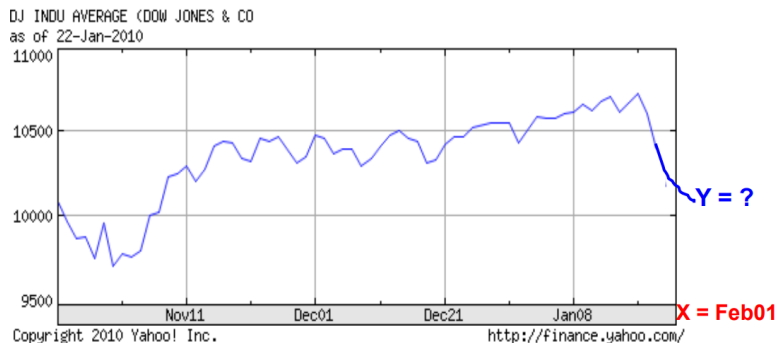
Algorithmic method: Decision Tree

# Machine Learning: Examples



Algorithmic methods that use data to improve their knowledge of a task

Task: Predict value of a stock (GOOG)

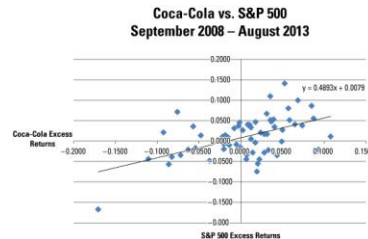


Data: Historical stock value  
(time, price/share)

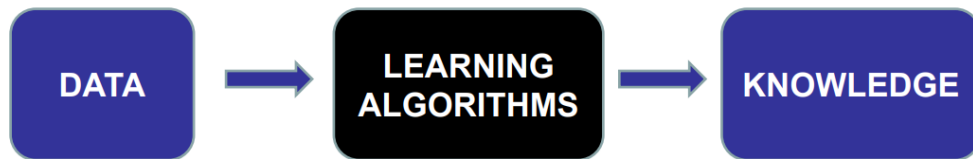
Knowledge: Model coefficients

Improve →  
Predict stock  
to 95% of its  
value

Algorithmic method: Linear Regression



# Machine Learning: Examples

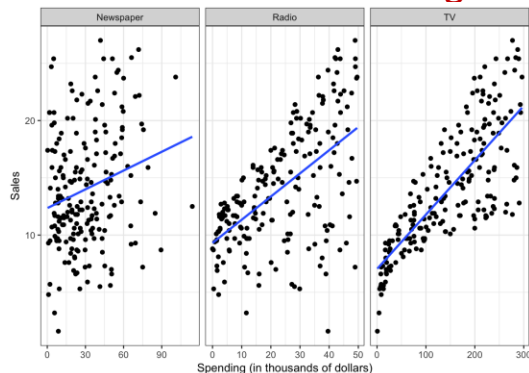


Algorithmic methods that use data to improve their knowledge of a task

Task: Predict effect of advertising on 'furniture' sales



Algorithmic method: Linear Regression

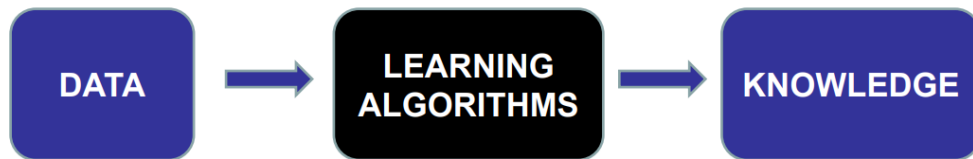


Data: Amount spent on ad spots in TV, radio, newspaper

	TV	Radio	Newspaper	Sales
0	230.1	37.8	69.2	22.1
1	44.5	39.3	45.1	10.4
2	17.2	45.9	69.3	9.3
3	151.5	41.3	58.5	18.5
4	180.8	10.8	58.4	12.9

Knowledge: For a given amount of TV, newspaper advertising spending additional 10,000 rupees on FM radio leads to an additional sale of 150 units

# Machine Learning: Examples



Algorithmic methods that use data to improve their knowledge of a task

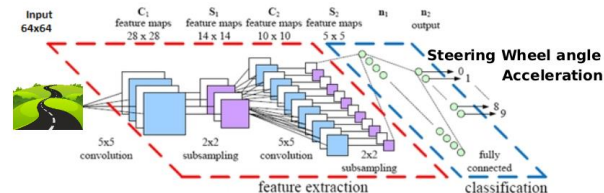
Task: Drive car 'safely' without human intervention



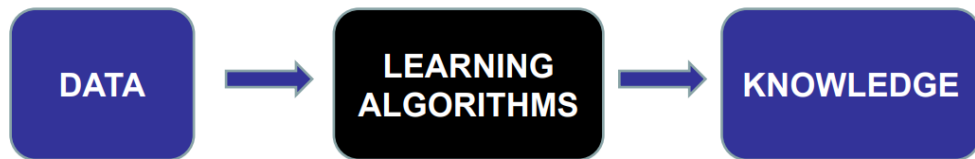
Data: Camera, Laser, GPS data ;  
Synthetic data

Knowledge: Model coefficients  
Improve → Drive 160,000  
miles without accident/human  
intervention

Algorithmic method: Deep Reinforcement Learning

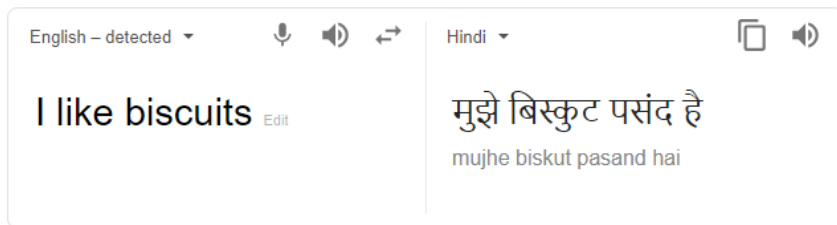


# Machine Learning: Examples



Algorithmic methods that use data to improve their knowledge of a task

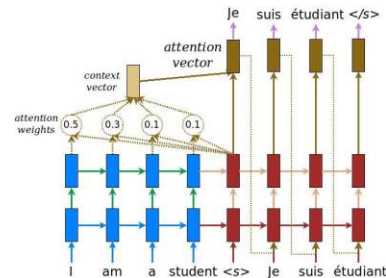
Task: Translate text from one language to another



Data: Paired sentences from source and target languages

Knowledge: Model coefficients

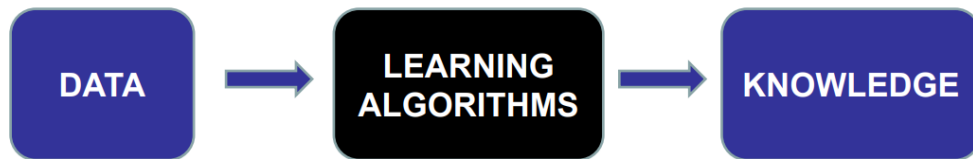
Improve → Reduce number of mistakes by 78%



Algorithmic method: Deep Recurrent Neural Networks

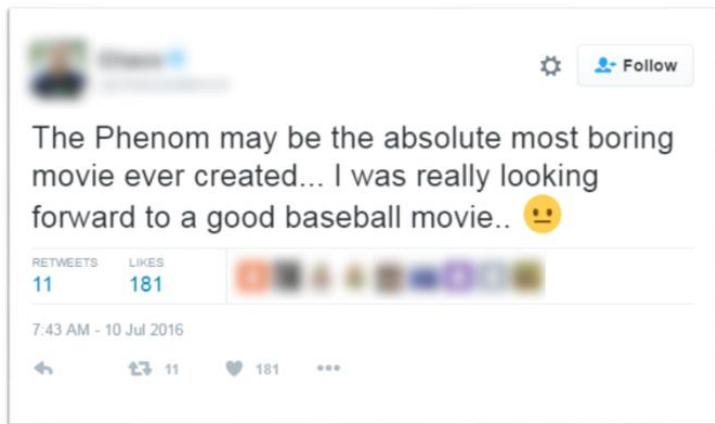


# Machine Learning: Examples



Algorithmic methods that use data to improve their knowledge of a task

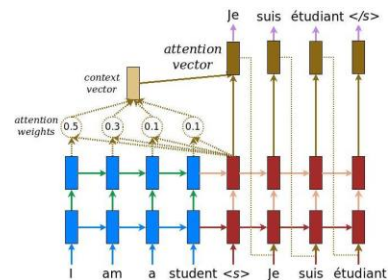
## Task: Sentiment Analysis



Sentiment: Negative  
Confidence: 99%  
Trend: Boring

Data: Text and 'Sentiment' label

Knowledge: Model coefficients  
Improve → Reduce number of sentiment mislabelings by 80%



Algorithmic method: Deep Recurrent Neural Networks

# What is ML ?

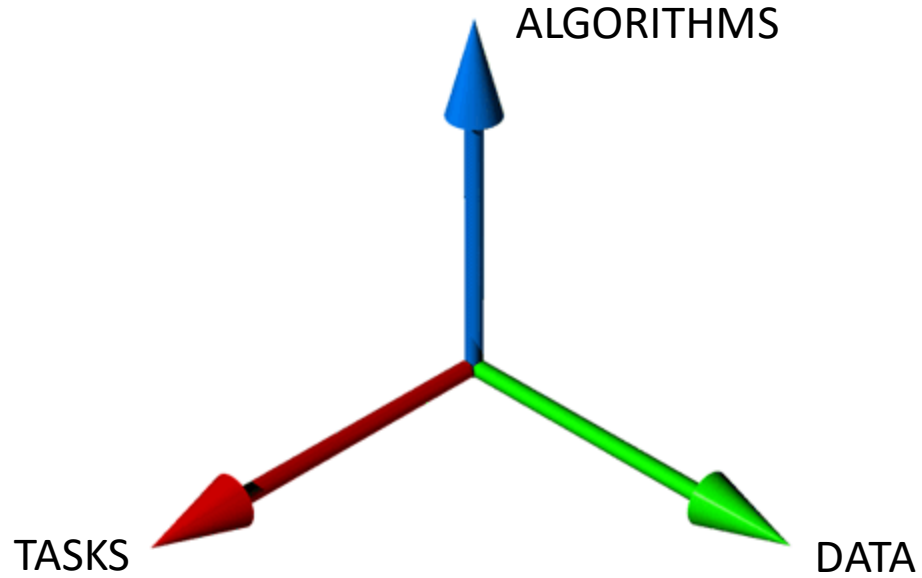
- Computer program whose behavior evolve based on empirical data (Wikipedia)
- Computer program that learns from **experience E** in order to improve its **performance P** on a **task T** (Tom Mitchell)

**experience E** : images, text, sensor measurements, biological data

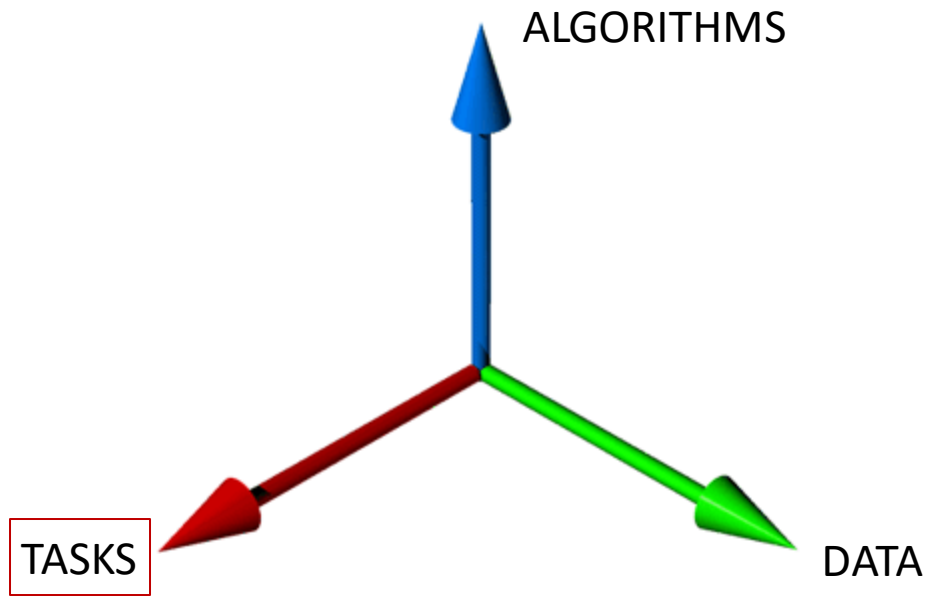
**task T** : estimating probabilities, predicting object label,  
dimensionality reduction, clustering

**performance P** : probability of success, money/time saved,

# 3 axes of ML



# 3 axes of ML



# ML Tasks

```
graph TD; A[ML Tasks] --> B[Predictive]; A --> C[Descriptive];
```

Predictive

Given an input,  
estimate output

Descriptive

# ML::Tasks → Predictive

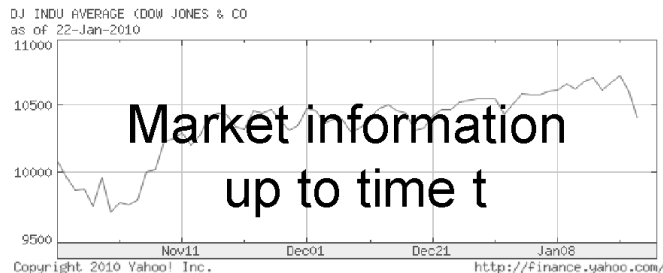
**Feature Space**  $\mathcal{X}$



Words in a document

**Label Space**  $\mathcal{Y}$

“Sports”  
“News”  
“Science”  
...



Share Price  
“\$ 24.50”



**Task:** Given  $X \in \mathcal{X}$ , predict  $Y \in \mathcal{Y}$ .

# ML::Tasks → Predictive → Classification

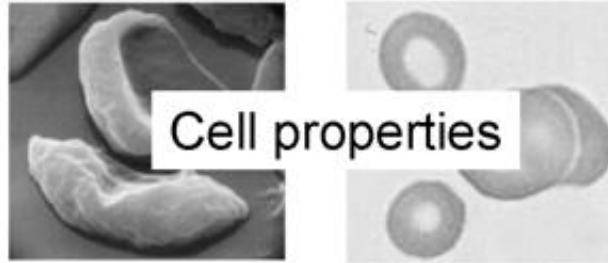
**Feature Space**  $\mathcal{X}$



**Label Space**  $\mathcal{Y}$



"Sports"  
"News"  
"Science"  
...



"Anemic cell"  
"Healthy cell"

**Discrete Labels**

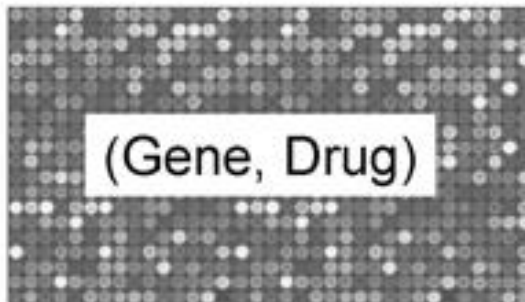
# ML::Tasks → Predictive → Regression

Feature Space  $\mathcal{X}$

Label Space  $\mathcal{Y}$



Share Price  
"\$ 24.577"



Expression level  
"6.88"

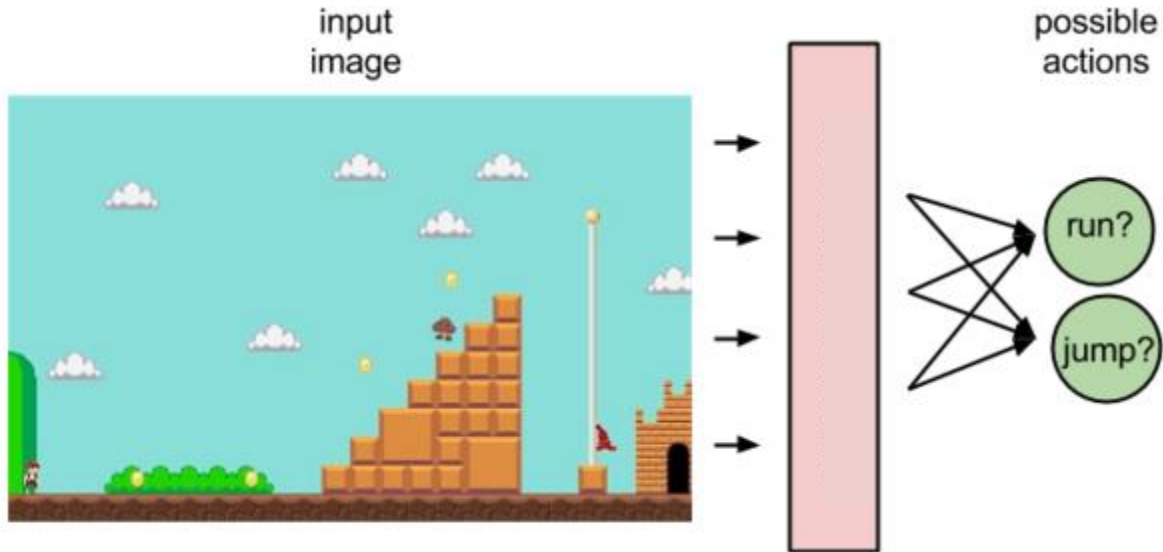
**Continuous Labels**



ML::Tasks → Predictive → Reinforcement Learning

**Feature Space**  $\mathcal{X}$

**Label Space**  $\mathcal{Y}$



# ML::Tasks $\rightarrow$ Predictive $\rightarrow$ Reinforcement Learning

Feature Space  $\mathcal{X}$

Label Space  $\mathcal{Y}$



# ML Tasks



```
graph TD; ML[ML Tasks] --> Predictive[Predictive]; ML --> Descriptive[Descriptive]; Predictive --> Classification[Classification]; Predictive --> Regression[Regression]; Predictive --> RL[Reinforcement Learning];
```

Predictive

Descriptive

Classification

Regression

Reinforcement  
Learning

# ML Tasks

```
graph TD; A[ML Tasks] --> B[Predictive]; A --> C[Descriptive];
```

A hierarchical diagram with a root node 'ML Tasks' in a grey box. A blue line connects it to two child nodes: 'Predictive' in a red box on the left and 'Descriptive' in a purple box on the right.

Predictive

Descriptive

# ML::Tasks → Descriptive

- Study/Exploit the ‘structure’ of data
  - Density Estimation
  - Clustering
  - Dimensionality Reduction
- Also studied as ‘Unsupervised Learning’
  - ‘Input’ data without paired ‘Output’

# Unsupervised Learning → Density Estimation

**Aka “learning without a teacher”**

**Feature Space**  $\mathcal{X}$

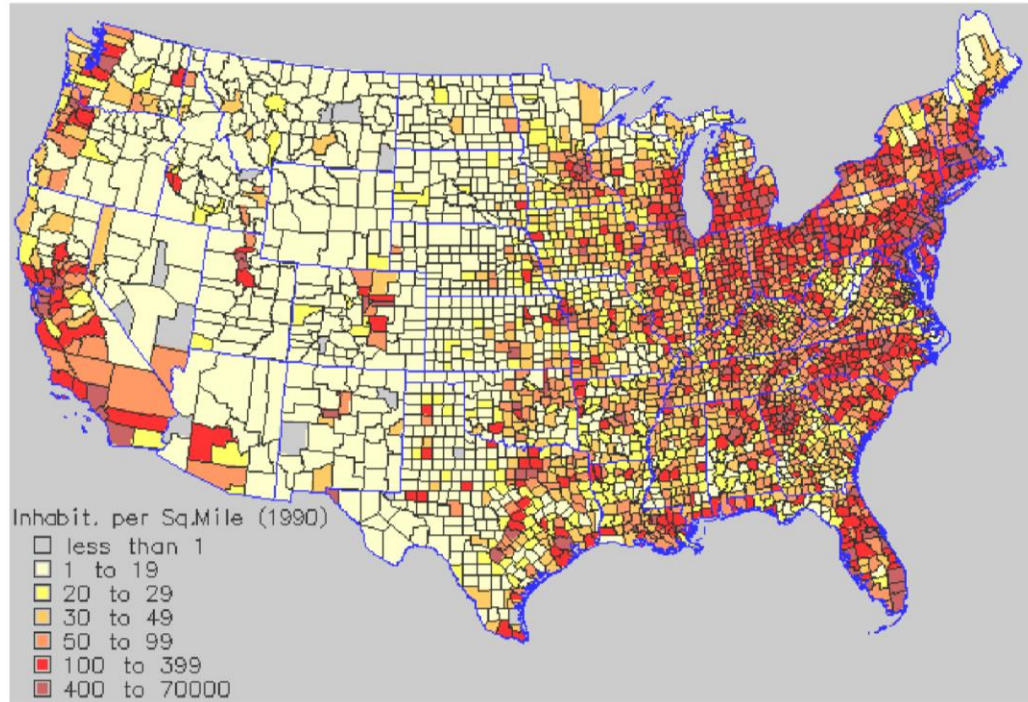


Word distribution  
(Probability of a word)

**Task:** Given  $X \in \mathcal{X}$ , learn  $f(X)$ .

# Unsupervised Learning → Density Estimation

## Population density



# Unsupervised Learning → Clustering

Group similar things e.g. images

[Goldberger et al.]








# Unsupervised Learning → Web Search

Google

alphabet



All

**Images**

News


Videos


Maps


More


Settings


Tools


 printable


 font


 calligraphy


 phonetic


 fancy


 cursive


 handwriting


 spanish


 a to z

 arabic


 military

 lettering

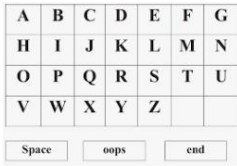
 sign language




Talk to Me Alphabet | ABCya!  
abcy.com




Morse code alphabet Royalty-free  
vectorstock.com




Patient Provider Communication  
patientprovidercommunication.org




Alphabet Vectors, Photos and PSD files  
freepik.com




Colorful Capital Letters Alphabet  
123rf.com




Why are the letters of the alphabet in ...  
theguardian.com




Cursive Alphabet Modern  
amazon.com




MFT Stitched Alphabet Die  
sevenhillscrafts.co.uk



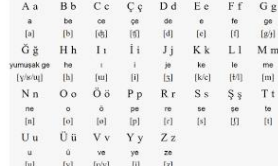
Fun english alphabet one  
vectorstock.com




Molodtsov alphabet - Wikipedia  
en.wikipedia.org



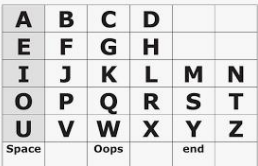
The Alphabet Chart Grade  
carsondellola.com




Turkish language, alphabets and  
omniglot.com



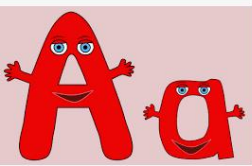
FolkArt Alphabet Heavy  
homedepot.com



Patient Provider Communication  
patientprovidercommunication.org

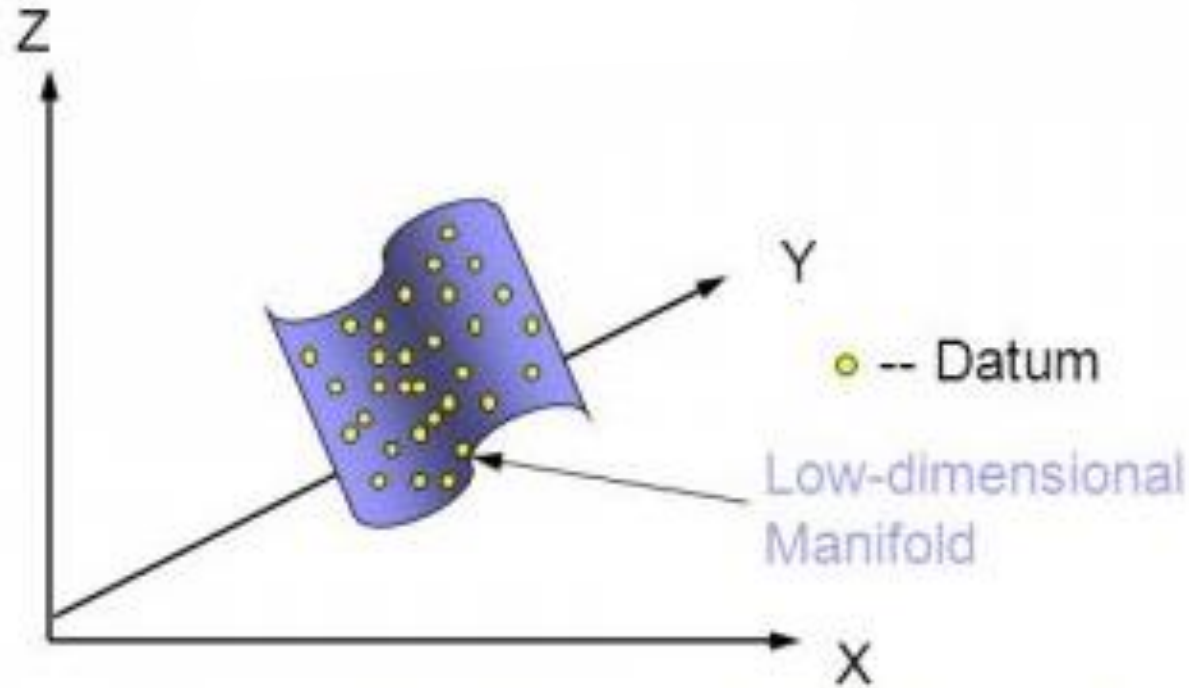


Definition of Alphabet by Merriam-Webster  
merriam-webster.com



We are the Alphabet - YouTube  
youtube.com

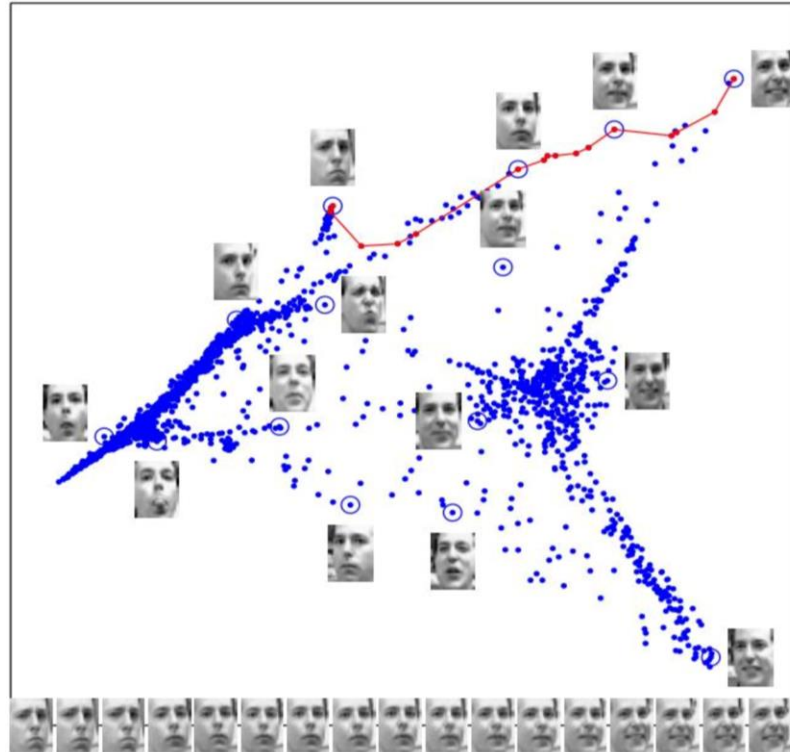
# Unsupervised Learning → Dimensionality Reduction



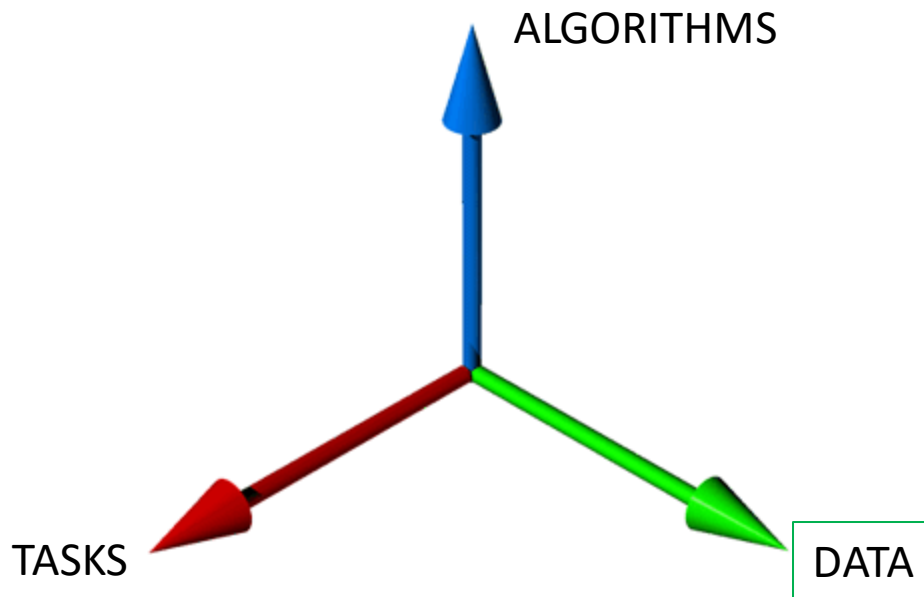
# Unsupervised Learning → Dimensionality Reduction + Visualization

Images have thousands or millions of pixels.

Can we give each image a coordinate, such that similar images are near each other?

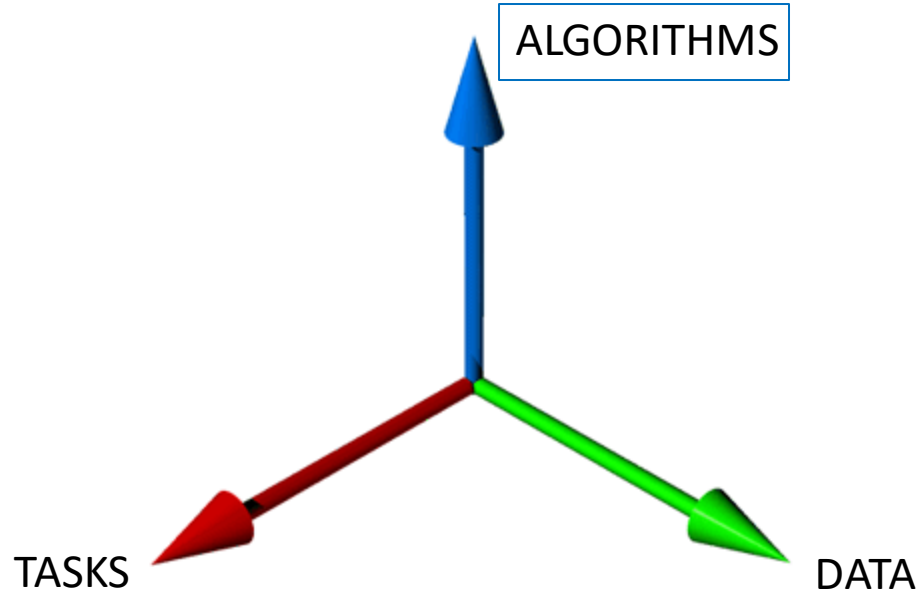


# 3 axes of ML



- Fully Observed
- Partially Observed
  - Some variables systematically not observed (e.g. 'topic' of a document)
  - Some variables missing some of the time (e.g. 'faulty sensor' readings)
- Actively collect / sense data (e.g. exploration robots)

# 3 axes of ML



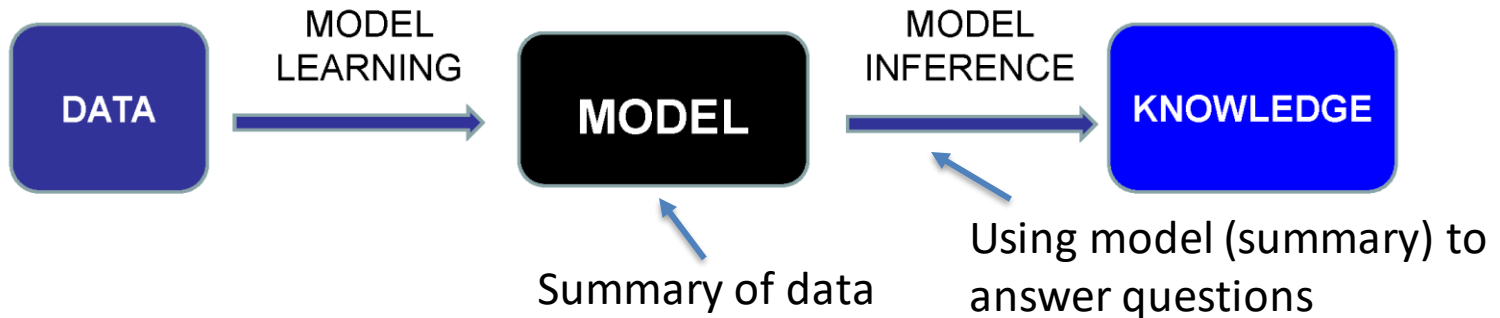
# Approaches

```
graph TD; A[Approaches] --> B[Model-based]; A --> C[Model-free];
```

Model-based

Model-free

# Model-based ML



Model-based  
ML

```
graph TD; A[Model-based ML] --> B[Parametric]; A --> C[Non-parametric]
```

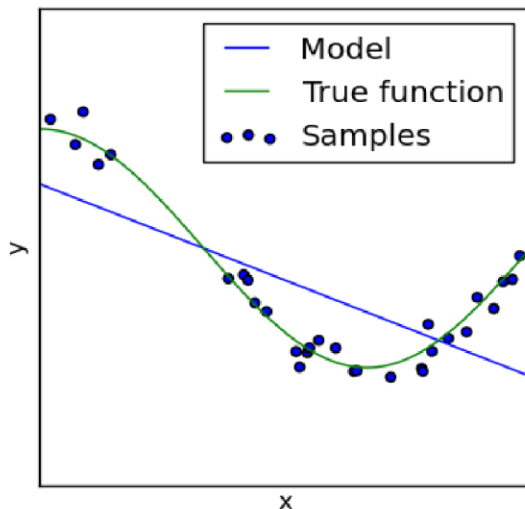
Parametric

Non-parametric



# Parametric Models

- “Fixed-size” models that do not “grow” with the data
- More data just means you learn/fit the model better

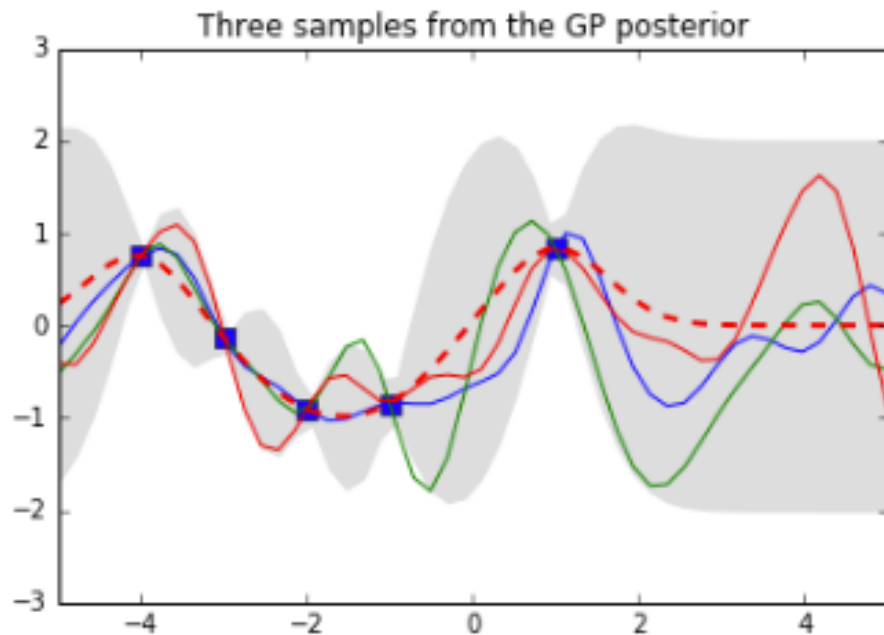


Fitting a simple line (2 params)  
to a bunch of one-dim. samples

Model: data = point on line + noise

# Nonparametric Models

- Models that grow with the data
- More data means a more complex model



Gaussian Process

# Approaches

```
graph TD; A[Approaches] --> B[Model-based]; A --> C[Model-free];
```

Model-based

Model-free

# Model-Free

- Occurs in context of Reinforcement Learning
- ...

# ML Tasks

```
graph TD; ML[ML Tasks] --> Predictive[Predictive]; ML --> Descriptive[Descriptive]; Predictive --> Classification[Classification]; Predictive --> Regression[Regression]; Predictive --> RL[Reinforcement Learning]; Descriptive --> DR[Dimensionality Reduction]; Descriptive --> DE[Density Estimation]; Descriptive --> Clustering[Clustering];
```

Predictive

Classification

Regression

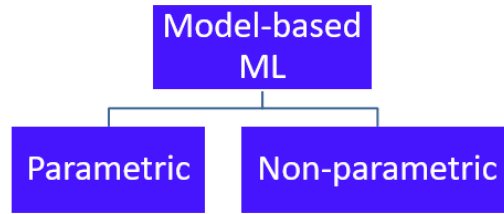
Reinforcement  
Learning

Descriptive

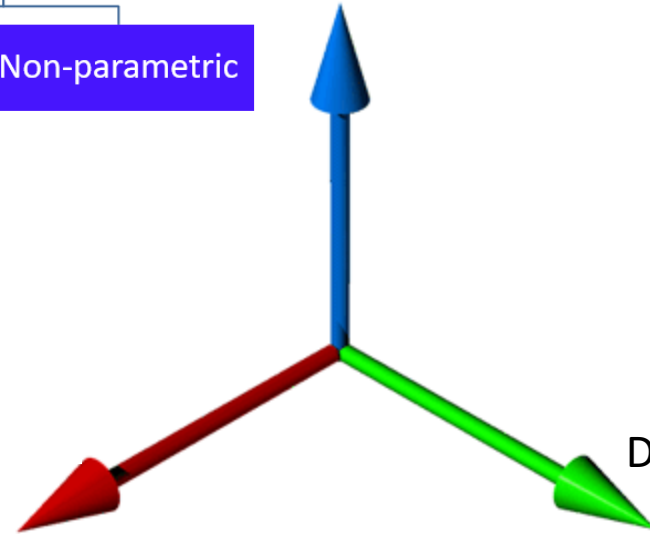
Dimensionality  
Reduction

Density  
Estimation

Clustering

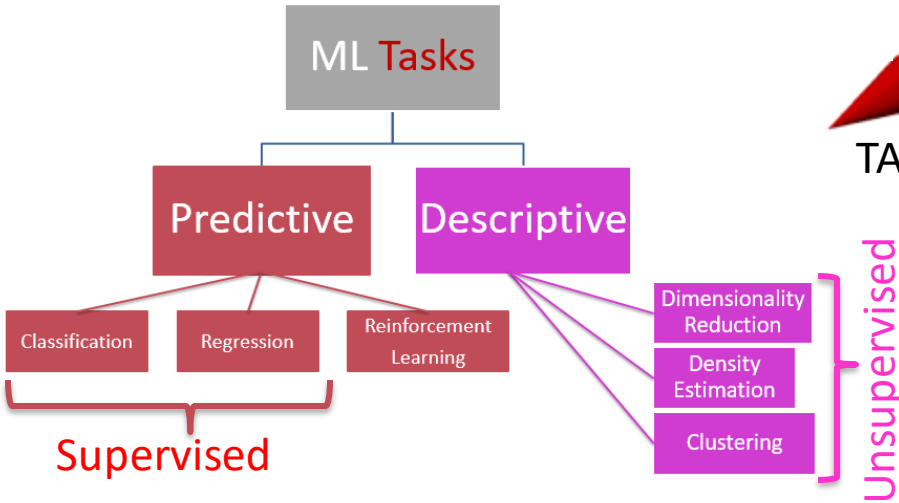


ALGORITHMS

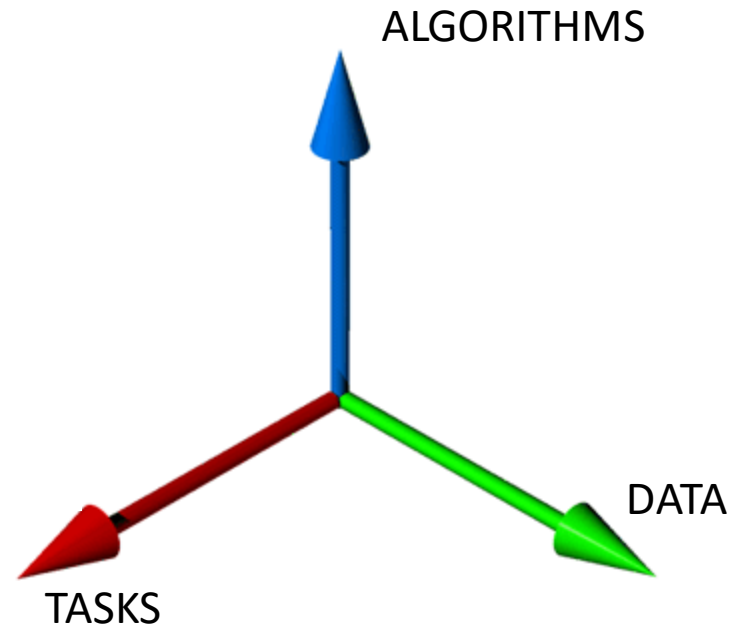


TASKS

DATA



- Fully Observed
- Partially Observed
  - Some variables systematically not observed (e.g. 'topic' of a document)
  - Some variables missing some of the time (e.g. 'faulty sensor' readings)
- Actively collect / sense data (e.g. exploration robots)



Strategy for fulfilling preferences

Optimization

Evaluation

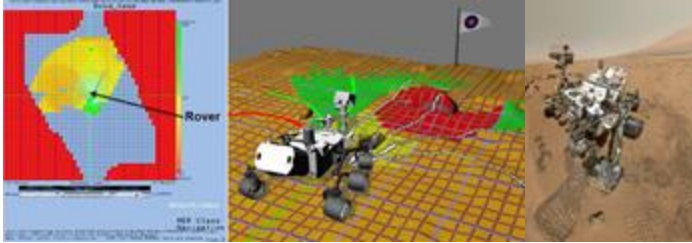
Representation

Preferences over the landscape

The landscape of allowed models



# When to “Learn”

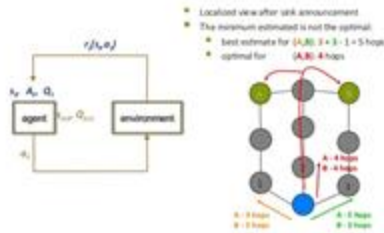


Human expertise does not exist  
(‘learning’ to navigate on Mars)



Humans unable to explain their expertise  
(‘learning’ to understand speech)

FROMS: Multicast routing with Q-Learning



Solution changes over time  
(‘learning’ to route network packet traffic)



Solution needs to be adapted to particular cases  
(user-specific ‘learning’)

# ML is everywhere !

- Wide applicability
- Very large-scale complex systems
  - Internet (billions of nodes)
  - Sensor network (new multi-modal sensing devices)
  - Genetics (human genome)
    - 20,000 genes x 10,000 drugs x 100 species x ...
- Improved machine learning algorithms
- Improved H/W
  - data capture (Terabytes, Petabytes of data)
  - Networking
  - faster computers (GPUs)

Pattern Recognition

Machine Learning

Data Science

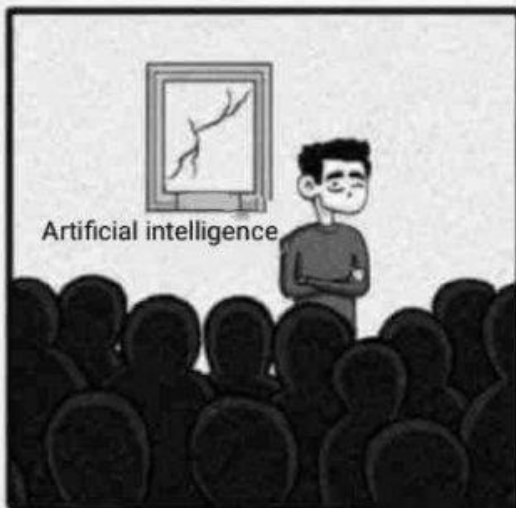
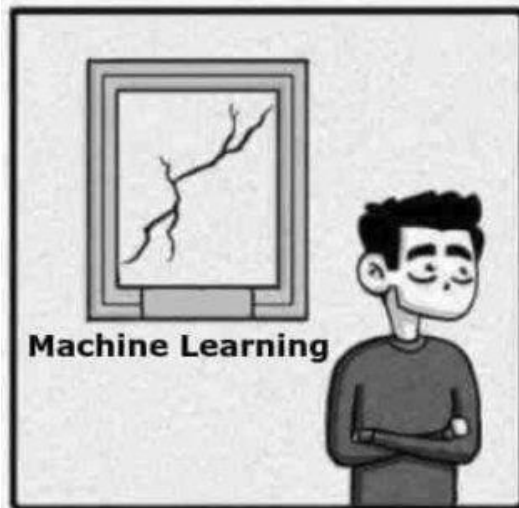
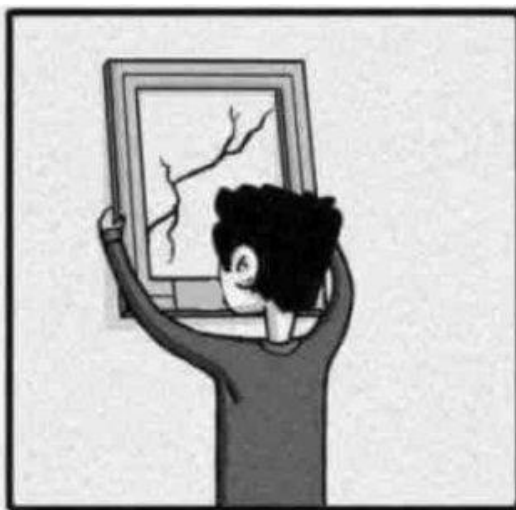
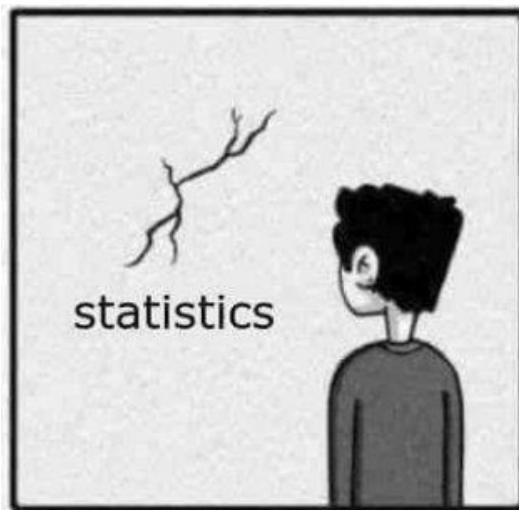
Artificial Intelligence

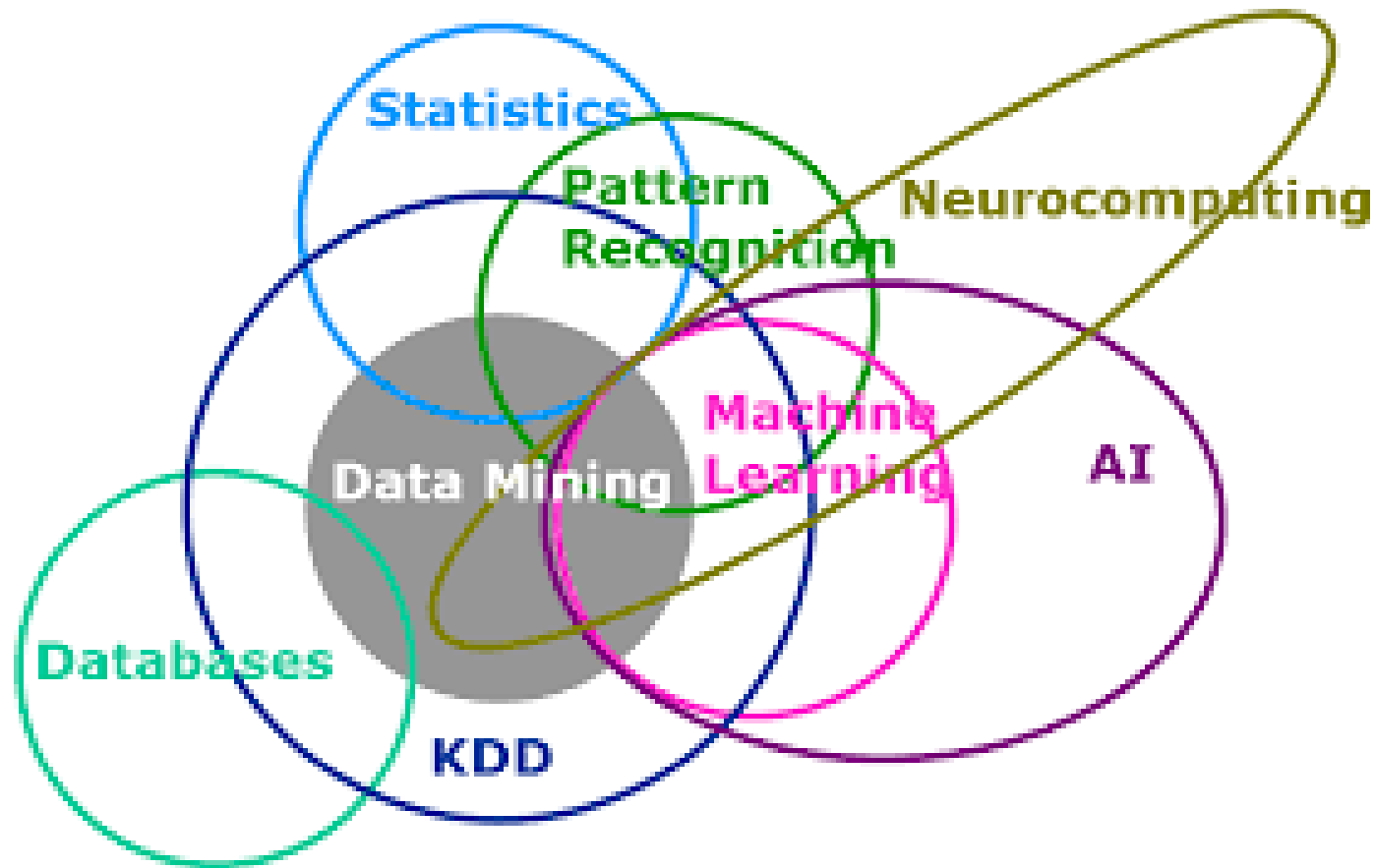
Statistical Learning

Information Retrieval

Data Mining

Statistics







# Concerns about ML/AI

- Ethics and Bias
- Will AI take over the world ?



**Suresh Venkatasubramanian**

@geomblog

Follow



People afraid of AI taking over the world should be required to install a package: preferably something in Julia or tensorflow on a nonstandard architecture.

5:31 PM - 29 Dec 2018

# About the course (471)

- Timings: Tue, Fri (Himalaya 205, 2.00p – 3.30p)
- Tutorial: Sat, Himalaya 205, 3.30p – 4.30p
- Website/Moodle :  
<https://moodle.iiit.ac.in/course/view.php?id=1472>



# Course Overview

- Part-1: Supervised Learning
- Part-2: Unsupervised Learning
- Part-3: Neural Networks
- Part-4: Model Selection and Statistical Estimation
- Part-5: ML for sequential data
- Part-6: Case studies [Vision, Robotics, NLP, Speech, Bioinformatics]

# Common Themes

- Mathematical framework
  - Well defined concepts based on explicit assumptions
- Representation
  - How do we encode text? Images?
- Model selection
  - Which model should we use? How complex should it be?
- Use of prior knowledge
  - How do we encode our beliefs? How much can we assume?

# Pre-requisites

- [MUST]
  - Programming
  - Data Structures
  - Algorithms
- [RECOMMENDED REVISION]
  - Linear Algebra
  - Statistics
  - Probability
  - Calculus

# Course Objectives

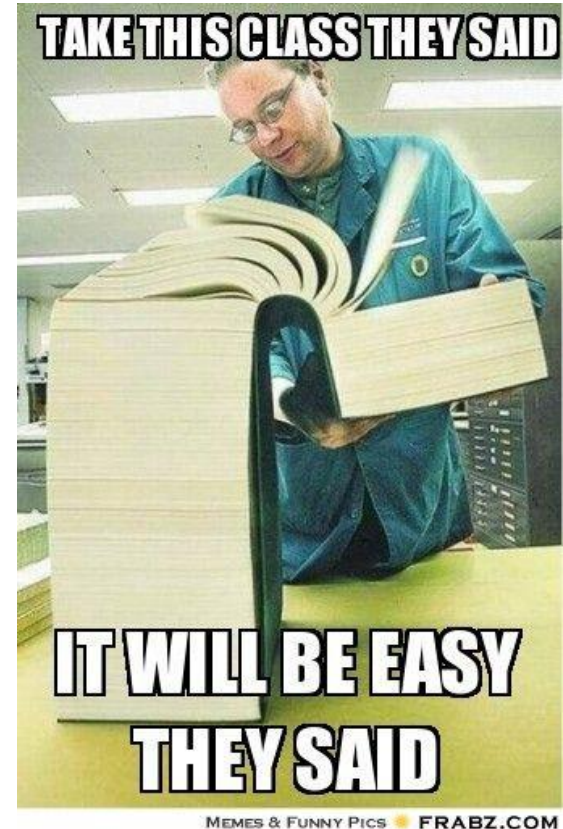
- Determine whether ML is suitable for a problem
- Formulate a problem as a ML problem (data ,representations, tasks, algorithms)
- **Understand** and apply ML method(s)
- Be aware of ML pitfalls, follow best practices
- Be ready to dive deeper (into ML theory or applied areas)

# About the course - TAs

- "Sarthak Sharma" <[sarthak.sharma@research.iiit.ac.in](mailto:sarthak.sharma@research.iiit.ac.in)>
- "Nikhil Gogate" <[nikhil.gogate@students.iiit.ac.in](mailto:nikhil.gogate@students.iiit.ac.in)>
- "Maheshwari Shubh Jagmohan" <[shubh.maheshwari@students.iiit.ac.in](mailto:shubh.maheshwari@students.iiit.ac.in)>
- "Aditya Aggarwal" <[aditya.aggarwal@students.iiit.ac.in](mailto:aditya.aggarwal@students.iiit.ac.in)>
- "Vachaspati R" <[vachaspathi.r@students.iiit.ac.in](mailto:vachaspathi.r@students.iiit.ac.in)>
- "Himanshi Sharma" <[himanshi.sharma@students.iiit.ac.in](mailto:himanshi.sharma@students.iiit.ac.in)>
- "Ranajit Saha" <[ranajit.saha@students.iiit.ac.in](mailto:ranajit.saha@students.iiit.ac.in)>
- "Sanjoy Chowdhury" <[sanjoy.chowdhury@students.iiit.ac.in](mailto:sanjoy.chowdhury@students.iiit.ac.in)>
- "Murtuza Bohra" <[murtuza.bohra@research.iiit.ac.in](mailto:murtuza.bohra@research.iiit.ac.in)>
- "Avinash Kumar" <[avinash.kumar@students.iiit.ac.in](mailto:avinash.kumar@students.iiit.ac.in)>
- "Satyam Mittal" <[satyam.mittal@students.iiit.ac.in](mailto:satyam.mittal@students.iiit.ac.in)>
- "Kanay Gupta" <[kanay.gupta@students.iiit.ac.in](mailto:kanay.gupta@students.iiit.ac.in)>

# About the course – Grading Policy

- Assessment
  - 2 mid semester exams ( $2 \times 15\% = 30\%$ )
  - 1 Final Exam (30%)
  - 13 Assignments ( $13 \times 2\% = 26\%$ )
  - 1 Project (14%)



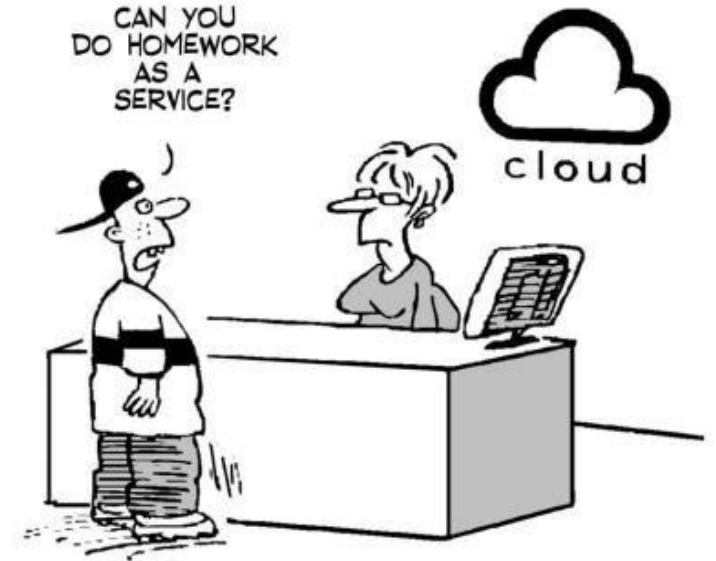
# About the course - assignments

- Code
  - **MATLAB**
  - \* Python (scikit-learn + jupyter notebook)
  - Neural Networks: TF, Pytorch, Keras
- This Saturday: Tutorials on MATLAB, Python (tentative)

# About the course – collaboration policy

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- OK to discuss assignment questions and approaches
- But work must be your own (no copying – partially or fully)
- If you worked with someone, mention their name(s)
- We will be checking for copying/plagiarism
- Better to own up than be caught !





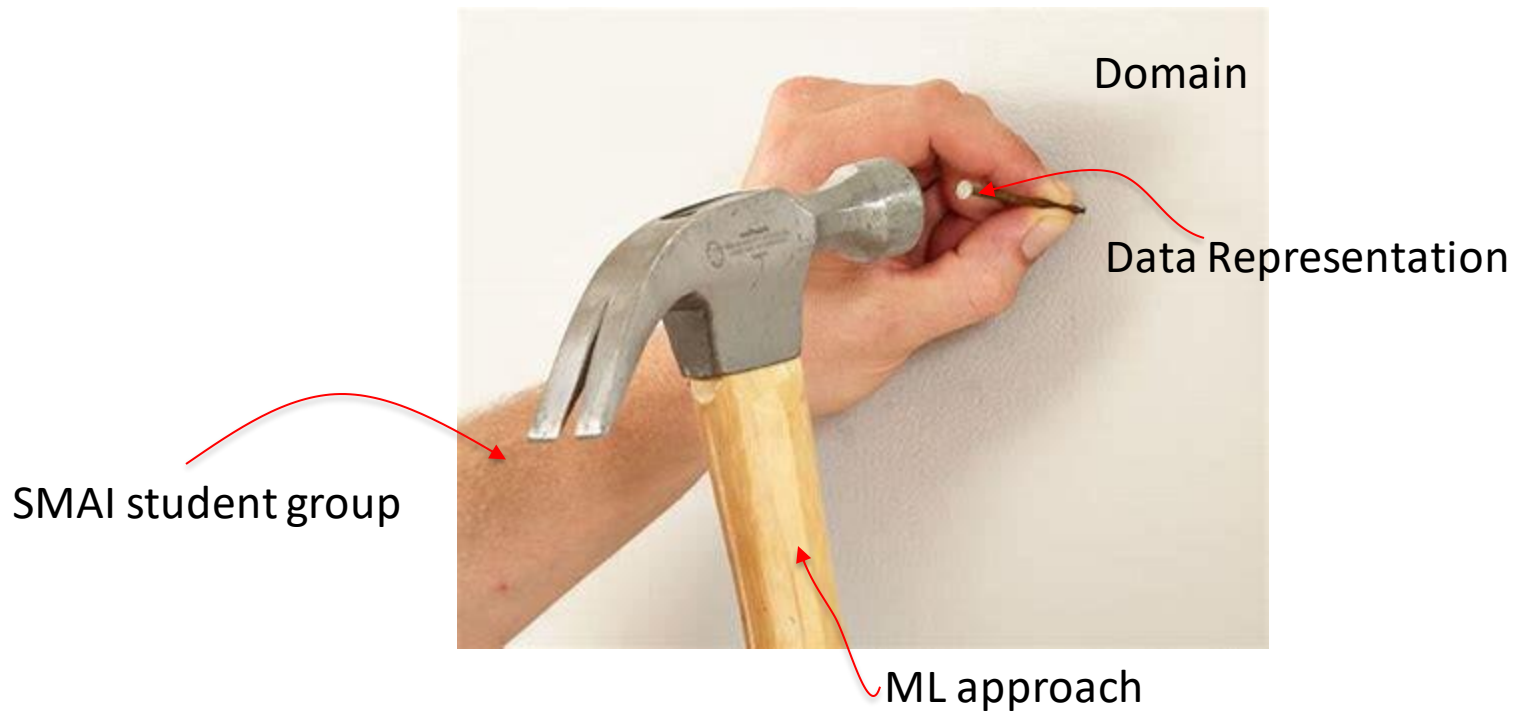
# About the course – Grading Policy

- **Homework Late Policy:** 50% if one day late; zero percent if more than one day late
- **A one time late submission bonus:** only applicable to HW (with maximum of three days delay). You must adhere to standard late submission policy after using your bonus. No exceptions will be made. You'll need to inform TAs beforehand if you wish to use the late submission bonus.

# About the course - Projects

- Groups (max 4 students/group)

# Projects



# Projects

- Problem/Task-first thinking
- Come up with a top-3 list and why the problem is interesting / novel to study
- Be creative / original
- Project-related guidelines will be shared later
- ...

# Some ideas

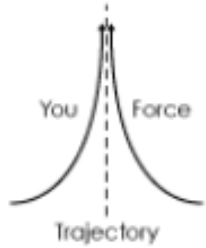
- For each subject exam (including SMAI)
  - collect anonymous data of
    - 1: # of hours studied before an exam
    - 2: # of hours slept before an exam
    - 3: Location in the classroom (# of rows away from front of the room)
    - marks obtained
  - Analyze above data
  - How well can marks be predicted from {1,2,3} above ?

# Some ideas

- Predict someone's mother tongue from the way they speak English/sing English songs 😊
- Solve a civic problem
  - E.g. Detect garbage from satellite imagery of Hyderabad
  - Predict traffic density at IIIT/DLF junction
- Predict if photo of biryani is from Paradise 😊

# Some ideas

- Generate charts for famous movie quotes



– Star Wars Episode IV, 1977

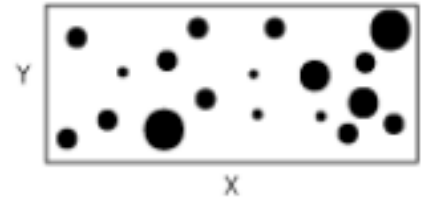


– Love Story, 1970



– Dr. No, 1962

UNCERTAIN AND RANDOM

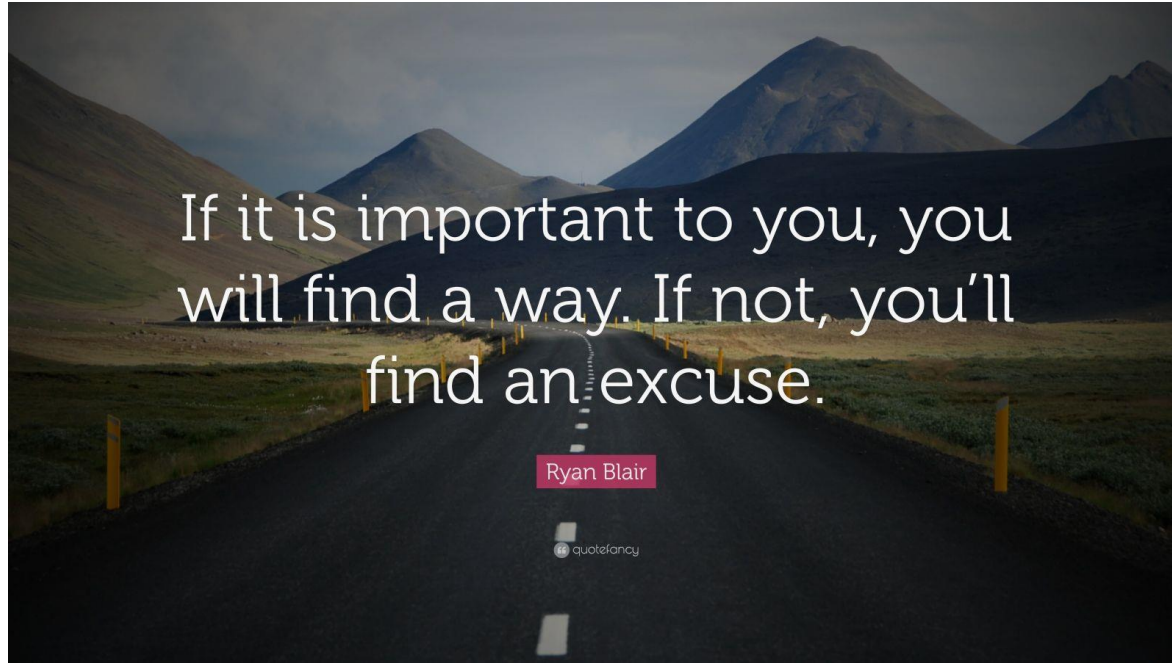


– Forrest Gump, 1994

- Indian Language movies 😊

# Some ideas

- Given a quote, find an accompanying picture (or pictures) which best `fit' the quote (and vice versa)





# Some ideas

- Given a quote, find an accompanying picture (or pictures) which best 'fit' the quote



# Some ideas

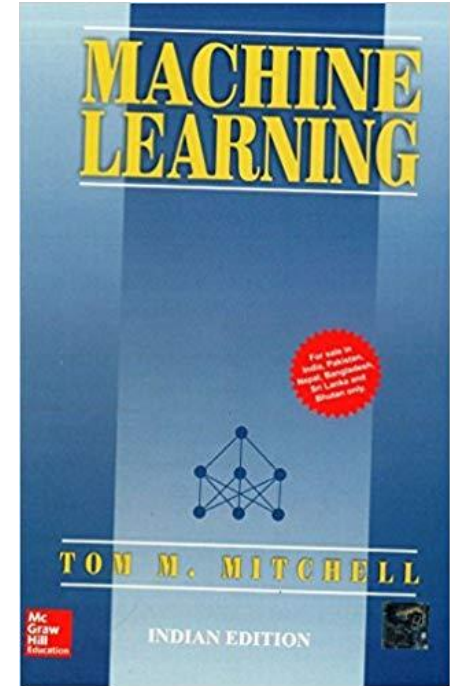
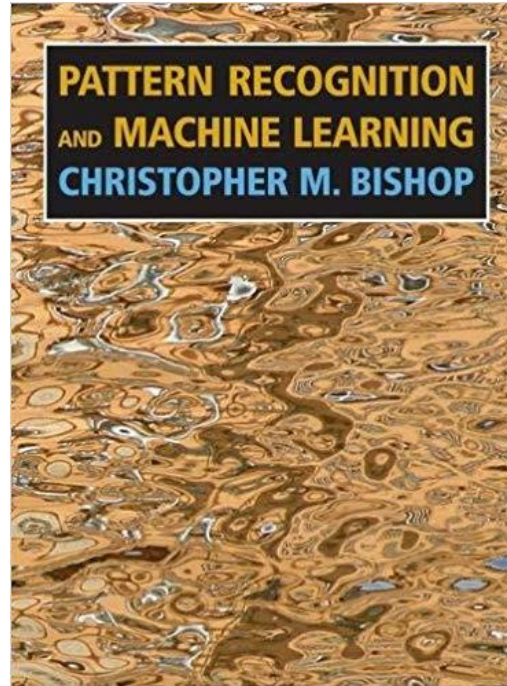
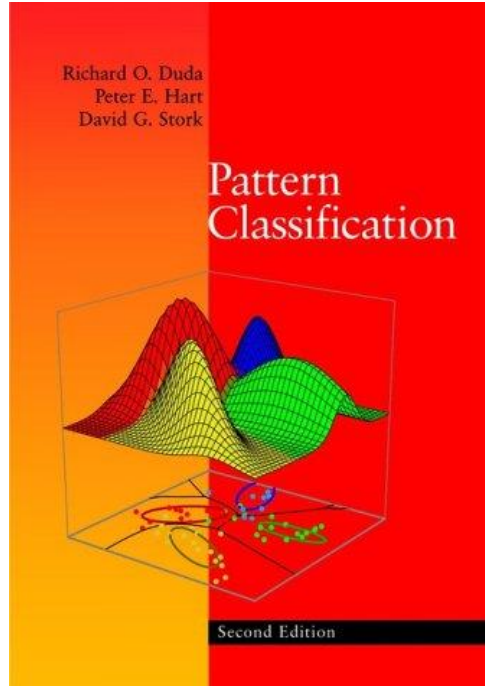
- Generating text whose rhyme matches song lyrics

*To the tune of Skyfall (by Adele)*

School hell is where we start,  
A thousand grades and marks apart,  
Where hell collides, and Sundays are dark  
You can have my control, You can take my brain  
But you'll never have my heart,

Let the grades fall, when they fail,  
I will stand tall, and face them all together  
Let the grades fall, when they fail  
I will stand tall, and face it all together  
At School Hell

# About the course - Material



# About the course - Material

- Will be provided on a per lecture basis
- Scattered Resources across Internet

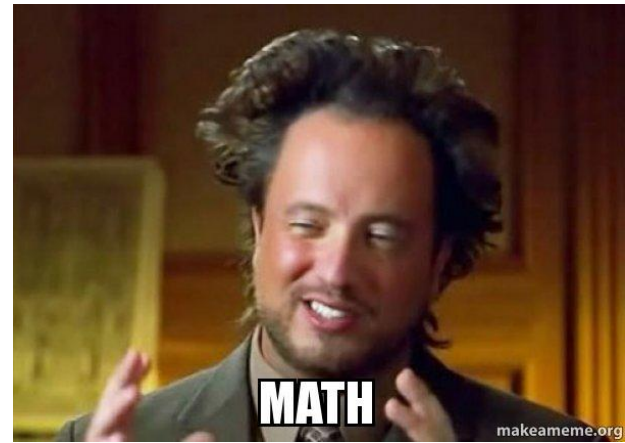
- SMAI = Introduction to **Machine Learning**
- Companion courses this semester
  - Artificial Intelligence (371) [Mon, Thu] (UG)
  - Optimization (481) [Mon, Thu]
  - Computer Vision (578) [Tue, Fri]
  - NLP Applications (573) [Mon, Thu]

# Survey

- For those **seriously** planning to take the course ...
- Take the anonymous survey: <https://bit.ly/2QOTIMr>
- Deadline to submit survey: Fri 4, 12pm
- ... Understand your background
- ... Will help tailor the course content

## Additionally ...

- **Understand**, don't just memorize
- Love the math, not the toolbox !
- Capture the broad ideas and insights (useful years down the line)
- Implement ! No substitute for experience.
- Just the beginning ....





# A tale of two airplanes



[“The Gimli Glider – 30 years later”](https://www.youtube.com/watch?v=3ffryZAd4Nw)

<https://www.youtube.com/watch?v=3ffryZAd4Nw>



[“Fatal Flight 447:Chaos in the Cockpit”](https://www.youtube.com/watch?v=YJzg6W2f7Ng)

<https://www.youtube.com/watch?v=YJzg6W2f7Ng>



# OK, so what !

- So many resources (and courses) online
- Why bother taking this course ?
- Answer: Look around you (and me)