

CS181: Introduction to Machine Learning

Finale Doshi-Velez



HARVARD

School of Engineering
and Applied Sciences

What this course is about

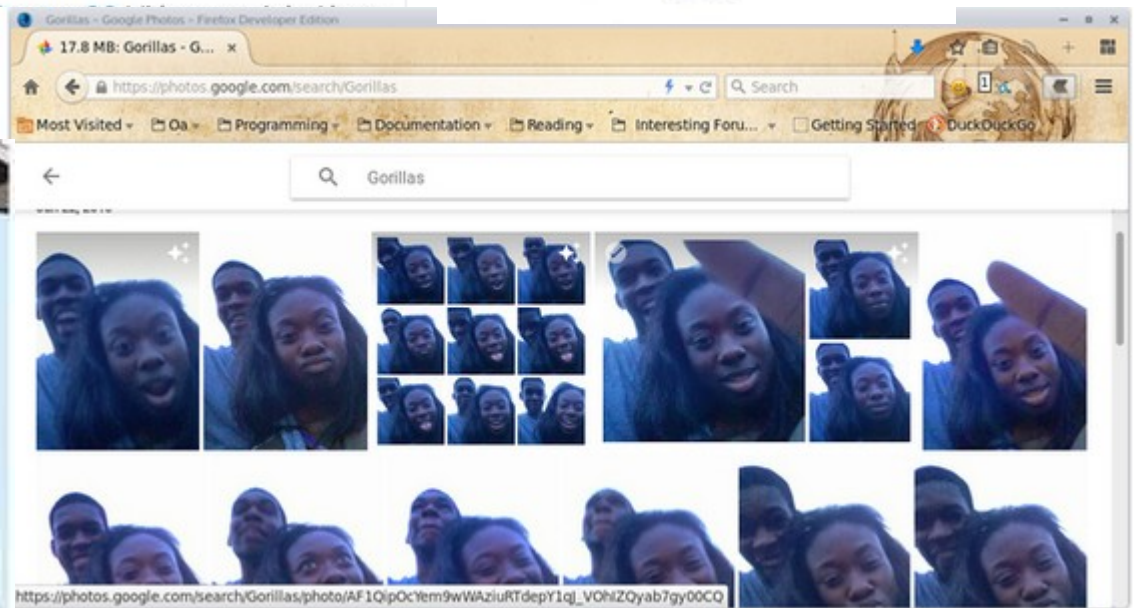


What this course is about

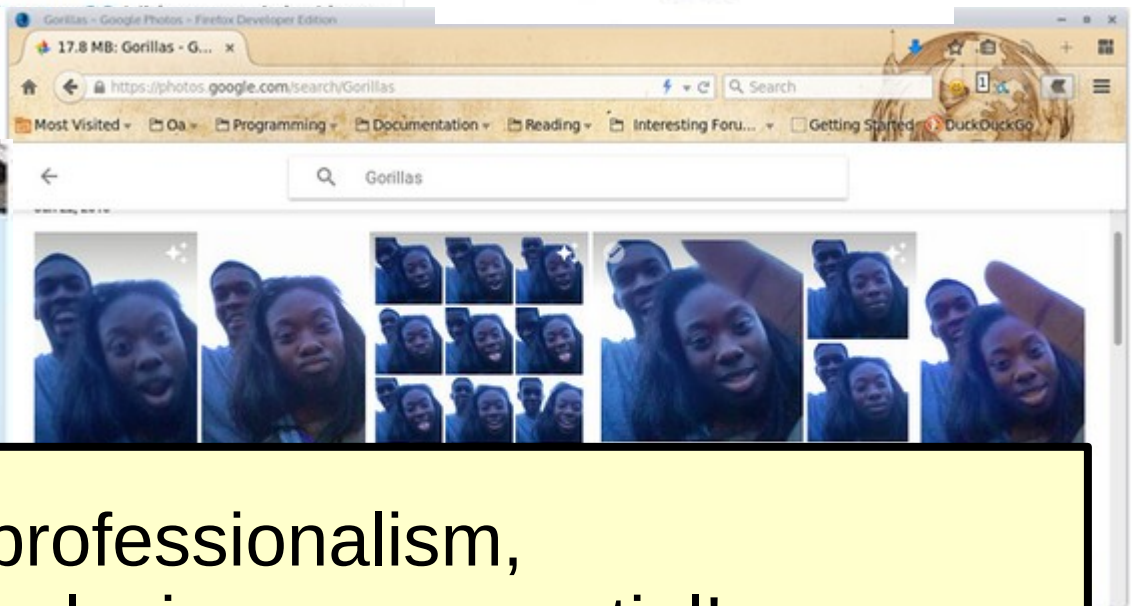


We can build the most amazing things!

What this course is about



What this course is about



Rigor, professionalism,
ethics, and inclusion are essential!

How we will get there

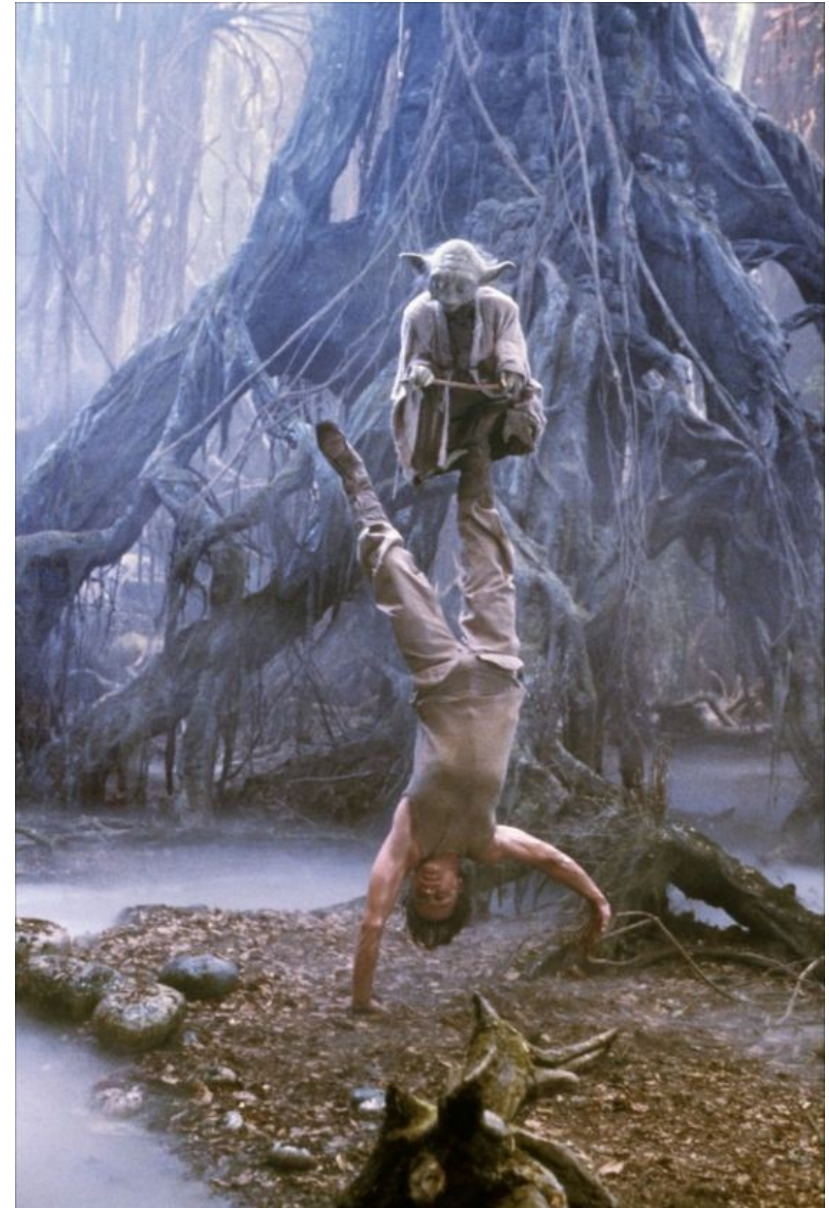


- Make appropriate model choices
- Have sufficient understanding to learn and apply the new techniques
- Identify sources of error
- Evaluate carefully

How we will get there

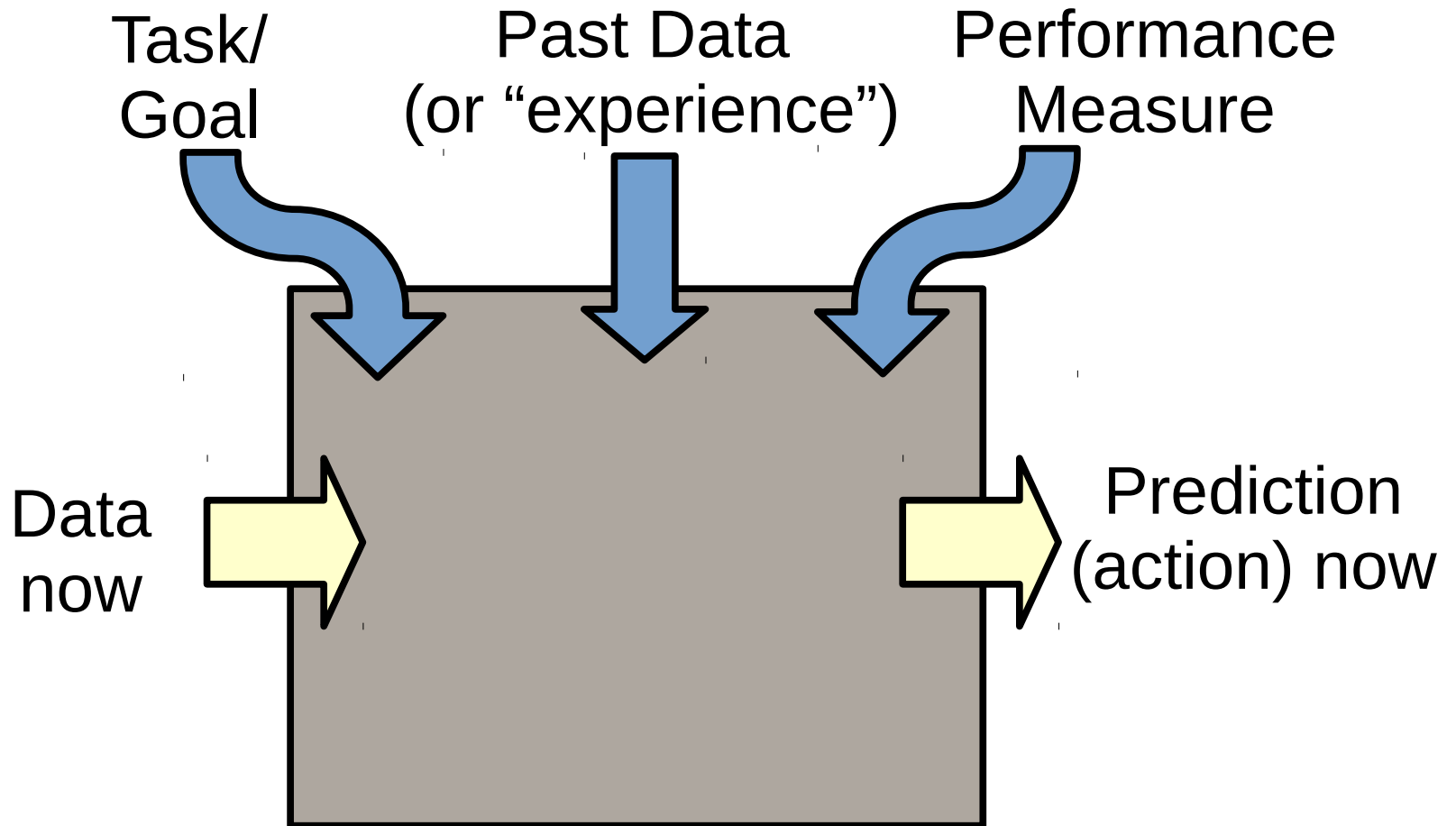


- Make appropriate model choices
- Have sufficient understanding to learn and apply the new techniques
- Identify sources of error
- Evaluate carefully

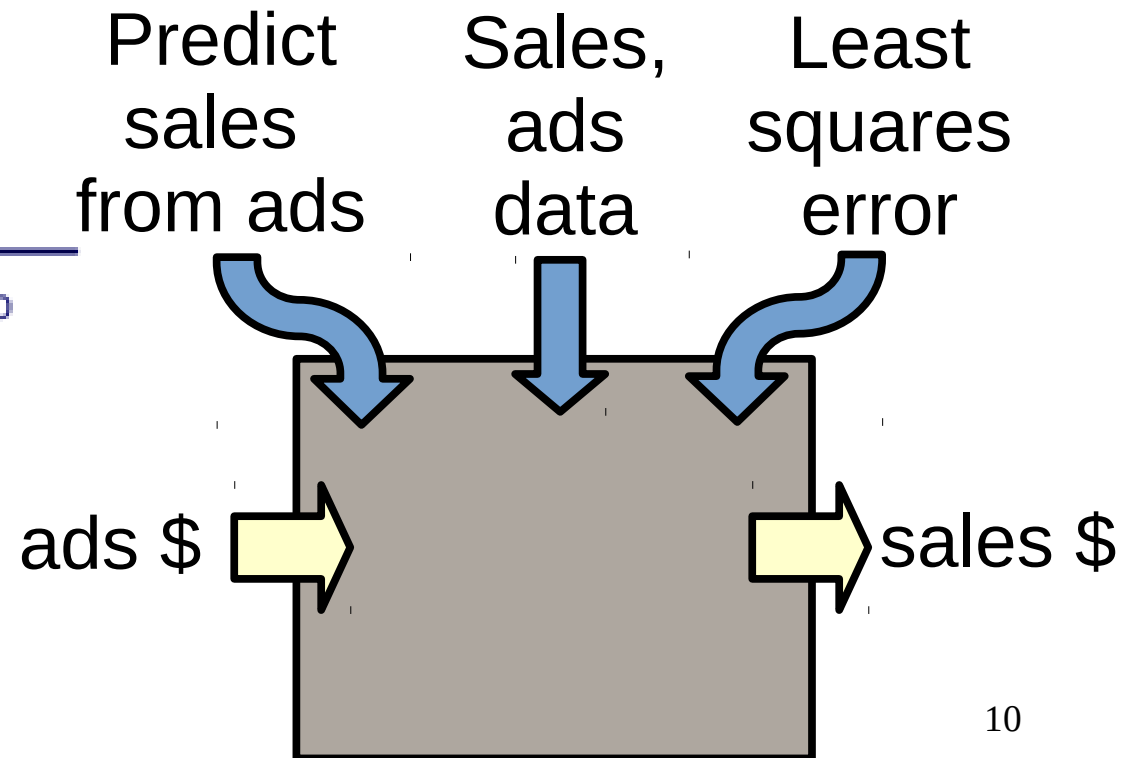
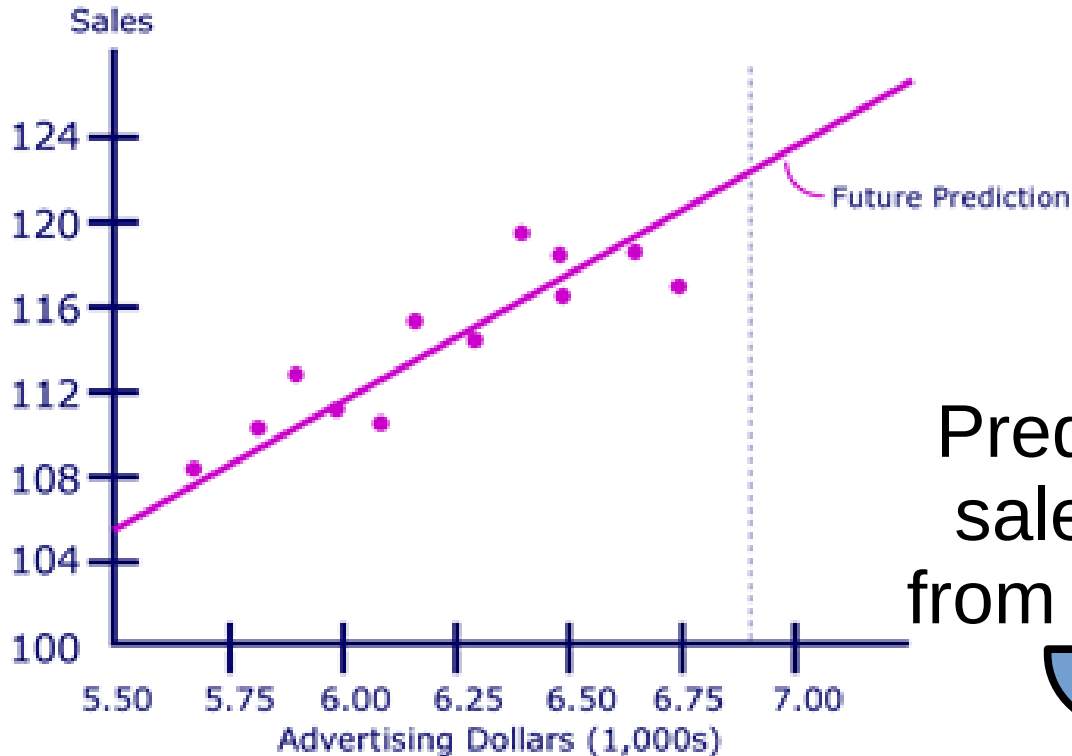


Let's get to it!

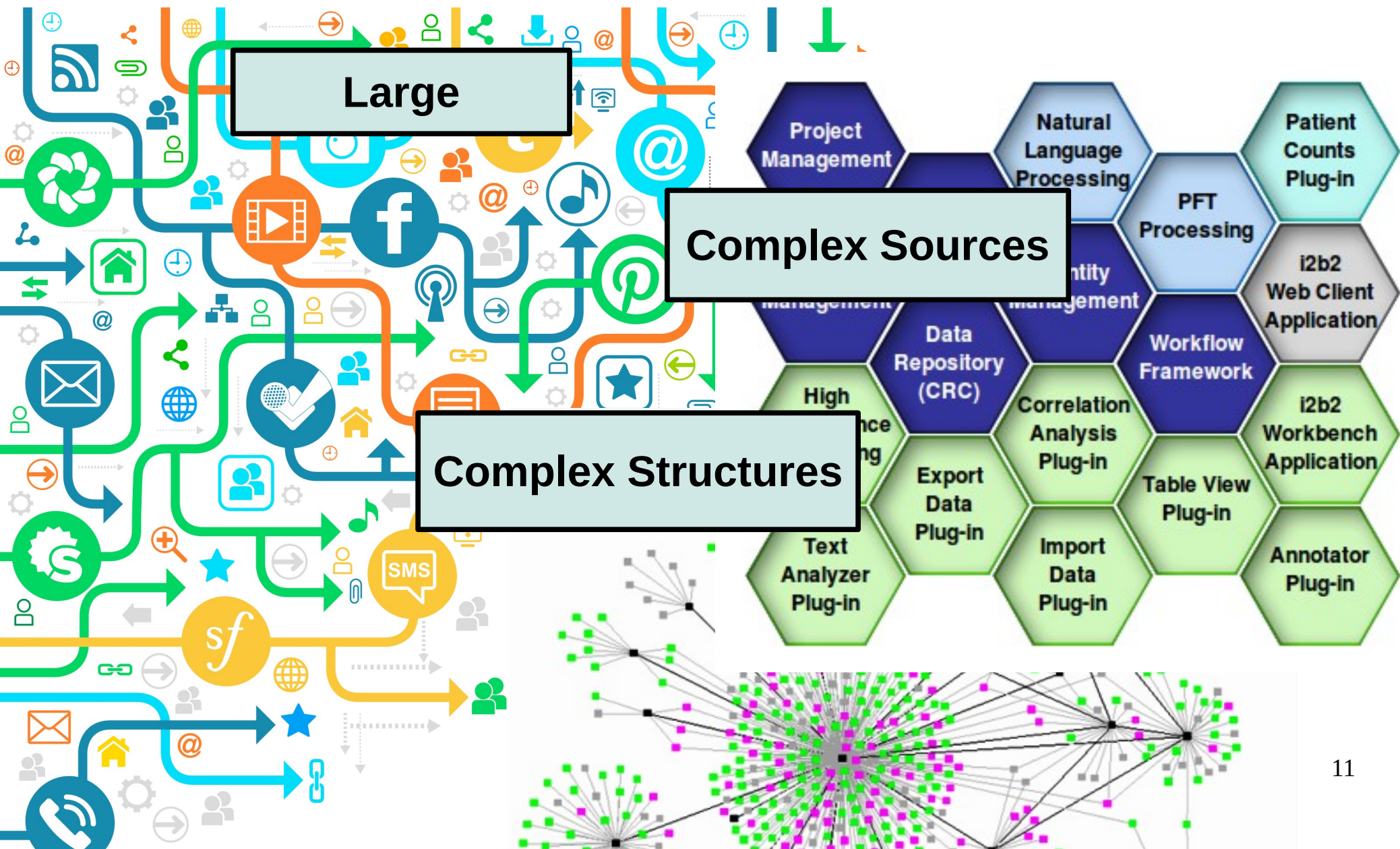
What is machine learning?



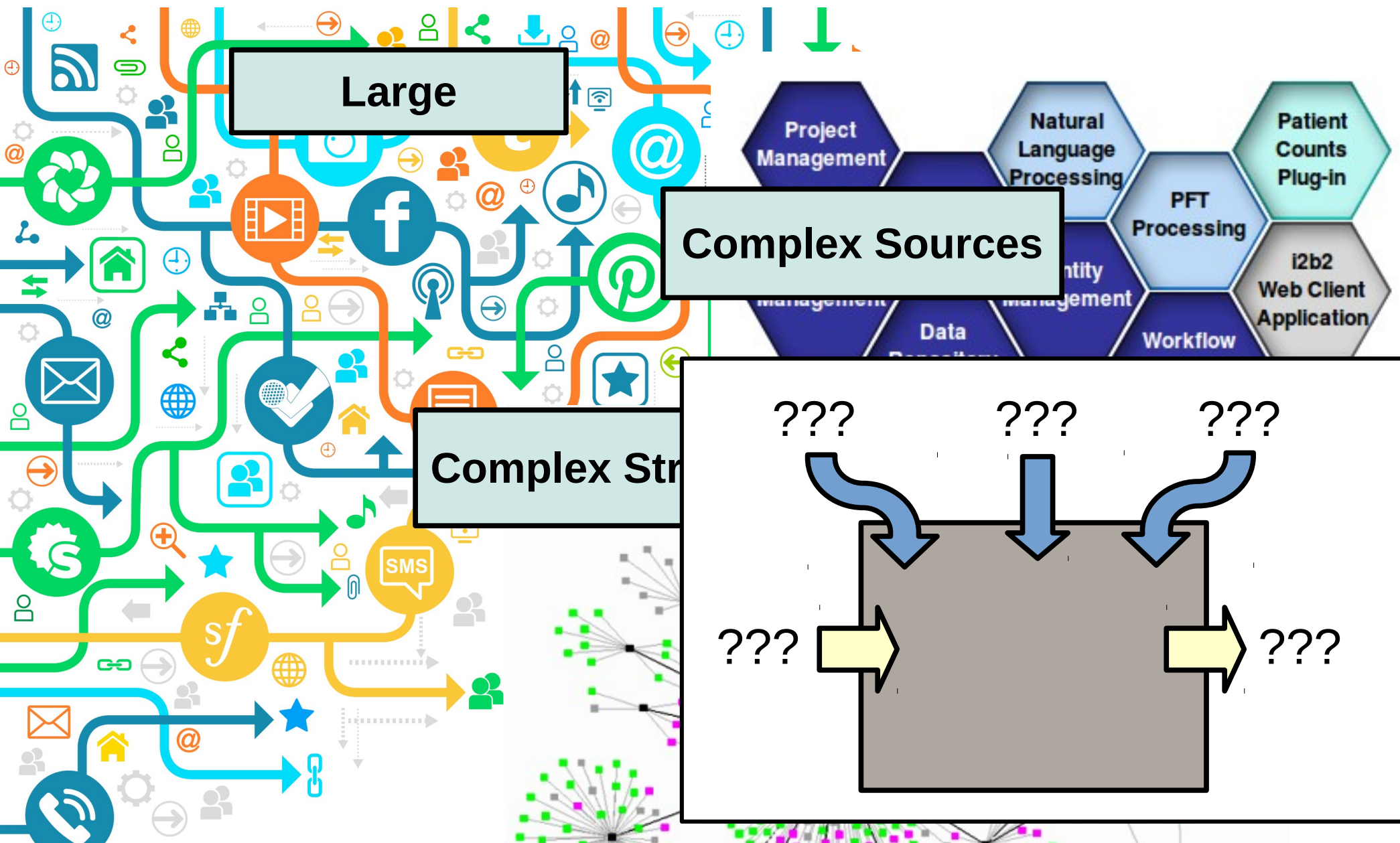
The starting point...



... where we are now



... where we are now



A Story: Treating Depression

Clinical Question: What meds to give what depression patients?



Clinical Question: What meds to give what depression patients?

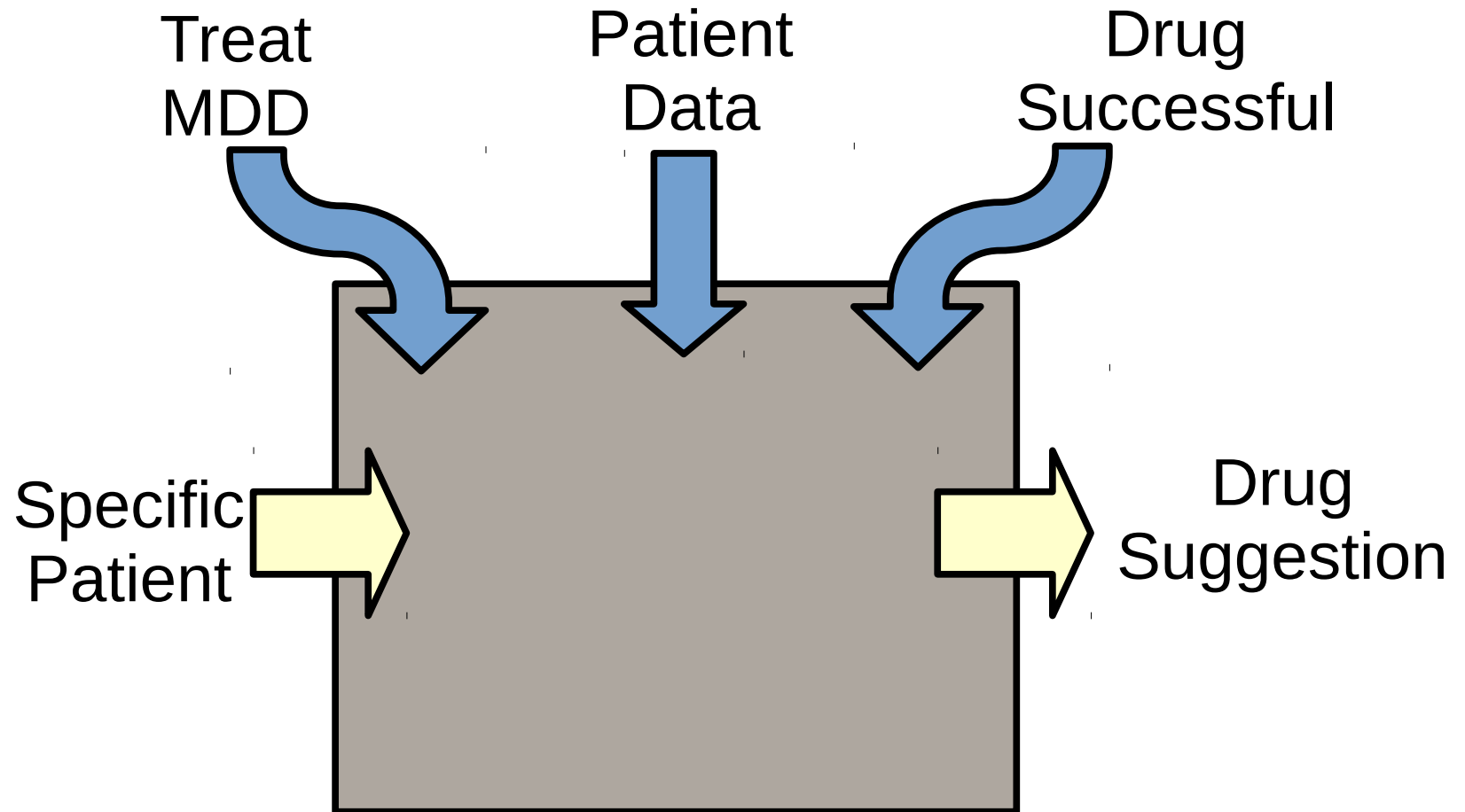


Clinical Question: What meds to give what depression patients?



Also: Can we **explain** who responds to what drug?

Formalizing...



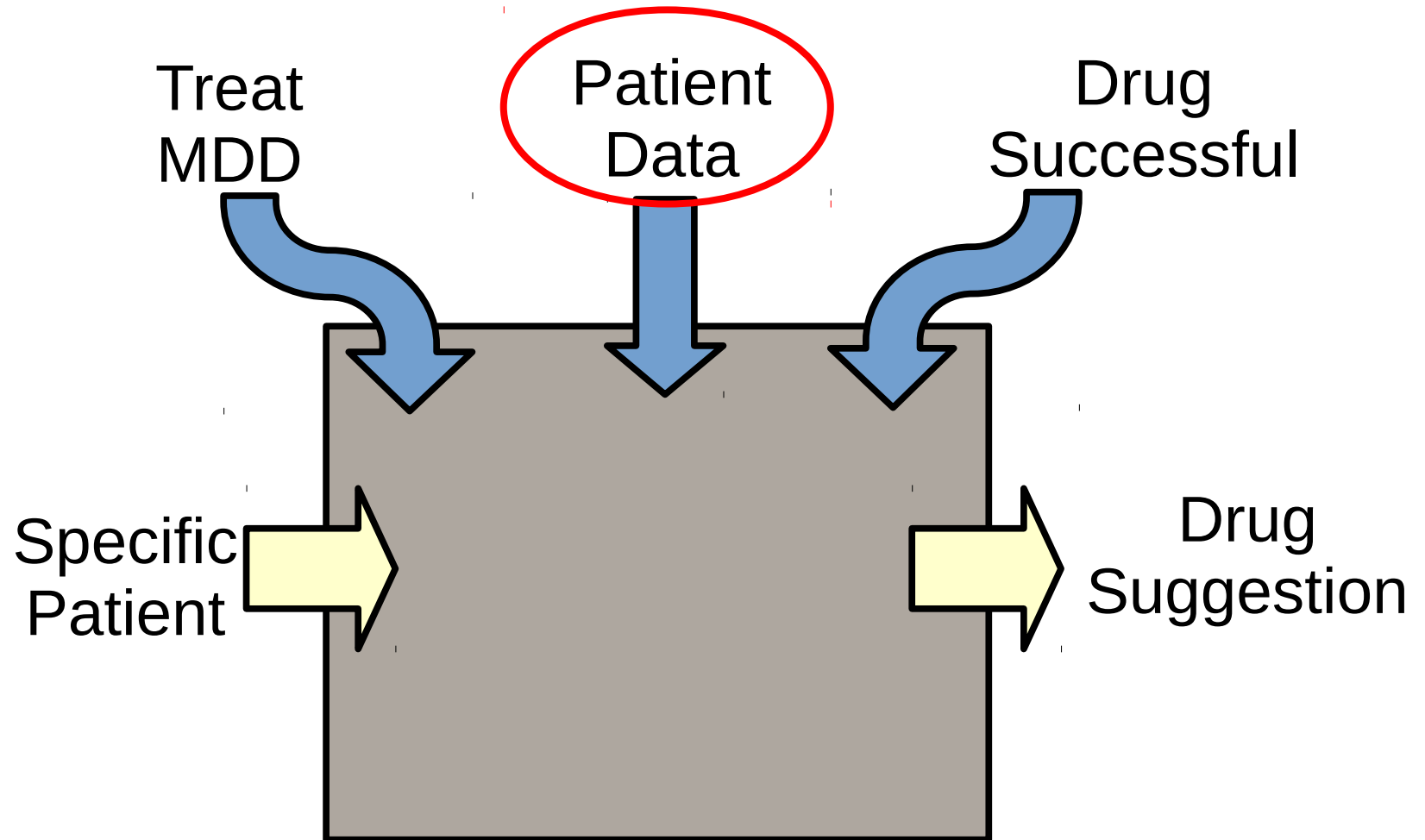
Current Approaches

Most current studies ask narrow questions and require specialized data. Examples:

- Large-scale clinical trial (STAR*D, COMED, iSPOT-D) analyses to decide between **certain features or pairs of drugs** (e.g. Chekroud et al., Joyce et al., Lavretsky et al.)
- **MRIs and biomarkers** to determine subtype and treatment choice (e.g. Liston et al., Craighead et al., Breitenstein et al.)

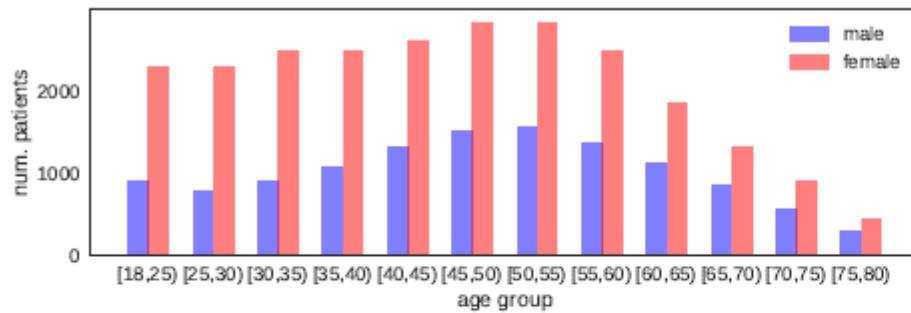
Our goal: We want to be able to recommend **all common drugs**, for patients with **any prior treatment history**.

Formalizing...



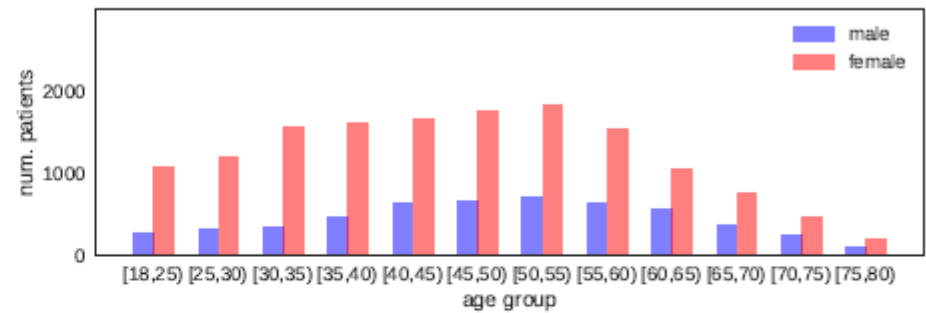
Cohort Statistics

Site A



	female	male	total	frac.
Asian	603	222	825	0.022
Black	959	412	1371	0.037
Hispanic	1006	402	1408	0.038
Other	2153	885	3038	0.082
White	20158	10415	30575	0.822
total	24879	12336	37217	
frac.	0.668	0.331		

Site B



	female	male	total	frac.
Asian	233	56	289	0.014
Black	1604	419	2023	0.100
Hispanic	2264	657	2921	0.145
Other	1026	386	1413	0.070
White	9662	3888	13551	0.671
total	14789	5406	20197	
frac.	0.732	0.268		

Featurization

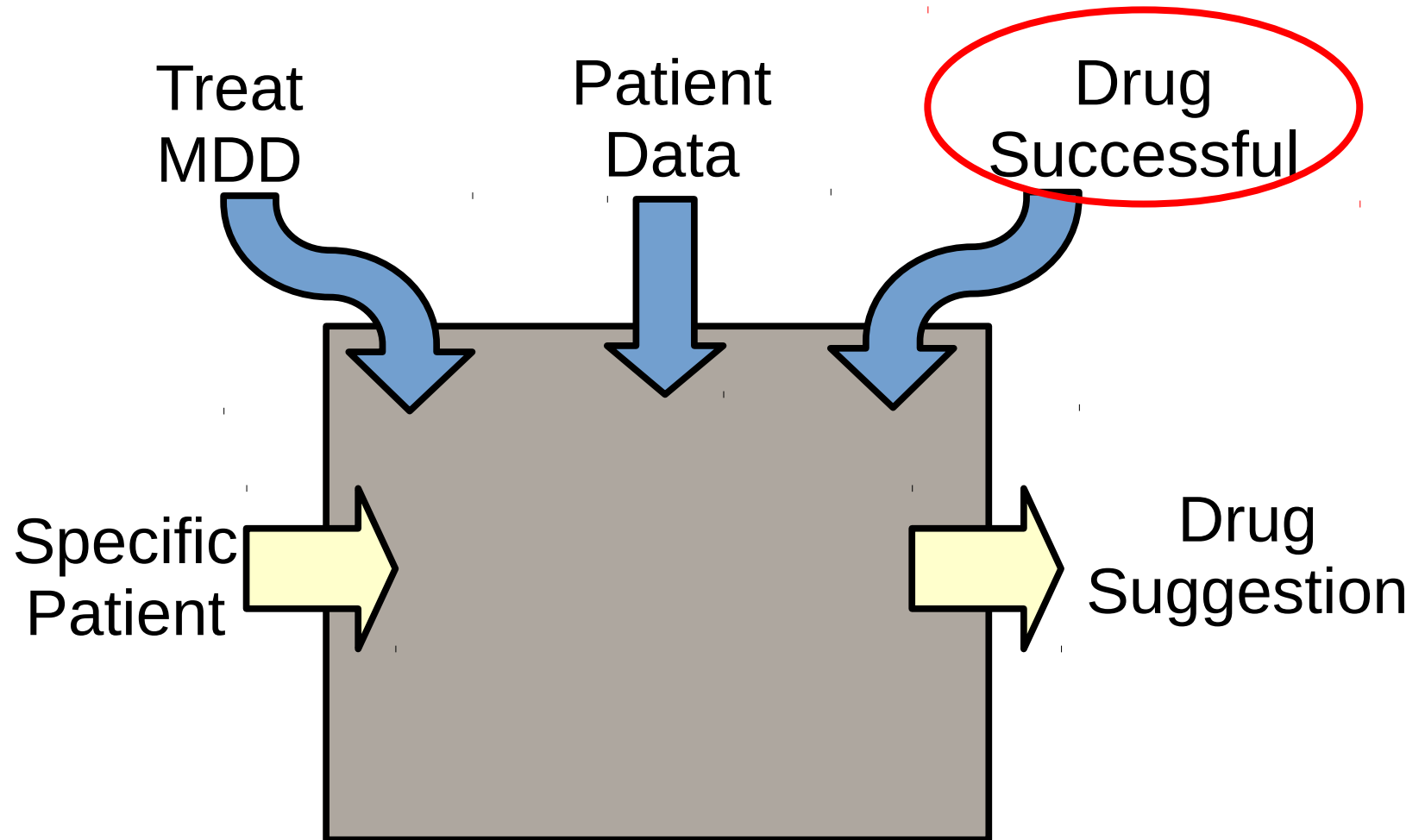
- Of the 22,000 unique codes (ICDs, CPTs, RXNORM) in the EHR, retain 7,291 which occur in at least 1,000 distinct patients.
- Focus on 10 primary drugs that are prescribed in at least 1000 patients

nortriptyline
amitriptyline
bupropion
fluoxetine

sertraline
paroxetine
venlafaxine

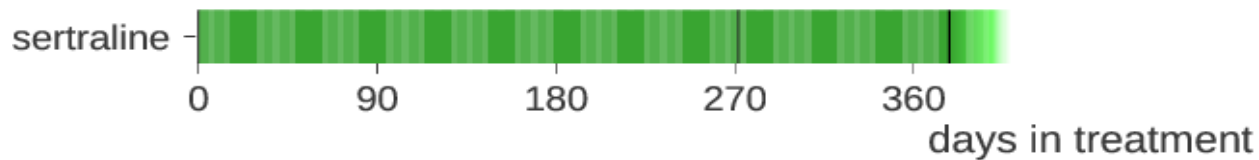
mirtazapine
citalopram
escitalopram

Formalizing...

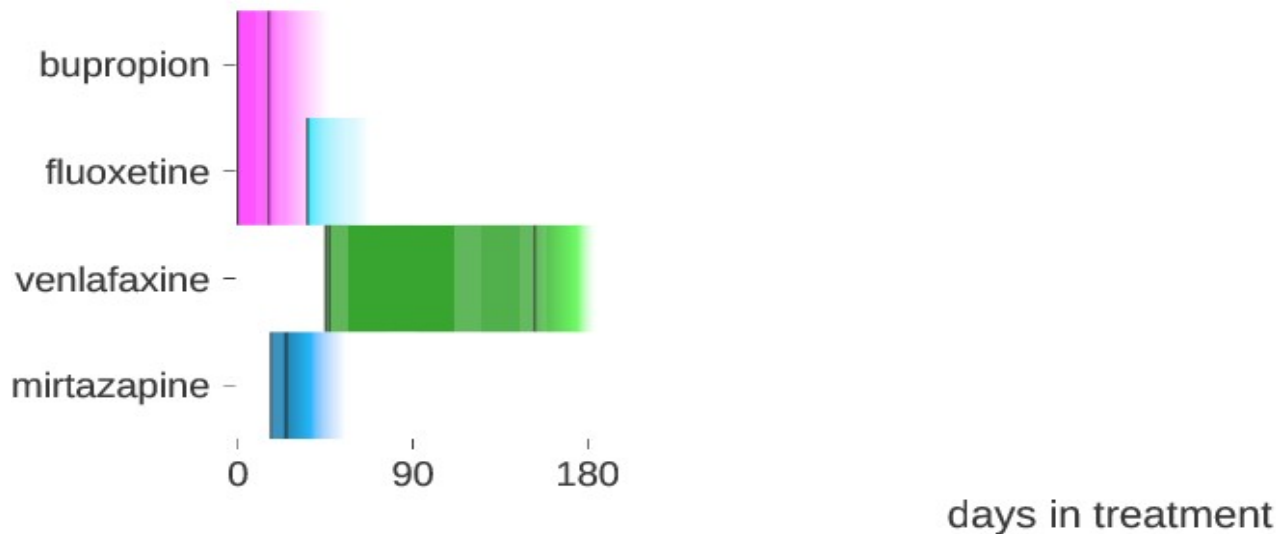


Performance Metric

“Instant Success” Patient

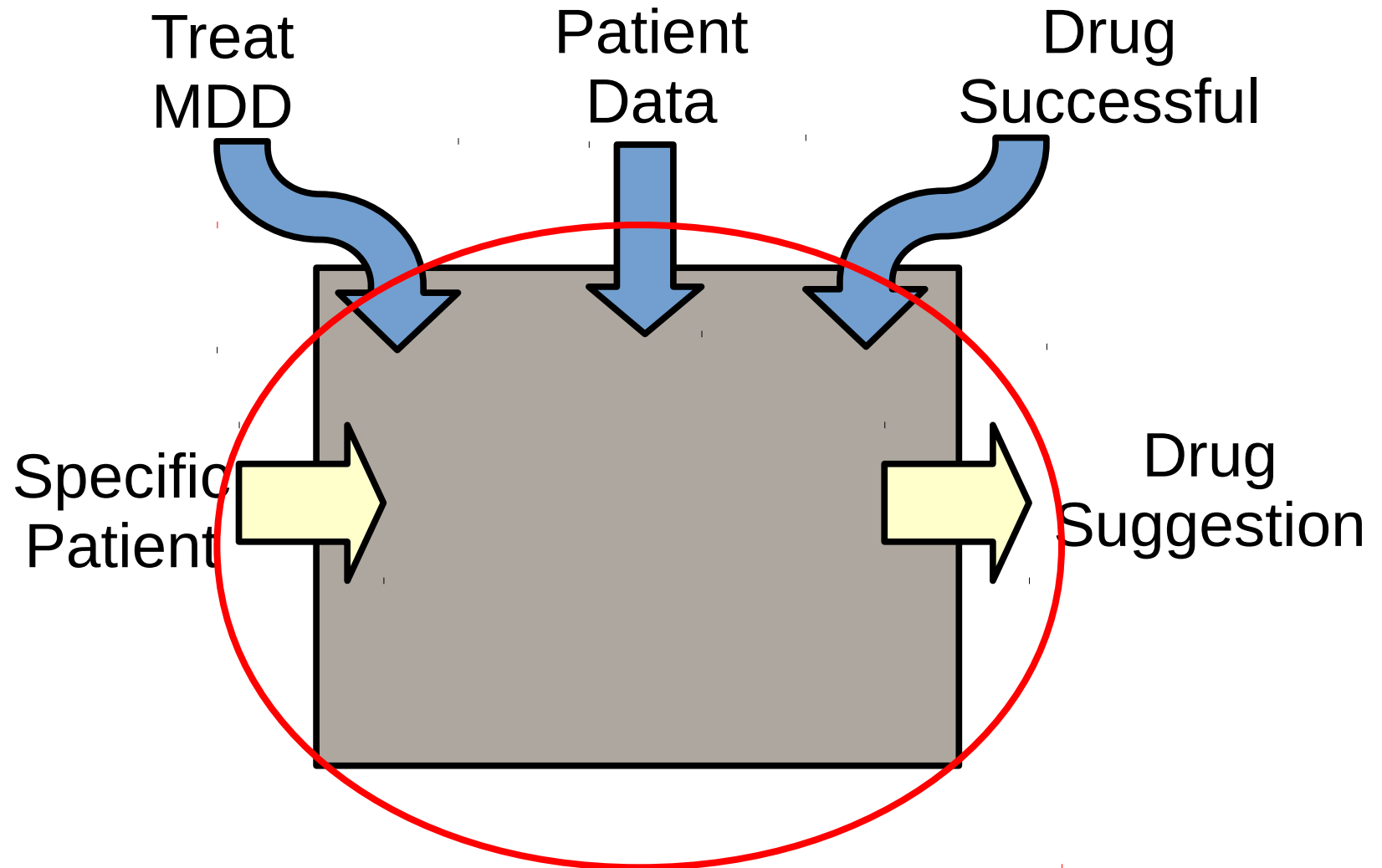


“Eventual Success” Patient



Success: require same primary over 90 days, with a visit frequency of at least every 13 months.

Formalizing...



Choices for Classifiers

In **high dimensions**, standard predictors (logistic regression, random forests, neural nets...) often have a **tension between sparsity and interpretability**.

- “Hip fracture” could code for “elderly”
- “Pregnant” could code for “female”

Thus, we choose to apply **topic models** for dimensionality reduction, and then predict based on the doc-topic probabilities.

Topic Models

Topics are distributions over words (codes)

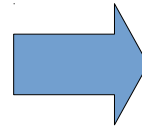
$$\phi_k \sim \text{Dir}(\alpha_v)$$

Patients are distributions over topics

$$\pi_d \sim \text{Dir}(\alpha_p)$$
$$w_d^i \sim \text{Dir}(\pi_d \phi)$$

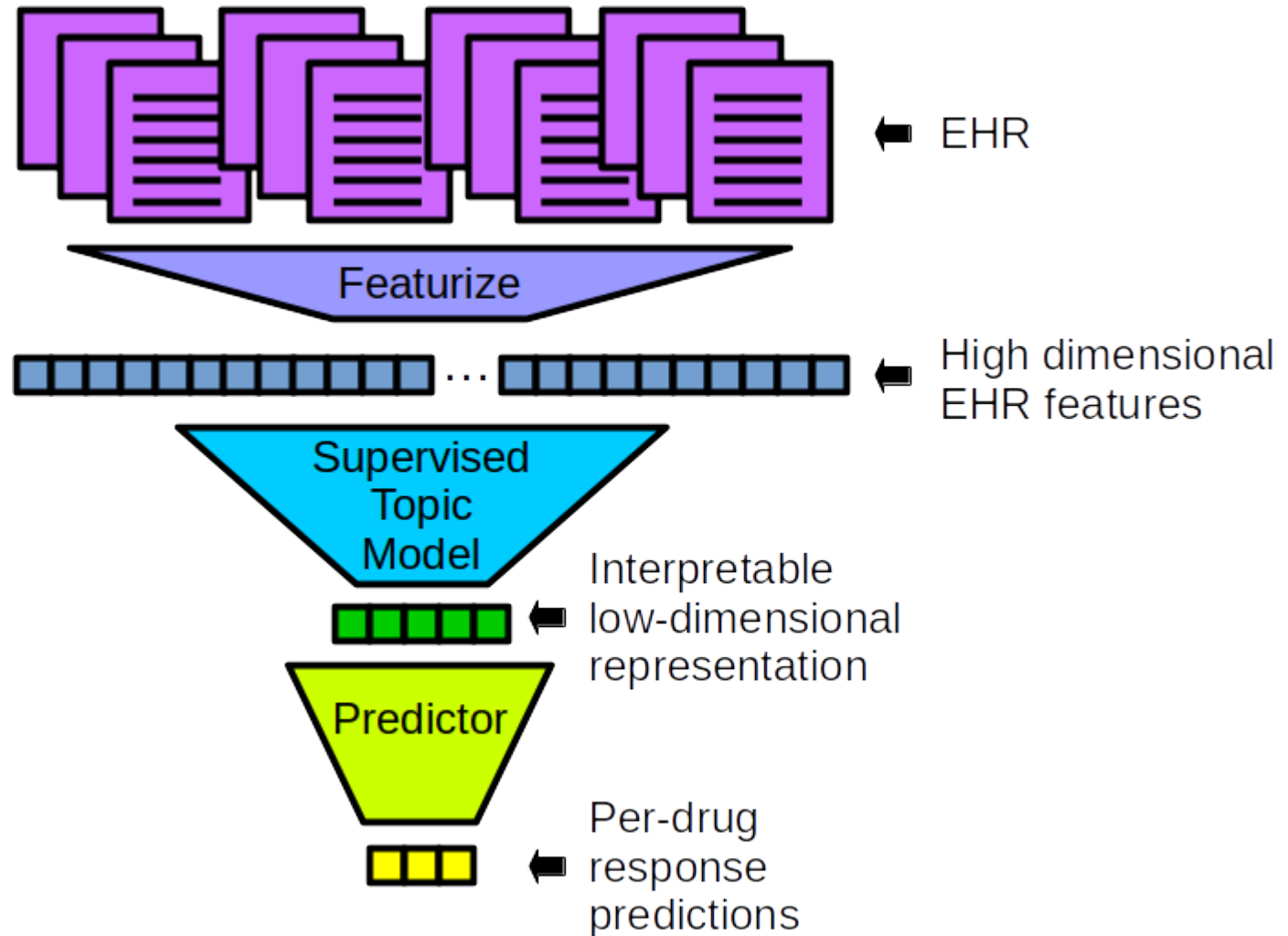
Example topic

```
1.0000 29650:bipolar_affective_disorder,_depres
0.9999 2967:bipolar_affective_disorder,_unspec
0.9999 29570:schizo-affective_type_schizophreni
0.9999 29660:bipolar_affective_disorder,_mixed,
0.9998 c90870:electroconvulsive_therapy_(include
0.9998 c00104:anesthesia_for_electroconvulsive_t
0.9997 29560:residual_schizophrenia,_unspecifie
0.9996 p9427:other_electroshock_therapy
0.9993 d00061:lithium
0.9993 29653:bipolar_affective_disorder,_depres
0.9985 29651:bipolar_affective_disorder,_depres
0.9985 d04825:aripiprazole
```

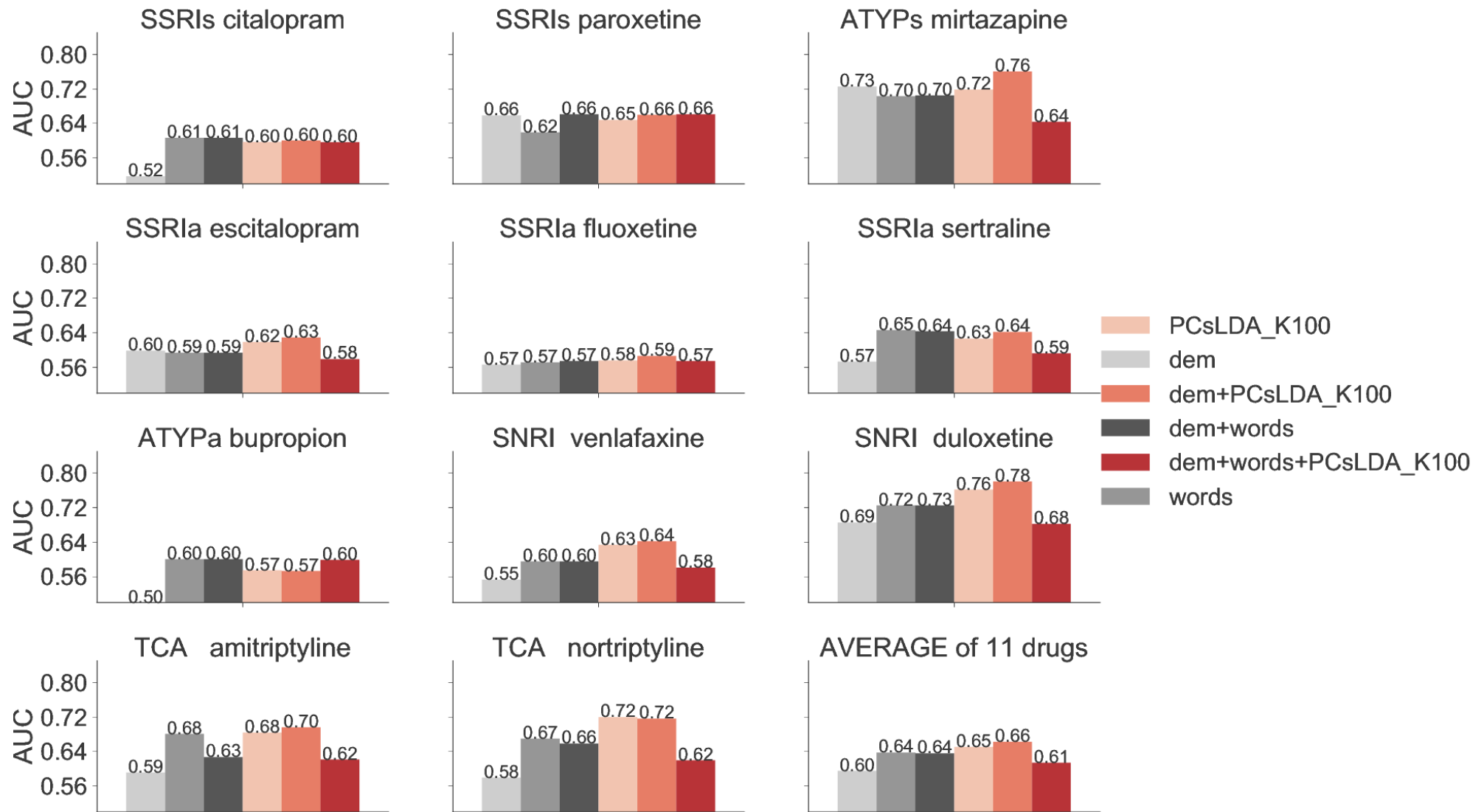


Patient has bipolar disorder

Pipeline



Drug-by-Drug Performance



Interpretation: Bupropion

BPsLDA +7.7

0.60 nortriptyline
0.27 nonspecific abnormal findings
0.21 other specified local infection
0.20 embrionic cyst of the fallopian tube
0.18 application of the intervertebrea...
0.16 other malignant neoplasm...
0.15 amoxicilllin/clarithromycin
0.15 need for prophylactic vaccine
0.15 observation or inpatient visit...

Gibbs -0.6

1.0000 bipolar, depressive
0.9999 bipolar, unspecified
0.9999 schizo-affective schizophrenia
0.9999 bipolar, mixed
0.9998 electroconvulsive therapy
0.9998 anesthesia for ECT
0.9997 residual schizophrenia
0.9996 other electroshock therapy
0.9993 lithium

PCLDA +3.8

0.99 migraine, unspecified, without...
0.99 other malaise and fatigue
0.99 common migraine...
0.99 sumatriptan
0.99 asa/butalbital/caffeine
0.99 zolmitriptan
0.99 migraine, unspecified, with...,
0.99 classical migraine, without...
0.99 classical migraine, with...

Interpretation: Bupropiom

BPsLDA -15.8

0.39 visual field defect, unspecified
0.39 citalopram
0.36 microdissection
0.35 need for prophylactic vaccine
0.31 pet imaging regional or wide area
0.29 visual discomfort
0.29 accident poison by heroin
0.29 personal history of alcohol
0.27 other specified intestinal disorder

Gibbs -2.7

0.9997 respiratory_failure
0.9995 cystic fibrosis...

PCLDA -26.4

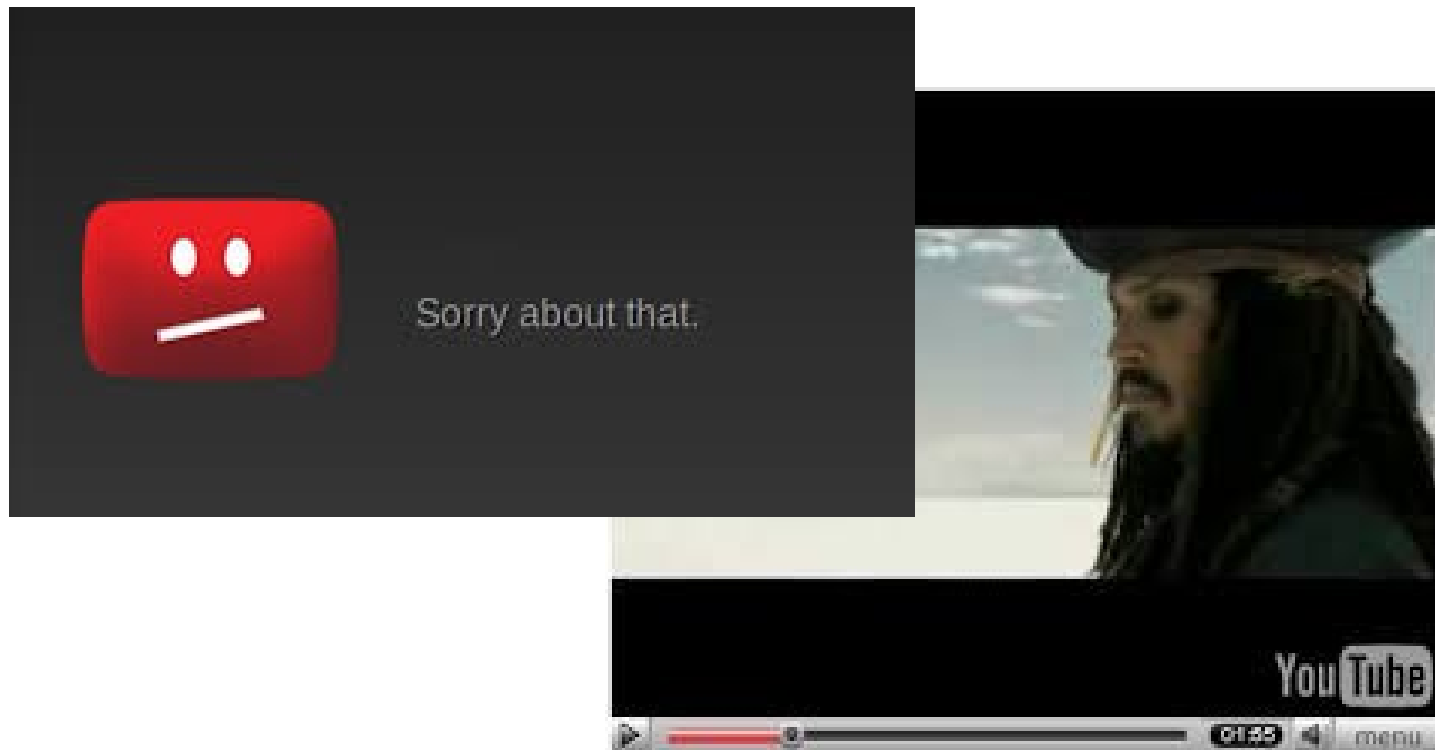
1.00 semen analysis, complete...
1.00 male infertility, unspecified
1.00 lipoprotein, direct measurement
0.99 sperm isolation, simple...
0.99 tissue culture for non-neoplasm...
0.99 conditions due to anomaly...
0.99 vasectomy, unilateral or...
0.99 arthrocentesis
0.99 scrotal varices

Currently working on how to present these
results in a helpful way to practicing clinicians

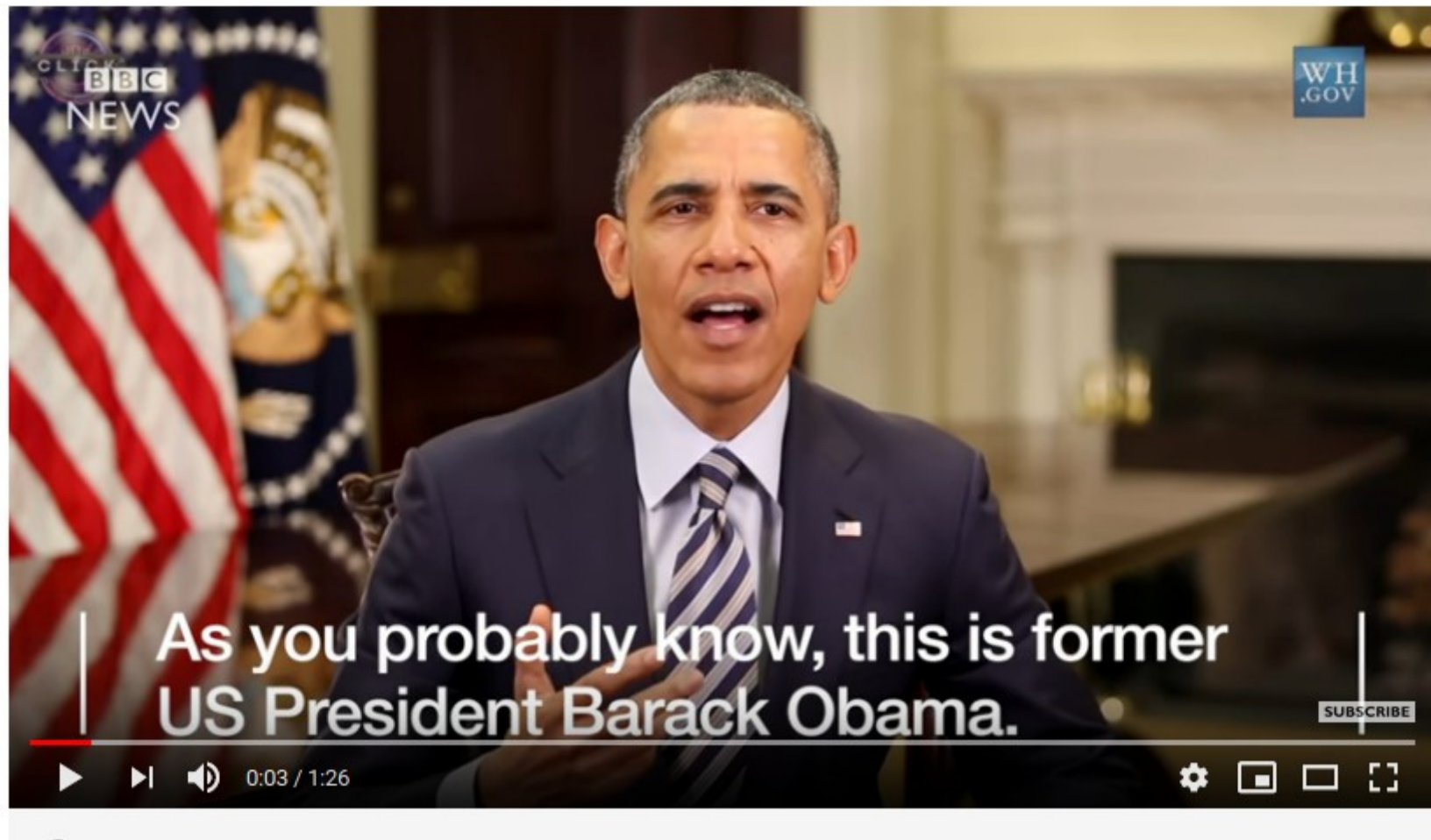
0.9964 continuous mech ventilation
0.9963 intubation endotracheal

Your Turn: Detecting Copyright Violations on Youtube...

(~300 hours of new video per minute)



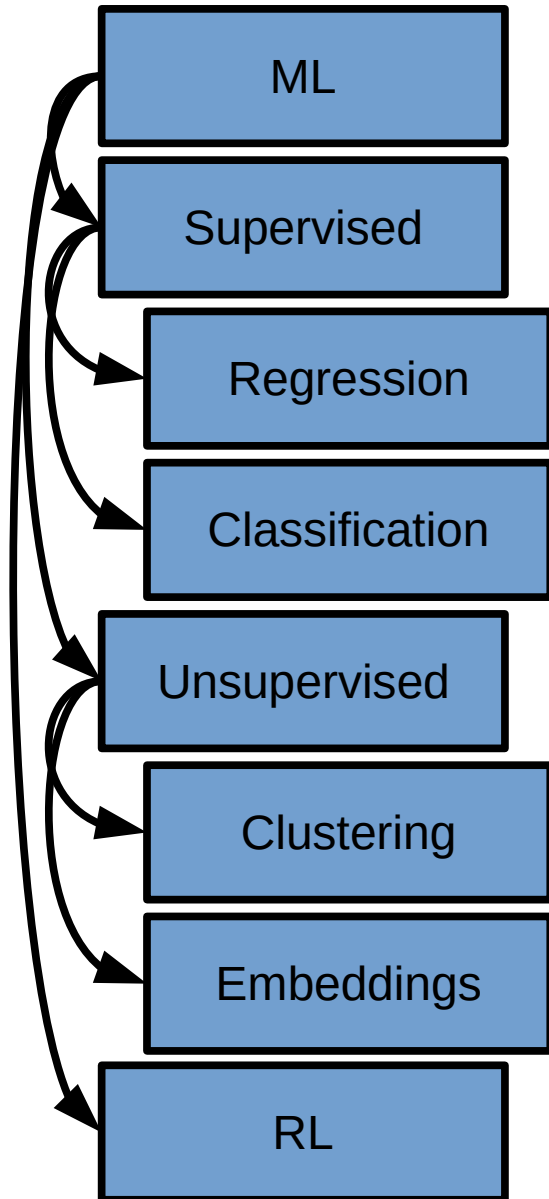
Your Turn: Detecting Fake Videos



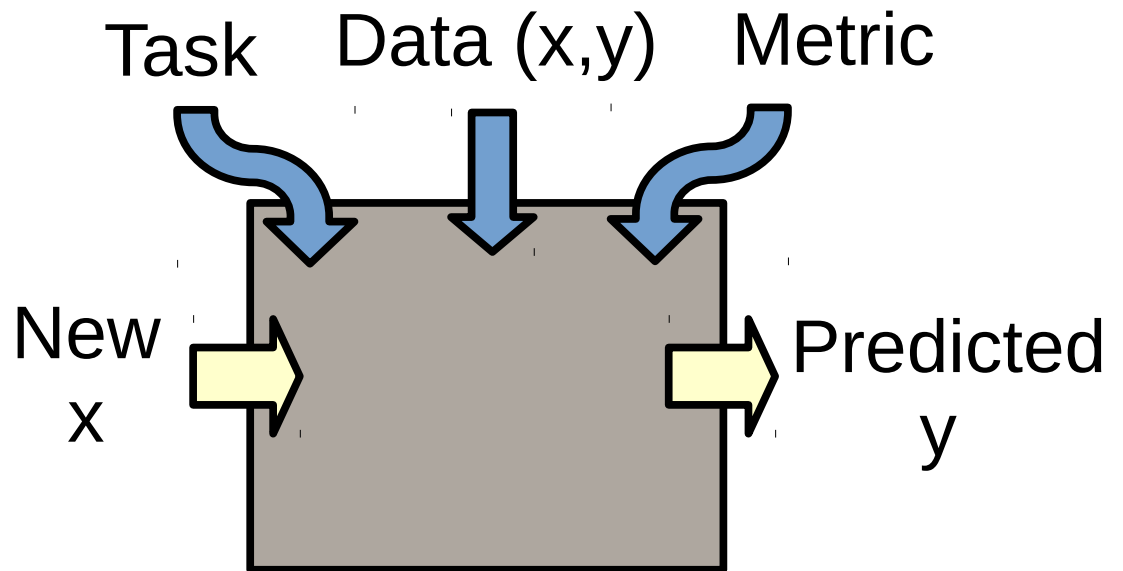
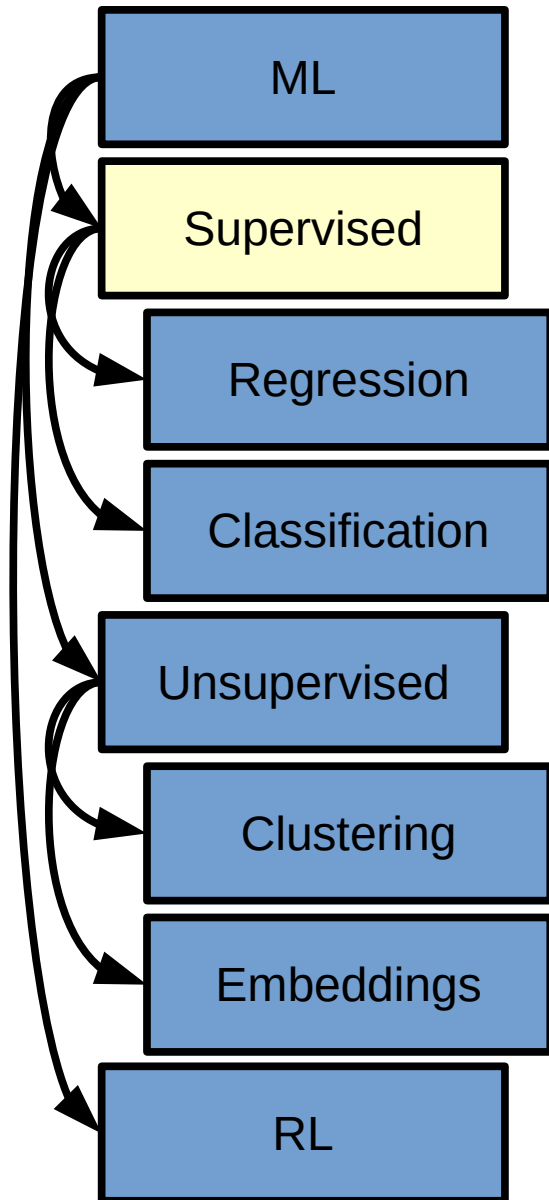
<https://www.youtube.com/watch?v=AmUC4m6w1wo&feature=youtu.be>

Taxonomy of Problems

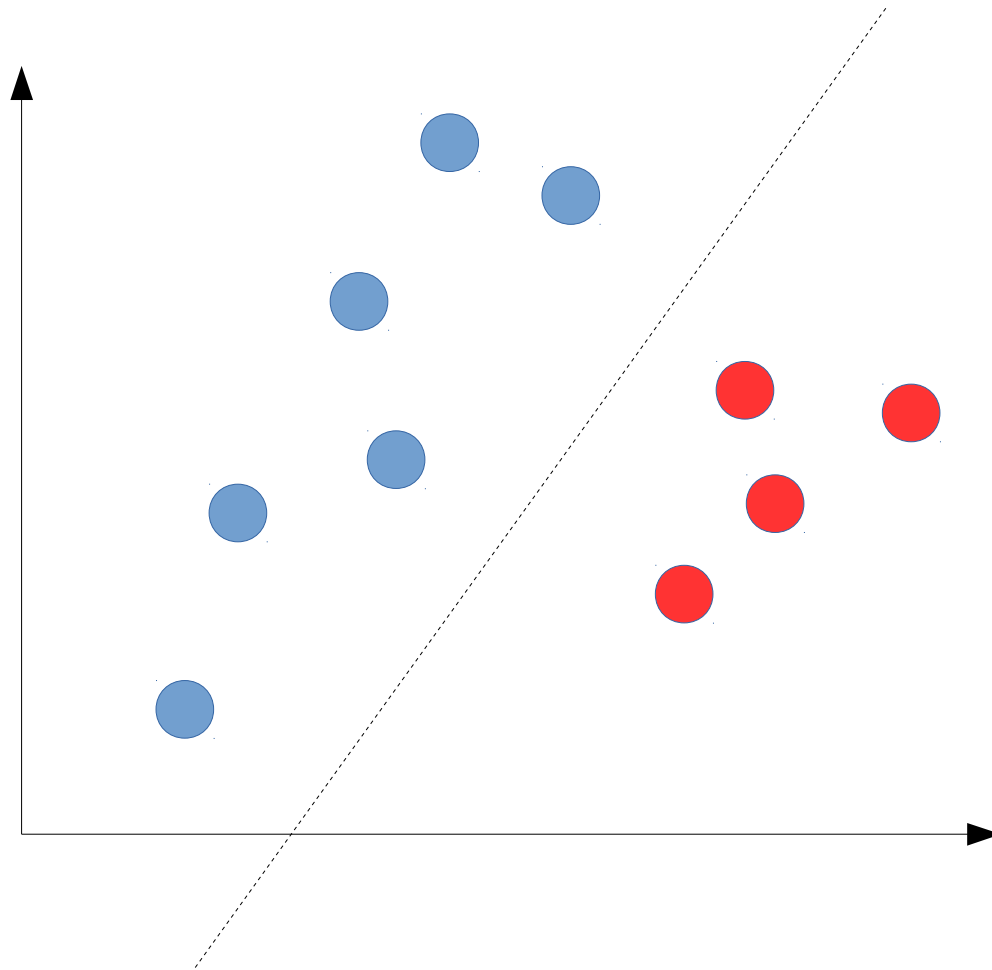
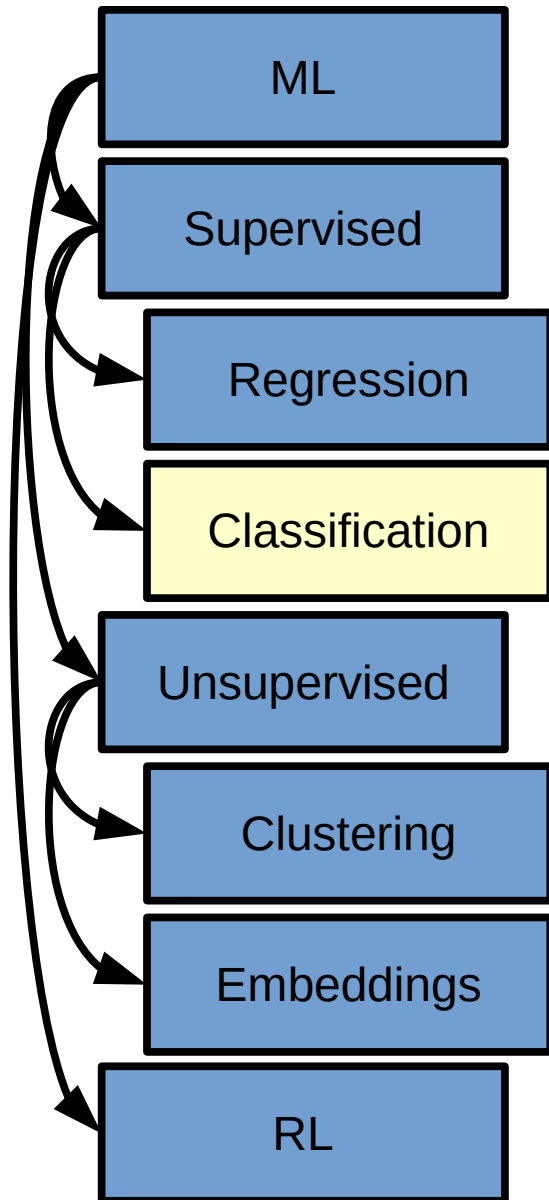
Machine Learning Taxonomy



Machine Learning Taxonomy



Terminology: Classification



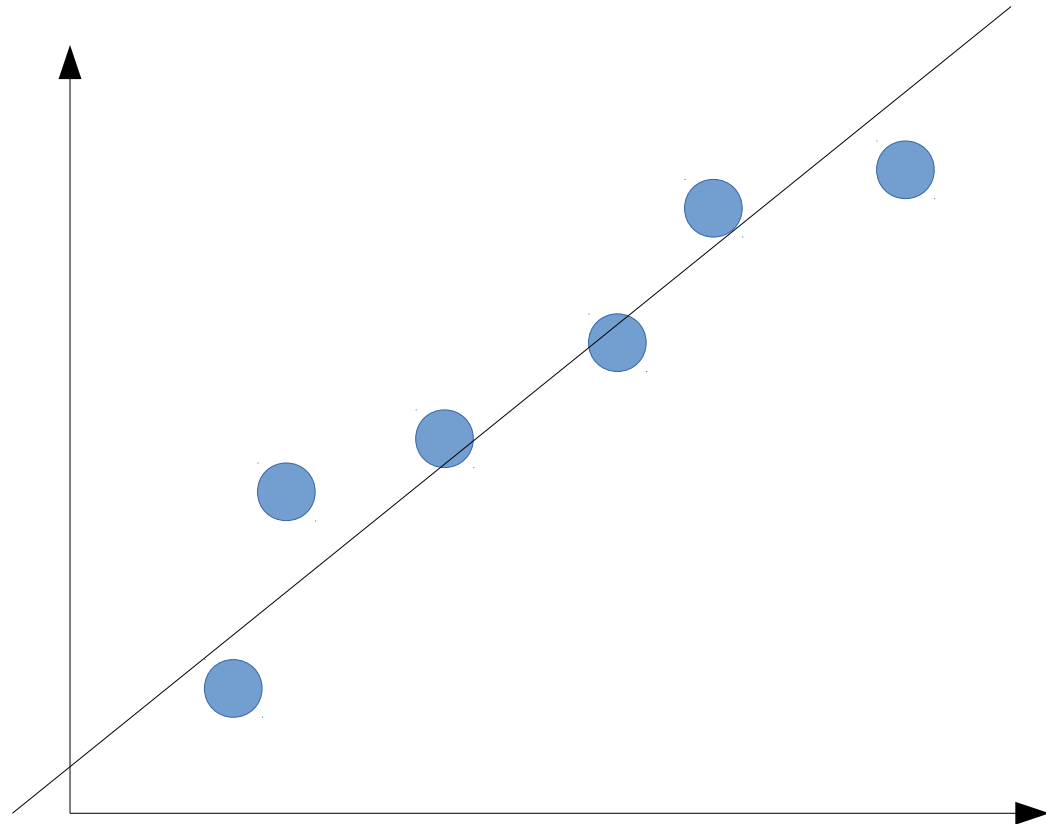
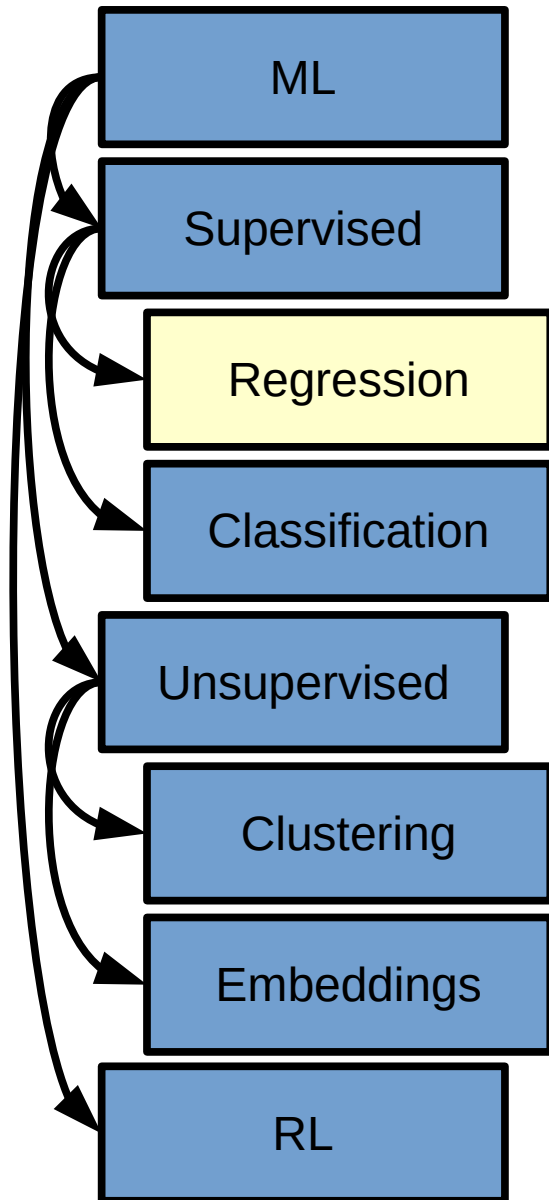
Example: Swype



Novel Product:
An easier way
to input text on
mobile devices



Terminology: Regression



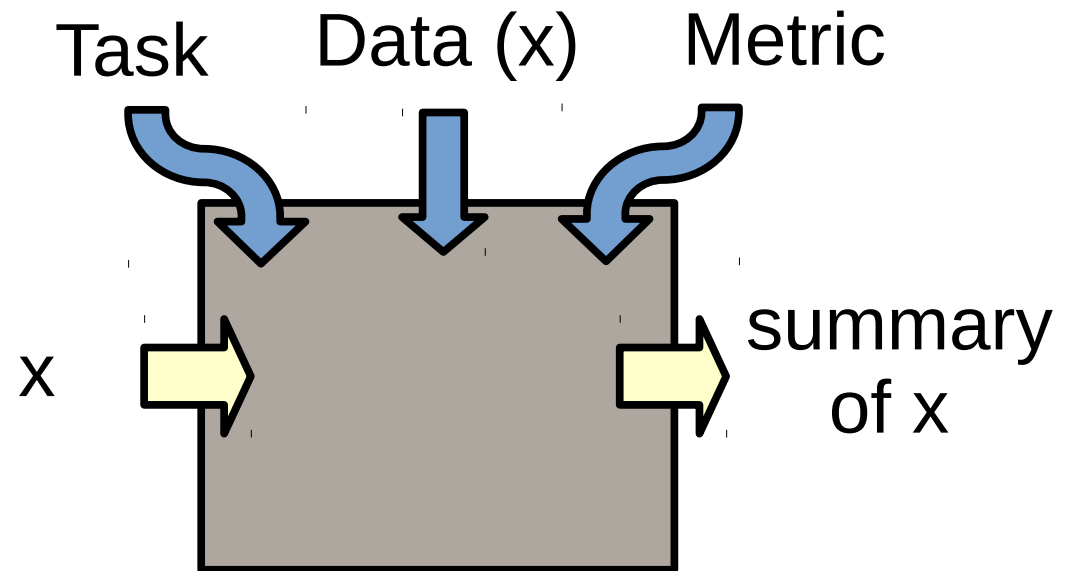
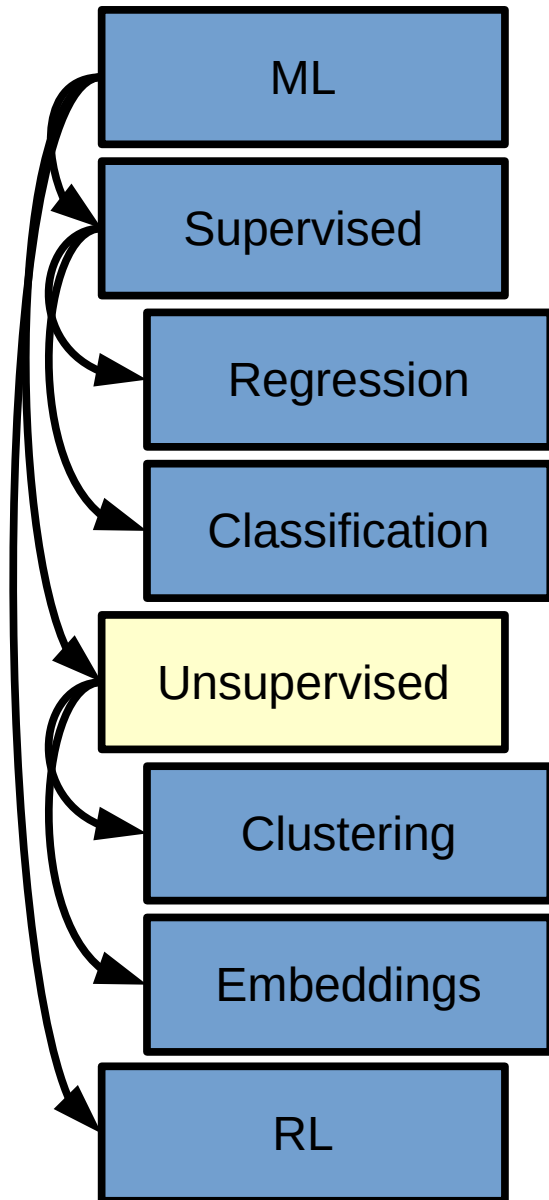
Example: Virtu



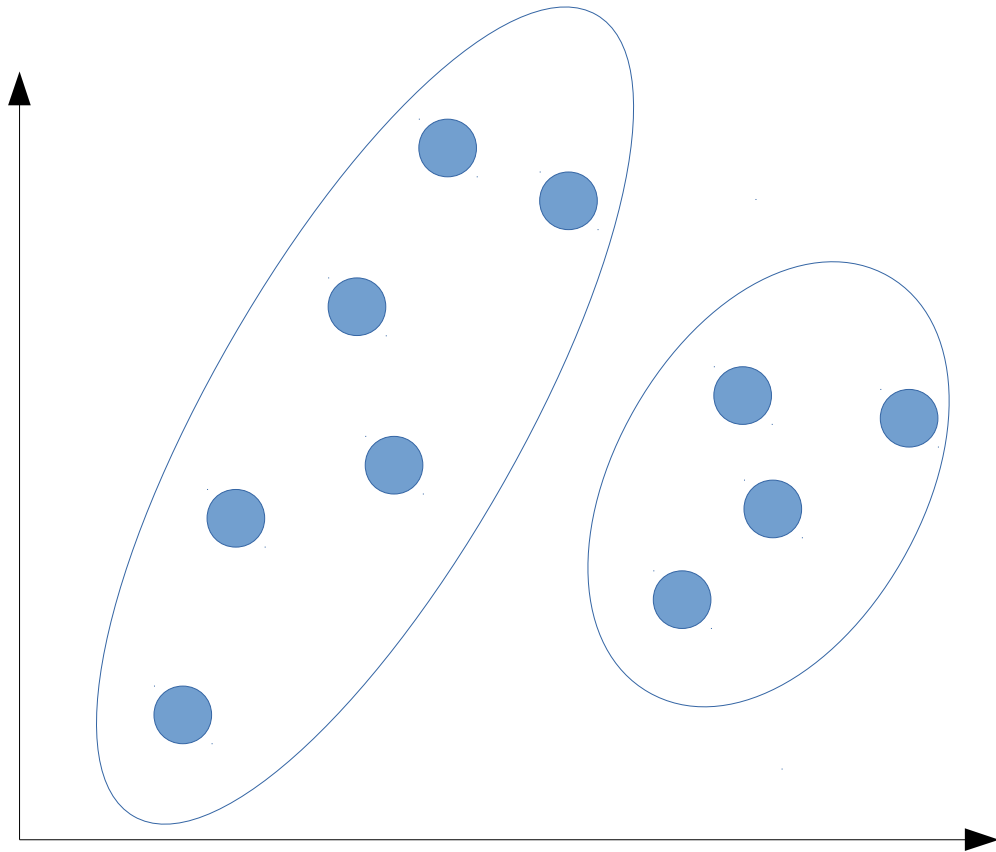
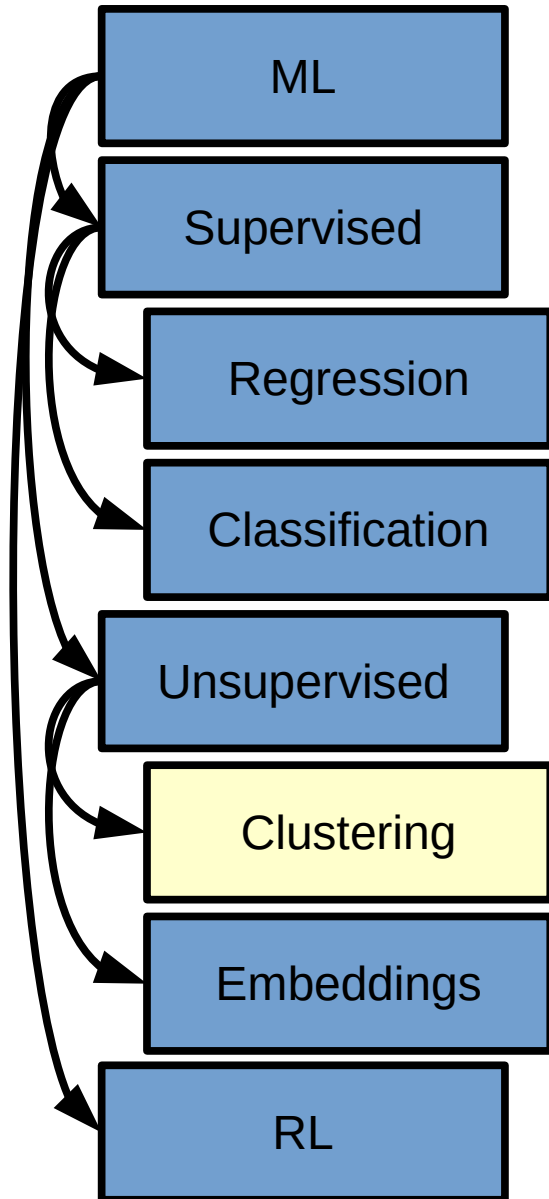
VIRTU FINANCIAL

Core technology: Choosing what to trade, and when

Machine Learning Taxonomy



Terminology: Clustering



Example: News

Top Stories



Fox News

[See realtime coverage](#)

Intensive manhunt underway after daring jail escape in California

Fox News - 37 minutes ago



An intensive manhunt was underway Monday for three inmates who pulled a "Shawshank"-style escape through a hole in their California jail cell -- and, who may have ties to notorious Vietnamese street gangs and Iran.

[Manhunt Expands For 'Dangerous' Trio After Daring Jailbreak](#)

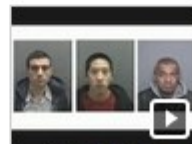
NBCNews.com

[Orange County manhunt: Officials suggest violent jail escapees could be hiding nearby](#) Los Angeles Times

Related

[California »](#)

In Depth: [Authorities struggling to piece together daring jail escape](#) Washington Post



OCRegister



City News Los A...



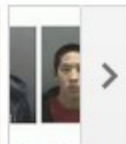
WOODTV.com



Los Angel...



Philly.com



OCRe



Huffington Post

[See realtime coverage](#)

HUFFPOLLSTER: Trump And Clinton Lead, But Iowa Polling Remains Volatile With A Week To Go

Huffington Post - 5 hours ago



Donald Trump has regained the lead in Iowa but things can still change. On the Democratic side, young voters could tip the caucus toward Bernie Sanders, but only if they turn out.

[Here's Bernie Sanders's best closing argument against Hillary Clinton in Iowa](#) Washington Post

[Bernie Sanders' One Answer on How He Would Get Anything Done](#) ABC News

Related

[Hillary Rodham Clinton »](#)

[Bernie Sanders »](#)

Opinion: [Democratic Iowa Forum: How to Watch the Live Stream Online](#) Daily Beast

Wikipedia: [Statewide opinion polling for the Democratic Party presidential primaries, 2016](#)



CNN



Kansas City Star



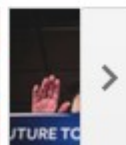
CNN



Reuters

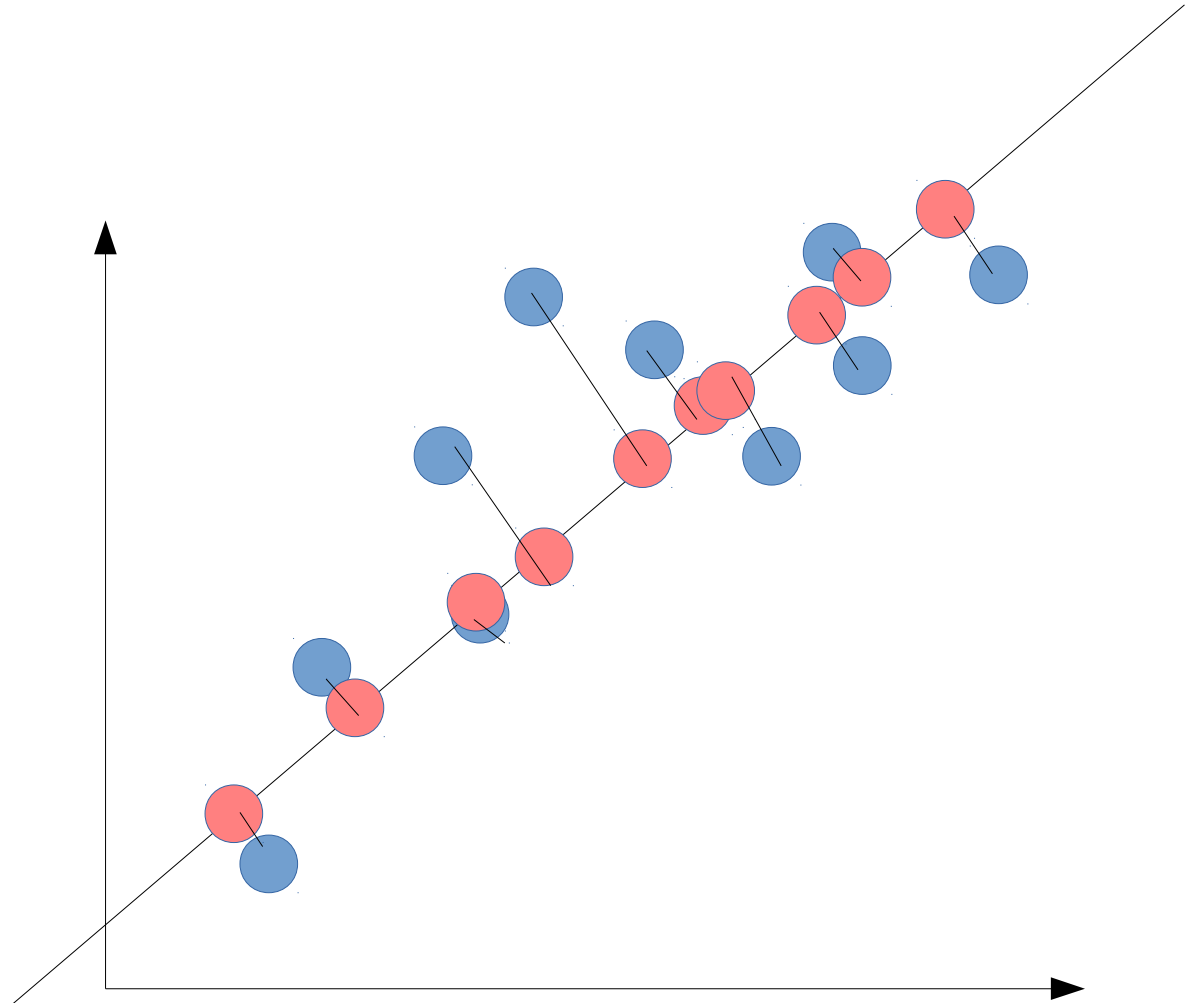
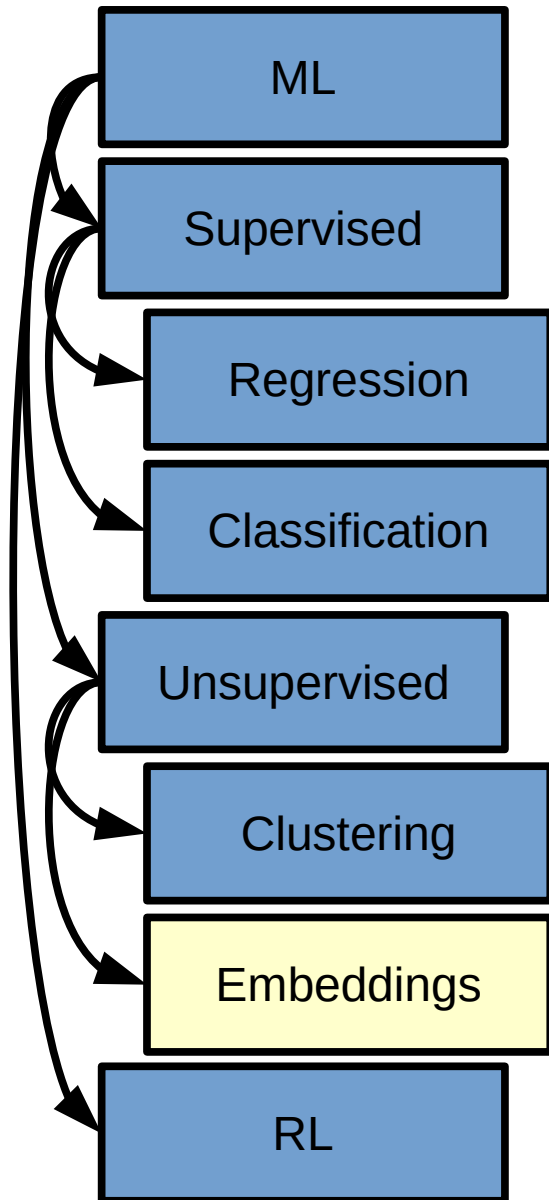


Washingto...

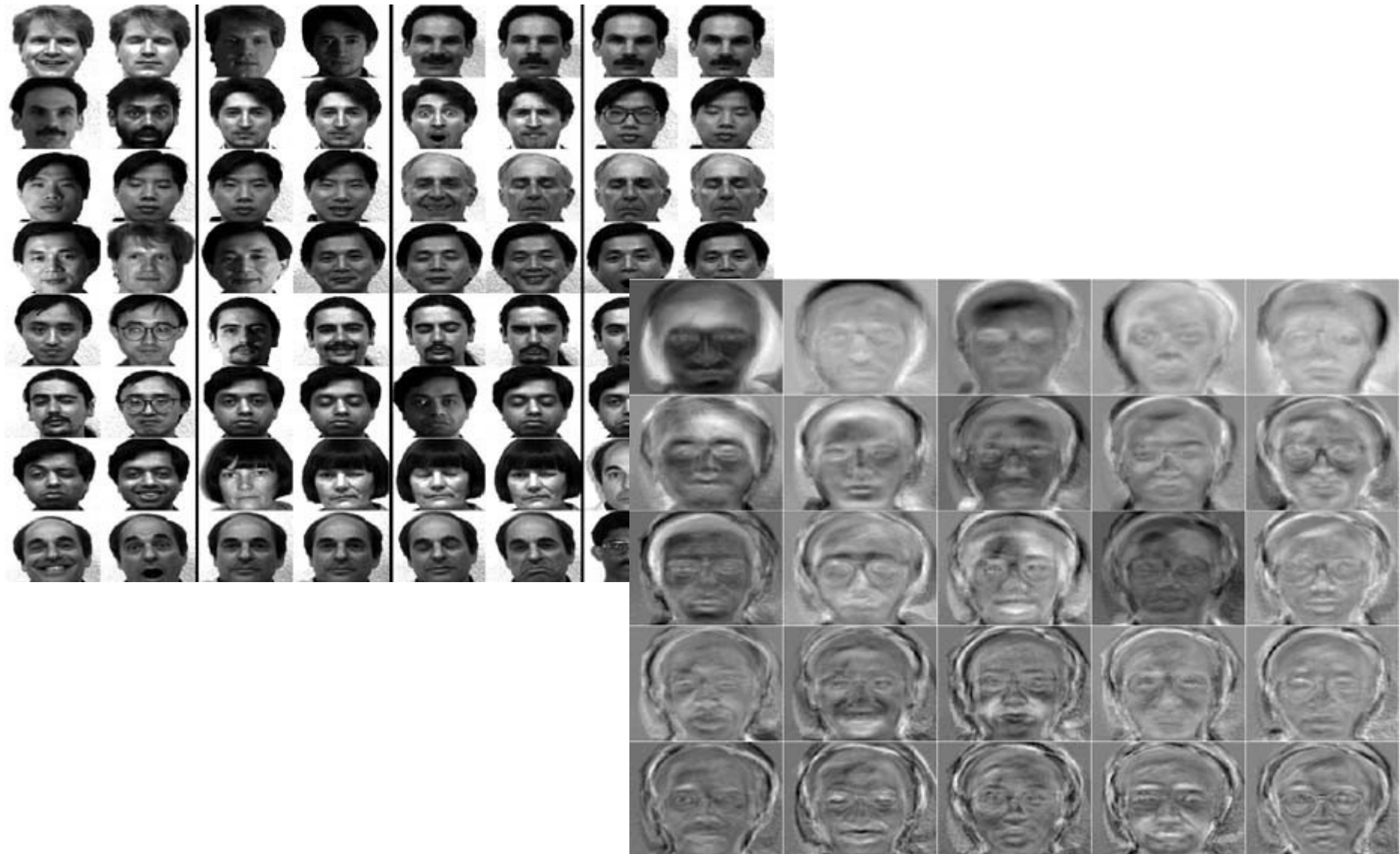


New Yc

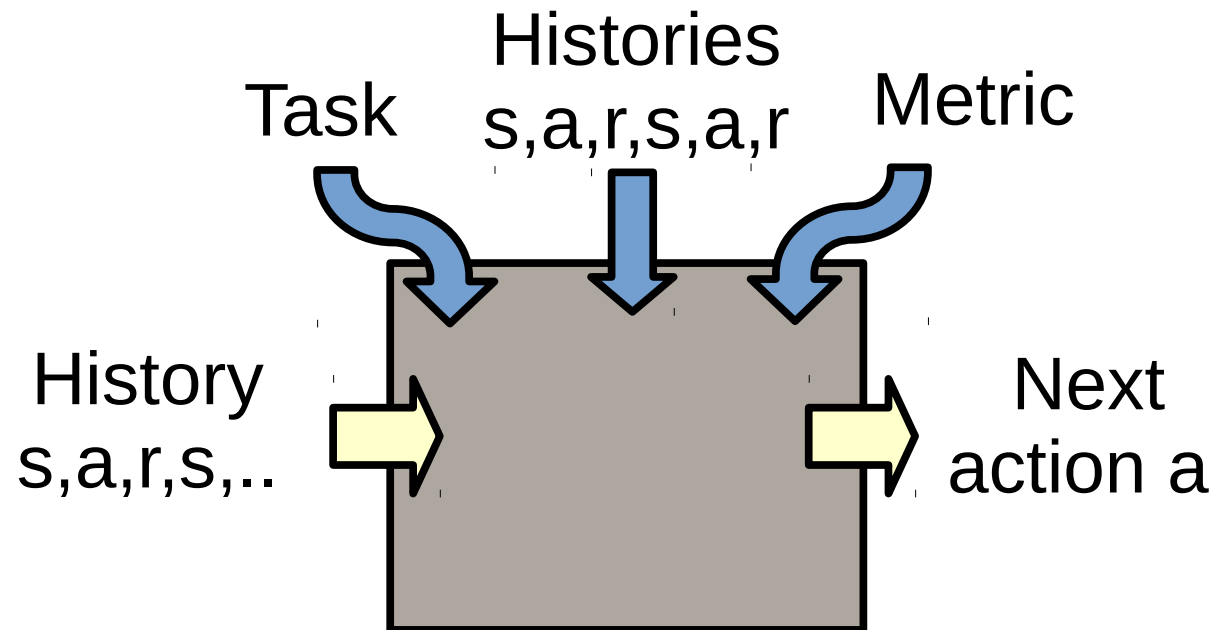
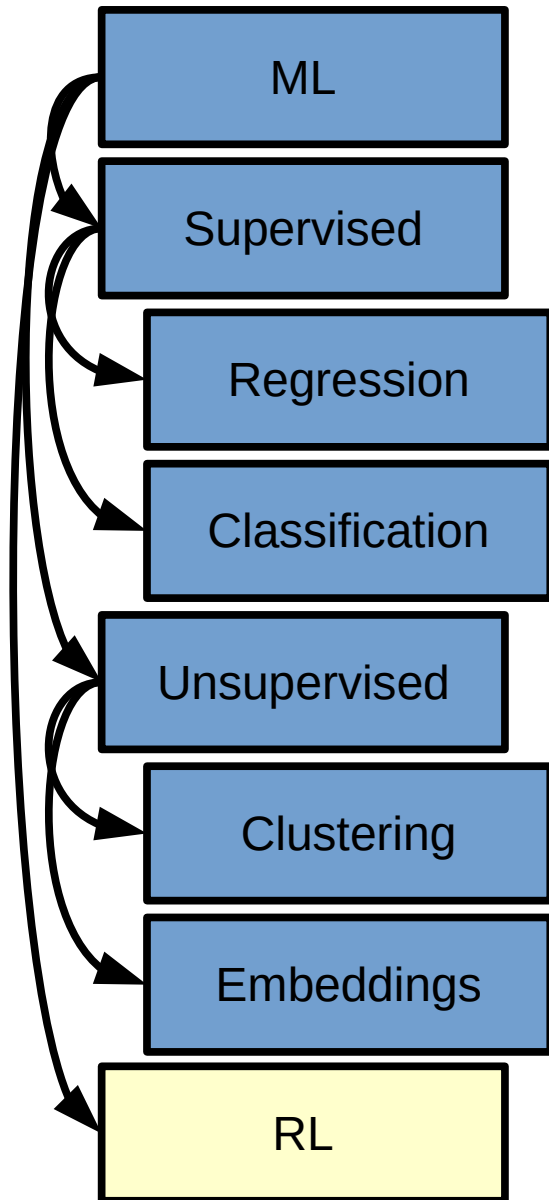
Terminology: Embedding



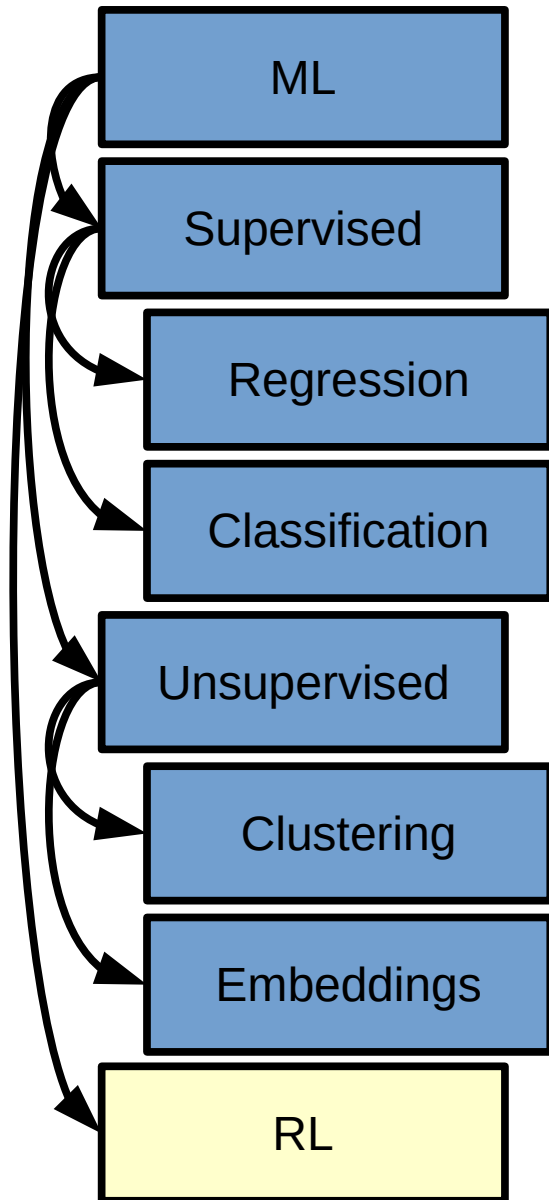
Example: Eigenfaces



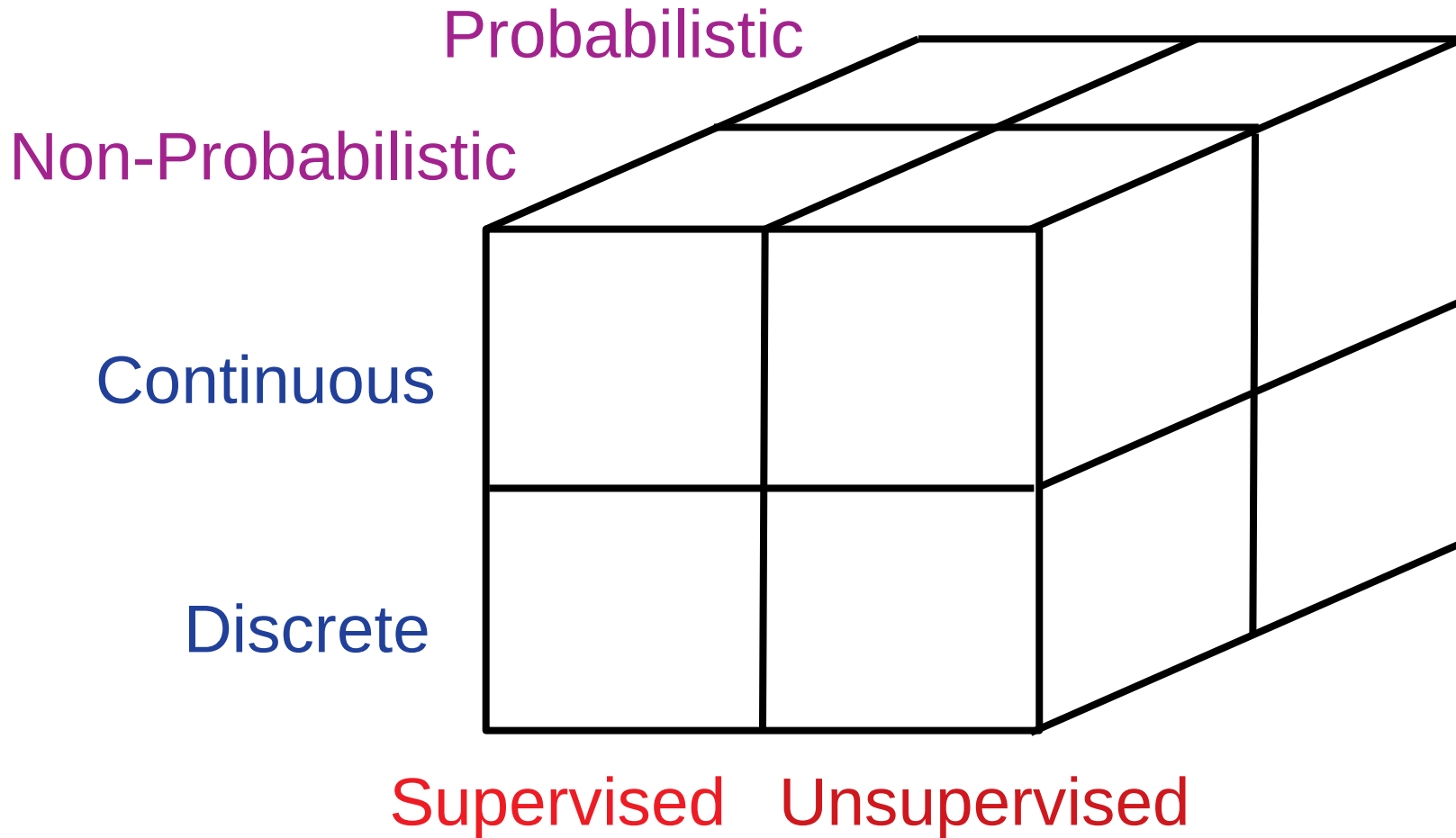
Terminology: Reinforcement Learning



Terminology: Reinforcement Learning



Peter Kormushev, Imperial College



+ Graphical models, reinforcement learning
(some overlap with CS182)

Course Structure

Structure of the Course

- Start with some basic regression problems.
- Discuss model selection and evaluation.
- Continue with the “cube”++
 - Supervised: regression, classification
 - Unsupervised: classification, embeddings
 - Reinforcement Learning

Lectures will include real world stories and concept exercises; we'll also have an embedded ethics component

Logistics

- Book: Bishop; also v0.0 notes at <https://github.com/harvard-ml-courses/cs181-textbook>
- Homeworks: smaller exercises, toy problems
 - MUST be in LaTeX
 - Distributed over Github
- Practicals: real data, compete in teams
- Sections: math review, then flipped classroom
- Piazza: Clarification and Content Tags
- Canvas: Announcements, Gradebook
- Staff organization: Instructor (content), Course manager (logistics), Head TF, TFs

Details on the website

<https://harvard-ml-courses.github.io/cs181-web>

Read the syllabus!

FAQs

- Can I sit in/audit/take the course? [Yes!]
- Can I do simultaneous enrollment? [Maybe]
 - “I will not take advantage of any 1-1 compensatory instruction. I further understand that I, and only I, am solely responsible for anything from lecture, including announcements that are may not be posted anywhere else.”
- Do I need all the prereqs? [Maybe]
 - What you need: programming, statistics, calculus, and linear algebra
 - check out <https://mml-book.com/>

FAQs

- Can I sit in/audit/take the course? [Yes!]
- Can I do simultaneous enrollment? [Maybe]
 - “I will not take advantage of any 1-1 compensatory instruction. I further understand that I, and only I, am solely responsible for anything from lecture, including announcements that are may not be posted anywhere else.”
- Do I need all the prereqs? [Maybe]
 - What you need: programming, statistics, calculus, and linear algebra
 - check out <https://mml-book.com/>

Problem 1.1:
Take the gradient with
respect to the vector of
weights w

...

Let's get technical!

Nonparametric Regression