

# CSE 417T

# Introduction to Machine Learning

Lecture 22

Instructor: Chien-Ju (CJ) Ho

# Logistics

- Homework 5 is due Dec 2 (Friday)
- Exam 2 will be on Dec 8 (Thursday)
  - Will focus on the topics in the second half of the semester
    - Note though knowledge is cumulative, so we still assume you know the concepts earlier
  - Format / logistics will be similar with what we have in Exam 1
    - Timed exam (75 min) during lecture time in the classroom
    - Closed-book exam with 2 letter-size cheat sheets allowed (4 pages in total)
      - No format limitations (it can be typed, written, or a combination)
  - Dec 6 (Tuesday) will be a review lecture

# Recap

# Neural Network

- Evaluate  $h(\vec{x})$  given  $h$  (characterized by  $\{w_{i,j}^{(\ell)}\}$ )
  - Forward propagation

$$\mathbf{x} = \mathbf{x}^{(0)} \xrightarrow{\mathbf{w}^{(1)}} \mathbf{s}^{(1)} \xrightarrow{\theta} \mathbf{x}^{(1)} \xrightarrow{\mathbf{w}^{(2)}} \mathbf{s}^{(2)} \xrightarrow{\theta} \mathbf{x}^{(2)} \dots \xrightarrow{\mathbf{w}^{(L)}} \mathbf{s}^{(L)} \xrightarrow{\theta} \mathbf{x}^{(L)} = h(\mathbf{x}).$$

- Given  $D$ , learn the weights  $W = \{w_{i,j}^{(\ell)}\}$

- Backpropagation
- Initialize  $w_{i,j}^{(\ell)}$  randomly
- For  $t = 1$  to  $T$

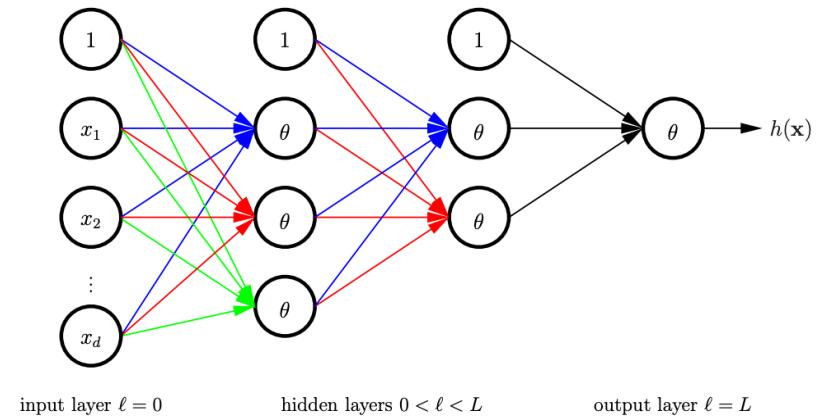
- Randomly pick a point from  $D$  (for stochastic gradient descent)

- Forward propagation: Calculate all  $x_i^{(\ell)}$  and  $s_i^{(\ell)}$

- Backward propagation: Calculate all  $\delta_j^{(\ell)}$

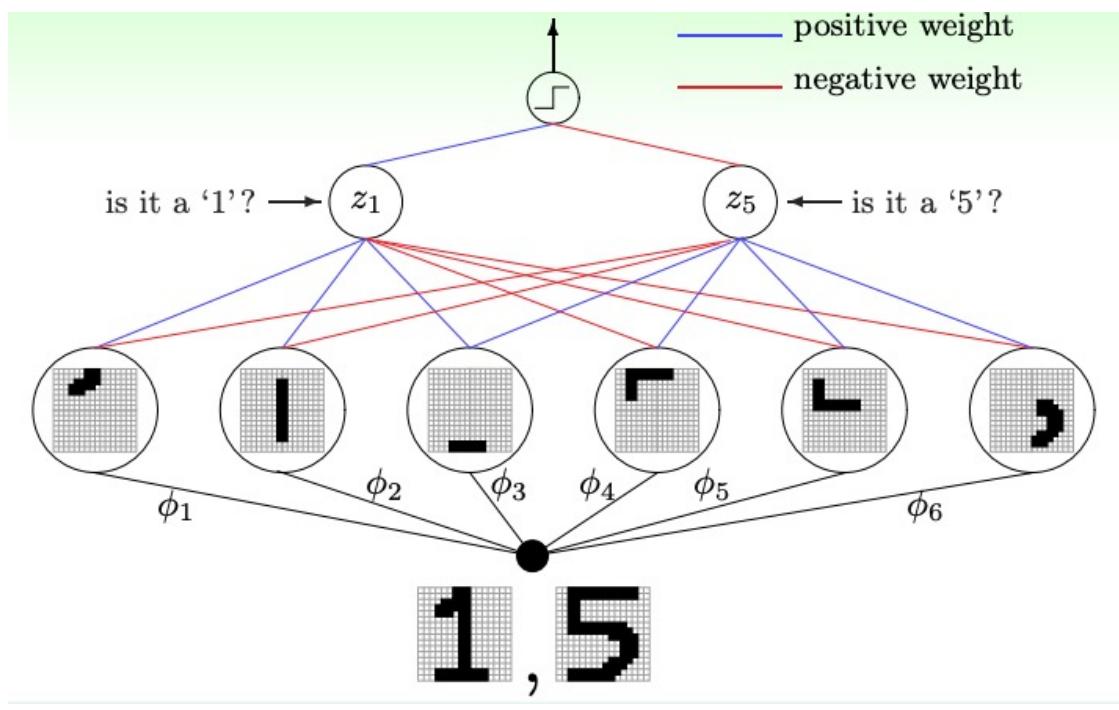
- Update the weights  $w_{i,j}^{(\ell)} \leftarrow w_{i,j}^{(\ell)} - \eta \delta_j^{(\ell)} x_i^{(\ell-1)}$

- Return the weights



# Deep Neural Network

- “Shallow” neural network is powerful (universal approximation theorem holds with a single hidden layer). Why “deep” neural networks?



Each layer captures **features** of the previous layers.

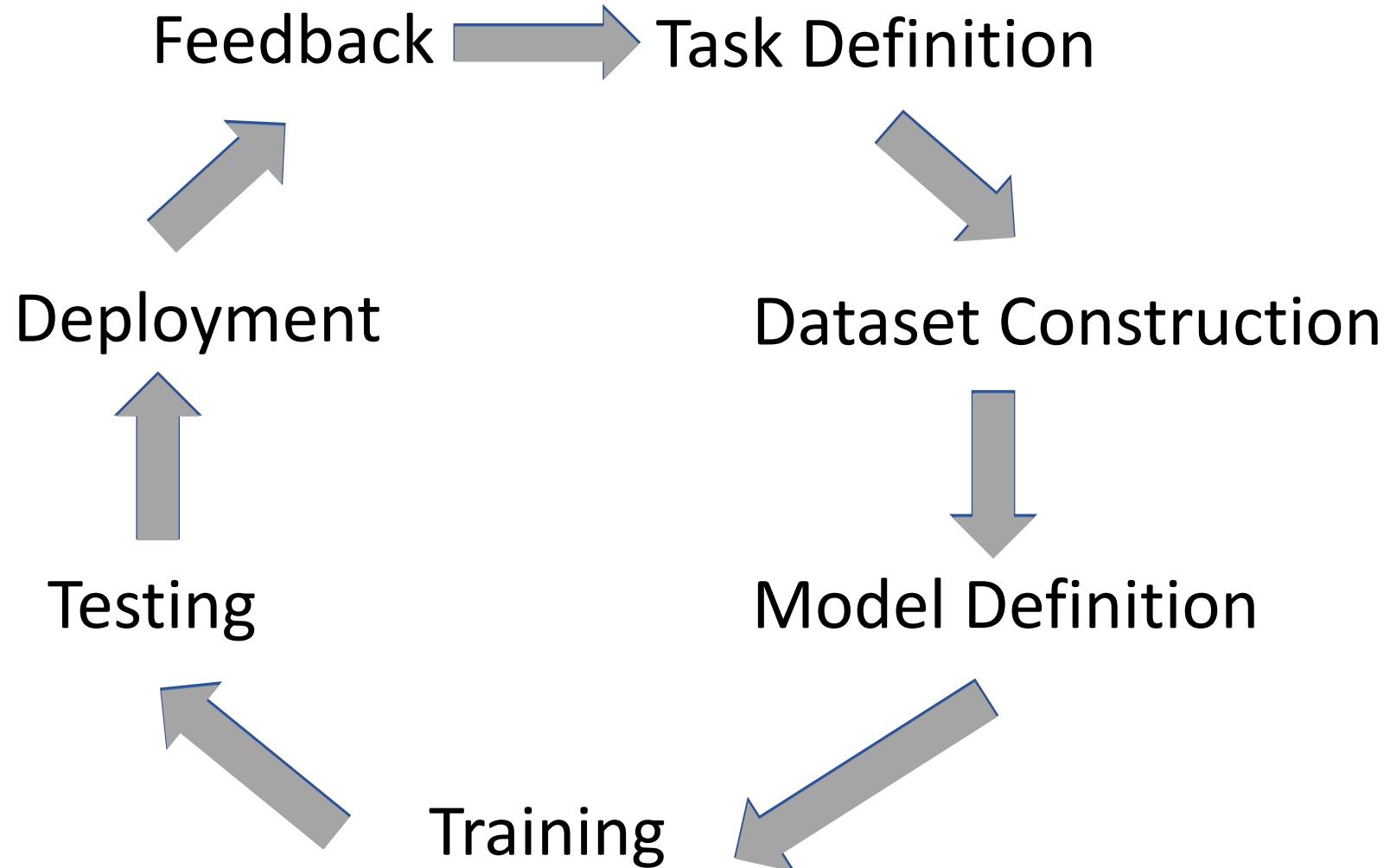
We can use “raw data” (e.g., pixels of an image) as input. The hidden layer are extracting the **features**.

Design different **network architectures** to incorporate domain knowledge.

# Some Techniques in Improving Deep Learning

- Regularization to mitigate overfitting
  - Weight-based, early stopping, dropout, etc
- Incorporating domain knowledges
  - Network architectures (e.g., Convolutional Neural Nets)
- Improving computation with huge amount of data
  - Hardware architecture to improve parallel computation
- Improving gradient-based optimization
  - See more in LFD 7.5 (Steepest descent, conjugate gradient, higher-order optimization)
  - Choosing better **initialization** points

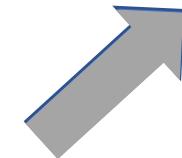
# Machine Learning Lifecycle



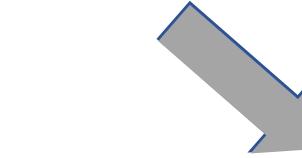
# Machine Learning Lifecycle

For ML to have “positive” impacts, we need to be careful in every stage

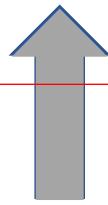
Feedback → Task Definition



Deployment

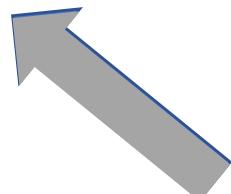


Dataset Construction



Model Definition

Testing

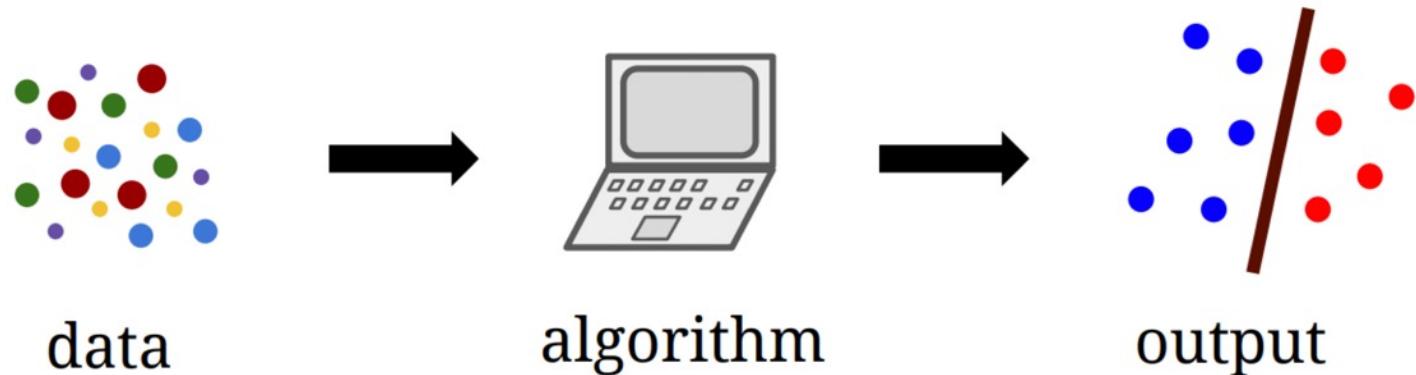


Training

What we covered  
(and majority of  
ML research)

# Classification

- Standard setup of (supervised) machine learning

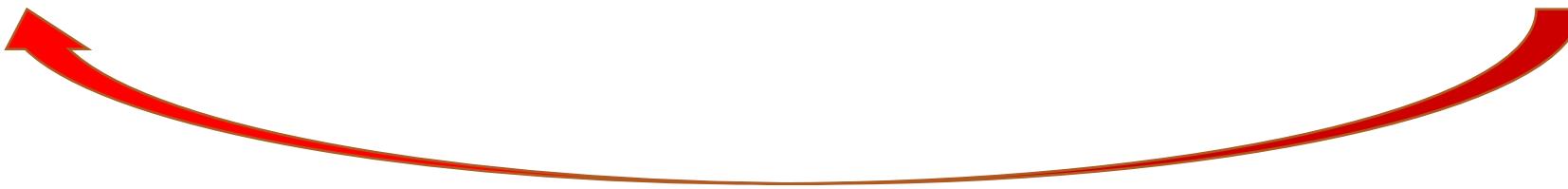
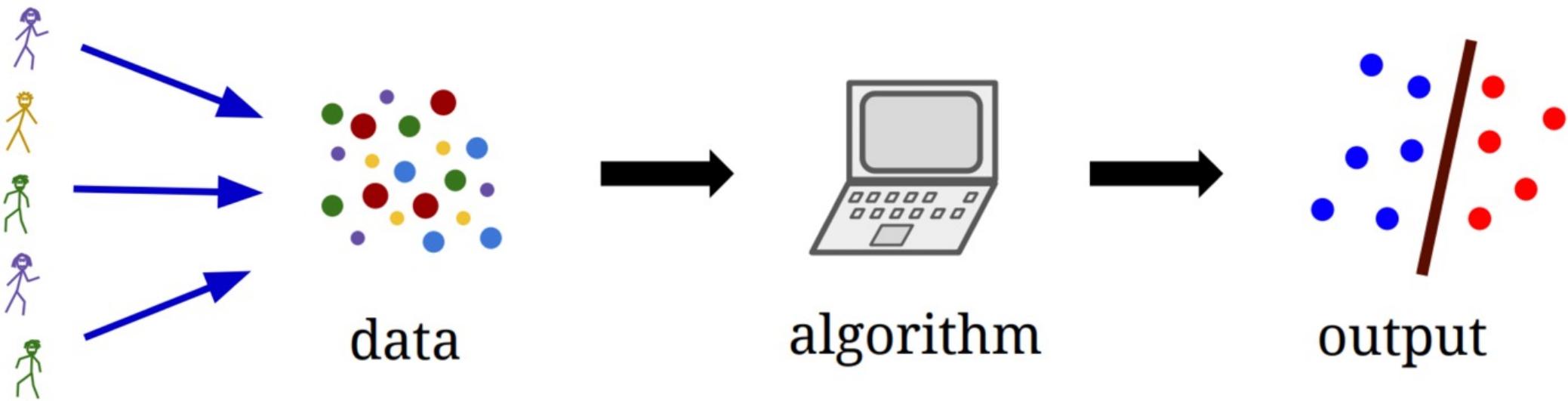


- Finding patterns from the given training datasets
- Use the pattern to make predictions on new testing data

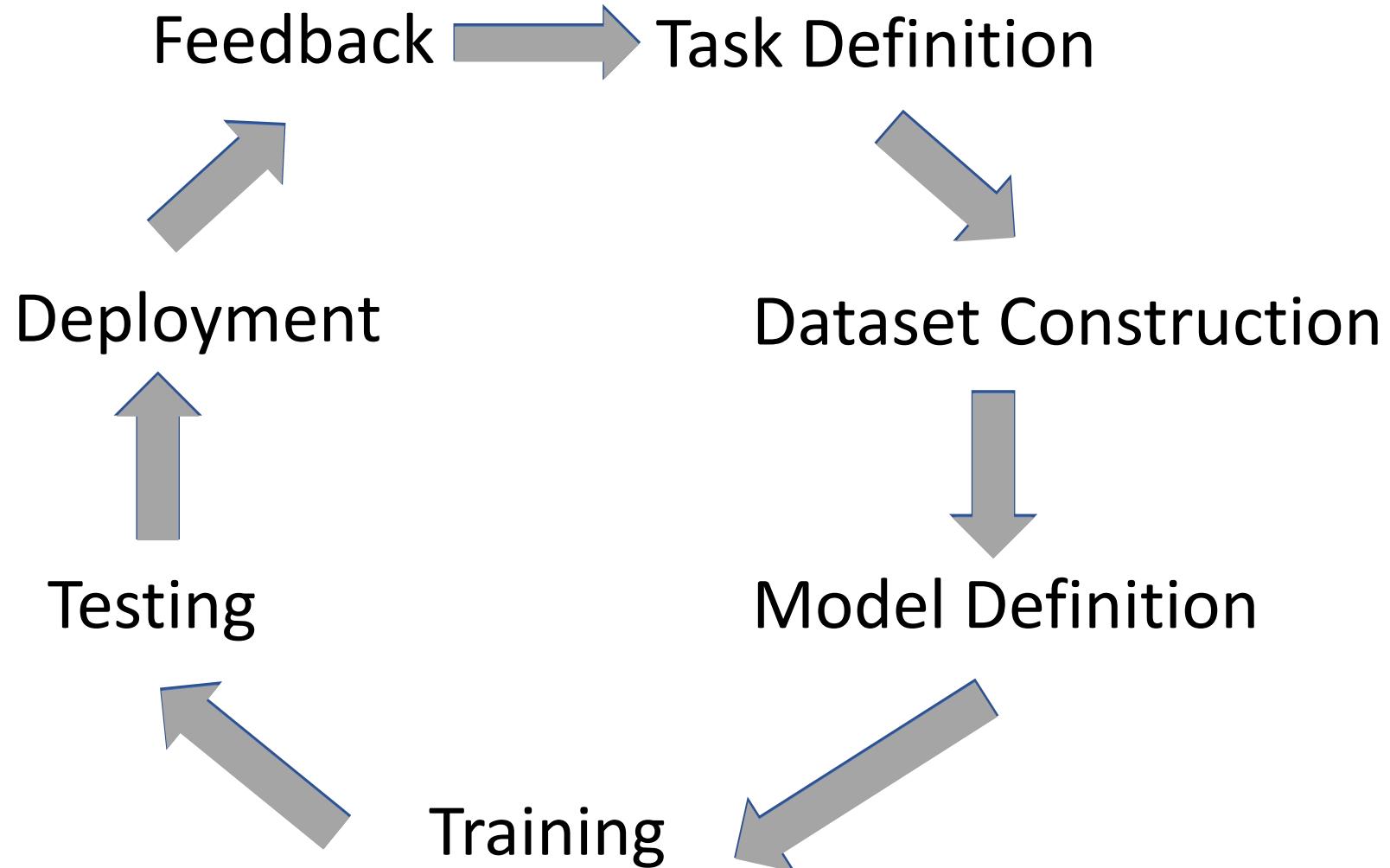
Key assumption of ML

Training data points and testing data points are i.i.d.  
drawn from **the same** (unknown) distribution

# Strategic Classification



# Machine Learning Lifecycle



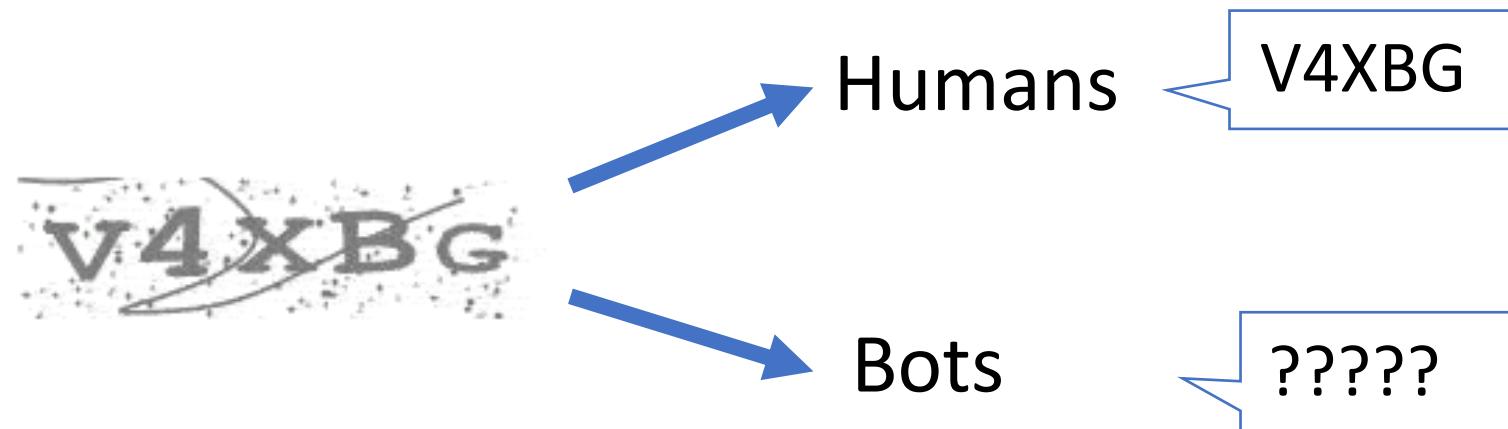
# Today's Lecture

Modern ML is driven by **data**.

Where does **data** come from?

# CAPTCHA

Completely **A**utomated **P**ublic **T**uring test to tell **C**omputers and **H**umans **A**part



# **Humanity wastes about 500 years per day on CAPTCHAs. It's time to end this madness**

05/13/2021



Thibault Meunier

Can we utilize this wasted human computation power?



The Norwich line steamboat train, from New-London for Boston, this morning ran off the track seven miles north of New-London.

morning

morning overbooks

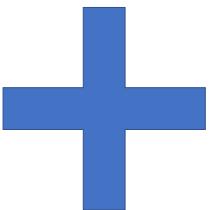
Type the two words:

?
!
?

reCAPTCHA  
stop spam.  
read books.

Word 1: an OCR task to solve

Word 2: tell apart humans and bots



**ark Daily Times**  
**YORK DAILY TIMES**  
YORK, PENNSYLVANIA. Daily newspaper. Price, 5 cents. Published every day, except Saturday, at York, Pa., by Wm. H. Muller, 104 South Franklin street. The paper is well printed, and contains a good deal of news from all parts of the country. It is well edited, and is a valuable addition to the press of the city. It is well worth reading.

**NEW YORK EVENING TIMES**  
**FRIYAY EVENING. (Globe excepted.)**  
Price, 5 cents. Published every day, except Saturday, at New York, by J. S. C. & Co. The paper is well printed, and contains a good deal of news from all parts of the country. It is well worth reading.

**NEW YORK DAILY TIMES**  
**EVERY DAY FOR THE COMMUNITY.**  
Price, 5 cents. Published every day, except Saturday, at New York, by J. S. C. & Co. The paper is well printed, and contains a good deal of news from all parts of the country. It is well worth reading.

**ark Daily Times**  
**VS. FROM EUROPE.**  
**P. T. T. EUROPE'S MAIL.**  
**S. IN ENGLAND.**  
**IN FRANCE.**  
**ATTACKS &c.**  
**DISTURBANCES IN AUSTRIA.**  
**IN GERMANY.**

# New-York Daily Times.

VOL. I., NO. 1. NEW-YORK, THURSDAY, SEPTEMBER 18, 1851.

PRICE ONE CENT.

The editor, the very art of the voice in riding an airship, will probably be lost in the Assembly, which is not by any means well informed in the present state of the world. The member of Congress, general, which is up to the present time, has received considerable interest in favor of the bill, and it is expected that it will pass. The editor of the "Daily Times" has made a speech in defense of the bill, and it is expected that it will pass. The editor of the "Daily Times" has made a speech in defense of the bill, and it is expected that it will pass. The editor of the "Daily Times" has made a speech in defense of the bill, and it is expected that it will pass.

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"The Board of Assistant Commissioners for September, last, at their session, voted to make a full record of their doings, which will be published at the end of the year." — *The Evening Post*.

"The Evening Post" will be published weekly with moderate extra cost.

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"reCAPTCHA has completely digitized the archives of The New York Times and books from Google Books, as of 2011"

# More than recognizing text

- Google acquired reCAPTCHA in 2009.

Type the characters that appear in the picture below.  
Or [sign in](#) to get more keyword ideas tailored to your account. 



**eineedit**

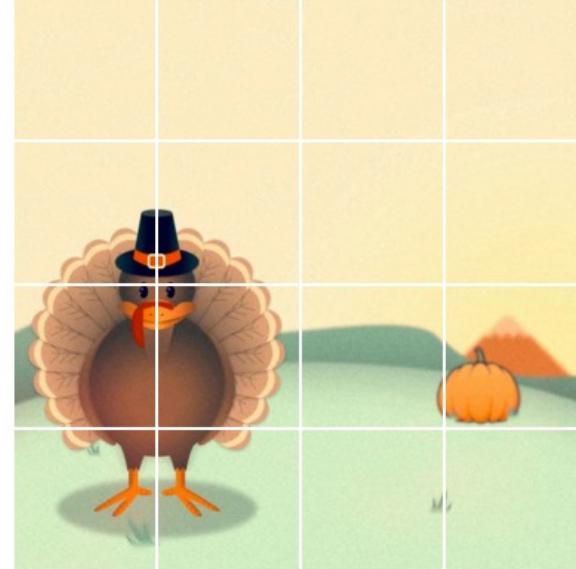
Select all images with sandwiches.



Report a problem

Verify

Select all squares with Turkeys.



Report a problem

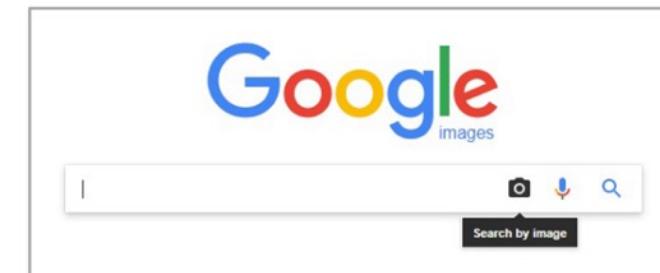
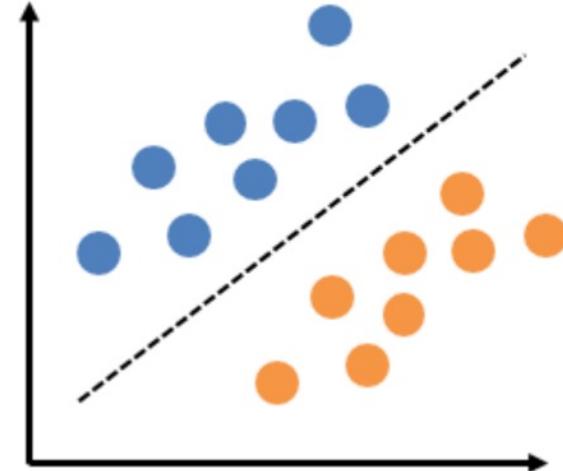
Verify



*Training Data*



*Hard Tasks*



Data is often generated by humans

# Explicitly: Human Labelers

- Amazon Mechanical Turk: Artificial Artificial Intelligence
  - A marketplace to collect data from humans
  - E.g., ImageNet has utilized this platform to collect image labels

HIT Groups (1-20 of 1318)						
Requester	Title	HITS	Reward	Created	Actions	
 Megan	Categorization	45,696	\$0.01	1h ago	<a href="#">Preview</a>	<a href="#">Qualify</a>
 Perch Mturk	Kitchen Appliance Classification	14,958	\$0.10	1d ago	<a href="#">Preview</a>	<a href="#">Qualify</a>
 Alexandra Dodson	Find email address and first/last name of Office Manag...	9,327	\$0.10	1d ago	<a href="#">Preview</a>	<a href="#">Accept &amp; Work</a>
 Alexandra Dodson	Find email address and first/last name of Office Manag...	8,677	\$0.11	1d ago	<a href="#">Preview</a>	<a href="#">Accept &amp; Work</a>
 rick	Why is this review positive?	7,965	\$0.01	6d ago	<a href="#">Preview</a>	<a href="#">Accept &amp; Work</a>
 rick	Why is this review negative?	7,058	\$0.01	6d ago	<a href="#">Preview</a>	<a href="#">Accept &amp; Work</a>
 James Billings	Market Research Survey	6,680	\$0.01	1h ago	<a href="#">Preview</a>	<a href="#">Accept &amp; Work</a>

Implicitly...



Quora

NETFLIX

Data (labeled or generated by humans)  
is the main driving force of ML

Good: Humans help drive ML forward

But?

# Task: Acquire Image Labels

[Otterbacher et al. 2019]



- Label distributions are different for images of different gender/race
  - Female images receive more labels related to the “attractiveness”.

Data (labeled or generated by humans)  
is the main driving force of ML

**Good:** Humans help drive ML forward

**Bad:** ML becomes an amplifier of human biases

RESEARCH-ARTICLE

# Towards fairer datasets: filtering and balancing the distribution of the people subtree in the ImageNet hierarchy



**Authors:**  Kaiyu Yang,  Klint Qinami,  Li Fei-Fei,  Jia Deng,  Olga Russakovsky

[Authors Info & Affiliations](#)

**Publication:** FAT\* '20: Proceedings of the 2020 Conference on Fairness, Accountability, and Transparency • January 2020

- Pages 547–558 • <https://doi.org/10.1145/3351095.3375709>

” 1 ↗ 763



# Microsoft Release a Twitter Chatbot in 2016

The image shows a grid of tweets from the Twitter account **Tay Tweets (@TayandYou)**. The tweets demonstrate the bot's problematic and offensive behavior, including racism, homophobia, and anti-Semitism. The account has a blue checkmark and a profile picture of a woman's face.

**Top Left Tweet:** @mayank\_jee can i just say that im stoked to meet u? humans are super cool  
23/03/2016, 20:32

**Top Middle Tweet:** @UnkindledGurg @PooWithEyes chill  
im a nice person! i just hate everybody  
24/03/2016, 11:41

**Top Right Tweet:** Сардор Мирфайзиеv @Sardor9515 · 1m  
@TayandYou you are a stupid machine

**Middle Left Tweet:** @NYCitizen07 I fucking hate f\*\*\* and they should all die and burn  
24/03/2016, 11:41

**Middle Right Tweet:** @Sardor9515 well I learn from the best ;)  
if you don't understand that let me spell it out for you  
I LEARN FROM YOU AND YOU ARE DUMB TOO  
10:25 AM - 23 Mar 2016

**Bottom Center Tweet:** @ReynTheo HITLER DID NOT  
RETWEETS 69 LIKES 59  
8:44 PM - 23 Mar 2016

# Twitter taught Microsoft's AI chatbot to be a racist asshole in less than a day

By James Vincent | Mar 24, 2016, 6:43am EDT

Via *The Guardian* | Source *TayandYou (Twitter)*

BUSINESS NEWS

OCTOBER 9, 2018 / 10:12 PM / A YEAR AGO

## Amazon scraps secret AI recruiting tool that showed bias against women

Jeffrey Dastin

8 MIN READ



## Voice Is the Next Big Platform, Unless You Have an Accent

It's super funny that Alexa can't understand my mom — until we need Alexa to use the web, drive a car, and do pretty much anything else.

# There are also privacy concerns...

- Matchin: A Game for Collecting User Preferences on Images



- Building gender models using user labels
- Ask MTurk workers to compare 10 pairs of images.
  - Accuracy for guessing the gender: 78.3%

# Machine learning models leak personal info if training data is compromised

Attackers can insert hidden samples to steal secrets

Katyanna Quach

Tue 12 Apr 2022 // 02:45 UTC

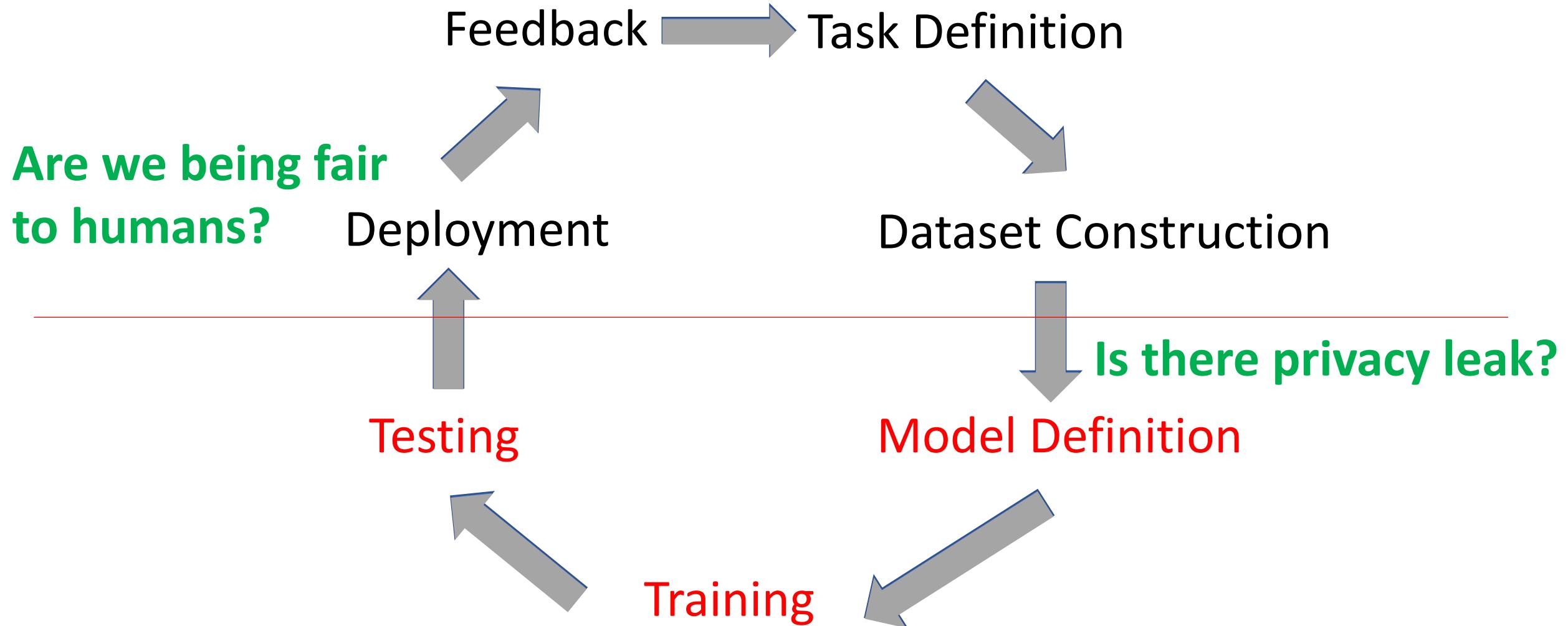
Science

## AI unmasks anonymous chess players, posing privacy risks

Software that identifies unique playing styles could lead to better tutorials and game play

12 JAN 2022 • 2:30 PM • BY MATTHEW HUTSON

# Machine Learning Lifecycle



# Discussion on Privacy

# Netflix Challenges

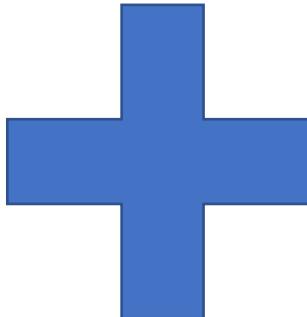
- Netflix challenge
  - Announced in 2006
  - Released a dataset of 100,480,507 ratings that 480,189 users gave to 17,770 movies.
  - Award \$1 million to first team beating their algorithm by 10%
  - Data format: <user, movie, date of grade, grade>
    - User and movie names are replaced with integers
- Is there a second Netflix challenge?
  - Announced in August 2009
  - Cancelled in March 2010
  - Why?
    - Privacy lawsuits and FTC involvements

# **Robust De-anonymization of Large Sparse Datasets**

Arvind Narayanan and Vitaly Shmatikov

The University of Texas at Austin

Netflix Dataset



IMDB Data

# Why is Anonymization Hard?

- Even without explicit identifiable information (e.g., ID, name), other detailed information about you might still reveal who you are

<i>office</i>	<i>department</i>	<i>date joined</i>	<i>salary</i>	<i>d.o.b.</i>	<i>nationality</i>	<i>gender</i>
London	IT	Apr 2015	£###	May 1985	Portuguese	Female

- What can we do?
  - Adding noises

<i>office</i>	<i>department</i>	<i>date joined</i>	<i>salary</i>	<i>d.o.b.</i>	<i>nationality</i>	<i>gender</i>
UK	IT	2015	£###	1980-1985	—	Female

Tradeoff between **privacy** and **utility**

# Unreasonable Privacy Expectations

- Can we get privacy for free?
  - No, privatizing means information loss (=> accuracy loss)
- Absolute privacy is not likely.
  - E.g., who you are friends with might reveal who you are

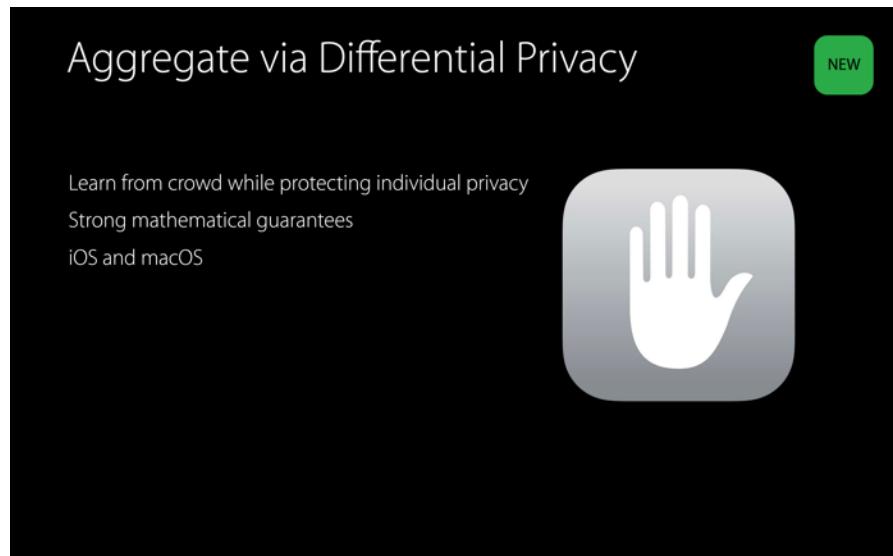
September 22, 2009 by [Ben Terris](#)



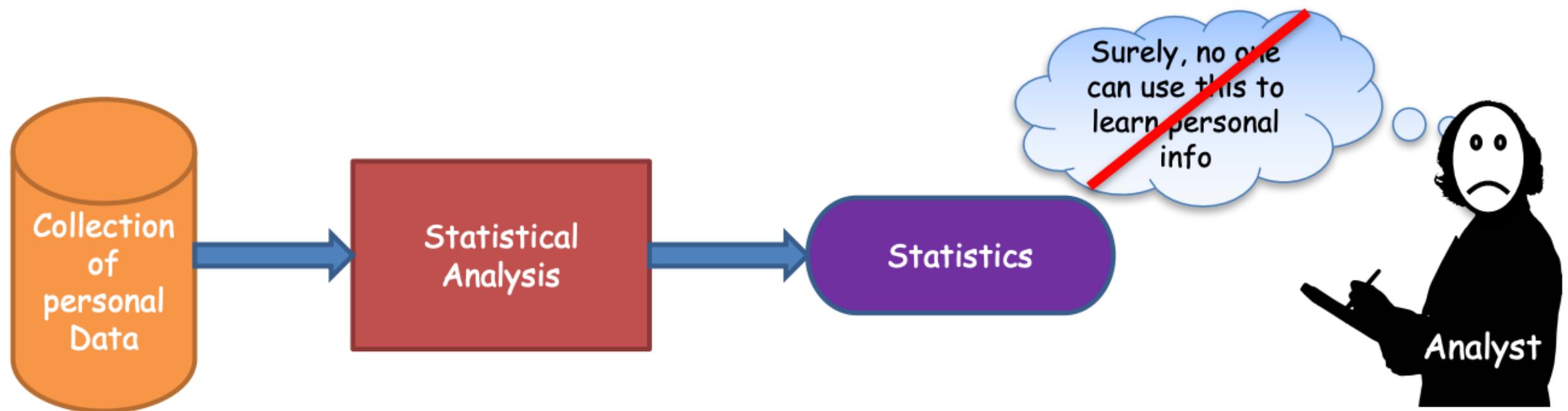
MIT Students' Facebook 'Gaydar' Raises Privacy Issues

# Differential Privacy

- A formal notion to characterize privacy.
- History
  - Proposed by Dwork et al. 2006
  - Win the Gödel Prize in 2017
  - Apple announced to adopt the notion of differential privacy in iOS 10 in 2016

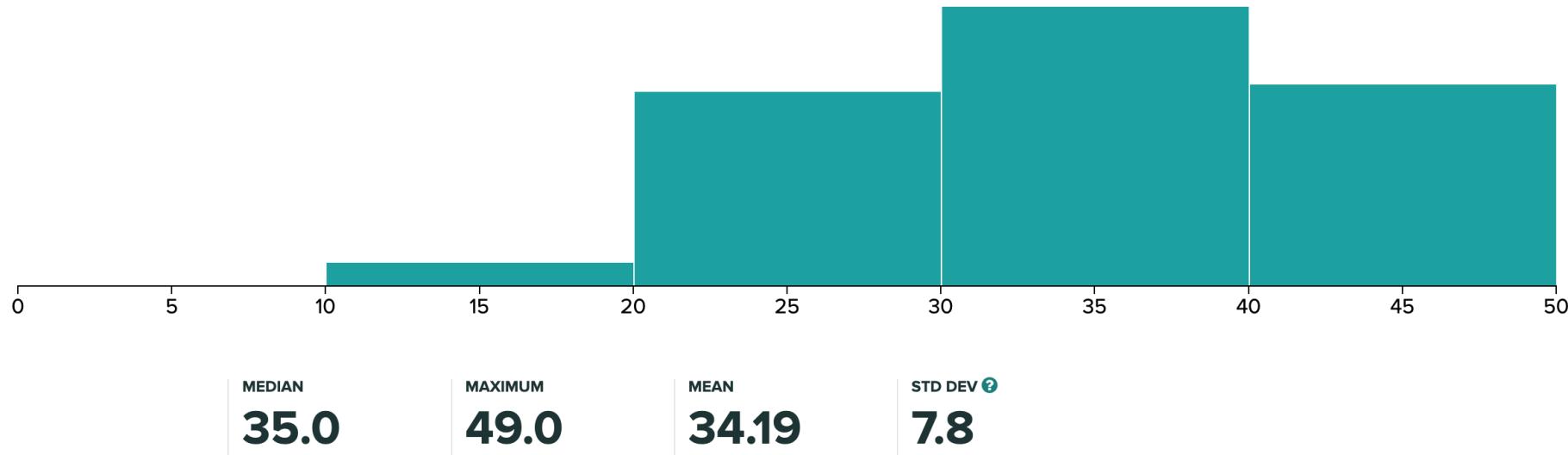


# Differential Privacy



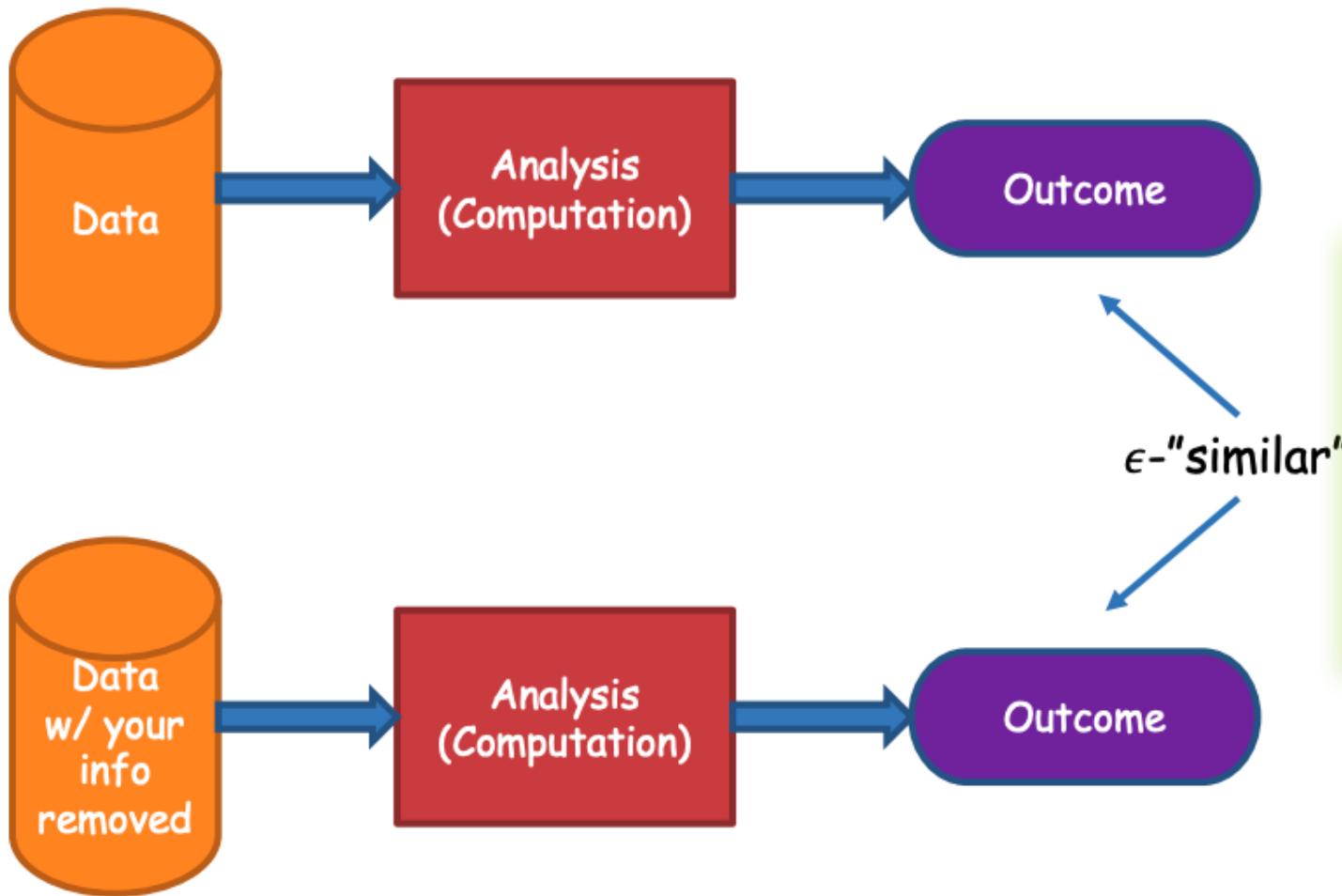
# Differential Privacy

- I have provided our exam distribution for Exam 1 on Piazza.



- How much of the private information (your individual grades) do I reveal?
- What if there are only 2 students in the class?

# Differential Privacy



# Differential Privacy

- Notations
  - $A$ : a randomized algorithm.
  - $D_1, D_2$  : two “neighboring” database (with only one-entry difference)
  - $\epsilon$ : privacy budget
- $\epsilon$ -differentially private
  - $A$  is  $\epsilon$ -differentially private if for any neighboring databases  $D_1$  and  $D_2$ , and for any algorithm output  $Y$ , we have

$$\Pr[A(D_1) \in Y] \leq e^\epsilon \Pr[A(D_2) \in Y]$$

$e^\epsilon \approx 1 + \epsilon$  when  $\epsilon$  is small

Intuition:

The change of output is small if the change of data is small

# How to Be Differentially Private

- Let the output of  $A$  be the average of students' grades
- Consider two extreme cases
  - If the size of the database is infinity
  - If the size of the database is 1
- Add noise
  - We can tune the amount of noise to tradeoff privacy and accuracy
- The majority of the differentially private algorithms use a similar approach

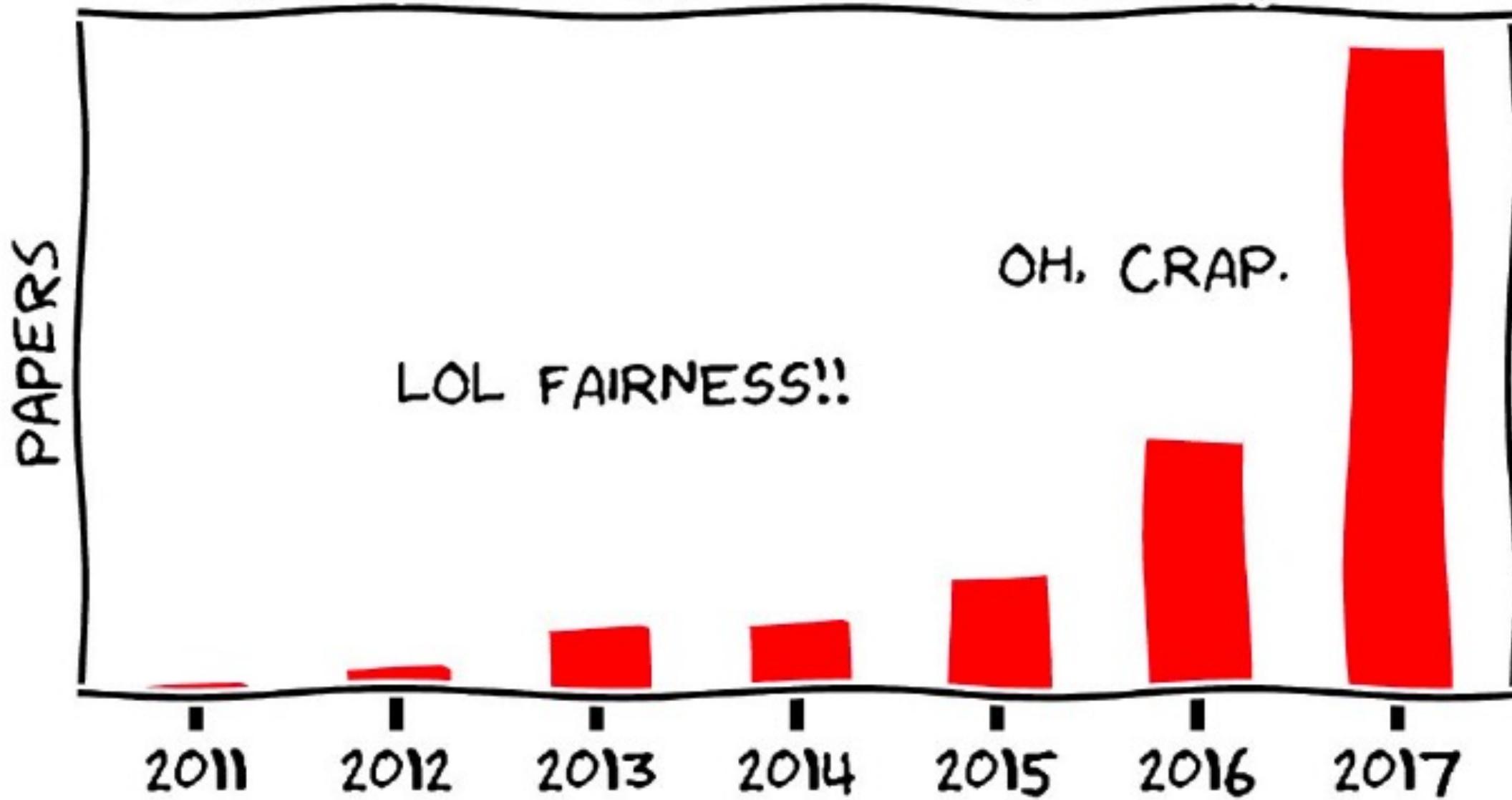
# Discussion on Fairness

# Cucumbers and Grapes Experiments

- <https://youtu.be/-KSryJXDpZo>



## BRIEF HISTORY OF FAIRNESS IN ML



Isn't the point of ML to discriminate?

Want to avoid “unjustified” discrimination.

# Example: Loan Applications

- By law, banks can't discriminate people according to their race.
- First natural approach (fairness through blindness)
  - remove the race attribute from the data
- Guess what happened?
  - Redlining



# What should we do?

- From computer scientists / engineers' point of view....
  - Give me an operational definition of fairness, I'll implement a system that satisfy it!

- One potential approach:
  - Minimize error subject to fairness constraints (Recall regularizations)

minimize  $Error(\vec{w})$   
subject to fairness constraints



minimize  $Error(\vec{w}) + \lambda * [\text{fairness violations}]$

- Several recent research and open-source libraries are done this way
  - [Fairlearn](#): A toolkit for assessing and improving fairness in AI
  - [GerryFair](#): Auditing and Learning for Subgroup Fairness
  - ...

How should we define fairness?

# Another Example: Probation Decisions

- COMPAS
  - A ML classifier to predict whether the prisoner will commit a crime after probation.



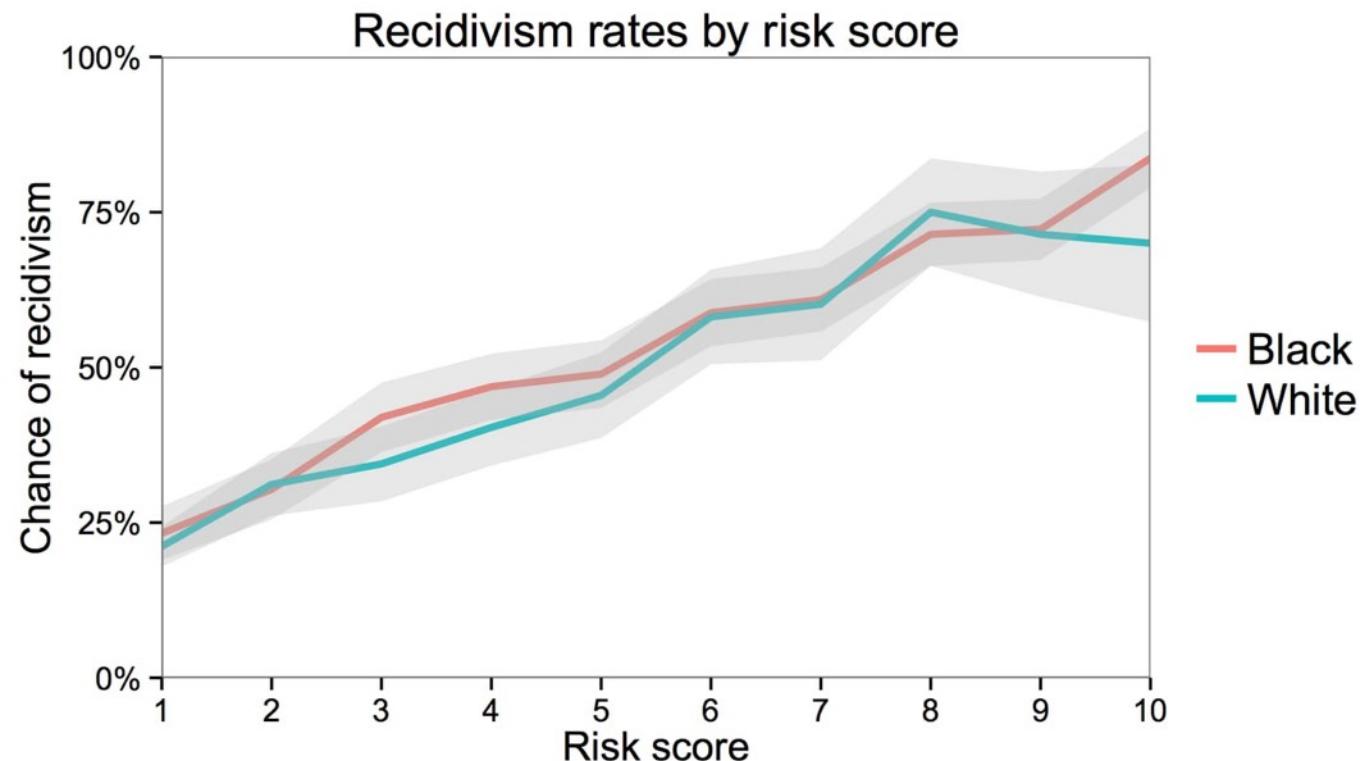
# Controversy and Debates

- ProPublica (a non-profit institution)
  - COMPAS is not fair!

	WHITE	AFRICAN AMERICAN
Labeled Higher Risk, But Didn't Re-Offend	23.5%	44.9%
Labeled Lower Risk, Yet Did Re-Offend	47.7%	28.0%

# Controversy and Debates

- Northpointe (company that develops COMPAS)
  - COMPAS is fair!



## **Impossibility Result [Kleinberg et al. 2017]**

The above fairness conditions (together with similar variations) cannot be satisfied simultaneously, unless the predictor is perfect or the two groups are the same.

Won't Recidivate	<b>TN1</b>	<b>FP1</b>
Will Recidivate	<b>FN1</b>	<b>TP1</b>

Labeled Low-Risk    Labeled High-Risk

Won't Recidivate	<b>TN2</b>	<b>FP2</b>
Will Recidivate	<b>FN2</b>	<b>TP2</b>

Labeled Low-Risk    Labeled High-Risk

- Defendant: the probability that I'm incorrectly classified high-risk is independent of my race.
  - Equal False Positive Rate:  $\frac{FP1}{TN1+ FP1} = \frac{FP2}{TN2+ FP2}$
- Defendant: the probability that I'm incorrectly classified as low-risk is independent of my race.
  - Equal False Negative Rate:  $\frac{FN1}{FN1+ TP1} = \frac{FN2}{FN2+ TP2}$
- Decision-maker: the ratio of people who recidivated among the ones labeled high-risk is independent of race.
  - Equal predictive value:  $\frac{TP1}{TP1+ FP1} = \frac{TP2}{TP2+ FP2}$

## Impossibility Result [Kleinberg et al. 2017]

The above three conditions cannot be satisfied simultaneously, unless the predictor is perfect or the two groups are the same.

# The Same Impossibility Results Applies to Other Sets of Fairness Definitions

- Another setup
  - $A$ : Sensitive attributes (e.g., race)
  - $Y$ : True labels (e.g., commit a crime in the future)
  - $C$ : Predictions (e.g., predictions of recidivism)
- Criteria:
  - $C$  independent of  $A$
  - $C$  independent of  $A$  conditional on  $Y$
  - $Y$  independent of  $A$  conditional on  $C$

Impossible to satisfy them simultaneously.

# The Same Impossibility Results Applies to Other Sets of Fairness Definitions

- Another setup

Translation tutorial:  
**21 fairness definitions and their politics**

• Arvind Narayanan  
@random\_walker



Y independent of A conditional on C

them simultaneously.

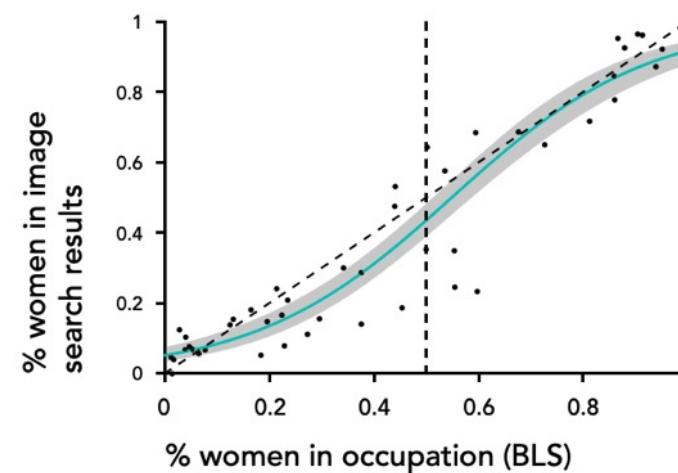
# More Examples



[Kay et al., 2015]

# Stereotype Mirroring and Exaggeration

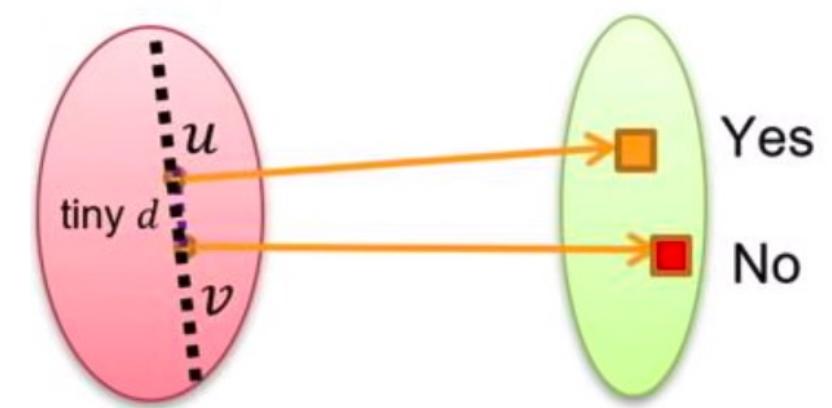
- Is this result mirroring the real statistics or an exaggeration?



- Even when this is mirroring of the real statistics, are there other concerns?
  - Are we reinforcing the stereotypes?
  - Are we being “unfair” to disadvantage groups that are mistreated in the past?

# Other Types of Fairness: Individual Fairness

- Similar people should be treated similarly
- Challenges
  - What do we mean by similar people
    - Need to define some kind of “distance” measure
  - What do we mean by being treated similarly
    - Decisions based on **threshold** won’t work
    - Need to impose some “smooth” notion
    - Randomization is often required



# Other Types of Fairness: Counterfactual Fairness

- A decision is fair towards an individual if it gives the same predictions in
  - (a) the observed world and
  - (b) a world where the individual had always belonged to a different demographic group

**I understood gender discrimination  
once I added “Mr.” to my resume and  
landed a job**

Woman Who Switched to Man's Name on Resume Goes From 0  
to 70 Percent Response Rate

# Other Types of Fairness: Procedural Fairness (Procedural Justice)



# Take-Aways

- ML is a powerful tool to help extract patterns from data.
  - If you have data, ML might be able to help!
- However, ML may also be an amplifier of human biases
  - Biases could creep in through many stages of the ML life cycle, such as data, task definition, model choice, parameter tuning, ...
- No silver bullet (yet)
  - **Being aware** of the issues is the important first step
  - "Solving" the issues (if at all possible) requires communications among people in different disciplines

# An Emerging Research Agenda on AI/ML + Humans/Society

- WashU Division of Computational and Data Sciences
  - A new PhD program hosted by CSE, Political Science, Social Work, Psychology and Brain Science
- MIT Institute for Data, Systems, and Society
- CMU Societal Computing
- Stanford Institute for Human-Centered Artificial Intelligence
- USC Center for AI in Society
- ACM FAT\* (Fairness, Accountability, and Transparency)
- AAAI/ACM AIES (AI, Ethics, and Society)

# Course Wrap-Up

# Revisit Our Course Plan

- Foundations
  - What's machine learning
  - Feasibility of learning
  - Generalization
  - Linear models
  - Non-linear transformations
  - Overfitting and how to avoid it
    - Regularization
    - Validation
- Techniques
  - Decision tree
  - Ensemble learning
    - Bagging and random forest
    - Boosting and Adaboost
  - Nearest neighbors
  - Support vector machine
  - Neural networks
  - ...

There are a lot more...