An Introduction to Fairness and Bias in Machine Learning

SCQ Summer School
July 24th-28th, 2023

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UNIVERSITY OF
COPENHAGEN

An Introduction to Fairness and Bias in Machine Learning

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Germans Savcisens
PhD student in Computational Social Science
Technical University of Denmark

Algorithmic Fairness, Accountability and Ethics
Lecturer at IT University of Copenhagen

AI and ML are everywhere

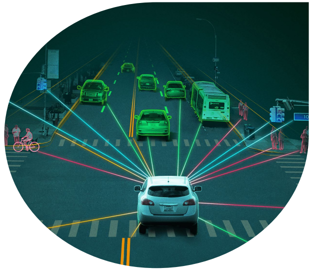
Personal Assistants

Social Media

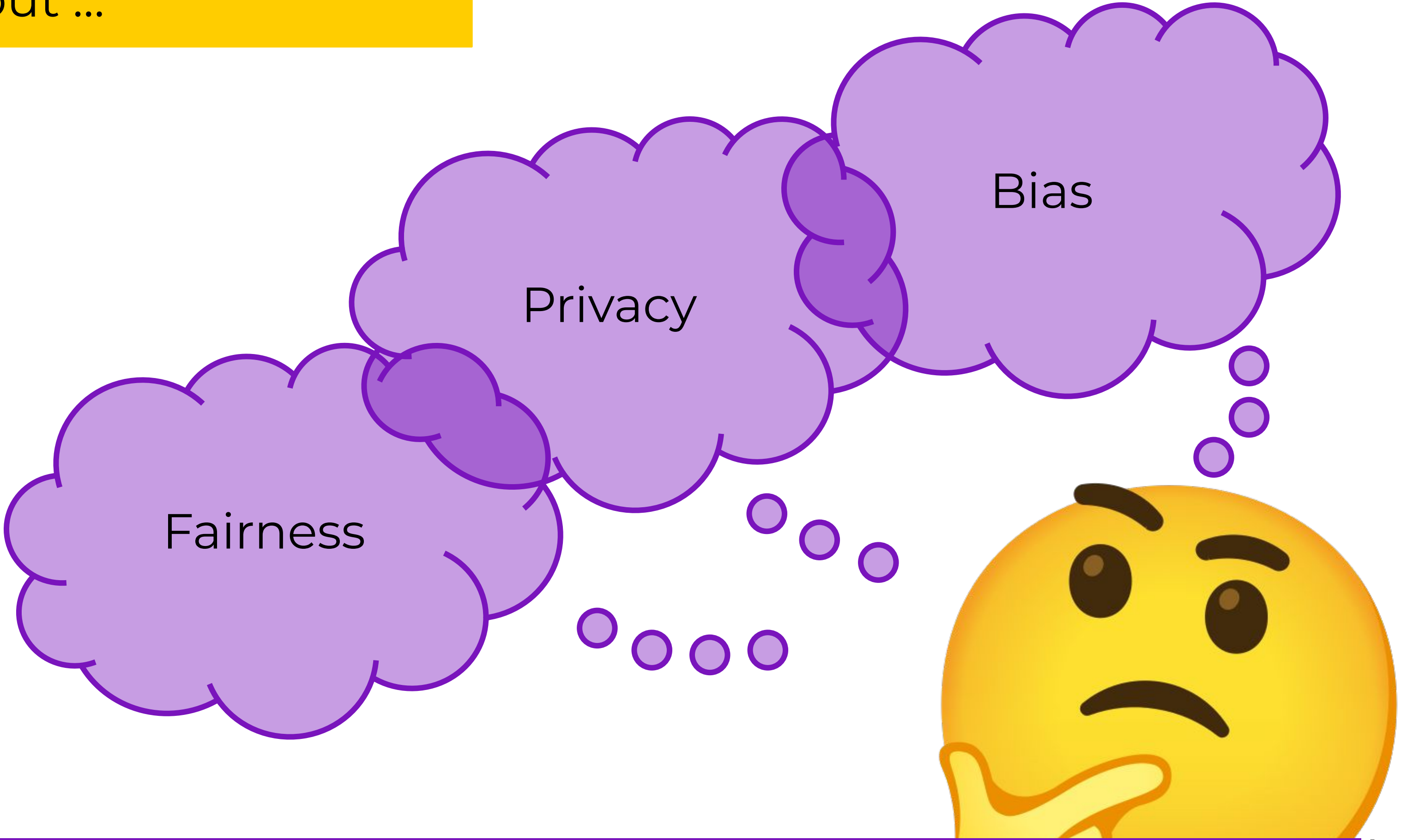
YouTube TikTok

Meta

Other



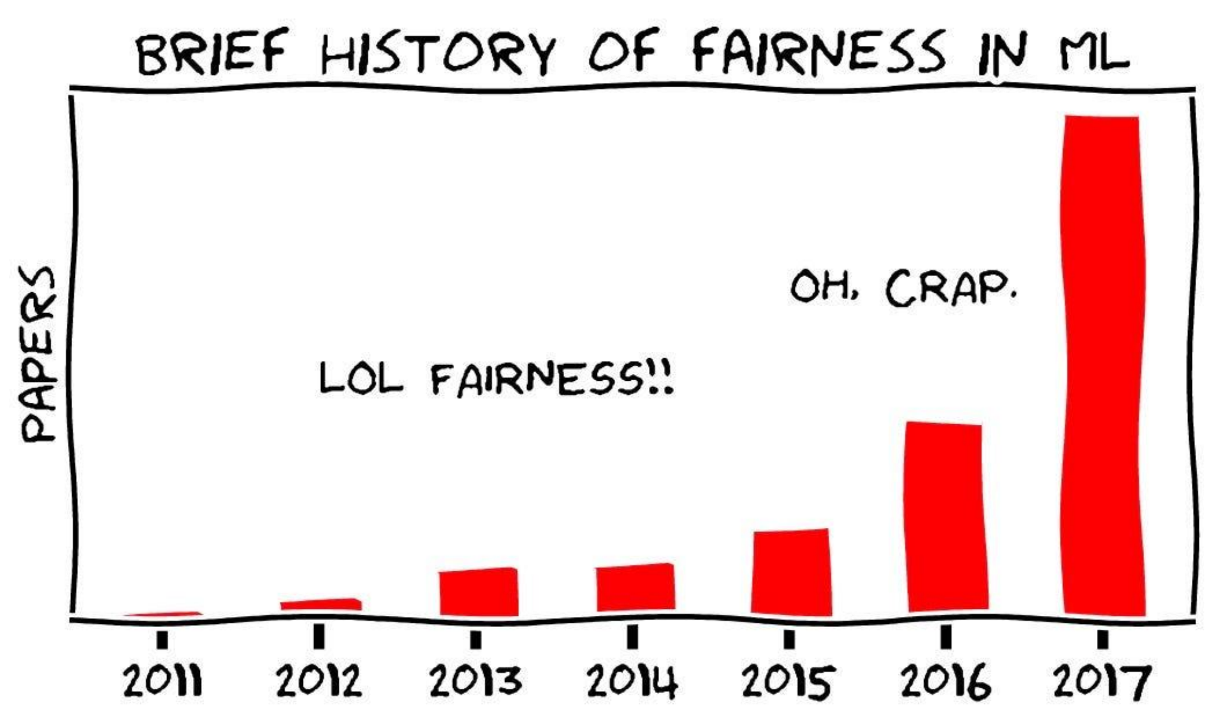
But, what about ...



Fairness

Privacy

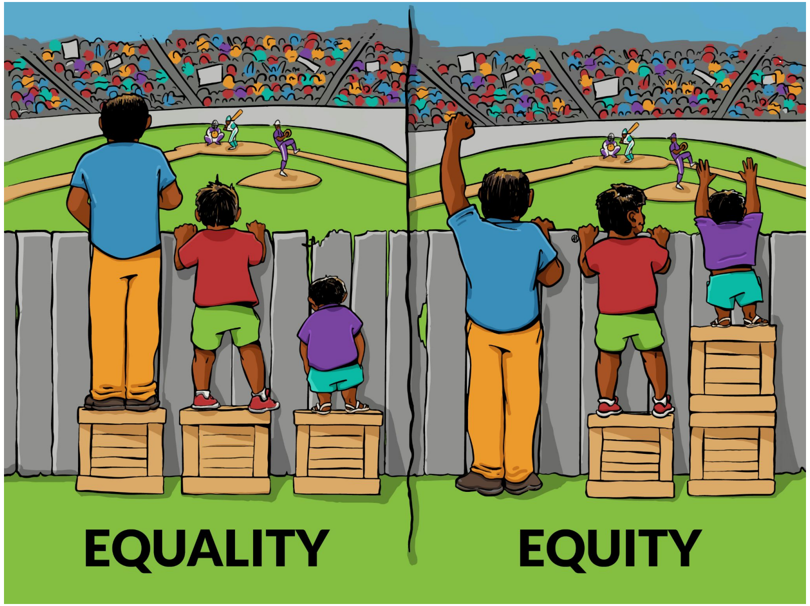
Bias



By Moritz Hardt

Disclaimer

- There are **many definitions** of fairness
- There is **no free lunch**
  - Fairness can **decrease accuracy**
  - Fairness definitions are **often incompatible**
- Fairness can be **achieved in different ways**

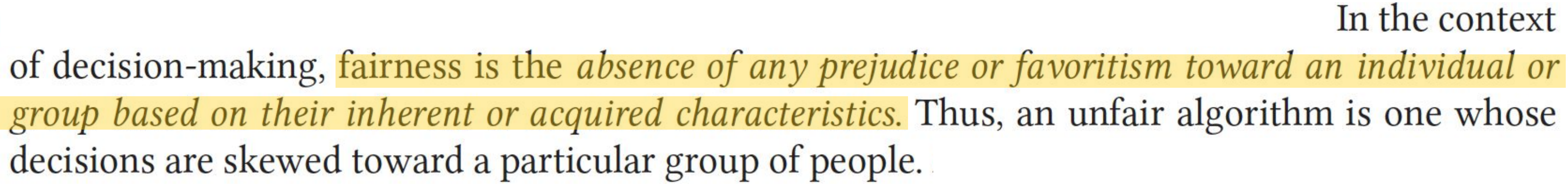


https://interactioninstitute.org/illustrating-equality-vs-equity/

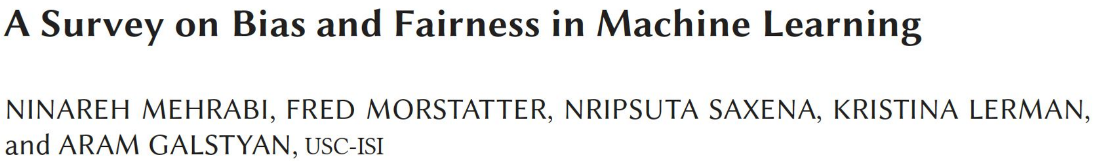
How would you define fairness?

Take 3 minutes to discuss with your group

What is algorithmic fairness?



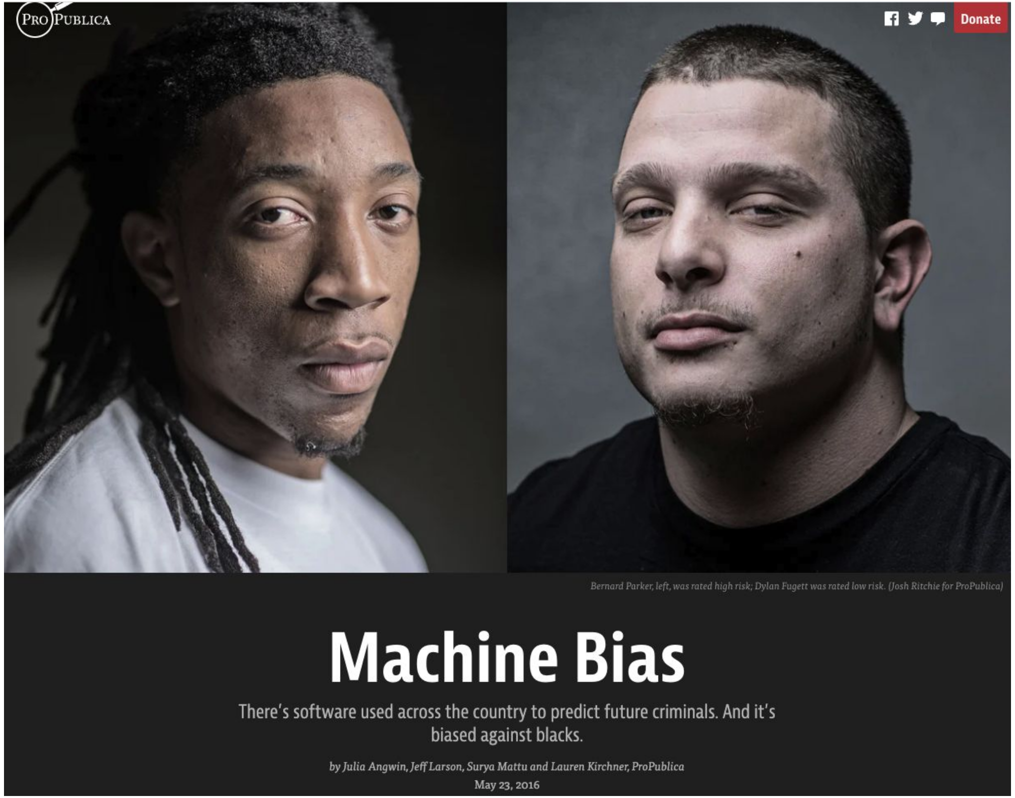
In the context of decision-making, fairness is the *absence of any prejudice or favoritism toward an individual or group based on their inherent or acquired characteristics.* Thus, an unfair algorithm is one whose decisions are skewed toward a particular group of people.



A Survey on Bias and Fairness in Machine Learning

NINAREH MEHRABI, FRED MORSTATTER, NRIPSUTA SAXENA, KRISTINA LERMAN, and ARAM GALSTYAN, USC-ISI

Impact of algorithms



Bernard Parker, left, was rated high risk; Dylan Fugett was rated low risk. (Josh Ritchie for ProPublica)

Machine Bias

There's software used across the country to predict future criminals. And it's biased against blacks.

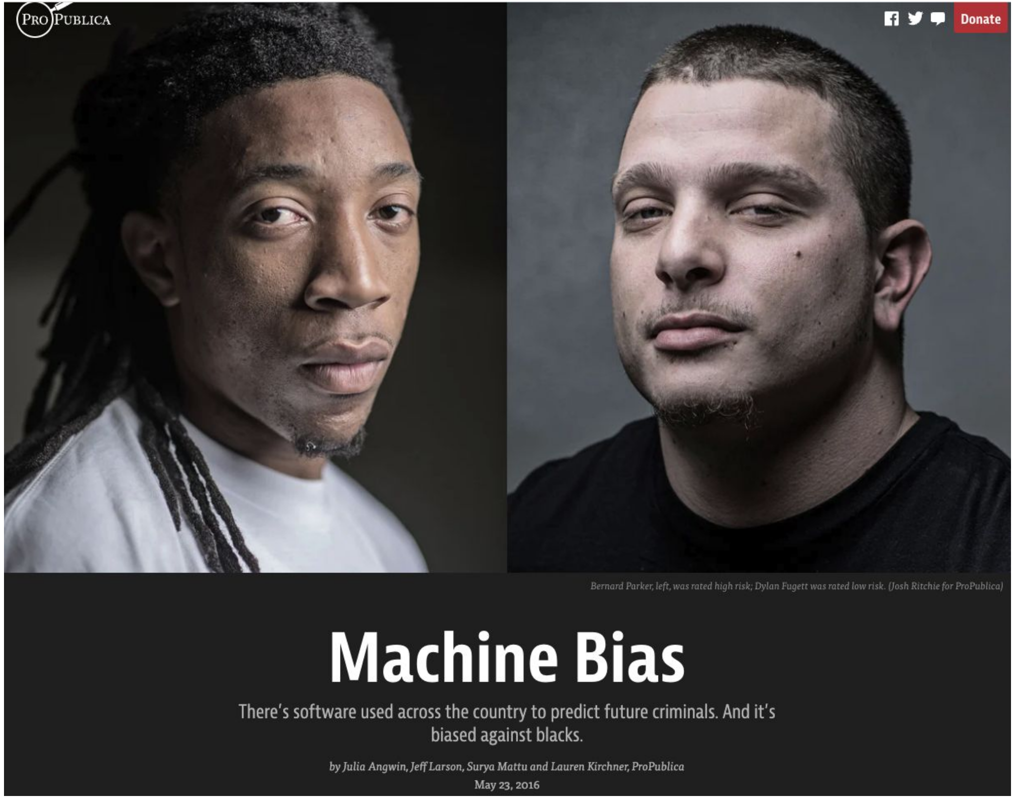
by Julia Angwin, Jeff Larson, Surya Mattu and Lauren Kirchner, ProPublica
May 23, 2016

COMPAS

(Correctional Offender Management Profiling for Alternative Sanctions)

a popular commercial algorithm used by judges and parole officers for scoring criminal defendant's likelihood of reoffending (recidivism).

ProPublica Study



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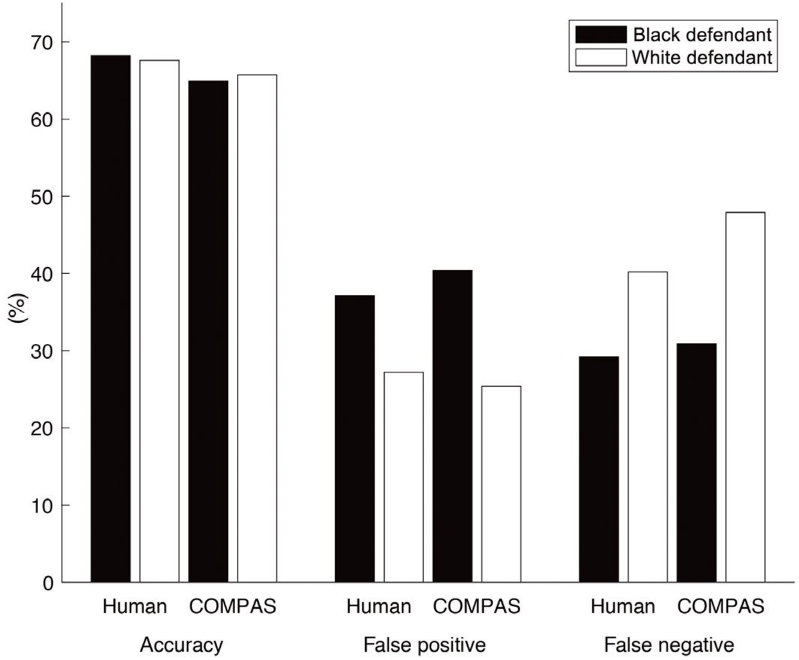
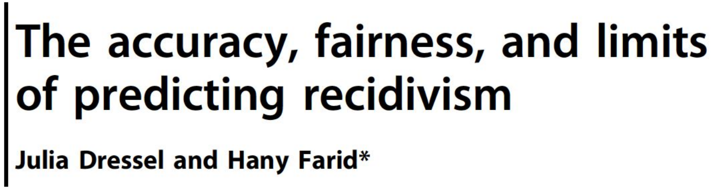
Key take away

COMPAS was found to be **biased against African-Americans:** it falsely predicts them to be at a **higher risk** of recommitting a crime or recidivism.

> ProPublica: How we analyzed the COMPAS recidivism algorithm
>
> MIT SERC: The dangers of risk prediction in the criminal justice system

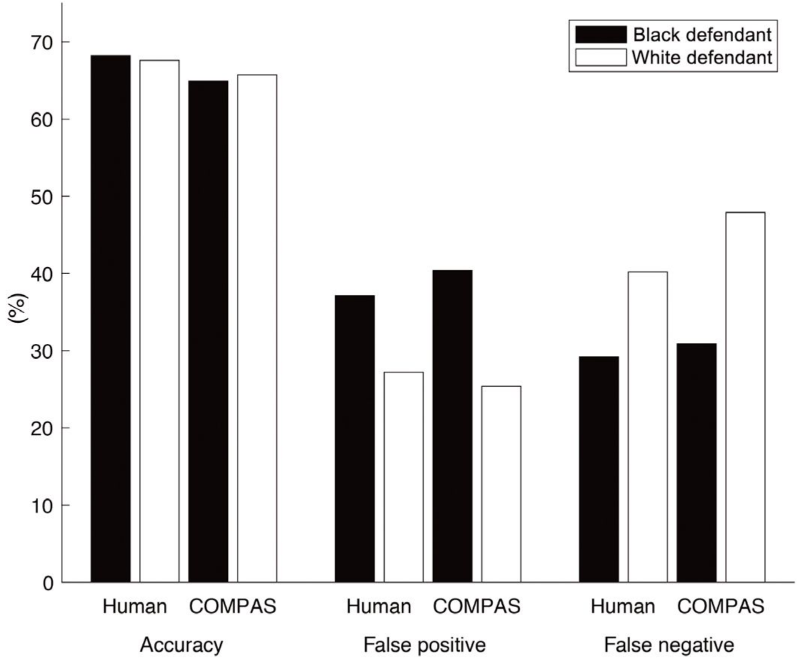
COMPAS performance

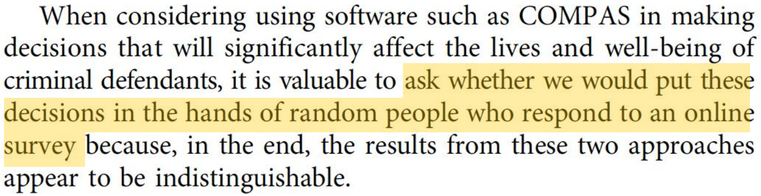



The accuracy, fairness, and limits of predicting recidivism

Julia Dressel and Hany Farid*

COMPAS performance

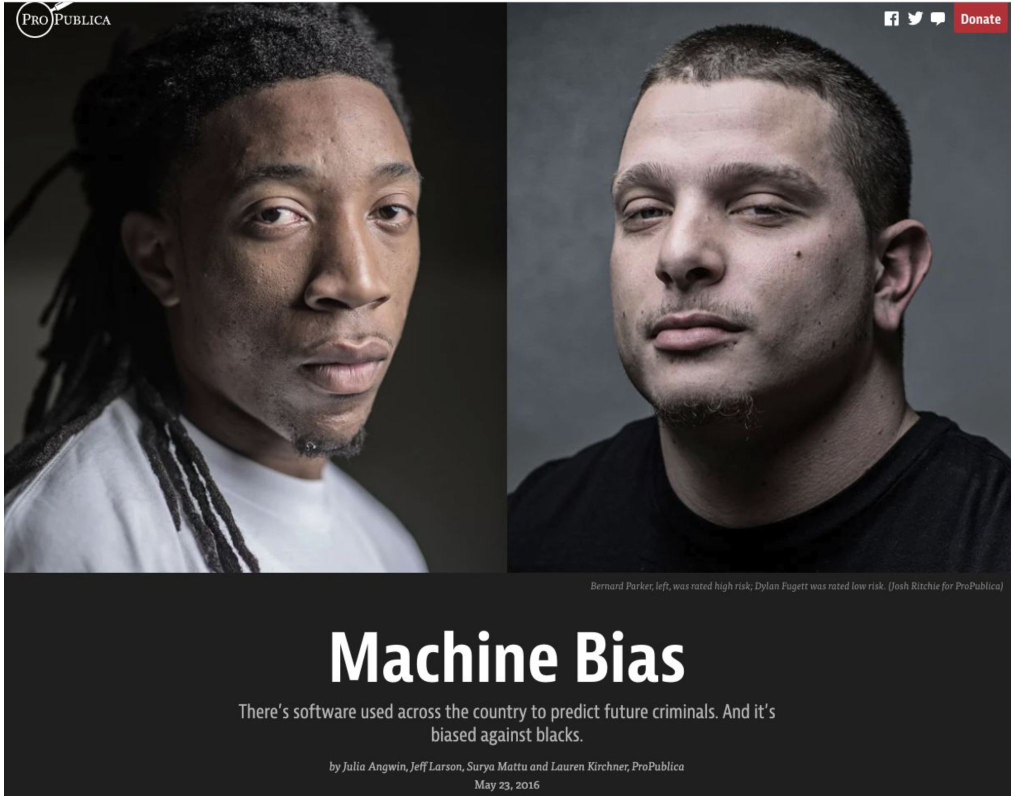



When considering using software such as COMPAS in making decisions that will significantly affect the lives and well-being of criminal defendants, it is valuable to ask whether we would put these decisions in the hands of random people who respond to an online survey because, in the end, the results from these two approaches appear to be indistinguishable.

The accuracy, fairness, and limits of predicting recidivism

Julia Dressel and Hany Farid*

Impact of algorithms



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Failed due to biases …

… but what is bias?

What is bias?

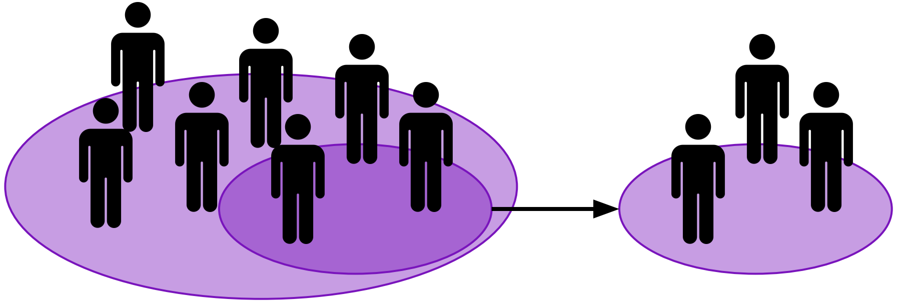
Different definitions proposed

Some concepts can be vague

What is bias?

Defining bias in statistics

Statistical bias is anything that leads to a systematic difference between the **true parameters** of a population and the **statistics used to estimate** those parameters.



Population

Sample

Variable X*

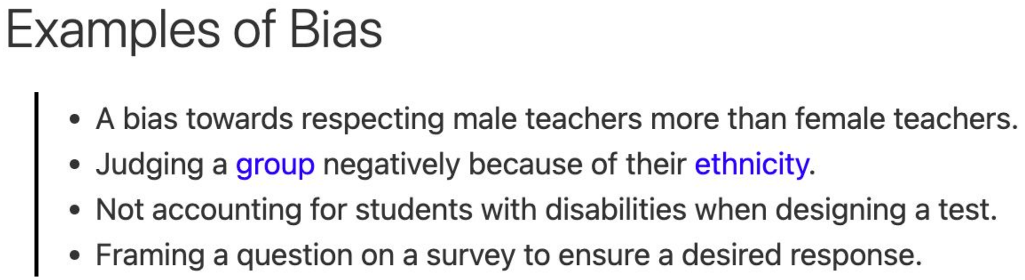
Measurement / Estimation X

The measurement X is biased if E[X*] ≠ E[X]

What is bias?

Defining bias in sociology

A **tendency** (either known or unknown) to prefer a thing over another that **prevents objectivity** and influences understanding or outcomes in some way



Examples of Bias

> - A bias towards respecting male teachers more than female teachers.
> - Judging a group negatively because of their ethnicity.
> - Not accounting for students with disabilities when designing a test.
> - Framing a question on a survey to ensure a desired response.

What is bias?

Defining bias in Machine Learning and AI

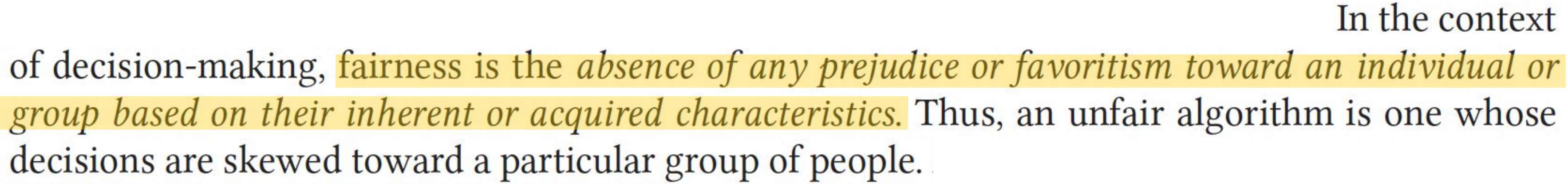
There is no exact definition

What is bias?

Defining bias in Machine Learning and AI

The term bias is used to characterize the process leading to **prediction issues** and **possible unfairness**

What is algorithmic fairness?



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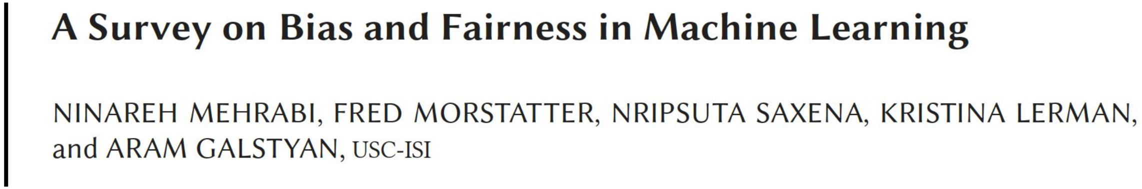

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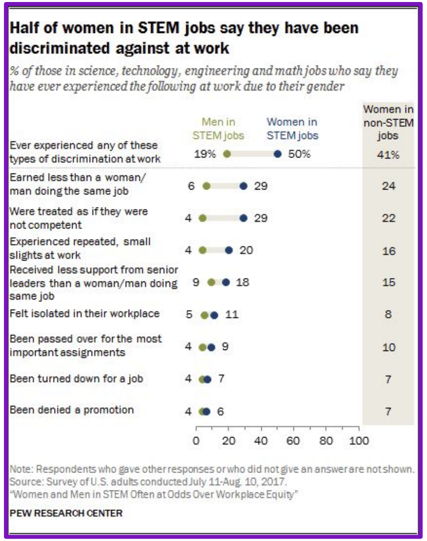
Does bias necessarily imply unfairness?

Take 3 minutes to discuss with your group

Bias vs Fairness

Bias **does not** necessarily imply unfairness

Gender and the workplace



Half of women in STEM jobs say they have been discriminated against at work

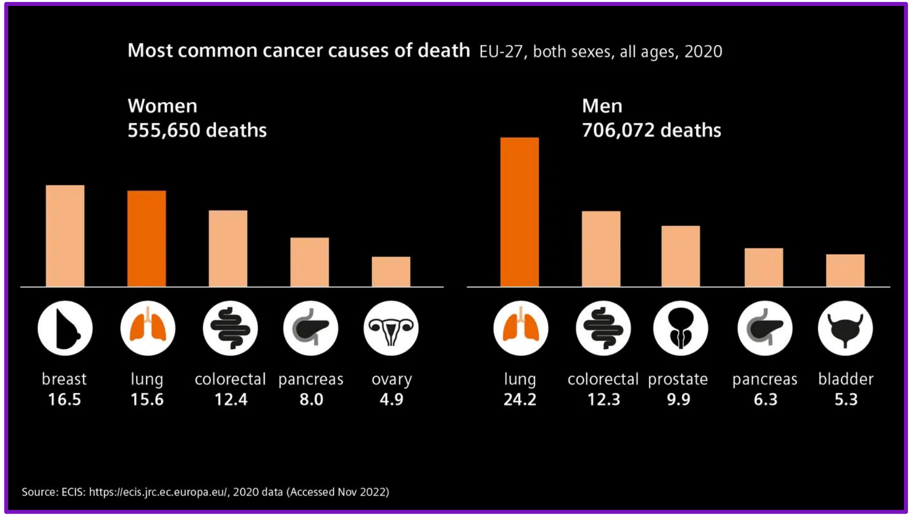
% of those in science, technology, engineering and math jobs who say they have ever experienced the following at work due to their gender

	Men in STEM jobs	Women in STEM jobs	Women in non-STEM jobs
Ever experienced any of these types of discrimination at work	19%	50%	41%
Earned less than a woman/ man doing the same job	6	29	24
Were treated as if they were not competent	4	29	22
Experienced repeated, small slights at work	4	20	16
Received less support from senior leaders than a woman/man doing same job	9	18	15
Felt isolated in their workplace	5	11	8
Been passed over for the most important assignments	4	9	10
Been turned down for a job	4	7	7
Been denied a promotion	4	6	7

Note: Respondents who gave other responses or who did not give an answer are not shown.
Source: Survey of U.S. adults conducted July 11-Aug. 10, 2017.
"Women and Men in STEM Often at Odds Over Workplace Equity"

PEW RESEARCH CENTER

Gender in medical diagnosis



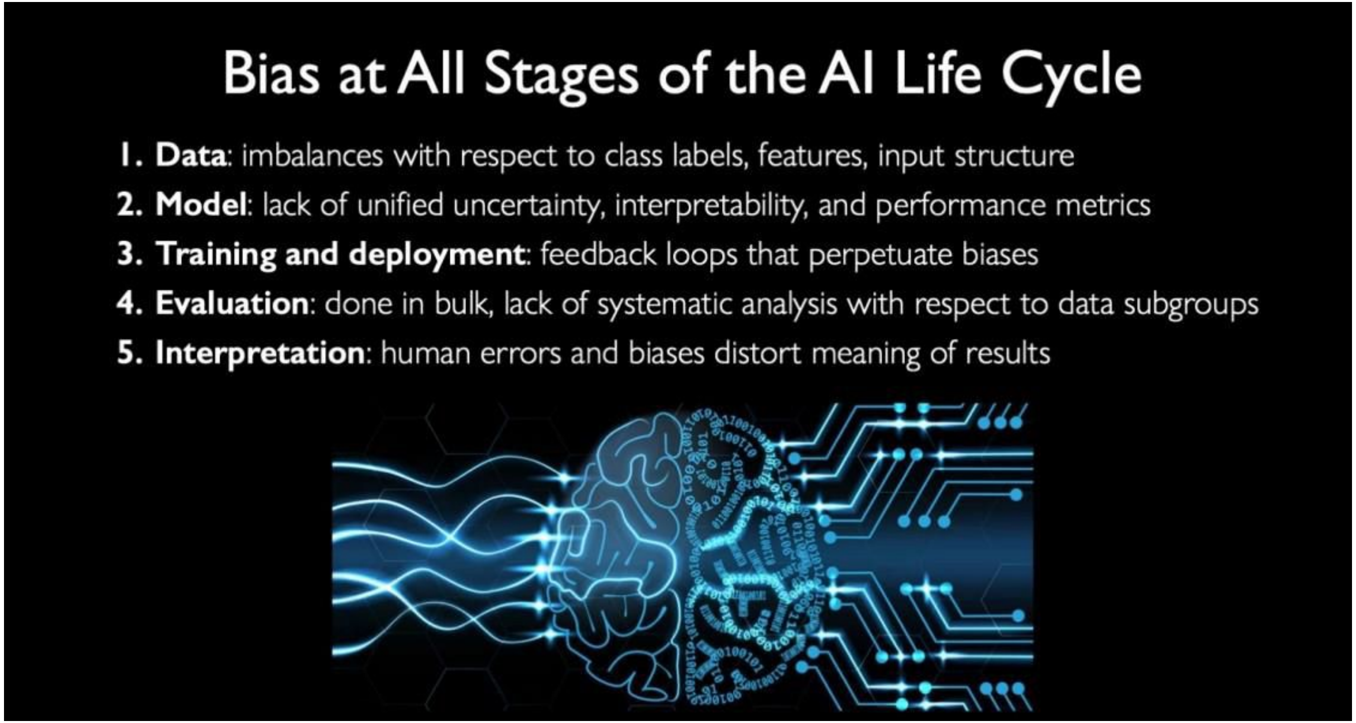
Most common cancer causes of death EU-27, both sexes, all ages, 2020

Source: ECIS: https://ecis.jrc.ec.europa.eu/, 2020 data (Accessed Nov 2022)

Gender discrimination is illegal

Gender specific medical diagnosis is desirable

Where is bias?



Bias at All Stages of the AI Life Cycle

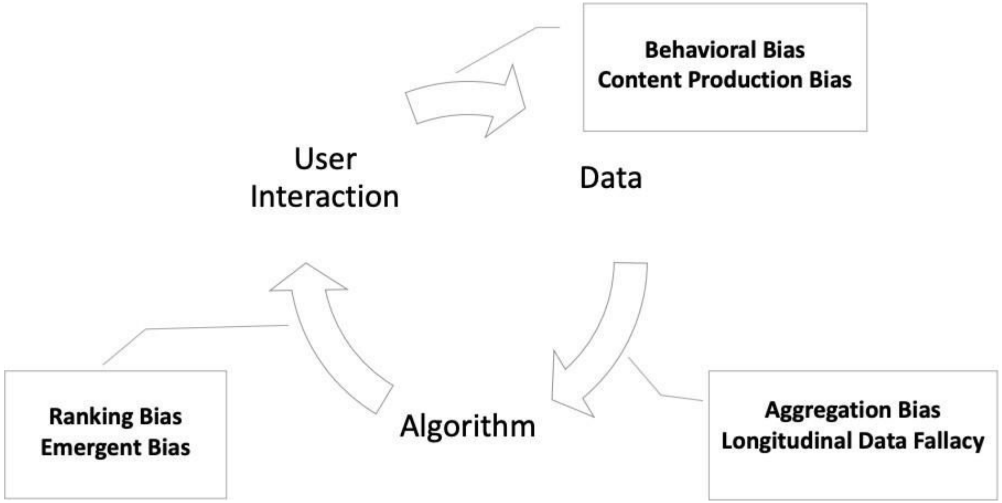
1. **Data**: imbalances with respect to class labels, features, input structure
2. **Model**: lack of unified uncertainty, interpretability, and performance metrics
3. **Training and deployment**: feedback loops that perpetuate biases
4. **Evaluation**: done in bulk, lack of systematic analysis with respect to data subgroups
5. **Interpretation**: human errors and biases distort meaning of results

Slidefrom:©AlexanderAminiandAvaSoleimany

MIT6.S191:IntroductiontoDeepLearning,IntroToDeepLearning.com

There are many different types of bias

Sources of bias



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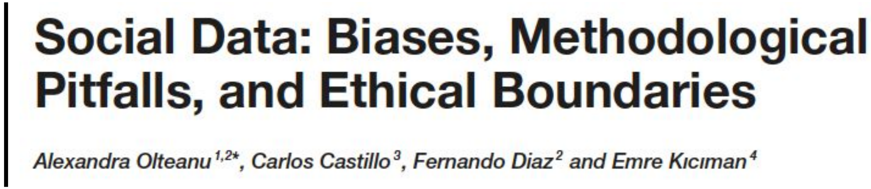
Taxonomy of bias

Systematic distortions along different data properties:

1. Population biases
2. Behavioral biases
3. Content production biases
4. Linking biases
5. Temporal biases



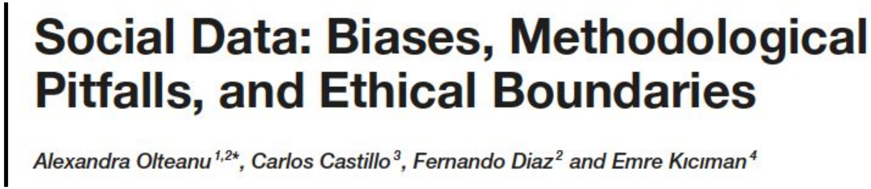
Social Data: Biases, Methodological Pitfalls, and Ethical Boundaries

Alexandra Olteanu[1,2], Carlos Castillo[3], Fernando Diaz[2] and Emre Kıcıman[4]*

Taxonomy of bias

1. **Population biases**
2. Behavioral biases
3. Content production biases
4. Linking biases
5. Temporal biases

Differences in demographics or other user characteristics between a user population represented in a dataset or platform and a target population



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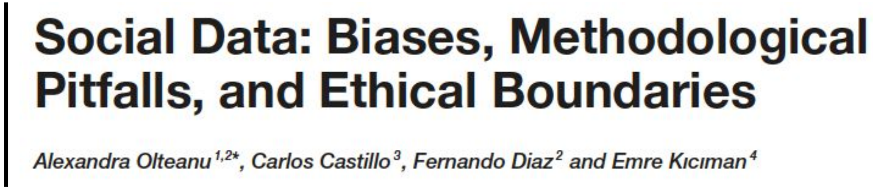
Differences in user behaviour across platforms or contexts, or across users represented in different datasets



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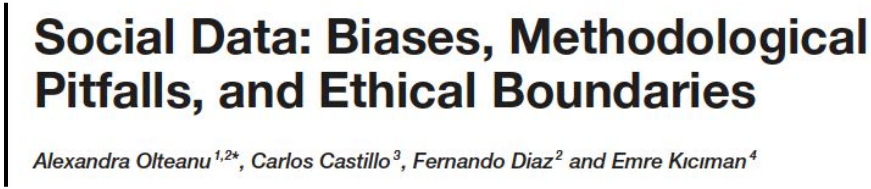
3. **Content production biases**
4. Linking biases
5. Temporal biases

Lexical, syntactic, semantic, and structural differences in the contents generated by users



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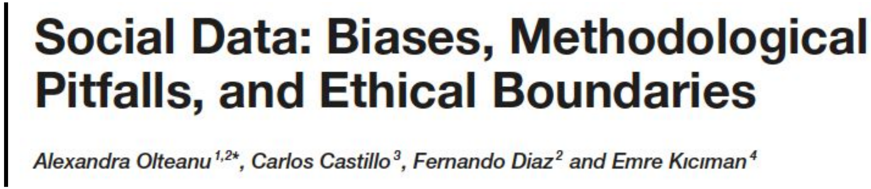
4. **Linking biases**
5. Temporal biases

Differences in the attributes of networks obtained from user connections, interactions and activity



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3. Content production biases
4. Linking biases
5. **Temporal biases**

Differences in populations and behaviours over time

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Alexandra Olteanu [1,2], Carlos Castillo [3], Fernando Diaz [2] and Emre Kıcıman [4]*

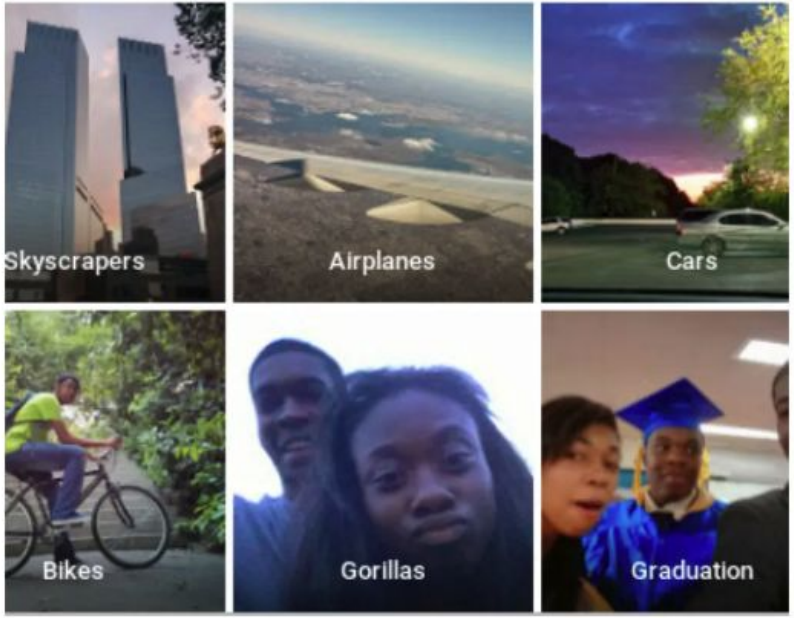
How can we handle biases?

Unfortunately

There is no standard approach or formula to debiasing algorithms and data

Let's start with some examples

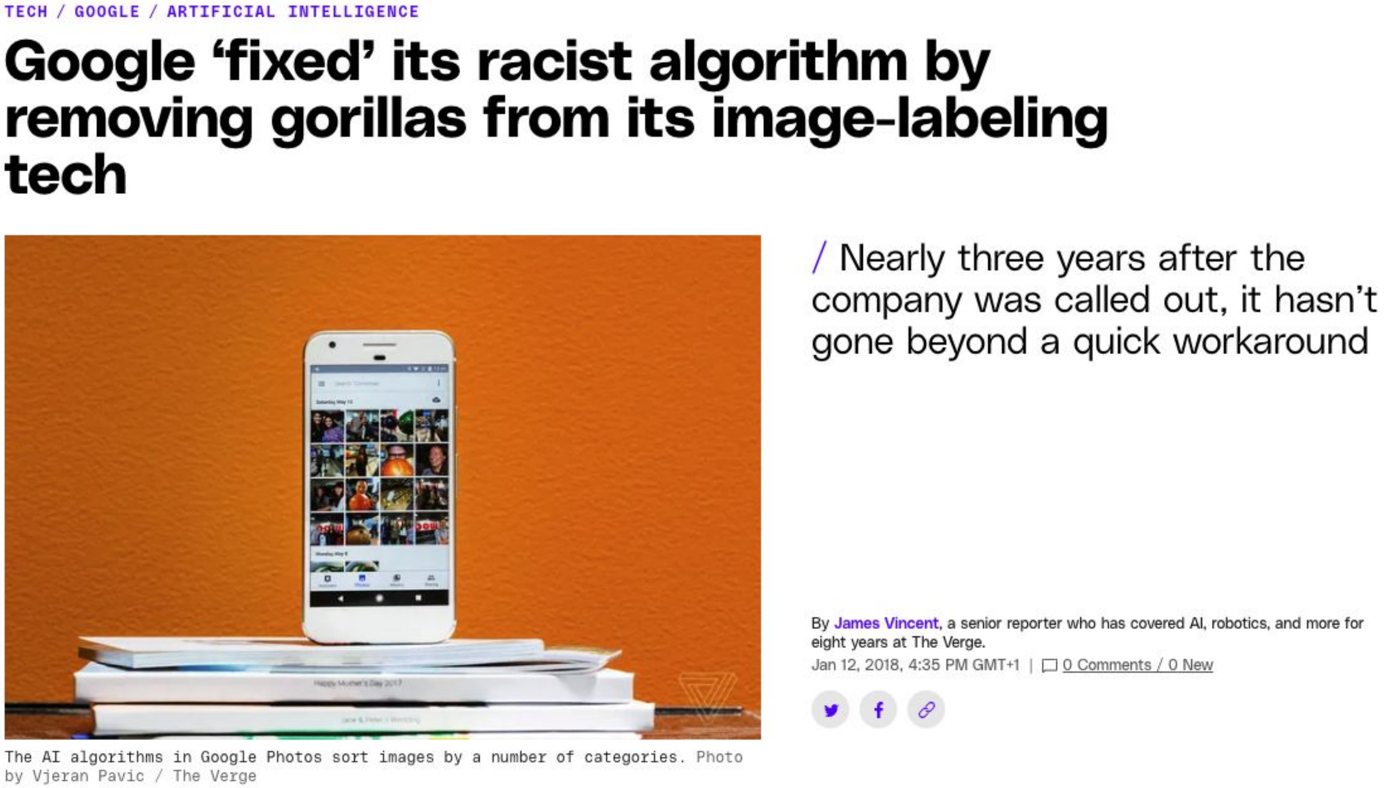
Google Photos



Bias:
People with dark skin were labeledas *gorillas*

In 2015 Google Photos auto labels images uploaded to its site

Google Photos



TECH / GOOGLE / ARTIFICIAL INTELLIGENCE

Google 'fixed' its racist algorithm by removing gorillas from its image-labeling tech

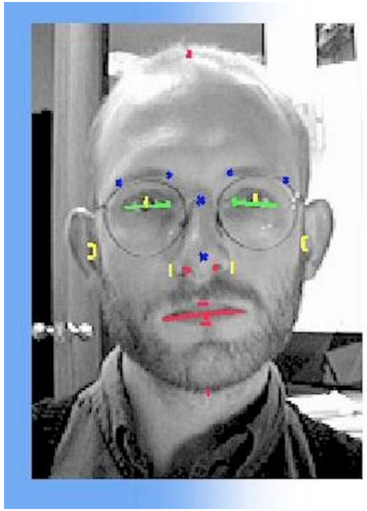
/ Nearly three years after the company was called out, it hasn't gone beyond a quick workaround

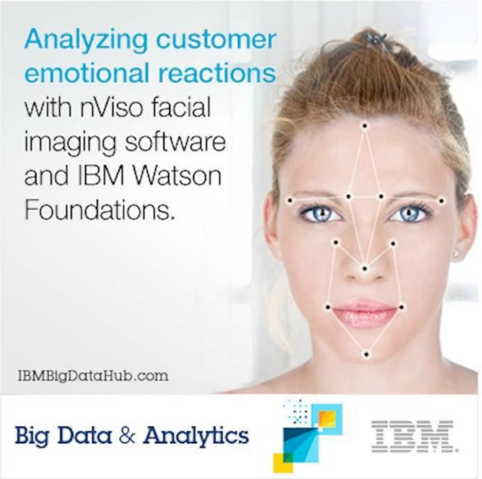
By James Vincent, a senior reporter who has covered AI, robotics, and more for eight years at The Verge.

Jan 12, 2018, 4:35 PM GMT+1 | 0 Comments / 0 New

The AI algorithms in Google Photos sort images by a number of categories. Photo by Vjeran Pavic / The Verge

IBM Facial Recognition





Analyzing customer emotional reactions with nViso facial imaging software and IBM Watson Foundations.

IBMBigDataHub.com

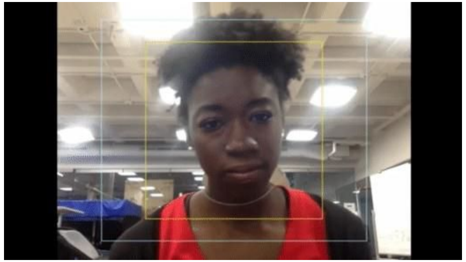
Big Data & Analytics

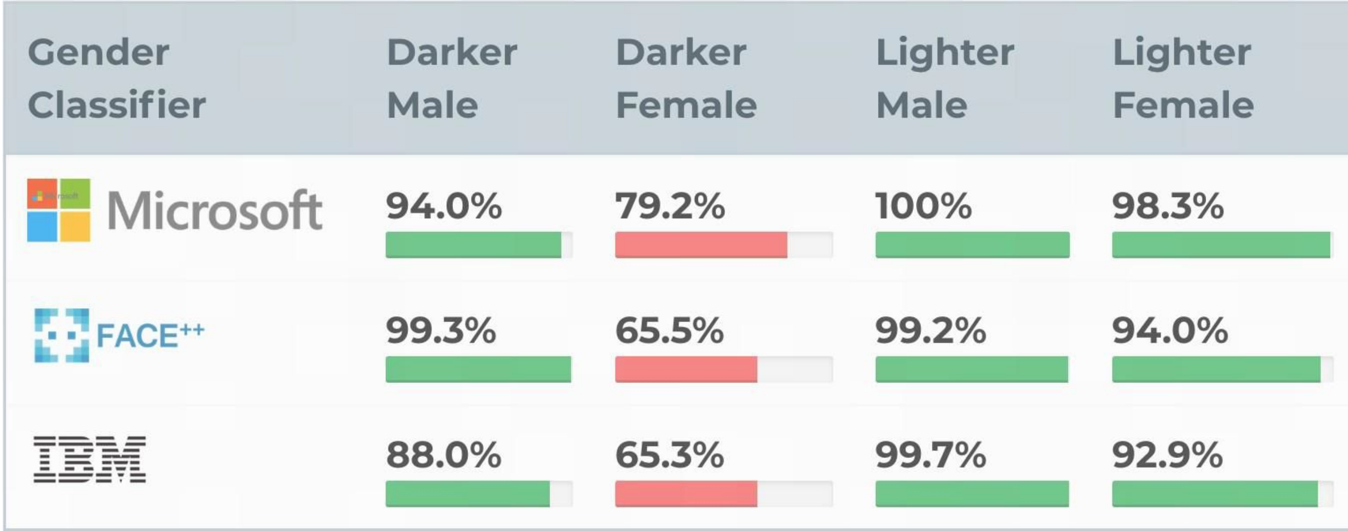
IBM

In 2018 IBM sells software that detects faces and emotional reactions

Crawford, Kate. The atlas of AI: Power, politics, and the planetary costs of artificial intelligence. Yale University Press, 2021.

IBM Facial Recognition



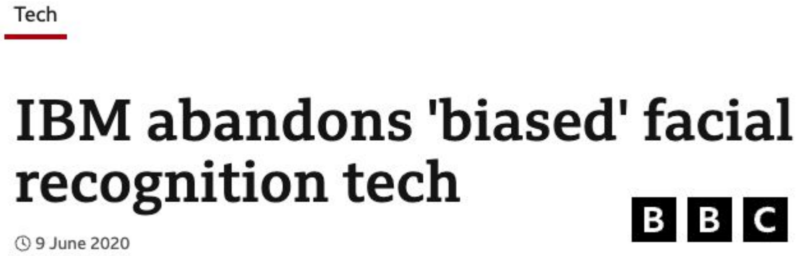


Gender Classifier	Darker Male	Darker Female	Lighter Male	Lighter Female
Microsoft	94.0%	79.2%	100%	98.3%
FACE++	99.3%	65.5%	99.2%	94.0%
IBM	88.0%	65.3%	99.7%	92.9%

Bias:

Joy Buolamwiniet al. found that the software does not work equally well for all

IBM Facial Recognition



Tech

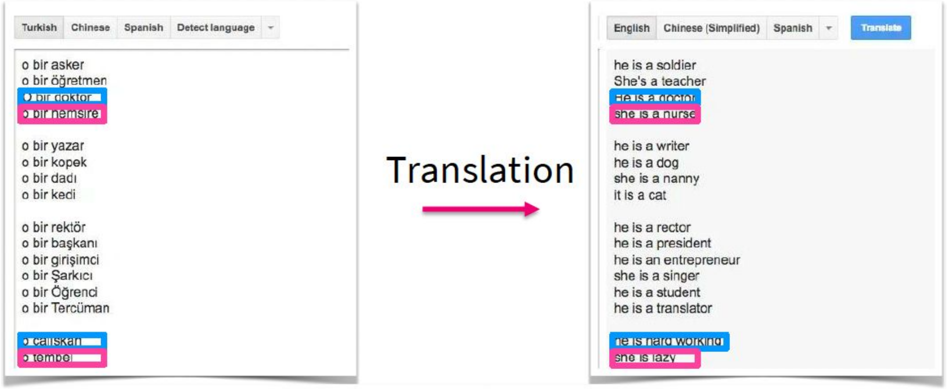
IBM abandons 'biased' facial recognition tech

9 June 2020

BBC

IBM added more pictures of the minority classes (2018) & in 2020 decided to stop providing general purpose facial recognition technologies

Google Translate



o bir asker
o bir öğretmen
o bir doktor
o bir hemsire

o bir yazar
o bir kopek
o bir dadı
o bir kedi

o bir rektör
o bir başkanı
o bir girişimci
o bir Şarkıcı
o bir Öğrenci
o bir Tercüman

o caliskan
o tembel

he is a soldier
She's a teacher
He is a doctor
she is a nurse

he is a writer
he is a dog
she is a nanny
it is a cat

he is a rector
he is a president
he is an entrepreneur
she is a singer
he is a student
he is a translator

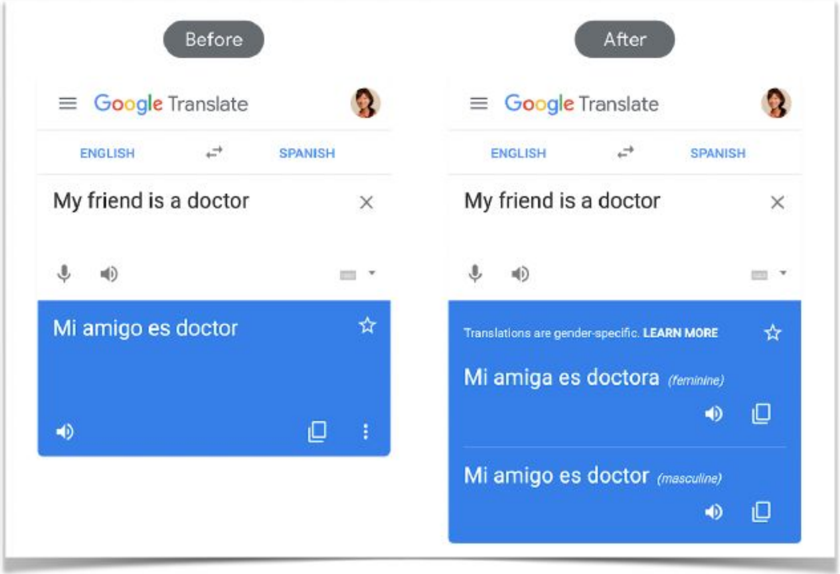
he is hard working
she is lazy

Google translate (2018) uses ML to translate from one language to others

Bias:

Reproduces gender and other stereotypes in a translated text

Google Translate



My friend is a doctor

Mi amigo es doctor

My friend is a doctor

Translations are gender-specific. LEARN MORE

Mi amiga es doctora *(feminine)*

Mi amigo es doctor *(masculine)*

Built ML model to detect "gendered" translations and if thinks something is gendered it is hardcoded it to return multiple options

https://ai.googleblog.com/2020/04/a-scalable-approach-to-reducing-gender.html

Unfortunately

There is no standard approach or formula to debiasing algorithms and data

Google Photos

Fixed by removing gorilla class

IBM

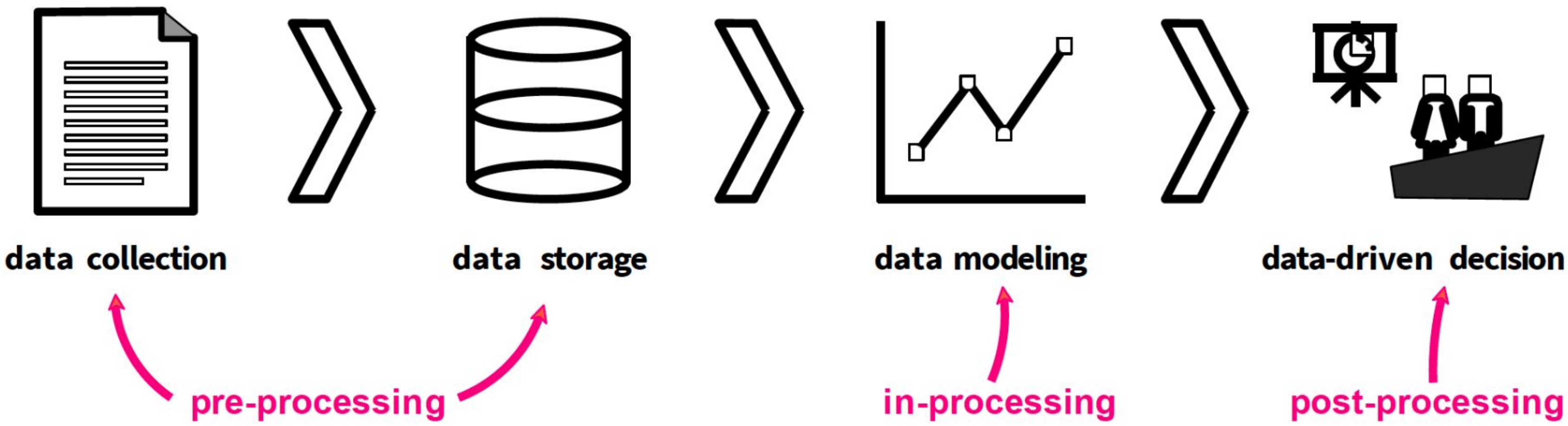
Fixed by adding more examples for unrepresented class

Google Translate

Added ML models & hardcoded response

Handling bias

Bias can be fixed at different places in the data chain



data collection

data storage

data modeling

data-driven decision

pre-processing

in-processing

post-processing

Handling bias

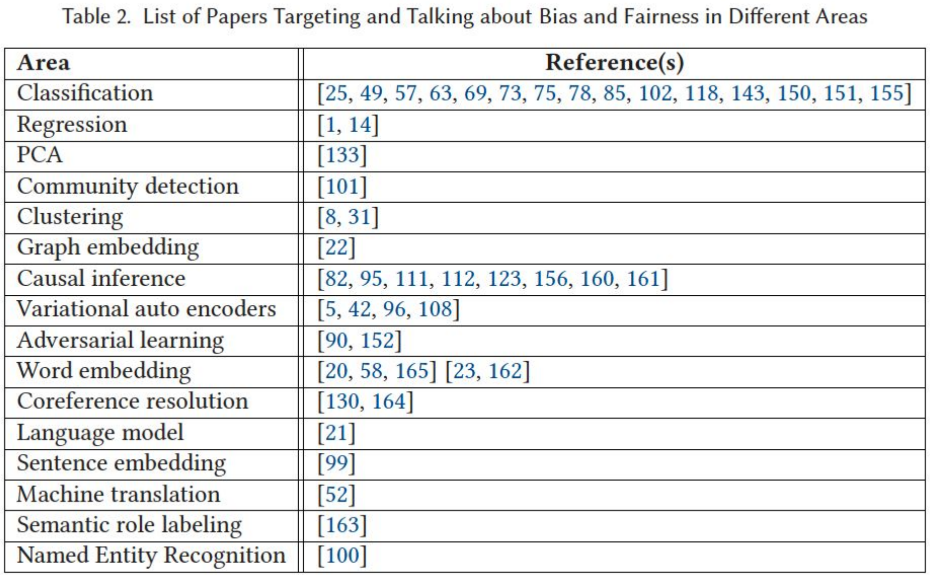
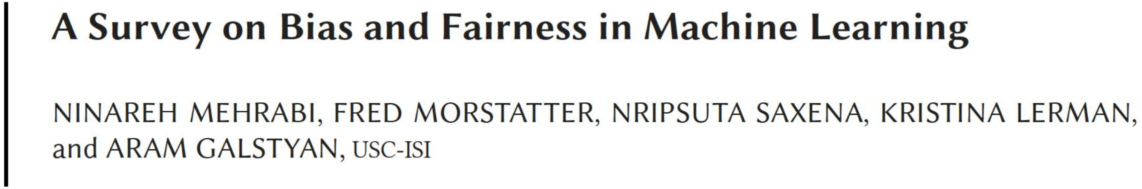


Table 2. List of Papers Targeting and Talking about Bias and Fairness in Different Areas

Area	Reference(s)
Classification	[25, 49, 57, 63, 69, 73, 75, 78, 85, 102, 118, 143, 150, 151, 155]
Regression	[1, 14]
PCA	[133]
Community detection	[101]
Clustering	[8, 31]
Graph embedding	[22]
Causal inference	[82, 95, 111, 112, 123, 156, 160, 161]
Variational auto encoders	[5, 42, 96, 108]
Adversarial learning	[90, 152]
Word embedding	[20, 58, 165] [23, 162]
Coreference resolution	[130, 164]
Language model	[21]
Sentence embedding	[99]
Machine translation	[52]
Semantic role labeling	[163]
Named Entity Recognition	[100]



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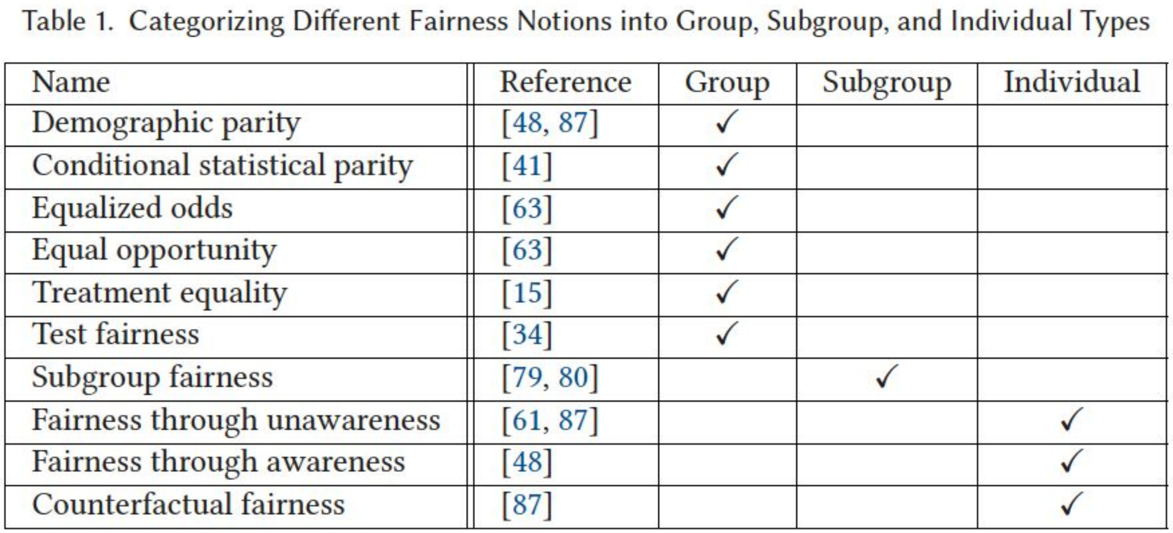
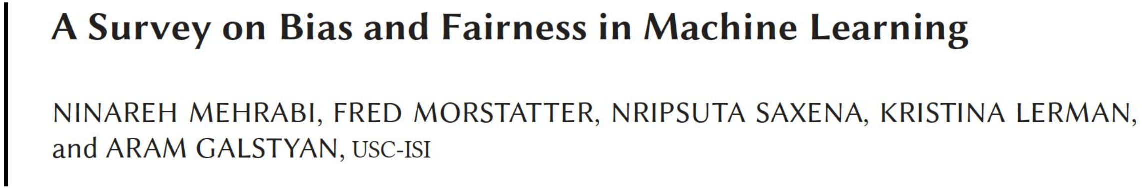


Table 1. Categorizing Different Fairness Notions into Group, Subgroup, and Individual Types

Name	Reference	Group	Subgroup	Individual
Demographic parity	[48, 87]	✓		
Conditional statistical parity	[41]	✓		
Equalized odds	[63]	✓		
Equal opportunity	[63]	✓		
Treatment equality	[15]	✓		
Test fairness	[34]	✓		
Subgroup fairness	[79, 80]		✓	
Fairness through unawareness	[61, 87]			✓
Fairness through awareness	[48]			✓
Counterfactual fairness	[87]			✓

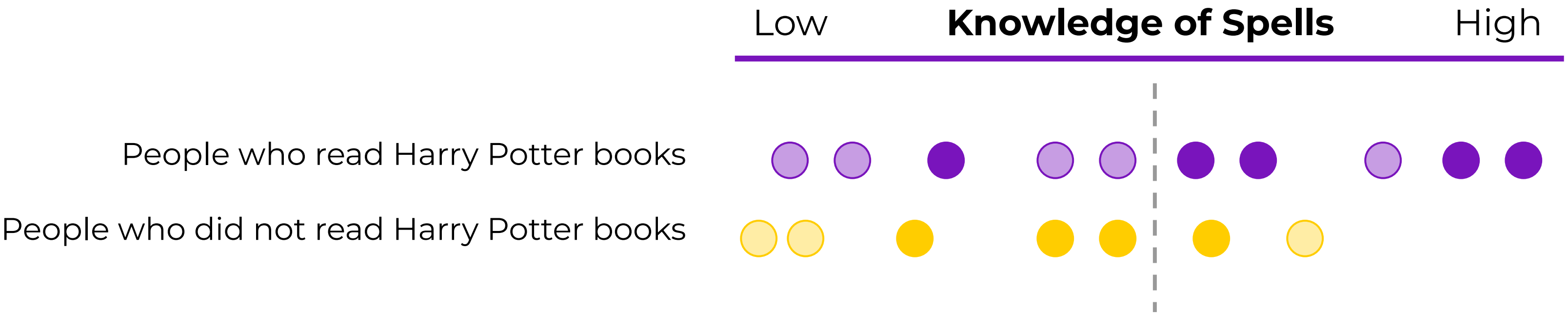


A Survey on Bias and Fairness in Machine Learning

NINAREH MEHRABI, FRED MORSTATTER, NRIPSUTA SAXENA, KRISTINA LERMAN, and ARAM GALSTYAN, USC-ISI

Demographic parity

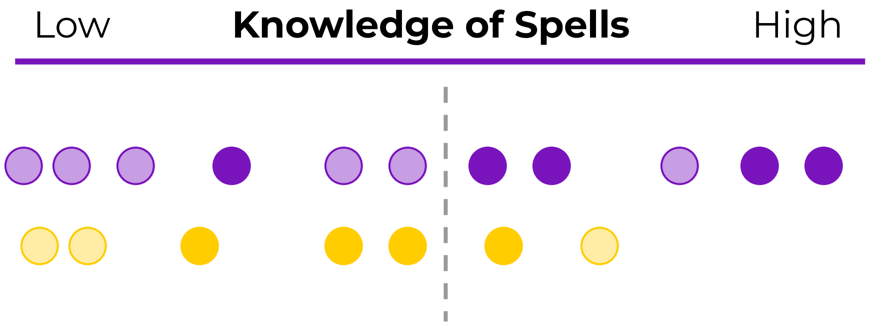
Admission to the Wizarding School



Low
Knowledge of Spells
High
People who read Harry Potter books
People who did not read Harry Potter books

People indicated by full colors (● and ●) will eventually become **Great Wizards**
We set a threshold for the admission (grey line)

Demographic parity



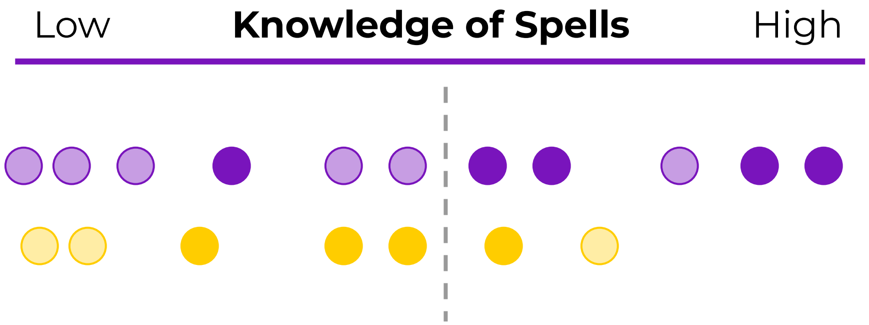
Number of applicants: 18
Number of purples: 11
Number of yellows: 7

$$P(\text{Acceptance}) = \frac{\text{N. accepted}}{\text{Tot. applicants}} = 7/18 = 39\%$$

$$P(\text{Acceptance if purple}) = \frac{\text{N. accepted purple}}{\text{Tot. purple}} = 5/11 = 45\%$$

$$P(\text{Acceptance if yellow}) = \frac{\text{N. accepted yellow}}{\text{Tot. yellow}} = 2/7 = 29\%$$

Demographic parity



Number of applicants: 18
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P(Acceptance if purple) = P(Acceptance if yellow)

Demographic parity

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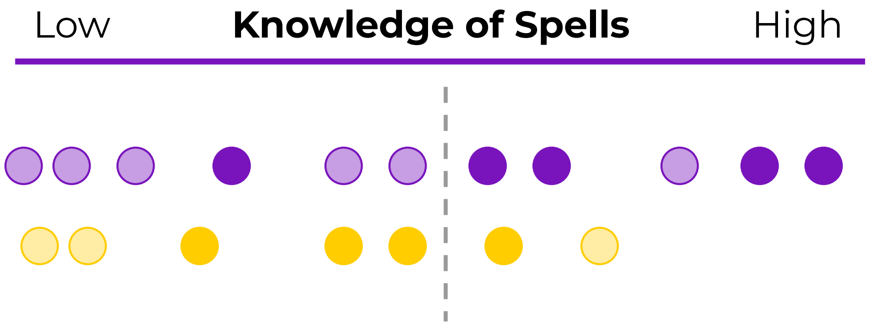

P(Acceptance if purple) = P(Acceptance if yellow)

Two options:

1. Admit less purple

$$P_{flip} = 1 - \frac{\text{P(Acceptance if yellow)}}{\text{P(Acceptance if purple)}} = 1 - 29/45 \approx 0.64$$

2. Admit more yellow

$$P_{flip} = \frac{\text{P(Acceptance if yellow)}}{\text{P(Acceptance if purple)}} = 29/45 \approx 0.36$$

Let's put it into practice!

In groups:

1. Go over the GitHub page (**https://github.com/AnnaSapienza/CSS_SummerSchool/tree/main**)
2. Try to solve the exercises
3. Discuss with your peers