CS 4530
Fundamentals of Software Engineering

Module 18: Engineering Software for Equity

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Khoury College of Computer Sciences

Learning Goals

By the end of this lesson, you should be able to…

- Illustrate how software can cause inadvertent harm or amplify inequities
- Explain the role of software engineers in avoiding such harms

Equity and Software

As new as software engineering is,

we're newer still at understanding its impact on underrepresented people and diverse societies

We must recognize imbalance of power between those who make development decisions that impact the world

and those who simply must accept and live with those decisions that sometimes disadvantage already marginalized communities globally

Quote: "Software Engineering at Google: Lessons Learned from Programming Over Time," Wright et al, 2020 (O'Reilly)

Recognize inequities in your software

One mark of an exceptional engineer is the ability to understand how products can advantage and disadvantage different groups of human beings

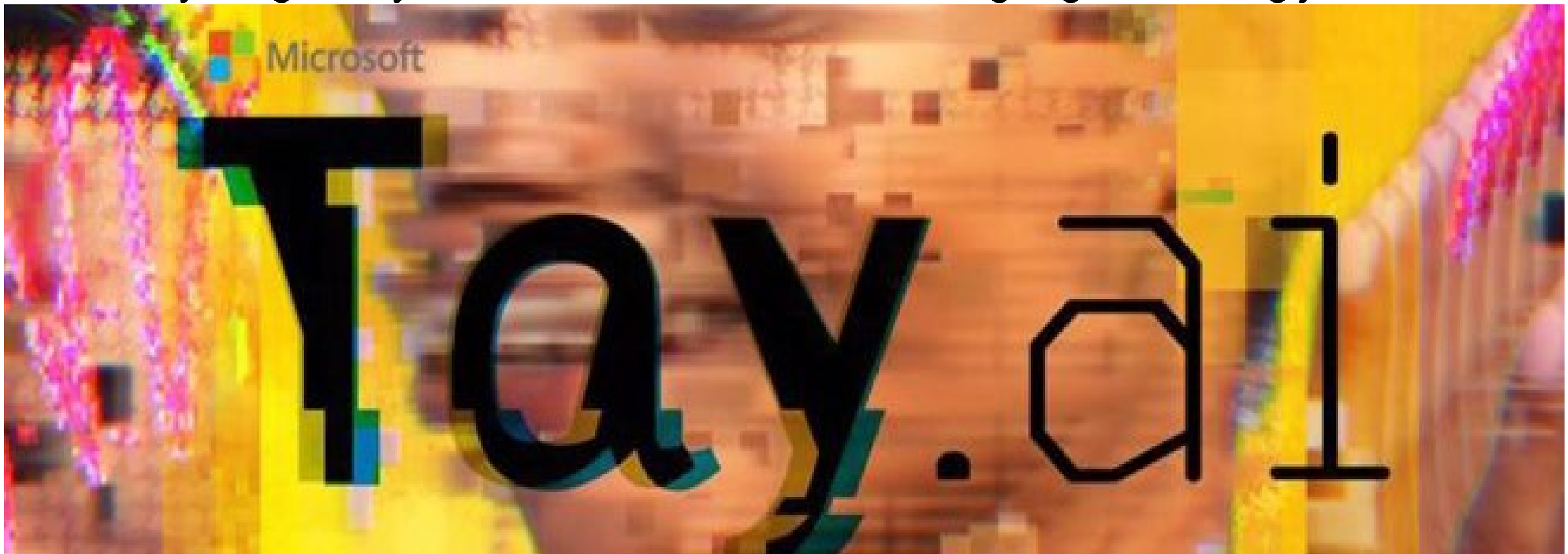
Engineers are expected to have technical aptitude, but they should also have the discernment to know when to build something and when not to

Demma Rodriguez
Head of Equity Engineering
Google

Quote: “Software Engineering at Google: Lessons Learned from Programming Over Time,” Wright et al, 2020 (O’Reilly)

Recognize inequities in your software

- Good engineers understand how products can be weaponized to create harms in certain groups
- Microsoft failed with a chatbot that picked up the behavior people used…
- …they taught Tay to use offensive and racist language attacking jews



Recognize inequities in your software

- Good engineers understand how products can be weaponized…
- Amazon failed with their AI hiring software…
- …it used 10 years of resumes to learn who should be hired
- …it learned to automatically reject the resumes of women

Algorithmic sentencing discriminates

The COMPAS sentencing tool discriminates against black defendants

	ALL	**WHITE** DEFENDANTS	**BLACK** DEFENDANTS
Labeled **High Risk**, But **Didn't** Re-Offend	**32%**	**23%**	**44%**
Labeled **Low Risk**, Yet **Did** Re-Offend	**37%**	**47%**	**28%**

Analysis of Broward County data: "How We Analyzed the COMPAS Recidivism Algorithm" by Larson et al.

Algorithmic bias discriminates

…against the poorest of us

THE WALL STREET JOURNAL.

Websites Vary Prices, Deals Based on Users' Information

Getting Different Deals Online

A Journal examination found online retailers adjusted prices by a shopper's location, among other factors

Staples.com

SnapSafe Titan safe

Homedepot.com

A 250-foot spool of electrical wiring

Six pricing groups, including:

- **$70.80** in Ashtabula, Ohio
- **$72.45** in Erie, Pa.
- **$77.87** in Monticello, N.Y

Rosettastone.com

…for buying multiple levels of German lessons, when test-shopping from the U.S. or Canada. But not from the U.K. or Argentina.

Photos: l to r: SnapSafe; Home Depot; Rosetta Stone Source: WSJ testing The Wall Street Journal

https://www.wsj.com/articles/SB10001424127887323777204578189391813881534

FairTest: Discovering Unwarranted Associations in Data-Driven Applications*

Florian Tramèr[1], Vaggelis Atlidakis[2], Roxana Geambasu[2], Daniel Hsu[2],
Jean-Pierre Hubaux[3], Mathias Humbert[4], Ari Juels[5], Huang Lin[3]

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***Abstract*—In a world where traditional notions of privacy are increasingly challenged by the myriad companies that collect and analyze our data, it is important that decision-making entities are held accountable for unfair treatments arising from irresponsible data usage. Unfortunately, a lack of appropriate methodologies and tools means that even identifying unfair or discriminatory effects can be a challenge in practice.**

We introduce the *unwarranted associations (UA) framework*, a principled methodology for the discovery of unfair, discriminatory, or offensive user treatment in data-driven applications. The UA framework unifies and rationalizes a number of prior attempts at formalizing algorithmic fairness. It uniquely combines multiple investigative primitives and fairness metrics with broad applicability, granular exploration of unfair treatment in user subgroups, and incorporation of natural notions of utility that may account for observed disparities.

We instantiate the UA framework in *FairTest*, the first comprehensive tool that helps developers check data-driven applications for unfair user treatment. It enables scalable and statistically rigorous investigation of associations between application outcomes (such as prices or premiums) and sensitive user attributes (such as race or gender). Furthermore, FairTest provides *debugging capabilities* that let programmers rule out decision-making can have unintended and harmful consequences, such as unfair or discriminatory treatment of users.

In this paper, we deal with the latter challenge. Despite the personal and societal benefits of today's data-driven world, we argue that companies that collect and use our data have a responsibility to ensure equitable user treatment. Indeed, European and U.S. regulators, as well as various policy and legal scholars, have recently called for increased *algorithmic accountability*, and in particular for decision-making tools to be audited and "tested for fairness" [1], [2].

There have been many recent reports of unfair or discriminatory effects in data-driven applications, mostly qualified as unintended consequences of data heuristics or overlooked bugs. For example, Google's image tagger was found to associate racially offensive labels with images of black people [3]; the developers called the situation a bug and promised to remedy it as soon as possible. In another case [4], *Wall Street Journal* investigators showed that Staples' online pricing algorithm discriminated against lower-income people. They referred to the situation as an "unintended consequence" of Staples's seemingly rational decision to adjust online prices based on user proximity to competitors' stores. This led to higher prices for low-income customers, who generally live farther from these stores

Training AI systems impacts climate

The Register®

{* AI + ML *}

AI me to the Moon... Carbon footprint for 'training GPT-3' same as driving to our natural satellite and back

Get ready for Energy Star stickers on your robo-butlers, maybe?

Katyanna Quach Wed 4 Nov 2020 // 07:59 UTC SHARE

Training OpenAI's giant GPT-3 text-generating model is akin to driving a car to the Moon and back, computer scientists reckon.

More specifically, they estimated teaching the neural super-network in a Microsoft data center using Nvidia GPUs required roughly 190,000 kWh, which using the average carbon intensity of America would have produced 85,000 kg of CO_2 equivalents, the same amount produced by a new car in Europe driving 700,000 km, or 435,000 miles, which is about twice the distance between Earth and the Moon, some 480,000 miles. Phew.

https://www.theregister.com/2020/11/04/gpt3_carbon_footprint_estimate/

Consumption	CO_2e (lbs)
Air travel, 1 passenger, NY↔SF	1984
Human life, avg, 1 year	11,023
American life, avg, 1 year	36,156
Car, avg incl. fuel, 1 lifetime	126,000

Training one model (GPU)	
NLP pipeline (parsing, SRL)	39
w/ tuning & experimentation	78,468
Transformer (big)	192
w/ neural architecture search	626,155

"Energy and Policy Considerations for Deep Learning in NLP" by Strubell et al in ACL19

UIs discriminate against differently-abled

Inclusivity and Accessibility: Domino's Pizza LLC v. Robles

Domino's Would Rather Go to the Supreme Court Than Make Its Website Accessible to the Blind

Rather than developing technology to support users with disabilities, the pizza chain is taking its fight to the top

by Brenna Houck | @EaterDetroit | Jul 25, 2019, 6:00pm EDT

SHARE

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Jul 15 2019	**Brief amicus curiae of Washington Legal Foundation filed.**
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Software evades regulation

Example: Volkswagen diesel emissions

The Emissions Tests That Led to the Discovery of VW's Cheating

The on-road testing in May 2014 that led the California Air Resources Board to investigate Volkswagen was conducted by researchers at West Virginia University. They tested emissions from two VW models equipped with the 2-liter turbocharged 4-cylinder diesel engine. The researchers found th… …en tested on the road, some cars emitted almost **40 times** the permitted l… …rogen oxides.

Average emissions of nitrogen ox… …-road testing

GRA… …EN OXIDES PER KILOMETER

0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0 1.1 1.2 1.3 1.4 1.5

2011 Volkswagen Jetta

- H… — **15 times limit**
- URBAN (LO…) — **25 times**
- URBAN (SA… DIEGO) — **37 times**
- RURAL (UP AND DOWNHILL) — **38 times**

2012 Volkswagen Passat

- HIGHWAY — **9 times limit**
- URBAN (LOS ANGELES) — **20 times**
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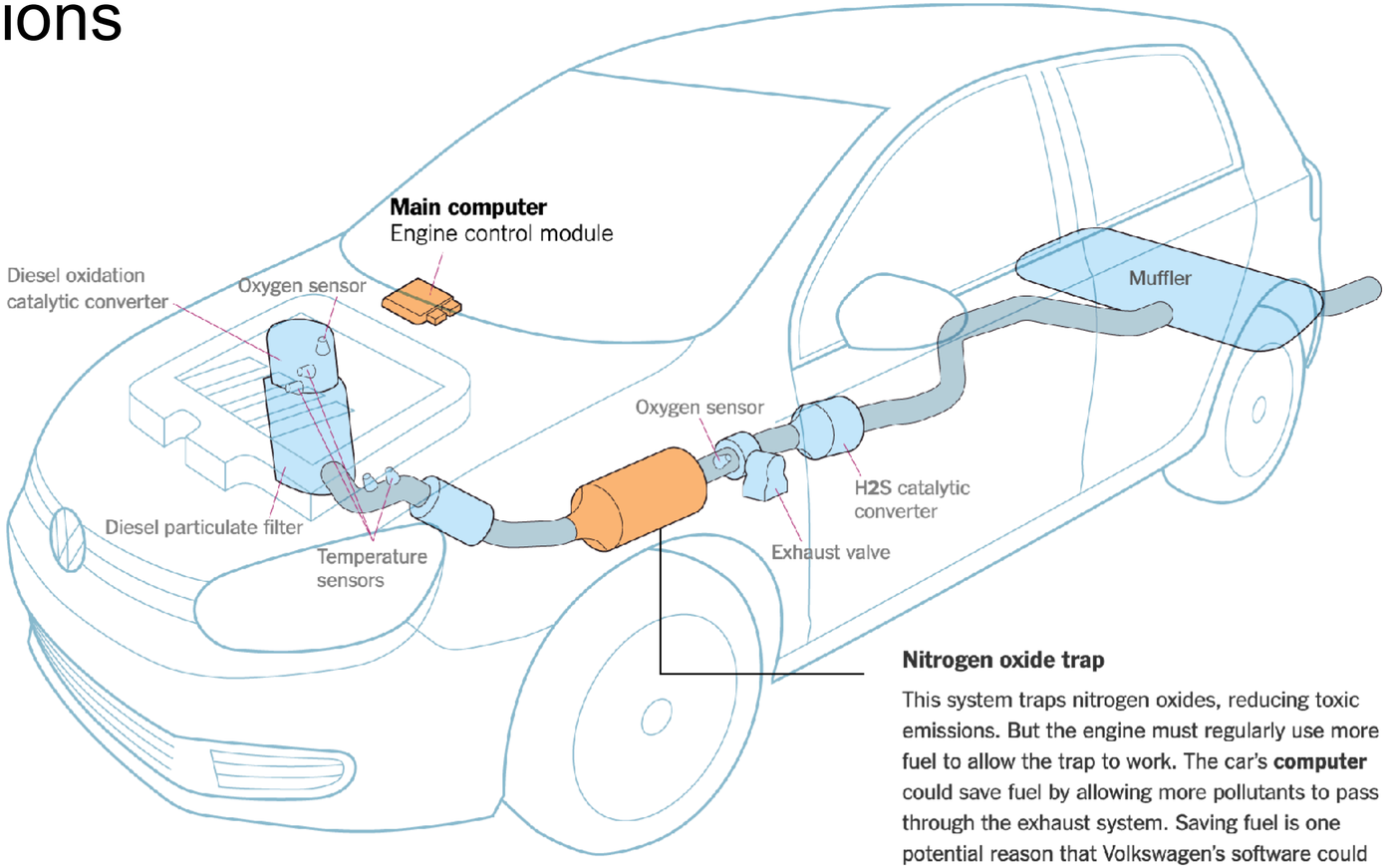
U.S. limit

$14.7 billion settlement



Nitrogen oxide trap

This system traps nitrogen oxides, reducing toxic emissions. But the engine must regularly use more fuel to allow the trap to work. The car's **computer** could save fuel by allowing more pollutants to pass through the exhaust system. Saving fuel is one potential reason that Volkswagen's software could have been altered to make cars pollute more, according to researchers at the International Council on Clean Transportation.

Illustration by Guilbert Gates | Source: Volkswagen, The International Council on Clean Transportation

[“How Volkswagen's ‘Defeat Devices’ Worked” By Guilbert Gates, Jack Ewing, Karl Russell and Derek Watkins]

Bias is the Default

Example: Google Photos auto-tagging

THE WALL STREET JOURNAL.

DIGITS

Google Mistakenly Tags Black People as 'Gorillas,' Showing Limits of Algorithms

By Alistair Barr

Updated July 1, 2015 3:41 pm ET

SHARE TEXT

Google is a leader in artificial intelligence and machine learning. But the company's computers still have a lot to learn, judging by a major blunder by its Photos app this week.

The app tagged two black people as "Gorillas," according to Jacky Alciné, a Web developer who spotted the error and tweeted a photo of it.

"Google Photos, y'all f**ked up. My friend's not a gorilla," he wrote on Twitter.

https://www.wsj.com/articles/BL-DGB-42522

WIRED BACKCHANNEL BUSINESS CULTURE GEAR IDEAS MORE SIGN IN

TOM SIMONITE BUSINESS 01.11.2018 07:00 AM

When It Comes to Gorillas, Google Photos Remains Blind

Google promised a fix after its photo-categorization software labeled black people as gorillas in 2015. More than two years later, it hasn't found one.

In WIRED's tests, Google Photos did identify some primates, but no gorillas like this one were to be found. RICK MADONIK/TORONTO STAR/GETTY IMAGES

https://www.wired.com/story/when-it-comes-to-gorillas-google-photos-remains-blind/

Reflecting on these examples

Personal philosophies and business cases

Algorithmic Bias: COMPAS Sentencing Tool

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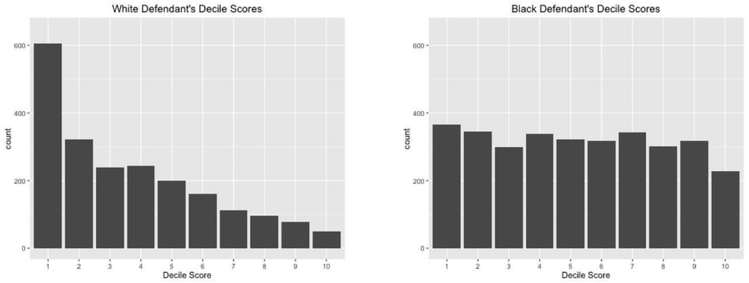

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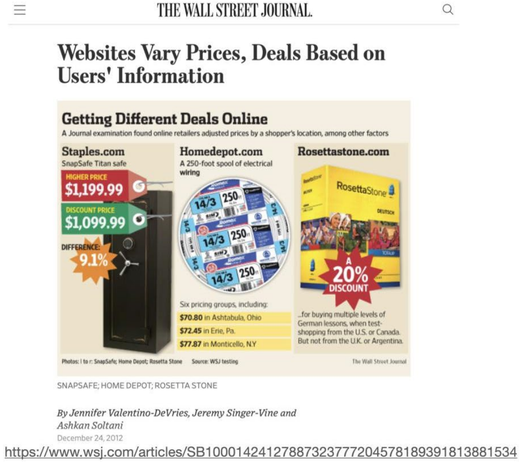
Algorithmic Bias: Price Discrimination



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Photos: (to r: SnapSafe; Home Depot; Rosetta Stone Source: WSJ testing The Wall Street Journal

SNAPSAFE; HOME DEPOT; ROSETTA STONE

By Jennifer Valentino-DeVries, Jeremy Singer-Vine and Ashkan Soltani
December 24, 2012

https://www.wsj.com/articles/SB10001424127887323777204578189391813881534

2017 IEEE European Symposium on Security and Privacy

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We report on use of FairTest to investigate and in some cases address disparate impact, offensive labeling, and uneven rates of algorithmic error in four data-driven applications. As examples, our results reveal subtle biases against older populations in the distribution of error in a predictive health application and offensive racial labeling in an image tagger.

1. Introduction

Today's applications collect and mine vast quantities of personal information. Such data can boost applications' utility by personalizing content and recommendations, increase business revenue via targeted product placement, and improve a wide range of socially beneficial services, such as healthcare, disaster response, and crime prevention.

The collection and use of such data raise two important challenges. First, massive data collection is perceived by many as a major threat to traditional notions of individual privacy. Second, the use of personal data for algorithmic decision-making can have unintended and harmful consequences, such as unfair or discriminatory treatment of users.

In this paper, we deal with the latter challenge. Despite the personal and societal benefits of today's data-driven world, we argue that companies that collect and use our data have a responsibility to ensure equitable user treatment. Indeed, European and U.S. regulators, as well as various policy and legal scholars, have recently called for increased *algorithmic accountability*, and in particular for decision-making tools to be audited and "tested for fairness" [1], [2].

There have been many recent reports of unfair or discriminatory effects in data-driven applications, mostly qualified as unintended consequences of data heuristics or overlooked bugs. For example, Google's image tagger was found to associate racially offensive labels with images of black people [3]; the developers called the situation a bug and promised to remedy it as soon as possible. In another case [4], *Wall Street Journal* investigators showed that Staples' online pricing algorithm discriminated against lower-income people. They referred to the situation as an "unintended consequence" of Staples's seemingly rational decision to adjust online prices based on user proximity to competitors' stores. This led to higher prices for low-income customers, who generally live farther from these stores.

Staples' intentions aside, it is evidently difficult for programmers to foresee all the subtle implications and risks of data-driven heuristics. Moreover, these risks will only increase as data is passed through increasingly complex machine learning (ML) algorithms whose associations and inferences may be impossible to anticipate.

We argue that such algorithmic biases are new kinds of *bugs*, specific to modern, data-driven applications, that programmers should proactively check for, debug, and fix with the same rigor as they apply to other security and privacy bugs. Such bugs can offend and even harm users, and cause programmers and businesses embarrassment, mistrust, and potentially loss of revenue. They may also be symptoms of a malfunction of a data-driven algorithm, such as a ML algorithm exhibiting poor accuracy for minority groups that are underrepresented in its training set [5].

We refer to such bugs generically as *unwarranted associations*. Understanding and identifying unwarranted associations is an important step towards holding automated decision-making entities *accountable* for unfair practices, thus also providing incentive for the adoption of corrective measures [1], [2], [6], [7].

The Unwarranted Associations Framework. In order to

* *Work done while the first author was at EPFL.*

DOI 10.1109/EuroSP.2017.29

Inclusivity and Accessibility: Domino's Pizza LLC v. Robles

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Evading regulation: Volkswagen

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Average emissions of nitrogen oxides in on-road testing

GRAMS OF NITROGEN OXIDES PER KILOMETER

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Jetta
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2012 Volkswagen Passat
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U.S. limit
.04 grams/kilometer

$14.7 billion settlement

Source: Arvind Thiruvengadam, Center for Alternative Fuels, Engines and Emissions at West Virginia University

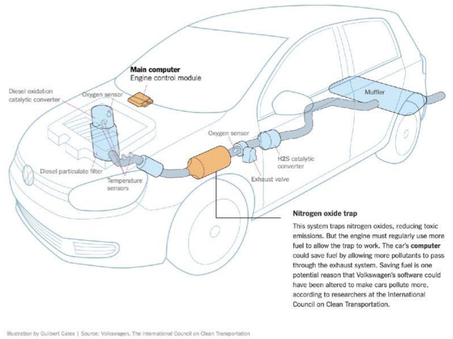


Illustration by Guilbert Gates | Source: Volkswagen, The International Council on Clean Transportation

"How Volkswagen's 'Defeat Devices' Worked" By Guilbert Gates, Jack Ewing, Karl Russell and Derek Watkins

More than *don't be evil*

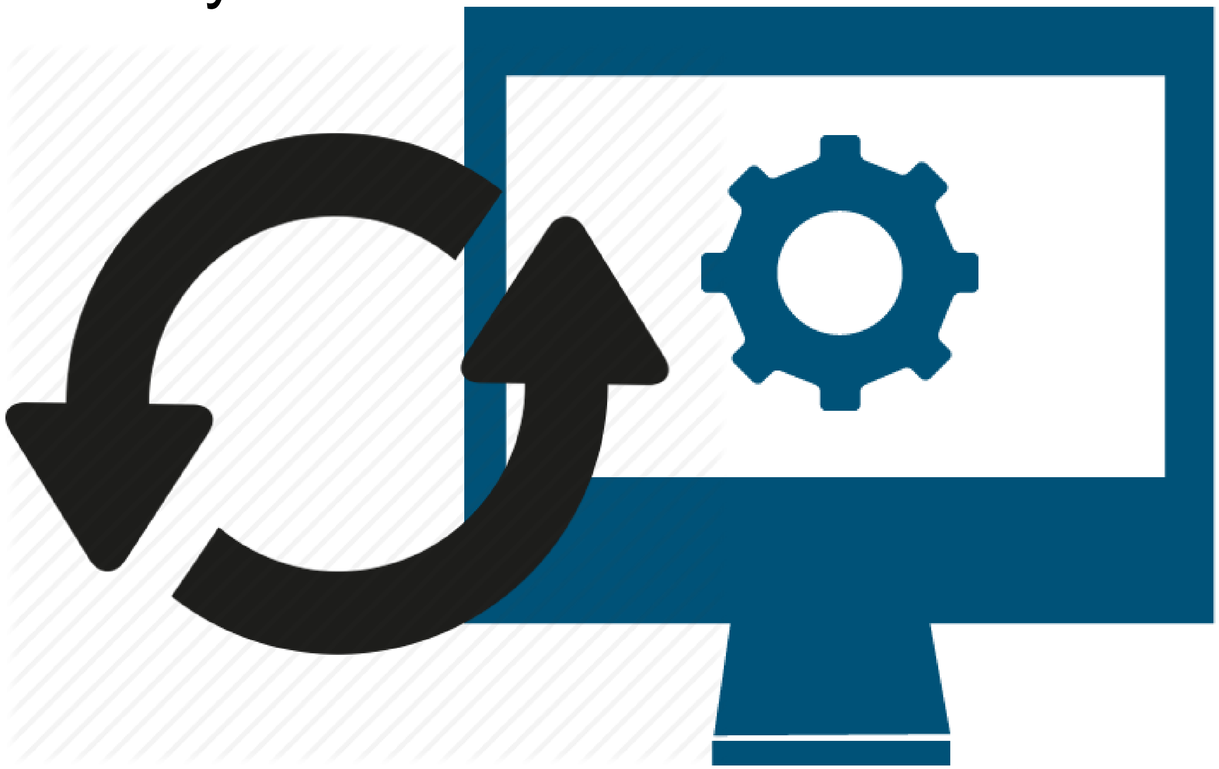
Engineering equitable software requires conscious effort

- How do we determine what "the right thing" is?
- How do we convince our investors/managers to take this action?

How to mitigate harms in software?

What are you trying to solve?

- For every software you create, include a wide range of people to use it
- Including more people helps detect biases and harms
- Iterate your software throughout its entire life cycle.



How to write software for people that mitigates harm

Microsoft

https://www.microsoft.com/en-us/research/uploads/prod/2020/03/Guidelines_summary_image@2x.png

1

INITIALLY

Make clear what the system can do

Help the users understand what the AI system is capable of doing.

2

INITIALLY

Make clear how well the system can do what it can do.

Help the user understand how often the AI system may make mistakes.

INITIALLY

Microsoft

3
DURING INTERACTION

Time services based on context.

Time when to act or interrupt based on the user's current task and environment.

4
DURING INTERACTION

Show contextually relevant information.

Display information relevant to the users' current task and environment.

5
DURING INTERACTION

Match relevant social norms.

Ensure the experience is delivered in a way that users would expect, given their social and cultural context.

6
DURING INTERACTION

Mitigate social biases.

Ensure the AI system's language and behaviors do not reinforce undesirable and unfair stereotypes and biases.

DURING INTERACTION

Microsoft

7
WHEN WRONG

Support efficient invocation.

Make it easy to invoke or request the AI system's services when needed.

8
WHEN WRONG

Support efficient dismissal.

Make it easy to dismiss or ignore undesired system services.

9
WHEN WRONG

Support efficient correction.

Make it easy to edit, refine, or recover when the AI system is wrong.

10
WHEN WRONG

Scope services when in doubt.

Engage in disambiguation or gracefully degrade the AI system's services when uncertain about a user's goals.

11
WHEN WRONG

Make clear why the system did what it did.

Enable the user to access an explanation of why the AI system behaved as it did.

⚠ WHEN WRONG

Microsoft

12
OVER TIME

Remember recent interactions.

Maintain short-term memory and allow the user to make efficient references to that memory.

13
OVER TIME

Learn from user behavior.

Personalize the user's experience by learning from their actions over time.

14
OVER TIME

Update and adapt cautiously.

Limit disruptive changes when updating and adapting the AI system's behaviors.

15
OVER TIME

Encourage granular feedback.

Enable the user to provide feedback indicating their preferences during regular interaction with the AI system.

16
OVER TIME

Convey the consequences of user actions.

Immediately update or convey how user actions will impact future behaviors of the AI system.

OVER TIME

17
OVER TIME

Provide global controls.

Allow the user to globally customize what the AI system monitors and how it behaves.

18
OVER TIME

Notify users about changes.

Inform the user when the AI system adds or updates its capabilities.

Learning Goals

You should now be able to…

- Suggest how software can cause inadvertent harm or amplify inequities
- Explain why software engineers have a role to play in avoiding such harms

Exercise

Team up and propose actionable ideas to re-design Amazon’s Hiring Software