

# CS 4530

## Fundamentals of Software Engineering

### Module 17: Engineering Software for Equity

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# Learning Goals

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- 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 human values in designing software systems
  - Explain some techniques that software engineers can use in producing software systems that are more congruent with human values.

# Ethically and morally implicated technology is **everywhere!**

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- Algorithms that gate access to loans, insurance, employment, government services...
- Algorithms that perpetuate or exacerbate existing discrimination
- Bad medical software can kill people (Therac-25)
- UIs that discriminate against differently-abled people (Domino's)
- Third-party data collection for hyper-targeted advertising
- GPT-3 !!
- And on... and on... and on...

# A few representative examples

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- Some of these are old, but things haven't changed...



# Following regulations alone is not enough

## Citigroup Center

- Design met building code, but did *not* account for all failure modes
- Last-minute changes to construction increased odds of failure
- Fixed before disaster could strike, but kept a secret for 20 years

[https://en.wikipedia.org/wiki/Citicorp\\_Center\\_engineering\\_crisis](https://en.wikipedia.org/wiki/Citicorp_Center_engineering_crisis)





# Badly-engineered software can kill people

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- Therac-25 (1985-1987)
- Bug in software caused 100x greater exposure to radiation than intended
- At least 6 died
- Likely far more suffered: deaths occurred over a period of 2 years!
- Weak accountability in manufacturer's organization



"Therac-25" by Catalina Márquez, Wikimedia commons, CC BY-SA 4.0

# Algorithmic sentencing can discriminate

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- The COMPAS sentencing tool discriminates against black defendants

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



# Algorithmic bias can discriminate

- ...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

HIGHER PRICE  
**\$1,199.99**

DISCOUNT PRICE  
**\$1,099.99**

DIFFERENCE:  
**9.1%**

**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**

**A 20% DISCOUNT**

...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

## FairTest: Discovering Unwarranted Associations in Data-Driven Applications\*

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

<sup>1</sup>Stanford, <sup>2</sup>Columbia University, <sup>3</sup>EPFL, <sup>4</sup>Saarland University, <sup>5</sup>Cornell Tech, Jacobs Institute

**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.



# Algorithms can be used for price gouging

- ...against all of us

THE WALL STREET JOURNAL.

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EXCLUSIVE RETAIL

## Amazon Used Secret 'Project Nessie' Algorithm to Raise Prices

The strategy, as described in redacted parts of FTC lawsuit, is part of agency's case that Amazon has outsize influence on consumer prices

By Dana Mattioli [Follow](#)  
Updated Oct. 3, 2023 4:54 pm ET

[Share](#) [Resize](#) [370](#) [Listen \(2 min\)](#)



Case 2:23-cv-01495 Document 1 Filed 09/26/23 Page 132 of 172

1 460. Amazon's Project Nessie pricing system [REDACTED]

2 [REDACTED]

3 461. [REDACTED]

4 [REDACTED]

5 462. Amazon's use of its Project Nessie pricing system is an unfair method of

6 competition in violation of Section 5(a) of the FTC Act, 15 U.S.C. § 45(a).

7 463. There is no valid and cognizable justification for Amazon's use of Project Nessie.

8 **COUNT V**

9 **MONOPOLY MAINTENANCE OF THE ONLINE SUPERSTORE MARKET**

10 **(15 U.S.C. § 2)**

11 464. State Plaintiffs re-allege and incorporate by reference the allegations in

12 paragraphs 1-463 above.

13 465. At all relevant times, Amazon has had monopoly power in the online superstore

14 market in the United States.

15 466. Amazon has willfully maintained its monopoly power through its course of

<https://www.youtube.com/watch?v=T1Bcupz77-Q>



# UIs can discriminate against the differently-abled

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

Pizza LLC v. Robles

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

[“Domino’s Would Rather Go to the Supreme Court Than Make Its Website Accessible to the Blind” by Brenna Houck, Eater Detroit](#)



Jul 15 2019	<b>Brief amicus curiae of Washington Legal Foundation filed.</b>
Jul 15 2019	<b>Brief amici curiae of Retail Litigation Center, Inc., et al. filed.</b>
Jul 15 2019	<b>Brief amicus curiae of Cato Institute filed.</b>
Jul 15 2019	<b>Brief amicus curiae of Restaurant Law Center filed.</b>
Jul 15 2019	<b>Brief amici curiae of Chamber of Commerce of the United States of America, et al. filed.</b>



# Software can help to evade regulation

## 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 that when tested on the road, some cars emitted almost **40 times** the permitted level of nitrogen oxides.

Average emissions of nitrogen oxides during on-road testing

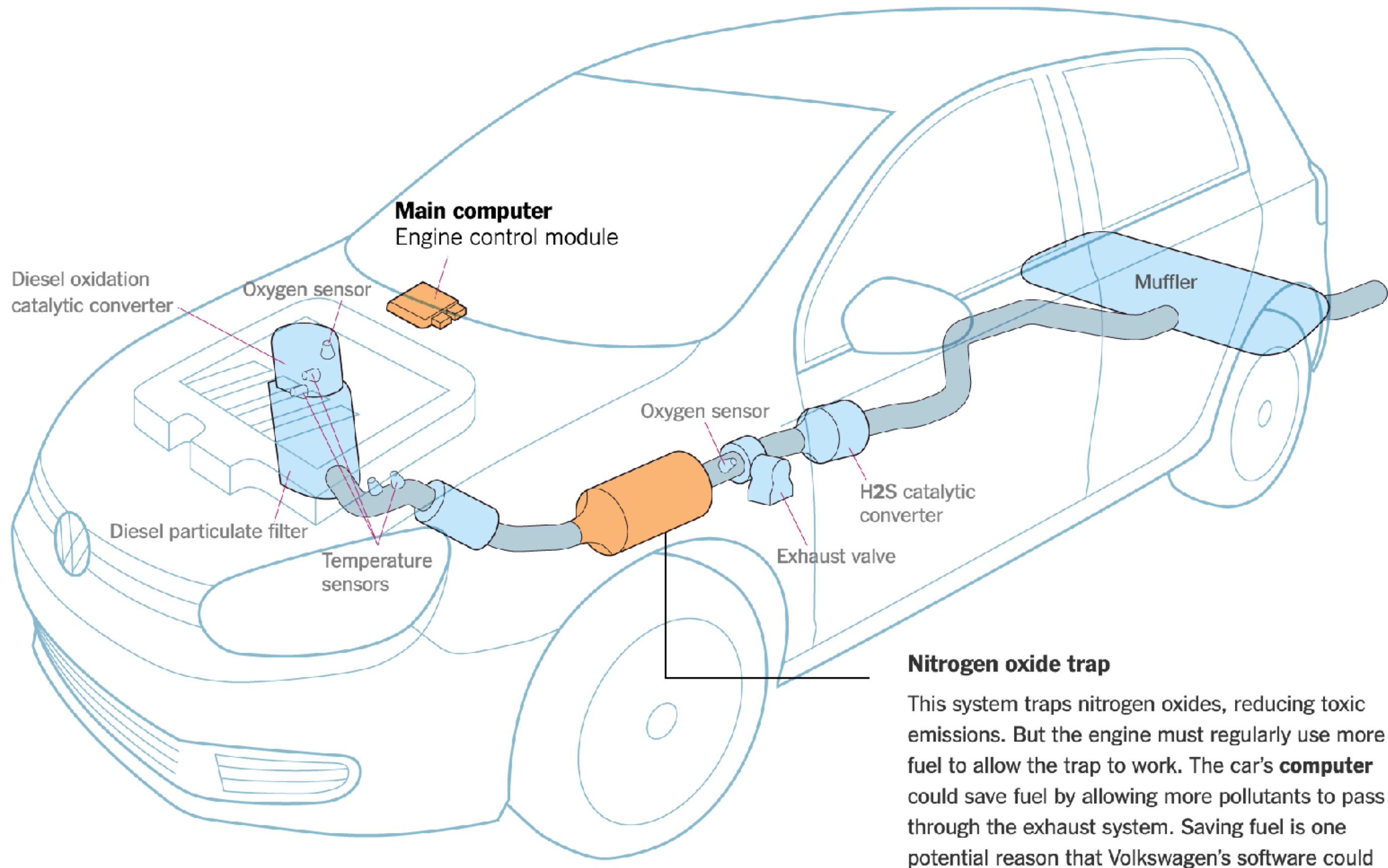
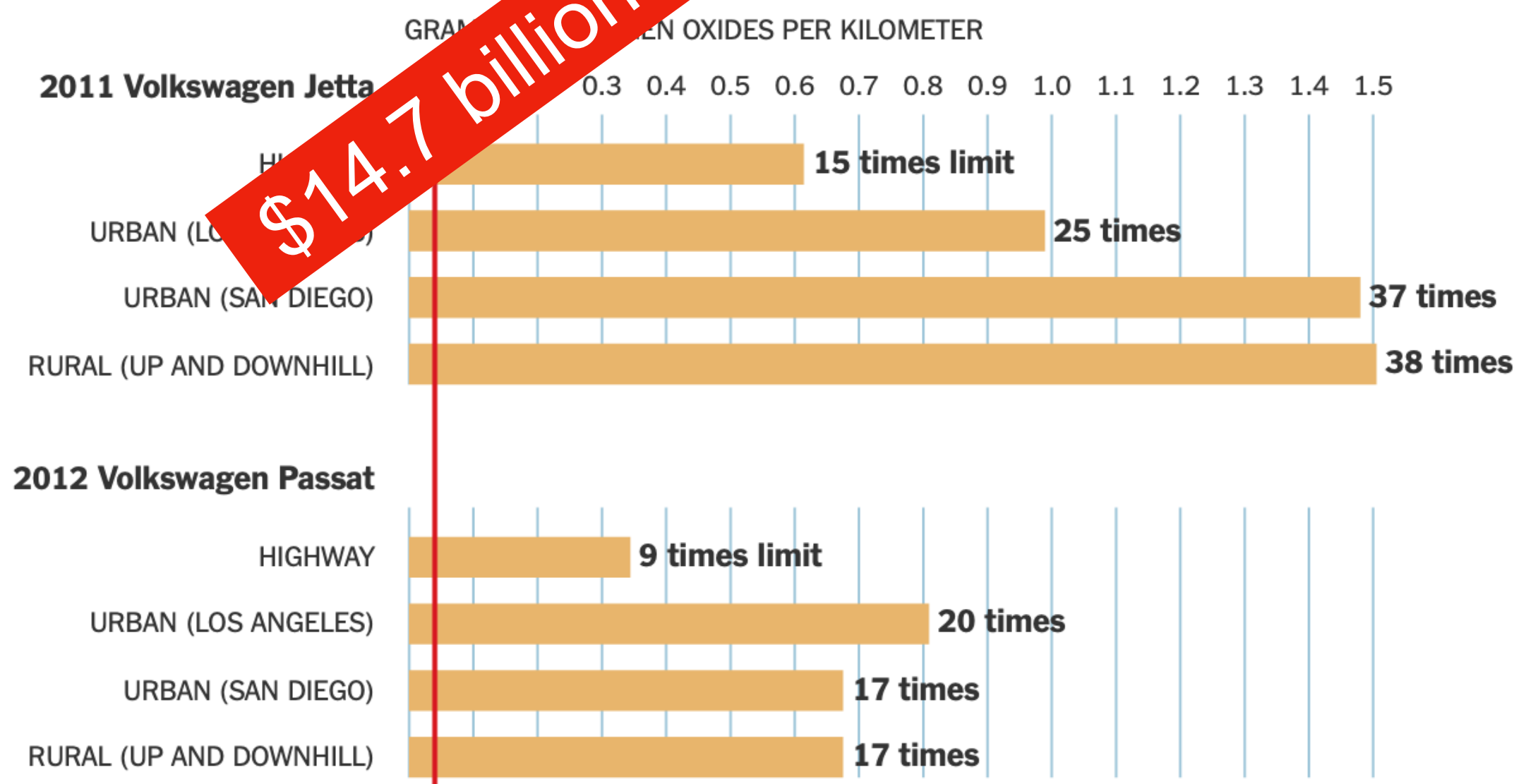


Illustration by Guilbert Gates | Source: Volkswagen, The International Council on Clean Transportation



# Training Data can be biased (and usually is)



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>

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

WIRED

BACKCHANNEL BUSINESS CULTURE GEAR IDEAS MORE

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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



# Training of AI systems can impact 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<sub>2</sub> 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/](https://www.theregister.com/2020/11/04/gpt3_carbon_footprint_estimate/)

### Consumption

CO<sub>2</sub>e (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

# AI programs can hallucinate

## Lawyer cites fake cases generated by ChatGPT in legal brief

The high-profile incident in a federal case highlights the need for lawyers to verify the legal insights generated by AI-powered tools.

Published May 30, 2023

### *The ChatGPT Lawyer Explains Himself*

In a cringe-inducing court hearing, a lawyer who relied on A.I. to craft a motion full of made-up case law said he “did not comprehend” that the chat bot could lead him astray.

### *Here's What Happens When Your Lawyer Uses ChatGPT*

A lawyer representing a man who sued an airline relied on artificial intelligence to help prepare a court filing. It did not go well.

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Article | [Open access](#) | [Published: 07 September 2023](#)

## Fabrication and errors in the bibliographic citations generated by ChatGPT

[William H. Walters](#) ✉ & [Esther Isabelle Wilder](#)

[Scientific Reports](#) **13**, Article number: 14045 (2023) | [Cite this article](#)

5866 Accesses | 2 Citations | 95 Altmetric | [Metrics](#)

ChatGPT is making up fake Guardian articles. Here's how we're responding  
*Chris Moran*





# And this is only the tip of the iceberg

- Other Challenges:
  - interfaces and systems designed to be addictive;
  - corporate ownership of personal data;
  - weak cyber security and personally identifiable information (PII) protection;
  - and many more ...

**SOCL 4528. Computers and Society. (4 Hours)**  
Focuses on the social and political context of technological change and development. Through readings, course assignments, and class discussions, offers students an opportunity to learn to analyze the ways that the internet, artificial intelligence, and other technological advances have required a reworking of every human institution—both to facilitate the development of these technologies and in response to their adoption.

Attribute(s): NUpath Difference/Diversity, NUpath Societies/Institutions



# More than *don't be evil*

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- Engineering equitable software requires conscious effort
  - How do we determine what “the right thing” is?
  - How do we weigh competing interests and values
  - How do we convince our investors/managers to take this action?

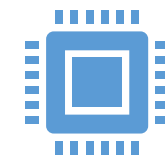


# An approach: consider human values in the design process.

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Technology is  
the result of  
human  
imagination



All  
technology  
involves  
design



All design  
involves  
choices  
among  
possible  
options



All choices  
reflects  
values



Therefore, all  
technologies  
reflect and affect  
human values



Ignoring  
values in the  
design  
process is  
irresponsible

Engaging with values in the design process offers creative opportunities for:

- Technical innovation
- Improving the human condition (*doing good and saving the world*)

# Technological Success takes a broader view

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In CS, we typically think about **technical success**

- Does the technology function?
- Does it achieve first-order objectives?

Example metrics:

- Test coverage and bug tracker
- Crash reports
- Benchmarks of speed, prediction accuracy, etc.
- Counts of app installations, user clicks, pages viewed, interaction time, etc.

Maybe we should think about **technological success**

- Is the technology beneficial to stakeholders, society, the environment, etc.?
- Is the technology fair or just?

Example metrics:

- Assessments of quality of life
- Measures of bias
- Reports of bullying, hate speech, etc.
- Carbon footprint



# Challenges: how to

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- Define success objectives?
- Identify the social structure in which a technology is situated?
- Identify legitimate direct and indirect stakeholders?
- Elicit the full range of values at play?
- Balance and address tensions between different values?
- Identify and mitigate unintended consequences?

# Identifying Stakeholders

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## Direct Stakeholders

The sponsor (your employer, etc.)

Members of the design team

Demographically diverse users

- Races and ethnicities, men and women, LGBTQIA, differently abled, US vs. non-US, ...

Special populations

- Children, the elderly, victims of intimate partner violence, families living in poverty, the incarcerated, indigenous peoples, the homeless, religious minorities, non-technology users, celebrities

Roles

- Content creators, content consumers, power users, ...

## Indirect Stakeholders

Bystanders

- Those who are around your users
- E.g. pedestrians near an autonomous car

“Human data points”

- Those who are passively surveilled by your system

Civil society

- E.g. people who aren't on social media are still impacted by disinformation
- People who care deeply about the issues or problem being addressed

Those without access

- Barriers include: cost, education, availability of necessary hardware and/or infrastructure, institutional censorship...

Whose values are impacted by a piece of technology?



# Filtering Stakeholders

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It is tempting to be overly comprehensive when enumerating stakeholders...

But not every impacted individual has legitimate values at play

Examples:

- Foreign election meddlers are affected by content moderation, want to protect their “free speech”
- Dictatorships are impacted by universal encryption, want unfettered surveillance capabilities
- Cyber criminals want to steal things, are against cybersecurity measures

These stakeholders are **not legitimate**, may be **safely ignored**

# Identifying the Full Range of Values

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- Some values are universal: accessibility, justice, human rights, privacy
- Others are tied to specific stakeholders and social contexts
- Identifying relevant values:
  - Start with a thorough understanding of the relevant features of the social situation
  - Add experience/knowledge from similar technologies or design decisions (case studies, etc.)
  - Add results of empirical investigation
- What are the **scale of impacts** to various stakeholders?



# Example Values

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**Human welfare** refers to people's **physical**, material, and psychological well-being



**Accessibility** refers to making all people successful users of information technology



**Respect** refers to treating people with politeness and consideration



**Calmness** refers to a peaceful and composed psychological state



**Freedom from bias** refers to systematic unfairness perpetrated on individuals or groups, including pre-existing social bias, technical bias, and emergent social bias

# More Example Values

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**Ownership and property** refers to a right to possess an object (or information), use it, manage it, derive income from it, and bequeath it



**Privacy** refers to a claim, an entitlement, or a right of an individual to determine what information about himself or herself can be communicated to others



**Trust** refers to expectations that exist between people who can experience good will, extend good will toward others, feel vulnerable, and experience betrayal



**Accountability** refers to the properties that ensures that the actions of a person, people, or institution may be traced uniquely to the person, people, or institution



# Addressing Value Tensions

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This is where the **hard choices** happen

What are the core values that cannot be violated?

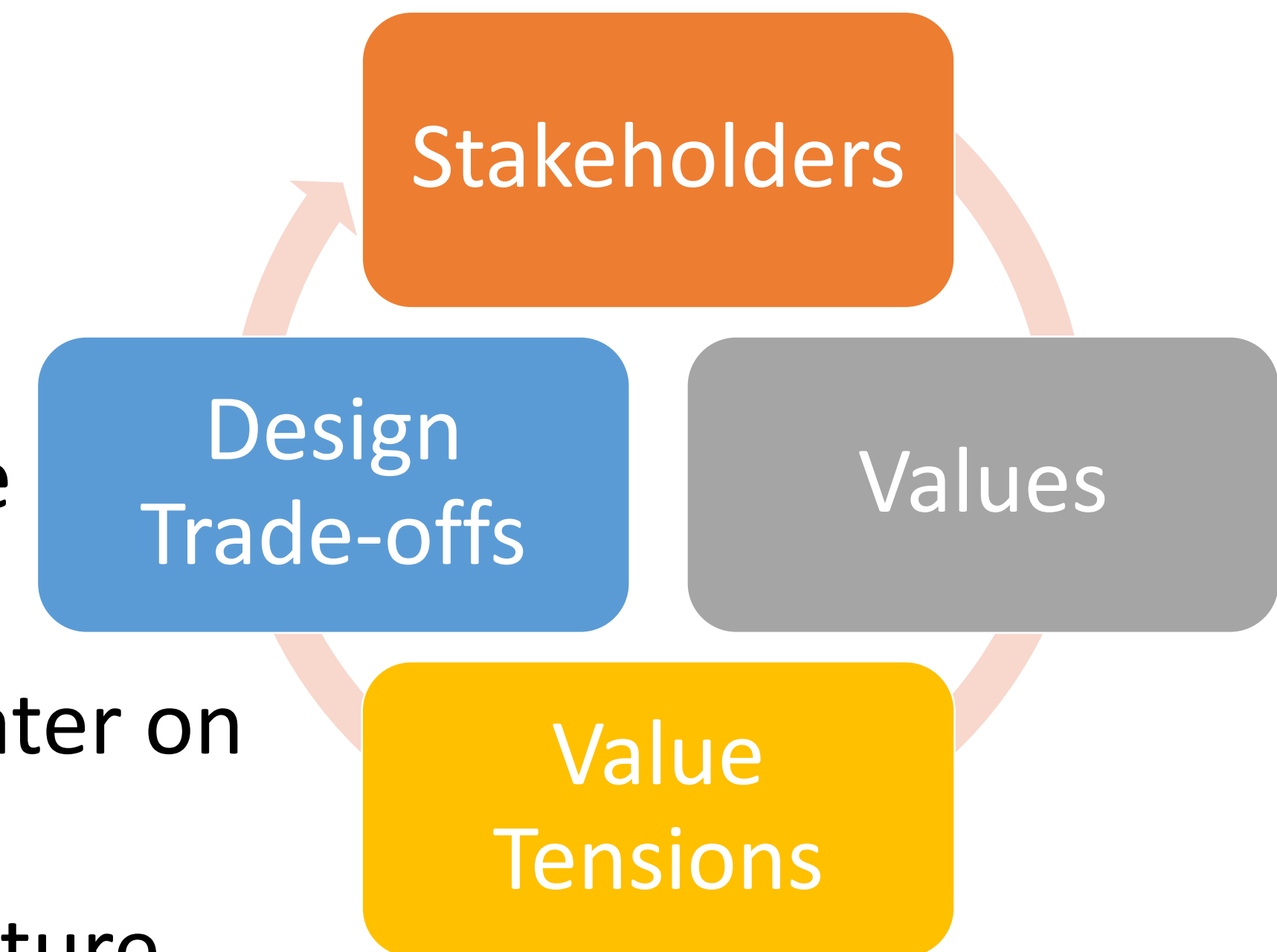
Which tensions can be addressed through:

- Technological mechanisms?
- Social mechanisms?

When a tension cannot be reconciled, whose values take precedence?

What tensions must be addressed immediately, versus later on through additional features?

- Early design decisions will unavoidably foreclose future design possibilities



# Identifying Unintended Consequences

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- Technology *will* be adopted in unanticipated ways. Being intellectually rigorous means considering and mitigating risks in designs ahead of time.
- What if:
  - Our recommendation system promotes misinformation or hate speech?
  - Our database is breached and publicly released?
  - Our facial recognition AI is used to identify and harass peaceful protestors?
  - Our child safety app is used to stalk women?
  - Our chatbot is sexist or racist?



# Example 1: Content Moderation

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The issue: *free expression* in tension with *welfare* and *respect*

- Some speech may be hurtful and/or violent
- Removing this speech may be characterized as censorship

Bad take: unyielding commitment to free speech, no moderation

- Trolls and extremists overrun the service, it becomes toxic, all other users leave
- Violent speech actually impedes free speech in general

Bad take: strict whitelists of acceptable speech

- Precludes heated debate, discussion of “sensitive topics”
- Disproportionately impacts already marginalized groups

Good take: recognizing that moderation will never be perfect, there will be mistakes and grey areas

- Doing nothing is not a viable option
- Clear guidelines that are earnestly enforced create a culture of accountability

# Example 2: Image Generation

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AI text-to-image generators have a well-documented bias problem. AI models are trained on images from the internet, so bias in, bias out. [A recent experiment](#) from Bloomberg on the image generator Stable Diffusion found that AI portraits of architects, doctors and CEOs skewed white and male, while images of cashiers and housekeepers skewed towards women of color.

Adobe's solution to the bias issue was to use data that estimates the skin tone distribution of a Firefly user's country, and apply it randomly to any human Firefly creates. In other words, if someone in the U.S. used Firefly to make an image of a doctor or a gardener, the chances that person would be a woman or have non-white skin would be roughly proportional to the percentage of women and people of color in the U.S.

In Firefly world, about [14% of doctors should be Black](#) — the same percentage as the Black population in the U.S. But in the messy, unequal real world, [only 6% of doctors are Black](#). So, should AI images depict the world as it is? Or as it should be? “That becomes almost like a philosophical question,” said Rumman Chowdhury, a Responsible AI Fellow at Harvard's Berkman Klein Center for Internet and Society.

<https://www.marketplace.org/2023/10/10/solutions-to-ai-image-bias-raise-their-own-ethical-questions/>



# Strategies for Addressing Value Tensions

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Identify Red Lines	<p><i>Red lines:</i> bedrock values that <b>cannot</b> be violated</p> <ul style="list-style-type: none"><li>• Address these first</li></ul>
Look for Win—Wins	<p>Look for <b>win-win</b> scenarios</p> <ul style="list-style-type: none"><li>• Some stakeholders may be agreement; others may want the same outcome but for different reasons</li></ul>
Embrace Tradeoffs	<p>Be open and honest when value tradeoffs are necessary</p> <ul style="list-style-type: none"><li>• e.g. when functionality and privacy are in tension, both can be addressed through informed consent</li></ul>
Don't Forget Social Solutions	<p>Creatively leverage technical and social solutions in concert</p> <ul style="list-style-type: none"><li>• e.g. if a new system is going to automate away jobs, pair it with a retraining program</li></ul>

# Practical Tips

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Adopt, Extend, Adapt	Adopt and extend the methods for your own purposes. Adapt for your sociotechnical setting.
Variety	Use a variety of empirical values-elicitation methods, rather than relying on a single one.
Continuous Evaluation	Continue to elicit stakeholder values throughout the design. If new values of import surface during the design process, engage them.
Anticipation	Anticipate unanticipated consequences: continue the process throughout the deployment of the technology
Collaborate	Particularly with people from other disciplines, and those with deep contextual knowledge of and expertise in your sociotechnical setting.



# Where does this leave us?

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- **So that we can sleep at night**
  - Consider the different ways that our software may **impact** others
  - Consider the ways in which our software **interacts** with the political, social, and economic systems in which we and our users live
  - Follow **best practices**, and actively push to improve them
  - Encourage **diversity** in our development teams
  - Engage in **honest conversations** with our co-workers and supervisors to explore possible ethical issues and their implications.

# Review

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- You should now be able to...
  - Illustrate how software can cause inadvertent harm or amplify inequities
  - Explain the role of human values in designing software systems
  - Explain some techniques that software engineers can use in producing software systems that are more congruent with human values.