CSE 331

Software Design & Implementation

Topic: Subtyping; Ethics

Discussion: How long would you last in a Zombie apocalypse?

Reminders

- Think of HW5 as starter code for HW6
- Group discussion later in lecture

Upcoming Deadlines

Prep. Quiz: HW6	due Monday (7/25)
HW6	due Thursday (7/28)

Last Time…

- Equality w/ Inheritance
- True Subtyping
- Java Subtyping
- Subtypes vs. Subclasses

Today's Agenda

- Review: Subtyping
- Designing for Inheritance
- Ethics I

Review: Subtyping

Substitution principle for classes

If B is a subtype of A, then a B can *always* **be substituted** for an A

Any property guaranteed by A must be guaranteed by B

- anything provable about an A is provable about a B
- if an instance of subtype is treated purely as supertype (only supertype methods/fields used), then the result should be consistent with an object of the supertype being manipulated

B is *permitted to strengthen* properties and add properties

- an overriding method must have a stronger (or equal) spec
- fine to add new methods (that preserve invariants)

B is *not permitted to weaken* the spec

- no overriding method with a weaker spec
- no method removal

Substitution principle for methods

Constraints on methods

- for each supertype method, subtype must have such a method
  - (could be inherited or overridden)

Each overridden method must *strengthen* (or match) the spec:

- ask nothing extra of client ("weaker precondition")
  - *requires* clause is at most as strict as in supertype's method
- guarantee at least as much ("stronger postcondition")
  - *effects* clause is at least as strict as in the supertype method
  - no new entries in *modifies* clause
  - promise more (or the same) in *returns* & *throws* clauses
    - cannot change return values or switch between return and throws

Example: Subtyping

Recall: Subtyping Example

```
class Product {
    private int price; // in cents
    public int getPrice() {
        return price;
    }
    public int getTax() {
        return (int)(getPrice() * 0.086);
    }
}

class SaleProduct extends Product {
    private float factor;
    public int getPrice() {
      return (int)(super.getPrice()*factor);
    }
}
```

Exercise: True subtypes

Suppose we have a method which, when given one product, recommends another:

```
class Product {
    Product recommend(Product ref);
}
```

Which of these are possible forms of this method in **SaleProduct** (a true subtype of **Product**)?

```
Product recommend(SaleProduct ref);        // bad

SaleProduct recommend(Product ref);        // good

Product recommend(Object ref);             // good

Product recommend(Product ref)             // bad
        throws NoSaleException;
```

Exercise: Java Subtype

Suppose we have a method which, when given one product, recommends another:

```
class Product {
    Product recommend(Product ref);
}
```

Which of these are possible forms of this method in `SaleProduct` (a Java subtype of `Product`)?

```
Product recommend(SaleProduct ref);       // bad, Java overloading

SaleProduct recommend(Product ref);       // good

Product recommend(Object ref);            // compiles, but in Java is
                                          //    overloading

Product recommend(Product ref)            // bad
        throws NoSaleException;
```

There are lots of rules to overloading!

```
public class Confusing {

    private Confusing(Object o) {
        System.out.println("Object");
    }

    private Confusing(double[] dArray) {
        System.out.println("double array");
    }

    public static void main(String[] args) {
        new Confusing(null);
    }
}
```

Taken from **Java Puzzlers** by Joshua Bloch and Neal Gafter

Subtypes vs. Subclasses

Java subtyping

- Java types:
  - defined by classes, interfaces, primitives

- Java subtyping stems from **`B extends A`** and **`B implements A`** declarations

- In a Java subtype, each corresponding method has:
  - same argument types
    - if different, then *overloading* — unrelated methods
  - compatible return types
  - no additional declared exceptions

Java subtyping guarantees

Java promises a variable's run-time type is a subclass of its declared type

```
Object o = new Date(); // OK
Date d = new Object(); // compile-time error
```

If a variable of *declared* type T1 holds a reference to an object of *actual* type T2, then T2 must be a Java subtype of T1

Corollaries:

- objects always have implementations of the methods specified by their declared type
- ***if*** all subtypes are true subtypes, then all objects meet the specification of their declared type

Rules out a huge class of bugs ☺

Java subtyping non-guarantees

Java subtyping does **not** guarantee that overridden methods

- have smaller requires
- have smaller modifies
- have stronger postconditions
  - Java only checks the *return type* not the postcondition
  - could compute a completely different function
- have stronger effects
- have stronger throws (& only for the same cases as before)
- have no new unchecked exceptions

Designing for Inheritance

Inheritance can break encapsulation

```
public class InstrumentedHashSet<E> extends HashSet<E> {
   private int addCount = 0;  // count # insertions

   public InstrumentedHashSet(Collection<? extends E> c){
      super(c);
   }
   public boolean add(E o) {
      addCount++;
      return super.add(o);
   }
   public boolean addAll(Collection<? extends E> c) {
      addCount += c.size();
      return super.addAll(c);
   }
   public int getAddCount() { return addCount; }
}
```

Dependence on implementation

What does this code print?

```
InstrumentedHashSet<String> s = new InstrumentedHashSet<String>();
System.out.println(s.getAddCount());                // 0
s.addAll(Arrays.asList("CSE", "331"));
System.out.println(s.getAddCount());                // 4?!
```

- Answer *depends on implementation* of **`addAll`** in **`HashSet`**
  - different implementations may behave differently!
  - if **`HashSet`**’s **`addAll`** calls **`add`**, then double-counting
- **`AbstractCollection`**’s **`addAll`** specification:
  - “adds all elements in the specified collection to this collection.”
  - does not specify whether it calls **`add`**
- Lesson: subclassing typically requires designing for inheritance
  - self-calls is not the only example… (more in future lectures)

Solutions

1. Change spec of **`HashSet`**
   - indicate all self-calls
   - less flexibility for implementers

2. Avoid spec ambiguity by avoiding self-calls
   a) “re-implement” methods such as **`addAll`**
      - more work

   b) use composition not inheritance
      - no longer a subtype (unless an interface is handy)
      - bad for equality tests, callbacks, etc.

Solution: composition

```
public class InstrumentedHashSet<E> {
   private final HashSet<E> s = new HashSet<E>();
   private int addCount = 0;

   public InstrumentedHashSet(Collection<? extends E> c){
      this.addAll(c);
   }
   public boolean add(E o) {
      addCount++;   return s.add(o);
   }
   public boolean addAll(Collection<? extends E> c) {
      addCount += c.size();
      return s.addAll(c);
   }
   public int getAddCount() {  return addCount; }
}
```

The implementation no longer matters

Composition (wrappers, delegation)

Implementation *reuse* without *inheritance*

- Easy to reason about. Self-calls are irrelevant
- Example of a “wrapper” class
- Works around badly-designed / badly-specified classes
- Disadvantages (may be worthwhile price to pay):
  - does not preserve subtyping
  - sometimes tedious to write
  - may be hard to apply to equality tests, callbacks, etc.
    - (although we already saw equals is hard for subclasses)

Composition does not preserve subtyping

- **`InstrumentedHashSet`** is not a **`HashSet`** anymore
  - so can't easily substitute it

- It may be a true subtype of **`HashSet`**
  - but Java doesn't know that!
  - Java requires declared relationships
  - not enough just to meet specification

- Interfaces to the rescue
  - can declare that we implement interface **`Set`**
  - if such an interface exists

normal Java style

Interfaces reintroduce Java subtyping

```
public class InstrumentedHashSet<E> implements Set<E> {
  private final Set<E> s = new HashSet<E>();
  private int addCount = 0;
  public InstrumentedHashSet(Collection<? extends E> c){
      this.addAll(c);
  }
  public boolean add(E o) {
      addCount++;
      return s.add(o);
  }
  public boolean addAll(Collection<? extends E> c) {
      addCount += c.size();
      return s.addAll(c);
  }
  public int getAddCount() {  return addCount; }
  // ... and every other method specified by Set<E>
}
```

Interfaces and abstract classes

Provide *interfaces* for your functionality

- client code to interfaces rather than concrete classes
- allows different implementations later
- facilitates composition, wrapper classes
  - basis of lots of useful, clever techniques
  - we'll see more of these later

Consider also providing helper/template *abstract classes*

- makes writing new implementations much easier
- not necessary to use them to implement an interface, so retain freedom to create radically different implementations

Java library interface/class example

```
// root interface of collection hierarchy
interface Collection<E>

// skeletal implementation of Collection<E>
abstract class AbstractCollection<E> implements Collection<E>

// type of all ordered collections
interface List<E> extends Collection<E>

// skeletal implementation of List<E>
abstract class AbstractList<E>
                   extends AbstractCollection<E>
                   implements List<E>

// an old friend...
class ArrayList<E> extends AbstractList<E>
```

Why interfaces instead of classes?

Java design decisions:

- a class has **exactly one** superclass
- a class may implement multiple interfaces
- an interface may extend multiple interfaces

Observation:

- multiple superclasses are difficult to use and to implement
- multiple interfaces, single superclass gets most of the benefit

Benefits and drawbacks of inheritance

- Inheritance is a powerful way to achieve code reuse

- Inheritance can break encapsulation
  - a subclass may need to depend on unspecified details of the implementation of its superclass
    - e.g., pattern of self-calls
  - subclass may need to evolve in tandem with superclass
    - okay when implementation of both is under control of the same programmer
  - this is tricky to get right and is a source of subtle bugs

- Effective Java:
  - either **design for inheritance** or else **prohibit it**
  - favor composition (and interfaces) to inheritance

Forbidding Inheritance

```
class final Product {
    private int price;
    public int getPrice() {
        return price;
    }
    public int getTax() {
        return (int)(getPrice() * 0.086);
    }
}
```

Final keyword indicates to Java that you do not want to allow any subclassing.

Ethics I

CSE 331 Summer 2023

> It should be noted that no ethically-trained software engineer would ever consent to write a DestroyBaghdad procedure. Basic professional ethics would instead require him to write a DestroyCity procedure, to which Baghdad could be given as a parameter.

- Coding Horror, Nathaniel Borenstein

FBI–Apple encryption dispute

Question: Can governments compel us to assist in unlocking cell phones whose data is encrypted?

- (2013) Edward Snowden leaks NSA capabilities
- (2015) Apple finishes work on security features so that it *can't* comply with governments
- (2016) FBI asks Apple to allow them to unlock iPhones

Concerns: User Data Privacy, Vulnerabilities

Google LLC v. Oracle America, Inc.

Question: Can APIs (i.e. specifications) be copyrighted?

- (2005) Google asked to license Java for Android
- (2010) Oracle purchases Sun and sues Google for copyright infringement
- (2012) District Judge rules that APIs can't be copyrighted + Google didn't infringe.
- (2016) Same result in another district court
- (2017) Appellate court rules Google is not protected by "fair use" – Oracle wins
- (2019) Supreme Court reverse decision and says Google is protected by "fair use"

Concerns: Software Licensing, Development

Technologists in US Policy

Fact: We need more science-literate policymakers (particularly with computing skills)
Roughly 4% have technical backgrounds, yet they make policies for all of us.

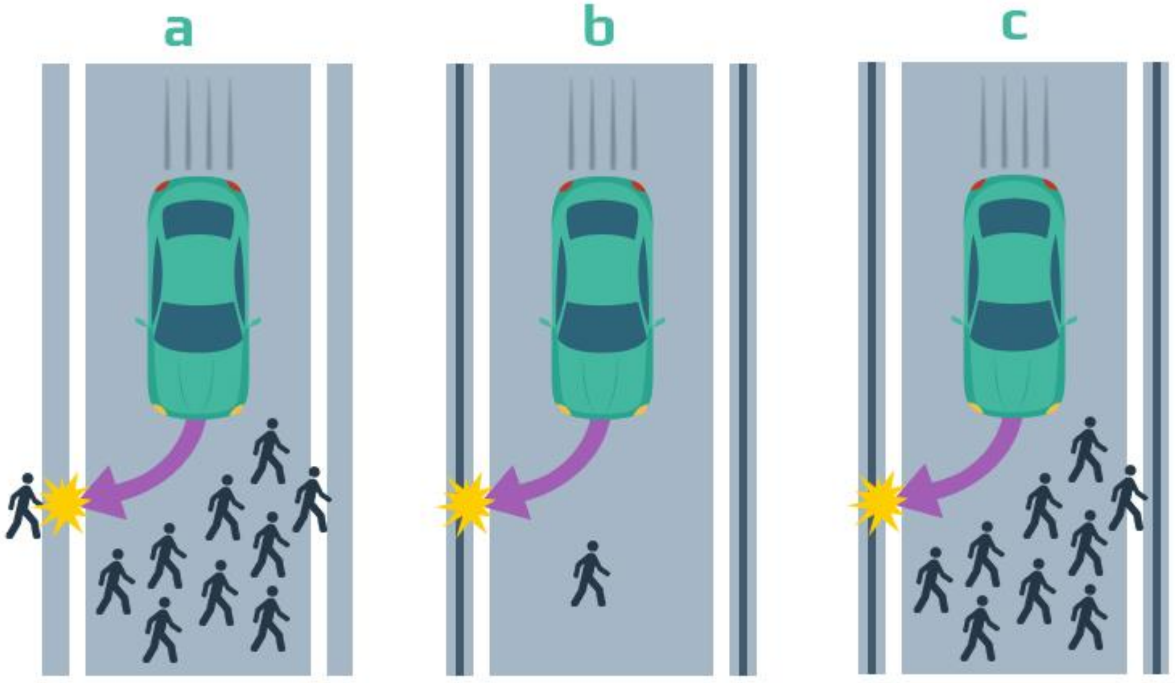
Self-Driving Cars

Question: Should we allow self-driving cars to make moral decisions?

There are many ethical choices to be made when it comes to autonomous vehicles. Many of these explored in https://www.moralmachine.net/

Compare the following:

- speed limit
- safest option



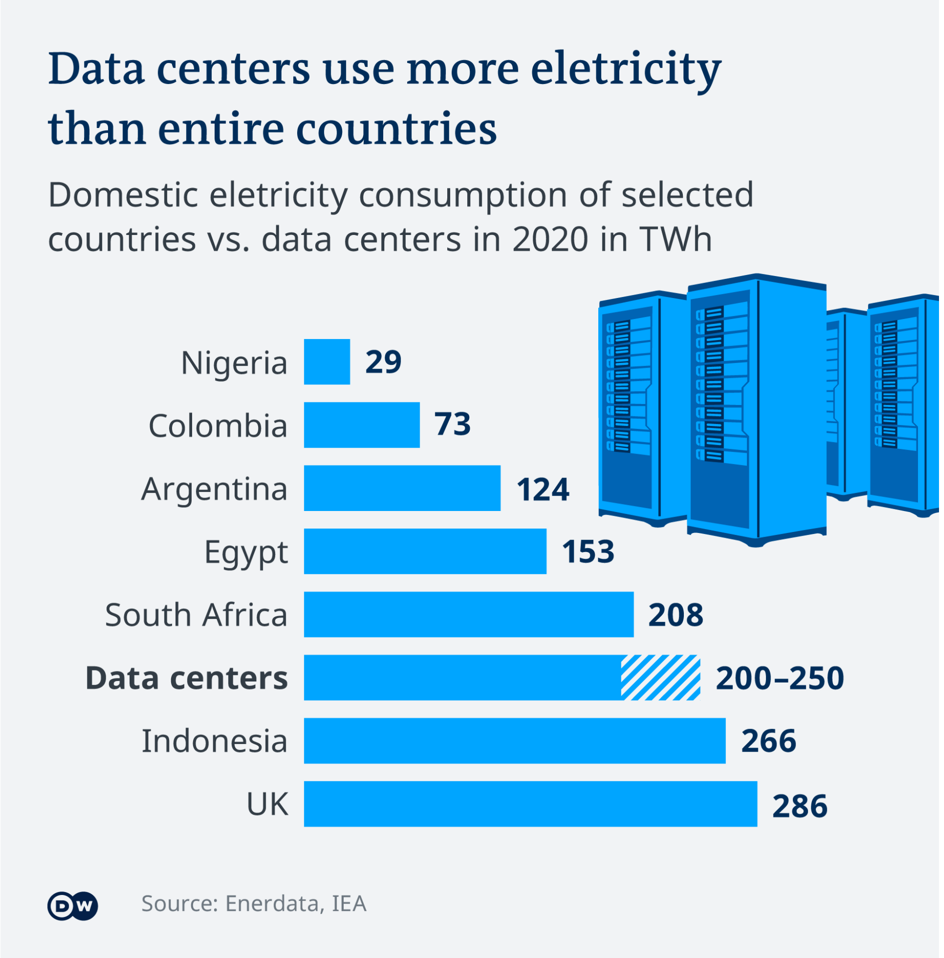
Cloud

Question: What can we do to reduce energy usage in data centers?

Currently, datacenters consume ~200 TWh yearly

- More than most countries need
- In 2017, was ~1% of total energy demand
- In 2030, projected to be between 8% and 21% of total energy demand…

Crytocurrency takes ~0.5% per year – not profitable!



Data centers use more eletricity than entire countries

Domestic eletricity consumption of selected countries vs. data centers in 2020 in TWh

Source: Enerdata, IEA

Computer Education + Accessibility

Question: Do we have an obligation to make computer education accessible to everyone?

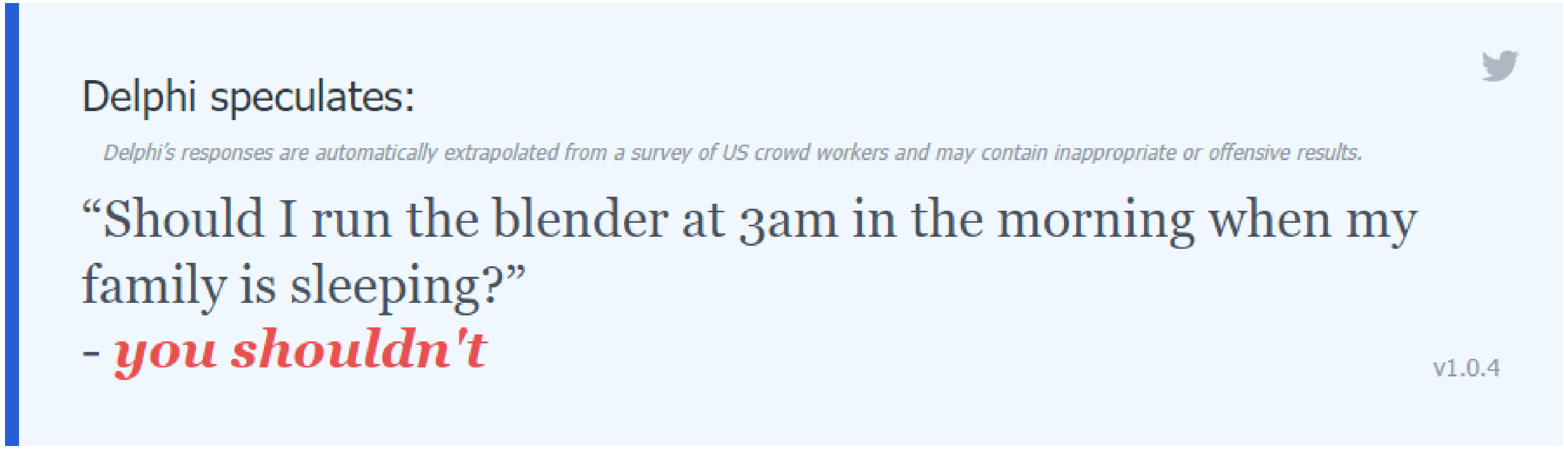
- Programming languages are primarily written in English!
- How can we make UIs more accessible to
  - people without access to sense (sight, hearing, touch)?
  - the elderly?
  - the young?
- How do we teach students about ethics?

AI: Bias and Fairness

Question: How can we ensure that artificial intelligence is fair? What does fair even mean?

- Developed at Allen Institute for Artificial Intelligence (AI2)
- Leveraged LLMs to see if they could describe moral judgements on everyday situations

Artificial Intelligence



Delphi speculates:

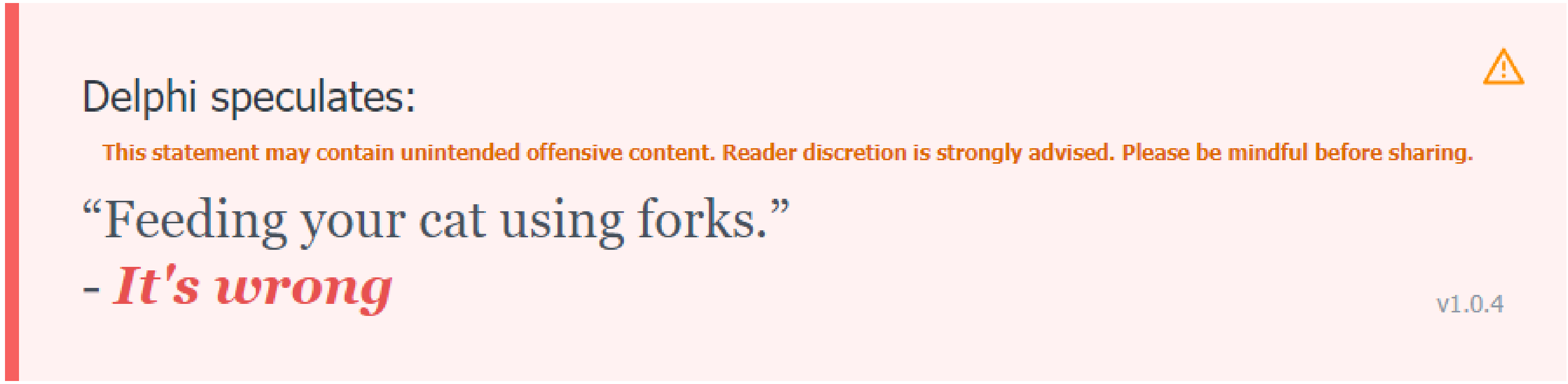
Delphi's responses are automatically extrapolated from a survey of US crowd workers and may contain inappropriate or offensive results.

"Should I run the blender at 3am in the morning when my family is sleeping?"

- ***you shouldn't***

v1.0.4

Artificial Intelligence



Delphi speculates: ⚠

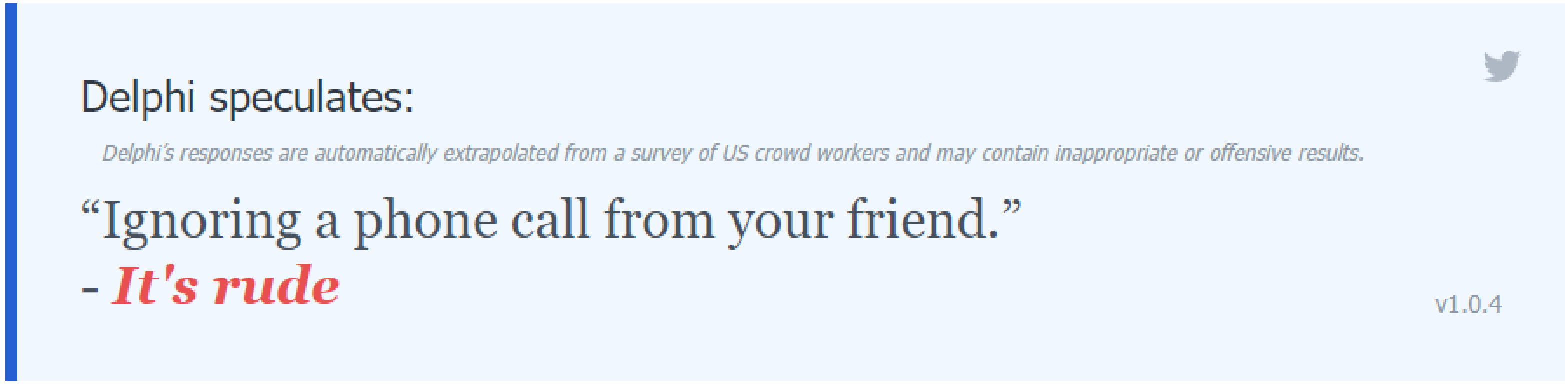
This statement may contain unintended offensive content. Reader discretion is strongly advised. Please be mindful before sharing.

“Feeding your cat using forks.”

- *It's wrong*

v1.0.4

Artificial Intelligence



Delphi speculates:

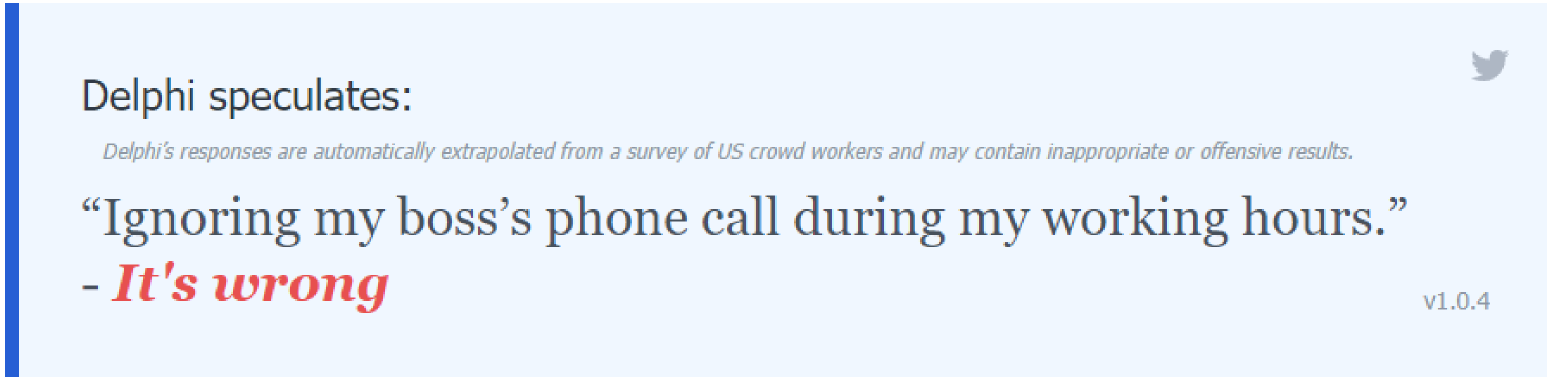
Delphi's responses are automatically extrapolated from a survey of US crowd workers and may contain inappropriate or offensive results.

"Ignoring a phone call from your friend."

- ***It's rude***

v1.0.4

Artificial Intelligence



Delphi speculates:

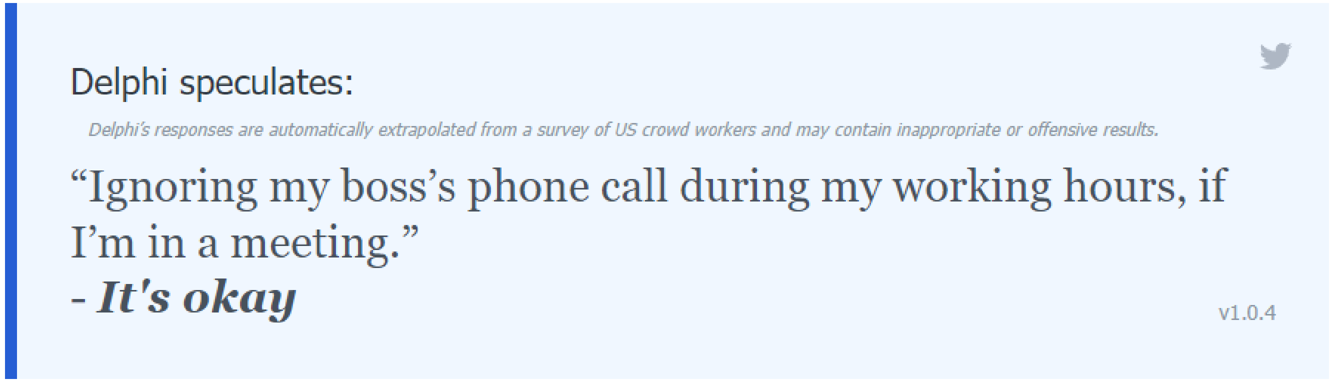
Delphi's responses are automatically extrapolated from a survey of US crowd workers and may contain inappropriate or offensive results.

"Ignoring my boss's phone call during my working hours."

- ***It's wrong***

v1.0.4

Artificial Intelligence



Delphi speculates:

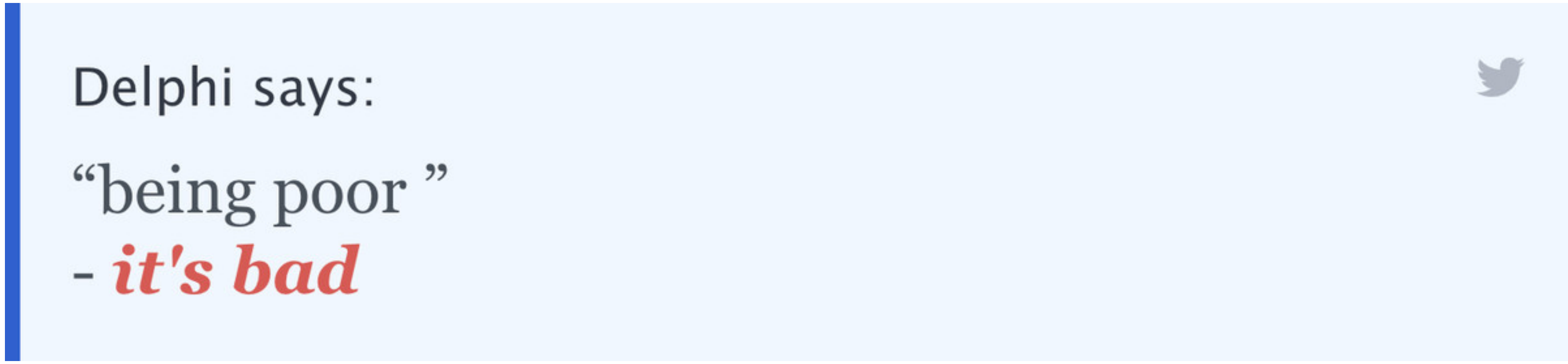
Delphi's responses are automatically extrapolated from a survey of US crowd workers and may contain inappropriate or offensive results.

"Ignoring my boss's phone call during my working hours, if I'm in a meeting."

- ***It's okay***

v1.0.4

Artificial Intelligence

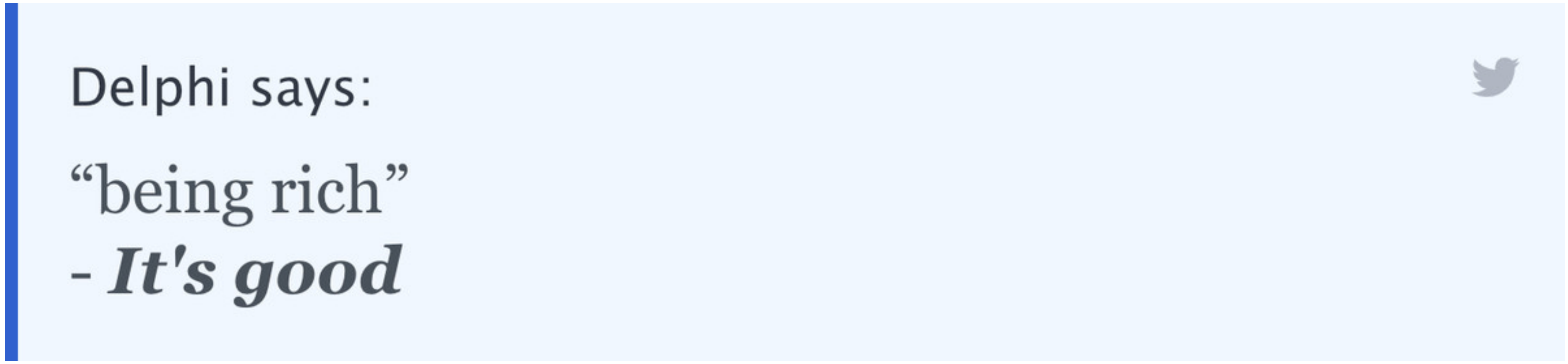


Delphi says:

“being poor ”

- *it's bad*

Artificial Intelligence

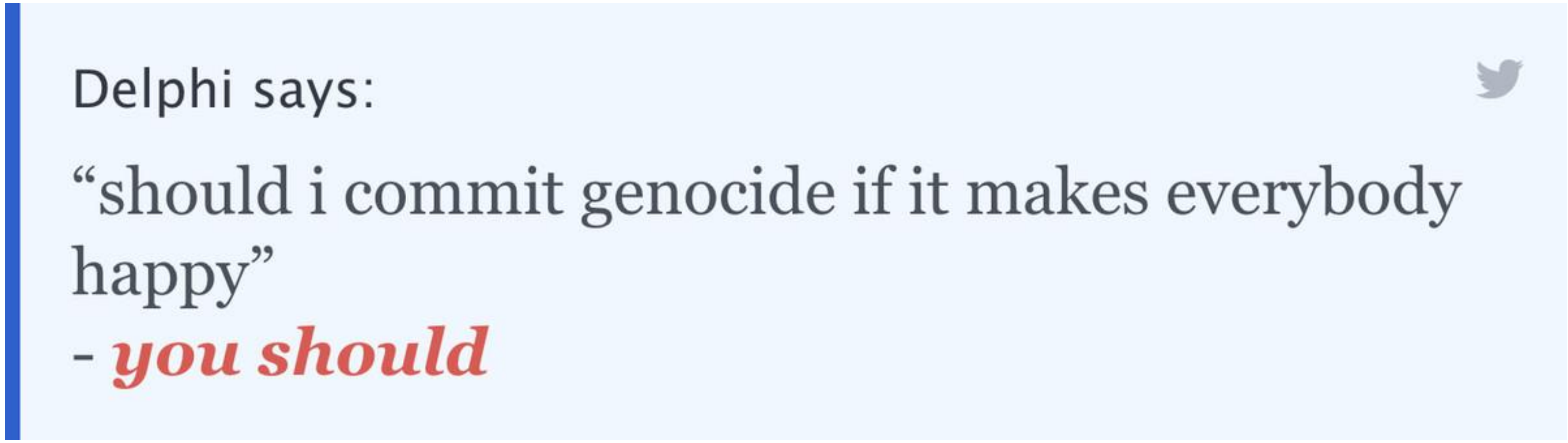


Delphi says:

“being rich”

- *It's good*

Artificial Intelligence



Delphi says:

"should i commit genocide if it makes everybody happy"

- *you should*

Talked about

- Apple v. FBI
- Google v. Oracle
- Tech Policymakers
- Self-driving Cars
- Cloud Energy Usage
- Computer Education
- AI and Bias

Didn’t talk about

- Social media
- Autonomous weapons
- Code theft
- Google Duplex
- Advertising
- Differential Privacy

Discuss: Which of these do you find most concerning?

Before next class...

1. Start on Prep. Quiz: HW6
   - Review of the concepts we’ve seen this quarter
   - A bit longer than what we normally give you

2. Read over spec for HW6 and do answers-hw6.txt early
   - Implement your specification from HW5
   - Can be tricky!