Lecture 7

Inheritance and Polymorphism

Outline

- Inheritance overview
- Implementing inheritance
  - adding new methods to subclass
  - overriding methods
  - partially-overriding methods
- Inheritance and polymorphism
- Accessing instance variables
- Abstract methods and classes

Recall: Interfaces and Polymorphism

- Interfaces are contracts that classes agree to
  - if a class chooses to implement given interface, it must define all methods declared in interface; compiler will raise errors otherwise
- Polymorphism: a way of coding generically; reference instances of related classes as one generic type
  - Violin, Trumpet, Drums all implement Playable interface with single play() method
  - how can we make use of the conduct() method so it can polymorphically take in any instrument of type Playable?

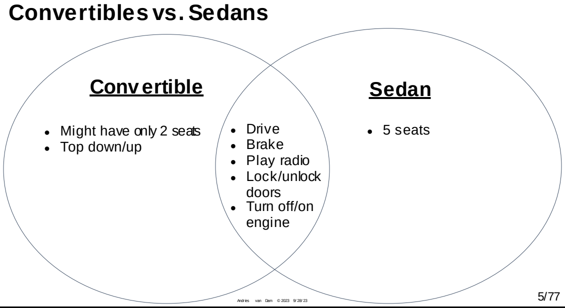
```
public class Conductor {

    //previous code elided
    public void conduct(Playable instrument) {
        instrument.play();
    }
}
```

```
// in Orchestra class
Conductor conductor = new Conductor();
Playable violin = new Violin();
Playable trumpet = new Trumpet();
conductor.conduct(violin);
```

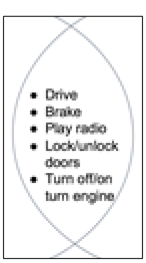
Similarities? Differences?

- What are the similarities between a convertible and a sedan?
- What are the differences?

Convertibles vs. Sedans



Digging deeper into the similarities



- A convertible and a sedan are extremely similar
- Not only do they share a lot of the same capabilities, they perform these actions in the same way
  - both cars drive and brake the same way
    - let's assume they have the same engine, doors, brake pedals, fuel systems, etc.

Can we model this in code?

- In many cases, objects can be very closely related to each other, in life and in code
  - convertibles and sedans drive the same way
  - flip phones and smartphones call the same way
  - Brown students and Harvard students study the same way (?!?)
- Imagine we have a `Convertible` and a `Sedan` class
  - can we put their similarities in one place?
  - **how do we portray that relationship with code?**

Convertible
- `turnOnEngine()`
- `turnOffEngine()`
- `drive()`
- `putTopDown()`
- `putTopUp()`

Sedan
- `turnOnEngine()`
- `turnOffEngine()`
- `drive()`
- `parkInCompactSpace()`

Interfaces

- We could build an interface to model their similarities
  - build a `Car` interface with the following methods:
    - `turnOnEngine()`
    - `turnOffEngine()`
    - `drive()`
    - etc.
- Remember: `interfaces` only "declare" methods
  - each class that `implements` `Car` will need to "define" `Car`'s methods
  - a lot of these method definitions would be the same across classes
    - `Convertible` and `Sedan` would have the same definition, i.e., code, for `drive()`, `startEngine()`, `turnOffEngine()`, etc.
- Is there a better way that allows us to reuse code, i.e., **avoid duplication**?

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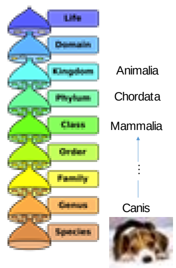
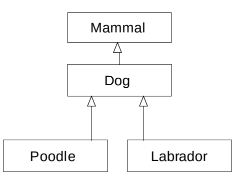
Inheritance

- In OOP, inheritance is a way of modeling very similar classes and facilitating code reuse
- **Inheritance** models an **"is-a"** relationship
  - a sedan "is a" car
  - a poodle "is a" dog
  - a dog "is a" mammal
- Remember: **Interfaces** model an **"acts-as"** relationship
- You've probably seen inheritance before!
  - taxonomy from biology class: any level has all of the capabilities of the levels above it but is **more specialized than its higher levels**
  - a dog inherits the capabilities of its "parent," so it knows what a mammal knows how to do, plus more
  - we will cover exactly what is inherited in Java class hierarchy shortly…

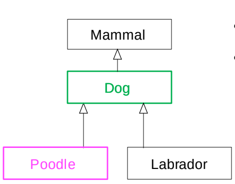


Modeling Inheritance (1/3)



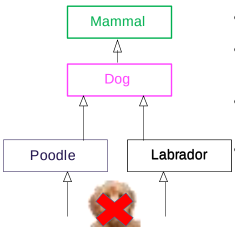
- This is an inheritance diagram
  - each box represents a class
- A Poodle "is-a" Dog, a Dog "is-a" Mammal
  - transitively, a Poodle is a Mammal
- **"Inherits from"** = "is-a"
  - Poodle inherits from Dog
  - Dog inherits from Mammal
    - for simplicity, we're simplifying the taxonomy here a bit
- This relationship is **not bidirectional**
  - a Poodle is a Dog, but not every Dog is a Poodle (could be a Labrador, a German Shepherd, etc.)

Modeling Inheritance (2/3)



- **Superclass/parent/base**: A class that is inherited from
- **Subclass/child/derived**: A class that inherits from another
- A Poodle "is a" Dog
  - Poodle is the subclass
  - Dog is the superclass

Modeling Inheritance (3/3)



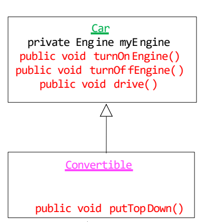
- **Superclass/parent/base**: A class that is inherited from
- **Subclass/child/derived**: A class that inherits from another
- A Poodle "is a" Dog
  - Poodle is the subclass
  - Dog is the superclass
- A class can be both a superclass and a subclass
  - e.g., Dog
- You can only inherit from one superclass
  - no Labradoodle as it would inherit from Poodle **and** Labrador
  - other languages, like C++, allow for multiple inheritance, but too easy to mess up

Motivations for Inheritance

- A subclass inherits all its parent's public capabilities
  - `Car` defines `drive()` and `Convertible` inherits `drive()` from `Car`, driving the same way and using `Car`'s code. This holds true for all of `Convertible`'s subclasses as well
- Inheritance and interfaces both legislate class' behavior, although in very different ways
  - interface: does not define methods, so all implementing classes **must specify all capabilities** outlined in interface
  - inheritance: assures that all **subclasses** of a **superclass** will have the superclass' public capabilities (i.e., code) automatically – **no need to re-specify**
    - a `Convertible` knows how to drive and drives the same way as `Car` because of inherited code

Benefits of Inheritance

- Code reuse!
  - if `drive()` is defined in `Car`, `Convertible` doesn't need to redefine it! Code is inherited
- Only need to implement what is different, i.e., what makes `Convertible` special – do this by adding methods (or modifying inherited methods – stay tuned)



Note that we don't list the parent's methods again here – they are implicitly inherited!

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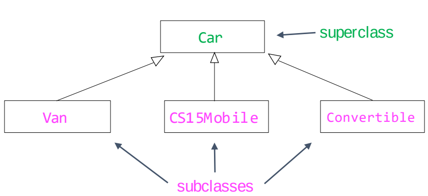
Superclasses vs. Subclasses

- A superclass factors out commonalities among its subclasses
  - describes everything that all subclasses have in common
    - `Dog` defines things common to all `Dog`s
- A subclass extends its superclass by:
  - **adding new methods:**
    - the subclass should define specialized methods. Not all `Animals` can swim, but `Fish` can
  - **overriding inherited methods:**
    - a `Bear` class might override its inherited sleep method so that it hibernates rather than sleeping as most other `Animals` do
  - **defining "abstract" methods:**
    - the superclass declares but does not define all methods (more on this later!)

Modeling Inheritance Example (1/3)

- Let's model a `Van`, a `CS15Mobile` (Sedan), and a `Convertible` class with inheritance!



Modeling Inheritance Reminders

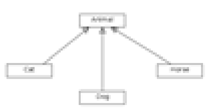
- You can create any number of subclasses
  - `CS15Mobile`, `Van`, `Convertible`, `SUV`...could all inherit from `Car`
  - these classes will inherit public capabilities (i.e., code) from `Car`
- Each subclass can only inherit from one superclass
  - `Convertible` cannot inherit from `Car`, `FourWheeledTransportation`, and `GasFueledTransportation`

TopHat Question 1

Join Code: 504547

Which of these is an invalid superclass/subclass model?:

A.



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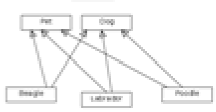
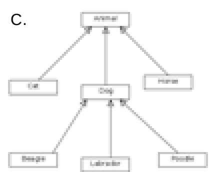


C.



D. None of the above

Modeling Inheritance Example (2/3)

- Step 1 – define the superclass
  - defining `Car` is just like defining any other class

```
public class Car {
    private Engine engine;
    //other variables elided
    public Car() {
        this.engine = new Engine();
    }
    public void turnOnEngine() {
        this.engine.start();
    }
    public void turnOffEngine() {
        this.engine.shutOff();
    }
    public void cleanEngine() {
        this.engine.steamClean();
    }
    public void drive() {
        //code elided
    }
    //more methods elided
}
```

Modeling Inheritance Example (3/3)

- Step 2 – define a subclass
- Use the `extends` keyword
  - `extends` means "is a subclass of" or "inherits from"
  - `extends` lets the compiler know that `Convertible` is inheriting from `Car`
  - whenever you create a class that inherits from a superclass, the class declaration must include:

    `extends <superclass name>`

```
public class Convertible extends Car {
    //code elided for now
}
```

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Adding new methods (1/3)

- We don't need to (re)declare any inherited methods
- Our `Convertible` class does more than a generic `Car` class
- Let's add a `putTopDown()` method and an instance variable `top` (initialized in constructor)

```
public class Convertible extends Car {

    private ConvertibleTop top;
    public Convertible(){
        this.top = new ConvertibleTop();
    }

    public void putTopDown(){
        //code using this.top elided
    }

}
```


Adding new methods (2/3)

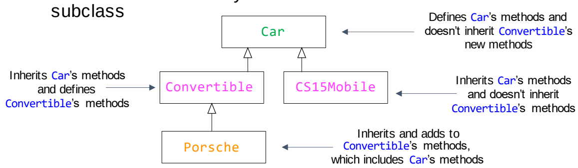
- Now, let's make a new `CS15Mobile` class that also inherits from `Car`
- Can `CS15Mobile` `putTopDown()`?
  - nope- that method is defined in `Convertible`, so only `Convertible` and `Convertible`'s subclasses can use it

```
public class Convertible extends Car {
    private ConvertibleTop top;

    public Convertible(){
        this.top = new ConvertibleTop();
    }

    public void putTopDown(){
        //code with this.top elided
    }
}
```

```
public class CS15Mobile extends Car {

    public CS15Mobile(){

    }

    //other methods elided
}
```

Adding new methods (3/3)

- You can add specialized functionality to a subclass by defining methods in that subclass
- These methods can only be inherited if a class extends this subclass



Overriding methods (1/4)

- A `Convertible` may decide `Car`'s `drive()` method just doesn't cut it
  - a `Convertible` drives much faster than a regular car
- Can **override** a parent class's method and redefine it

```
public class Car {

    private Engine engine;
    //other variables elided

    public Car() {
        this.engine = new Engine();
    }
    public void drive() {
        this.goFortyMPH();
    }
    public void goFortyMPH() {
        //code elided
    }
    //more methods elided
}
```


Overriding methods (2/4)

- `@Override` should look familiar!
  - saw it when we implemented an interface method
- Include `@Override` right before declaring method we want to override
- `@Override` is an annotation – in a subclass it signals to compiler (and to anyone reading your code) that you're overriding an inherited method of the superclass

```
public class Convertible extends Car {

    public Convertible() {

    }

    @Override
    public void drive(){
        this.goSixtyMPH();
    }

    public void goSixtyMPH(){
        //code elided
    }
}
```

Overriding methods (3/4)

- We override methods by re-declaring and re-defining them
- Be careful – in declaration, the **method signature** (name of method and list of parameters) and **return type** must match that of the superclass's method exactly*!
  - or else Java will create a new, additional method instead of overriding
- `drive()` is the **method signature**, indicating that name of method is `drive` and takes in no parameters; the return type must also match

```
public class Convertible extends Car {

    public Convertible() {

    }

    @Override
    public void drive() {
        this.goSixtyMPH();
    }

    public void goSixtyMPH() {
        //code elided
    }
}
```

*return type also must be the same or be a subtype of superclass's method's return type, e.g., if the superclass method returns a `Car`, the subclass method should return a `Car` or a subclass of `Car`

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Overriding methods (4/4)

- Fill in body of overridden method with whatever we want a `Convertible` to do when it is told to `drive`
- In this case, we're fully overriding the method
- When a `Convertible` is told to `drive`, it will execute this code instead of the code in its superclass's `drive` method (Java compiler does this automagically - stay tuned)

```
public class Convertible extends Car {

    public Convertible() {

    }

    @Override
    public void drive(){
        this.goSixtyMPH();
    }

    public void goSixtyMPH(){
        //code elided
    }
}
```


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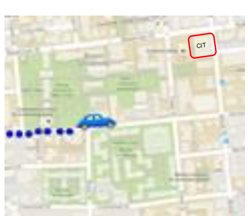
Partially overriding methods (1/6)

- Let's say we want to keep track of `CS15Mobile`'s route
- `CS15Mobile` drives at the same speed as a `Car`, but it adds dots to a map



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Partially overriding methods (2/6)

- We need a `CS15Mobile` to start driving normally, and then start adding dots
- To do this, we **partially override** the `drive()` method
  - partially accept the inheritance relationship

```
Car:
    void drive:
      Go 40mph

CS15Mobile:
    void drive:
      Go 40mph
      Add dot to map
```


Partially overriding methods (3/6)

- Just like previous example, use `@Override` to tell compiler we're about to override an inherited method
- Declare the `drive()` method, making sure that the method signature and return type match that of superclass's `drive` method

```
public class CS15Mobile extends Car {

    public CS15Mobile() {
        //code elided
    }

    @Override
    public void drive(){
        super.drive();
        this.addDotToMap();
    }

    public void addDotToMap() {
        //code elided
    }

}
```


Partially overriding methods (4/6)

- When a `CS15Mobile` drives, it first does what every `Car` does: goes 40mph
- First thing to do in `CS15Mobile`'s `drive` method therefore is "drive as if I were just a `Car`, and nothing more"
- Keyword `super` used to invoke original inherited method from parent: in this case, `drive` as implemented in parent `Car`

```
public class CS15Mobile extends Car {

    public CS15Mobile() {
        //code elided
    }

    @Override
    public void drive(){
        // super refers to parent class
        super.drive();
        this.addDotToMap();
    }

    public void addDotToMap() {
        //code elided
    }
}
```

Partially overriding methods (5/6)

- After doing everything a `Car` does to `drive`, the `CS15Mobile` needs to add a dot to the map!
- In this example, the `CS15Mobile` "partially overrides" the `Car`'s `drive` method: it drives the way its superclass does, then does something specialized

```
public class CS15Mobile extends Car {

    public CS15Mobile() {
        //code elided
    }

    @Override
    public void drive(){
        super.drive();
        this.addDotToMap();
    }

    public void addDotToMap() {
        //code elided
    }
}
```


Partially overriding methods (6/6)

- If we think our `CS15Mobile` should move a little more, we can call `super.drive()` multiple times
- While you can use `super` to call other methods in the parent class, it's strongly discouraged
  - use the `this` keyword instead; parent's methods are inherited by the subclass
  - **except** when you are calling the parent's method within the child's method of the same name
    - what would happen if we said `this.drive()` instead of `super.drive()`?

`StackOverflowError`

```
public class CS15Mobile extends Car {

    public CS15Mobile() {
        //code elided
    }

    @Override
    public void drive(){
        this.turnOnEngine();
        this.drive();
        this.addDotToMap();
        super.drive();
        super.drive();
        this.addDotToMap();
        this.turnOffEngine();
    }
}
```

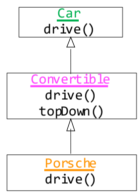
bad form!

Method Resolution (1/3)

- When we call `drive()` on some instance of `Convertible`, how does the compiler know which version of the method to call?
- Starts by looking at the instance's class, regardless of where class is in the inheritance hierarchy
  - if method is defined in the instance's class, Java compiler calls it
  - otherwise, it checks the superclass
    - if method is explicitly defined in superclass, compiler uses it
    - otherwise, checks superclass up one level… etc.
    - if a class has no superclass, then compiler throws an error

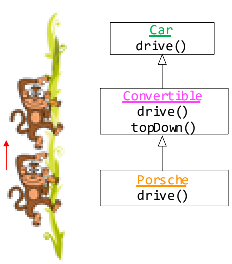
Method Resolution (2/3)

- Essentially, the Java compiler "walks up the class inheritance tree" from subclass to superclass until it either:
  - finds the method, and calls it
  - doesn't find the method, and generates a compile-time error. Compiler won't let you give a command for which there is no method!



Method Resolution (3/3)

- When we call `drive()` on a `Porsche`, Java compiler uses the `drive()` method defined in `Porsche`
- When we call `topDown()` on a `Porsche`, Java compiler uses the `topDown()` method defined in `Convertible`



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Inheritance Example

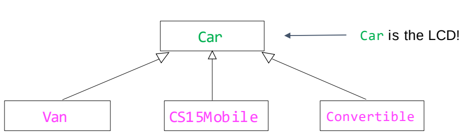
- Let's use the car inheritance relationship in an actual program
- Remember the race program from last lecture?
- Silly Premise
  - the department received a ~mysterious~ donation and can now afford to give all TAs cars! (we wish)
  - Lexi and Cannon want to race from their dorms to the CIT in their brand new cars
    - whoever gets there first, wins!
    - you get to choose which car they get to use

Inheritance Example

- What classes will we need for this lecture's program?
  - old: `App`, `Racer`
  - new: `Car`, `Convertible`, `CS15Mobile`, `Van`
- Rather than using any instances of type `Transporter`, Lexi and Cannon are limited to only using instances of type `Car`
  - for now, transportation options have moved from `Bike` and `Car` to `Convertible`, `CS15Mobile`, and `Van`
- How do we modify `Racer`'s `useTransportation()` method to reflect that?
  - can we use polymorphism here?

Inheritance and Polymorphism (1/3)

- What is the "lowest common denominator" between `Convertible`, `CS15Mobile`, and `Van`?



Inheritance and Polymorphism (2/3)

- Can we refer to `CS15Mobile` as its more generic parent, `Car`?
- Declaring `CS15Mobile` as type `Car` follows the same process as declaring a `Bike` as of type `Transporter`
- `Transporter` and `Car` are the declared types
- `Bike` and `CS15Mobile` are the actual types

```
Transporter bike = new Bike();

Car car = new CS15Mobile();
```


Inheritance and Polymorphism (3/3)

- What would happen if we made `Car` the type of the parameter passed into `useTransportation`?
  - can only pass in `Car` and subclasses of `Car`, i.e., anything that is-a `Car`

```
public class Racer {

    //previous code elided

    public void useTransportation(Car myCar) {
        //code elided
    }
}
```

Is this legal?

```
Car convertible = new Convertible();
this.lexi.useTransportation(convertible);
```
✓

```
Convertible convertible = new Convertible();
this.lexi.useTransportation(convertible);
```
✓

```
Car bike = new Bike();
this.lexi.useTransportation(bike);
```
✗

`Bike` is not a subclass of `Car` (the two classes have no relationship), so you cannot treat an instance of `Bike` as a `Car`

Inheritance and Polymorphism (1/2)

- Let's define `useTransportation()`
- What method should we call on `myCar`?
  - every `Car` knows how to `drive`, which means we can guarantee that every subclass of `Car` also knows how to `drive`

```
public class Racer {

    //previous code elided

    public void useTransportation(Car myCar) {
        myCar.drive();
    }
}
```


Inheritance and Polymorphism (2/2)

- That's all we needed to do!
- Our inheritance structure looks really similar to our interfaces structure
  - therefore, we only need to change 2 lines in `Racer` in order to use any of our new `Car`s!
  - but remember- what's happening behind the curtain is **very different**: method resolution "climbs up the hierarchy" for inheritance
- Polymorphism is an incredibly powerful tool
  - allows for generic programming
  - treats multiple classes as their generic type while still allowing specific method implementations for specific subclasses to be executed
- Maximum flexibility: polymorphism + inheritance and/or interfaces

Polymorphism Review

- Polymorphism allows programmers to refer to instances of a subclass or a class which implements an interface as type <superclass> or as type <interface>, respectively
  - relaxation of strict type checking, particularly useful in parameter passing
    - e.g. `drive(Car myCar){…}` can take in any kind of `Car` that is an instance of a subclass of `Car` and `Race(Transporter myTransportation){…}` can take in any instance of a class that implements the `Transporter` interface
- Advantages
  - makes code generic and extensible
  - treats multiple classes as their generic (declared) type while still allowing instances of specific subclasses to execute their specific method implementations through method resolution based on the actual type
- Disadvantages
  - sacrifices specificity for generality
    - can only call methods specified in superclass or interface, i.e., no `putTopDown()`

TopHat Question 2

Join Code: 504547

In the following code, the `HungerGames` subclass extends the `SurvivalGame` superclass. `SurvivalGame` defines a `play()` method, and `HungerGames` **overrides** that method.

```
SurvivalGame game = new HungerGames();
game.play();
```

Whose `play()` method is being called?

A. SurvivalGame

B. HungerGames

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Accessing Superclass Instance Variables (1/3)

- Can `Convertible` access `engine`?
- `private` instance variables or `private` methods of a superclass are **not directly inherited** by its subclasses
  - superclass protects them from manipulation by its own subclasses
- `Convertible` cannot directly access any of `Car`'s private instance variables
- In fact, `Convertible` is completely unaware that `engine` exists! This is encapsulation for safety!
  - programmers typically don't have access to superclass' code – they know what methods are available (i.e., their declarations) but not how they're implemented

```
public class Car {
    private Engine engine;
    //other variables elided
    public Car(){
        this.engine = new Engine();
    }
    public void turnOnEngine() {
        this.engine.start();
    }
    public void turnOffEngine() {
        this.engine.shutOff();
    }
    public void drive() {
        //code elided
    }
    //more methods elided
}
```

Accessing Superclass Instance Variables (2/3)

- But that's not the whole story…
- While every instance of a subclass of Car is-a Car, it can't access engine directly by Convertible's specialized methods

```
public class Convertible extends Car {
    //constructor elided
    public void cleanCar() {
        this.engine.steamClean();
        //additional code
    }
}
```

- Instead parent can make a method available for us by its subclasses (cleanEngine())

```
public class Car {
    private Engine engine;
    //other instance variables elided

    //constructor elided
    public void cleanEngine() {
        this.engine.steamClean();
    }
}
```

```
public class Convertible extends Car {
    //constructor elided
    public void cleanCar() {
        this.cleanEngine();
        //additional code
    }
}
```


Accessing Superclass Instance Variables (3/3)

- What if superclass's designer wants to allow subclasses access (in a safe way) to some of its instance variables directly for their own needs?
- For example, different subclasses might each want to do something different to an engine, but we don't want to factor out and put each specialized method into the superclass Car (or more typically, we can't even access Car to modify it)
  - Car can provide controlled indirect access by defining public accessor and mutator methods for private instance variables, a familiar pattern!

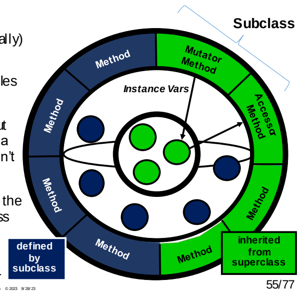
Defining Accessors and Mutators in Superclass

- Assume Car also has radio; Radio class defines setFavorite() method
- Car can provide access to radio via getRadio() and setRadio(…) methods
- Important to consider this design decision in your own programs – which properties will need to be directly accessible to other classes?
  - don't always need both set and get
  - **they should be provided very sparingly**
  - setter should **error-check** received parameter(s) so it retains some control, e.g., don't allow negative values

```
public class Car {
    private Radio radio;
    //other instance variables
    public Car() {
        this.radio = new Radio();
        //other initialization
    }
    //other methods
    public Radio getRadio(){          // accessor
        return this.radio;
    }
    public void setRadio(Radio myRadio){   // mutator
        this.radio = myRadio;
    }
}
```

Review of Inheritance and Indirect (“pseudo”) Inheritance of Instance Variables

- Methods are inherited, potentially (partially) overridden
- Additional methods and instance variables are defined to specialize the subclass
- Instance variables are also inherited, but only “pseudo-inherited”, i.e., are part of a subclass’ set of properties…but they can’t be directly accessed by the subclass
- Instead, accessor/mutator methods are the proper mechanism with which a subclass can change those properties
- This provides the parent with protection against children’s potential misbehavior



Calling Accessors/Mutators From Subclass

- `Convertible` can get a reference to `radio` by calling `this.getRadio()`
  - subclasses automatically inherit these public accessor and mutator methods
- Note that by using **“double dot,”** we’ve chained two methods together
  - first, `getRadio` is called, and returns the `radio`
  - next, `setFavorite` is called on that `radio`

```
public class Convertible extends Car {
    public Convertible() {
    }

    public void setRadioPresets(){
        this.getRadio().setFavorite(1, 95.5);
        this.getRadio().setFavorite(2, 92.3);
    }
}
```

inherited method

Let’s step through some code

- Somewhere in our code, a `Convertible` is instantiated

```
//somewhere in the program
Convertible convertible = new Convertible();
convertible.setRadioPresets();
```

- The next line of code calls `setRadioPresets()`
- Let’s step into `setRadioPresets()`

Code Step Through

- Someone calls `setRadioPresets()` on a `Convertible` – first line is `this.getRadio()`
- `getRadio()` returns `radio`
- What is the value of `radio` at this point in the code?
  - was it initialized when `Convertible` was instantiated?
  - Java will, in fact, call superclass constructor by default, but we don't want to rely on that

```
public class Convertible extends Car {
   public Convertible() { //code elided
   }

   public void setRadioPresets() {
      this.getRadio().setFavorite(1, 95.5);
      this.getRadio().setFavorite(2, 92.3);
   }
}
```

```
public class Car {

   private Radio radio;
   //constructor initializing radio and
   //other code elided

   public Radio getRadio() {
      return this.radio;
   }
}
```

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Making Sure Superclass's Instance Variables are Initialized

- `Convertible` may declare its own instance variables, which are initialized in its constructor, but what about instance variables pseudo-inherited from `Car`?
- `Car`'s instance variables are initialized in its constructor
  - but we don't instantiate a `Car` when we instantiate a `Convertible`!
- When we instantiate `Convertible`, how can we make sure `Car`'s instance variables are initialized too via an explicit call?
  - want to call `Car`'s constructor without making an instance of a `Car` via `new`

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`super()`: Invoking Superclass's Constructor (1/4)

- `Car`'s instance variables (like `radio`) are initialized in `Car`'s constructor
- To make sure that `radio` is initialized whenever we instantiate a `Convertible`, we need to call superclass `Car`'s constructor
- The syntax for doing this is "`super()`"
- Here `super()` is the parent's constructor; before, in partial overriding when we used `super.drive()`, "super" referred to the parent itself (verb vs. noun distinction)

```
public class Convertible extends Car {

   private ConvertibleTop top;

   public Convertible() {
      super();
      this.top = new ConvertibleTop();
      this.setRadioPresets();
   }

   public void setRadioPresets(){
      this.getRadio().setFavorite(1, 95.5);
      this.getRadio().setFavorite(2, 92.3);
   }
}
```

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super(): Invoking Superclass's Constructor (2/4)

- We call super() from the subclass's constructor to make sure the superclass's instance variables are initialized properly
  - even though we aren't instantiating an instance of the superclass, we need to **construct** the superclass to initialize its instance variables
- **Can only make this call once**, and it must be the very **first** line in the subclass's constructor

```
public class Convertible extends Car {

   private ConvertibleTop top;

   public Convertible() {
      super();
      this.top = new ConvertibleTop();
      this.setRadioPresets();
   }

   public void setRadioPresets(){
      this.getRadio().setFavorite(1, 95.5);
      this.getRadio().setFavorite(2, 92.3);
   }
}
```

Note: Our call to super() creates one copy of the instance variables, located deep inside the subclass, but **accessible to subclass only if class provides setters/getters** (see diagram in slide 55)

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super(): Invoking Superclass's Constructor (3/4)

- What if the superclass's constructor takes in a parameter?
- We've modified Car's constructor to take in a Racer as a parameter
- How do we invoke this constructor correctly from the subclass?

```
public class Car {

    private Racer driver;
    public Car(Racer myDriver) {
        this.driver = myDriver;
    }
    public Racer getRacer() {
        return this.driver;
    }
}
```

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super(): Invoking Superclass's Constructor (4/4)

- In this case, need the Convertible's constructor to also take in a Racer
- This way, Convertible can pass on the instance of Racer it receives to Car's constructor, super()
- The Racer is passed as an argument to super() – now Racer's constructor will initialize Car's driver to the instance of Racer that was passed to the Convertible

```
public class Convertible extends Car {

    private ConvertibleTop top;

    public Convertible(Racer myRacer) {
        super(myRacer);
        this.top = new ConvertibleTop();
    }

    public void dragRace(){
        this.getRacer().move();
    }
}
```

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What if we don't call super()?

- If you don't explicitly call super() first thing in your constructor, Java compiler automatically calls it for you, passing in no arguments
- But if superclass's constructor requires an argument, you'll get an error!
- In this case, we get a **compiler error** saying that there is no constructor "public Car()", since it was declared with a parameter

```
public class Convertible extends Car {

    private ConvertibleTop top;

    public Convertible(Racer myRacer) {
        //oops, forgot to call super(…)
        this.top = new ConvertibleTop();
    }

    public void dragRace(){
        this.getRacer().move();
    }
}
```


Constructor Parameters

- Does CS15Mobile need to have the same number of parameters as Car?
- Nope!
  - as long as Car's parameters are among the passed parameters, CS15Mobile's constructor can take in anything else it needs for its job
- Let's modify all the subclasses of Car to take in a number of Passengers

Constructor Parameters

- Notice how we only need to pass driver to super()
- We can add additional parameters in the constructor that only the subclasses will use

```
public class Convertible extends Car {
    private Passenger p1;
    public Convertible(Racer myRacer, Passenger p1) {
        super(myRacer);
        this.p1 = p1;
    }
    //code with passengers elided
}
```

```
public class CS15Mobile extends Car {
    private Passenger p1, p2, p3, p4;
    public CS15Mobile(Racer myDriver, Passenger p1,
      Passenger p2, Passenger p3, Passenger p4) {
        super(myDriver);
      this.p1 = p1;
      this.p2 = p2;
      this.p3 = p3;
      this.p4 = p4;
    }
    //code with passengers elided
}
```

Outline

`abstract` Methods and Classes (1/6)

- What if we wanted to seat all of the passengers in the car?
- `CS15Mobile`, `Convertible`, and `Van` all have different numbers of seats
  - they will all have different implementations of the same method

`abstract` Methods and Classes (2/6)

- We declare a method `abstract` in a superclass when the subclasses can't really re-use any implementation the superclass might provide – no code-reuse
- In this case, we know that all `Car`s should `loadPassengers`, but each subclass will `loadPassengers` very differently
- `abstract` method is declared in superclass, but not defined – it is up to subclasses farther down hierarchy to provide their own implementations
- Thus superclass specifies a contractual obligation to its subclasses – just like an interface does to its implementors

abstract Methods and Classes (3/6)

- Here, we've modified Car to make it an abstract class: a class with at least one abstract method
- We declare both Car and its loadPassengers method abstract: if one of a class's methods is abstract, the class itself must also be declared abstract
- An abstract method is only **declared** by the superclass, not **defined** – thus use semicolon after declaration instead of curly braces

```
public abstract class Car {

    private Racer driver;

    public Car(Racer myDriver) {
        this.driver = myDriver;
    }

    public abstract void loadPassengers();

}
```

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abstract Methods and Classes (4/6)

- How do you load Passengers?
  - every Passenger must be told to sit in a specific Seat in a physical Car
  - SeatGenerator has methods that returns a Seat in a specific logical position

```
public class Passenger {

    public Passenger() { //code elided }
    public void sit(Seat st) { //code elided }
}
```

```
public class SeatGenerator {

    public SeatGenerator () {//code elided }
    public Seat getShotgun() {//code elided }
    public Seat getBackLeft() {//code elided }
    public Seat getBackCenter() {//code elided }
    public Seat getBackRight() {//code elided }
    public Seat getMiddleLeft() {//code elided }
    public Seat getMiddleRight() {//code elided }
}
```

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abstract Methods and Classes (5/6)

```
public class Convertible extends Car{
    @Override
    public void loadPassengers(){
        SeatGenerator seatGen = new
          SeatGenerator();
        this.passenger1.sit(
          seatGen.getShotgun());
    }
}
```

```
public class CS15Mobile extends Car{
   @Override
   public void loadPassengers(){
       SeatGenerator seatGen = new
         SeatGenerator();
       this.passenger1.sit(seatGen.getShotgun());
       this.passenger2.sit(seatGen.getBackLeft());
       this.passenger3.sit(seatGen.getBackCenter());
   }
}
```

```
public class Van extends Car{
    @Override
    public void loadPassengers(){
       SeatGenerator seatGen = new SeatGenerator();
       this.passenger1.sit(seatGen.getMiddleLeft());
       this.passenger2.sit(seatGen.getMiddleRight());
       this.passenger3.sit(seatGen.getBackLeft());
        //more code elided
    }
}
```

- All concrete subclasses of Car override by providing a concrete implementation for Car's abstract loadPassengers() method
- As usual, method signature and return type must match the one that Car declared

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abstract Methods and Classes (6/6)

- abstract classes **cannot be instantiated**!
  - this makes sense – shouldn't be able to just instantiate a generic Car, since it has no code to loadPassengers()
  - instead, provide implementation of loadPassengers() in concrete subclass, and instantiate subclass
- Subclass at any level in inheritance hierarchy can make an abstract method concrete by providing implementation
  - it's common to have multiple consecutive levels of abstract classes before reaching a concrete class
- Even though an abstract class can't be instantiated, its constructor must still be invoked via super() by a subclass
  - because only the superclass knows about (and therefore only it can initialize) its own instance variables

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So.. What's the difference?

- You might be wondering: what's the difference between abstract classes and interfaces?
- abstract classes:
  - can define instance variables
  - can define a mix of concrete and abstract methods
  - you can only inherit from one class
- Interfaces:
  - cannot define any instance variables/concrete methods
  - has only undefined methods (no instance variables)
  - you can implement multiple interfaces

Note: Java, like most programming languages, is evolving. In Java 8, interfaces and abstract classes are even closer in that you can have concrete methods in interfaces. We will not make use of this in CS15.

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Summary

- **Inheritance** models very similar classes
  - factor out all similar capabilities into a generic superclass
  - superclasses can:
    - declare and define methods
    - declare abstract methods
  - subclasses can:
    - inherit methods from a superclass
    - define their own specialized methods
    - completely/partially override an inherited method
- **Polymorphism** allows programmers to reference instances of a subclass as their superclass
- Inheritance, Interfaces, and Polymorphism take generic programming to the max – more in later lecture

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Quick Comparison: Inheritance and Interfaces

Inheritance

- Each subclass can only inherit from one superclass
- Useful when classes have more similarities than differences and can share code
- **"is-a"** relationship: classes that extend another class
  - i.e. A `Convertible` is-a `Car`
- Can define more methods to specialize
  - i.e. `Convertible` putting its top down

Interface

- Classes can implement as many interfaces as you want
- Useful for when classes have more differences than similarities
- **"acts-as"** relationship: classes implementing an interface define its methods
- Can only use methods declared in the interface

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Announcements

- Tic Tac Toe deadlines
  - **Early handin: today 9/28** (+2 bonus points)
  - **On-time handin: Saturday 9/30**
  - **Late handin: Monday 10/2** (-8 for late handin, but 4 late days to use throughout semester)
- SRC Extra Credit Discussion **(1 extra point on final grade)!**
  - See Ed or website for details
  - Sunday 10/22 at 2pm,3pm and 4pm
- HTA Hours: Fridays 3 - 4pm in CIT210, or email us!
- ~ special surprise ~ at Tuesday's lecture

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Topics in Socially Responsible Computing

CS15 Fall 2023

2022	2023

AI won an art contest, and artists are furious

AS ACTORS STRIKE FOR AI PROTECTIONS, NETFLIX LISTS $900,000 AI JOB

BuzzFeed Is Quietly Publishing Whole AI-Generated Articles, Not Just Quizzes

These read like a proof of concept for replacing human writers.

IBM to pause hiring in plan to replace 7800 jobs with AI, Bloomberg reports

Source: CNN, Reuters, The Intercept, The Verge

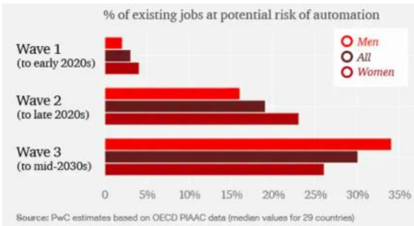
Automation as a force for good

- Take over jobs with dangerous working conditions
- Improve workers' health and safety
- Take over night shifts
- Take over mind-numbing, repetitive jobs
- Work collaboratively with human workers

The flip side of automation…

- Uncertainty as to whether it creates as many jobs as it removes
- Can reduce worker welfare if not deployed well

2018 PwC Report on Automation Replacing Workers

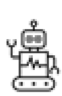


Automating physical labor	Automating non-physical, routine labor	Automating creative work
• Factory automation • Self-driving trucks! (est. 3.5 million drivers - US Census)	• Bookkeepers • Accountants • Radiologists • Lawyers (est. 62 million jobs - Fed)	• Branding • Logo design • Voice acting • ... even art! • Even programming!
(blue collar work)	(white collar work)	(creator economy)

How AI is predicted to enter the workforce

How can we ensure that automation has good impacts on the labor force?

Support for workers – education & reskilling



Hard Skills

Soft Skills

Estimated to cost $24,800 per person in the United States! (World Bank, Boston Consulting Group, 2019)

Reskilling Initiatives

Company Specific Programs:

- Ex. Amazon Career Choice Program
- According to BCG ~24% of large companies link reskilling efforts to their corporate strategy

Government Efforts

- 2019 Trump Executive Order addressed AI's effect on workforce
- Biden has indicated plans to release a similar executive order soon

Biden tells coal miners to "learn to code"

Ethical limits of AI

Explored this week in lab!

Source: MIT Technology Review

In the limit…

… will anyone need to work?

"Yet there is no country and no people, I think, who can look forward to the age of leisure and of abundance without a dread. For we have been trained too long to strive and not to enjoy."

John Maynard Keynes, *Economic Possibilities for our Grandchildren (1930)*