CSE201: Monsoon 2024
Advanced Programming

Lecture 05: Interfaces and Polymorphism

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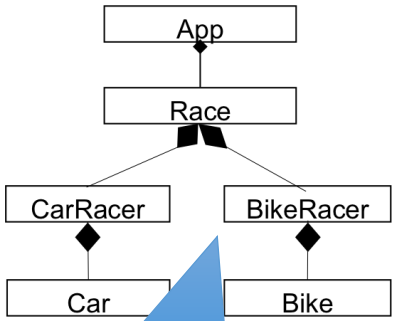
Last Lecture



- Imagine this program:
  - Sophia and Dan are racing from their home to city center
    - whoever gets there first, wins!
    - catch: they don't get to choose their method of transportation
- Design a program that
  - assigns mode of transportation to each racer
  - starts the race
- For now, assume transportation options are `Car` and `Bike`

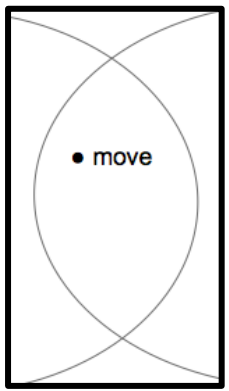
Do we need two different Racer classes??

How about one Racer class with different methods?

```
public class Racer {

    public Racer() {
        //constructor
    }
    public void useCar(Car myCar){//code elided}
    public void useBike(Bike myBike){//code elided}
    public void useHoverboard(Hoverboard myHb){//code elided}
    public void useHorse(Horse myHorse){//code elided}
    public void useScooter(Scooter myScooter){//code elided}
    public void useMotorcycle(Motorcycle myMc) {//code elided}
    public void usePogoStick(PogoStick myPogo){//code elided}
    // And more…
}
```

Any similarities?



Interfaces in Java

- Group similar capabilities/function of different classes together
- Interfaces can only declare methods - not define them
- Interfaces are contracts that classes agree to
- If classes choose to implement given interface, it must define all methods declared in interface
  - if classes don't implement one of interface's methods, the compiler raises error

Declaring an Interface

```
public interface Transporter {

    public void move();

}
```

`@Override` is an annotation – a signal to the compiler (and to anyone reading your code)

Implementing an Interface

```
public class Car implements
Transporter {
    public Car() {
        //code elided
    }
    public void drive(){
        //code elided
    }
    @Override
    public void move(){
        this.drive();
        this.brake();
        this.drive();
    }
    //more methods elided
}
```

This Lecture

- Interfaces and Polymorphism

Slide acknowledgements: CS15, Brown University

Back to the Race

- Let's make transportation classes use an interface

```
public class Car implements Transporter{

    public Car() {
        //code elided
    }
    public void drive(){
        //code elided
    }
    @Override
    public void move() {
        this.drive();
    }
    //more methods elided
}
```

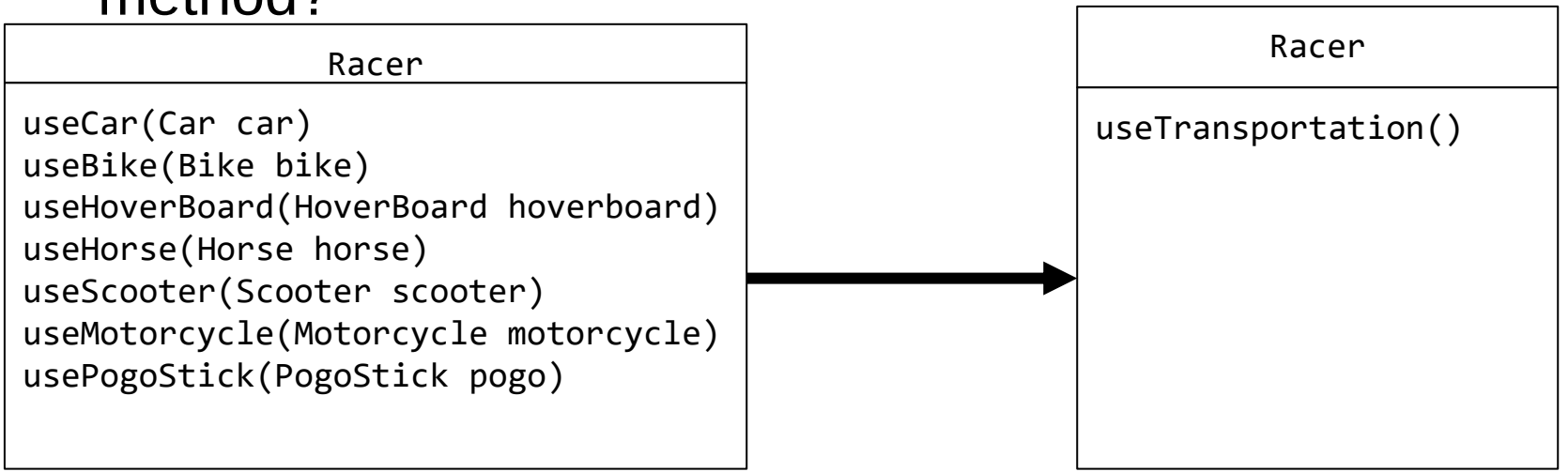
```
public class Bike implements Transporter{

    public Bike() {
        //code elided
    }
    public void pedal(){
        //code elided
    }
    @Override
    public void move() {
        this.pedal();
    }

    //more methods elided
}
```

Leveraging Interfaces

- Given that there's guarantee anything that implements `Transporter` knows how to `move`, how can it be leveraged to create single `useTransportation()` method?



Introducing Polymorphism

- Poly = many, morph = forms
- A way of coding generically
  - way of referencing many related objects as one generic type
    - cars and bikes can both `move()` → refer to them as `Transporter` objects
    - phones and camera can both `getCharged()` → refer to them as `Chargeable` objects, i.e., objects that implement `Chargeable` interface
    - cars and mobile phones can both `playRadio()` → refer to them as `RadioPlayer` objects
- How do we write one generic `useTransportation()` method?

What would this look like in code?

```
public class Racer {

    //previous code elided
    public void useTransportation(Transporter transportation) {
        transportation.move();
    }

}
```


This is polymorphism! `transportation` object passed in could be instance of `Car`, `Bike`, etc., i.e., any class that implements the interface

Let’s break this down.

```
public class Racer {

    //previous code elided
    public void useTransportation(Transporter transportation) {
        transportation.move();
    }

}
```

1. Actual vs. Declared Type
2. Method resolution

Actual vs. Declared Type (1/2)

- Consider following piece of code:

```
Transporter dansCar = new Car();
```

- ...is that legal?
  - doesn't Java do strict type checking? (type on LHS = type on RHS)
  - how can instances of `Car` get stored in `Transporter` variable?

Actual vs. Declared Type (2/2)

- Can treat `Car`/`Bike` object as `Transporter` objects
- `Car` is the actual type
  - Java will look in this class for the definition of the method
- `Transporter` is declared type
  - Java will limit caller so it can only call methods on instances that are declared as `Transporter` objects
- If `Car` defines `playRadio()` method. Is `transportation.playRadio()` correct?

```
Transporter transportation = new Car();
transportation.playRadio();
```

Nope. The `playRadio()` method is not declared in `Transporter` interface, therefore Java does not recognize it as viable method call

Determining the Declared Type

- What methods do `Car` and `Bike` have in common?
  - `move()`
- How do we know that?
  - they implement `Transporter`
    - guarantees that they have `move()` method
- Think of `Transporter` like the "lowest common denominator"
  - it's what all transportation classes will have in common

```
Bike implements Transporter
void move();
void dropKickstand();//etc.
```

```
Car implements Transporter
void move();
void playRadio();//etc.
```

Is this legal?

```
Transporter sophiasBike = new Bike();
```

```
Transporter sophiasCar = new Car();
```

```
Transporter sophiasRadio = new Radio();
```

`Radio` wouldn't implement `Transporter`. Since `Radio` cannot "act as" a `Transporter`, you cannot treat it as `Transporter`.

Motivations for Polymorphism

- Many different kinds of transportation but only care about their shared capability
  - i.e. how they move
- Polymorphism let programmers sacrifice specificity for generality
  - treat any number of classes as their lowest common denominator
  - limited to methods declared in that denominator
    - can only use methods declared in `Transporter`
- For this program, that sacrifice is ok!
  - `Racer` doesn't care if instance of `Car` can `playRadio()` or if instance of `Bike` can `dropKickstand()`
  - only method `Racer` wants to call is `move()`

Polymorphism in Parameters

- What are implications of this method declaration?

```
public void useTransportation(Transporter transportation) {
    //code elided
}
```

- `useTransportation` will accept any object that implements `Transporter`
- `useTransportation` can only call methods declared in `Transporter`

Is this legal?

```
Transporter sophiasBike = new Bike();
_sophia.useTransportation(sophiasBike);

Car sophiasCar = new Car();
_sophia.useTransportation(sophiasCar);

Radio sophiasRadio = new Radio();
_sophia.useTransportation(sophiasRadio);
```

Even though `sophiasCar` is declared as a `Car`, the compiler can still verify that it implements `Transporter`.

A `Radio` wouldn't implement `Transporter`. Therefore, `useTransportation()` cannot treat it like a `Transporter` object.

Why `move()`? (1/2)

- Why call `move()`?
- What `move()` method gets executed?

```
public class Racer {

    //previous code elided
    public void useTransportation(Transporter transportation) {
        transportation.move();
    }

}
```

Why `move()`? (2/2)

- Only have access to `Transporter` object
  - cannot call `transportation.drive()`or `transportation.pedal()`
    - that's okay, because all that's needed is `move()`
  - limited to the methods declared in `Transporter`

Method Resolution: Which `move()` is executed?

- Consider this line of code in `Race` class:

```
_sophia.useTransportation(new Bike());
```

- Remember what `useTransportation` method looked like

```
public void useTransportation(Transporter transportation) {
    transportation.move();
}
```

What is “actual type” of transportation in this method invocation?

Method Resolution (1/4)

```
public class Race {

    private Racer_sophia;
    //previous code elided

    public void startRace() {
        _sophia.useTransportation(new Bike());
    }
}
```

```
public class Racer {
    //previous code elided

    public void useTransportation(Transporter
    transportation) {
        transportation.move();
    }

}
```

- `Bike` is actual type
  - `Racer` was handed instance of `Bike`
    - `new Bike()` is argument
- `Transporter` is declared type
  - `Racer` treats `Bike` object as `Transporter` object
- So… what happens in `transportation.move()`?
  - What `move()` method gets used?

Method Resolution (2/4)

```
public class Race {
    //previous code elided
    public void startRace() {
        _sophia.useTransportation(new Bike());
    }
}
```

```
public class Racer {
    //previous code elided
    public void useTransportation(Transporter
    transportation) {
        transportation.move();
    }
}
```

```
public class Bike implements Transporter {
    //previous code elided
    public void move() {
        this.pedal();
    }
}
```

- `_Sophia` is a Racer
- `Bike`'s `move()` method gets used
- Why?
  - `Bike` is actual type
    - Java will execute methods defined in `Bike` class
  - `Transporter` is declared type
    - Java limits methods that can be called to those declared in `Transporter` interface

Method Resolution (3/4)

- What if `_sophia` received instance of `Car`?
  - What `move()` method would get called then?
    - `Car`'s!

```
public class Race {

    //previous code elided

    public void startRace() {
        _sophia.useTransportation(new Car());
    }
}
```

Method Resolution (4/4)

- This method resolution is example of dynamic binding, which is when actual method implementation used is not determined until runtime
  - contrast with static binding, in which method gets resolved at compile time
- `move()` method is bound dynamically – Java does not know which `move()` method to use until program runs
  - same "`transport.move()`" line of code could be executed indefinite number of times with different method resolution each time

Clicker Question

Given the following class:

```
public class Laptop implements Typeable, Clickable {
    public void type() {
      // code elided
    }
    public void click() {
        //code elided
}
```

Given that typeable has declared the type method and clickable has declared the click method, which of the following calls is/are valid?

A.
```
Typeable macBook= new Typeable();
macBook.type();
```

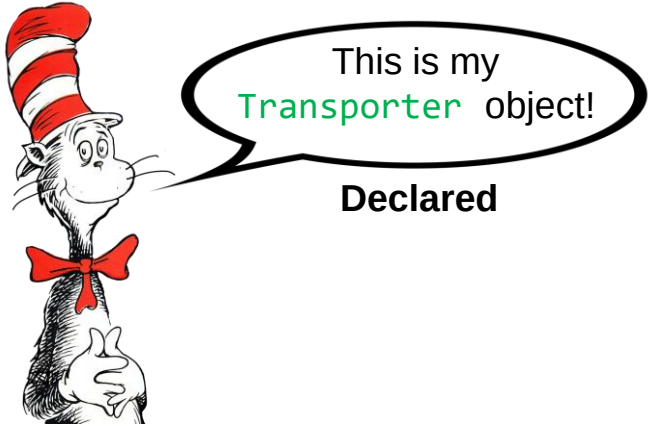
B.
```
Clickable macBook = new Clickable();
macBook.type();
```

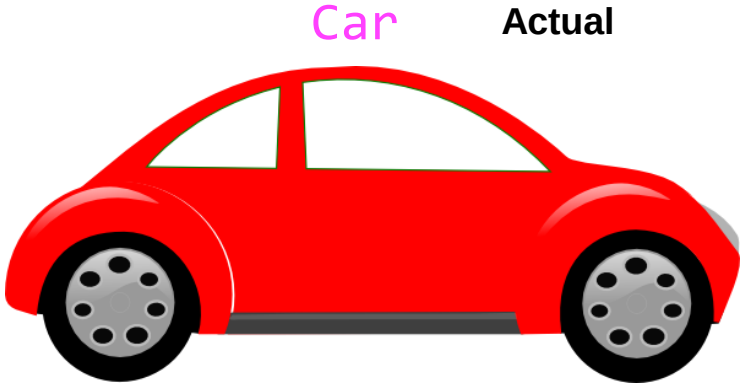
C.
```
Typable macBook= new Laptop();
macBook.click();
```

D.
```
Clickable macBook = new Laptop();
macBook.click();
```

Why does that work? (1/2)

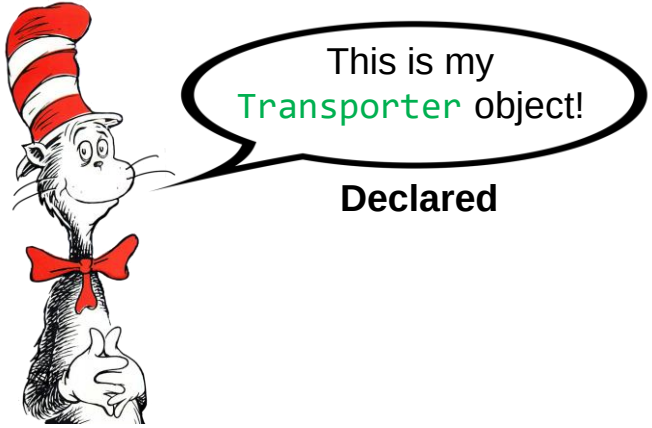
- Declared type and actual type work together
  - declared type keeps things generic
    - can reference a lot of objects using one generic type
  - actual type ensures specificity
    - when defining implementing class, the methods can get implemented in any way

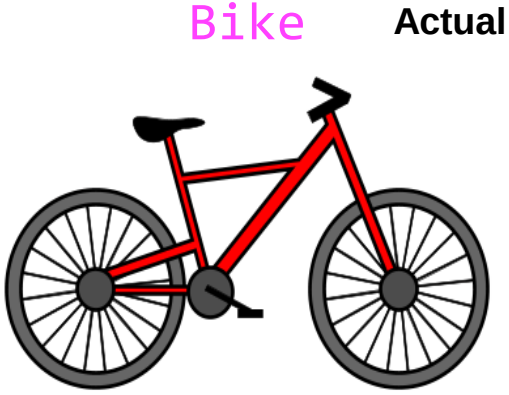




Why does that work? (2/2)

- Declared type and actual type work together
  - declared type keeps things generic
    - can reference a lot of objects using one generic type
  - actual type ensures specificity
    - when defining implementing class, the methods can get implemented in any way





When to use polymorphism?

- Using only functionality declared in interface or specialized functionality from implementing class?
  - if only using functionality from the interface → polymorphism!
  - if need specialized methods from implementing class, don't use polymorphism

Why use interfaces?

- Contractual enforcement
  - will guarantee that class has certain capabilities
    - `Car` implements `Transporter`, therefore it must know how to `move()`
- Polymorphism
  - Can have implementation-agnostic classes and methods
    - know that these capability exists, don't care how they're implemented
    - allows for more generic programming
      - `useTransportation` can take in any `Transporter` object
      - can easily extend this program to use any form of transportation, with minimal changes to existing code
    - an extremely powerful tool for extensible programming

Why is this important?

- With 2 modes of transportation!
- Old Design:
  - need more classes → more specialized methods (`useRollerblades()`, `useBike()`, etc)
- New Design:
  - as long as the new classes implement `Transporter`, `Racer` doesn't care what transportation it has been given
  - don't need to change `Racer`!
    - less work for you!
    - just add more transportation classes that implement `Transporter`

The Program

```
public class App {
    public App() {
        Race r = new Race();
        r.startRace();
    }
}
```

```
public class Race {
    private Racer _dan, _sophia;

    public Race(){
        _dan = new Racer();
        _sophia = new Racer();
    }
    public void startRace() {
        _dan.useTransportation(new Car());
        _sophia.useTransportation(new Bike());
    }
}
```

```
public interface Transporter {
    public void move();
}
```

```
public class Racer {
   public Racer() {}

   public void useTransportation(Transporter transport){
       transport.move();
   }
}
```

```
public class Car implements Transporter {
   public Car() {}
   public void drive() {
      //code elided
   }
   public void move() {
       this.drive();
   }
}
```

```
public class Bike implements Transporter {
   public Bike() {}
   public void pedal() {
       //code elided
   }
   public void move() {
       this.pedal();
   }
}
```

In Summary

- Interfaces are contracts
  - force classes to define certain methods
- Polymorphism allows for extremely generic code
  - treats multiple classes as their “generic type” while still allowing specific method implementations to be executed
- Polymorphism + Interfaces
  - generic coding
- Why is it helpful?
  - want you to be the laziest (but cleanest) programmer you can be

Next Lecture

- Inheritance and polymorphism