CS 520

Theory and Practice of Software Engineering
Fall 2020

Object Oriented (OO) Design Principles

September 3, 2020

Today

- OO design principles
  - Information hiding (and encapsulation)
  - Polymorphism
  - Open/closed principle
  - Inheritance in Java
  - The diamond of death
  - Liskov substitution principle
  - Composition/aggregation over inheritance

OO design principles

- **Information hiding (and encapsulation)**
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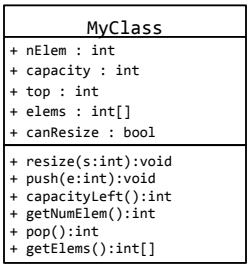
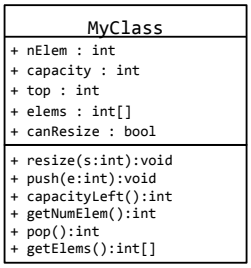
Information hiding




```
public class MyClass {
  public int nElem;
  public int capacity;
  public int top;
  public int[] elems;
  public boolean canResize;
  ...
  public void resize(int s){...}
  public void push(int e){...}
  public int capacityLeft(){...}
  public int getNumElem(){...}
  public int pop(){...}
  public int[] getElems(){...}
}
```

Information hiding

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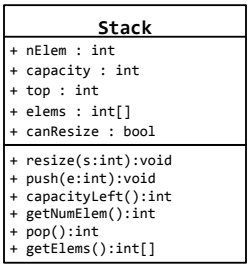
  public int pop(){...}
  public int[] getElems(){...}
}
```

What does MyClass do?

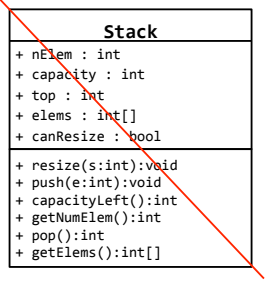
Information hiding

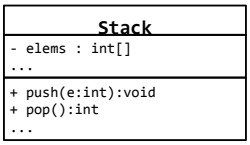



```
public class Stack {
  public int nElem;
  public int capacity;
  public int top;
  public int[] elems;
  public boolean canResize;
  ...
  public void resize(int s){...}
  public void push(int e){...}
  public int capacityLeft(){...}
  public int getNumElem(){...}
  public int pop(){...}
  public int[] getElems(){...}
}
```

Anything that could be improved in this implementation?

Information hiding

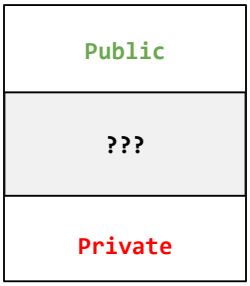




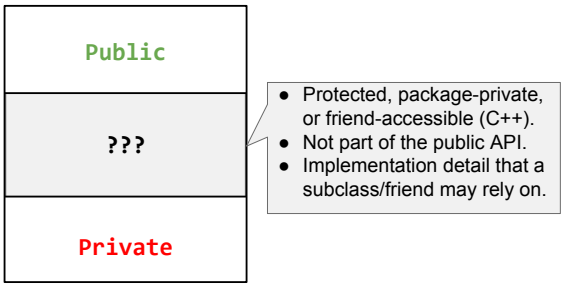
Information hiding:

- Reveal as little information about internals as possible.
- Separate public interface from implementation details.
- Reduce complexity.

Information hiding vs. visibility



Information hiding vs. visibility



OO design principles

- Information hiding (and encapsulation)
- **Polymorphism**
- Open/closed principle
- Inheritance in Java
- The diamond of death
- Liskov substitution principle
- Composition/aggregation over inheritance

A little refresher: what is Polymorphism?

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An object's ability to provide different behaviors.

Types of polymorphism

- Ad-hoc polymorphism (e.g., operator overloading)
  - `a + b` ⇒ String vs. int, double, etc.
- Subtype polymorphism (e.g., method overriding)
  - `Object obj = ...; obj.toString();` ⇒ toString() can be overridden in subclasses and therefore provide a different behavior.
- Parametric polymorphism (e.g., Java generics)
  - `class LinkedList<E> { void add(E) {...} E get(int index) {...}` ⇒ A LinkedList can store elements regardless of their type but still provide full type safety.

https://www.destroyallsoftware.com/talks/wat

A little refresher: what is Polymorphism?

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Types of polymorphism

- Subtype polymorphism (e.g., method overriding)
  - `Object obj = ...;` ⇒ toString() can be overridden in subclasses
    `obj.toString();` and therefore provide a different behavior.

Subtype polymorphism is essential to many OO design principles.

OO design principles

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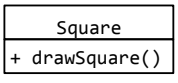
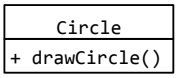
Open/closed principle

Software entities (classes, components, etc.) should be:
- **open** for extensions
- **closed** for modifications

```
public static void draw(Object o) {
  if (o instanceof Square) {
    drawSquare((Square) o)
  } else if (o instanceof Circle) {
    drawCircle((Circle) o);
  } else {
    ...
  }
}
```

Good or bad design?





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```
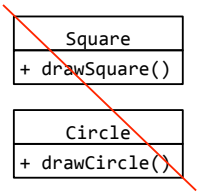

Violates the open/closed principle!



Open/closed principle

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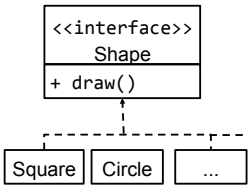
```
public static void draw(Object s) {
  if (s instanceof Shape) {
     s.draw();
  } else {
     …
  }
}
```

```
public static void draw(Shape s) {
  s.draw();
}
```



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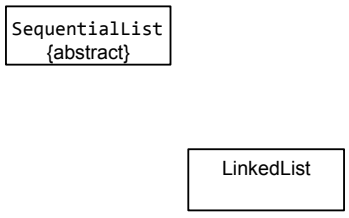
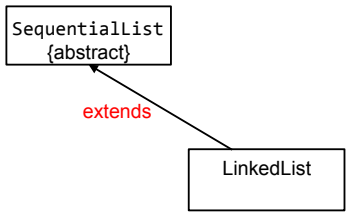
Inheritance: (abstract) classes and interfaces



Inheritance: (abstract) classes and interfaces

LinkedList extends SequentialList



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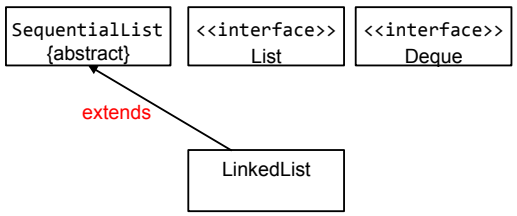
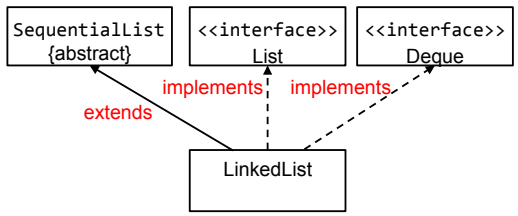
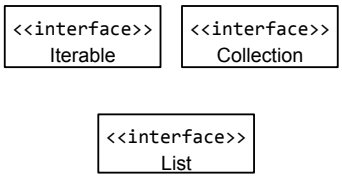


Inheritance: (abstract) classes and interfaces

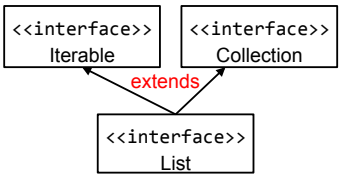
LinkedList extends SequentialList implements List, Deque



Inheritance: (abstract) classes and interfaces

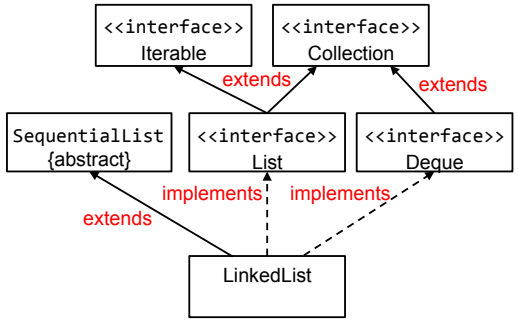


Inheritance: (abstract) classes and interfaces



List extends Iterable, Collection

Inheritance: (abstract) classes and interfaces



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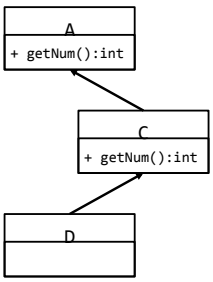
The “diamond of death”: the problem

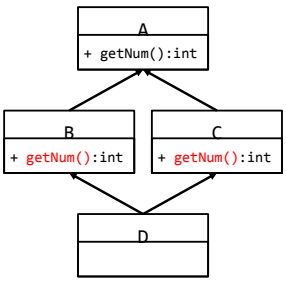
```
...
A a = new D();
int num = a.getNum();
...
```



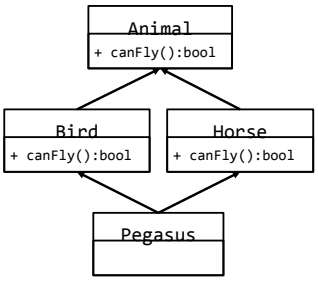
The “diamond of death”: the problem

```
...
A a = new D();
int num = a.getNum();
...
```

Which getNum() method should be called?



The “diamond of death”: concrete example



Can this happen in Java? Yes, with default methods in Java 8.

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Design principles: Liskov substitution principle

Motivating example

We know that a square is a special kind of a rectangle. So, which of the following OO designs makes sense?

Design principles: Liskov substitution principle

Subtype requirement

Let object x be of type T1 and object y be of type T2. Further, let T2 be a subtype of T1 (T2 <: T1). Any provable property about objects of type T1 should be true for objects of type T2.

Is the subtype requirement fulfilled?

Design principles: Liskov substitution principle

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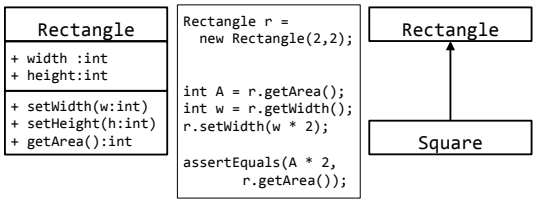

Design principles: Liskov substitution principle

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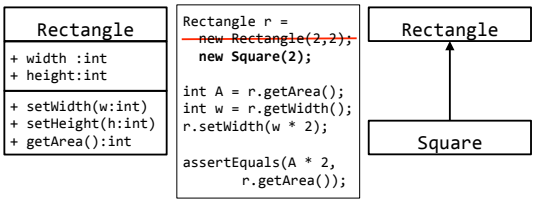

Design principles: Liskov substitution principle

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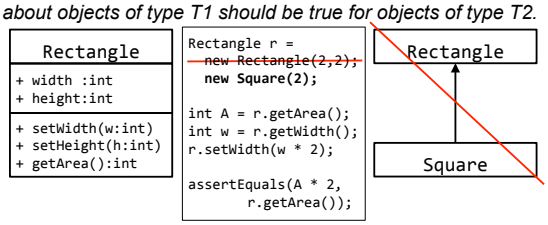

Violates the Liskov substitution principle!

Design principles: Liskov substitution principle

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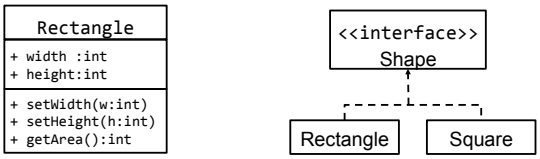

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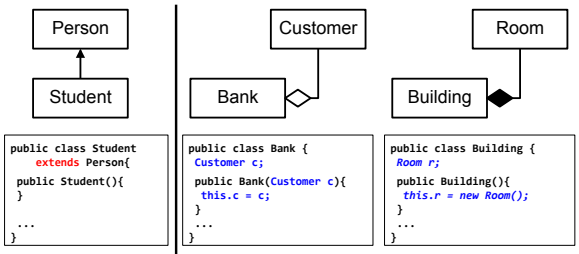
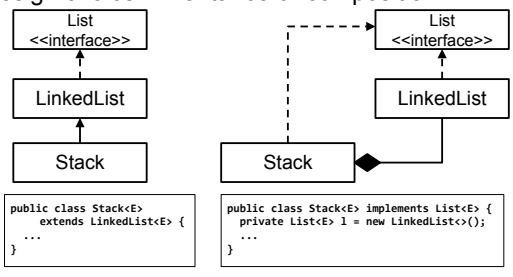
Inheritance vs. (Aggregation vs. *Composition*)



is-a relationship

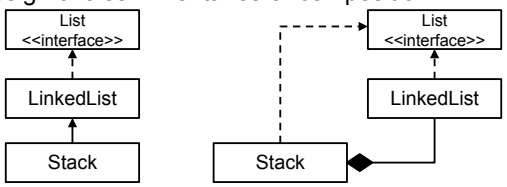
has-a relationship

Design choice: inheritance or composition?



Hmm, both designs seem valid -- what are pros and cons?

Design choice: inheritance or composition?



Pros
- No delegation methods required.
- Reuse of common state and behavior.

Cons
- Exposure of all inherited methods (a client might rely on this particular superclass -> can't change it later).
- Changes in superclass are likely to break subclasses.

Pros
- Highly flexible and configurable: no additional subclasses required for different compositions.

Cons
- All interface methods need to be implemented -> delegation methods required, even for code reuse.

Composition/aggregation over inheritance allows more flexibility.

OO design principles: summary

- Information hiding (and encapsulation)
- Open/closed principle
- Liskov substitution principle
- Composition/aggregation over inheritance

Final project description

- Each team of 4-5 will carry out **one** of the following projects:
  - MSR 2020 Mining Challenge
  - Replication Study
  - Model Inference for Inferring Processes
  - EleNa: Elevation-based Navigation
- The key phases of the project are: topic selection, mid-point presentation, final presentation (and documentation)
- More details available here: https://people.cs.umass.edu/~hconboy/class/2020Fall/CS520/finalProject.pdf