Designing for Inheritance

Ch6

If all you have is a hammer, everything looks like a nail.
-- Abraham Masslow, 1966

 © Dr. B. Fraser

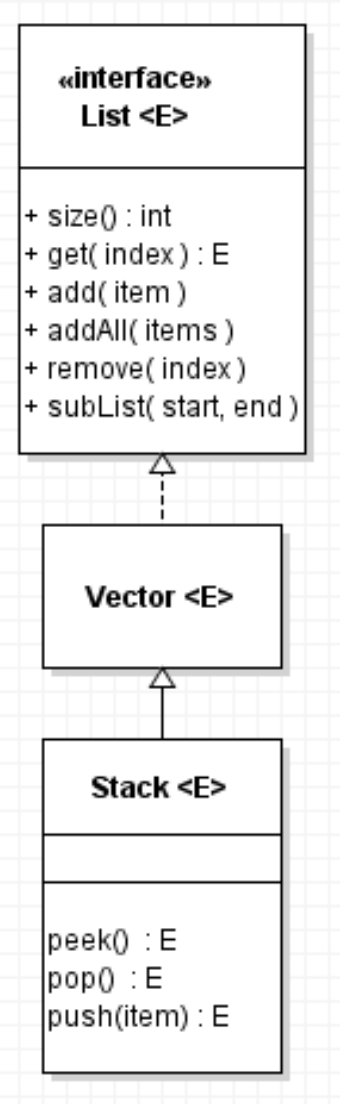
Topics

1) What makes inheritance useful?
2) What makes inheritance problematic?

Ex: Java Stack Inherits from Vector

- Java 1.0 had Stack is-a Vector
- What's good about its inheritance?

good:
-supports polymorphism with vector/list
-does not need to re-implement storage, size(),…



- What's bad about its inheritance?

bad:
-stack has list functions for direct access, add/remove away from top
-violates command/query

Encapsulation Goal

- Encapsulation goal with Inheritance:

  each class manages its own state

  - use super in constructors and for overridden methods.
  - use visibility modifiers to provide sufficient access but maintain encapsulation.
  - avoid protected: fields should be private except for a “protected interface” to derived classes
- But, inheritance is not great for encapsulation (more later).

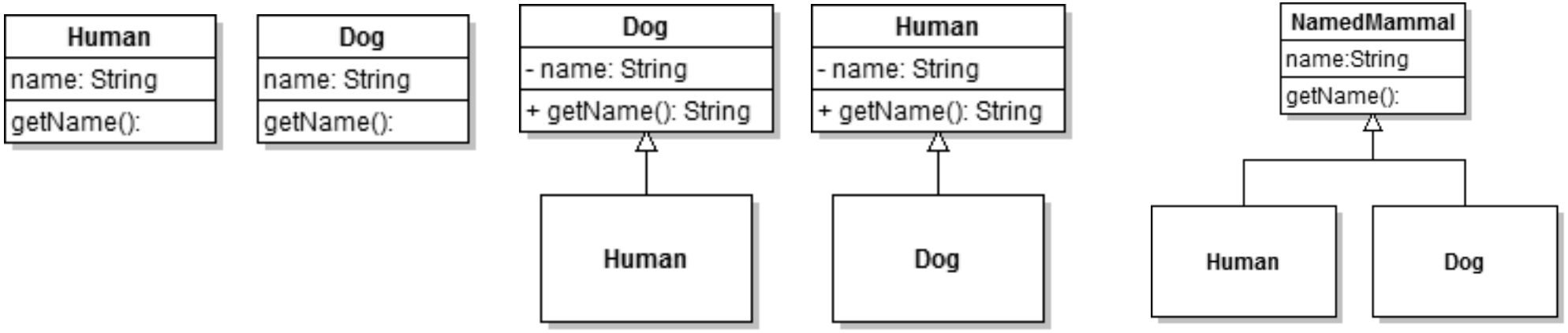
When to use Inheritance?

- What is sufficient grounds to use inheritance?
  - Code reuse?
  - Is-a relationship?
  - Polymorphism?

should question ourselves: is this good enough?

Reason 1: Code Reuse

- Idea: Inherit shared functionality from a base class.



  - Human & Dog have duplicate code (fields & methods), but..neither “is-a” the other

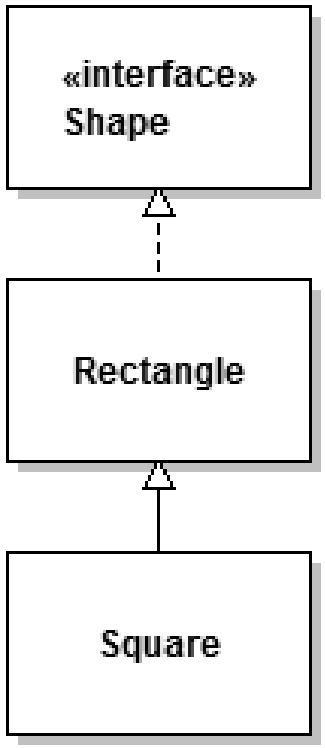
- Limitation

  code reuse does not justify inheritance

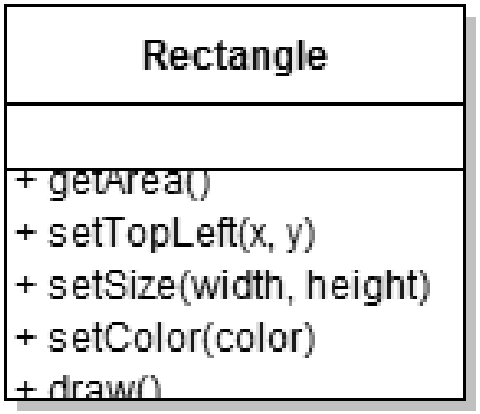
  - (Could create a “NamedMammal” base-class)

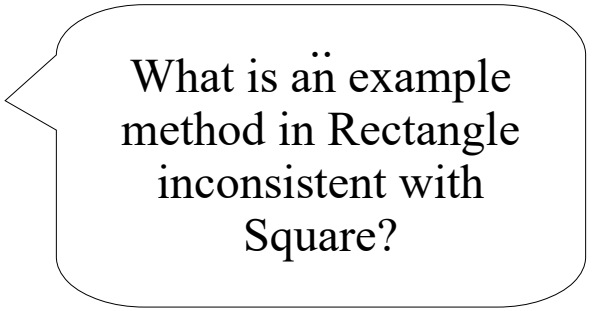
Reason 2: Is-A

- Idea: Inheritance represents a.. sub-set relationship
- Example:



  - Square is-a Rectangle, and gives reuse.
  - But.. sub-class is inconsistent with behaviour of super-class





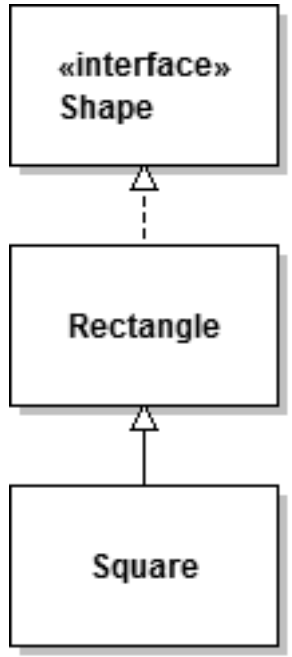
  - How can we describe this problem?

Is-A: LSP

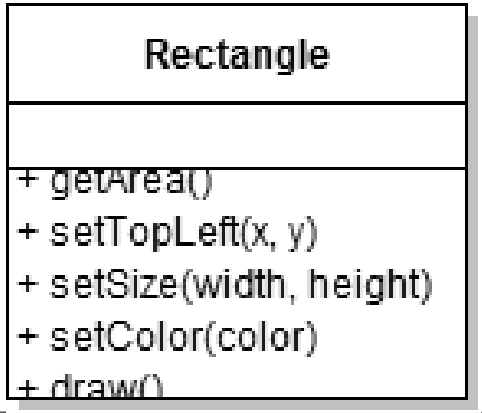
- Liskov Substitution Principle (LSP)
  B can inherit from A only if..
  for each method in A, B's method:

  1).. accepts all parameters
  that A's method accepts (or more) and

  2).. does everything with those values
  that A's method does (or more).



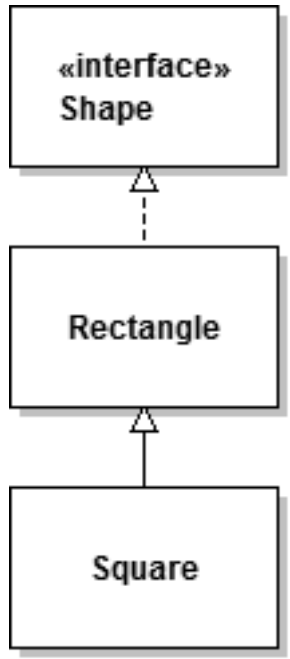
- What methods in Rectangle fail LSP for Square?
  - setSize(): a Square cannot have its width and height changed independently
  - Square does not do the same things with all values as Rectangle: fails LSP.



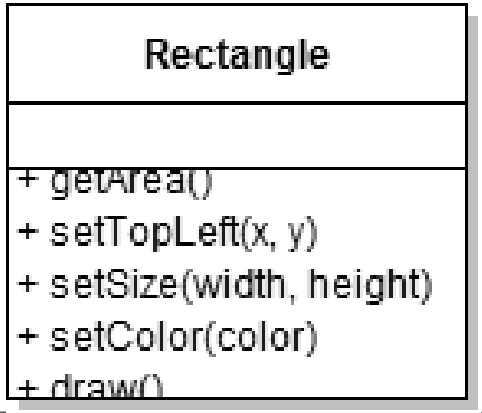
Is-A: LSP & Immutable

- LSP & Immutable
  - Would making Rectangle and Square immutable help?
  - yes, it removes the methods causing a problem

//////????????????



- Is-A Limitation: Must satisfy LSP
  (in order for inheritance to make sense)

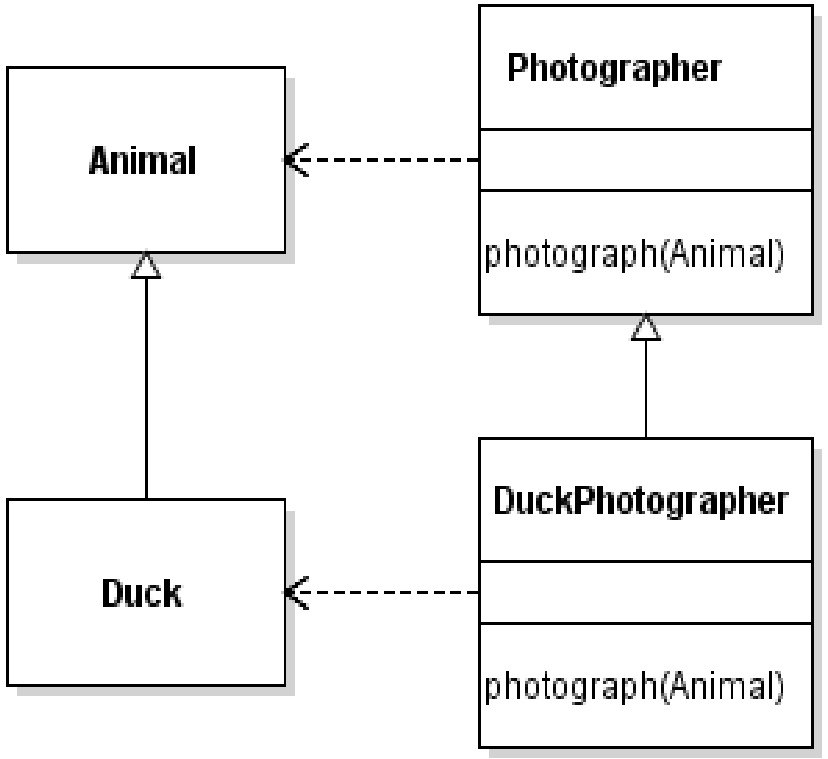


Is-A LSP: Example

- Photographer can photograph any Animal. DuckPhotographer only wants to photograph Ducks.
- DuckPhotographer::photograph() wants to reject non-ducks
  - Could throw an IllegalArgumentException?
- DuckPhotographer

  violates LSP:

  - does not handle the full set of objects that the base class does




```
class DuckPhotographer {
   private Photographer photographer;

   public DuckPhotographer(Photographer photographer) {
      this.photographer = photographer;
   }

   public void photographDuck(Duck duck) {
      photographer.photograph(duck);
   }
}
```

solution: change this is-a to has-a (i.e: has a Photographer object as member inside DuckPhotographer)

Is-A LSP

- Rephrase LSP:
  - Client code using a reference to the base class must be able to..

    use the derived class without ever knowing it

  - i.e., behaviour is unchanged.

Is-A LSP: SOLID

LSP is part of a common set of 5 OOD principles:

- S SRP Single Responsibility Principle
  "Class has one responsibility"
- O OCP Open Closed Principle
  "Be open for extension, closed for modification"
- L LSP Liskov Substitution Principle
  "Subtype objects interchangeable with base objects"
  client can change between them, never know, never care
- I ISP Interface Segregation Principle
  "Favour many client specific interfaces"
- D DIP Dependency Inversion Principle
  "Depend on abstractions, not concrete classes"

Reason 3: Polymorphism

- Idea: Work with derived classes through..

  variables (references) of type base-class

- Client code can flexibly work with new derived types without needing to change
  - Open-Closed Design Principle:
    Code is open for reuse, but closed for modification.
- Example: New TextBox inherit Rectangle
  - Share code: code to draw border
  - Is-a: TextBox is-a Rectangle
  - Polymorphism: add to a PicturePanel
- But, is that enough?

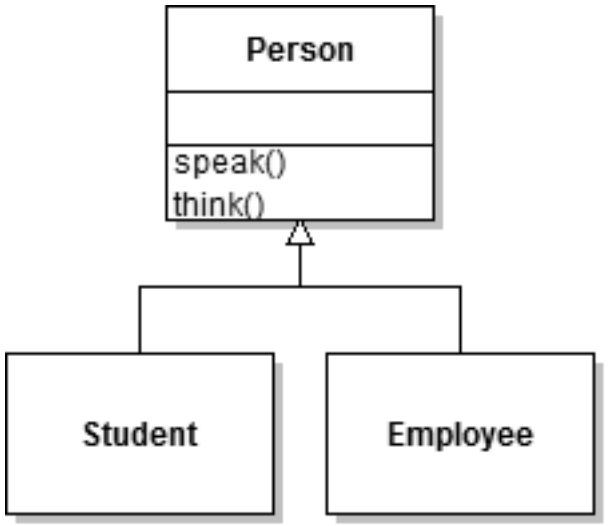
=> there are some other constraints
one question could ask: should TextBox inherits from Rectangle or both inherit from Shape?

Limits of Inheritance

Pixabay [Pexel]

Inflexible type ??????????????????

- Example



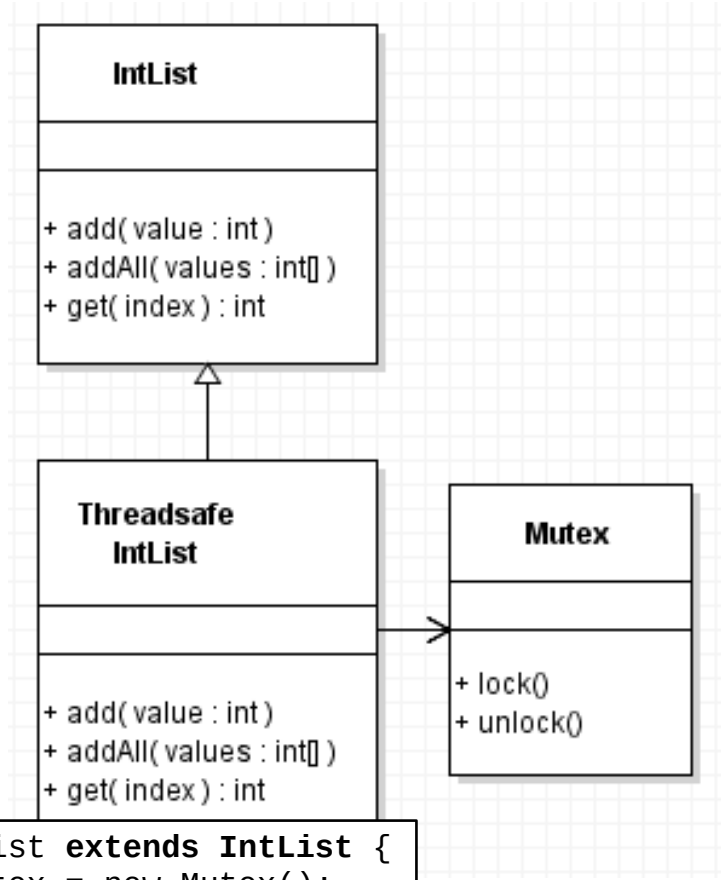
  - What about when a student..
    becomes a TA?
  - Cannot..
    dynamically change object type

- Limitation
  inheritance is rigid
  - Don't use inheritance for anything that may change type
  - Use composition (references) vs inheritance

Encapsulation

- Consider using inheritance to modify the behaviour of a class to make a threadsafe variety
  - Derived class can override each method of base class
  - Add a lock() and unlock() to each method
- What's good?
  - Code reuse
  - Polymorphism
- What's bad?

  see below




```
class ThreadsafeIntList extends IntList {
    private Mutex mutex = new Mutex();

    @Override
    void add(int value) {
        mutex.lock();
        super.add(value);
        mutex.unlock();
    } ...
```

IntList Problems

can't call bcuz add has a lock
(which still be locked by addAll function below)
-> problem: self-use

```
class IntList {
    private int[] data = new int[0];

    void add(int value) {
        int newSize = data.length + 1;
        int[] big = new int[newSize];
        IntStream.range(0, data.length)
             .forEach(i -> big[i] = data[i]);
        big[newSize - 1] = value;
        data = big;
    }

    void addAll(int[] values) {
        for (int value : values) {
            add(value);
        }
    }

    int get(int index) {
        return data[index];
    }
}
```

Self Use:
- addAll() calls add()

```
class ThreadsafeIntList extends IntList {
    private Mutex mutex = new Mutex();

    @Override
    void add(int value) {
        mutex.lock();
        super.add(value);
        mutex.unlock();
    }

    @Override
    void addAll(int[] values) {
        mutex.lock();
        super.addAll(values);
        mutex.unlock();
    }

    @Override
    int get(int i) {
        mutex.lock();
        int value = super.get(i);
        mutex.unlock();
        return value;
    }
}
```

start here

Should addAll() call lock() / unlock()?

Self Use

- Self Use
  - base class calls a method which can be overriden by derived class
- Problem
  - Derived class needs to know when its functions will be called so it does not try to double lock.
  - Derive class depends on the internal implementation details of the base.
  - This breaks encapsulation
- Solution
  - Base class must either
    - avoid self-use, document it

```
class IntList {
    void add(int value) {
        ...
    }

    void addAll(int[] values) {
        for (int value : values) {
            add(value);
        }
    }
}
```

```
class ThreadsafeIntList extends IntList {
    @Override
    void add(int value) {
        mutex.lock();
        super.add(value);
        mutex.unlock();
    }

    @Override
    void addAll(int[] values) {
        mutex.lock();
        super.addAll(values);
        mutex.unlock();
    }
}
```

Self use solution

- Self use is a problem when base class calls its own methods which can be overridden
- Solutions
  - Move shared functionality to private helper function and call it (cannot be overriden)

    or
  - Document any self-use (and commit to it) so derived class can account for it

```
class IntList {
    private void addInternal(int value) {
        ... (same as add() )
    }

    void add(int value) {
        addInternal(value);
    }

    void addAll(int[] values) {
        for (int value : values) {
            addInternal(value);
        }
    }
}
```

```
class ThreadsafeIntList extends IntList {
    @Override
    void add(int value) {
        mutex.lock();
        super.add(value);
        mutex.unlock();
    }

    @Override
    void addAll(int[] values) {
        mutex.lock();
        super.addAll(values);
        mutex.unlock();
    }
}
```

Limits of Inheritance

- inheritance is rigid
  - Cannot change object type after instantiation
- inheritance breaks encapsulation
  - Self-use must be avoided or documented
- inheritance tightly couples derived class to base class
  - Local change to base class has non-local effects
  - Adding method to base class adds behaviour to derived class:
    - may break guarantees of derived class.
    - may unexpectedly override a derived class's extra function, changing its behaviour.
    - may not compile if added function would override a derived class's extra function but different return type.

Better Inheritance

Polymorphism using Interfaces

- Implementation Inheritance
  - ..inheriting from a concrete class to reuse its code
  - *Problematic*!
- Interface Inheritance
  - Implementing an interface to support polymorphism
  - *Very useful!*
- Basic Plan
  - When needing polymorphism, use composition:

    ..have your client code depend on interfaces
  - Have small classes which implement the interfaces.
  - Flexibly compose objects at runtime
  - Flexibly add new small objects

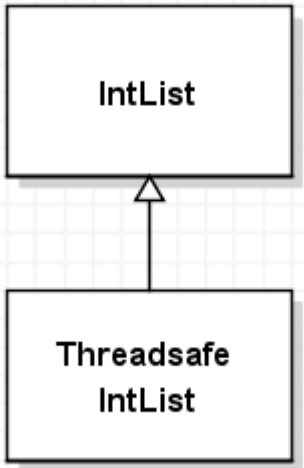
Replace Inheritance with Wrapper

- Instead of inheriting from concrete class IntList, have "derived" class holds a reference to it.
  - ArrayIntList implements the IntList interface
  - Wrapper Object

    Hold a reference to a concrete IntList
  - forwarding

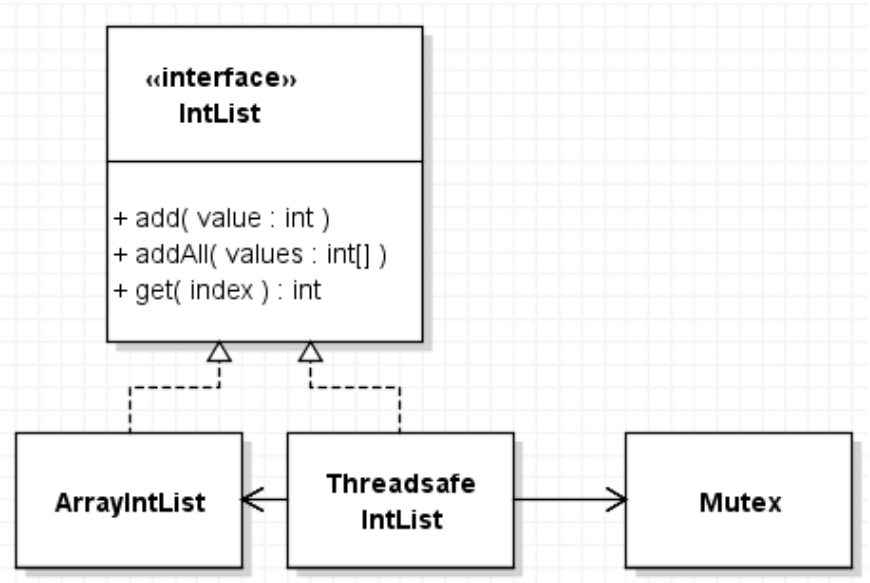
    Each derived method calls the wrapped object
  - Forwarding is also called

    delegation




```
class ThreadsafeIntList implements IntList {
    private Mutex mutex = new Mutex();
    private IntList list = new ArrayIntList();

    @Override
    void add(int value) {
        mutex.lock();
        list.add(value);
        mutex.unlock();
    } ...
```



IntList with Wrapper Class

```
interface IntList {
    void add(int value);
    void addAll(int[] values);
    int get(int index);
}

final class ArrayIntList implements IntList {
    private int[] data = new int[0];

    @Override
    public void add(int value) {
        ...
    }

    @Override
    public void addAll(int[] values) {
        for (int value : values) {
            add(value);
        }
    }

    @Override
    public int get(int index) {
        return data[index];
    }
}
```

```
final class ThreadsafeIntList implements IntList {
    private Mutex mutex = new Mutex();
    private IntList list = new ArrayIntList();

    @Override
    public void add(int value) {
        mutex.lock();
        list.add(value);
        mutex.unlock();
    }

    @Override
    public void addAll(int[] values) {
        mutex.lock();
        list.addAll(values);
        mutex.unlock();
    }

    @Override
    public int get(int i) {
        mutex.lock();
        int value = list.get(i);
        mutex.unlock();
        return value;
    }
}
```

Could use DI

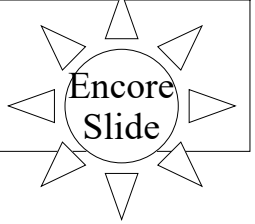
delegate: call list to do the work

ThreadsafeIntList:
- Is-a IntList and
- Has-a IntList

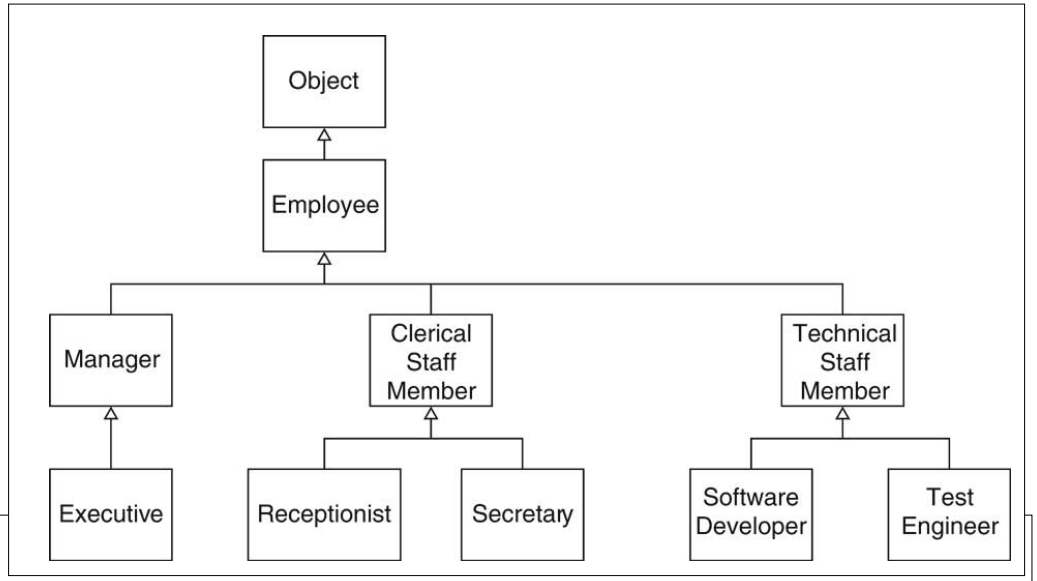
It is the Decorator Pattern

inheriting something or implementing an interface, at the same time, holding a reference to it

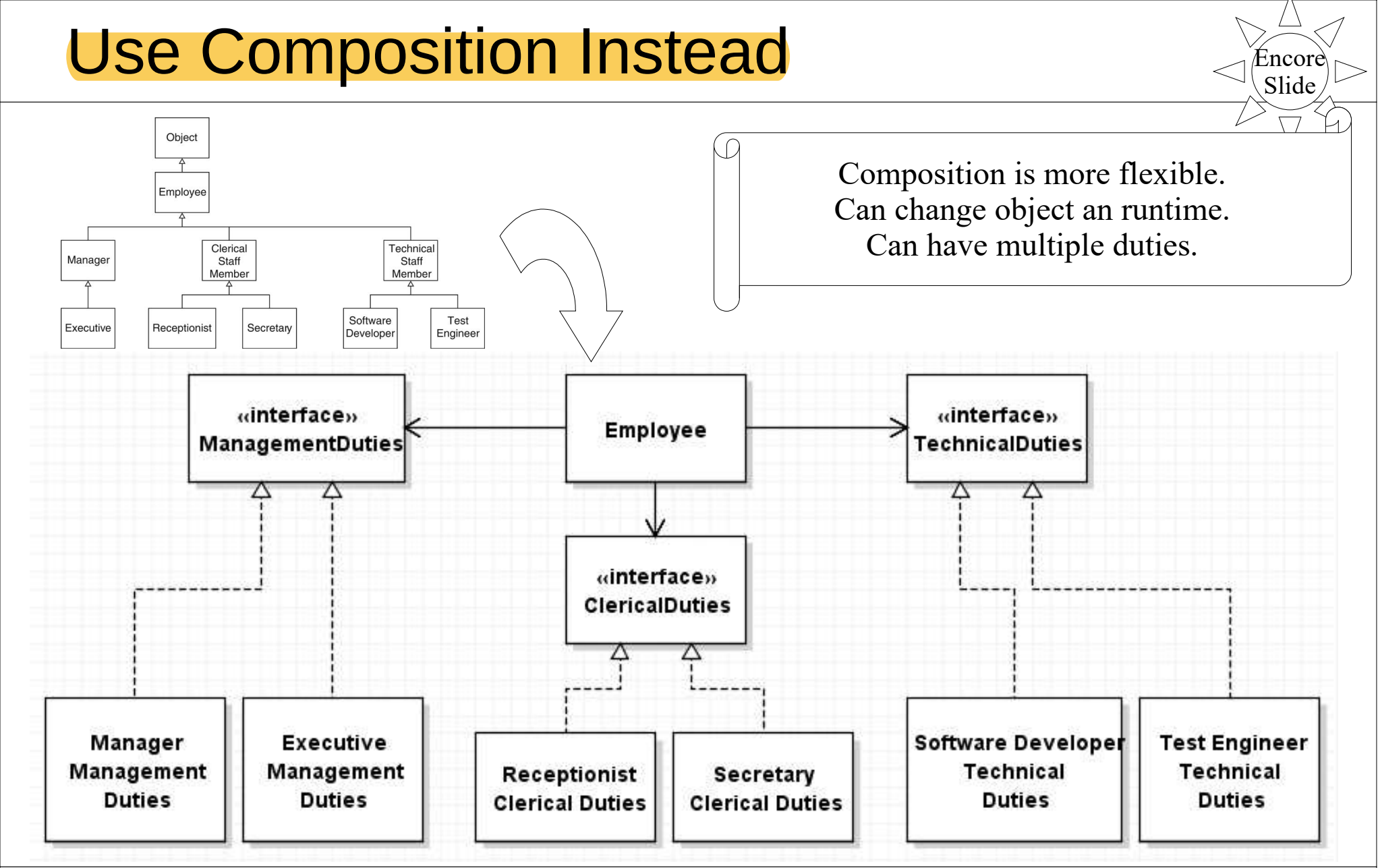
Replacing Implementation Inheritance



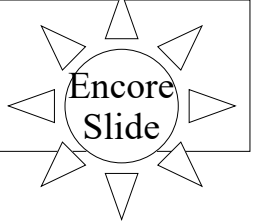
- Inheritance hierarchies of concrete classes are bad
  - Rigid types for all objects
  - Reuse of implementation (code) means many dependencies on super classes.
- Ex: Add a “senior” role to Manager and Clerical Staff:
  - Senior feature:
    Get more money
    Can sign for credit card
  - Not clear how to fit into inheritance hierarchy



Use Composition Instead



Design Principles



- **Design Principle:**
  Program to an interface, not an implementation
  - Flexibility to reference a different concrete class later

- **Design Principle:**
  Prefer composition over inheritance
  - Composition allows.. runtime flexibility to change (reference a new object)
  - Reduces rigid coupling from static inheritance hierarchy

  we still use (interface) inheritance, but just bring in an extra layer of composition to isolate from negative effects of inheritance's features

Summary

- Use inheritance only when supported by:
  - is-a relationship & LSP
  - polymorphism
- Limits on Inheritance
  - Good to “Inherit” (implement) interfaces!
  - OK to inherit from classes you control (same package)
  - OK to inherit from classes designed for inheritance (Ex: “Template Pattern”)
  - Only when you are OK living with base class’s API
- Consider using composition instead (as well).