Principles of Software Construction: Objects, Design, and Concurrency

Part 1: Designing classes

Design patterns for reuse (continued) and design heuristics

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Administrivia

- Reading due today: UML and Patterns Chapters 9 and 10
- Optional reading for Thursday:
  - UML and Patterns Chapter 17
  - Effective Java items 39, 43, and 57ff
- Homework 3 due Thursday at 11:59 p.m.
- Midterm exam next Thursday (September 28th)
  - Review session, practice exam info coming soon

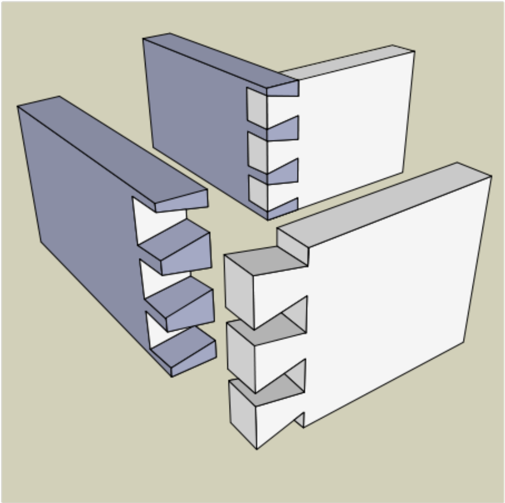
Key concepts from Thursday

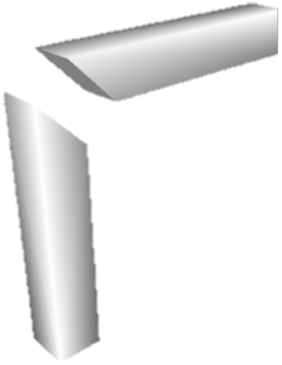
UML you should know

- Interfaces vs. classes
- Fields vs. methods
- Relationships:
  - "extends" (inheritance)
  - "implements" (realization)
  - "has a" (aggregation)
  - non-specific association
- Visibility: + (public) - (private) # (protected)
- Basic best practices…

Design patterns

- Carpentry:
  - "Is a dovetail joint or a miter joint better here?"
- Software Engineering:
  - "Is a strategy pattern or a template method better here?"





Strategy pattern

- Problem: Clients need different variants of an algorithm
- Solution: Create an interface for the algorithm, with an implementing class for each variant of the algorithm
- Consequences:
  - Easily extensible for new algorithm implementations
  - Separates algorithm from client context
  - Introduces an extra interface and many classes:
    - Code can be harder to understand
    - Lots of overhead if the strategies are simple

Avoiding `instanceof` with the template method pattern

```
public void doSomething(Account acct) {
  float adj = 0.0;
  if (acct instanceof CheckingAccount) {
    checkingAcct = (CheckingAccount) acct;
     adj = checkingAcct.getFee();
  } else if (acct instanceof SavingsAccount) {
    savingsAcct = (SavingsAccount) acct;
     adj = savingsAcct.getInterest();
  }
  …
}
```

Instead:

```
public void doSomething(Account acct) {
  long adj = acct.getMonthlyAdjustment();
  …
}
```

The abstract `java.util.AbstractList<E>`

```
abstract T   get(int i);
abstract int size();
boolean      set(int i, E e);          // pseudo-abstract
boolean      add(E e);                 // pseudo-abstract
boolean      remove(E e);              // pseudo-abstract
boolean      addAll(Collection<? extends E> c);
boolean      removeAll(Collection<?> c);
boolean      retainAll(Collection<?> c);
boolean      contains(E e);
boolean      containsAll(Collection<?> c);
void         clear();
boolean      isEmpty();
abstract Iterator<E>  iterator();
Object[]     toArray()
<T> T[]      toArray(T[] a);
…
```

Today

- More design patterns for reuse
  - Iterator pattern
  - Decorator pattern
- Design goals and design principles

Traversing a collection

- Old-school Java for loop for ordered types

```
List<String> arguments = …;
for (int i = 0; i < arguments.size(); i++) {
  System.out.println(arguments.get(i));
}
```

- Modern standard Java for-each loop

```
List<String> arguments = …;
for (String s : arguments) {
  System.out.println(s);
}
```

Works for every implementation of `Iterable`:

```
public interface Iterable<E> {
   public Iterator<E> iterator();
}
```

The `Iterator` interface

```
public interface java.util.Iterator<E> {
  boolean hasNext();
  E next();
  void remove();  // removes previous returned item
}                 // from the underlying collection
```

- To use explicitly, e.g.:

```
List<String> arguments = …;
for (Iterator<String> it = arguments.iterator();
     it.hasNext();  ) {
  String s = it.next();
  System.out.println(s);
}
```

Iterator design pattern

- Problem: Clients need uniform strategy to access all elements in a container, independent of the container type
  - Order is unspecified, but access every element once
- Solution: A strategy pattern for iteration
- Consequences:
  - Hides internal implementation of underlying container
  - Easy to change container type
  - Facilitates communication between parts of the program

Getting an Iterator

```
public interface Collection<E> extends Iterable<E> {
  boolean      add(E e);
  boolean      addAll(Collection<? extends E> c);
  boolean      remove(Object e);
  boolean      removeAll(Collection<?> c);
  boolean      retainAll(Collection<?> c);
  boolean      contains(Object e);
  boolean      containsAll(Collection<?> c);
  void         clear();
  int          size();
  boolean      isEmpty();
  Iterator<E> iterator();
  Object[]     toArray()
  <T> T[]      toArray(T[] a);
  …
}
```

Defines an interface for creating an Iterator, but allows Collection implementation to decide which Iterator to create.

An Iterator implementation for Pairs

```
public class Pair<E> {
  private final E first, second;
  public Pair(E f, E s) { first = f; second = s; }









}
```

```
Pair<String> pair = new Pair<String>("foo", "bar");
for (String s : pair) { … }
```

An Iterator implementation for Pairs

```
public class Pair<E> implements Iterable<E> {
  private final E first, second;
  public Pair(E f, E s) { first = f; second = s; }
  public Iterator<E> iterator() {
    return new PairIterator();
  }
  private class PairIterator implements Iterator<E> {
    private boolean seenFirst = false, seenSecond = false;
    public  boolean hasNext() { return !seenSecond; }
    public  E next() {
      if (!seenFirst)  { seenFirst  = true; return first;  }
      if (!seenSecond) { seenSecond = true; return second; }
      throw new NoSuchElementException();
    }
    public void remove() {
      throw new UnsupportedOperationException();
    }
  }
}
```

```
Pair<String> pair = new Pair<String>("foo", "bar");
for (String s : pair) { … }
```

Using a `java.util.Iterator<E>`: A warning

- The default Collections implementations are mutable…
- …but their `Iterator` implementations assume the collection does not change while the `Iterator` is being used
  - You will get a `ConcurrentModificationException`

Using a `java.util.Iterator<E>`: A warning

- The default Collections implementations are mutable…
- …but their `Iterator` implementations assume the collection does not change while the `Iterator` is being used
  - You will get a `ConcurrentModificationException`
  - If you simply want to remove an item:

```
List<String> arguments = …;
for (Iterator<String> it = arguments.iterator();
     it.hasNext();  ) {
  String s = it.next();
  if (s.equals("Charlie"))
    arguments.remove("Charlie"); // runtime error
}
```

Using a `java.util.Iterator<E>`: A warning

- The default Collections implementations are mutable…
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  String s = it.next();
  if (s.equals("Charlie"))
    it.remove();
}
```

Today

- More design patterns for reuse
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Limitations of inheritance

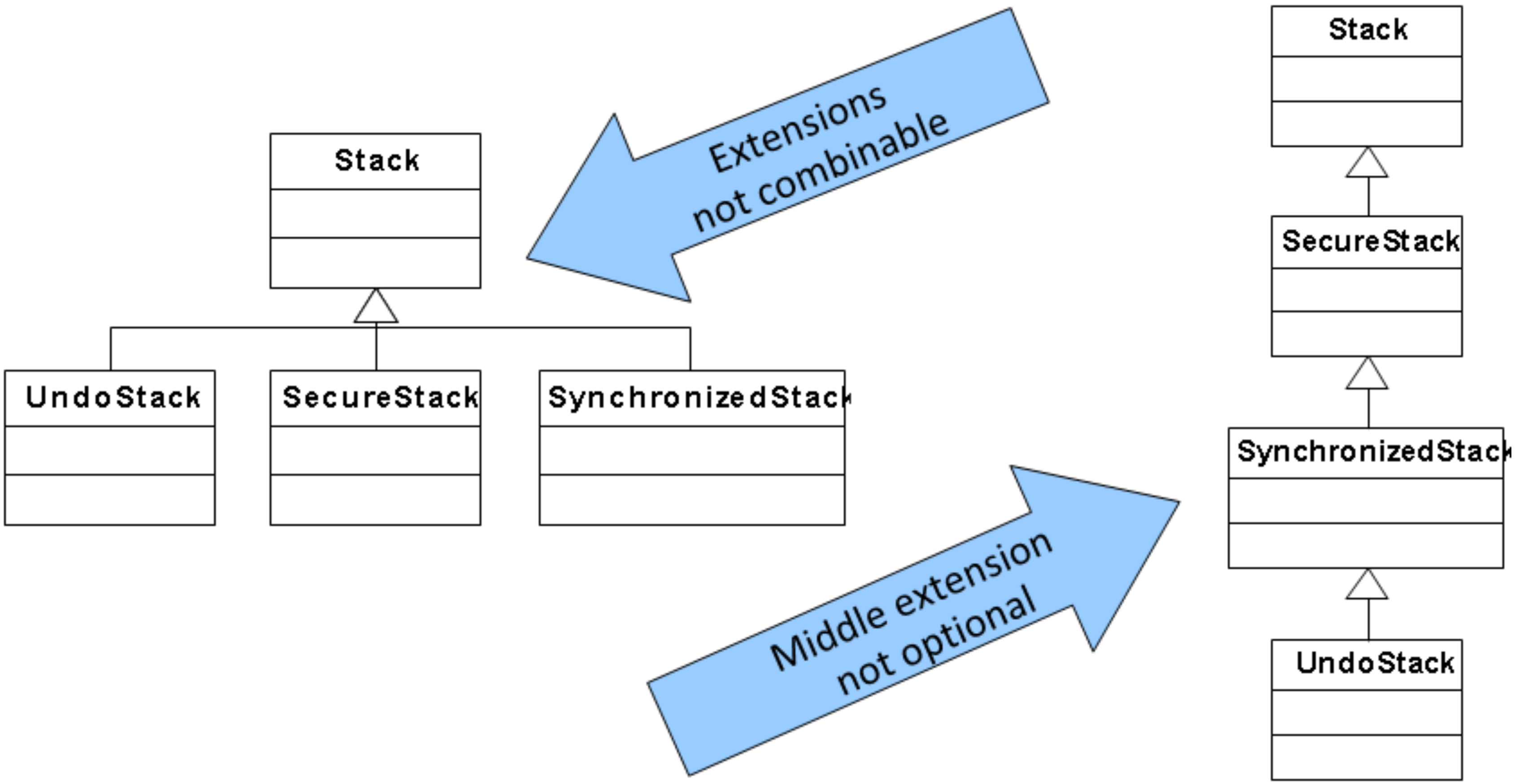
- Suppose you want various extensions of a `Stack` data structure…
  - `UndoStack`: A stack that lets you undo previous push or pop operations
  - `SecureStack`: A stack that requires a password
  - `SynchronizedStack`: A stack that serializes concurrent accesses

Limitations of inheritance

- Suppose you want various extensions of a `Stack` data structure…
  - `UndoStack`: A stack that lets you undo previous push or pop operations
  - `SecureStack`: A stack that requires a password
  - `SynchronizedStack`: A stack that serializes concurrent accesses
  - `SecureUndoStack`: A stack that requires a password, and also lets you undo previous operations
  - `SynchronizedUndoStack`: A stack that serializes concurrent accesses, and also lets you undo previous operations
  - `SecureSynchronizedStack`: …
  - `SecureSynchronizedUndoStack`: …

Goal: arbitrarily composable extensions

Limitations of inheritance



Workarounds?

- Combining inheritance hierarchies?
- Multiple inheritance?

The decorator design pattern

- Problem: You need arbitrary or dynamically composable extensions to individual objects.
- Solution: Implement a common interface as the object you are extending, add functionality, but delegate primary responsibility to an underlying object.
- Consequences:
  - More flexible than static inheritance
  - Customizable, cohesive extensions
  - Breaks object identity, self-references

Decorators use both subtyping and delegation

```
public class LoggingList<E> implements List<E> {
  private final List<E> list;
  public LoggingList<E>(List<E> list) { this.list = list; }
  public boolean add(E e) {
      System.out.println("Adding " + e);
      return list.add(e);
  }
  public E remove(int index) {
      System.out.println("Removing at " + index);
      return list.remove(index);
  }
  …
```

The AbstractStackDecorator forwarding class

```
public abstract class AbstractStackDecorator
           implements Stack {
  private final Stack stack;
  public AbstractStackDecorator(Stack stack) {
      this.stack = stack;
  }
  public void push(Item e) {
       stack.push(e);
  }
  public Item pop() {
       return stack.pop();
  }
  …
}
```

The concrete decorator classes

```
public class UndoStack extends AbstractStackDecorator
        implements Stack {
  private final UndoLog log = new UndoLog();
  public UndoStack(Stack stack) { super(stack); }
  public void push(Item e) {
        log.append(UndoLog.PUSH, e);
        super.push(e);
  }
  …
}
```

Using the decorator classes

- To construct a plain stack:

```
Stack stack = new ArrayStack();
```

- To construct an undo stack:

Using the decorator classes

- To construct a plain stack:

```
Stack stack = new ArrayStack();
```

- To construct an undo stack:

```
UndoStack stack = new UndoStack(new ArrayStack());
```

Using the decorator classes

- To construct a plain stack:

```
Stack stack = new ArrayStack();
```

- To construct an undo stack:

```
UndoStack stack = new UndoStack(new ArrayStack());
```

- To construct a secure synchronized undo stack:

Using the decorator classes

- To construct a plain stack:

```
Stack s = new ArrayStack();
```

- To construct an undo stack:

```
UndoStack s = new UndoStack(new ArrayStack());
```

- To construct a secure synchronized undo stack:

```
SecureStack s = new SecureStack(new SynchronizedStack(
                       new UndoStack(new ArrayStack())));
```

Decorators from `java.util.Collections`

- Turn a mutable collection into an immutable collection:

```
static List<T>  unmodifiableList(List<T>  lst);
static Set<T>   unmodifiableSet( Set<T>   set);
static Map<K,V> unmodifiableMap( Map<K,V> map);
```

- Similar for synchronization:

```
static List<T>  synchronizedList(List<T>  lst);
static Set<T>   synchronizedSet( Set<T>   set);
static Map<K,V> synchronizedMap( Map<K,V> map);
```

The UnmodifiableCollection (simplified excerpt)

```
public static <T> Collection<T> unmodifiableCollection(Collection<T> c)
        return new UnmodifiableCollection<>(c);
}
class UnmodifiableCollection<E> implements Collection<E>, Serializable
        final Collection<E> c;
        UnmodifiableCollection(Collection<> c) {this.c = c; }
        public int size() {return c.size();}
        public boolean isEmpty() {return c.isEmpty();}
        public boolean contains(Object o) {return c.contains(o);}
        public Object[] toArray() {return c.toArray();}
        public <T> T[] toArray(T[] a) {return c.toArray(a);}
        public String toString() {return c.toString();}
        public boolean add(E e) {throw new UnsupportedOperationExceptior
        public boolean remove(Object o) { throw new UnsupportedOperatior
                public boolean containsAll(Collection<?> coll) {  return
        public boolean addAll(Collection<? extends E> coll) { throw new
        public boolean removeAll(Collection<?> coll) { throw new Unsuppo
        public boolean retainAll(Collection<?> coll) { throw new Unsuppo
        public void clear() {  throw new UnsupportedOperationException()
    }
```

The decorator pattern vs. inheritance

- Decorator composes features at run time
  - Inheritance composes features at compile time
- Decorator consists of multiple collaborating objects
  - Inheritance produces a single, clearly-typed object
- Can mix and match multiple decorations
  - Multiple inheritance is conceptually difficult

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Metrics of software quality

Source: Braude, Bernstein, Software Engineering. Wiley 2011

- Sufficiency / functional correctness
  - Fails to implement the specifications … Satisfies all of the specifications
- Robustness
  - Will crash on any anomalous event … Recovers from all anomalous events
- Flexibility
  - Must be replaced entirely if spec changes … Easily adaptable to changes
- Reusability
  - Cannot be used in another application … Usable without modification
- Efficiency
  - Fails to satisfy speed or storage requirement … satisfies requirements
- Scalability
  - Cannot be used as the basis of a larger version … is an outstanding basis…
- Security
  - Security not accounted for at all … No manner of breaching security is known

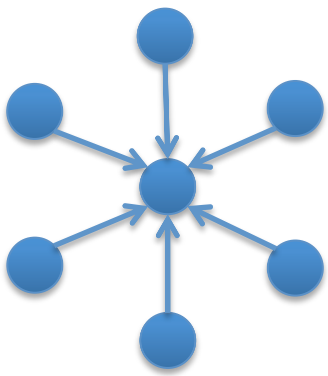
Design challenges/goals

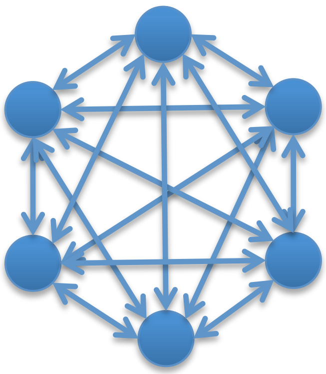
Design principles

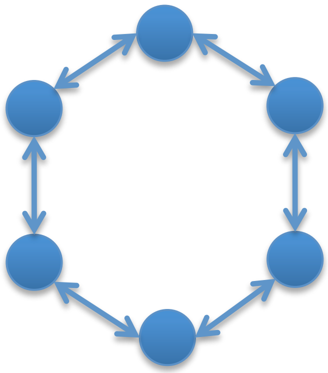
- Low coupling
- Low representational gap
- High cohesion

A design principle for reuse: *low coupling*

- Each component should depend on as few other components as possible

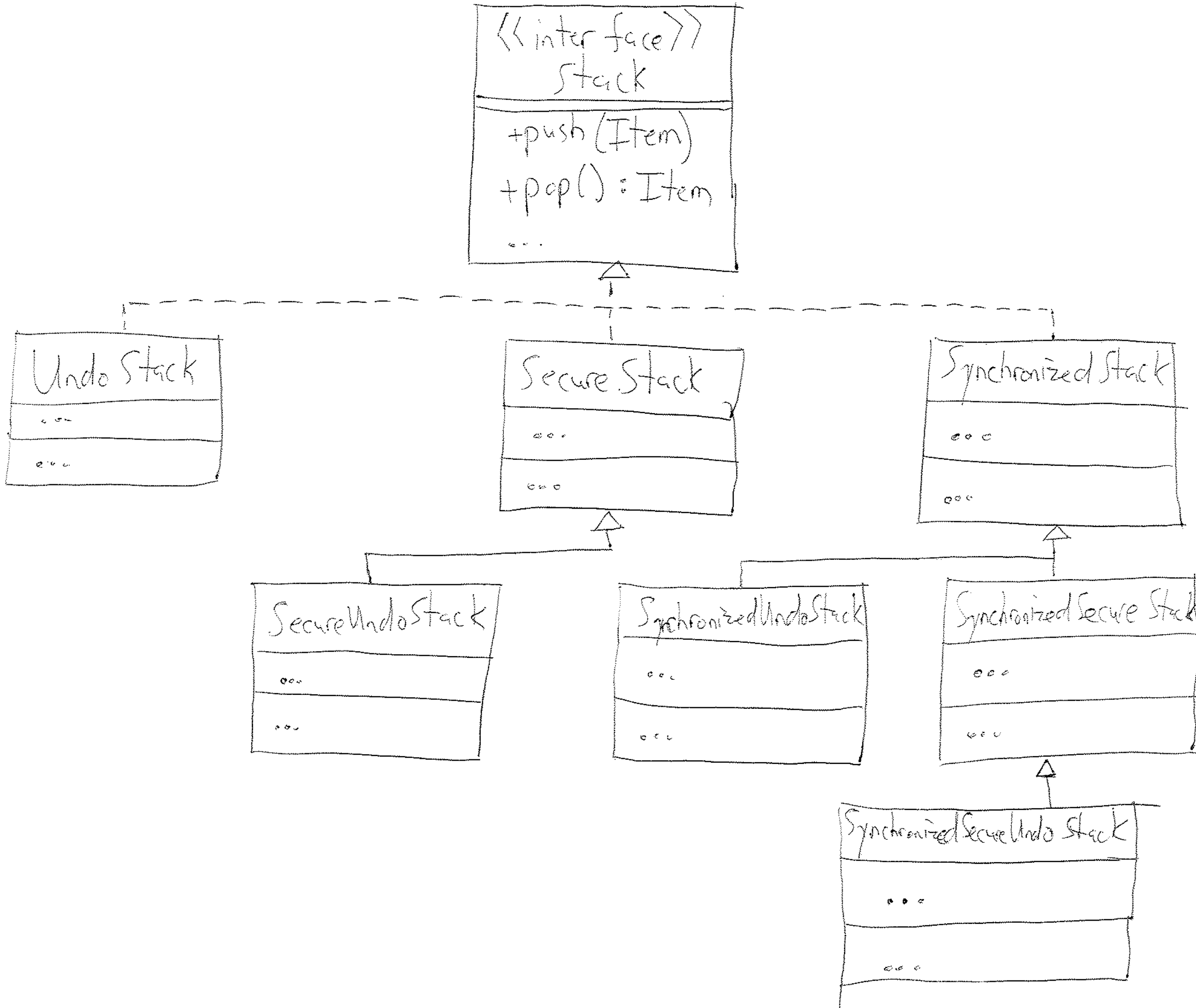




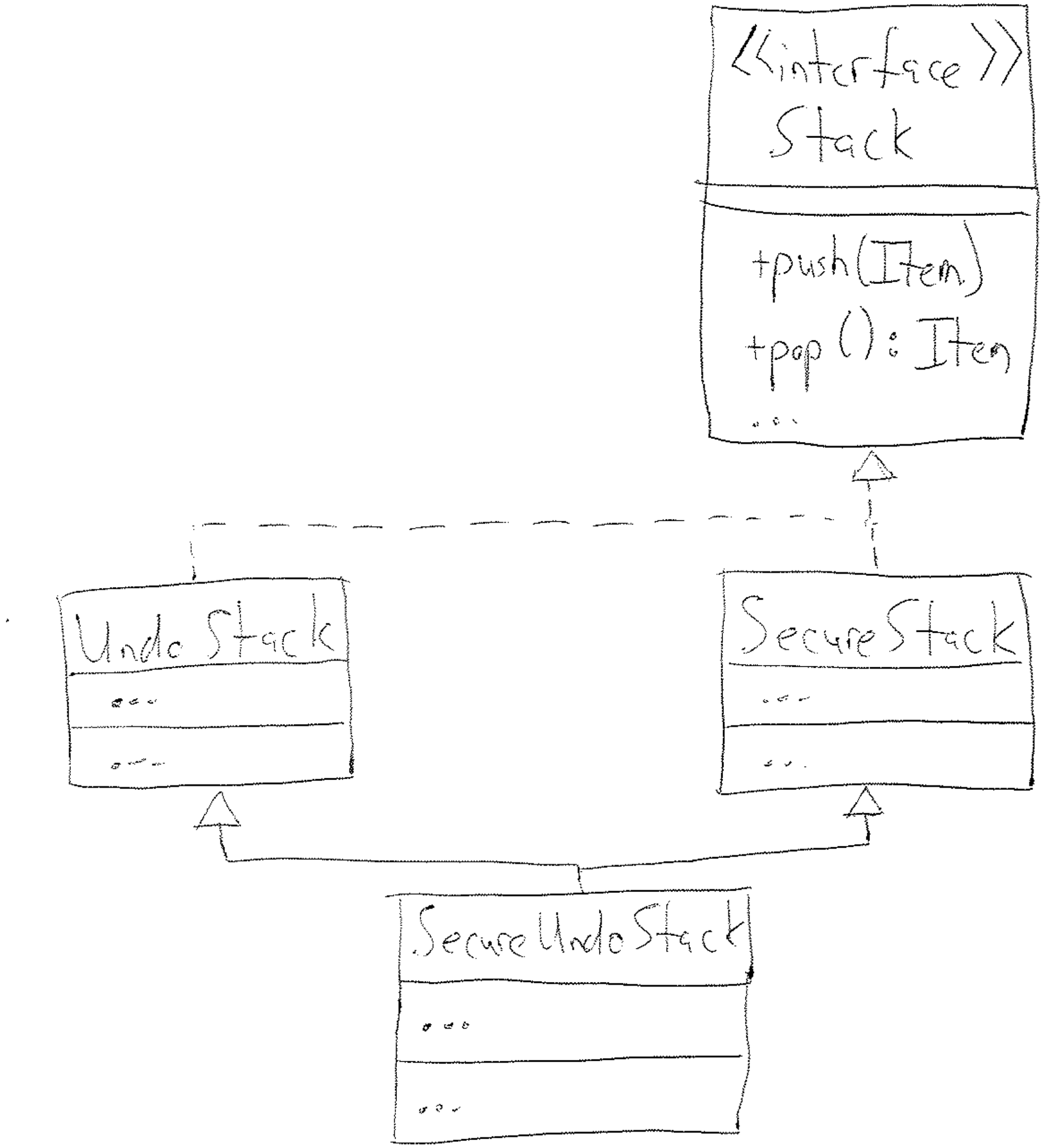


- Benefits of low coupling:
  - Enhances understandability
  - Reduces cost of change
  - Eases reuse

Design principles to be continued Thursday..

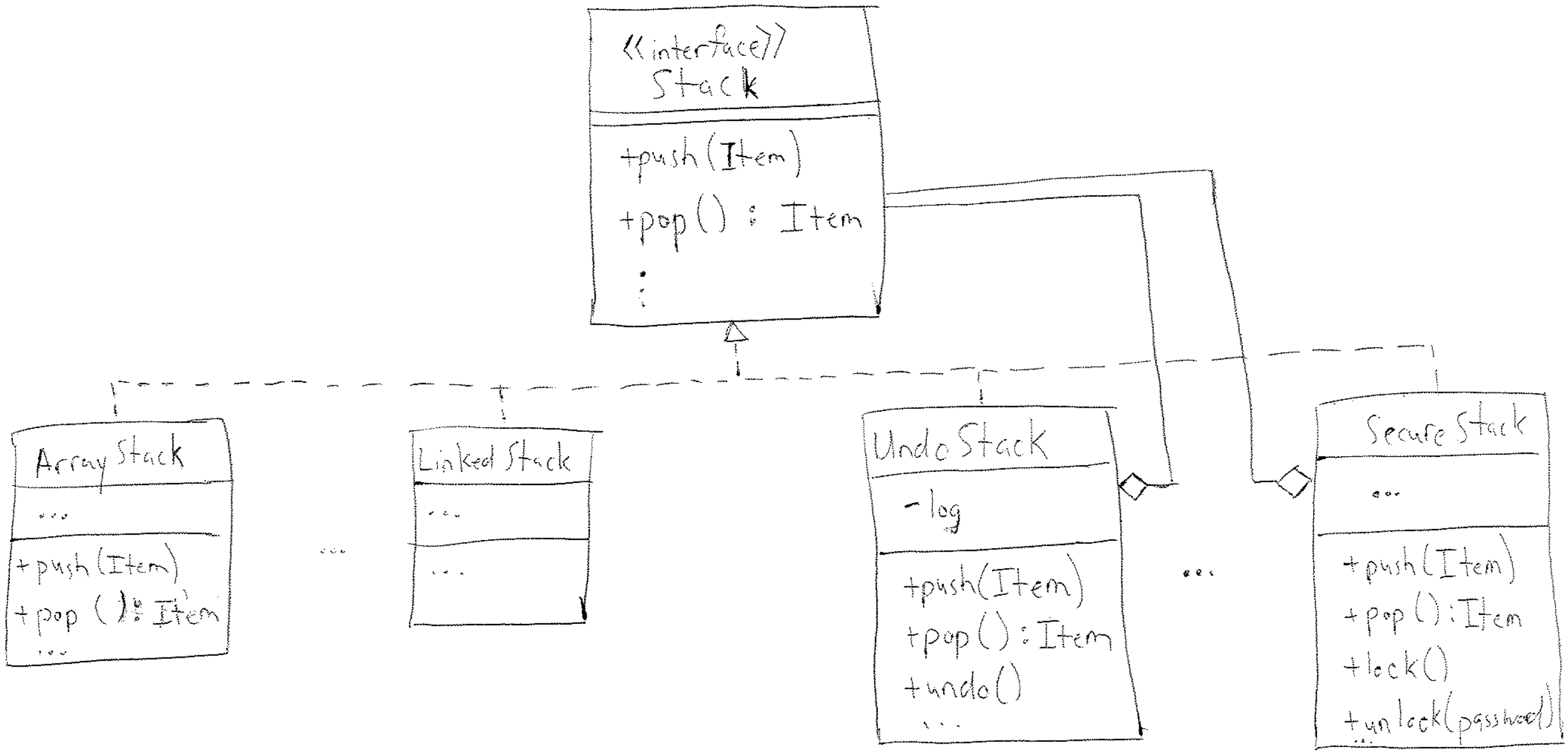


<<interface>>
Stack
+push(Item)
+pop() : Item
...
UndoStack
SecureStack
SynchronizedStack
SecureUndoStack
SynchronizedUndoStack
SynchronizedSecureStack
SynchronizedSecureUndoStack

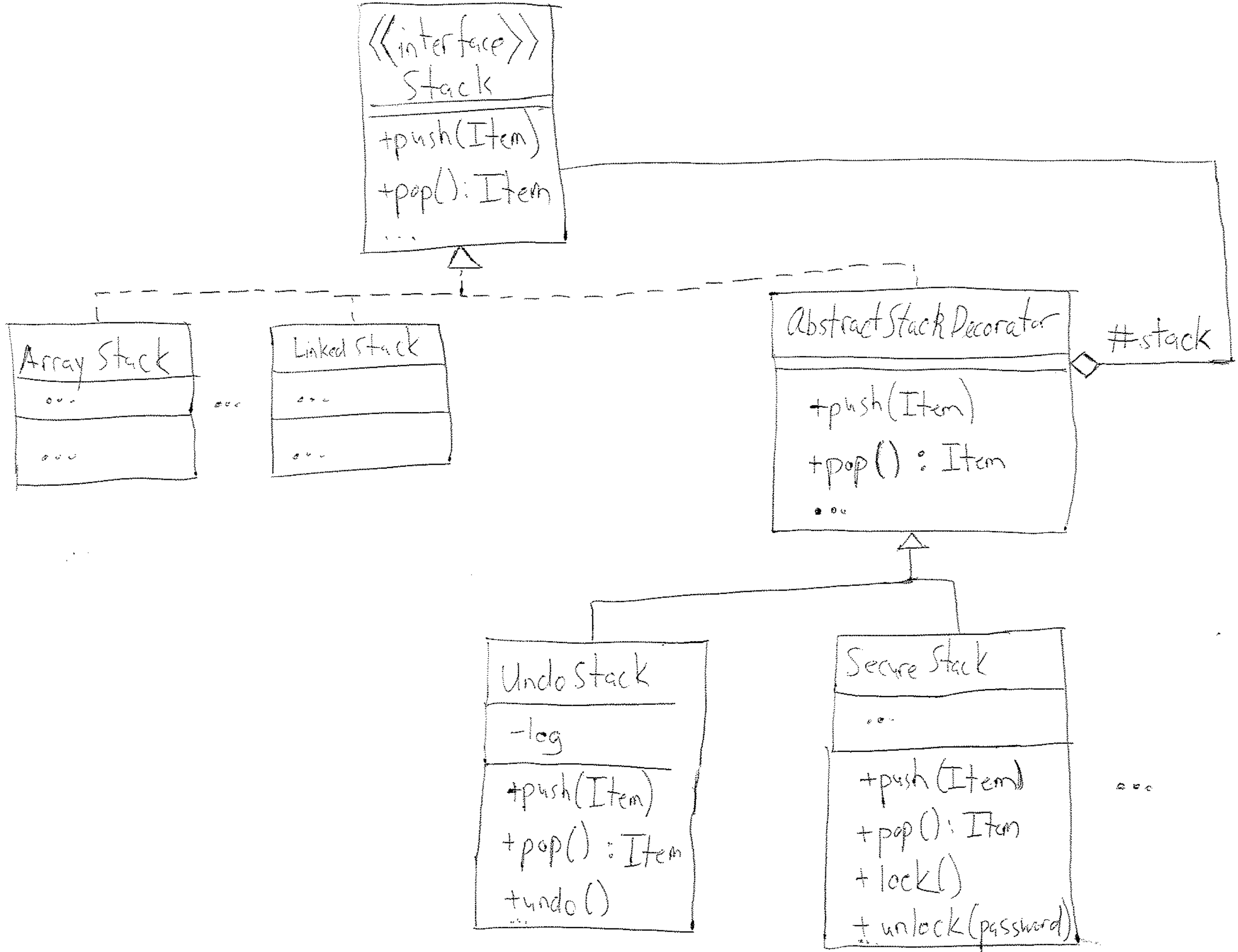


<<interface>>
Stack
+push(Item)
+pop(): Item
...
UndoStack
...
...
SecureStack
...
...
SecureUndoStack
...
...

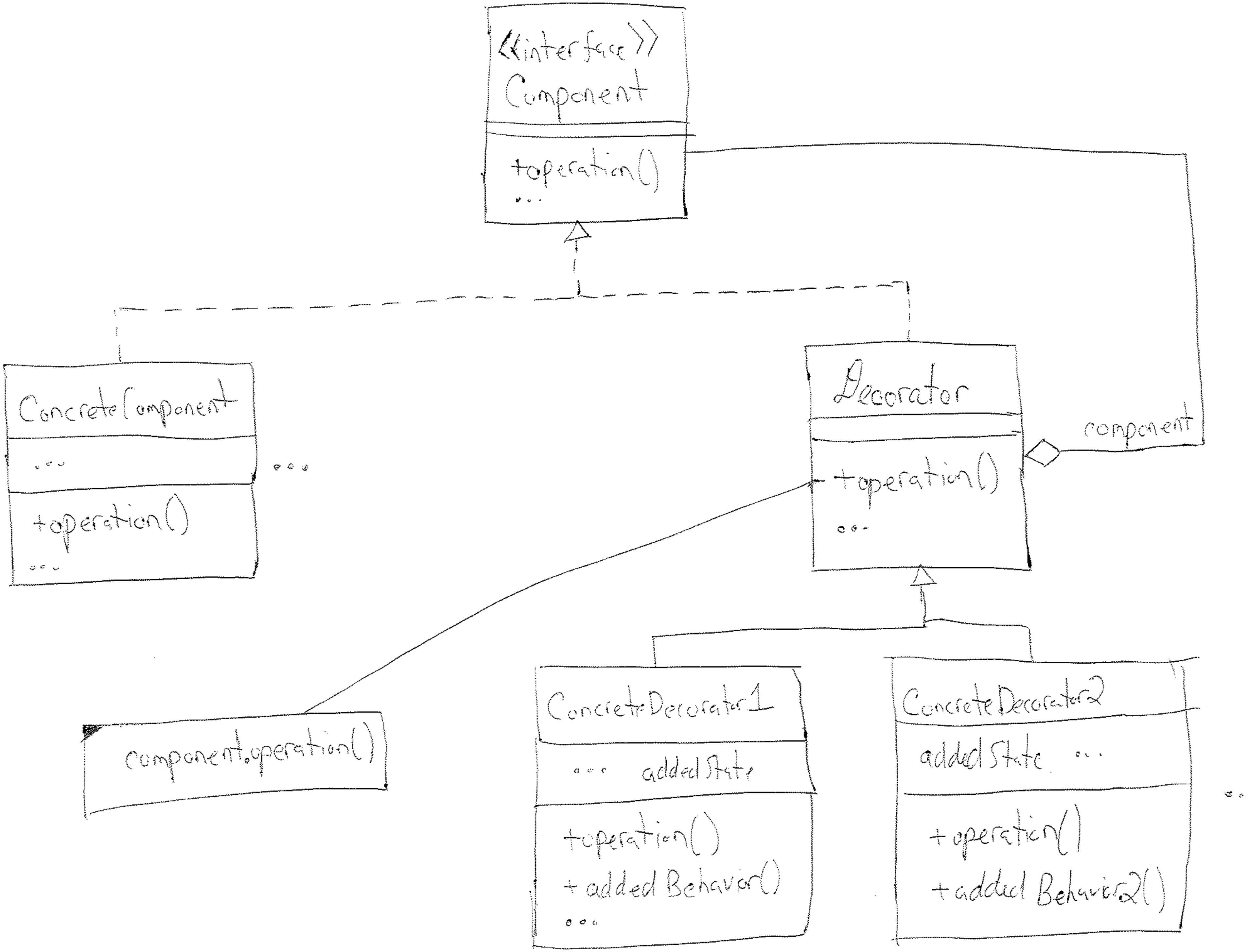
...



«interface»
Stack
+push(Item)
+pop() : Item
⋮
ArrayStack
...
+push(Item)
+pop() : Item
...
LinkedStack
...
...
...
UndoStack
-log
+push(Item)
+pop() : Item
+undo()
...
...
SecureStack
...
+push(Item)
+pop() : Item
+lock()
+unlock(password)
...



«interface» Stack
+push(Item)
+pop(): Item
...
Array Stack
...
...
...
Linked Stack
...
...
Abstract Stack Decorator
+push(Item)
+pop() : Item
...
#stack
Undo Stack
-log
+push(Item)
+pop() : Item
+undo()
Secure Stack
...
+push(Item)
+pop(): Item
+lock()
+unlock(password)
...


<<interface>>
Component
+operation()
...
component
ConcreteComponent
...
+operation()
...
...
Decorator
+operation()
...
component.operation()
ConcreteDecorator1
... addedState
+operation()
+addedBehavior()
...
ConcreteDecorator2
addedState ...
+operation()
+addedBehavior2()
...