Principles of Software Construction: Objects, Design, and Concurrency

Introduction to Design Patterns

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Administrivia

- Homework 1 feedback in your GitHub repository
- Homework 2 due tonight 11:59 p.m.
- Homework 3 available tomorrow
- Optional reading due today: Effective Java Items 18, 19, and 20
  - Required reading due next Tuesday: UML & Patterns Ch 9 and 10

Key concepts from Tuesday

Delegation vs. inheritance summary

- Inheritance can improve modeling flexibility
- Usually, favor composition/delegation over inheritance
  - Inheritance violates information hiding
  - Delegation supports information hiding
- Design and document for inheritance, or prohibit it
  - Document requirements for overriding any method

Continued: `instanceof`

- Operator that tests whether an object is of a given class

```
public void doSomething(Account acct) {
    long adj = 0;
    if (acct instanceof CheckingAccount) {
        checkingAcct = (CheckingAccount) acct;
            adj = checkingAcct.getFee();
    } else if (acct instanceof SavingsAccount) {
        savingsAcct = (SavingsAccount) acct;
            adj = savingsAcct.getInterest();
    }
    …
}
```

Do not do this. This code is bad.

- Advice: avoid `instanceof` if possible
  - Never(?) use `instanceof` in a superclass to check type against subclass

Continued: `instanceof`

- Operator that tests whether an object is of a given class

```
public void doSomething(Account acct) {
    long adj = 0;
    if (acct instanceof CheckingAccount) {
        checkingAcct = (CheckingAccount) acct;
            adj = checkingAcct.getFee();
    } else if (acct instanceof SavingsAccount) {
        savingsAcct = (SavingsAccount) acct;
            adj = savingsAcct.getInterest();
    } else if (acct instanceof InterestCheckingAccount) {
        icAccount = (InterestCheckingAccount) acct;
        adj = icAccount.getInterest();
        adj -= icAccount.getFee();
    }
    …
}
```

Do not do this. This code is bad.

Continued: Use polymorphism to avoid `instanceof`

```
public interface Account {
    …
    public long getMonthlyAdjustment();
}

public class CheckingAccount implements Account {
    …
    public long getMonthlyAdjustment() {
        return getFee();
    }
}

public class SavingsAccount implements Account {
    …
    public long getMonthlyAdjustment() {
        return getInterest();
    }
}
```

Continued: Use polymorphism to avoid `instanceof`

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

Today

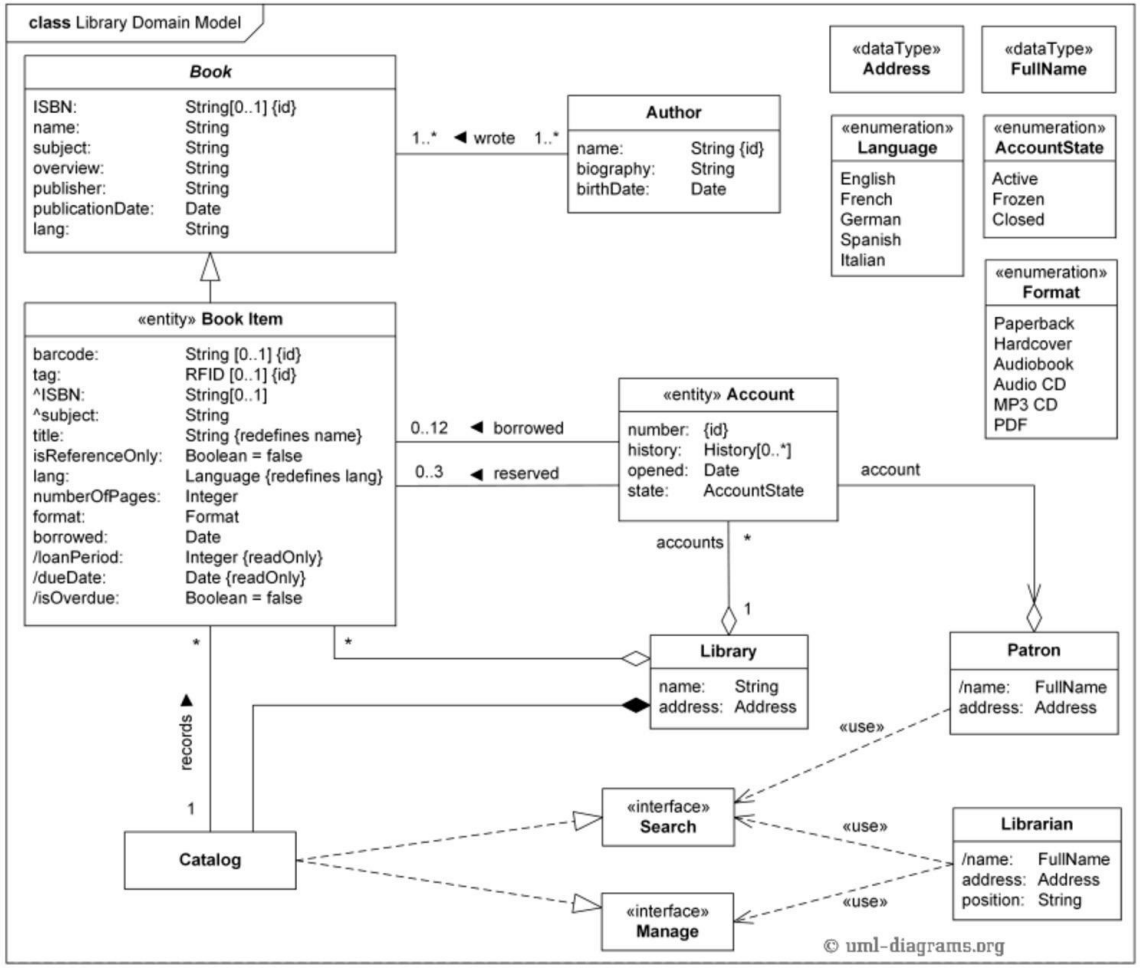
- UML class diagrams
- Introduction to design patterns
  - Strategy pattern
  - Command pattern
- Design patterns for reuse:
  - Template method pattern
  - Iterator pattern (probably next week)
  - Decorator pattern (next week)

Religious debates…

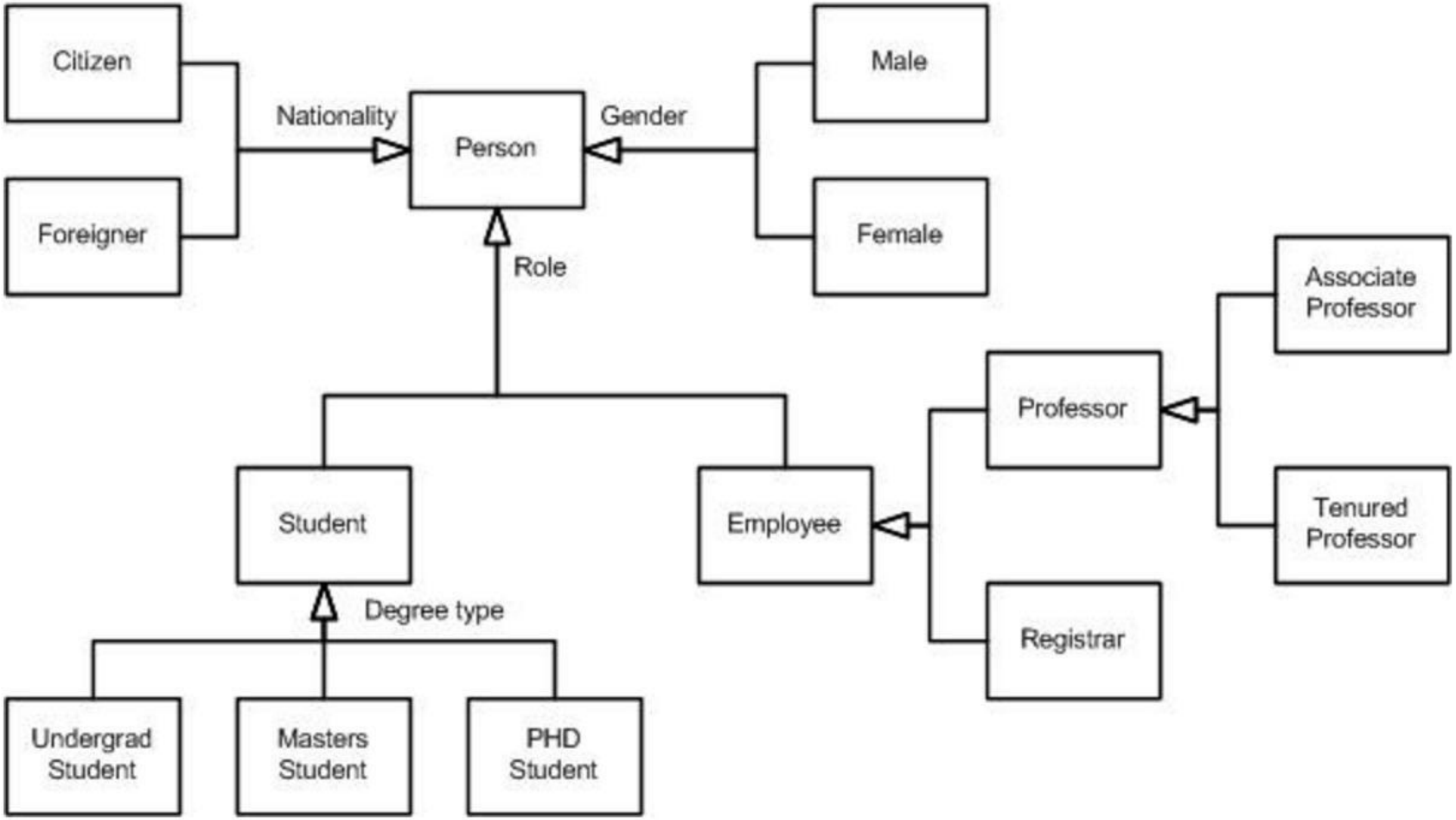
"Democracy is the worst form of government, except for all the others…"

-- (allegedly) Winston Churchill

UML: Unified Modeling Language



UML: Unified Modeling Language



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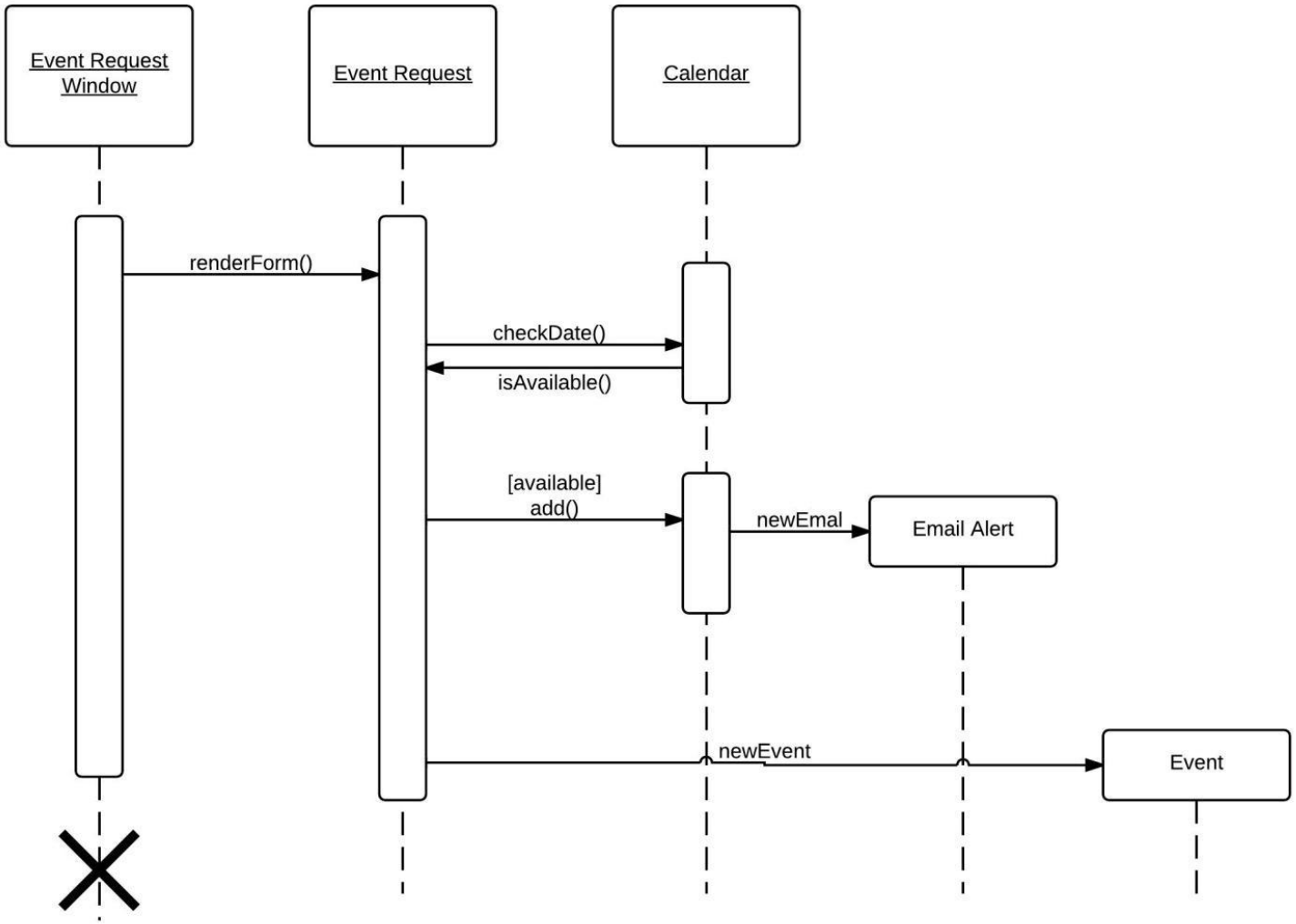
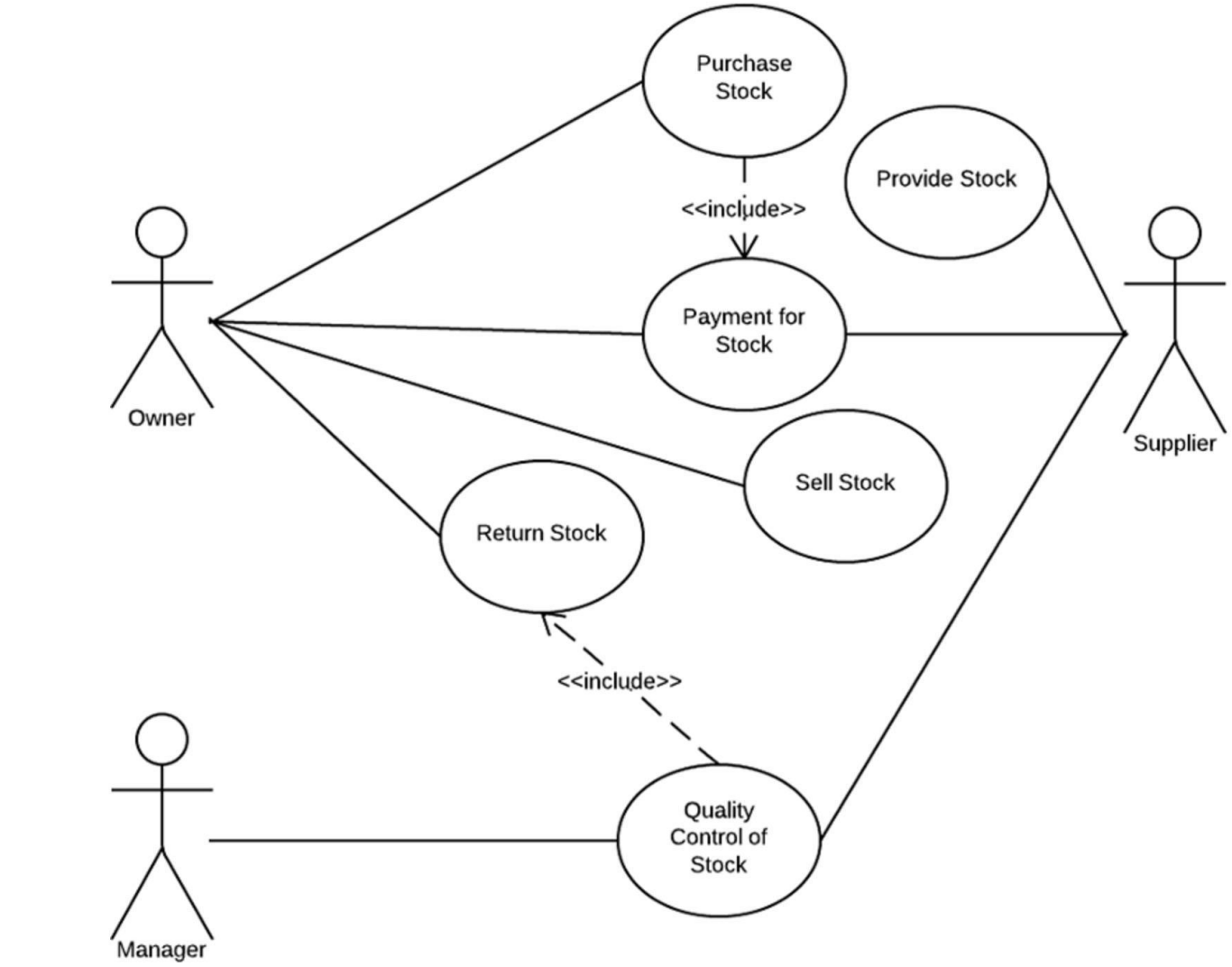


UML: Unified Modeling Language



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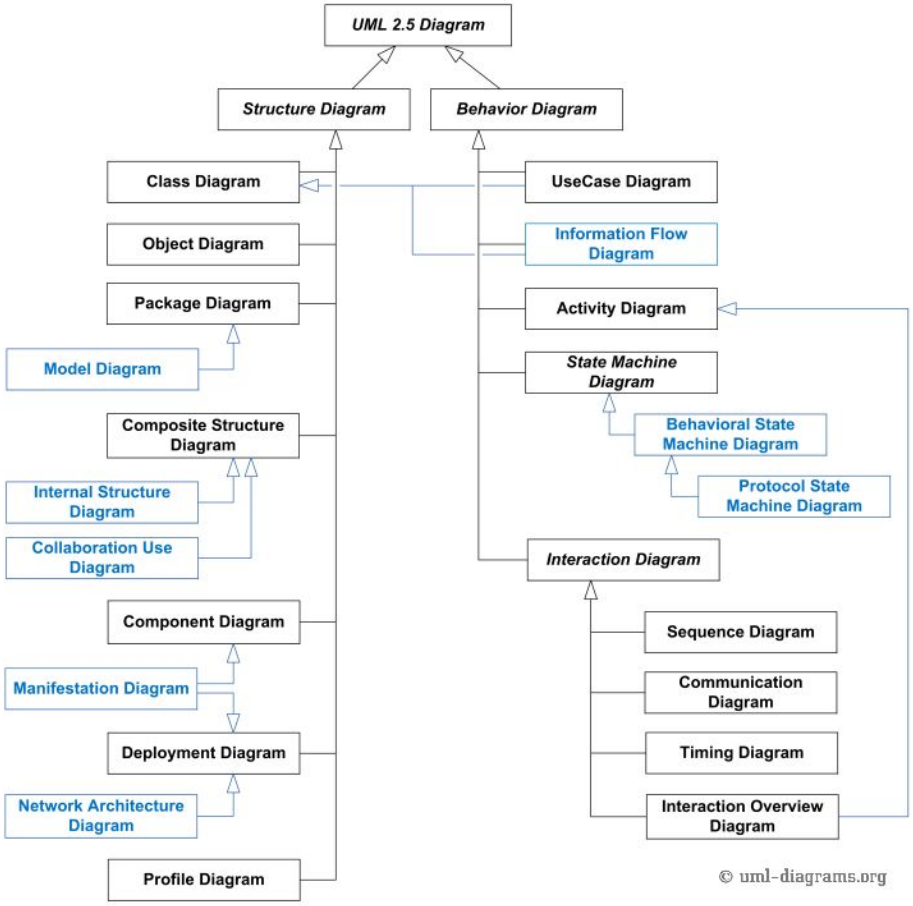


UML in this course

- UML class diagrams
- UML sequence diagrams

UML class diagrams (interfaces and inheritance)

```
public interface Account {
    public long getBalance();
    public void  deposit(long amount);
    public boolean withdraw(long amount);
    public boolean transfer(long amount, Account target);
    public void monthlyAdjustment();
}

public interface CheckingAccount extends Account {
    public long getFee();
}

public interface SavingsAccount extends Account {
    public double getInterestRate();
}

public interface InterestCheckingAccount
                        extends CheckingAccount, SavingsAccount {
}
```

UML class diagrams (classes)

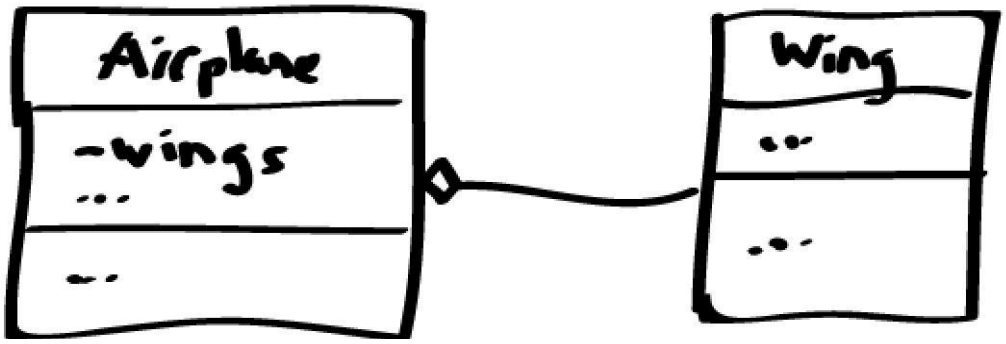
```
public abstract class AbstractAccount
        implements Account {
    protected long balance = 0;
    public long getBalance() {
        return balance;
    }
    abstract public void
   monthlyAdjustment();
    // other methods…
}

public class CheckingAccountImpl
        extends AbstractAccount
        implements CheckingAccount {
    public void monthlyAdjustment() {
        balance -= getFee();
    }
    public long getFee() { … }
}
```

UML you should know

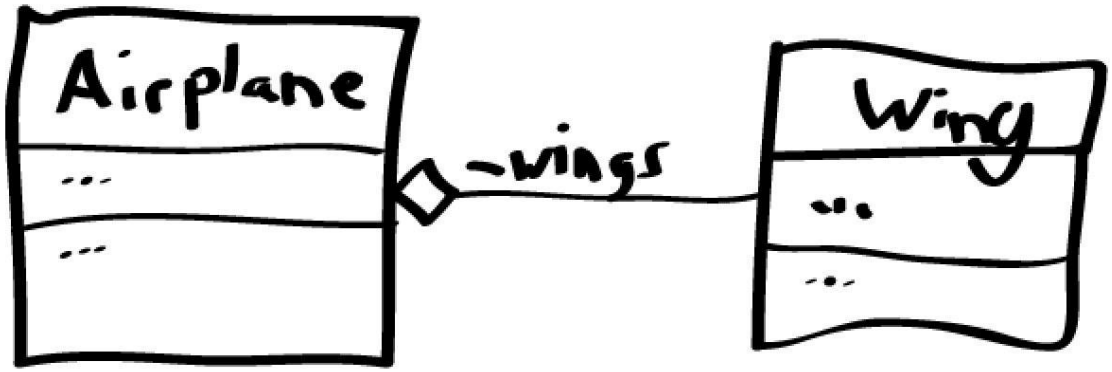
- Interfaces vs. classes
- Fields vs. methods
- Relationships:
  - "extends" (inheritance)
  - "implements" (realization)
  - "has a" (aggregation)
  - non-specific association
- Visibility: + (public) - (private) # (protected)
- Basic best practices…

UML advice

- Best used to show the big picture
  - Omit unimportant details
    - But show they are there: …
- Avoid redundancy
  - e.g., bad:



good:



Today

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- Introduction to design patterns
  - Strategy pattern
  - Command pattern
- Design patterns for reuse:
  - Template method pattern
  - Iterator pattern
  - Decorator pattern (next week)

One design scenario

- Amazon.com processes millions of orders each year, selling in 75 countries, all 50 states, and thousands of cities worldwide. These countries, states, and cities have hundreds of distinct sales tax policies and, for any order and destination, Amazon.com must be able to compute the correct sales tax for the order and destination.

Another design scenario

- A vision processing system must detect lines in an image. For different applications the line detection requirements vary. E.g., for a vision system in a driverless car the system must process 30 images per second, but it's OK to miss some lines in some images. A face recognition system can spend 3-5 seconds analyzing an image, but requires accurate detection of subtle lines on a face.

A third design scenario

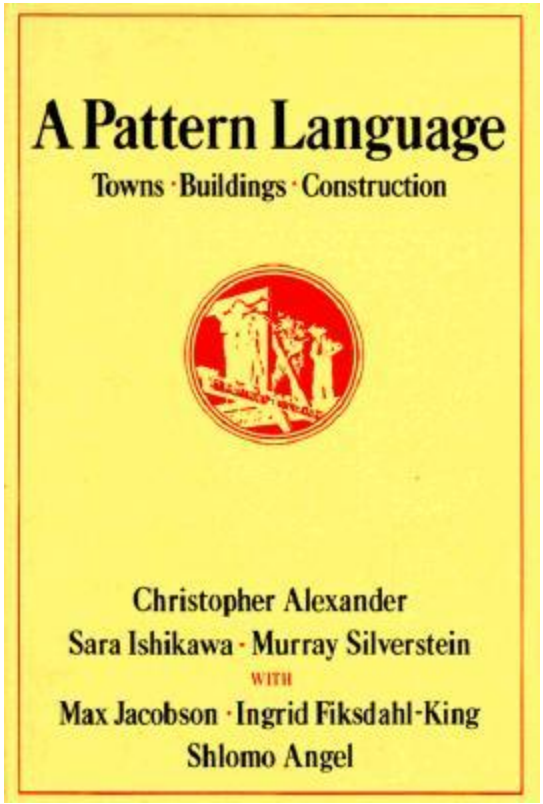
- Suppose we need to sort a list in different orders…

```
interface Order {
  boolean lessThan(int i, int j);
}

final Order ASCENDING =  (i, j) -> i < j;
final Order DESCENDING = (i, j) -> i > j;

static void sort(int[] list, Order cmp) {
  …
  boolean mustSwap =
    cmp.lessThan(list[i], list[j]);
  …
}
```

Design patterns

"Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice"

– Christopher Alexander, Architect (1977)



How not to discuss design (from Shalloway and Trott)

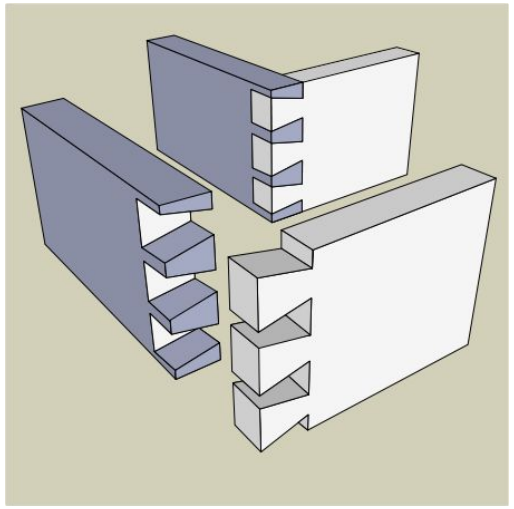
- Carpentry:
  - How do you think we should build these drawers?
  - Well, I think we should make the joint by cutting straight down into the wood, and then cut back up 45 degrees, and then going straight back down, and then back up the other way 45 degrees, and then going straight down, and repeating…

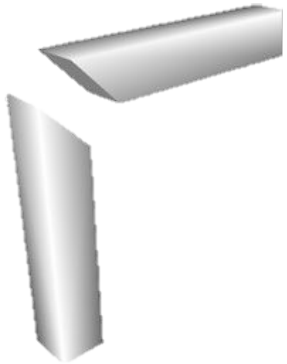
How not to discuss design (from Shalloway and Trott)

- Carpentry:
  - How do you think we should build these drawers?
  - Well, I think we should make the joint by cutting straight down into the wood, and then cut back up 45 degrees, and then going straight back down, and then back up the other way 45 degrees, and then going straight down, and repeating…
- Software Engineering:
  - How do you think we should write this method?
  - I think we should write this if statement to handle … followed by a while loop … with a break statement so that…

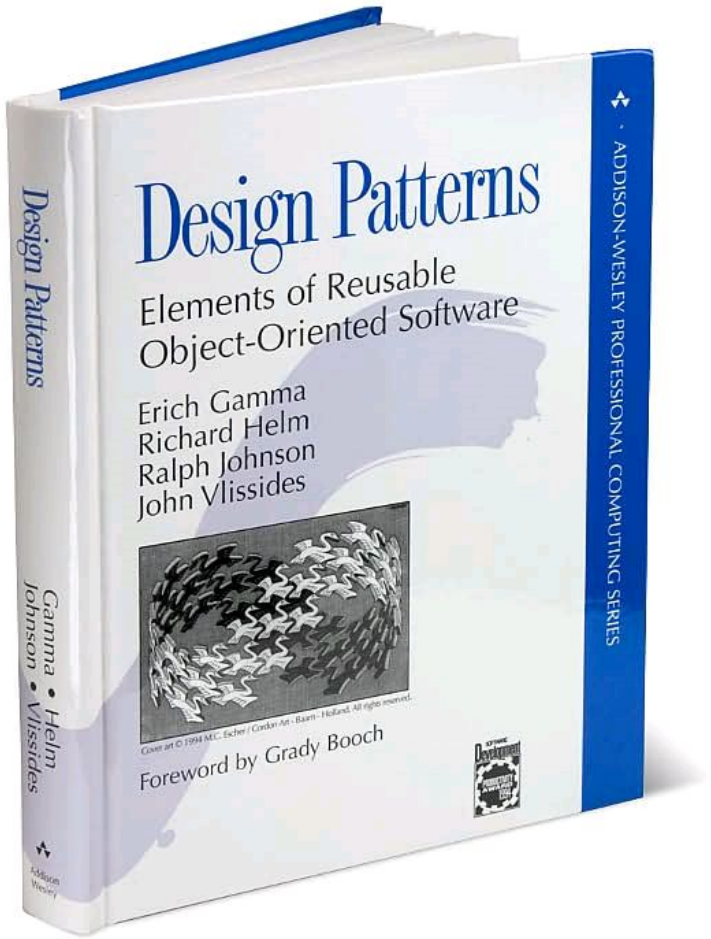
Discussion with design patterns

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





History: *Design Patterns* (1994)



Elements of a design pattern

- Name
- Abstract description of problem
- Abstract description of solution
- Analysis of consequences

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

Patterns are more than just structure

- Consider: A modern car engine is constantly monitored by a software system. The monitoring system must obtain data from many distinct engine sensors, such as an oil temperature sensor, an oxygen sensor, etc. More sensors may be added in the future.

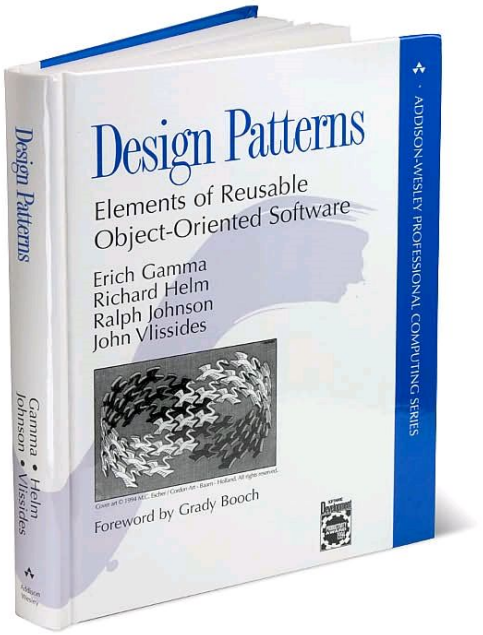
Different patterns can have the same structure

Command pattern:

- Problem: Clients need to execute some (possibly flexible) operation without knowing the details of the operation
- Solution: Create an interface for the operation, with a class (or classes) that actually executes the operation
- Consequences:
  - Separates operation from client context
  - Can specify, queue, and execute commands at different times
  - Introduces an extra interface and classes:
    - Code can be harder to understand
    - Lots of overhead if the commands are simple

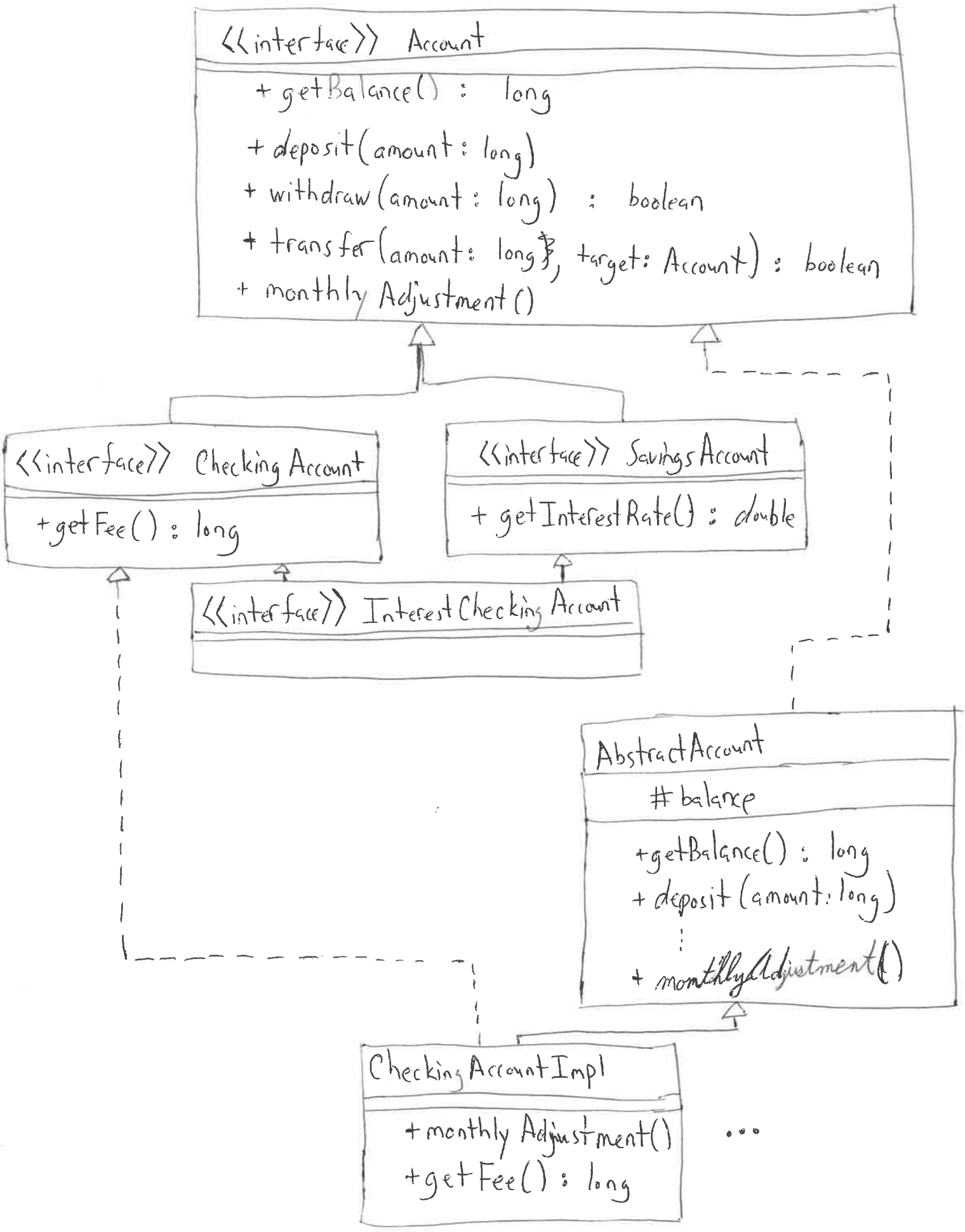
Design pattern conclusions

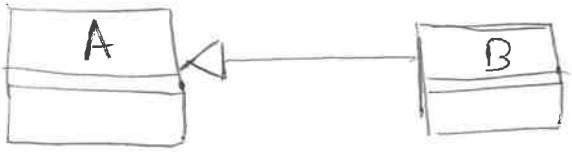
- Provide shared language
- Convey shared experience
- Can be system and language specific



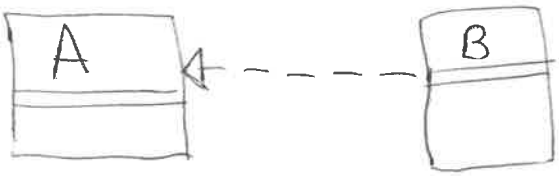
Summary

- Use UML class diagrams to simplify communication
- Design patterns…
  - Convey shared experience, general solutions
  - Facilitate communication
- Specific design patterns for reuse:
  - Strategy
  - Command


<<interface>> Account
+ getBalance() : long
+ deposit(amount: long)
+ withdraw(amount: long) : boolean
+ transfer(amount: long, target: Account) : boolean
+ monthlyAdjustment()
<<interface>> CheckingAccount
+ getFee() : long
<<interface>> SavingsAccount
+ getInterestRate() : double
<<interface>> InterestCheckingAccount
AbstractAccount
balance
+ getBalance() : long
+ deposit(amount: long)
+ monthlyAdjustment()
CheckingAccountImpl
+ monthlyAdjustment()
+ getFee() : long
...

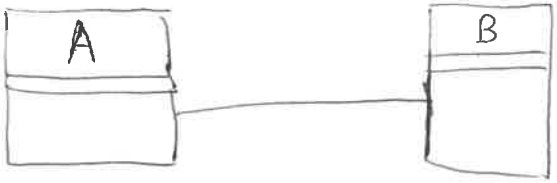


B extends A

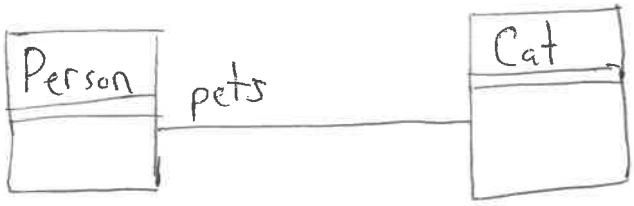


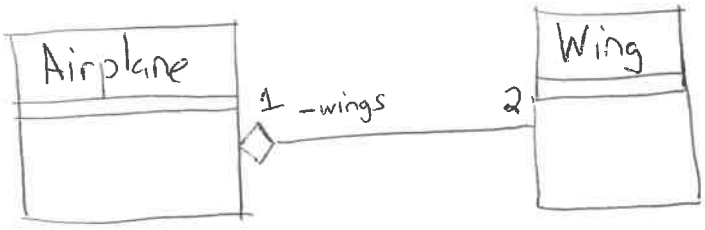
B implements A

B has a A



B is associated with A

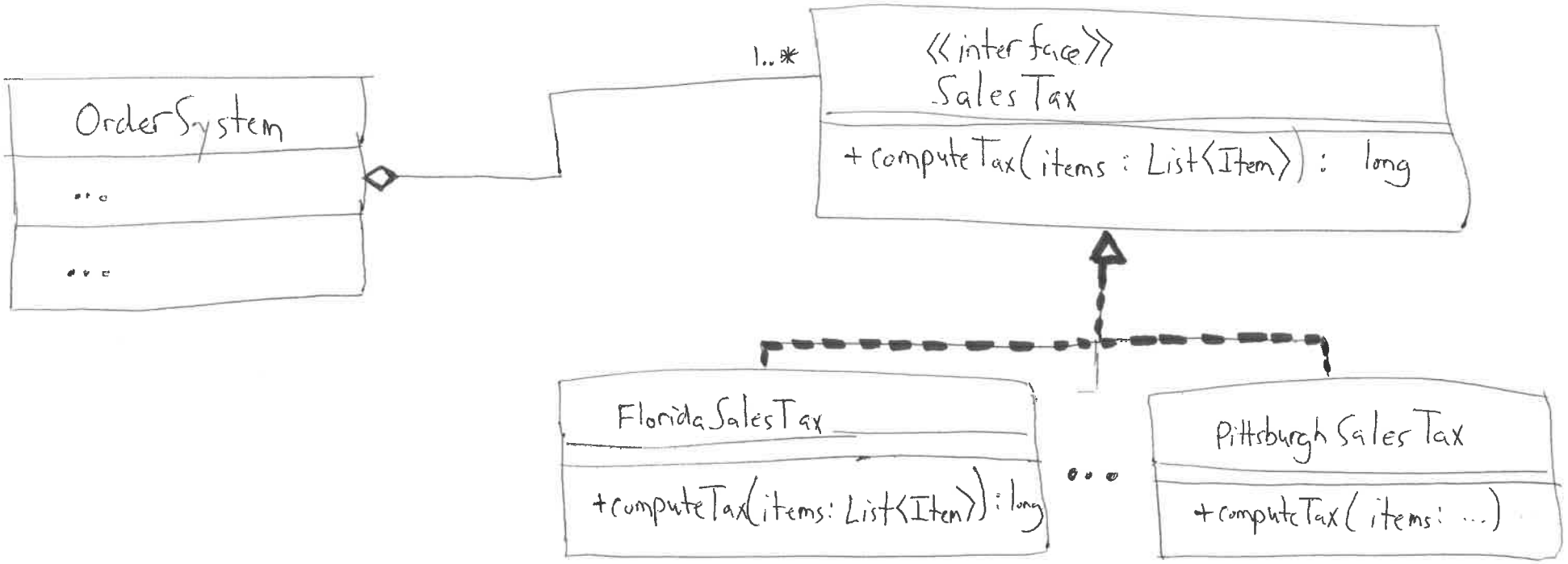


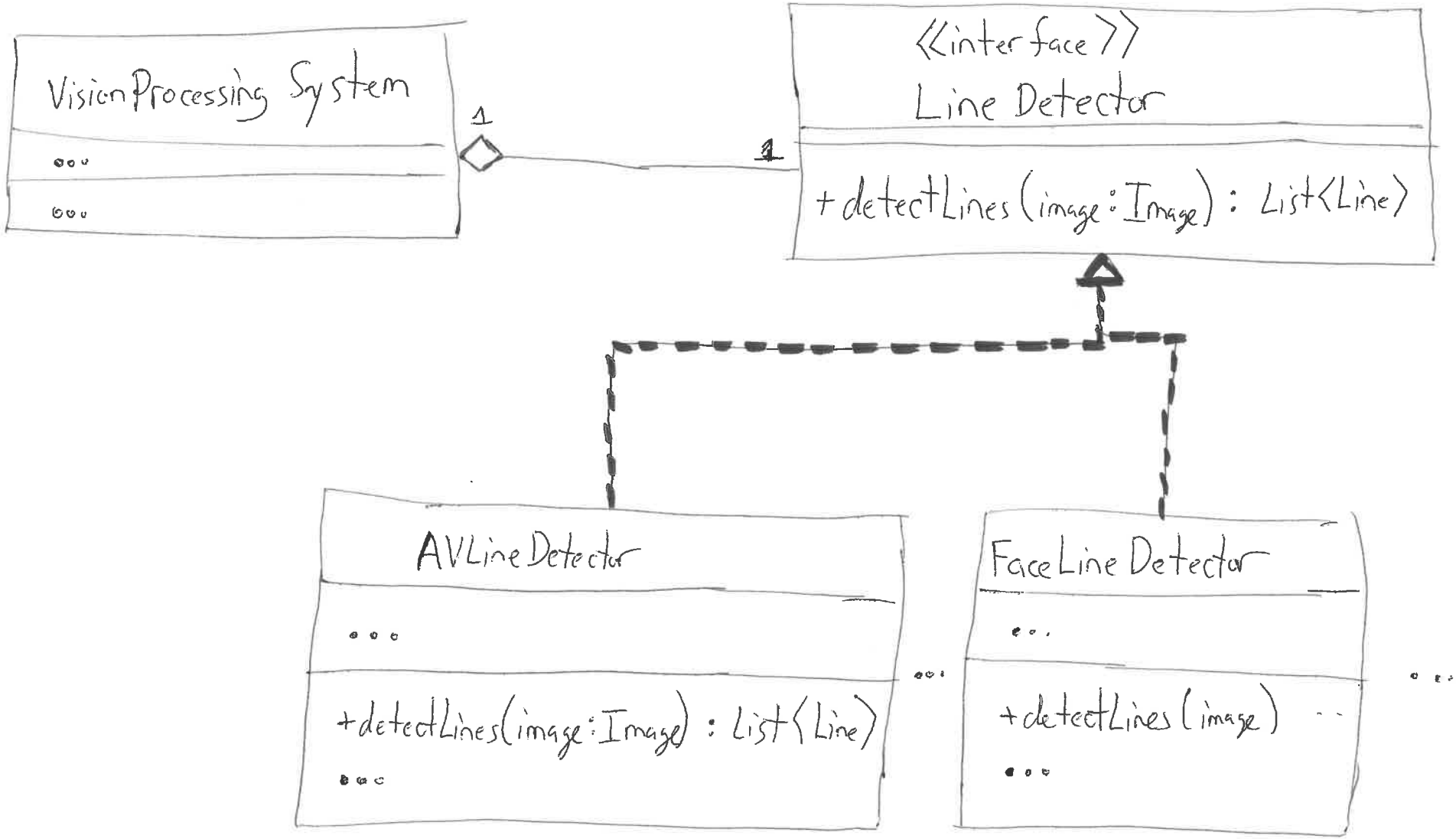


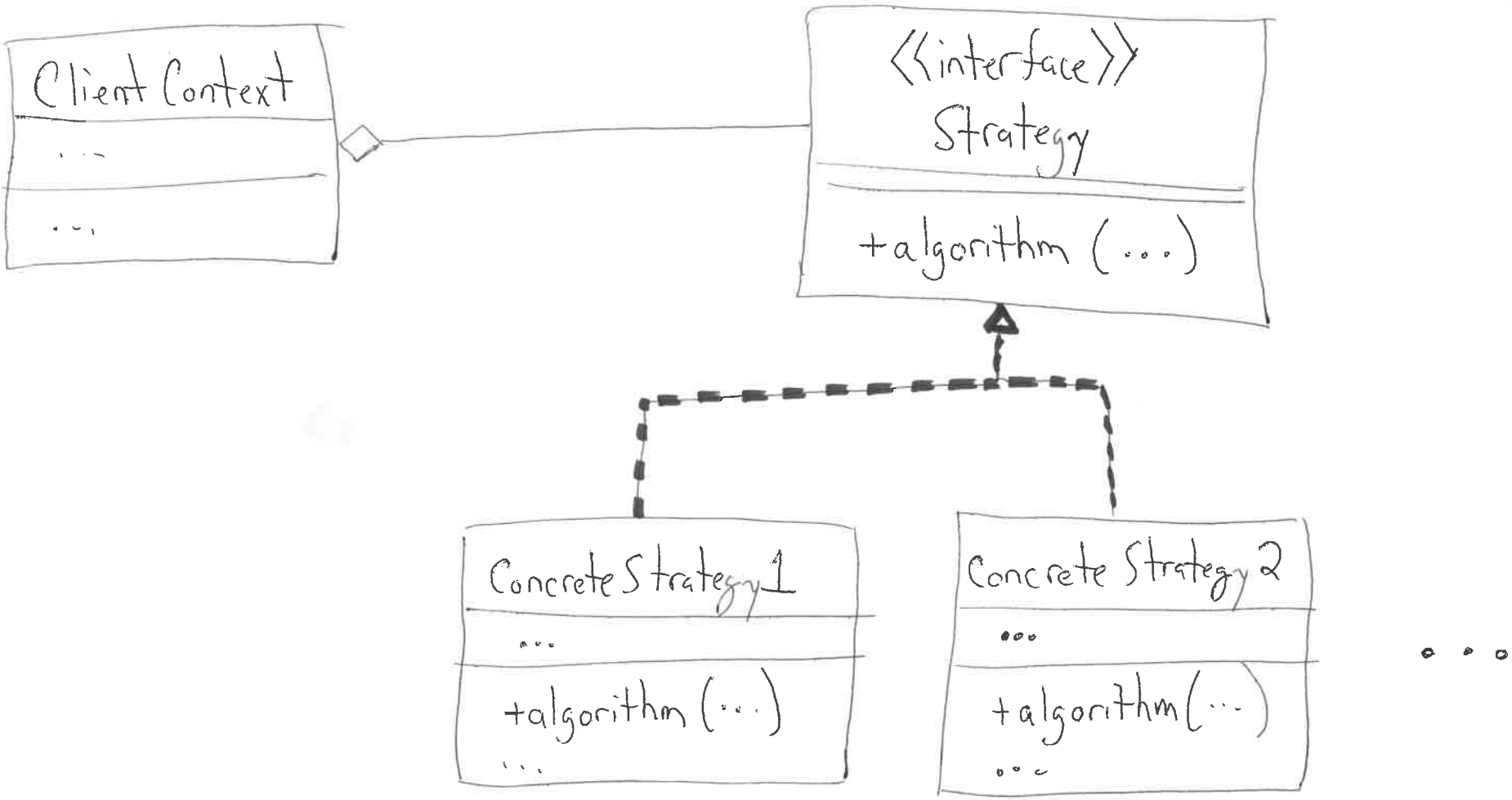
An airplane has exactly two wings.

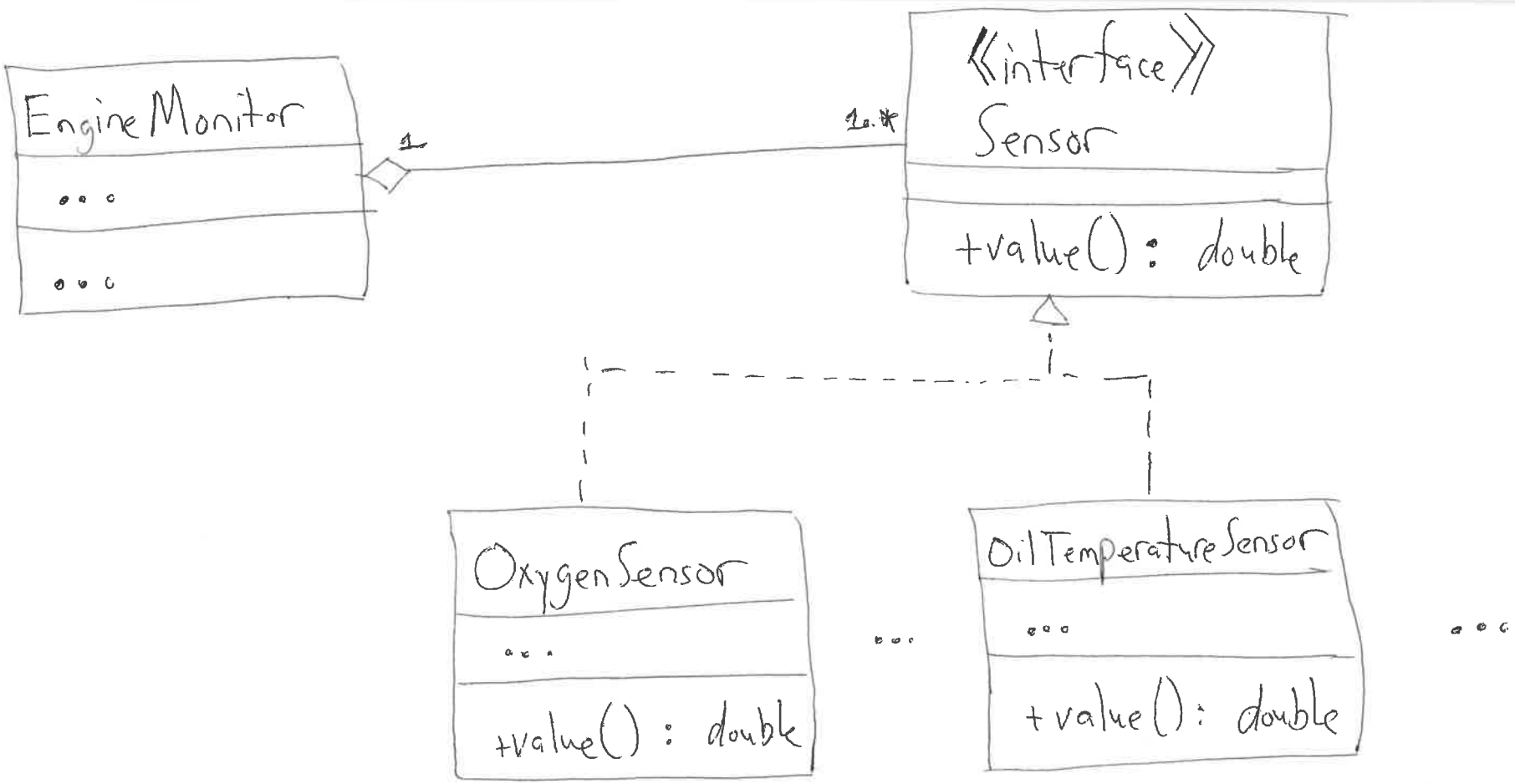
A wing is in/on exactly one airplane.

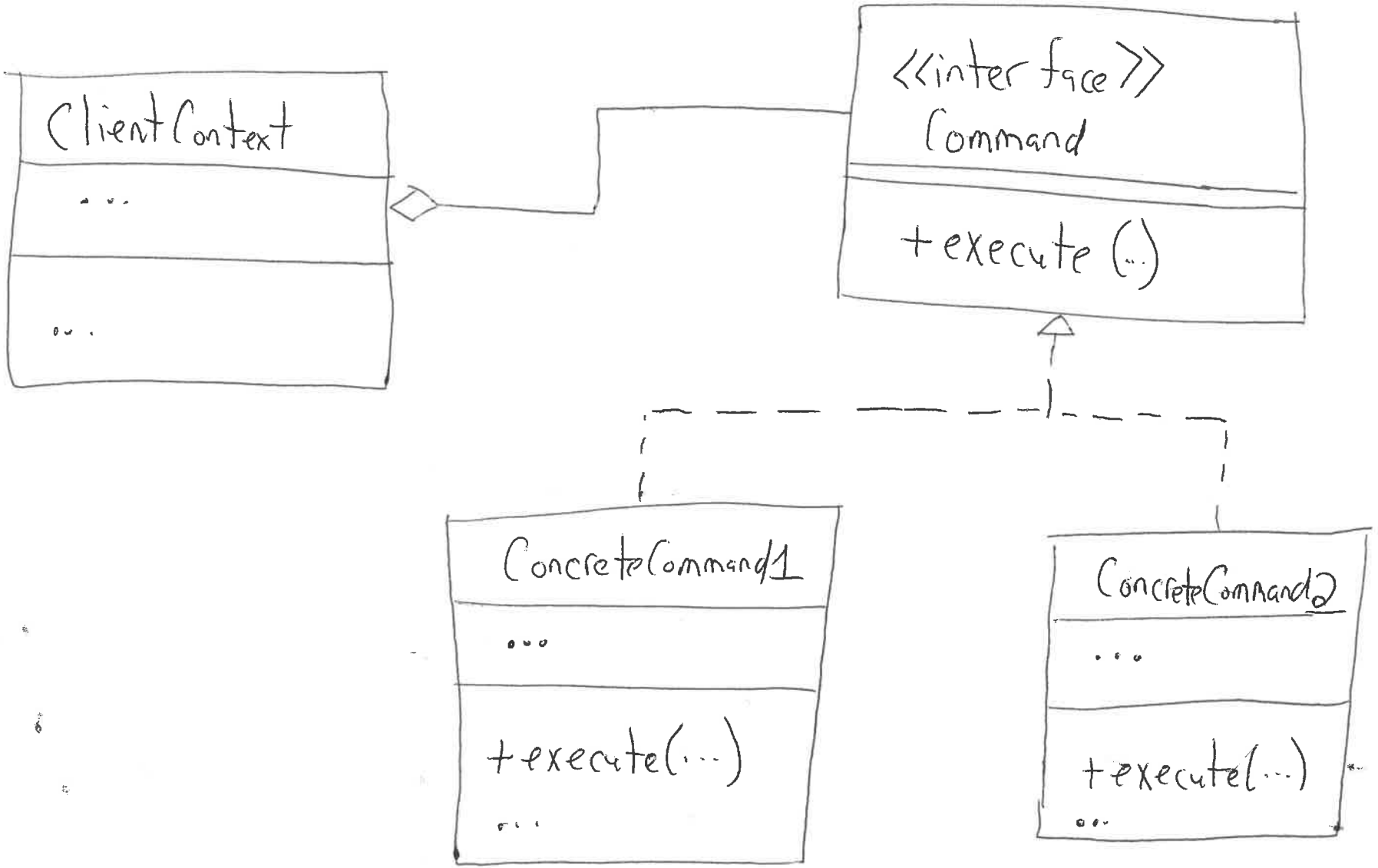
The wings are a private variable called wings.


OrderSystem
...
...
1..*
«interface»
SalesTax
+computeTax(items : List<Item>) : long
FloridaSalesTax
+computeTax(items: List<Item>): long
...
PittsburghSalesTax
+computeTax(items: ...)


VisionProcessing System
...
...
1
1
«interface»
Line Detector
+detectLines(image:Image) : List<Line>
AVLine Detector
...
+detectLines(image:Image) : List<Line>
...
FaceLine Detector
...
+detectLines(image)
...


Client Context
...
...
<<interface>>
Strategy
+algorithm (...)
ConcreteStrategy1
...
+algorithm (...)
...
ConcreteStrategy2
...
+algorithm(...)
...
...


EngineMonitor
...
...
1
1..*
«interface»
Sensor
+value(): double
OxygenSensor
...
+value(): double
...
OilTemperatureSensor
...
+value(): double
...


ClientContext
...
...
<<interface>>
Command
+execute(...)
ConcreteCommand1
...
+execute(...)
...
ConcreteCommand2
...
+execute(...)
...