Universität Zürich^UZH

Institut für Informatik

# Software Engineering HS'14

# Lecture: Software Design

Thomas Fritz & Martin Glinz

*Many thanks to Philippe Beaudoin, Gail Murphy, David Shepherd, Neil Ernst, Meghan Allen, and Elisa Baniassad*

# High Level Overview of the Design Unit

- Introduction to Design
- Architectural Design
- Detailed Design
- Modular Design / Design Principles
- Design Patterns

# Learning Goals

By the end of this unit, you will be able to:

- Describe the context (goals and constraints) of the activity of software design and the process for developing it
- Define what is meant by “architectural style” and describe characteristics of main styles
- Understand the use of diagrams in software development
- Create a design for a given system and specify it in correct UML class/sequence diagram syntax

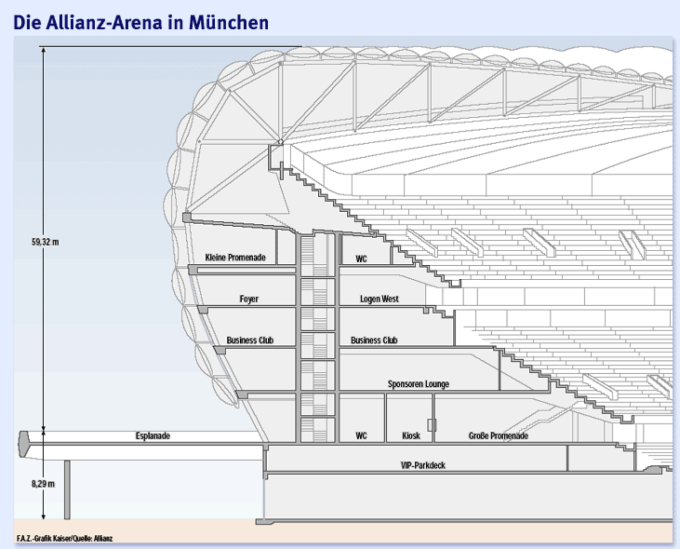
# What is Clothing Design?

Picture from www.arcteryx.com

- Why might a designer decide to design such a jacket?
- What might have influenced the designer?

# What is Building Design?

- Münchner Allianz Arena, built for FC Bayern and TSV1860 (2002-2005)
- Inputs?
- Constraints?



F.A.Z.-Grafik Kaiser/Quelle: Allianz

Picture from http://de.academic.ru/pictures/dewiki/65/Allianzarenacombo.jpg and www.faz.net

# What is software design?

Requirements specification was about **WHAT** the system will do

Design is about **HOW** the system will perform its functions

# What is design?

*What is design? What makes something a design problem? It's where you stand with* ***a foot in two worlds*** *– the world of technology and the world of people and human purposes – and you try to bring the two together.*

- Mitchel Kapor, A Software Design Manifesto (1991)

# Kapor goes on to say…

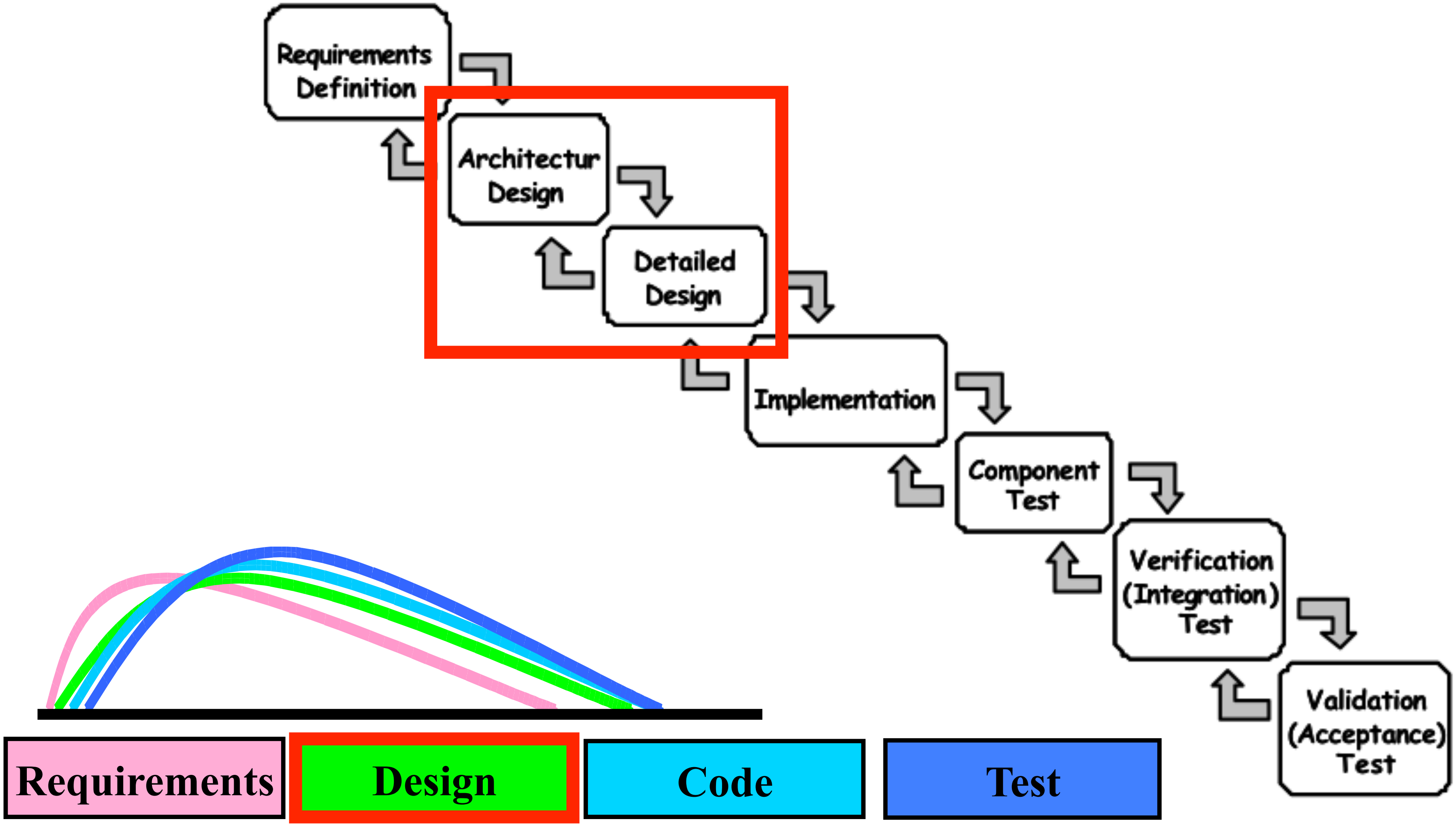
*Design disciplines are concerned with making artifacts for human use. Architects work in the medium of buildings, graphic designers work in paper and other print media, industrial designers on mass-produced manufactured goods, and software designers on software.* ***The software designer should be the person with overall responsibility for the conception and realization of the program.***

from G. Murphy

# Software Design in this course

- Mainly focusing on technological (developer/ engineer) view of software design
- How do we realize the conceived product?
- Inputs include requirements (functional and non-functional), developer’s experience
- Constraints include development organization, technical platform
- Goals: decomposition and determination of relationships, communication and more

# Where does it fit in the process?



Requirements Definition

Architectur Design

Detailed Design

Implementation

Component Test

Verification (Integration) Test

Validation (Acceptance) Test

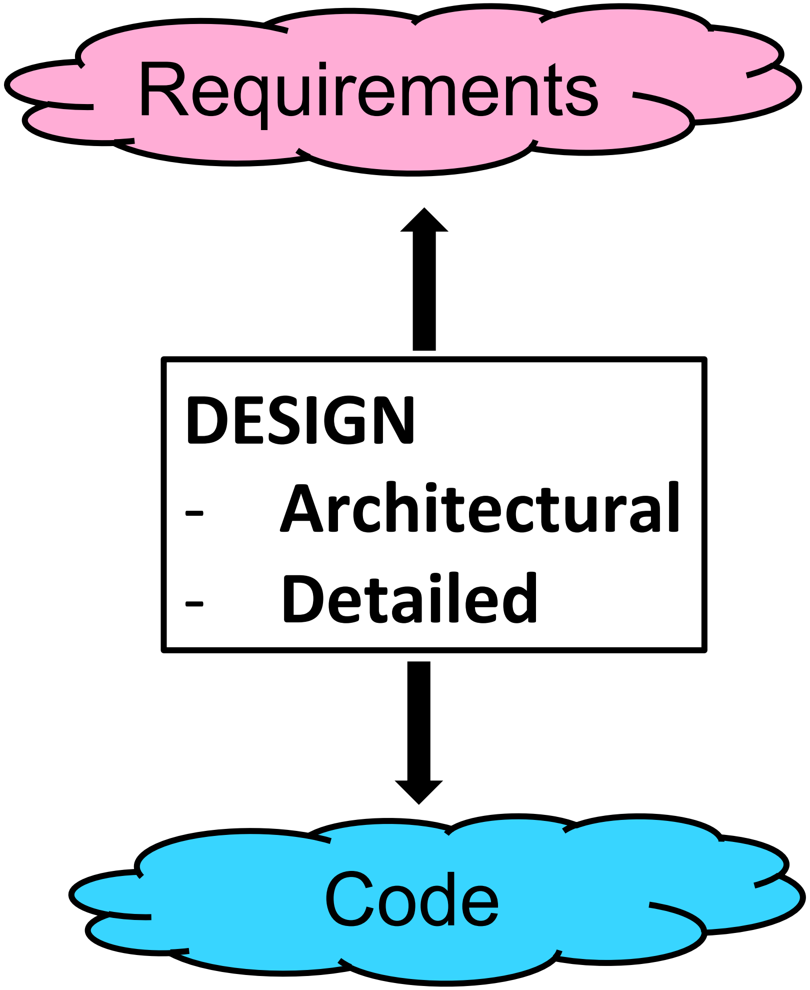
Requirements

Design

Code

Test

# Design to Bridge the Gap



Requirements

DESIGN

- Architectural
- Detailed

Code

# Why Design?

Facilitates communication

Eases system understanding

Eases implementation

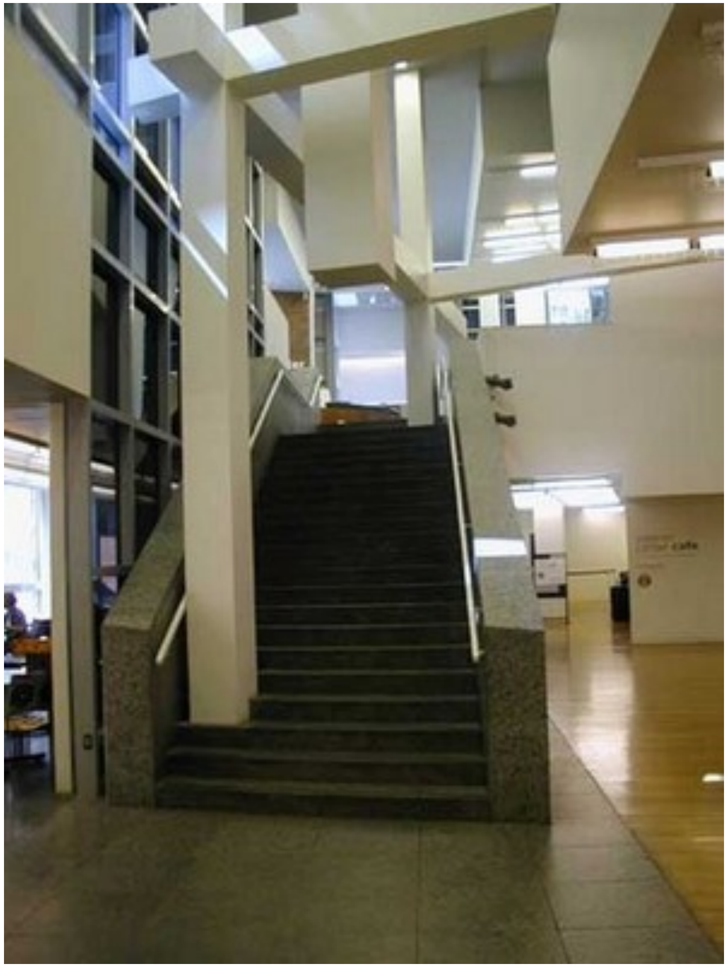
Helps discover problems early

Increases product quality

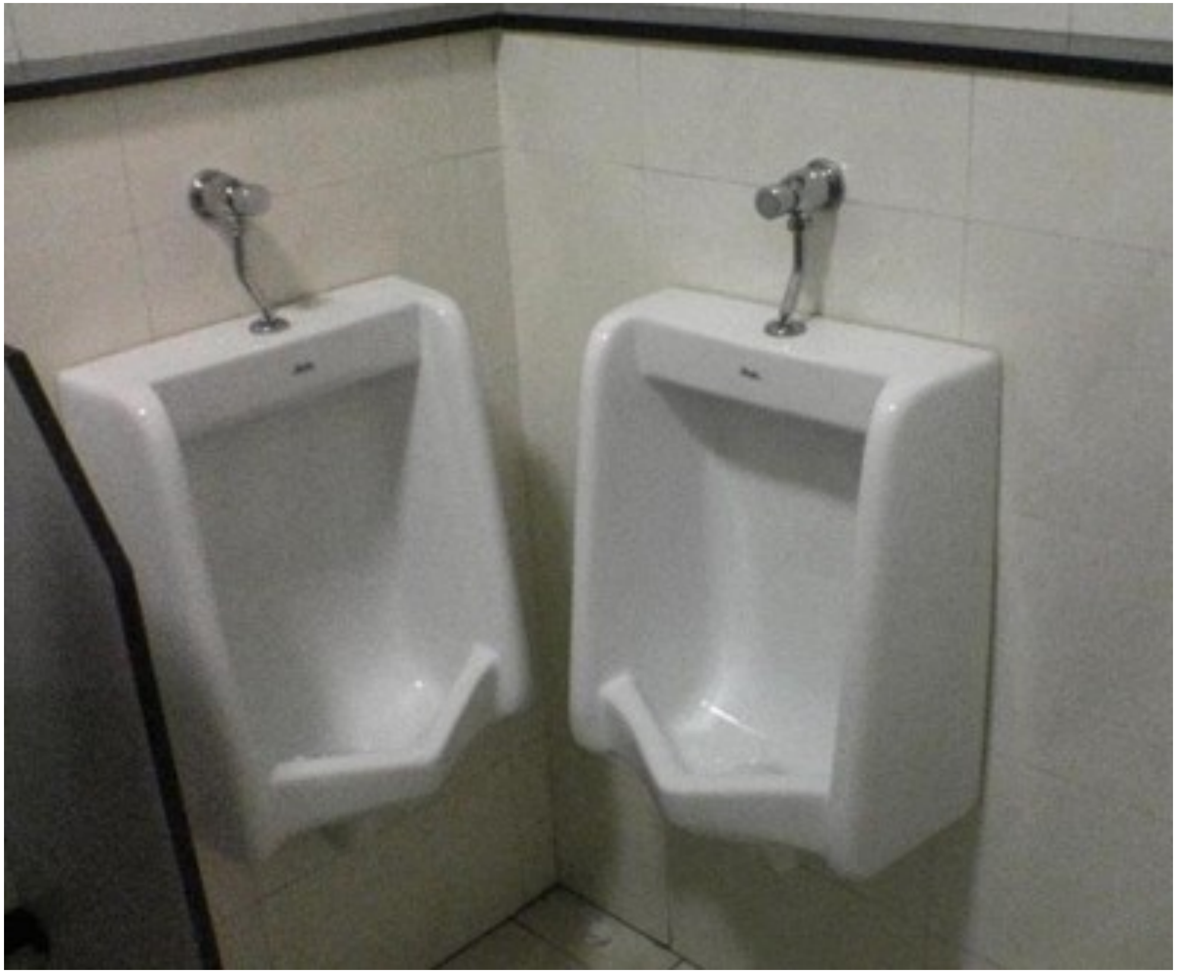
Reduces maintenance costs

Facilitates product upgrade

# Cost of not planning…



# Another example of poor planning



# How to approach Design?

*“Treat design as a wicked, sloppy,* ***heuristic*** *process. Don’t settle for the first design that occurs to you.* ***Collaborate.*** *Strive for* ***simplicity****. Prototype when you need to. Iterate, iterate and* ***iterate again****. You’ll be happy with your designs.”*

McConnell, Steve. *Code Complete*. Ch. 5

# How to approach Design?

Study and understand the problem from different viewpoints

Identify potential solutions and evaluate the trade-offs

Develop different models of system at different levels of abstraction: start global, subdivide (top-down), iterate
(design is often a combination of top-down and bottom-up)

# Two common phases of Software Design

**Architectural** design

- Overall structure: main components and their connections; determining which sub-systems you need (e.g., web server, DB…)

**Detailed** design

- Inner structure of main components
- Take programming language into account

# Software Architecture

*The **fundamental concepts** or properties of a system in its environment embodied in its **elements**, **relationships**, and in the principles of its **design** and **evolution**.*

IEEE Standard 1471-2011

*The structure or **structures of the system**, which comprise software **elements**, the **externally visible properties** of those elements and the **relationships** among them.*

Software Architecture in Practice (2nd edition), Bass, Clements, Kazman

# Software Architecture

A software architectures for a system describes

- Subsystems and components that comprise the system
  (client/server, web service, software package, …)
- Overall structure of those components and subsystems
  (e.g. pipe and filter, blackboard, MVC, …)
- Connectors
  (interactions and rules that govern interactions, e.g. client-server network protocol, procedure calls)
- Constraints
  (environmental constraints, quality attributes or non-functional requirements)

# Architectural Styles & Patterns

Architectural styles constrain architectural design decisions and dictate qualities the system will have

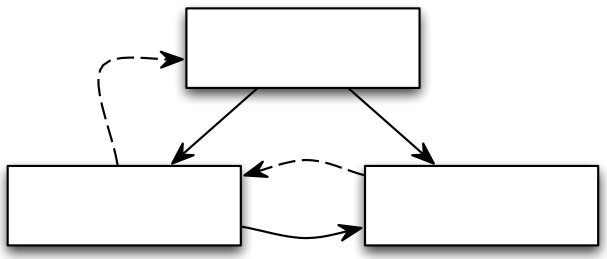
- e.g., modifiable? secure? scalable? reliable? Etc.

Architectural style is a name given to a common architectural design. Architectural pattern is a way of solving a common architectural pattern. (sometimes used interchangeably)

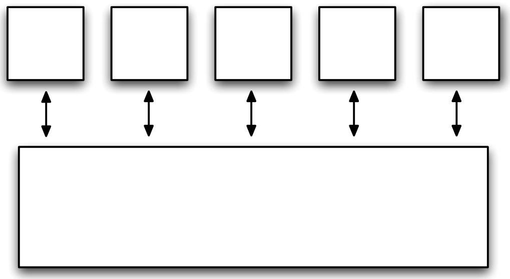
Both provide common language of software architecture

from G. Murphy

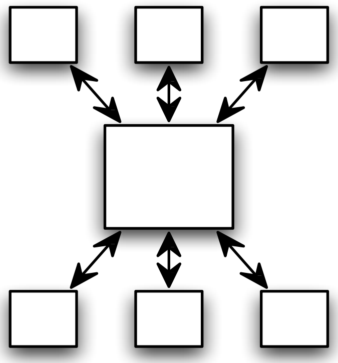
# Common Architectural Styles & Patterns



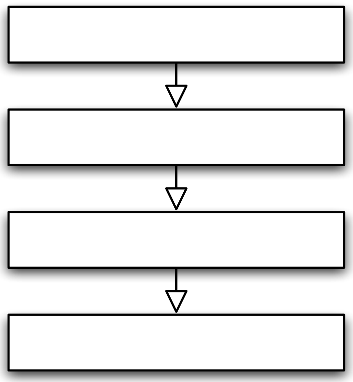
model view controller



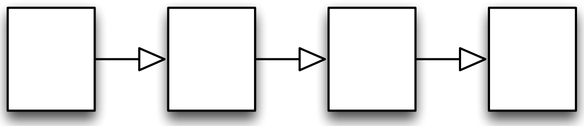
blackboard



client/server



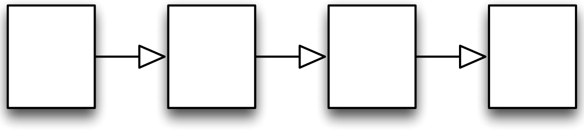
layered



pipe-and-filter

from E. Baniassad

# Pipe-and-Filter



**Components:** **filters** that read input data stream and transform it into output data stream

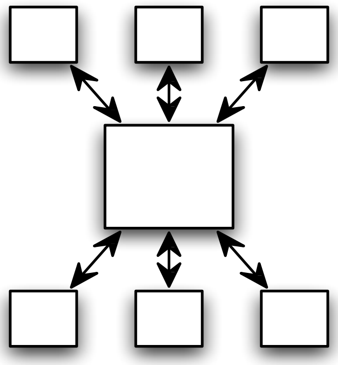
**Connectors:** **pipes** that provide output of filter as input to other filter

**Advantages:** simple, no complex interaction, high reusability, portability

**Disadvantages:** require common data format, no shared state, redundancy in (un)parsing

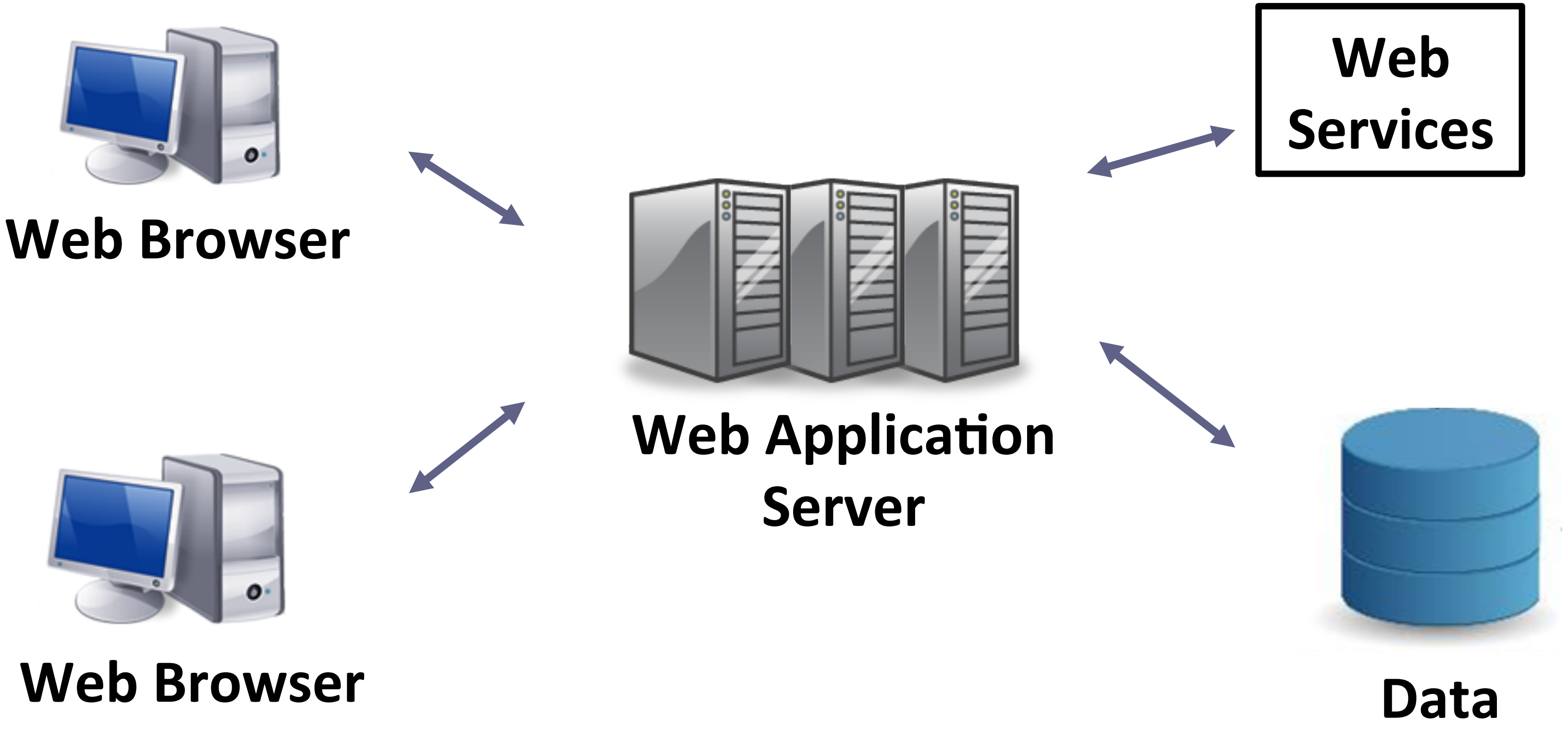
**Example:** unix shell (ls –l | grep key | more …)

# Client/Server



| | |
|---|---|
| **Components:** | **server** subsystem provides services to multiple instances of **client** subsystem; |
| **Connectors:** | network; client typically request services from server |
| | |
| **Advantages:** | distribution, scalability |
| **Disadvantages:** | responsiveness (if network is slow), robustness (if server goes down) |

# Web Architecture (Client / Server Style)



Web Browser

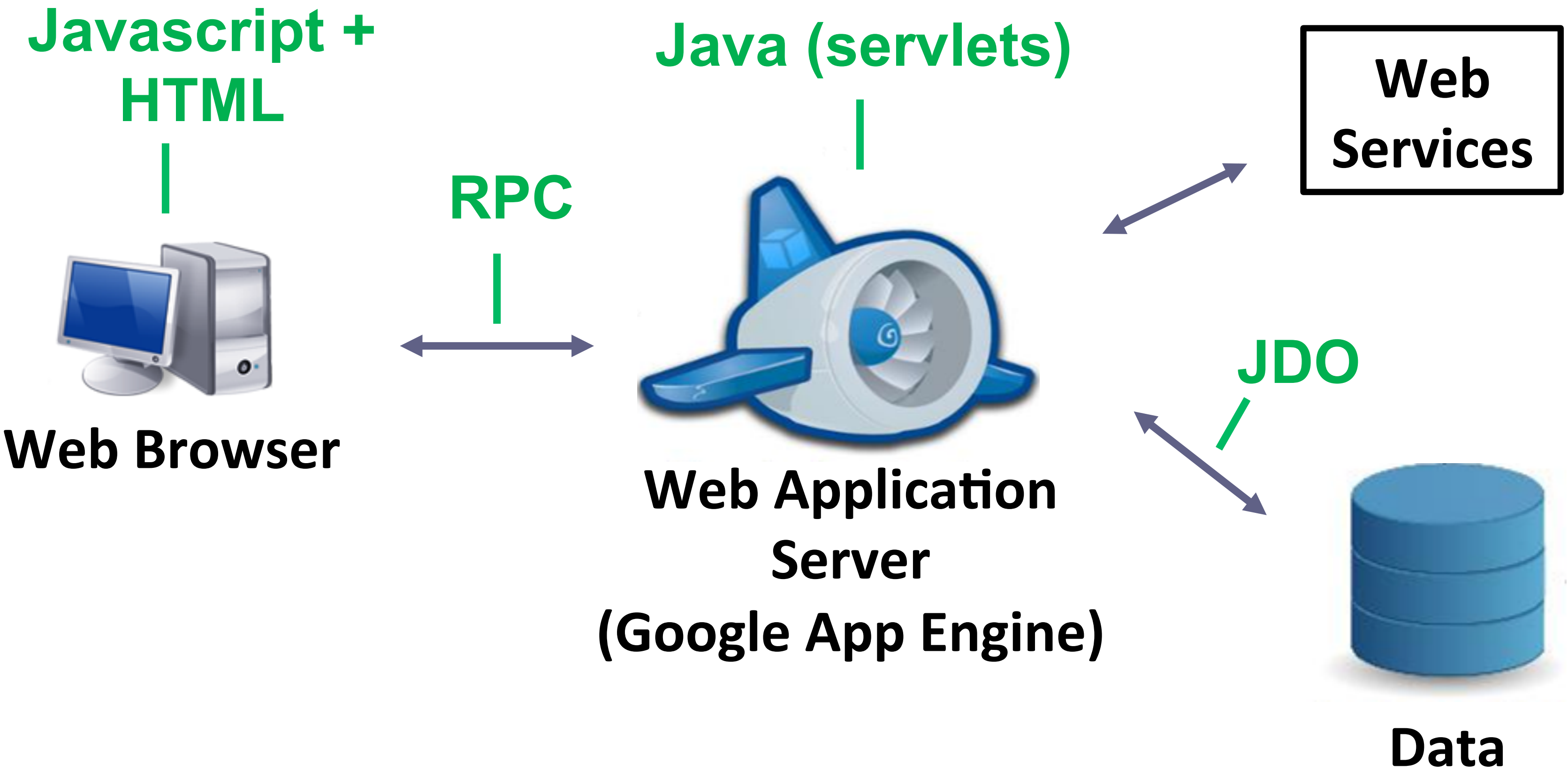
Web Browser

Web Application Server

Web Services

Data

# Google App Engine



Javascript + HTML

Web Browser

RPC

Java (servlets)

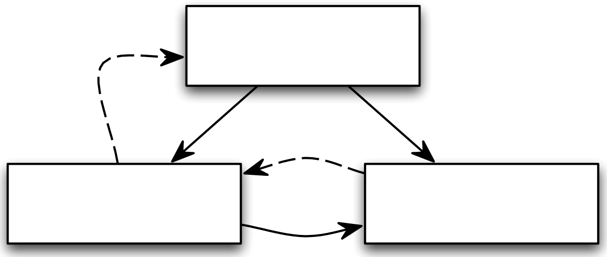
Web Application Server (Google App Engine)

Web Services

JDO

Data

# Model View Controller



**Components:** **model** contains core functionality and data, **views** display information to the user, and **controllers** handle user input

**Connectors:** change-propagation mechanism (observer)

**Advantages:** interactivity, expandability, separation of model vs presentation

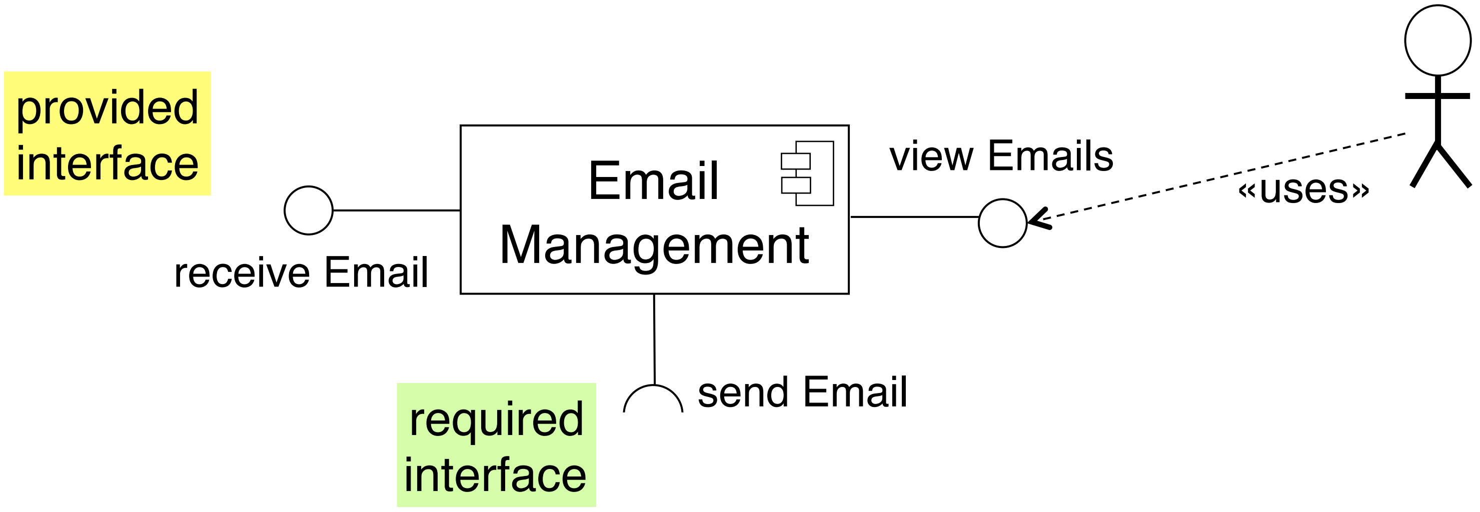
**Disadvantages:** very small scale (heavy design), might get complex

# Class Activity

- In groups of two, find an example of a use of the Model-View-Controller pattern

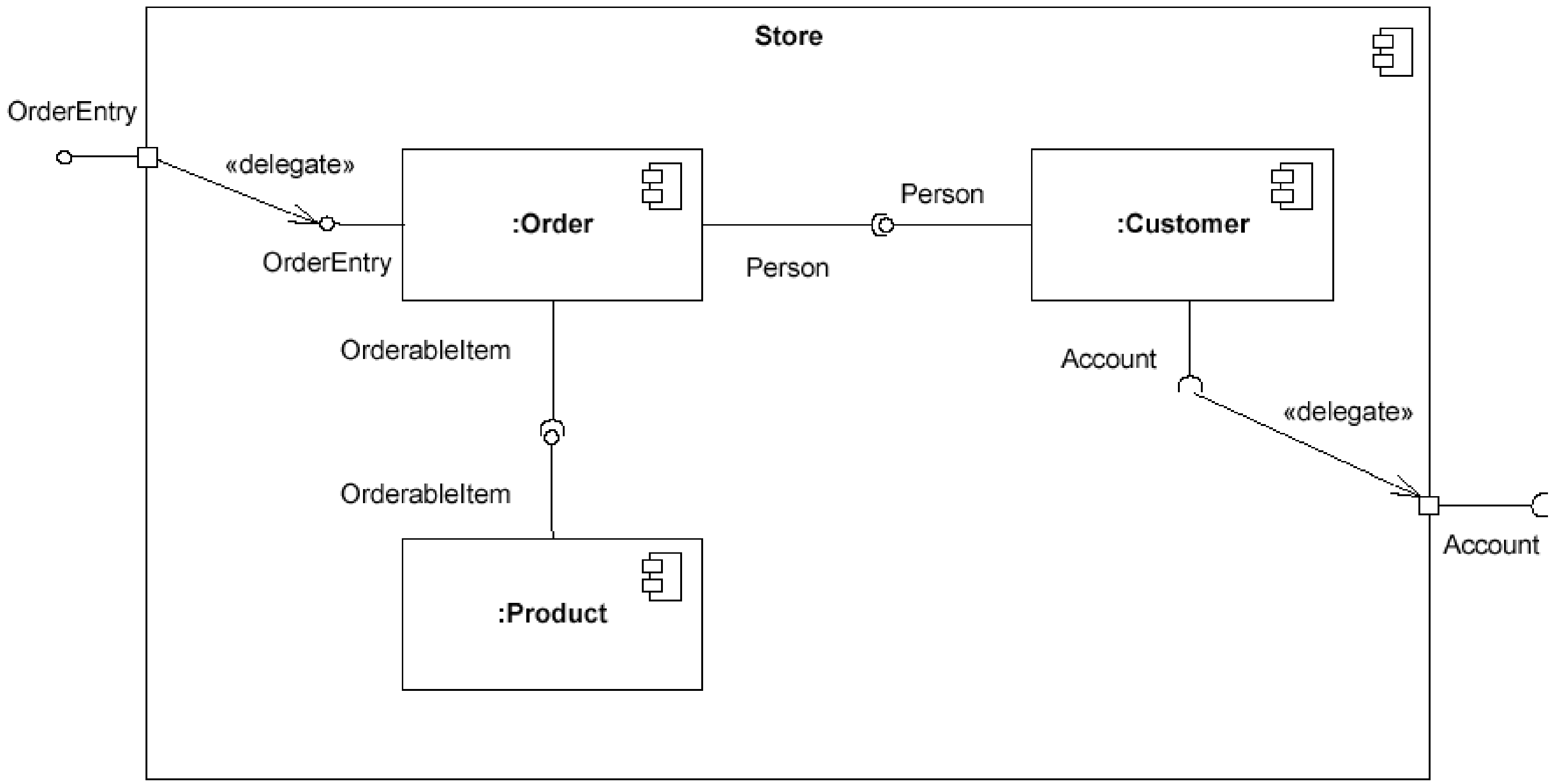
# UML Component Diagram

- Several ways to depict architecture, depending on what is important
- UML Component Diagram to depict components and interfaces



More ways of documenting: http://en.wikipedia.org/wiki/4%2B1_architectural_view_model, https://sites.google.com/site/softwarearchitectureinpractice/9-documenting-software-architecture

# UML Component Diagram – Hierarchy



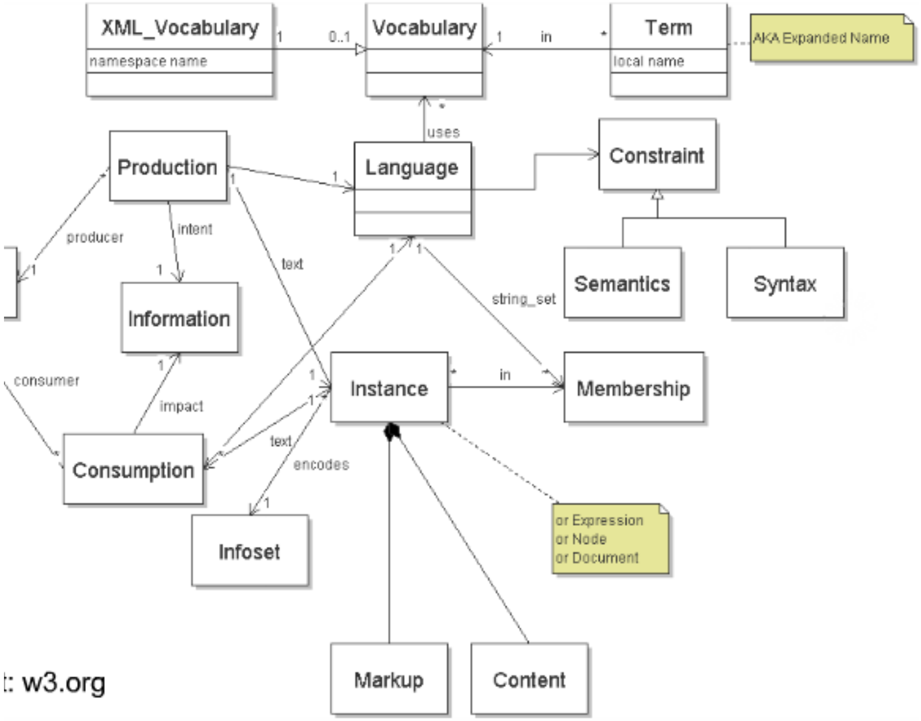
Components can be composed of other components or classes

# Detailed Design

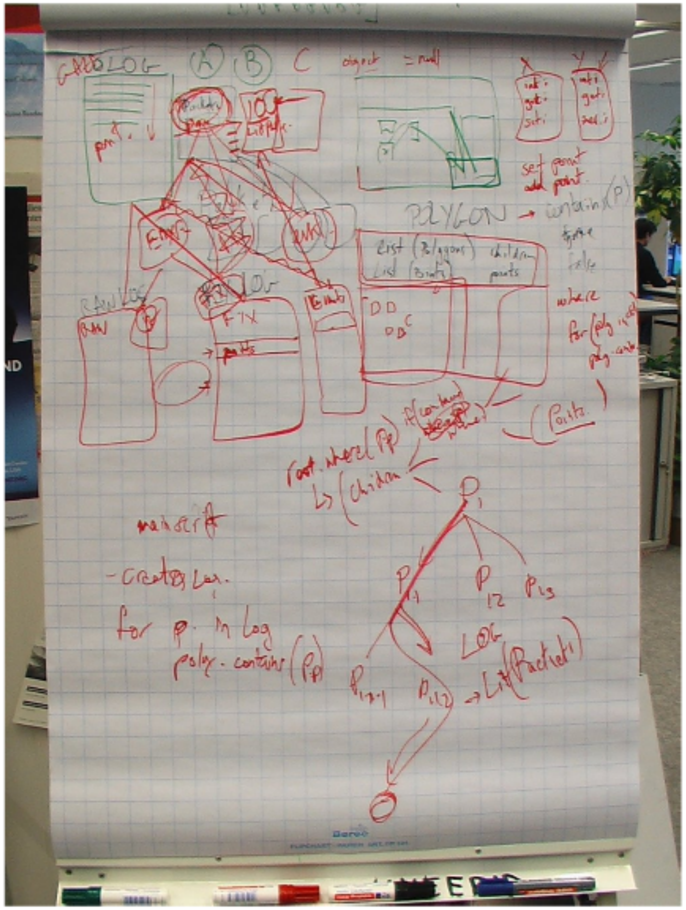
- Concerned with programming concepts
  - Classes, Packages
  - Files
  - Communication protocols
  - Synchronization
  - …
- Mid-level design
  - class diagrams
- Low-level design
  - sequence diagrams

# Class Activity

- Vote: Which of these two diagrams is more useful to software developers?



t: w3.org



Cherubini, Venolia, Ko, DeLine

# Diagrams

Diagrams are a ***communication*** tool

- End product is important, but discussion just as important

Quality of communication = Quality of design

- Hence, quality of end product

Tip for efficient communication:

- Start light-weight and flexible
- Then move on to details and more focused

In terms of diagrams:

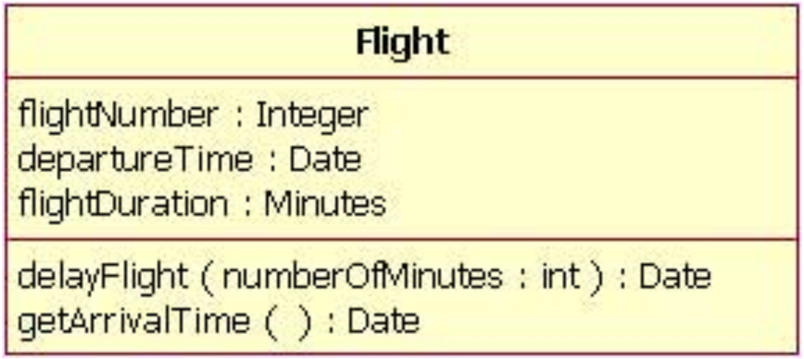
- Start with draft, hand-written diagrams that can change
- Towards the end, clean-up and make more readable
- Use a mutually understood language (a standard: UML)

# Class Diagrams

- Mid-level design tool
- Used to describe the relationships between classes (and/or packages) in the system

- UML: Unified Modeling Language *(not only class diagrams)*
- Elements of UML class diagrams
  - Classes
  - Relationships
    - Generalization
    - Association
    - Aggregation

# Class Diagrams: Class



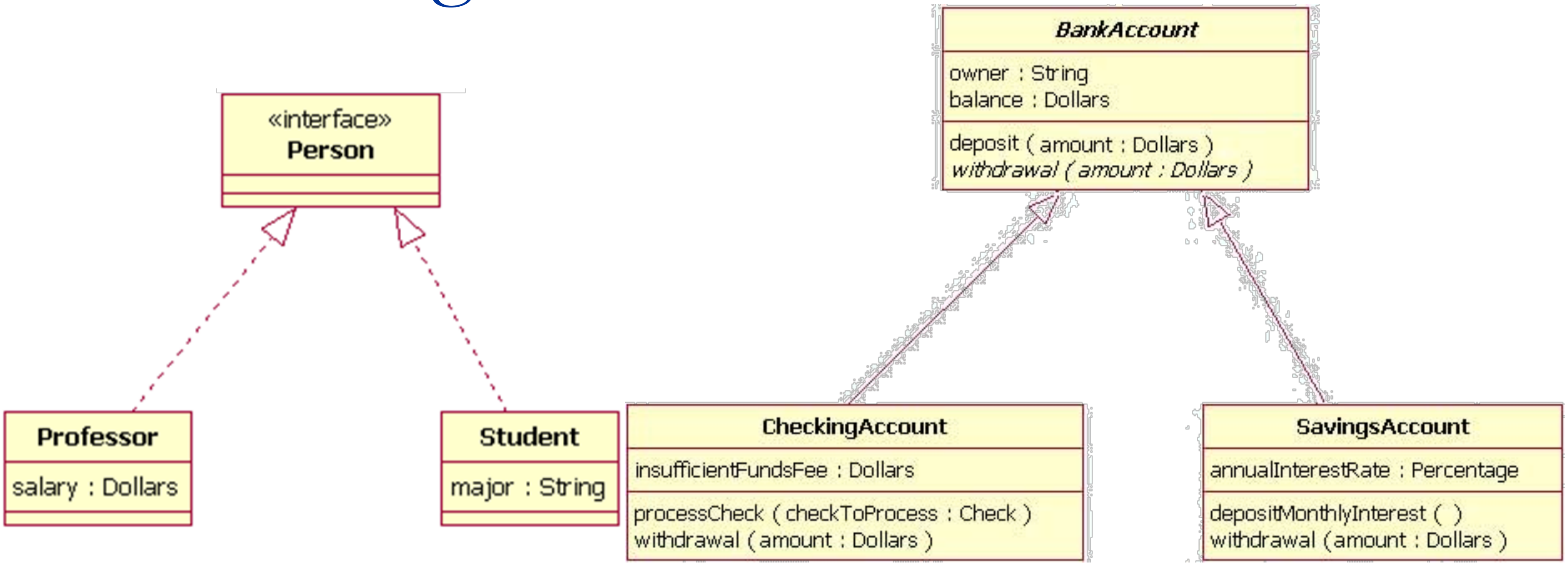
```
Flight
flightNumber : Integer
departureTime : Date
flightDuration : Minutes
delayFlight ( numberOfMinutes : int ) : Date
getArrivalTime ( ) : Date
```

- Class name (*Italics* means abstract)
- Attributes (fields)

  `Name : Type`
- Operations (methods)

  `Parameters : Return Type`
- Can also be used for interfaces (without fields)

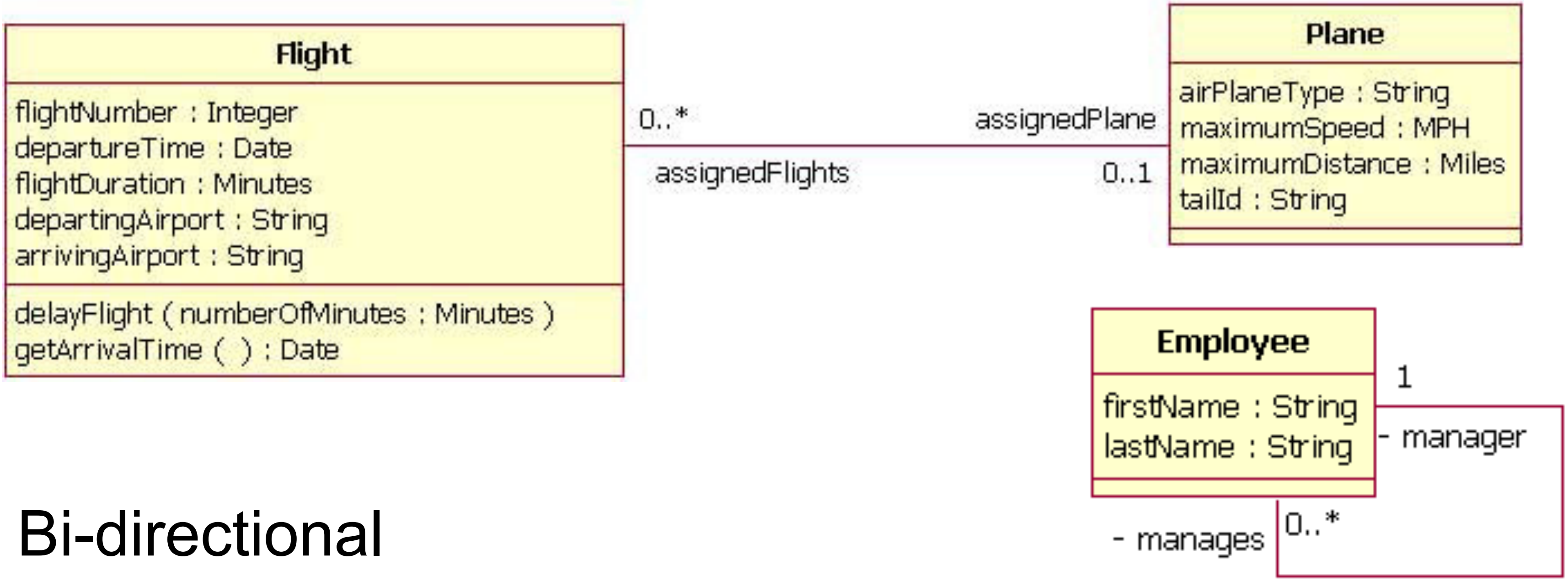
# Class Diagrams: Generalization


BankAccount
owner : String
balance : Dollars
deposit ( amount : Dollars )
withdrawal ( amount : Dollars )
«interface»
Person
Professor
salary : Dollars
Student
major : String
CheckingAccount
insufficientFundsFee : Dollars
processCheck ( checkToProcess : Check )
withdrawal ( amount : Dollars )
SavingsAccount
annualInterestRate : Percentage
depositMonthlyInterest ( )
withdrawal (amount : Dollars )

Used for:

- Inheritance
- Interface implementation

# Class Diagrams: Association



**Flight**

flightNumber : Integer
departureTime : Date
flightDuration : Minutes
departingAirport : String
arrivingAirport : String

delayFlight ( numberOfMinutes : Minutes )
getArrivalTime ( ) : Date

**Plane**

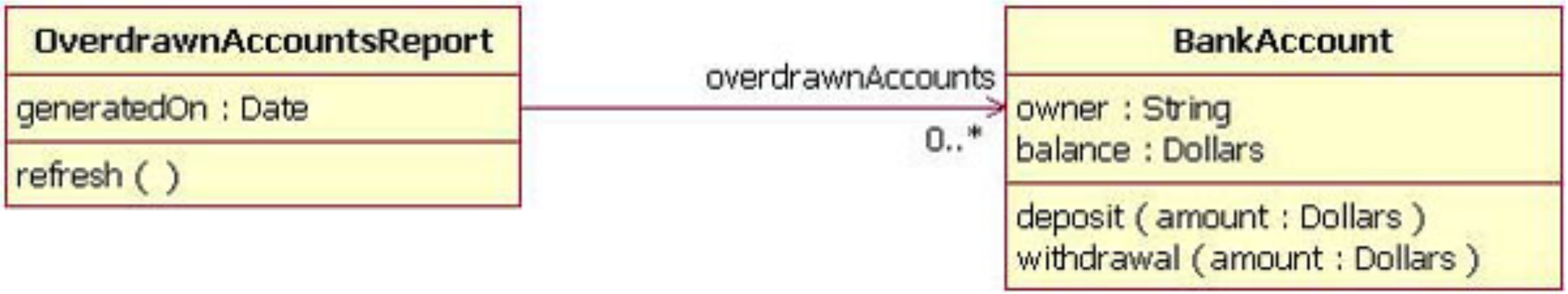
airPlaneType : String
maximumSpeed : MPH
maximumDistance : Miles
tailId : String

**Employee**

firstName : String
lastName : String

- Bi-directional
  - Both classes are aware of each other
- Role
  - Usually maps to a field name
- Multiplicity
  - Indicates how many instances can be linked (*i.e.* a list of…)

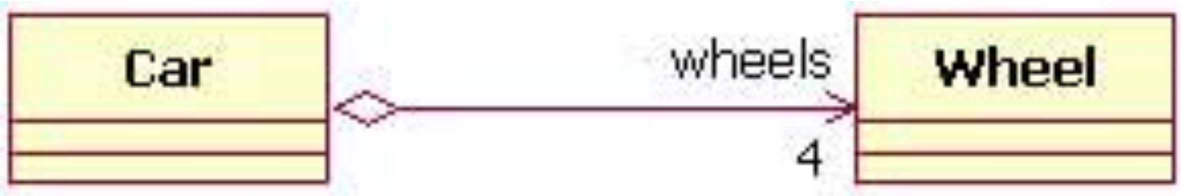
# Class Diagrams:
# Uni-directional Association



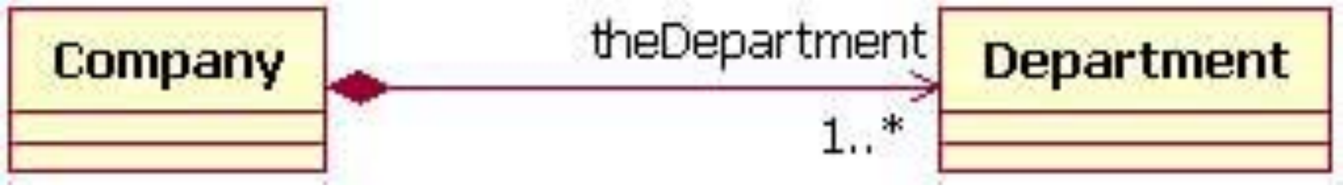
- Only one class knows of the other
- Role
  - Only in one direction
- Multiplicity
  - Only on one end (BankAccount doesn’t know report)

# Class Diagrams: Aggregation

- An advanced type of association
- The contained object is *part* of the container
- Two type:
  - Basic aggregation: children can outlive parent

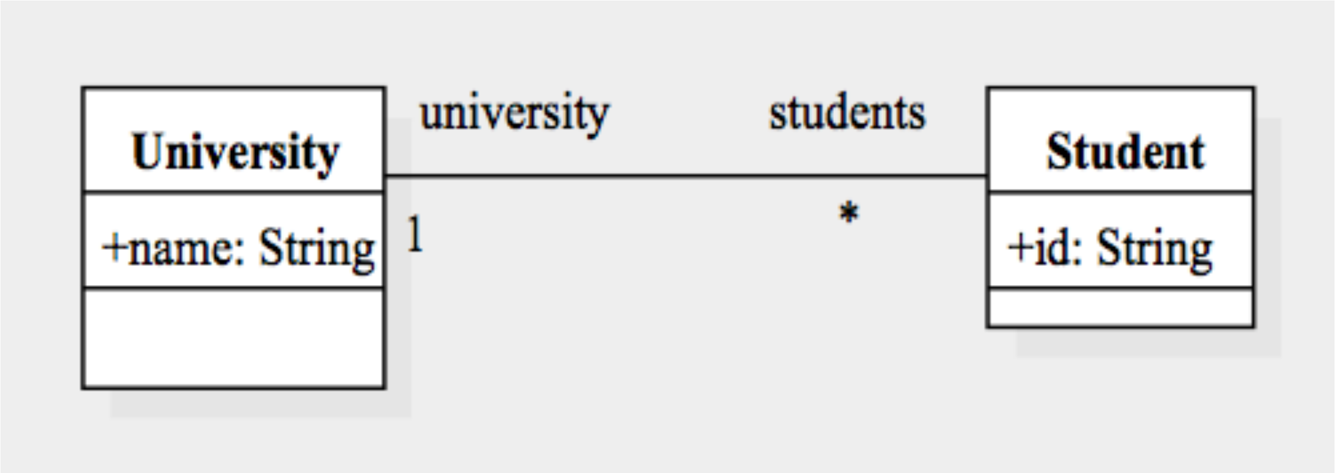


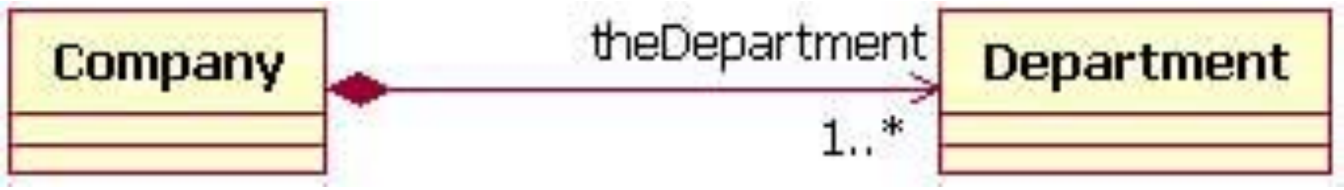
  - Composite aggregation: children life depends on parent



# Class Activity

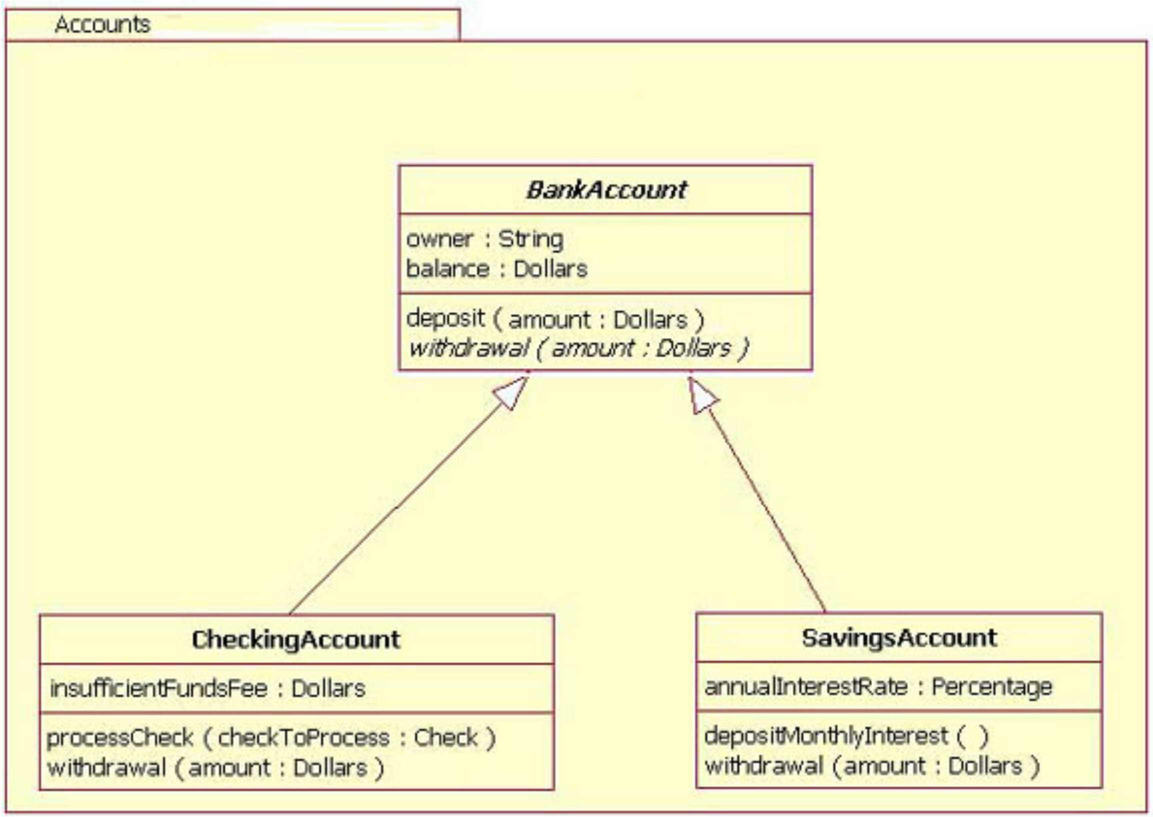
- How would you implement these two examples in Java?





# Class Diagrams: Packages

- Group classes together



Accounts
*BankAccount*
owner : String
balance : Dollars
deposit ( amount : Dollars )
*withdrawal ( amount : Dollars )*
CheckingAccount
insufficientFundsFee : Dollars
processCheck ( checkToProcess : Check )
withdrawal ( amount : Dollars )
SavingsAccount
annualInterestRate : Percentage
depositMonthlyInterest ( )
withdrawal ( amount : Dollars )

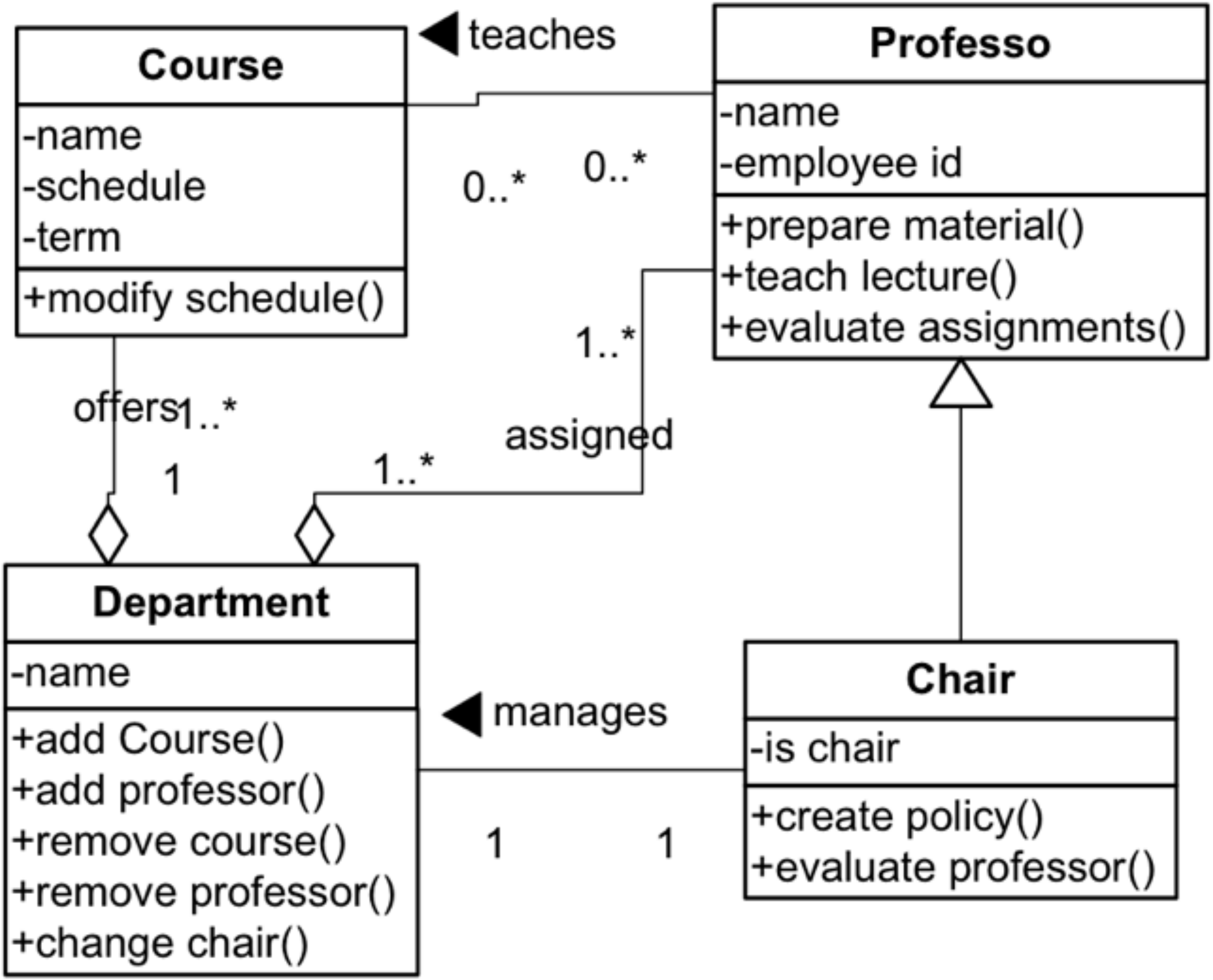
# Class Activity

- In teams of 2, draw a class diagram for
- A software system for modeling a bank
- Each of the bank’s customers can access their account(s) through withdrawals, deposits, or balance inquiries at a bank machine. Each transaction (ie, withdrawal, deposit or balance inquiry) must store the date and time that the transaction occurred. Once a month, a statement that contains a list of all of the transactions that were completed over the last month is generated for each account and mailed to the customer. The bank must be able to produce a list of all of its customers as well as a list of transactions that were completed by a particular bank machine
- Use classes that appear in the text.
- Ask questions if needed.

# Class Activity

In small groups, draw a class diagram for the structure of professors, students, departments, dept. heads, and courses.

- Ask questions if needed.


◀ teaches
Course
-name
-schedule
-term
+modify schedule()
0..*
0..*
Professo
-name
-employee id
+prepare material()
+teach lecture()
+evaluate assignments()
1..*
offers
1..*
1
assigned
1..*
Department
-name
+add Course()
+add professor()
+remove course()
+remove professor()
+change chair()
◀ manages
1
1
Chair
-is chair
+create policy()
+evaluate professor()

# Comments on Diagrams

- Think about association/aggregation/composition as well as direction of them

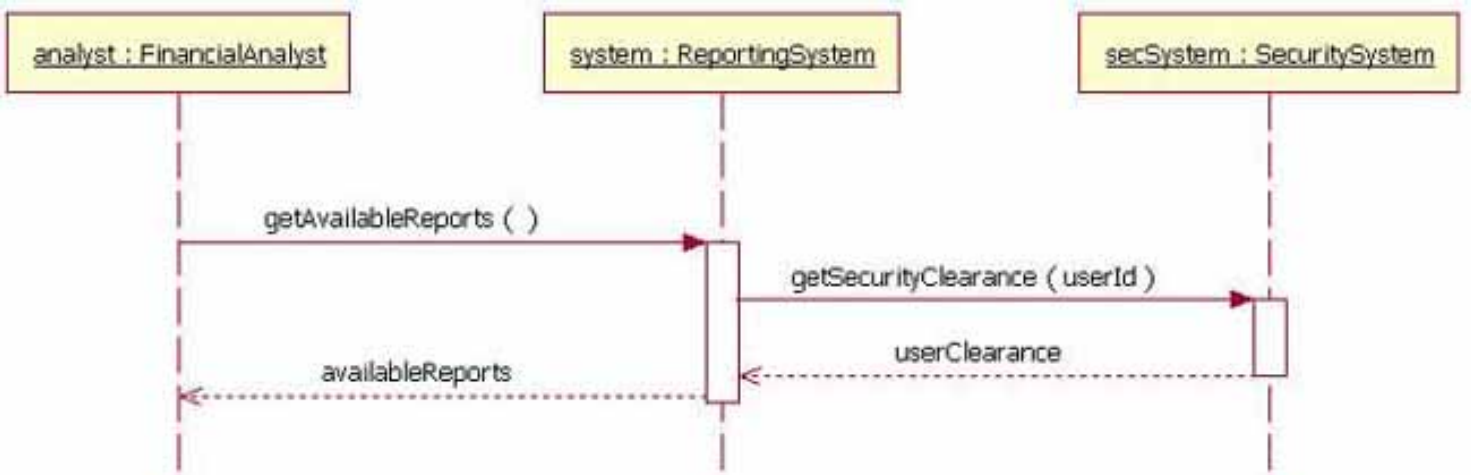
- Make sure to specify roles if necessary (especially if there are two relations between two classes)

- Think about methods and attributes and where they belong

# Sequence Diagrams

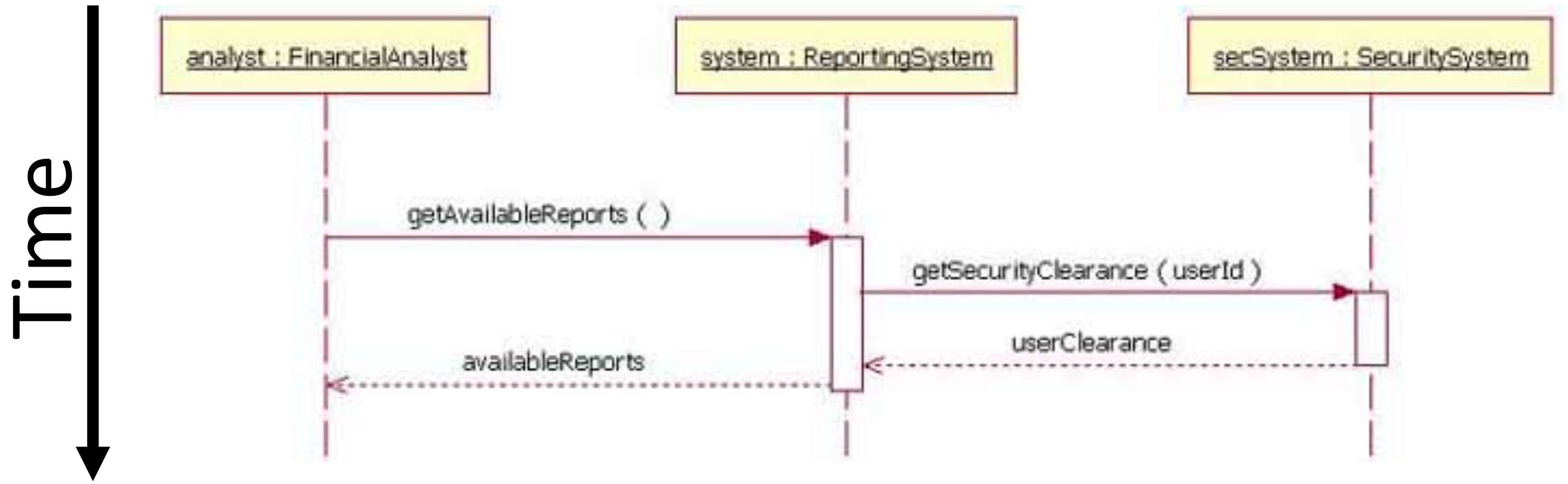
- Low-Level design tool
- Used to describe sequences of invocations between the objects that comprise the system
  - Focus less on *type of messages*, more on the *sequence* in which they are received
- UML (again!)
- Elements of UML sequence diagrams:
  - Lifelines
  - Messages
  - …

# Sequence Diagrams: Lifeline


analyst : FinancialAnalyst
system : ReportingSystem
secSystem : SecuritySystem
getAvailableReports ( )
getSecurityClearance ( userId )
userClearance
availableReports

- Roles or object instances
- Participate in the sequence being modeled

# Sequence Diagrams: Messages

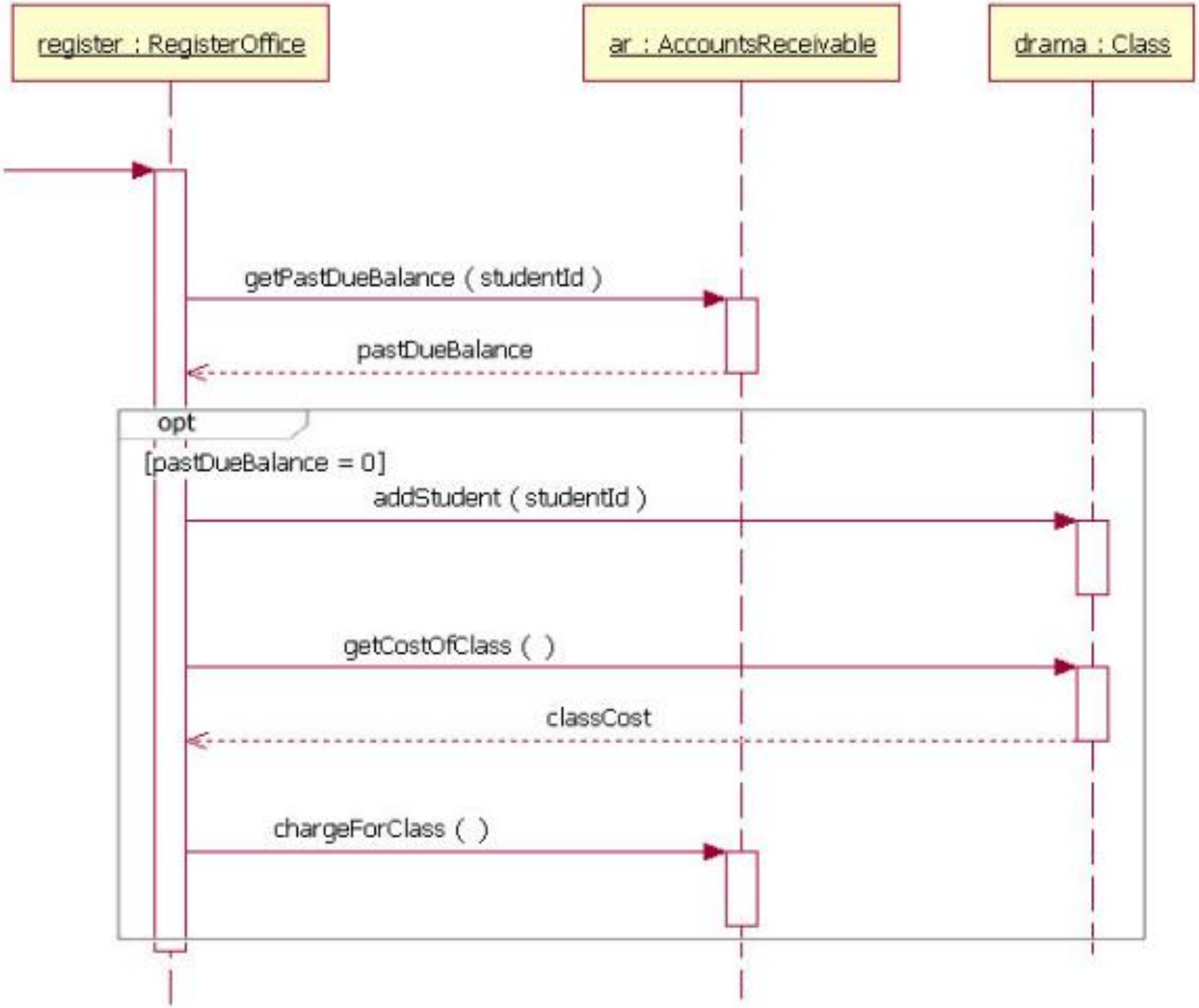

Time
analyst : FinancialAnalyst
system : ReportingSystem
secSystem : SecuritySystem
getAvailableReports ( )
getSecurityClearance ( userId )
userClearance
availableReports

- Includes method name
- A box in the receiver’s lifeline indicates activation (object’s method is on the stack)
- Full arrow: synchronous (blocking)
- Optionally: information returned

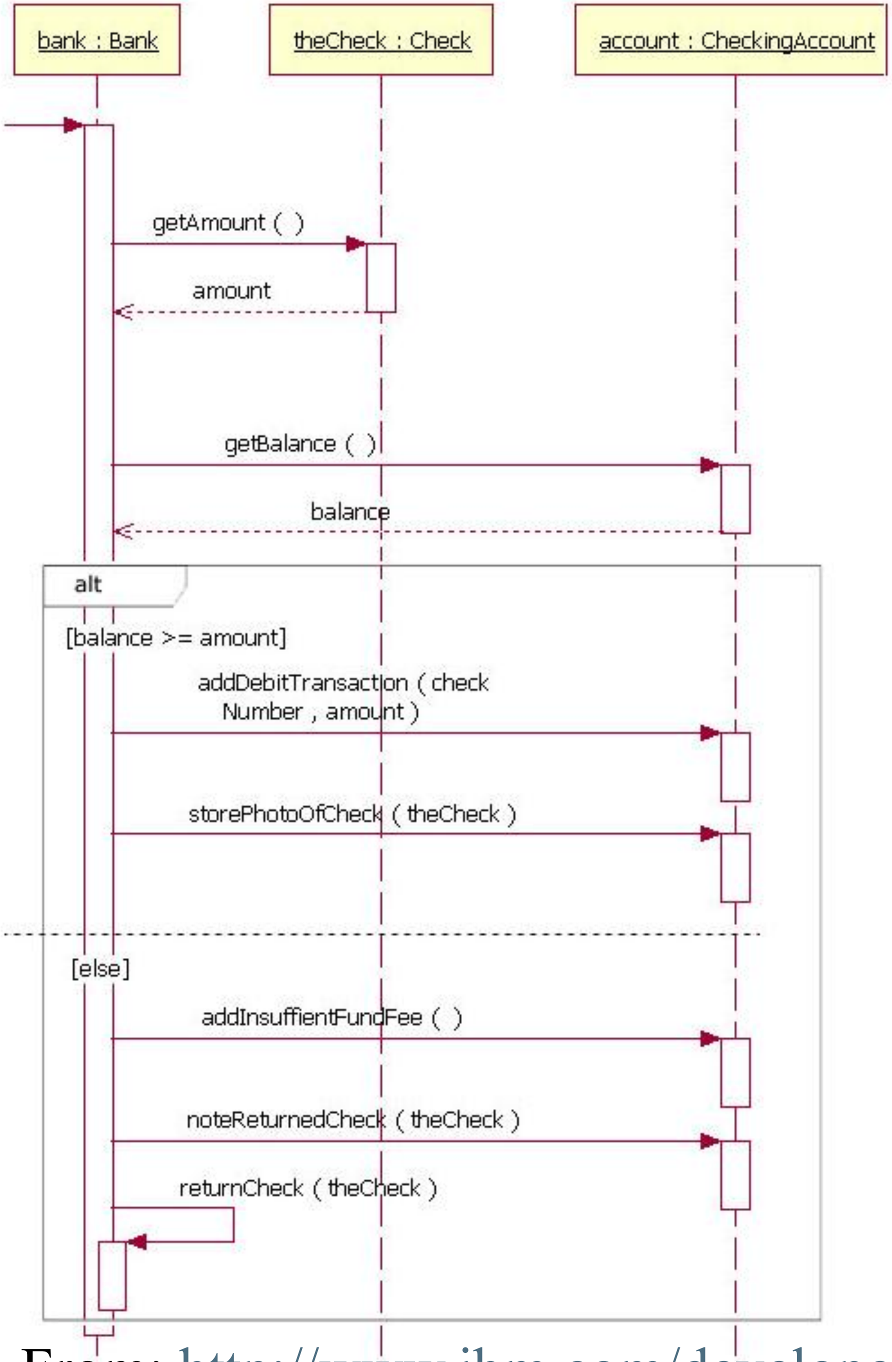
# How do you start? (Sequence Diagram)

1. Identify process/algorithm/activity you want to capture (may be a use case)
2. Identify major objects involved
3. Map out flow of control/messages to achieve the result

# Sequence diagram when some actions are inside an if



From: http://www.ibm.com/developerworks/rational/library/3101.html



Sequence diagram when some actions are inside an if/else

Loops are similar - put the actions inside a box labeled “loop”

From: http://www.ibm.com/developerworks/rational/library/3101.html

# Class Activity

- In teams of 2, draw a sequence diagram illustrating what happens when *a customer withdraws money at a bank machine* .

# Class Activity

- In teams of 2, draw a sequence diagram illustrating what happens when *a user searches for a course by course label* .

- Or for registering for a course.

# What is the Software Design?

- The design consists of multiple views of the software
  - Static view (e.g. class diagram) shows decomposition of problem into parts and relationships
  - Dynamic view (e.g. sequence diagram) shows how parts interact to solve the problem
- Views have varying levels of granularity
- We can analyze these views to see if they support the requirements?
  - Modifiable (i.e. adding new view)?
  - …

# How to Design? (Recap)

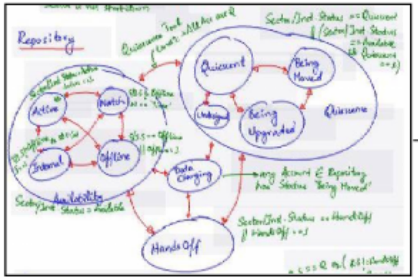
- “Treat design as a wicked, sloppy, heuristic process.”
  - Pen & Paper, Whiteboard
- “Don’t settle for the first design that occurs to you.”
  - Scribble, Scratch, Thrash
- “Collaborate”
  - Brainstorm, Discuss, Argue
- “Strive for simplicity”
  - Reduce, Clean-up (with UML tools)
- “Iterate, iterate and iterate again.”
  - Iterate!

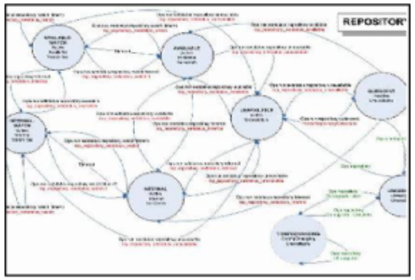
# How to Design?

- Start global
  - Architectural Design
  - Global concepts: components & connectors
- Subdivide
  - Detailed Design
  - Mid-level: classes and relationships
  - Low-level: how operations are carried out – what messages are sent and when
- Iterate
  - Are these the right subsystems? Update!
  - Are these the right classes? Update!

# How to Design in a Team?

- Suggested steps
  1. Discussion
  2. Discussion with paper diagrams
  3. Clean-up with UML tools
  4. Discussion with printed diagrams
  5. Iterate over 3 and 4

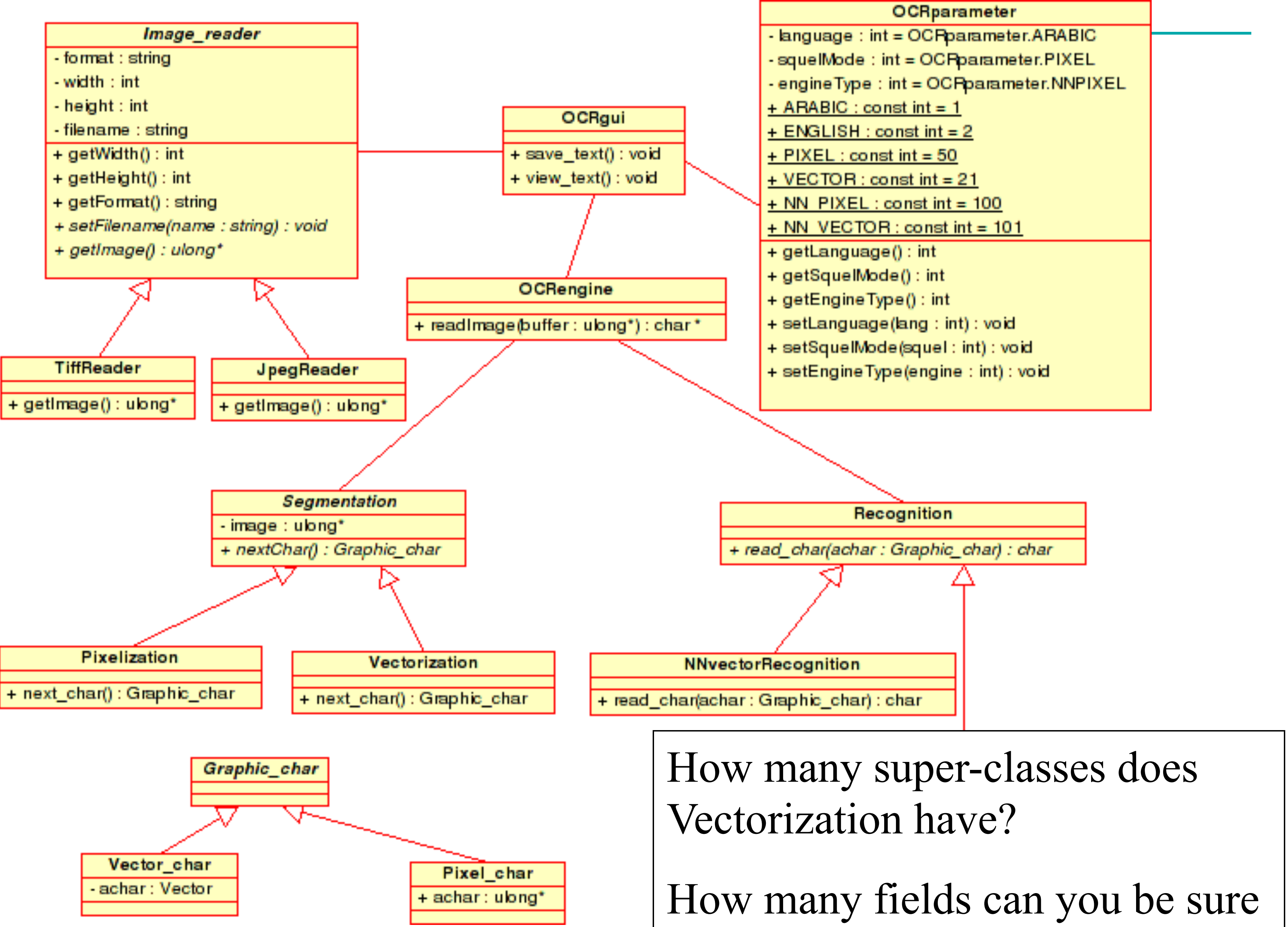




- Again
  - First light-weight and flexible (words, hand drawn diagrams)
  - Then details and focused (printed diagrams)

# Design Summary

- Design consists of multiple views
  - High-Level: Component Diagrams
  - Medium-Level: Class Diagrams
  - Low-Level: Sequence Diagrams
- Architectural styles encode common patterns for achieving certain quality goals
- Diagrams are *communication tools*
- Designing is an iterative refinement process



Image_reader
- format : string
- width : int
- height : int
- filename : string
+ getWidth() : int
+ getHeight() : int
+ getFormat() : string
+ *setFilename(name : string) : void*
+ *getImage() : ulong**

OCRgui
+ save_text() : void
+ view_text() : void

OCRparameter
- language : int = OCRparameter.ARABIC
- squelMode : int = OCRparameter.PIXEL
- engineType : int = OCRparameter.NNPIXEL
+ ARABIC : const int = 1
+ ENGLISH : const int = 2
+ PIXEL : const int = 50
+ VECTOR : const int = 21
+ NN_PIXEL : const int = 100
+ NN_VECTOR : const int = 101
+ getLanguage() : int
+ getSquelMode() : int
+ getEngineType() : int
+ setLanguage(lang : int) : void
+ setSquelMode(squel : int) : void
+ setEngineType(engine : int) : void

OCRengine
+ readImage(buffer : ulong*) : char *

TiffReader
+ getImage() : ulong*

JpegReader
+ getImage() : ulong*

Segmentation
- image : ulong*
+ *nextChar() : Graphic_char*

Recognition
+ *read_char(achar : Graphic_char) : char*

Pixelization
+ next_char() : Graphic_char

Vectorization
+ next_char() : Graphic_char

NNvectorRecognition
+ read_char(achar : Graphic_char) : char

Graphic_char

Vector_char
- achar : Vector

Pixel_char
+ achar : ulong*

How many super-classes does Vectorization have?

How many fields can you be sure that OCRgui has?