# CS 535 Object-Oriented Programming & Design
Fall Semester, 2011
Doc 16 Some Design
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# References


Wirfs-Brock, Designing Object-Oriented Software , chapters 1- 5

Mark Lorenz, Object-Oriented Software Development: A Practical Guide , 1993, Appendix I Measures and Metrics

Wikipedia

Ralph Johnson Lecture notes, Lecture 3 Data Abstraction and Encapsulation, http://st-www.cs.uiuc.edu/users/cs497/lectures.html

# Software Development Process

Software Process

Structure imposed on the development of a software product



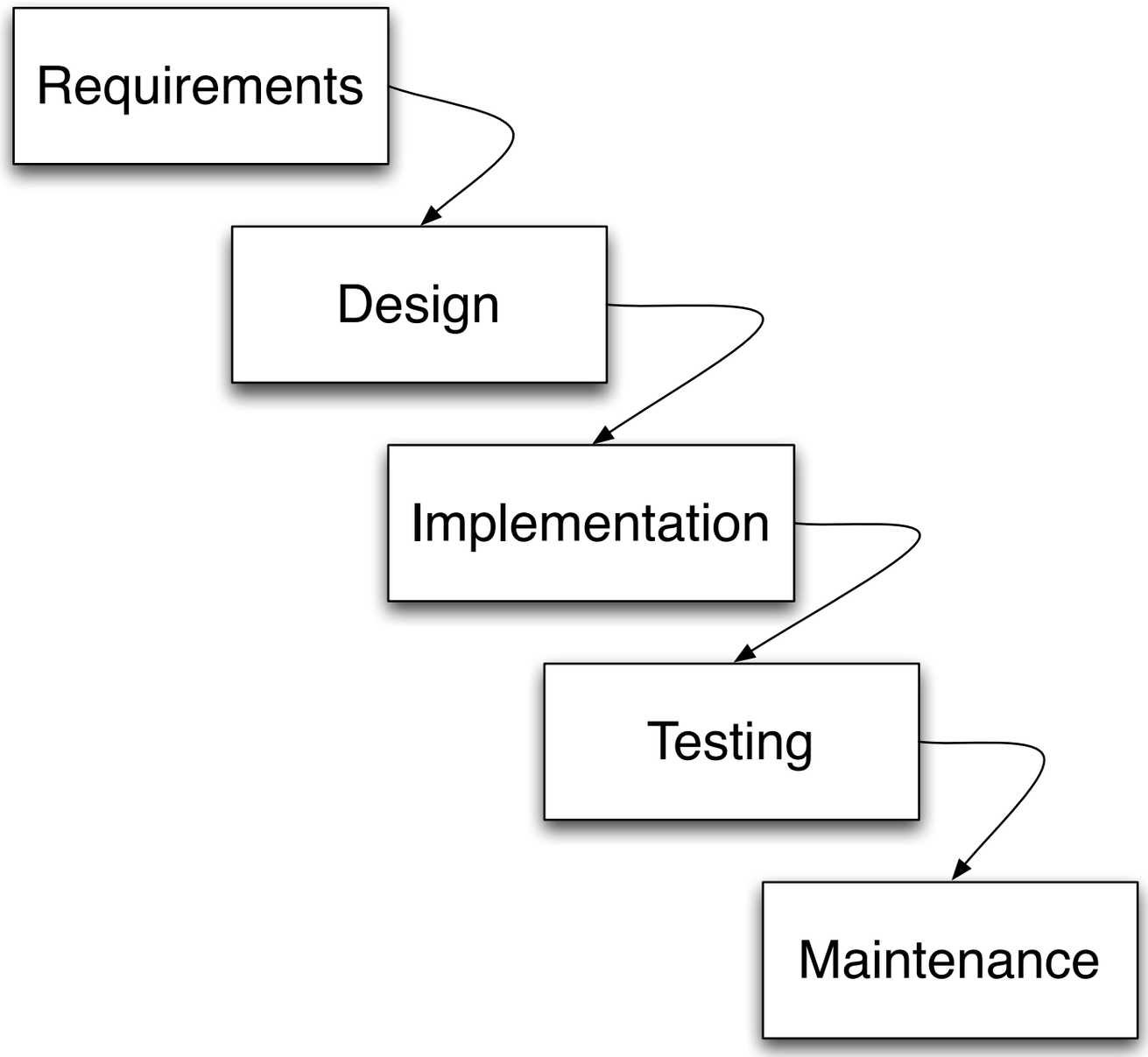


From Wikipedia http://en.wikipedia.org/wiki/Software_life_cycle

# Software Development Activities

Requirements
Design
Implementation
Testing
Maintenance

# Waterfall Methods



# Software development is a learn process

Learning is non-linear

What should it do

What is the design

How to make it work

That was the wrong way

# Software development is a Group process

Large groups of people need structure to function

# Iterative Methods

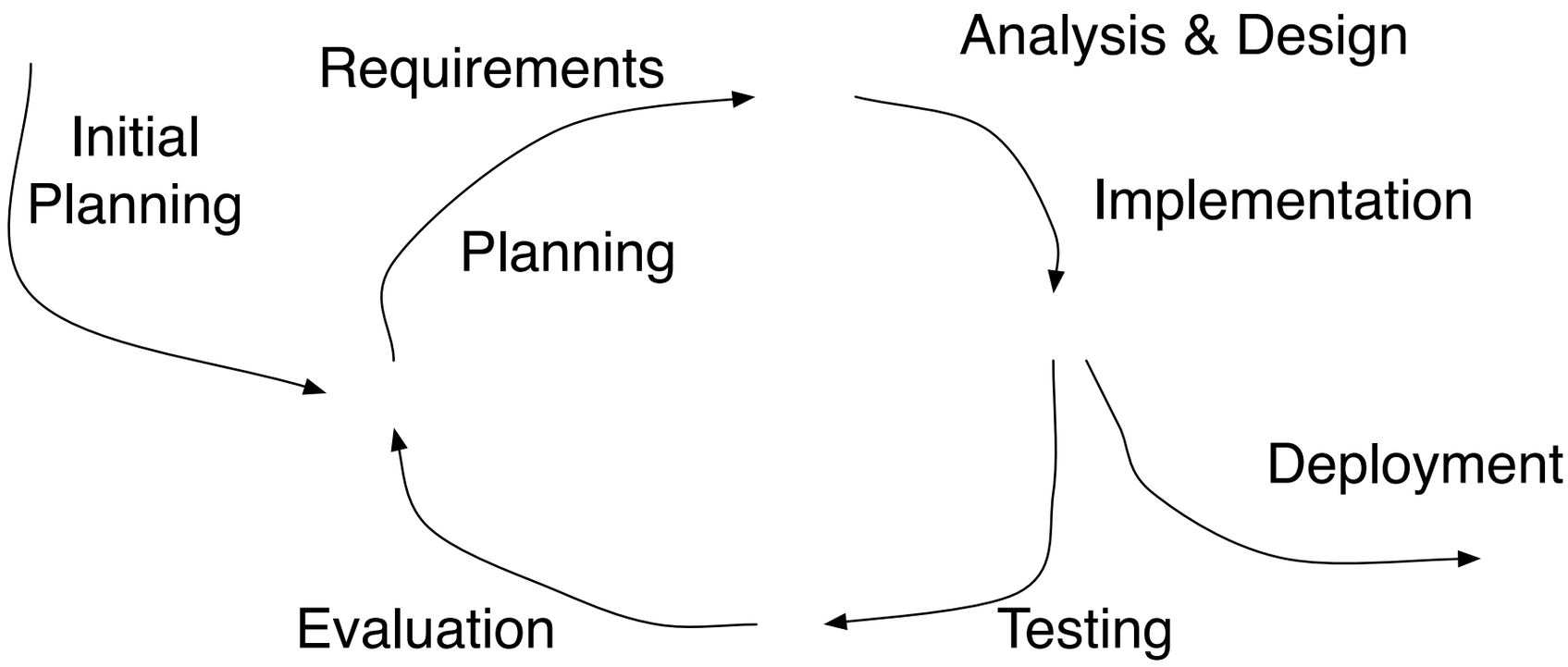







Image from http://en.wikipedia.org/wiki/Iterative_and_incremental_development

# Rational Unified Process (RUP)

Formal software process

Heavy weight

Developed by Rational Software

Unified three existing OO software processes

Unified Modeling Language (UML)
- Diagrams to support design

Contains
- 3 building blocks
- 4 project lifecycle phases
- 6 engineering disciplines

Process is highly configurable

# Agile Manifesto

| Value these | Over these |
| --- | --- |
| Individuals and interactions | processes and tools |
| Working software | comprehensive documentation |
| Customer collaboration | contract negotiation |
| Responding to change | following a plan |

# Agile Methodologies

Short development cycle
    1-4 weeks

Plan only for current cycle

Customer specifies priorities for cycle

Working software at end of cycle

Scrum
Extreme Programming (XP)

# Why so many Processes?

People operate differently

Companies operate differently

Projects are different

Customers have different requirments

# One OO Design Process

Exploratory Phase

Who is on the team?
What are their tasks, responsibilities?
Who works with whom?

Analysis Phase

Who's related to whom?
Finding sub teams
Putting it all together





This is known as the Responsibility-Driven process. See the Wirfs-Brock book listed in the references.

# Exploratory Phase

Who is on the team?

What are the goals of the system?
What must the system accomplish?
What objects are required to model the system and accomplish the goals?

Finding the initial list of classes for the system

# Exploratory Phase

What are their tasks, responsibilities?

What does each object have to know in order to accomplish its tasks?
What steps toward accomplishing each goal is it responsible for?

Candidate list of fields and methods

# Exploratory Phase

Who works with whom?

With whom will each object collaborate in order to accomplish each of its responsibilities?
What is the nature of the objects' collaboration?

How do the objects interact

# How to Find Abstractions

Look at nouns in requirements specification or system description

A refrigerator has a motor, a temperature sensor, a light and a door. The motor turns on and off primarily as prescribed by the temperature sensor. However, the motor stops when the door is opened. The motor restarts when the door is closed if the temperature is too high. The light is turned on when the door opens and is turned off when the door is closed.





Look at these phrases. Some will be obvious classes, some will be obvious nonsense, and some will fall between obvious and nonsense. Skip the nonsense, keep the rest. The goal is a list of candidate objects. Some items in the list will be eliminated, others will be added later. Finding good objects is a skill, like finding a good functional decomposition

# Finding Classes

Noun phrases in requirements specification or system description

Model physical objects

Disks Printers Airplanes

Model conceptual entities that form a cohesive abstraction

Window File Bank Account

If more than one word applies to a concept select the one that is most meaningful





Look at these phrases. Some will be obvious classes, some will be obvious nonsense, and some will fall between obvious and nonsense. Skip the nonsense, keep the rest. The goal is a list of candidate objects. Some items in the list will be eliminated, others will be added later. Finding good objects is a skill, like finding a good functional decomposition.

# Finding Classes

Be wary of the use of adjectives

- Adjective-noun phrases may or may not indicate different objects
- Is selection tool different than creation tool?
- Is start point different from end point from point?

Be wary of passive voice

- A sentence is passive if the subject of the verb receives the action
- Passive:
  - The music was enjoyed by us
- Active:
  - We enjoyed the music

Model categories of classes

- Categories may become abstract classes
- Keep them as individual classes at this point

# Finding Classes

Model known interfaces to outside world

- User interfaces
- Interfaces to other programs

Write a description of how people will use the system. This description is a source of interface objects.

Model the values of attributes, not the attributes themselves

- Height of a rectangle
- Height is an attribute of rectangle
- Value of height is a number
- Rectangle can record its height

# Categories of Classes

Data Managers

- Principle responsibility is to maintain data
- Examples: stack, collections, sets

Data Sinks or Data Sources

- Generate data or accept data and process it further
- Do not hold data for long
- Examples: Random number generator, File IO classes

View or Observer classes

- Example: GUI classes

Facilitator or Helper classes

- Maintain little or no state information
- Assist in execution of complex tasks

# Ralph Johnson's Suggestions for Finding Abstractions

Do one thing
Eliminate duplication
Keep rate of change similar
Decrease coupling, increase cohesion
Minimize interfaces
Minimize size of abstractions
Minimize number of abstractions

# Do One Thing

Methods should do one thing

Method's name should tell what it does

findString:startingAt:
asNumber
asUppercase
dropFinalVowels

Class should be what its name says

String
OrderedCollection
Array
ReadStream

Break complex classes/methods into simpler ones

# Eliminate Duplication

(self asInteger - $a asInteger + anInteger) \\ 26 – (self asInteger - $a asInteger)

(self alphabetValue + anInteger) \\ 26 - self alphabetValue.

# Keep rate of change similar

An object should not contain both

- An instance variable that changes every second
- An instance variable that changes once a month

- Code that is different for each hardware platform
- Code that is different for each OS

Separate tax tables from employee data from time cards

# Minimize interfaces

Use the smallest interface you can

Use Number instead of Float

Avoid embedding classes in names

add: instead of addNumber:

# Minimize the size of abstractions

Lots of Little Pieces

Methods should be small

Median size is 3 lines
10 lines is starting to smell

Classes should be small

7 variables is starting to smell
40 methods is starting to smell

VW 7.6

| | Average | Median | Max |
|---|---|---|---|
| Variables / class | 2.1 | 1 | 72 |
| Methods / class | 16.6 | 8 | 359 |
| LOC / method | 3.0 | 2 | 156 |

# Code used to generate Numbers

Variables Per Class

```
classes :=Smalltalk allClasses reject: [:each | each isMeta]
variablesInClass :=classes collect: [:each | each instVarNames size].
average :=((variablesInClass fold: [:sum :each | sum + each] )/
                variablesInClass size) asFloat.
median := variablesInClass asSortedCollection at: variablesInClass size // 2.
max := variablesInClass fold: [:partialMax :each | partialMax max: each]
```

Methods Per Class

```
classes :=Smalltalk allClasses reject: [:each | each isMeta]
methodsInClass :=classes collect: [:each | each selectors size].
average :=((methodsInClass fold: [:sum :each | sum + each] )/
                methodsInClass size) asFloat.
mean := methodsInClass asSortedCollection at: methodsInClass size // 2.
max := methodsInClass fold: [:partialMax :each | partialMax max: each]
```





Note how the above code could use the application of these ideas

# LOC / Method

```
methodSizes := OrderedCollection new.
classes
	do: [:class |
		class selectors
			do: [:method |
				| periodCount |
				periodCount := (class compiledMethodAt: method) decompiledSource
					occurrencesOf: $..
				methodSizes add: periodCount + 1]].
average :=((methodSizes fold: [:sum :each | sum + each] )/
			methodSizes size) asFloat.
median := methodSizes asSortedCollection at: methodSizes size // 2.
max := methodSizes fold: [:partialMax :each | partialMax max: each]
```

# Minimize number of abstractions

A class hierarchy 6-7 levels deep is hard to learn

Break large system into subsystems, so people only have to learn part of the system at a time

# Record Your Candidate Classes

| Class: Account | |
|---|---|
| | |
| | |

An account representing a customer's account in the bank's database





Record the class name on the front of an index card. One class per card. Write a brief description of the overall purpose of the class. The front of the card will be filled in with information as the design process continues. If you prefer to use some other medium (8 1/2" by 11" sheets of paper, computer program) do so. The goal is a tool that will enhance exploring the model. Once you are experienced with object-oriented design, you may find better tools. However, while learning, it is hard to find a cheaper tool than index cards. Even when you have a fancy case tool you might find yourself using these cards to help with designing parts of programs.

# Finding Abstract Classes

An abstract class springs from a set of classes that share a useful attribute. Look for common attributes in classes, as described by the requirement

Grouping related classes can identify candidates for abstract classes

Name the superclass that you feel each group represents

Record the superclass names

| Class: Drawing | |
|---|---|
| Superclass name | |
| Subclass name | |
| | |

# Finding Abstract Classes

If you can't name a group:

- List the attributes shared by classes in the group and derive the name from those attributes
- Divide groups into smaller, more clearly defined groups

If you still can't find a name, discard the group

# Responsibilities

The knowledge an object maintains

The actions an object can perform

General Guidelines

Consider public responsibilities, not private ones

Specify what gets done, not how it gets done

Keep responsibilities in general terms

Define responsibilities at an implementation-independent level

Keep all of a class's responsibilities at the same conceptual level

# Identifying Responsibilities

Requirements specification

- Verbs indicate possible actions
- Information indicates object responsibilities

The classes

- What role does the class fill in the system?
- Statement of purpose for class implies responsibilities

Walk-through the system

- Imagine how the system will be used
- What situations might occur?
- Scenarios of using system

# Scenarios

Scenario

A sequence of events between the system and an outside agent, such as a user, a sensor, or another program

Outside agent is trying to perform some task

The collection of all possible scenarios specify all the existing ways to use the system

Normal case scenarios

Interactions without any unusual inputs or error conditions

Special case scenarios

Consider omitted input sequences, maximum and minimum values, and repeated values

Error case scenarios

Consider user error such as invalid data and failure to respond

# Identifying Scenarios

Read the requirement specification from user's perspective

Interview users of the system

# Normal ATM Scenario

The ATM asks the user to insert a card; the user inserts a card.

The ATM accepts the card and reads its serial number.

The ATM requests the password; the user enters "1234."

The ATM verifies the serial number and password with the ATM consortium; the consortium checks it with the user's bank and notifies the ATM of acceptance.

The ATM asks the user to select the kind of transaction; the user selects "withdrawal."

The ATM asks the user for the amount of cash; the user enters "$100."

The ATM verifies that the amount is within predefined policy limits and asks the consortium to process the transaction; the consortium passes the request to the bank, which confirms the transaction and returns the new account balance.

The ATM dispenses cash and asks the user to take it; the user takes the cash.

The ATM asks whether the user wants to continue; the user indicates no.

The ATM prints a receipt, ejects the card and asks the user to take them; the user takes the receipt and the card.

The ATM asks a user to insert a card.

# Special Case ATM Scenario

The ATM asks the user to insert a card; the user inserts a card.

The ATM accepts the card and reads its serial number.

The ATM requests the password; the user enters "9999."

The ATM verifies the serial number and password with the ATM consortium; the consortium checks it with the user's bank and notifies the ATM of rejection.

The ATM indicates a bad password and asks the user to reenter it; the user hits "cancel."

The ATM ejects the card and asks the user to take it; the user takes the card.

The ATM asks a user to insert a card.

# Assigning Responsibilities

Assign each responsibility to the class(es) it logically belongs to

Evenly Distribute System Intelligence

Intelligence:

- What the system knows
- Actions that can be performed
- Impact on other parts of the system and users

Example: Personnel Record

Dumb version

- A data structure holding name, age, salary, etc.

Smart version

- An object that:
- Matches security clearance with current project
- Salary is in proper range
- Health benefits change when person gets married

# Evenly Distribute System Intelligence

The extremes:

- A dictator with slaves
- Dumb data structure with all intelligence in main program and few procedures
- Class with no methods
- Class with no fields

Object utopia

- All objects have the same level of intelligence

Reality

- Closer to utopia than to dictator with slaves

Reality check

- Class with long list of responsibilities might indicate budding dictator

# Metric Rules of Thumb

The average method size should be less than

8 lines of code (LOC) for Smalltalk

24 LOC for C++

Bigger averages indicate object-oriented design problems

The average number of methods per class should be less than 20

Bigger averages indicate too much responsibility in too few classes

The average number of fields per class should be less than 6.

Bigger averages indicate that one class is doing more than it should

The class hierarchy nesting level should be less than 6

Start counting at the level of any framework classes you use or the root class if you don't





From Mark Lorenz, *Object-Oriented Software Development: A Practical Guide* , 1993, Appendix I Measures and Metrics

# Assigning Responsibilities

State responsibilities as generally as possible

Assume that each kind of drawing element knows how to draw itself. It is better to say "drawing elements know how to draw themselves" than "a line knows how to draw itself, a rectangle knows how to draw itself, etc."

Keep behavior with related information

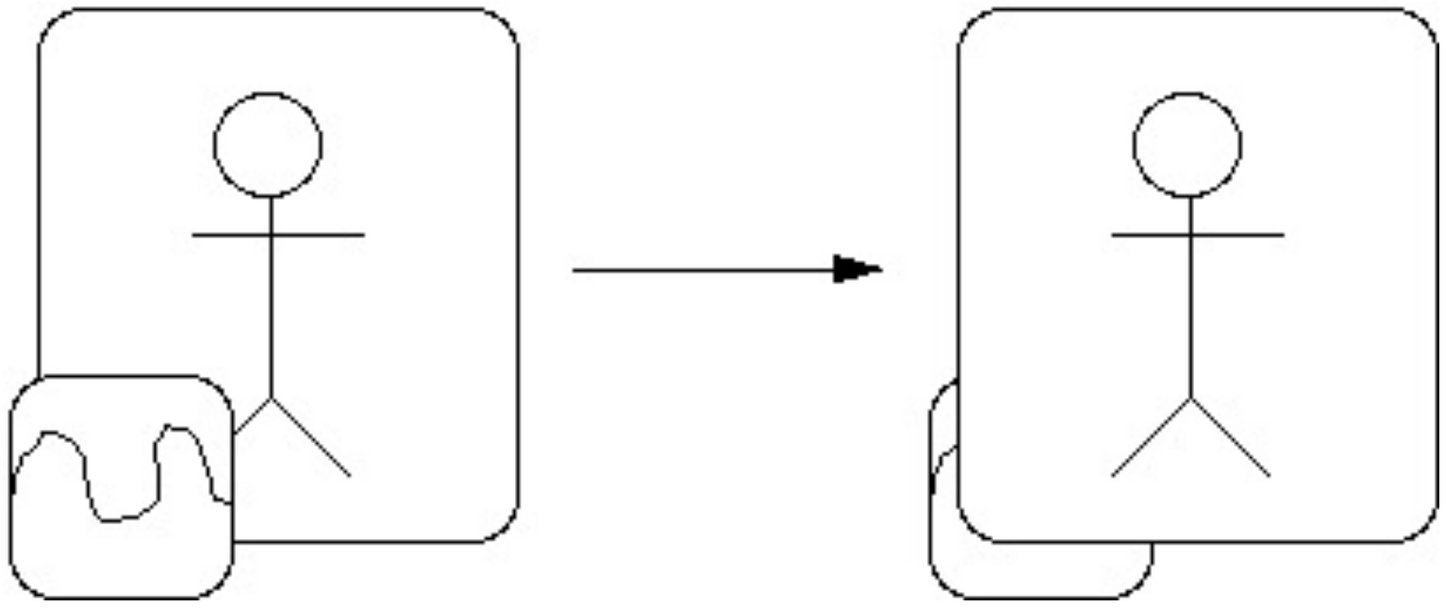
Abstraction implies we should do this

Keep information about one thing in one place

If two or more objects need the same information:

- Create a new object to hold the information
- Collapse the objects into a single object
- Place information in the more natural object

# Share Responsibilities



Who is responsible for updating screen when window moves?

# Examining Relationships Between Classes

is-kind-of or is-a

- Implies inheritance
- Place common responsibilities in superclass

is-analogous-to

- If class X is-analogous-to class Y then look for superclass

is-part-of or has-a

- If class A is-part-of class B then there is no inheritance
- Some negotiation between A and B for responsibilities may be needed

Example:

- Assume A contains a list that B uses
- Who sorts the list? A or B?

# Common Difficulties

Missing classes

A set of unassigned responsibilities may indicate a need for another class

Group related unassigned responsibilities into a new class

Arbitrary assignment

Sometimes a responsibility may seem to fit into two or more classes

Perform a walk-through the system with each choice

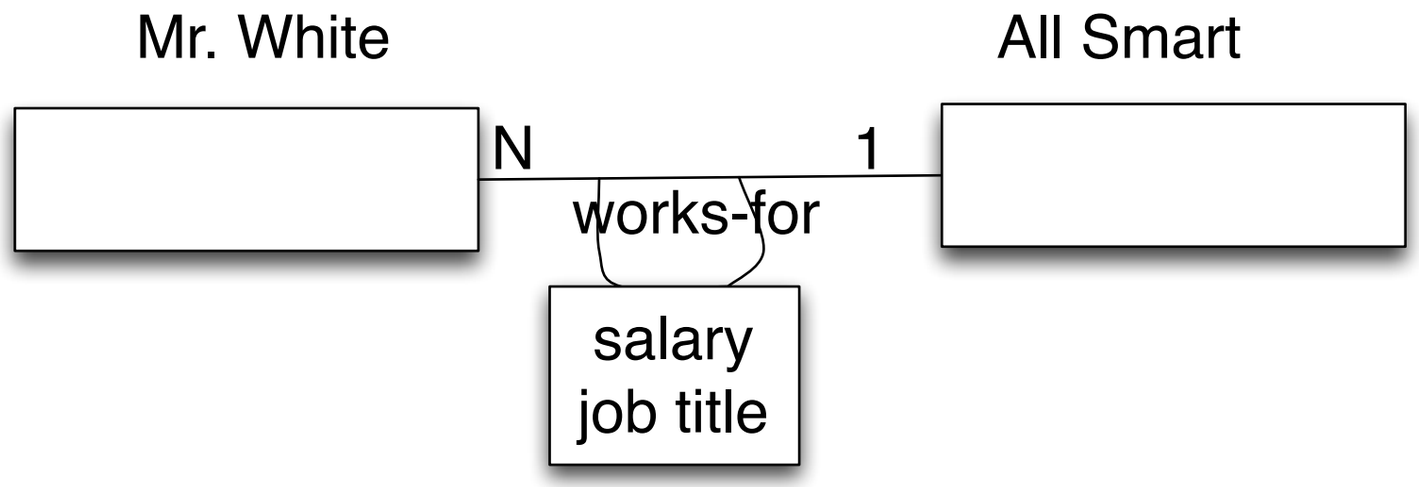
Ask others

Explore ramifications of each choice

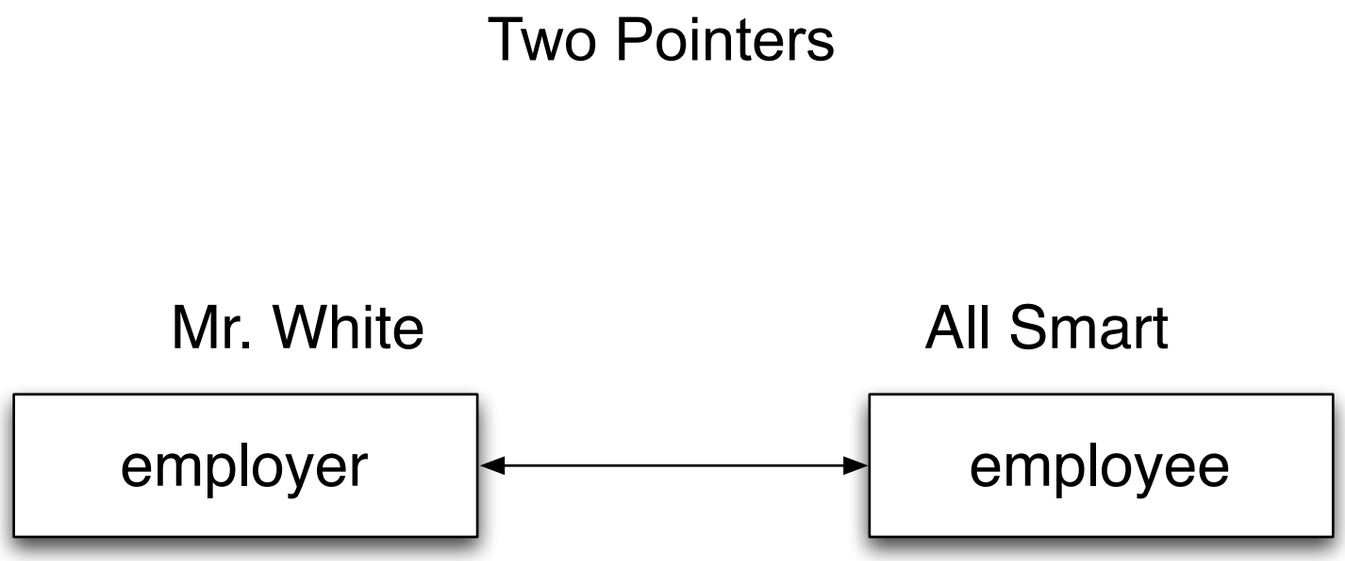
If the requirements change then which choice seems better?

# Relations


# Model View



# If need both directions



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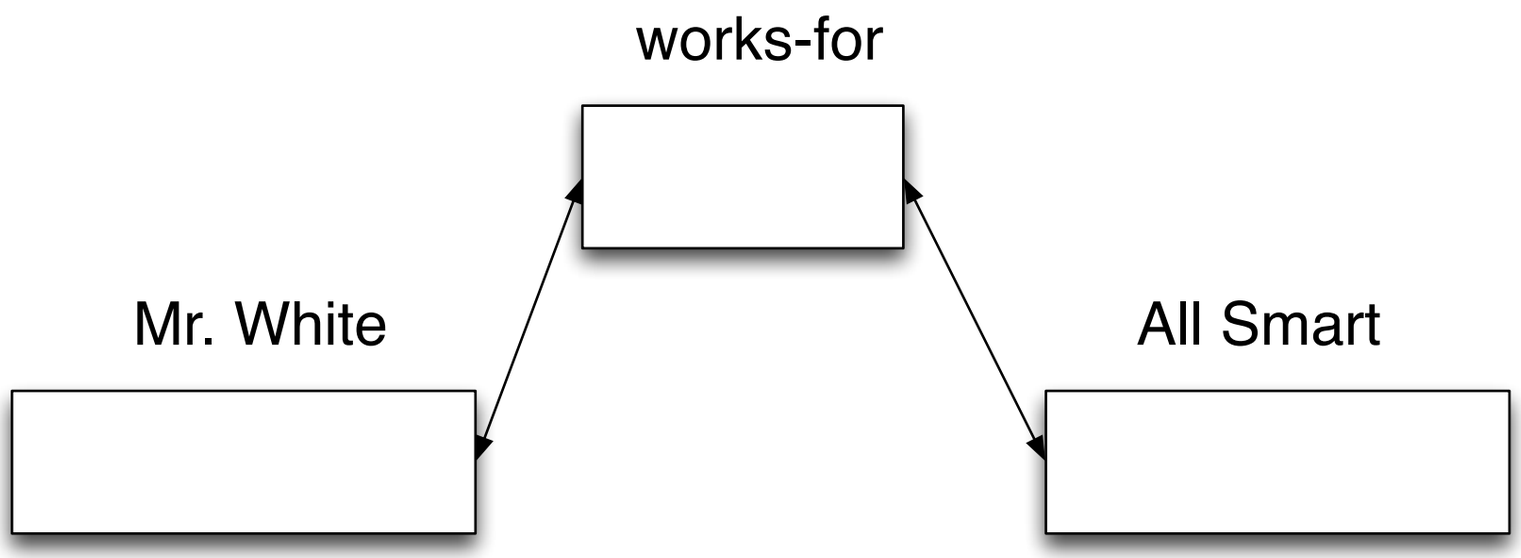

# Recording Responsibilities

| Class: Drawing | |
|---|---|
| | |
| | |
| List responsibilities here | |

| Class: Drawing | |
|---|---|
| | |
| | |
| Know which elements it contains<br><br>Maintain ordering between elements | |

# Collaboration

Represents requests from a client to a server in fulfillment of a client responsibility

Interaction between objects

# Finding Collaborations

Examine class responsibilities for dependencies

For each responsibility:

- Is class capable of fulfilling this responsibility?
- If not, what does it need?
- From what other class can it acquire what it needs?

For each class:

- What does this class do or know?
- What other classes need the result or information?
- If class has no interactions, discard it

# Finding Collaborations

Examine scenarios

Interactions in the scenarios indicate collaboration

# Common Collaboration Types

The is-part-of relationship

X is composed of Y's

- Composite classes
- Drawing is composed of drawing elements

- Some distribution of responsibilities required

Container classes

- Arrays, lists, sets, hash tables, etc.
- Some have no interaction with elements

# Recording Collaborations

| Class: Drawing | |
|---|---|
| | |
| | |
| Know which elements it contains<br><br>Maintain ordering between elements | <br><br>Drawing element |