

# Systems Analysis and Design

## Functional / Structural Modeling

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CIS641

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*Adapted from materials provided by Gregory Schymik and the textbook  
(Systems Analysis and Design 5th/6th Ed.)*

# Outline!

CRC cards

UML diagrams

Class diagrams

Object diagrams

Relationships between models

Resources → Chapter 4!

- Jurgen Borstler's paper: OO Analysis and Design Through Scenario Role-Play  
[https://www8.cs.umu.se/kurser/TDBA63/CRC\\_UMINF04.04.pdf](https://www8.cs.umu.se/kurser/TDBA63/CRC_UMINF04.04.pdf)

Resources on the UML

- <http://www.uml.org/index.htm>
- Find your own! There may be better resources on this for you out there

# Requirements vs. User Stories

## Requirement:

- Something the system must do to meet a business need/objective or contractual obligation

## User Story (Agile):

- (Brief) statement of intent describing what the system must do for a user

# Structural modeling

Or, let's take our requirements and turn them into *functional* models

Remember: models are **logical**

- Independent of implementation → hand-drawn or made on computer

Develop **use cases** from requirements

- Use case → business system interacting with environment
- Diagrams/descriptions of how users perform discrete activities

Develop **activity diagrams** from use cases

- Model business processes
- Depict **flow of data** between activities

# Both of these models...

## Discuss domain without implementation

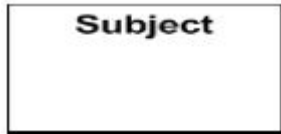
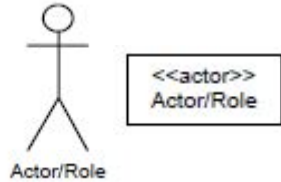
- AKA problem domain models



**Physical models** (later on) will tell us *how* implementation is supposed to be done

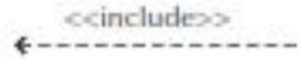
- For now, we care about *describing the problem*

# Use case diagrams

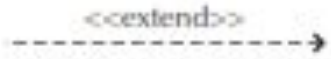


- Actors: user or system that interacts
  - Association: lines connecting actors and use cases
  - Inclusions, extensions, generalizations
- Major process in system (that gives a user benefit)
- Box describing scope of system
- Links an actor and a use case

# Use case diagrams



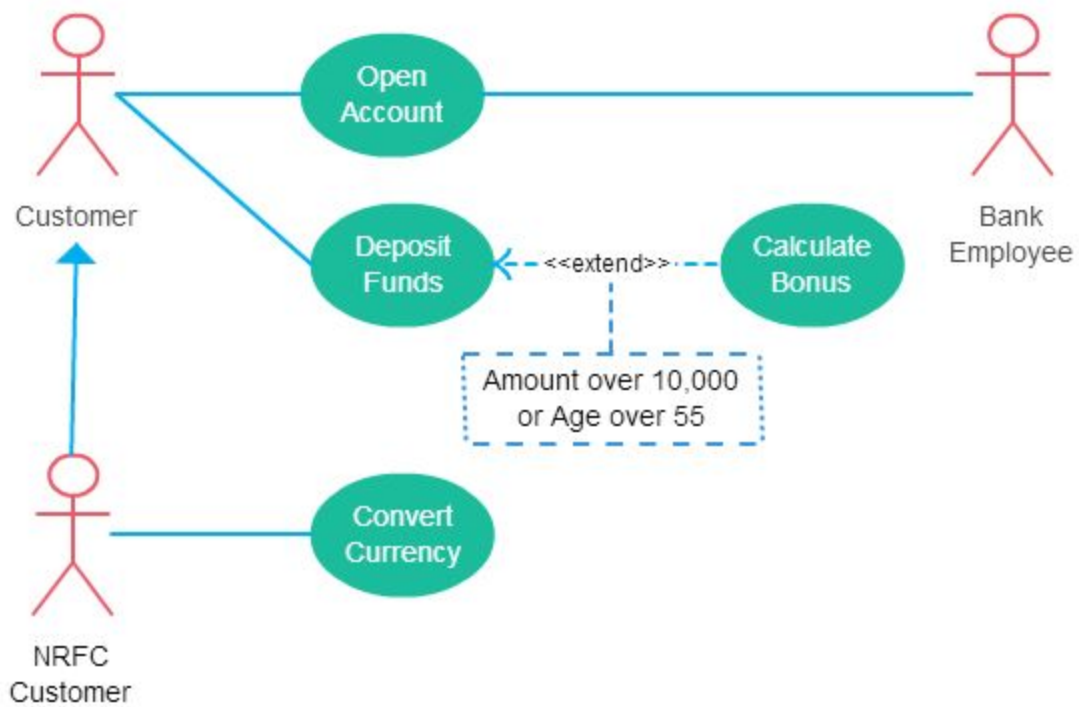
- Inclusion of one use case's functionality in another



- Extension of use case for optional behavior



- Specialized use case to be more generalized





# How do we identify use cases?

Review requirements definition

Identify subject boundaries

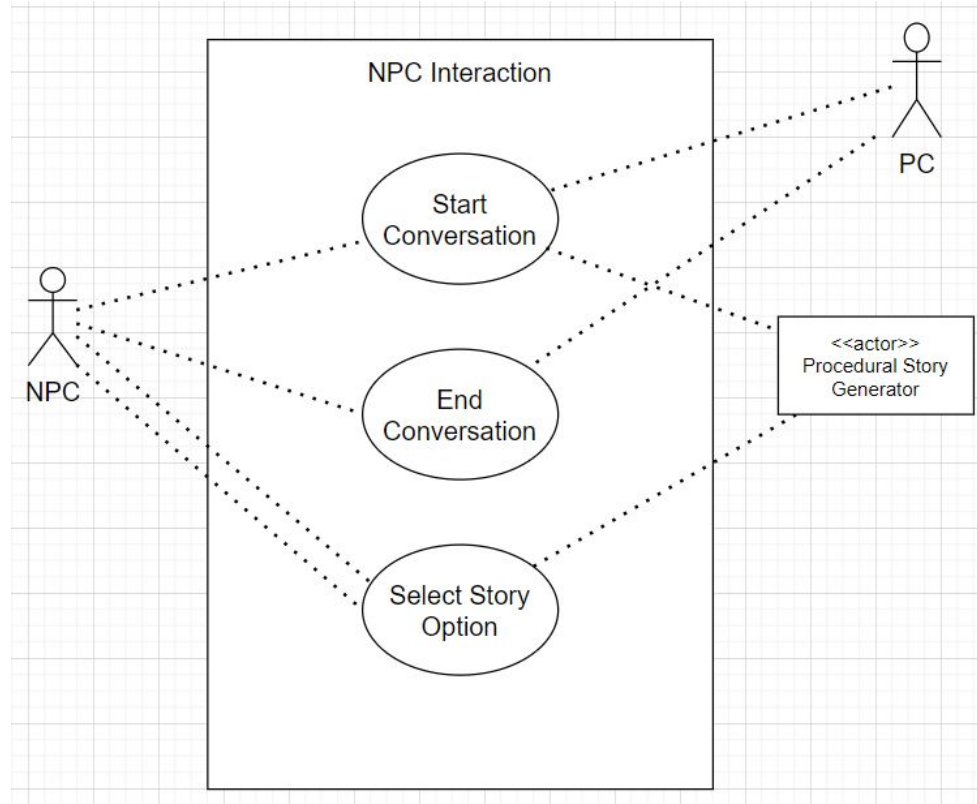
Identify primary actors and their goals

Identify business processes and major use cases

**Carefully** review current set of use cases

- Split/combine as necessary
- Identify additional (i.e., distinct) use cases

# EXAMPLE

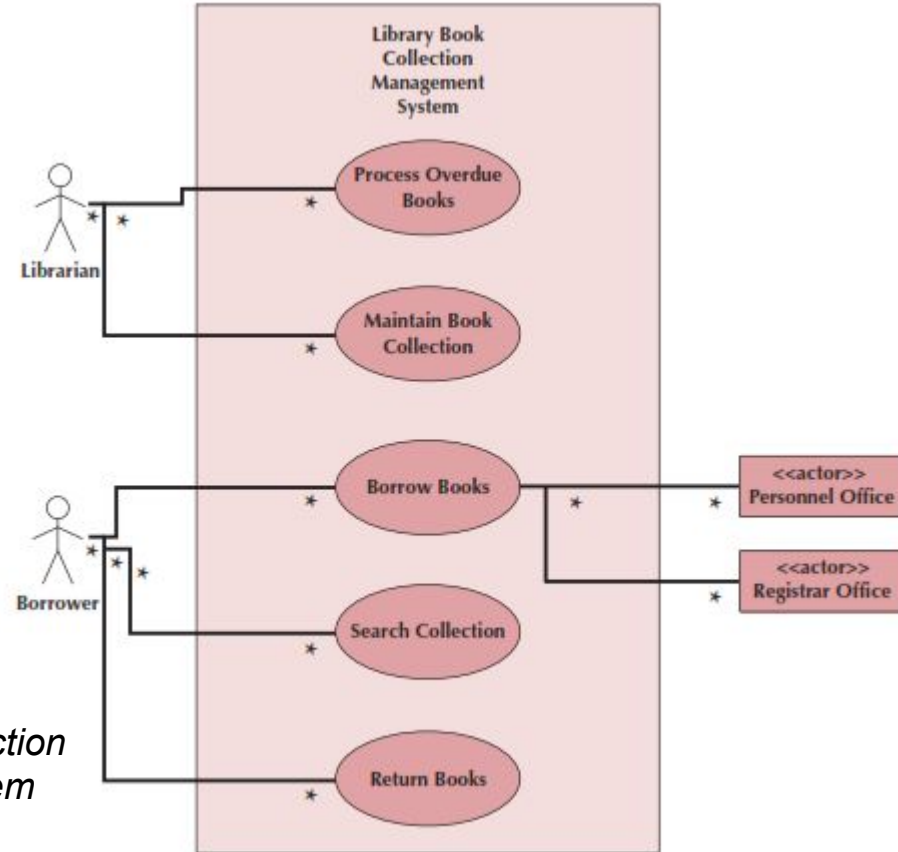


# Heuristic (adapt to your needs)

- 1) Place use cases
- 2) Place actors
- 3) Draw subject boundary
- 4) Add associations

(try to limit each diagram to 3-8 use cases)

*Library Book Collection  
Management System  
Use Case Diagram*



# Team task:

Develop **2** use case diagrams for your term project

Requirements:

- 1) The diagrams should describe a **unique feature**
- 2) There should be at least **three** use cases per diagram (max eight)

~15-20 minutes

- Summon me if you have questions!

- 1) Who are the **actors**
- 2) What is the **boundary**
- 3) What are the **use cases**
- 4) Are there any **associations?**

# But wait, there's more!

~~Now, I am going to shuffle a random person into each room~~

- ~~1) Describe your use case diagrams to the newcomer~~
- ~~2) Newcomer: give **constructive criticism**~~
- ~~3) Together, come up with a **third** feature for that team!~~

~~Come up with **three** use  
case diagrams and turn them  
in Friday (10/01) by midnight~~

# From use cases to activity (diagrams) (AD)

What is an activity again?

Activity diagram → **sequences of activities/actions**

- Abstract and describe generalities
- Model behavior **independent** of objects
- Use for **any** type or process!



# Activity diagram "parts"



- Action/activity



- Control flow



- Start (initial) node









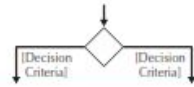



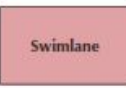


- End (final) node

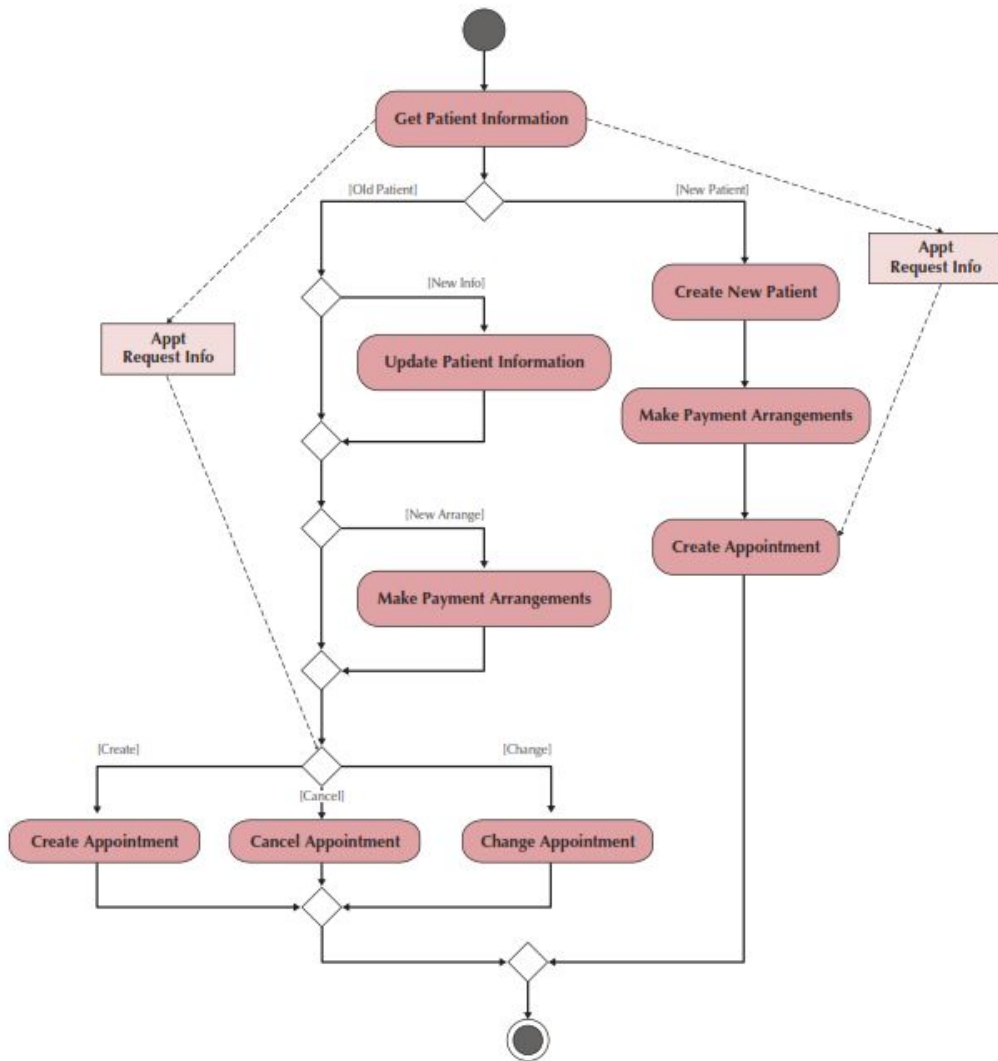


- Decision



<b>An action:</b> <ul style="list-style-type: none"> <li>■ Is a simple, nondecomposable piece of behavior.</li> <li>■ Is labeled by its name.</li> </ul>	
<b>An activity:</b> <ul style="list-style-type: none"> <li>■ Is used to represent a set of actions.</li> <li>■ Is labeled by its name.</li> </ul>	
<b>An object node:</b> <ul style="list-style-type: none"> <li>■ Is used to represent an object that is connected to a set of object flows.</li> <li>■ Is labeled by its class name.</li> </ul>	
<b>A control flow:</b> <ul style="list-style-type: none"> <li>■ Shows the sequence of execution.</li> </ul>	
<b>An object flow:</b> <ul style="list-style-type: none"> <li>■ Shows the flow of an object from one activity (or action) to another activity (or action).</li> </ul>	
<b>An initial node:</b> <ul style="list-style-type: none"> <li>■ Portrays the beginning of a set of actions or activities.</li> </ul>	
<b>A final-activity node:</b> <ul style="list-style-type: none"> <li>■ Is used to stop all control flows and object flows in an activity (or action).</li> </ul>	
<b>A final-flow node:</b> <ul style="list-style-type: none"> <li>■ Is used to stop a specific control flow or object flow.</li> </ul>	
<b>A decision node:</b> <ul style="list-style-type: none"> <li>■ Is used to represent a test condition to ensure that the control flow or object flow only goes down one path.</li> <li>■ Is labeled with the decision criteria to continue down the specific path.</li> </ul>	
<b>A merge node:</b> <ul style="list-style-type: none"> <li>■ Is used to bring back together different decision paths that were created using a decision node.</li> </ul>	
<b>A fork node:</b> <ul style="list-style-type: none"> <li>Is used to split behavior into a set of parallel or concurrent flows of activities (or actions)</li> </ul>	
<b>A join node:</b> <ul style="list-style-type: none"> <li>Is used to bring back together a set of parallel or concurrent flows of activities (or actions)</li> </ul>	
<b>A swimlane:</b> <ul style="list-style-type: none"> <li>Is used to break up an activity diagram into rows and columns to assign the individual activities (or actions) to the individuals or objects that are responsible for executing the activity (or action)</li> <li>Is labeled with the name of the individual or object responsible</li> </ul>	

# Sample AD

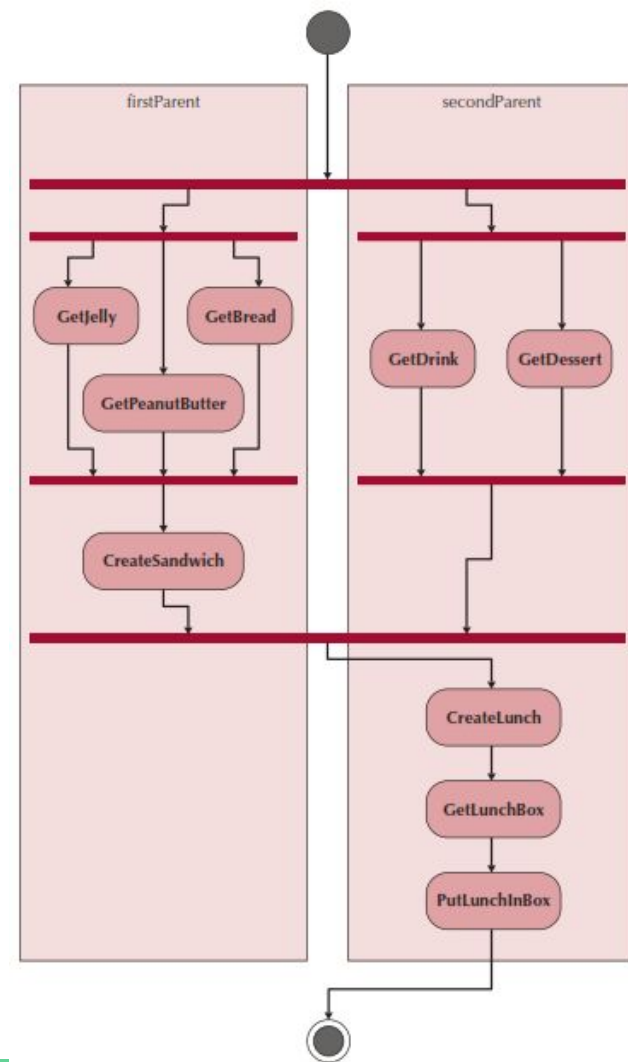


# Swim lanes

Assign responsibility to objects/individuals that perform the activity

Separation of roles

Vertical or horizontal, depending on what works best for you
















# AD guidelines

1. Scope the modeled activity
2. Identify activities and connect with flows
3. Identify (any) decisions that are needed
4. Identify potential parallelisms
5. Draw the diagram!

# Build an activity diagram for your term project

(This will be due in a few days!!!)

- 1) What is the activity and what do you need to model it?

<b>An action:</b> <ul style="list-style-type: none"><li>■ is a simple, nondecomposable piece of behavior.</li><li>■ is labeled by its name.</li></ul>	
<b>An activity:</b> <ul style="list-style-type: none"><li>■ is used to represent a set of actions.</li><li>■ is labeled by its name.</li></ul>	
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Come up with **two activities** and turn them in Tuesday (09/30) by midnight (with your use cases)

Shall syntax!

PERSONAL INFORMATION!

Also, I can't click links submitted - please use the full URL when submitting things.

# Back to use cases

Important -- this is the primary aspect of all UML activities!

- Defines actions performed by users
  - Describes basic system functions
- 1) Use cases are the **building blocks** of the whole system
  - 2) Each use case describes **one function**
    - a) And one function only!

# Types of use cases

		Amount of information	
		Overview	Detail
Purpose	Essential	High-level <b>overview</b> of issues <b>essential</b> to understanding required functionality	<b>Detailed</b> description of issues <b>essential</b> to understanding required functionality
	Real	High-level <b>overview</b> of a specific set of steps performed on the <b>real</b> system once implemented	<b>Detailed</b> description of a specific set of steps performed on the <b>real</b> system once implemented



# Use case description

## Overview:

- Name, ID Number, Type, Primary Actor, Brief Description, Importance Level, Stakeholder(s), Trigger(s)

## Relationships:

- Association: Communication between the use case and the actors
- Extend: Extends the functionality of a use case
- Include: Includes another use case
- Generalization: Allows use cases to support inheritance

## Flow of events

- Normal flow: the usual set of activities
- Sub-flows: decomposed normal flows to simplify the use-case
- Alternate or exceptional flows: those not considered the norm

**Optional characteristics** (complexity, time, etc.)

# Use case description guidelines

1. Write in the form of subject-verb-direct object
2. Make sure it is clear who the initiator of the step is
3. Write from independent observer's perspective
4. Write at about the same level of abstraction
5. Ensure the use case has a sensible set of steps
6. Apply the KISS principle liberally.
7. Write repeating instructions after the set of steps to be repeated

# Creating a use case description

1. Pick a high priority use-case and create an overview:
  - List the primary actor
  - Determine its type (overview or detail; essential or real)
  - List all stakeholders and their interests
  - Determine the level of importance of the use case
  - Briefly describe the use case
  - List what triggers the use case
  - List its relationship to other use cases
2. Fill in the steps of the normal flow of events required to complete the use-case

# Creating a use case description

1. Ensure that the steps listed are not too complicated or long and are consistent in size with other steps
2. Identify and write the alternate or exceptional flows
3. Carefully review the use-case description and confirm that it is correct
4. Iterate over the entire set of steps again

# Sample use case description

Use Case Name: Borrow Books		ID: 2	Importance Level: High
Primary Actor: Borrower		Use Case Type: Detail, Essential	
Stakeholders and Interests: Borrower - wants to check out books Librarian - wants to ensure borrower only gets books deserved			
Brief Description: This use case describes how books are checked out of the library.			
Trigger: Borrower brings books to check out desk.			
Type: External			
Relationships: Association: Borrower, Personnel Office, Registrar's Office Include: Extend: Generalization:			
Normal Flow of Events: 1. The Borrower brings books to the Librarian at the check out desk. 2. The Borrower provides Librarian their ID card. 3. The Librarian checks the validity of the ID Card. If the Borrower is a Student Borrower, Validate ID Card against Registrar's Database. If the Borrower is a Faculty/Staff Borrower, Validate ID Card against Personnel Database. If the Borrower is a Guest Borrower, Validate ID Card against Library's Guest Database. 4. The Librarian checks whether the Borrower has any overdue books and/or fines. 5. The Borrower checks out the books.			
SubFlows:			
Alternate/Exceptional Flows: 4a. The ID Card is invalid, the book request is rejected. 5a. The Borrower either has overdue books, fines, or both, the book request is rejected.			

# Verifying and validating a use case

Use-cases must be verified and validated before beginning structural and behavioral modeling

Utilize a walkthrough:

- Perform a review of the models and diagrams created so far
- Performed by individuals from the development team and the client (very interactive)
  - **Facilitator:** schedule and set up the meeting
  - **Presenter:** the one who is responsible for the specific representation being reviewed
  - **Recorder** (scribe) to take notes and especially to document errors

# Rules for verification and validation

1. Ensure one recorded event in the flows of the use-case description for each action/activity on the activity diagram
2. All objects in an activity diagram must be mentioned in an event of the use-case description
3. The sequence of the use-case description should match the sequence in the activity diagram
4. One and only one description for each use-case

## Rules pt. 2

5. All actors listed in a use-case description must be shown on the use-case diagram
6. Stakeholders listed in the use-case description may be shown on the use-case diagram (check local policy)
7. All relationships in the use-case description must be depicted on the use-case diagram
8. All diagram-specific rules must be enforced





**On to Chapter 5!**

But first!

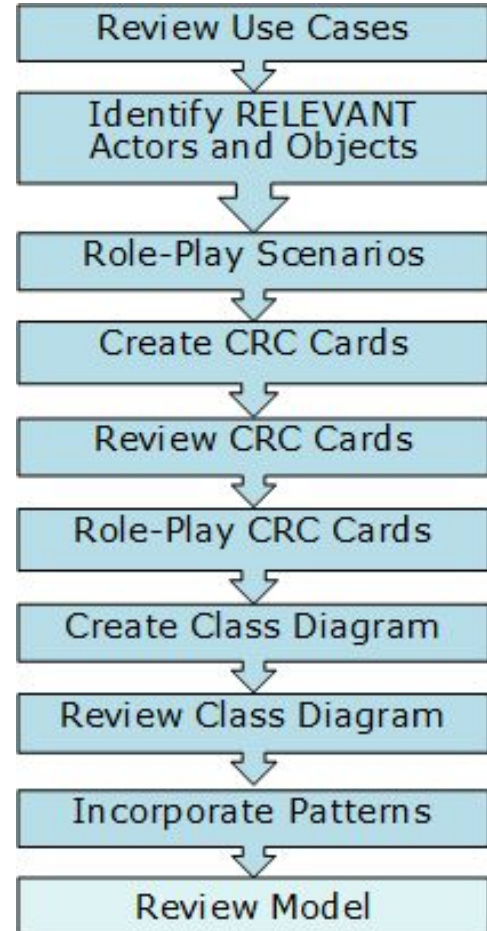


TBD

# A process!

Very iterative!

- We'll see this as we go



# Models

Functional models → represent system **behavior**

Structural models (i.e., what we're doing now) → represent **objects and their relationships**

- People
- Places
- Things
- etc.

# Structural models

Drawn **iteratively**

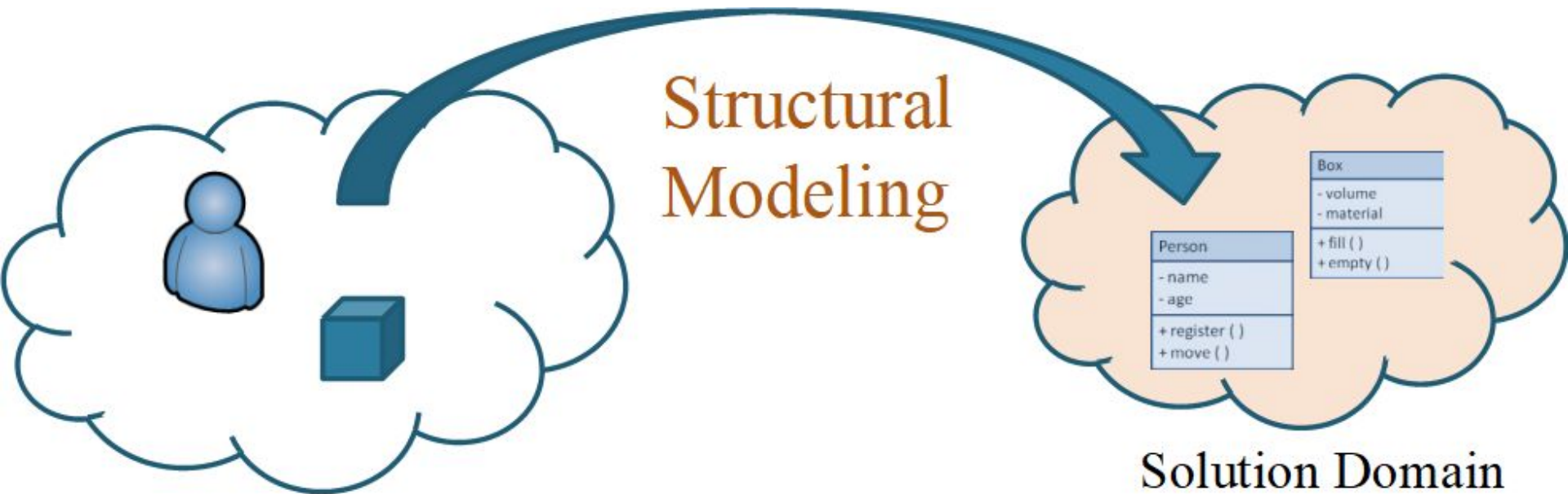
- Start conceptual, business-oriented
- **Refine** towards technology
  - Describe database, files, etc.

Create a **vocabulary** for users and analysts

- Enables **effective communication**

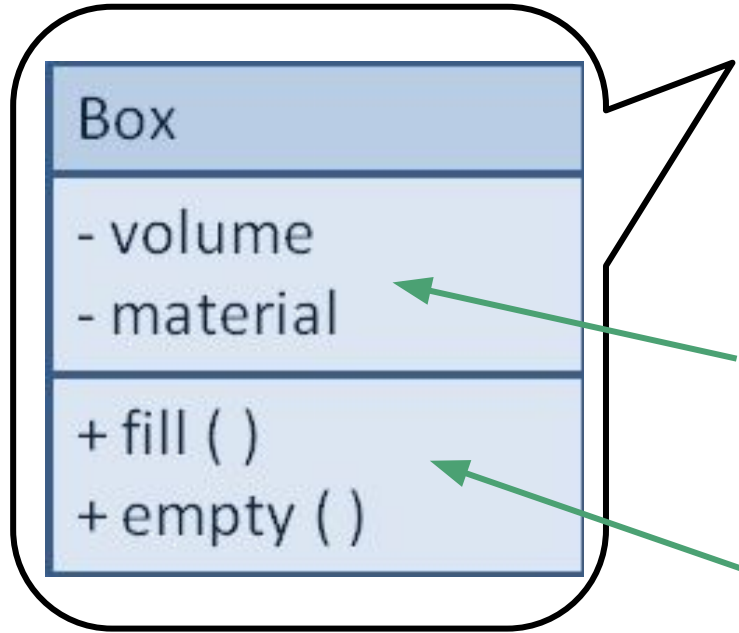
# Structural models

Discover key data in problem domain and **build structural model of objects**





# Classes, attributes, operations



## Classes

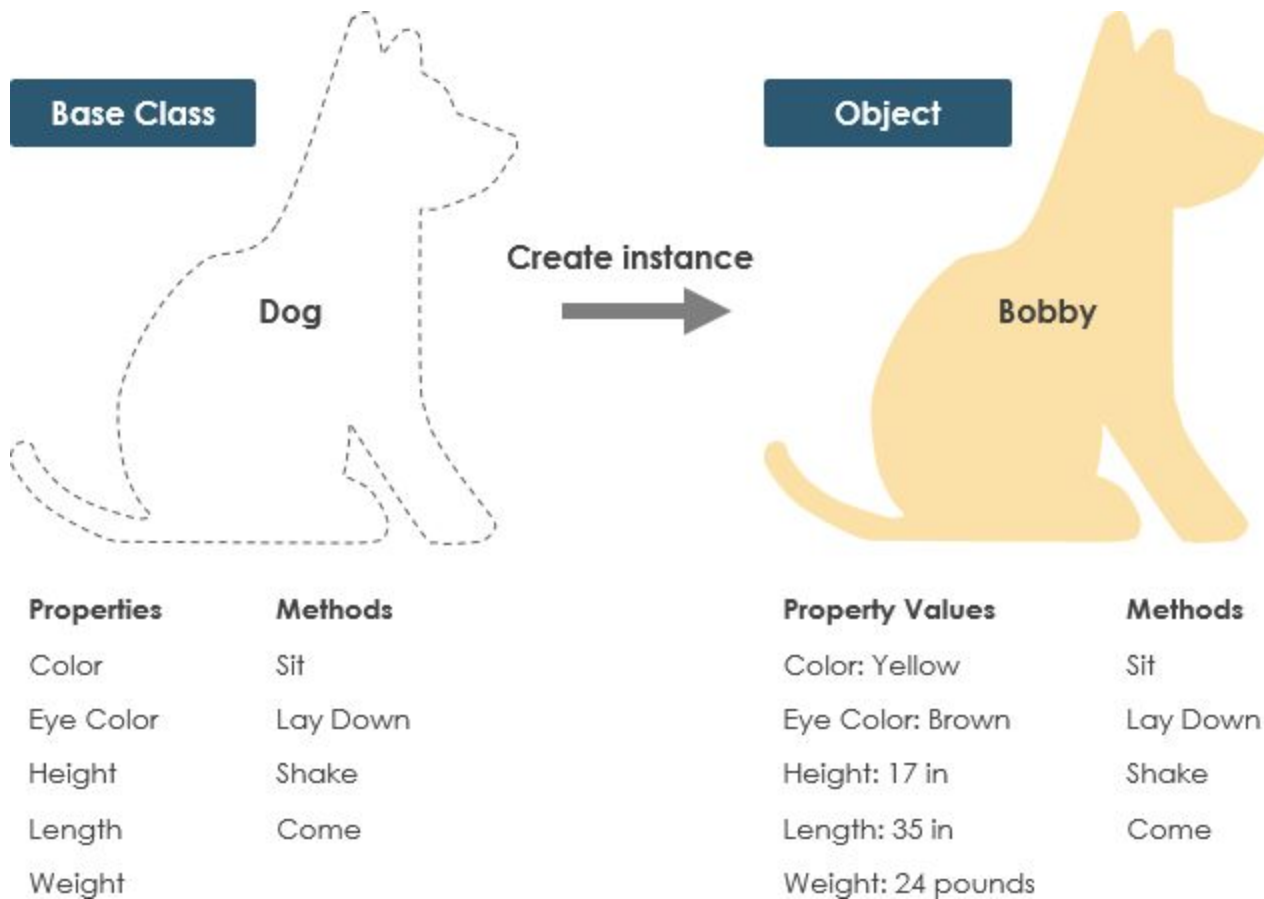
- Templates for instantiating people, objects, etc.
- Generally → SIMILAR objects!

## Attributes

- Properties that **describe** state of class instance

## Operations

- Actions/functions/methods that a class can perform





# Relationships

How classes relate to each other!

- Important for capturing dependencies, feature interactions, etc.

## **Generalization**

- Enables inheritance of attributes and operations
- Represents relationships that are “a-kind-of”

## **Aggregation**

- Relates parts to wholes or assemblies
- Represents relationships that are “a-part-of” or “has-parts”

## **Association**

- Miscellaneous relationships between classes
- Usually a weaker form of aggregation

# Object identification

## Analyze use cases

- Nouns → suggest classes
- Verbs → suggest methods
- (Rough outline for first iteration)

## Brainstorming!

- Initial list of classes (objects)
- Attributes, operations, relationships can be added in future iterations

# CRC cards

## Index cards (physical or virtual)

- Document responsibilities / collaborations for a class

<del>Book: The books that can be borrowed from the library</del>	
Class: <i>Book</i>	
Responsibilities	Collaborators
<i>knows whether on loan</i>	
<i>knows return date</i>	
<i>knows title</i>	
<i>knows if late</i>	<i>Date</i>
<i>check out</i>	

## Responsibility

- Knowing → what a class must **know** defined as attributes
- Doing → what a class must **do** defined as operations (manifested later)

## Collaboration

- Objects working **together** to service a request
  - Requestor (client)
  - Responder (server)
- Bound by a **contract**

(CRC → class responsibility collaboration card)

<https://www.youtube.com/watch?v=Bxgn6qJ-bYY>

# Front side (CRC)

<b>Class Name:</b> Old Patient	<b>ID:</b> 3	<b>Type:</b> Concrete, Domain
<b>Description:</b> An individual that needs to receive or has received medical attention		<b>Associated Use Cases:</b> 2
<b>Responsibilities</b>		<b>Collaborators</b>
Make appointment		Appointment
Calculate last visit		
Change status		
Provide medical history		Medical history

# Back side (CRC)

## Attributes:

Amount (double)

Insurance carrier (text)

## Relationships:

**Generalization (a-kind-of):** Person

**Aggregation (has-parts):** Medical History

**Other Associations:** Appointment

# CRC cards / role playing

Exercise to help discover additional objects, attributes, relationships, operations

Team members perform roles associated with the actors and objects previously identified



# CRC cards / role playing

Utilize activity diagrams to run through the steps in a scenario

- Identify an important use-case
- Assign roles based on actors and objects
- Team members perform each step in the scenario
- Discover and fix problems until a successful conclusion is reached
- Repeat for remaining use-cases



Why use CRC cards at all?

?

# Group work

Pick **one use case diagram** and create **one** CRC for one of your use cases  
(Just the front)

Be prepared to present it for

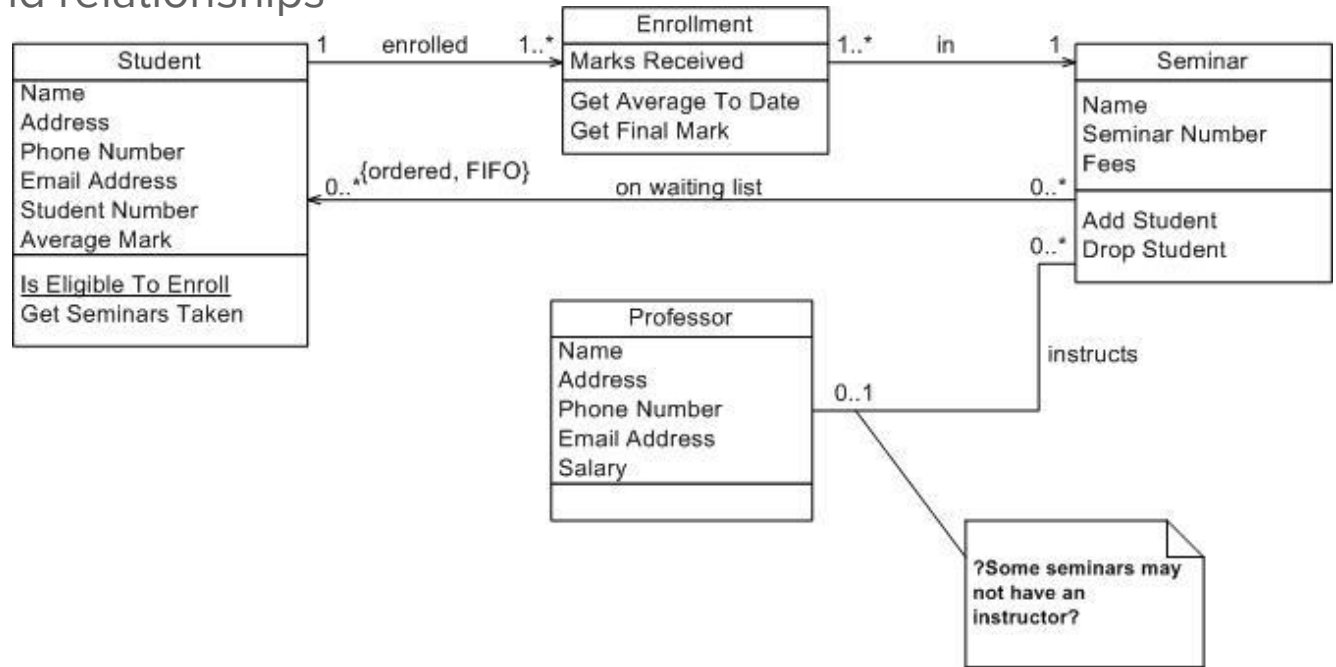
# constructive criticism

(You'll turn it in ~~tomorrow night~~ soon with a rough class diagram to support it, made later on)

<b>Class Name:</b> Old Patient	<b>ID:</b> 3	<b>Type:</b> Concrete, Domain
<b>Description:</b> An individual that needs to receive or has received medical attention		<b>Associated Use Cases:</b> 2
<p style="text-align: center;"><b>Responsibilities</b></p> <p>Make appointment</p> <hr/> <p>Calculate last visit</p> <hr/> <p>Change status</p> <hr/> <p>Provide medical history</p> <hr/> <hr/> <hr/> <hr/>		<p style="text-align: center;"><b>Collaborators</b></p> <p>Appointment</p> <hr/> <hr/> <hr/> <p>Medical history</p> <hr/> <hr/> <hr/> <hr/>

# Class diagrams

Illustrates classes and relationships



Helpful → <https://www.visual-paradigm.com/guide/uml-unified-modeling-language/uml-class-diagram-tutorial/>

# Class diagrams

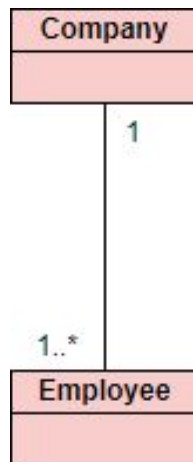
(Generally) static model

## Classes

- Objects within system
- Stores/manages:
  - Attributes
  - Methods

## Relationships

- Associations between classes
- "Lines" between classes
- Multiplicity →  $n$  objects associated with  $m$  other objects



## Multiplicities examples:

1	Exactly one, no more and no less
0..1	Zero or one
*	Many
0..*	Zero or many
1..*	One or many

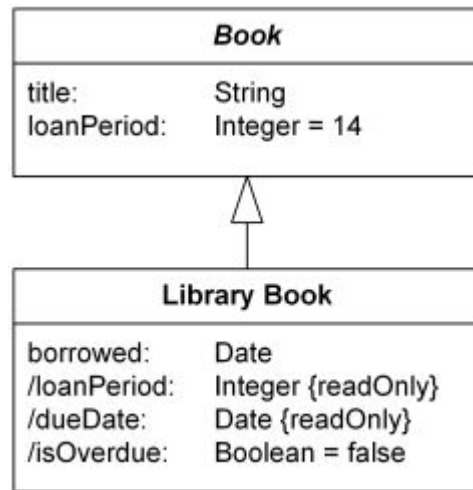
# Class diagrams → Attributes

## Properties:

- E.g., **Person**: last name, first name, address, etc.
- Can be derived:
  - Preceded with slash (/)
  - E.g., age derived from birth

## Visibility:

- Restricts access for consistency
- Public (+) → visible to **all** classes
- Private (-) → visible **only** to instance of defined class
- Protected (#) → visible **only** to instance of defined class **and** its descendents



# Class diagrams → Operations

Common operations **not shown**

- Create/delete instance
- Get/set value

Types of operations

- Constructor → creates an object
- Query → retrieves object information
- Update → changes some value
- Destructor → destroys (delete/remove) an object

# Class diagrams → Relationships

## Associations between classes

- Line labeled with relationship name
- *May be* directional (triangle)
  - Patient schedules an appointment

Classes can be self-related (e.g., employees and managers are both people)

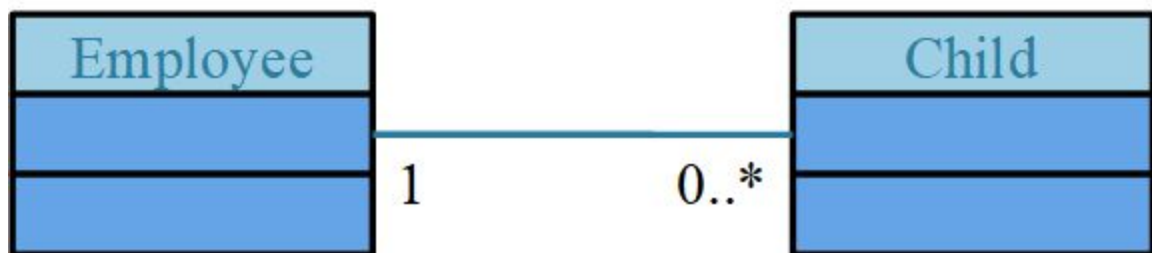
Multiplicity: how many of each class are related to each other





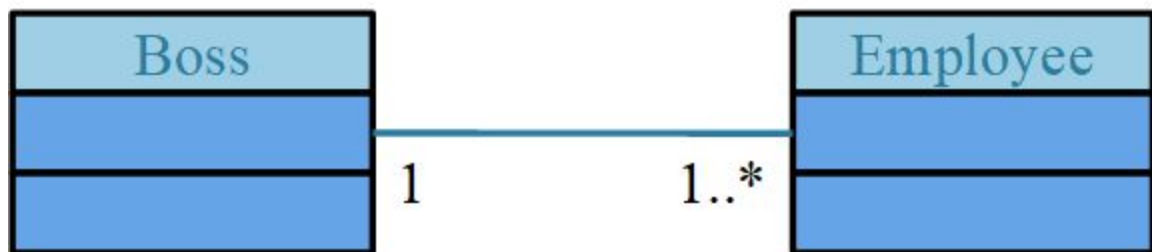
**Exactly one:**

A department has one and only one boss



**Zero or more:**

An employee has zero to many children



**One or more:**

A boss is responsible for one or more employees

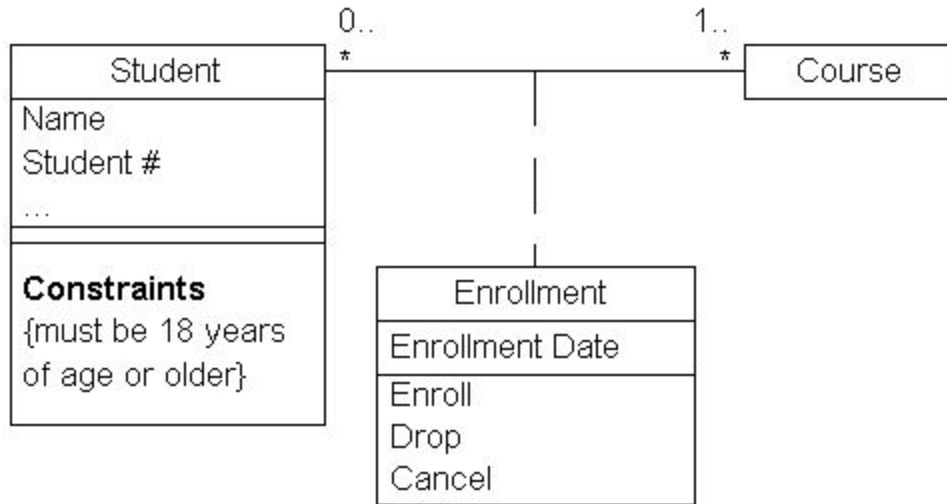
# Association classes

Common with many-to-many relationships

Used when attributes about relationship needs recording

- Students related to courses
  - Grade class provides attribute to describe relationship
- Illness related to symptoms
  - Treatment class provides attribute to describe as well

# Sample association



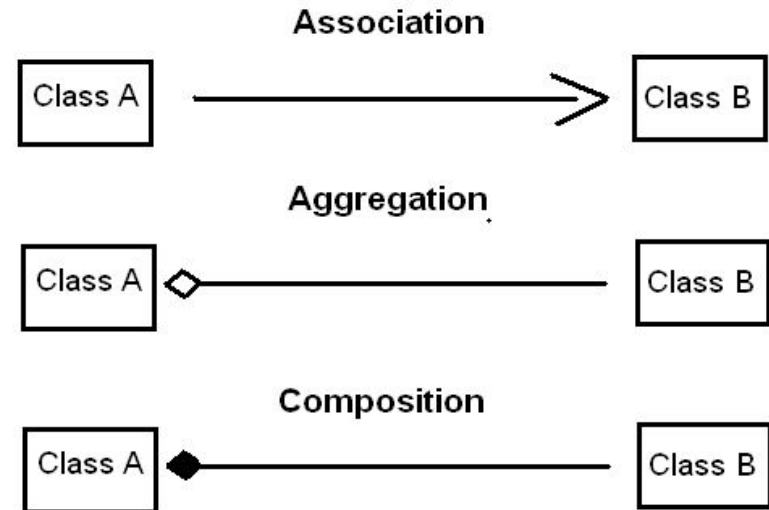
# Generalization/Aggregation associations

Generalization denotes *inheritance*

- Properties/operations of *superclass* also valid for subclass
- Solid line with hollow arrow pointing at superclass

Aggregation: **logical** "part-of" relationship

Composition: **physical** "part-of" relationship



Generalization (*is a kind of*):

- Cardinal *is a kind of* Bird
- Truck *is a kind of* Land Vehicle (which *is a kind of* Vehicle)

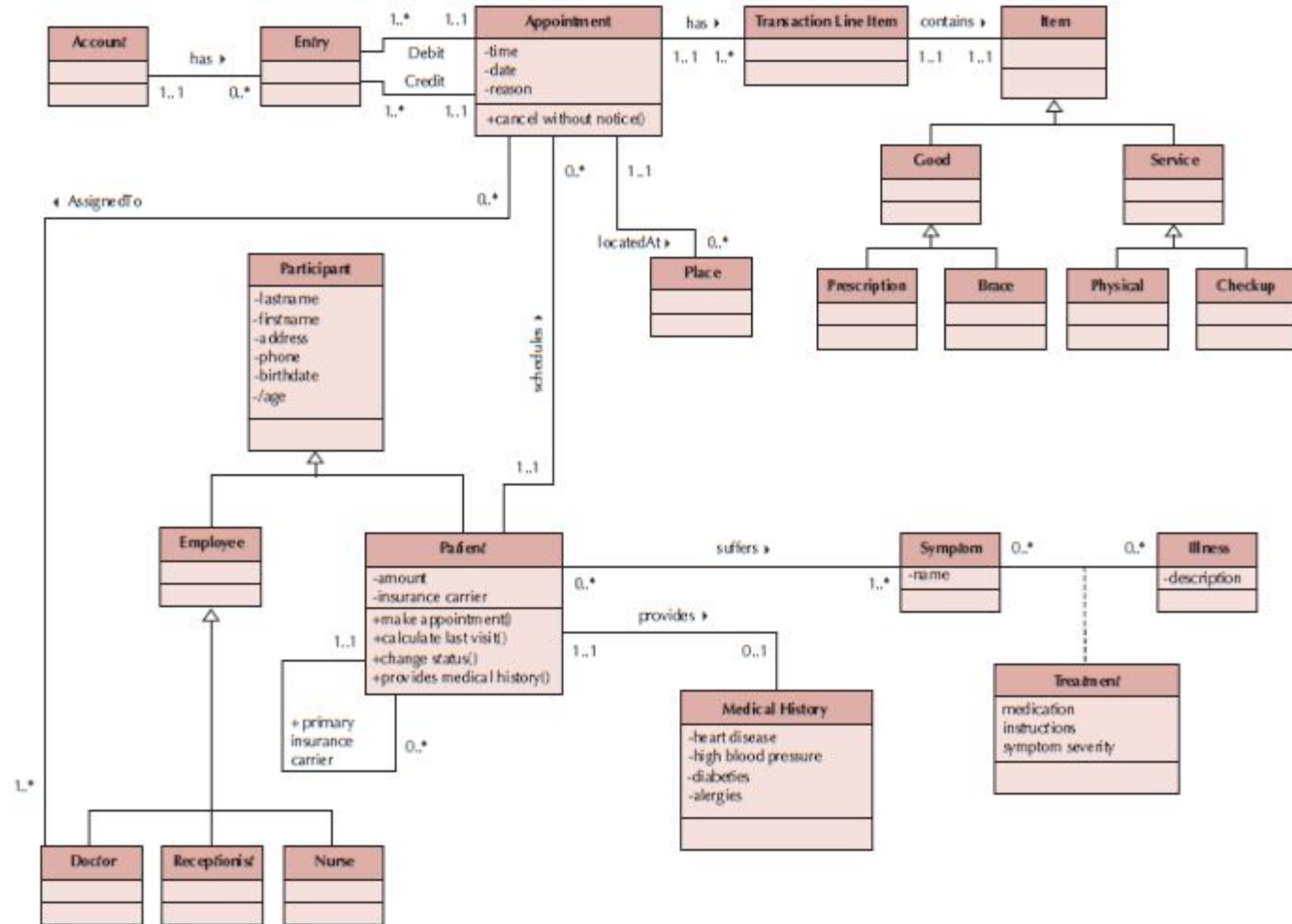
Aggregation (**logical** *is a part of*):

- Wheel instance *is a part of* a Vehicle instance

Composition (**physical** *is a part of*):

- Door instance *is a part of* only a single Vehicle instance

# Sample CD

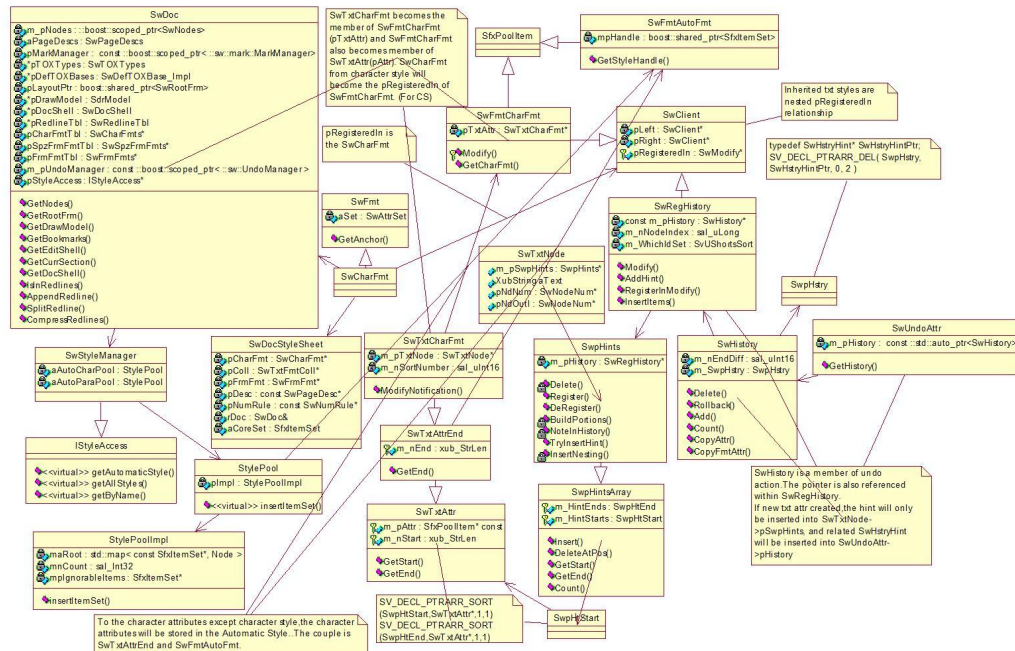


# Simplifying class diagrams!

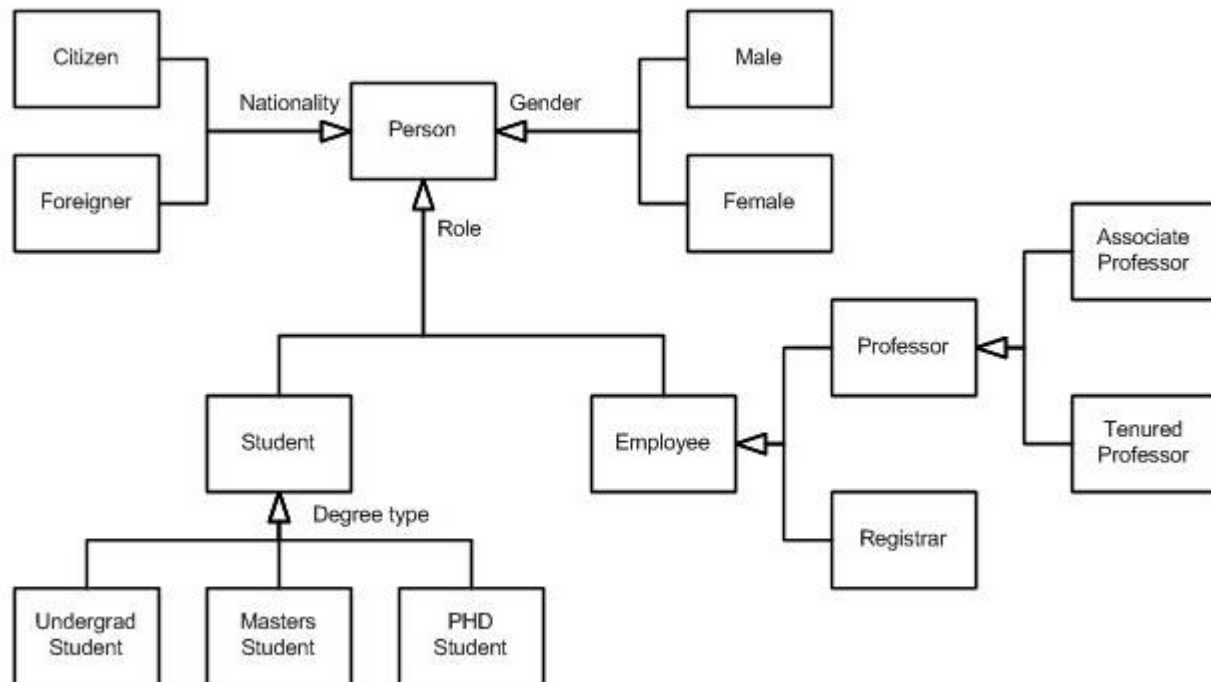
Fully-populated class diagrams can be horrendously complex

## Simplify:

- Show only concrete classes
- View mechanism shows subset of classes
- Packages show aggregations of classes (or any UML element)



# Disqus



<http://www.agilemodeling.com/artifacts/classDiagram.htm>



Let's create an example *together*



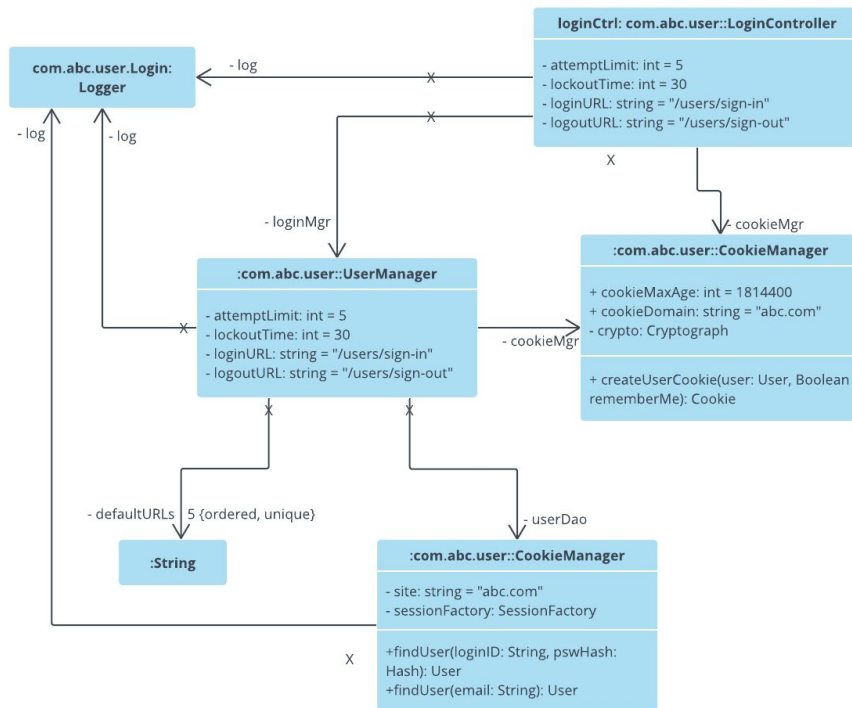
# Object diagrams

Class diagrams with **instantiated** classes

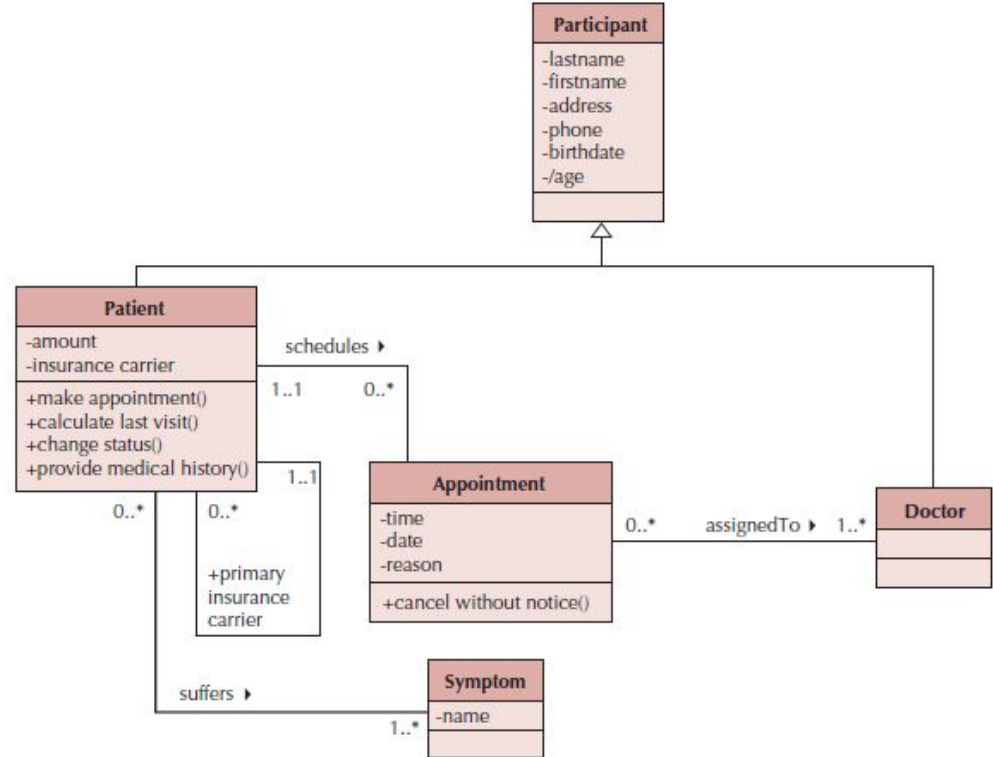
- Doctor class → Dr. Fredericks (ha)
- Attributes have **values**

Discover additional attributes/relationships/etc.

- Also find out what has been misplaced or misconfigured!



# Example



Let's create *an example together*

# Seven steps to structural models

1. Create CRC Cards
2. Review CRC Cards and identify missing objects, attributes, operations and/or relationships
3. Role-play the CRC cards—look for breakdowns & correct; create new cards as necessary
4. Create the class diagram
5. Review the class diagram—remove unnecessary classes, attributes, operations and/or relationships
6. Incorporate patterns
7. Review and validate the model

# More group work!

Take that CRC card you made earlier and:

- 1) Make a rough class diagram out of it
- 2) Create an object model to demonstrate it working

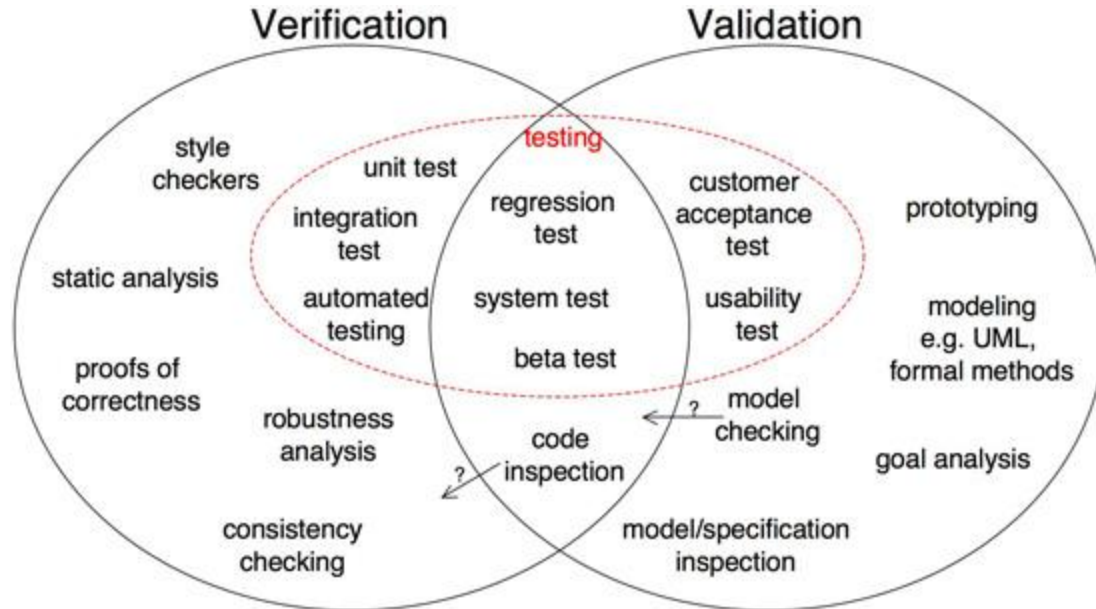
**Turn in these materials by tomorrow night at midnight**

**→ Keyword -- rough (these don't have to be perfect, we'll formalize some soon)**

# Verifying and validating the model

Analyst presents to developers and users

- Walks through the model
- Provides explanations and reasoning behind each class





# Verifying and validating the model

## Rules

1. Each CRC card is associated with a class
2. Responsibilities on the front of the card are included as operations on the class diagram
3. Collaborators on the front of the card imply a relationship on the back of the card
4. Attributes on the back of the card are listed as attributes on the class diagram
5. Attributes on the back of the CRC card each have a data type (e.g., salary implies a number format)
6. Relationships on the back of the card must be properly depicted on the class diagram
  - a. Aggregation/Association
  - b. Multiplicity
7. Association classes are used only to include attributes that describe a relationship

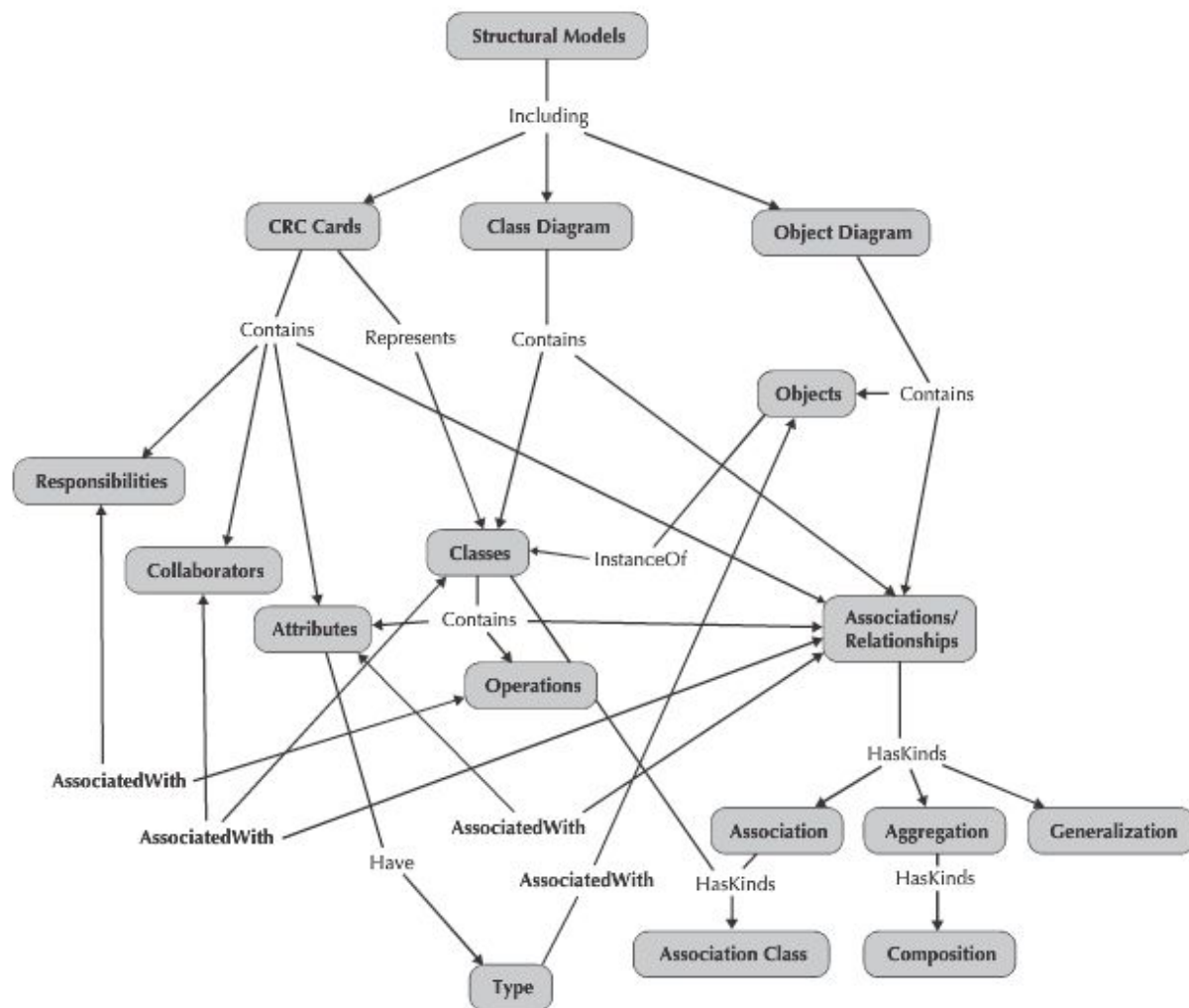


FIGURE 5-26 Interrelationships among Structural Models

# Interlude :: Gantt Charts, Burn-Down/Burn-Up

Seems we forgot to go into these, especially important as *you'll be selecting one and doing it for your midterm presentations!*

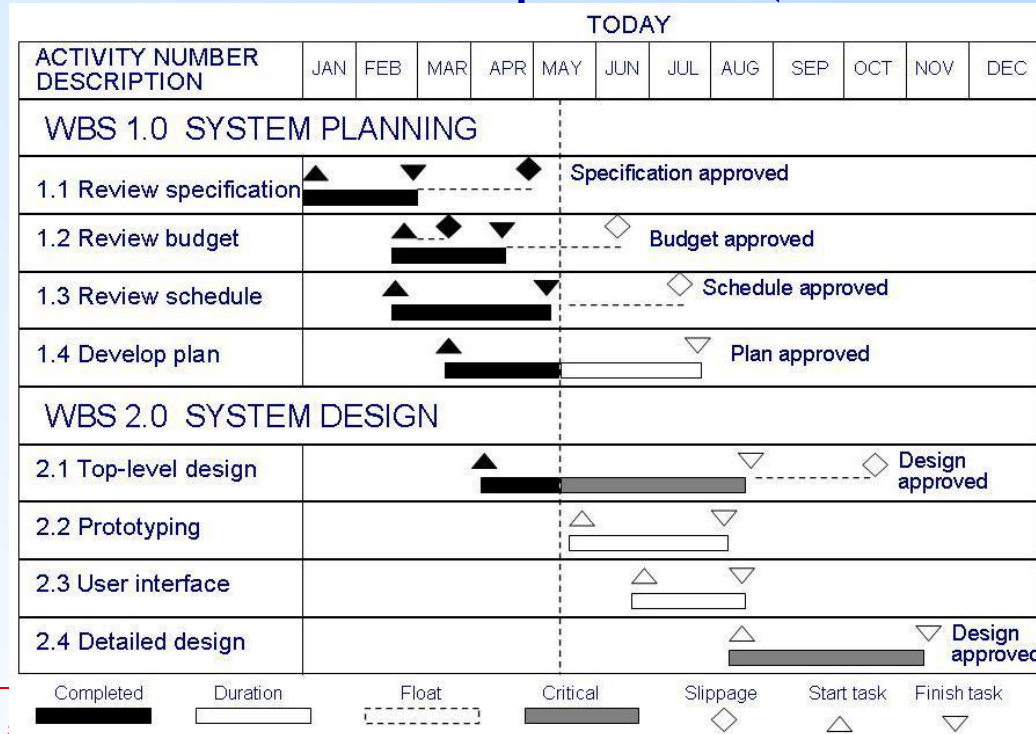
*Which will be Oct. 18*

*There are details in Blackboard under 'Term Project'*

# 3.1 Tracking Progress

## Tools to Track Progress: Gantt Chart

- Activities shown in parallel (shows task concurrency)



# Wot about Agile?

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Gantt charts are so *passé*  
Let's burn up and burn down

