Software Engineering
G22.2440-001

Session 7 – Sub-Topic Presentation 6
Introduction to OOAD Modeling and UML

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Agenda

- Concepts of OO
- Review of Object Technology
- Review of SDLC
- OOAD Modeling and UML

Part I

Concepts of OO

Objectives: Concepts of Object Orientation

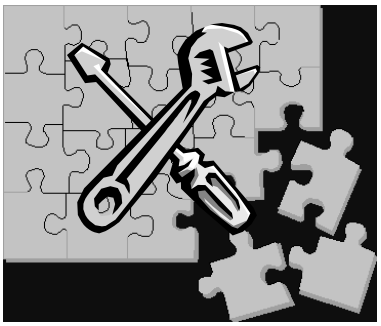
- Review the basic principles of object orientation
- Review the basic concepts and terms of object orientation and the associated UML notation
- Review the strengths of object orientation
- Review some basic UML modeling notation

Best Practices Implementation

- Object Technology helps implement these Best Practices.
  - Develop iteratively: tolerates changing requirements, integrates elements progressively, facilitates reuse.
  - Use component-based Architectures: architectural emphasis, component-based development.
  - Model visually: easy understanding, easy modification.

What Is Object Technology?

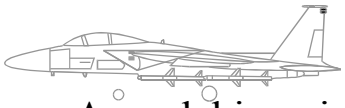
- Object Technology
  - A set of principles guiding software construction together with languages, databases, and other tools that support those principles. (*Object Technology - A Manager's Guide*, Taylor, 1997)



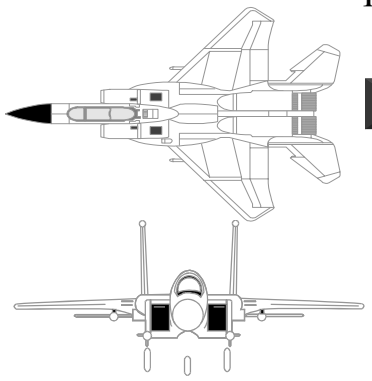
Strengths of Object Technology

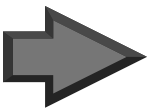
- A single paradigm
  - A single language used by users, analysts, designers, and implementers
- Facilitates architectural and code reuse
- Models more closely reflect the real world
  - More accurately describes corporate entities
  - Decomposed based on natural partitioning
  - Easier to understand and maintain
- Stability
  - A small change in requirements does not mean massive changes in the system under development
- Adaptive to change

What Is a Model?



- A model is a simplification of reality.



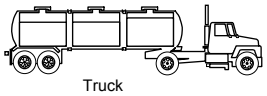


Why Do We Model?

- We build models to better understand the system we are developing.
- Modeling achieves four aims. Modeling:
  - Helps us to visualize a system as we want it to be.
  - Permits us to specify the structure or behavior of a system.
  - Gives us a template that guides us in constructing a system.
  - Documents the decisions we have made.
- We build models of complex systems because we cannot comprehend such a system in its entirety.

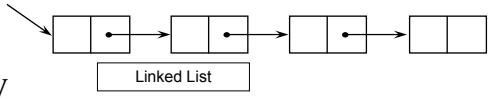
What Is an Object?

- Informally, an object represents an entity, either physical, conceptual, or software.
  - Physical entity



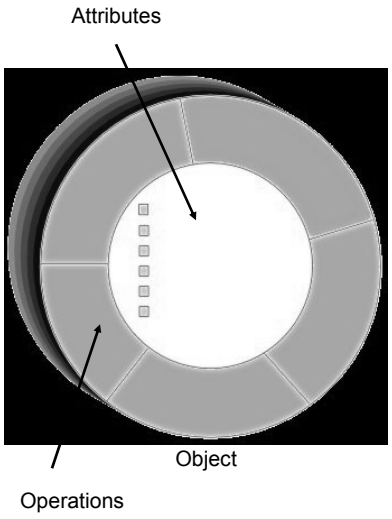
  - Conceptual entity

  - Software entity



A More Formal Definition

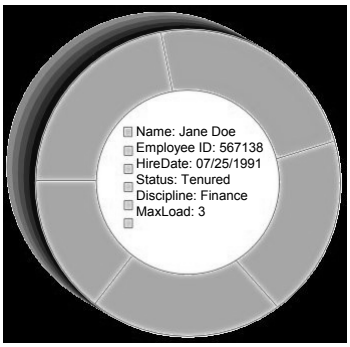
- An object is an entity with a well-defined boundary and identity that encapsulates *state* and *behavior.*
  - State is represented by attributes and relationships.
  - Behavior is represented by operations, methods, and state machines.



An Object Has State

- The state of an object is one of the possible conditions in which an object may exist.
- The state of an object normally changes over time.

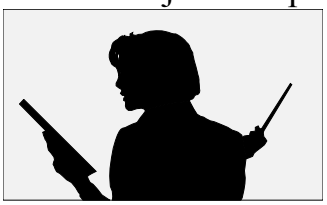
Name: Jane Doe
Employee ID: 567138
Date Hired: July 25, 1991
Status: Tenured
Discipline: Finance
Maximum Course Load: 3 classes



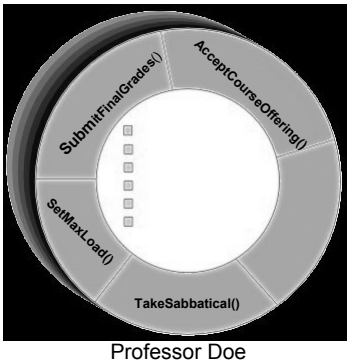
Professor Doe

An Object Has Behavior

- Behavior determines how an object acts and reacts.
- The visible behavior of an object is modeled by the set of messages it can respond to (operations the object can perform).



Professor Doe's behavior
- Submit Final Grades
- Accept Course Offering
- Take Sabbatical
- Maximum Course Load: 3 classes



Professor Doe

An Object Has Identity

- Each object has a unique identity, even if the state is identical to that of another object.

Professor "Jane Doe" teaches Biology

Professor "Jane Doe" teaches Biology

Representing Objects in the UML

- An object is represented as a rectangle with an underlined name.

Professor J Clark

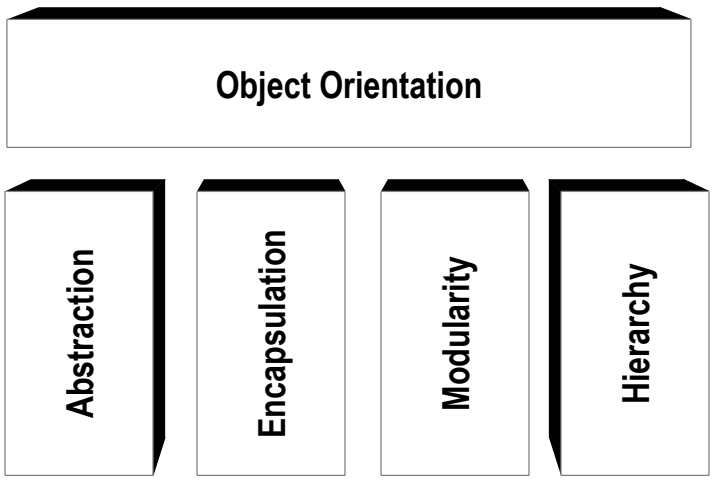
J Clark : Professor

Named Object

: Professor

Unnamed Object

Basic Principles of Object Orientation



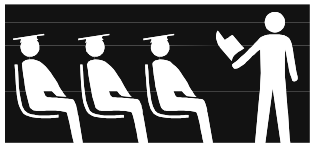
What Is Abstraction?

- The essential characteristics of an entity that distinguish it from all other kinds of entities
- Defines a boundary relative to the perspective of the viewer
- Is not a concrete manifestation, denotes the ideal essence of something

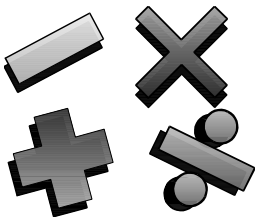
Example: Abstraction

Student

Professor



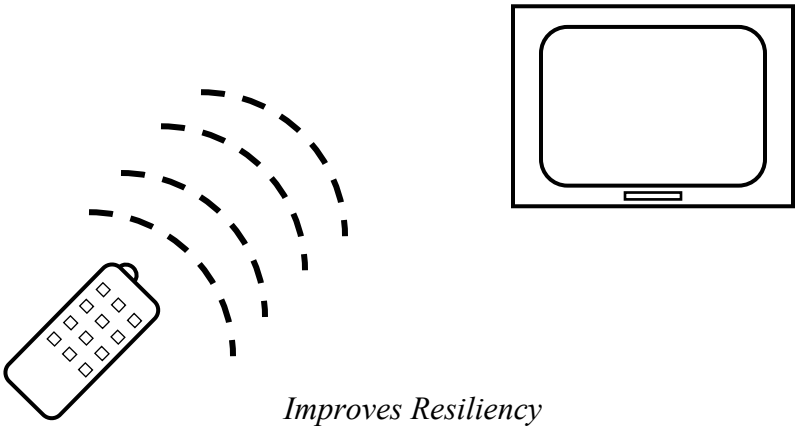
Course Offering (9:00 AM, Monday-Wednesday-Friday)



Course (e.g. Algebra)

What Is Encapsulation?

- Hide implementation from clients.
  - Clients depend on interface.

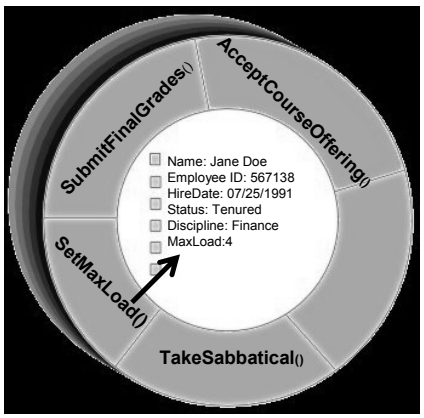


Improves Resiliency

Encapsulation Illustrated

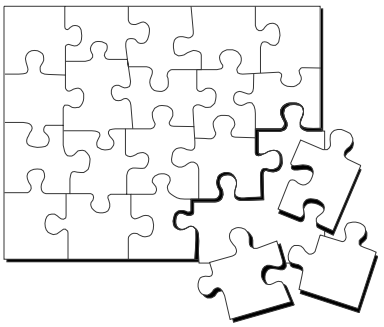
- needs to be able to teach four classes in the next semester.

SetMaxLoad(4)



What Is Modularity?

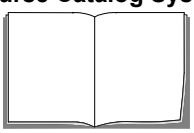
- Modularity is the breaking up of something complex into manageable pieces.
- Modularity helps people to understand complex systems.



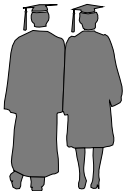
Example: Modularity

Billing System

Course Catalog System



Student Management System



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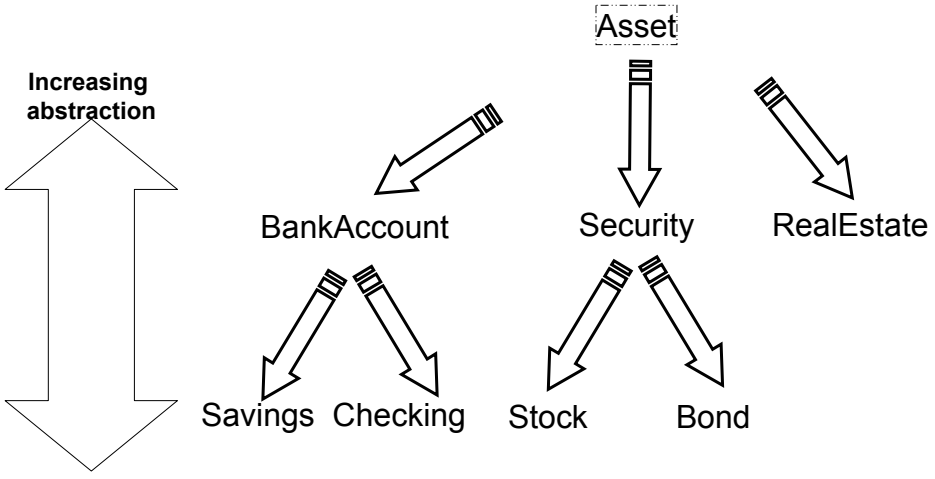
Course Registration System

What Is Hierarchy?



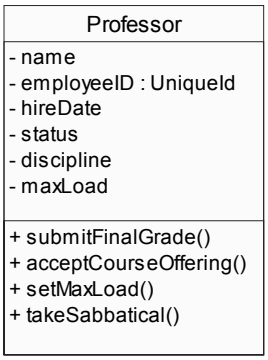
Elements at the same level of the hierarchy should be at the same level of abstraction.

What Is a Class?

- A class is a description of a set of objects that share the same *attributes*, *operations*, *relationships*, and semantics.
  - An object is an instance of a class.
- A class is an abstraction in that it
  - Emphasizes relevant characteristics.
  - Suppresses other characteristics.

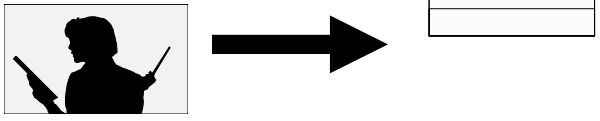
Representing Classes in the UML

- A class is represented using a rectangle with compartments.



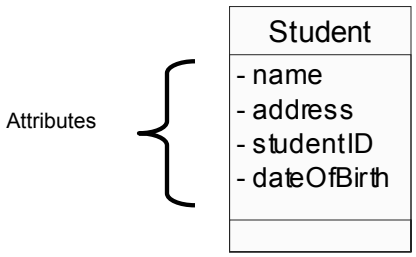
The Relationship Between Classes and Objects

- A class is an abstract definition of an object.
  - It defines the structure and behavior of each object in the class.
  - It serves as a template for creating objects
- Objects are grouped into classes.



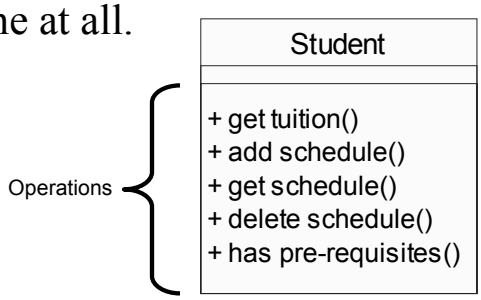
What Is an Attribute?

- An attribute is a named property of a class that describes a range of values that instances of the property may hold.
  - A class may have any number of attributes or no attributes at all.



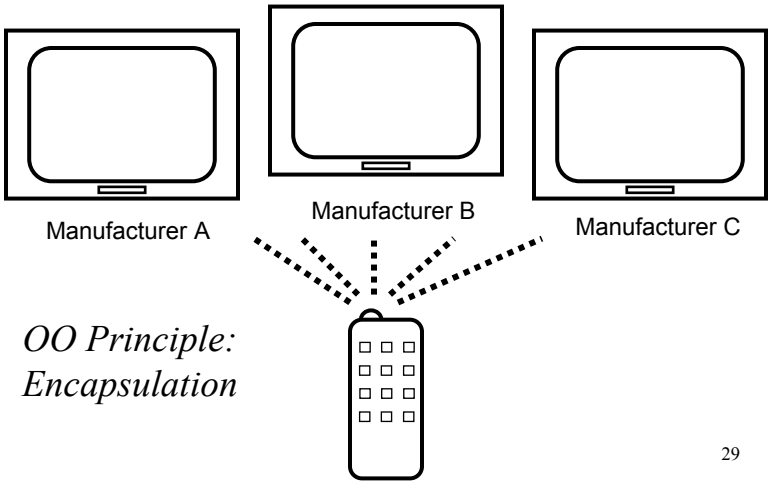
What Is an Operation?

- An operation is the implementation of a service that can be requested from any object of the class to affect behavior.
- A class may have any number of operations or none at all.



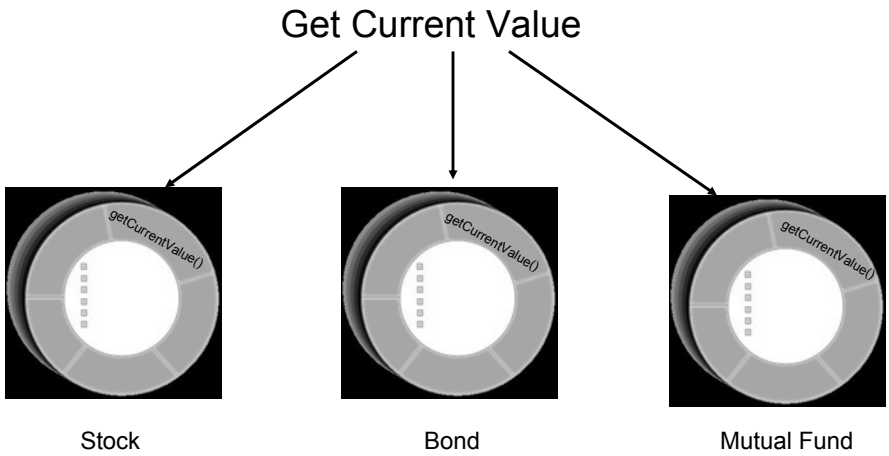
What Is Polymorphism?

- The ability to hide many different implementations behind a single interface



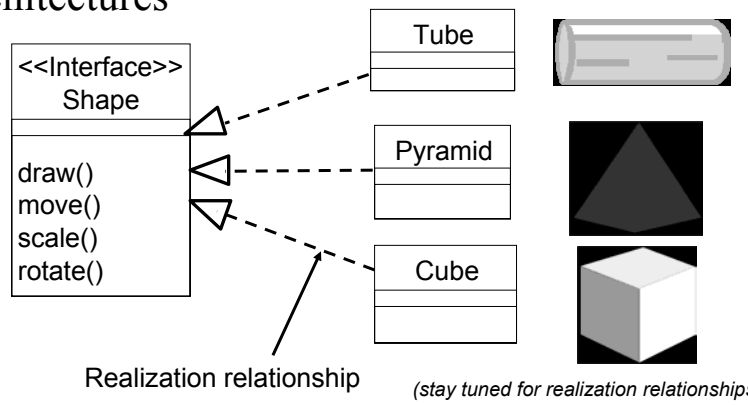
OO Principle: Encapsulation

Example: Polymorphism



What is an Interface?

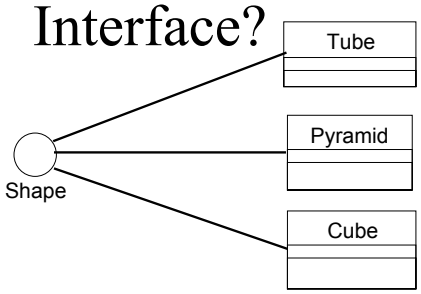
- Interfaces formalize polymorphism
- Interfaces support "plug-and-play" architectures



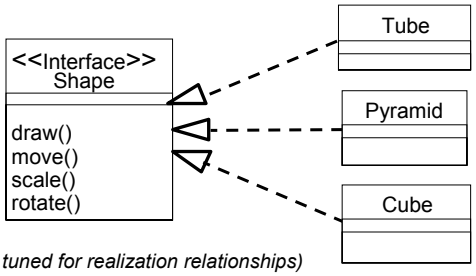
(stay tuned for realization relationships)

How Do You Represent An Interface?

Elided/Iconic Representation ("lollipop")



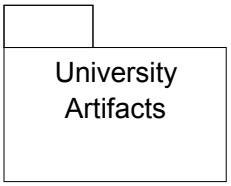
Canonical (Class/Stereotype) Representation



(stay tuned for realization relationships)

What Is a Package?

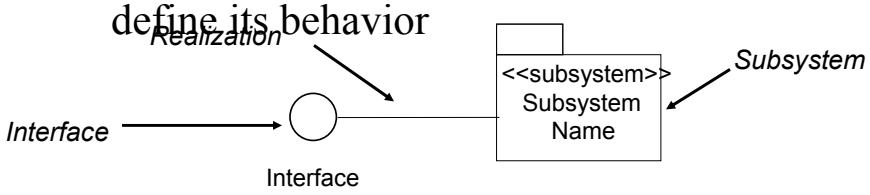
- A package is a general purpose mechanism for organizing elements into groups.
- It is a model element that can contain other model elements.



- A package can be used
  - To organize the model under development.
  - As a unit of configuration management.

What is a Subsystem?

- A combination of a package (can contain other model elements) and a class (has behavior)
- Realizes one or more interfaces which define its behavior



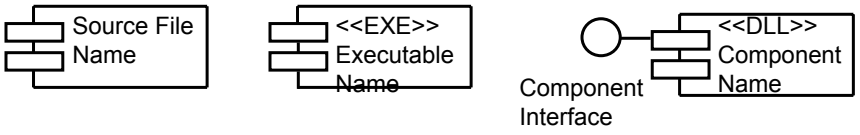
OO Principles: Encapsulation and Modularity

(stay tuned for realization relationship)

What is a Component?

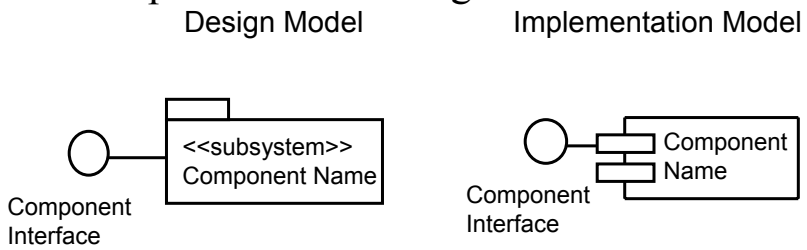
- A non-trivial, nearly independent, and replaceable part of a system that fulfills a clear function in the context of a well-defined architecture
- A component may be
  - A source code component
  - A run time components or
  - An executable component

OO Principle: Encapsulation



Subsystems and Components

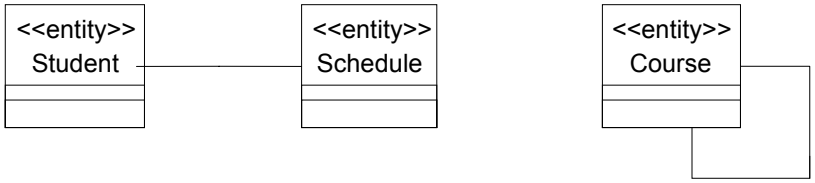
- Components are the physical realization of an abstraction in the design
- Subsystems can be used to represent the component in the design



OO Principles: Encapsulation and Modularity

What Is an Association?

- The semantic relationship between two or more classifiers that specifies connections among their instances
  - A structural relationship, specifying that objects of one thing are connected to objects of another



What Is Multiplicity?

- Multiplicity is the number of instances of one class relates to ONE instance of another class.
- For each association, there are two multiplicity decisions to make, one for each end of the association.
  - For each instance of Professor, many Course Offerings may be taught.
  - For each instance of Course Offering, there may be either one or zero Professor as the instructor.

Multiplicity Indicators

- Unspecified
- Exactly one
- Zero or more (many, unlimited)
- One or more
- Zero or one (optional scalar role)
- Specified range
- Multiple, disjoint ranges

1

0..*

*

1..*

0..1

2..4

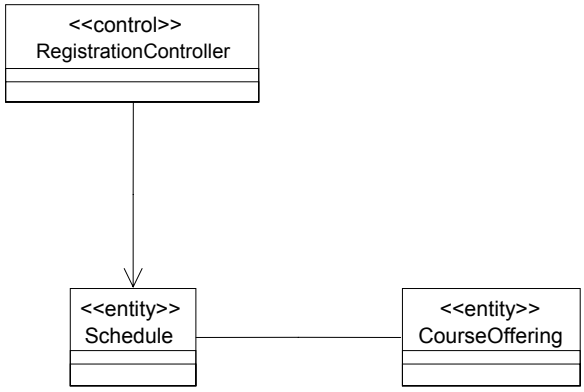
2, 4..6

What Is Aggregation?

- An aggregation is a special form of association that models a whole-part relationship between an aggregate (the whole) and its parts.
  - An aggregation "Is a part-of" relationship.
- Multiplicity is represented like other associations.

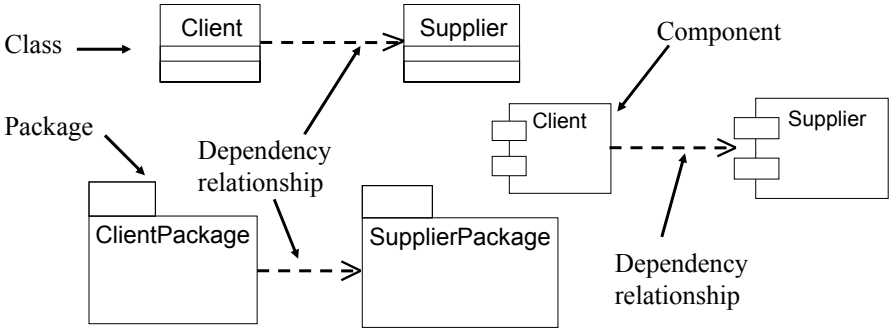
What Is Navigability?

- Indicates that it is possible to navigate from a associating class to the target class using the association



Relationships: Dependency

- A relationship between two model elements where a change in one may cause a change in the other
- Non-structural, "using" relationship

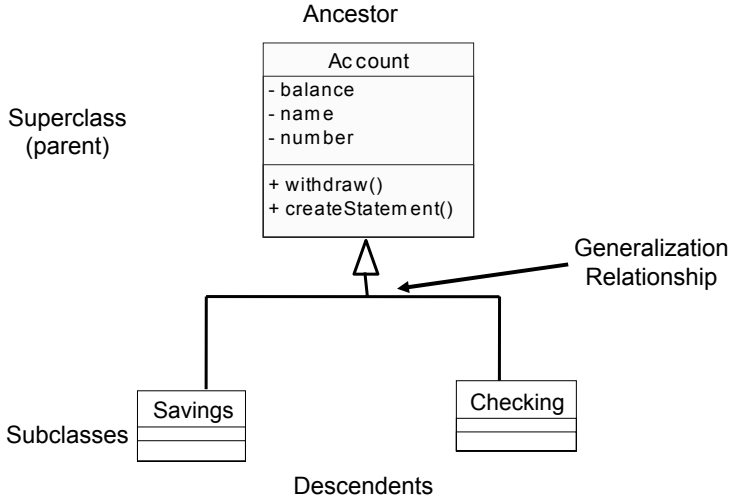


What Is Generalization?

- A relationship among classes where one class shares the structure and/or behavior of one or more classes
- Defines a hierarchy of abstractions in which a subclass inherits from one or more superclasses
  - Single inheritance
  - Multiple inheritance
- Is an "is a kind of" relationship

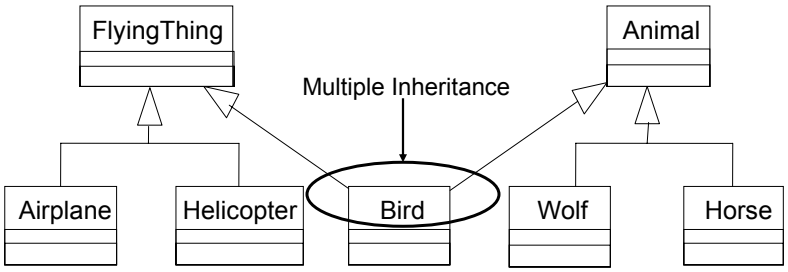
Example: Single Inheritance

- One class inherits from another



Example: Multiple Inheritance

- A class can inherit from several other classes.



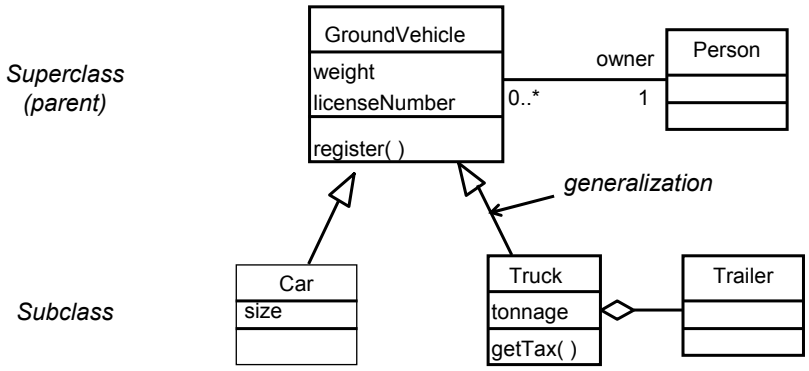
Use multiple inheritance only when needed and always with caution!

What Gets Inherited?

- A subclass inherits its parent's attributes, operations, and relationships
- A subclass may:
  - Add additional attributes, operations, relationships
  - Redefine inherited operations (use caution!)
- Common attributes, operations, and/or relationships are shown at the highest applicable level in the hierarchy

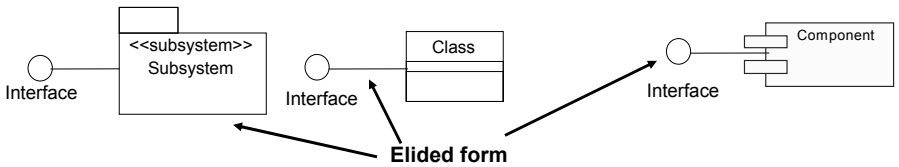
Inheritance leverages the similarities among classes

Example: What Gets Inherited

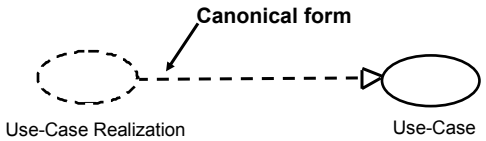


What Is Realization?

- One classifier serves as the contract that the other classifier agrees to carry out
- Found between:
  - Interfaces and the classifiers that realize them

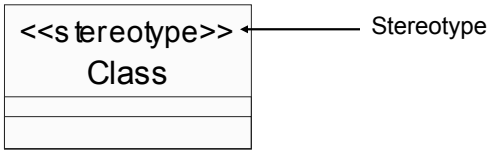


- Use cases and the collaborations that realize them



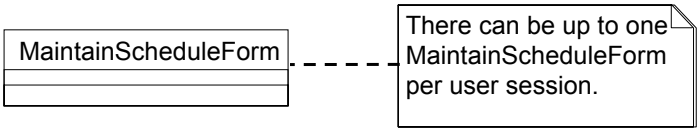
What Are Stereotypes?

- Stereotypes define a new model element in terms of another model element.
- Sometimes, you need to introduce new things that speak the language of your domain and look like primitive building blocks.



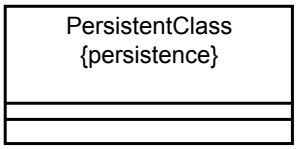
What Are Notes?

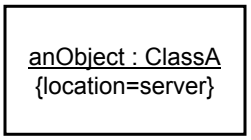
- A comment that can be added to include more information on the diagram
- May be added to any UML element
- A 'dog eared' rectangle
- May be anchored to an element with a dashed line



Tagged Values

- Extensions of the properties, or specific attributes, of a UML element
- Some properties are defined by UML
  - Persistence
  - Location (e.g., client, server)
- Properties can be created by UML modelers for any purpose





Review: Concepts of Object Orientation

- What are the four basic principles of object orientation? Provide a brief description for each.
- What is an object and what is a class? What is the difference between the two?
- What is an attribute?
- What is an operation?
- What is an interface? What is polymorphism?

Review: Concepts of Object Orientation (continued)

- What is a package?
- What is a subsystem? How does it relate to a package? How does it relate to a class?
- Name the four basic UML relationships and describe each.
- Describe the strengths of object orientation
- What are stereotypes?

Part II

Review of Object Technology:
Basics of Objects, Definitions, Effects on SDLC

Basics of Objects

- The newer object world concentrates on: Encapsulation, Message Passing & Polymorphism, and Classes & Inheritance
- The older structured world concentrated on sequence, selection, and iteration

Basics of Objects

- First what is an object?
- A software packet that abstracts the salient behavior and characteristics of a real object into a software package that simulates the real object

Basics of Objects

Examples of objects:

- Number
- Drop Down List Box
- Window
- ATM (Automated Teller Machine)
- Customer

Basics of Objects

Types of objects:

Example	Type
• Number	primitive
• List Box	control
• Window	GUI
• ATM	system
• Customer	business

Basics of Objects

Characteristic of objects:

Example	Characteristic
• Number	5
• List Box	location
• Window	size
• ATM	amount on hand
• Customer	balance

Basics of Objects

Behavior of objects:

Example	Behavior
• Number	add
• Drop Down List Box	drop down
• Window	open
• ATM	give cash
• Customer	pay bill

Basics of Objects

Encapsulation of objects:

	(nouns)	(adjectives)	(verbs)
	Example	Characteristic	Behavior
•	Number	5	add
•	List Box	location	drop down
•	Window	size	open
•	ATM	amount on hand	give cash
•	Customer	balance	pay bill

Basics of Objects

The Three Keys to Object Technology

- A software object has both characteristics and behavior encapsulated in it
- Software objects communicate by messages
- Software objects can inherit characteristics and behavior just like many real objects

Basics of Objects

Encapsulation:

- The containment of the data behind a software membrane consisting of methods. The data can only be accessed through the encapsulated behavior

Basics of Objects

Message:

- A signal from a client object requesting services from a server object
- The message may contain arguments
- The server object may return a response

Basics of Objects

Polymorphism:

- Messages mean different things to different objects:

  Print Word document

  Print Excel document

- This means different implementations can be hidden behind a common interface

Basics of Objects

Class:

- A Collection of like objects
- A template for defining new object instances
- The behaviors reside in the class
- Behavior is implemented by methods

Classes & Inheritance

Instance:

- A term used to refer to an software object
- It is a common synonym of object

Classes & Inheritance

Inheritance:

- A technique to allow classes to use a parent classes methods and data
- Inheritance can have many levels

The Ten Big Definitions

- Object - A software package
- Method - An objects procedure
- Message - A signal from one object to another
- Class - A template to create objects
- Subclass - A special case of a class

The Ten Big Definitions

- Instance - An objects other name
- Inheritance - A mechanism to use another objects innards
- Encapsulation - Data & methods Together
- Abstraction - Capturing behaviors & characteristics
- Polymorphism - Hiding alternative methods behind a common interface

Effect on SDLC

- SDLC - System Development Life Cycle
- A system must be developed that encompasses the theory of objects
- The program code must be divided into methods that are placed in objects with business meanings

Effect on SDLC

- These objects are called domain objects
- Together they make up the business or domain model
- If model is created correctly the system is very easy to maintain

Effect on SDLC

Many languages now support this model

- Smalltalk
- C++
- Java

Effect on SDLC

Many CASE tool vendors also support this model

- Rational Corporation * http://www.rational.com/
- Popkin Software http://www.popkin.com/
- Peter Coad http://www.powerj.com/

* We will be using Rational Rose (or a similar tool for business/application modeling)

Effect on SDLC

- "The most single important ability in object- oriented analysis and design is to skillfully assign responsibilities to software components"
- "… a close second in terms of importance is finding suitable objects or abstractions"
- Craig Larman - author of Applying UML & Patterns

Summary

- If you have not guessed it by now, the points are:
  - Encapsulation
  - Message Passing & Polymorphism
  - Classes & Inheritance
- The ten big definitions must be understood
- The outcome of the SDLC is a business object model

Part III

Review of SDLC

What is a SDLC

System Development Life Cycle:

- It is developing a computer system
- It concerns a process which takes from two months to two years
- This is called a system development life cycle

What is a SDLC

There are two forms:

- Rapid (Prototype)
  - Plan and Elaborate
  - Developmental Cycle 1
  - Developmental Cycle 2
- And Waterfall (classical)

What is a SDLC

- Waterfall (classical)
  - Requirements
  - Analysis
  - Design
  - Construction
  - Implementation

What is a SDLC

Both forms are followed by a maintenance cycle:

- Maintenance is the most expensive part
- If all the steps are done carefully maintenance is reduced
- For maintenance to be effective , documentation must exist

What is a SDLC

The system really consists of two parts:

- Model
  - Prototypes
  - Diagrams and supporting Documents
- System
  - Hardware
  - Software

Definitions

Prototype:

- A first system usually done with a rapid development tool
- Usually has limited functionality
- Users can see results very quickly

Definitions

- Planning
- The process of gathering what is needed to solve a business problem
- Includes a feasibility study
- Includes project steps

Definitions

- Analysis
- The process of determining detail requirements in the form of a model

Definitions

- Design
- The process of drawing blueprints for a new system

Definitions

- Construction
- The actual coding of the model into a software package
- Uses one of three languages:
  - Java
  - Smalltalk
  - C++

Definitions

- Implementation
- Doing whatever is necessary to startup a system
- Includes:
  - Database
  - Networks
  - Hardware configuration

Definitions

- Maintenance
- Doing whatever is necessary to keep a system running
- Includes:
  - repairs to correct errors
  - enhancements to accommodate changes in requirements

Deliverables

- Deliverables consist mainly of diagrams and their supporting documentation
- For example:
  - Models that emphasize dynamics
  - Models that emphasize structure
  - Models can be used for specifying the outcome of analysis
  - Models can be used for specifying the outcome of design

Deliverables

Planning:

- System Functions
- A simple list of each requirement a system must do
- For example:
  - record video rental
  - calculate fine

Deliverables

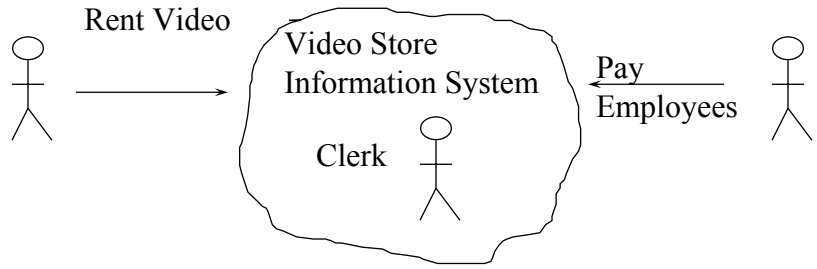
Planning:

- System Attributes
- A simple property describing each requirement of a system
- For example:
  - record video rental under 15 seconds
  - calculate fine and return response in 5 seconds

Deliverables

- Planning:

Environmental Diagram



Deliverables

Planning:

- Prototype
- Recall it is a first system usually done with a rapid development tool
- Since users can see results very quickly they will pay attention
- Final product is seldom created in same tool as the prototype

Deliverables

Analysis:

- Use case
- Shows the dynamics between the users (actors) of the system and the system itself
- This is a narrative representation

Deliverables

Analysis:

- Conceptual Diagram
- Shows the structure of the objects and their relationships
- This is a graphical representation

Deliverables

Analysis:

- System Sequence Diagram
- Shows the dynamics between the users (actors) of the system and the system itself
- This is a graphical representation

Deliverables

Analysis:

- Contracts
- Shows the state of each object before each action
- This is a narrative representation

Deliverables

Design:

- Interaction Diagram
- Shows the interaction between objects
- This is a graphic representation
- It is a dynamic blueprint

Deliverables

Design:

- Class Diagram
- Shows the structure between objects
- Shows the structure inside objects
- This is a graphic representation
- It is a static blueprint

Summary

UML provides a standard for the following artifacts:

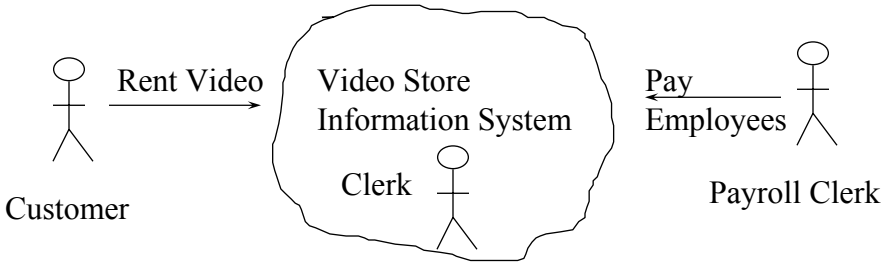
- Use Case (Dynamic Analysis Output)
- Conceptual Model (Static Analysis Output)
- Interaction Diagram (Dynamic Design Blueprint)
- Class Diagram (Static Design Blueprint)

Part IV

OO Analysis and Design and UML

What it is

- Environmental Diagram



What it is

- A picture containing all the important players (Actors)
- Includes players both inside and outside of the system
- Actors are a critical component
- External events are a second critical component

Creating the Diagram

- To create an environmental diagram
- 1. Identify all the initiating actors
- 2. Identify all the related external events associated with each actor

Why it is used

- A diagram is needed to show the context or scope of the proposed system
- At this time actors and external events are the critical components
- It is helpful to include all the participants as well

Creating the Diagram

- 3. Identify all the participating Actors
- These actors may be inside (internal) or outside (external) to the system

Creating the Diagram

- Examples of an internal actor
  - Clerk who enters the purchase into a Point of Sale terminal
  - Clerk who places paper in the printer
  - Accountant who audits report

Creating the Diagram

- Examples of an external actor
  - Accountant who audits report
  - A credit authorizing service
  - A DMV check for renting a car

Creating the Diagram

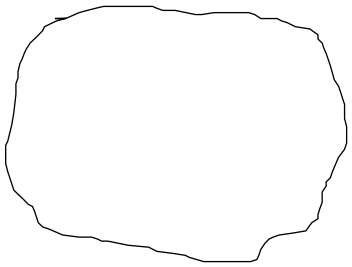
- 4. Draw a cloud
- 5. Then draw initiating actors on the left of the cloud
- 6. Then draw participating external actors outside the cloud
- 7. Then draw participating internal actors inside the cloud
- Recall actors are stick figures

Creating the Diagram

- 8. Lastly connect the initiation actors to the cloud
- 9. Label each connection with an external event name
- 10. It is not necessary to label connections to the participating external actors; just connect them

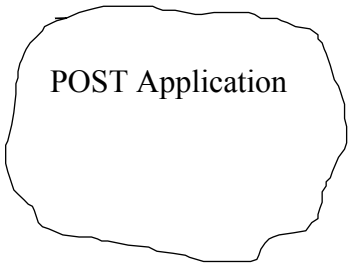
Creating the Diagram

- An example from the textbook
- First draw a cloud



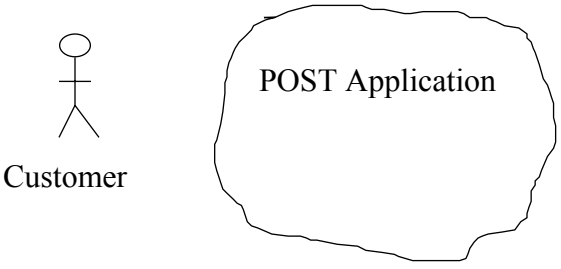
Creating the Diagram

- An example from the textbook
- Label the system



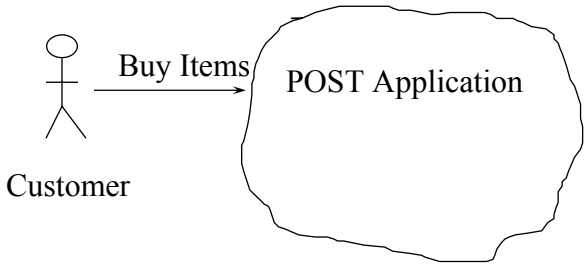
Creating the Diagram

- An example from the textbook
- Insert and label the initiating actor



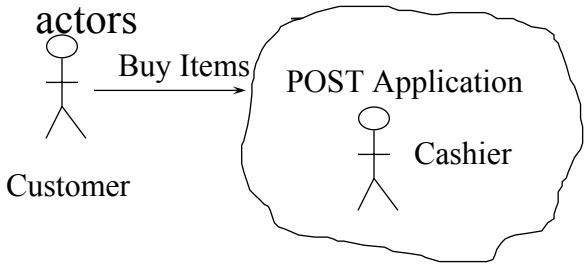
Creating the Diagram

- An example from the textbook
- Connect the actor with an external event



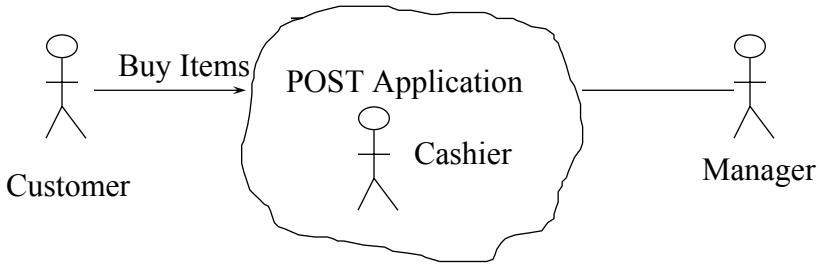
Creating the Diagram

- An example from the textbook
- Insert and label any internal participating actors



Creating the Diagram

- An example from the textbook
- Insert and label any external participating actors



Summary

- The environmental diagram is a useful to depict a lot of useful information
- At a glance it shows all the critical entities (actors) that interact with the system