INTRODUCTION TO SYSTEMS ANALYSIS AND DESIGN:

AN AGILE, ITERATIVE APPROACH

SATZINGER | JACKSON | BURD

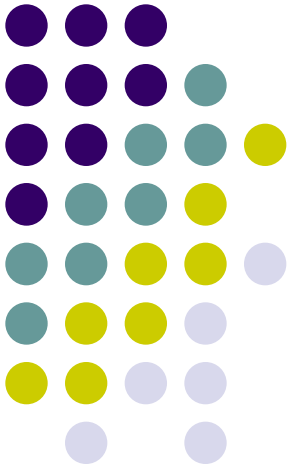
Chapter 10

Object-Oriented Design: Principles

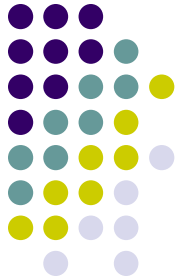
Chapter 10

Introduction to Systems Analysis and Design: An Agile, Iteractive Approach 6th Ed

Satzinger, Jackson & Burd

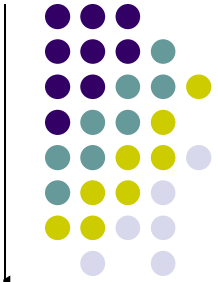


Chapter 10 Outline



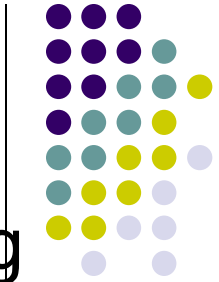
- Object-Oriented Design: Bridging from Analysis to Implementation
- Object-Oriented Architectural Design
- Fundamental Principles of Object-Oriented Detailed Design
- Design Classes and the Design Class Diagram
- Detailed Design with CRC Cards
- Fundamental Detailed Design Principles

Learning Objectives



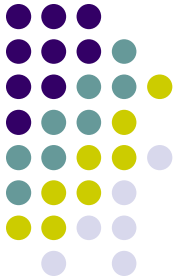
- Explain the purpose and objectives of object-oriented design
- Develop UML component diagrams
- Develop design class diagrams
- Use CRC cards to define class responsibilities and collaborations
- Explain some of the fundamental principles of object-oriented design

Overview



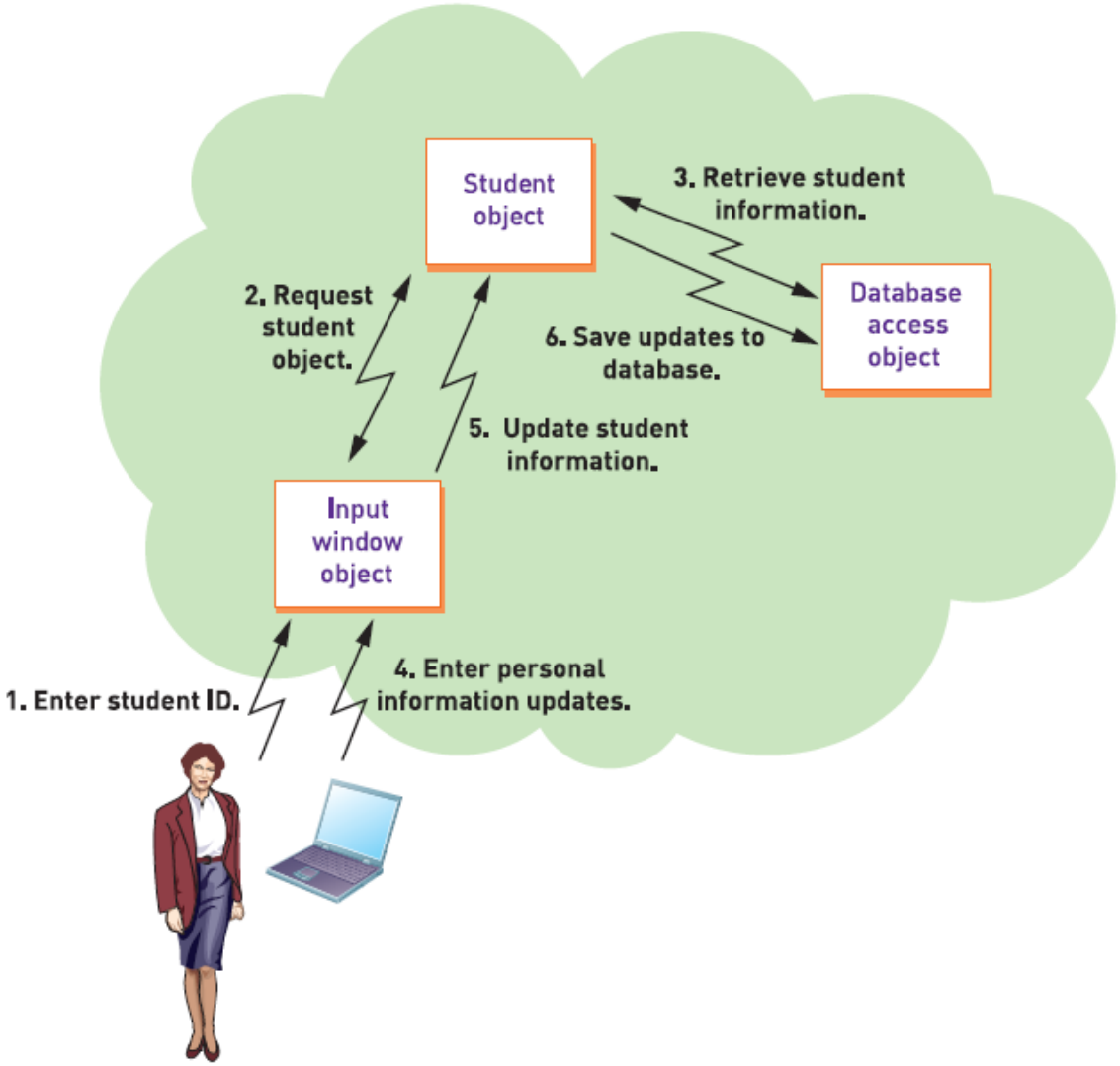
- This chapter and the next focus on designing software for the new system, at both the architectural and detailed level design
- Design models are based on the requirements models learned in Chapters 3, 4, and 5
- For architectural design, the model is shown as a UML component diagram
- For detailed design, the main models are design class diagrams and sequence diagrams
- In this chapter, the CRC Cards technique is used to design the OO software

OO Design:
The Bridge from Analysis to Design



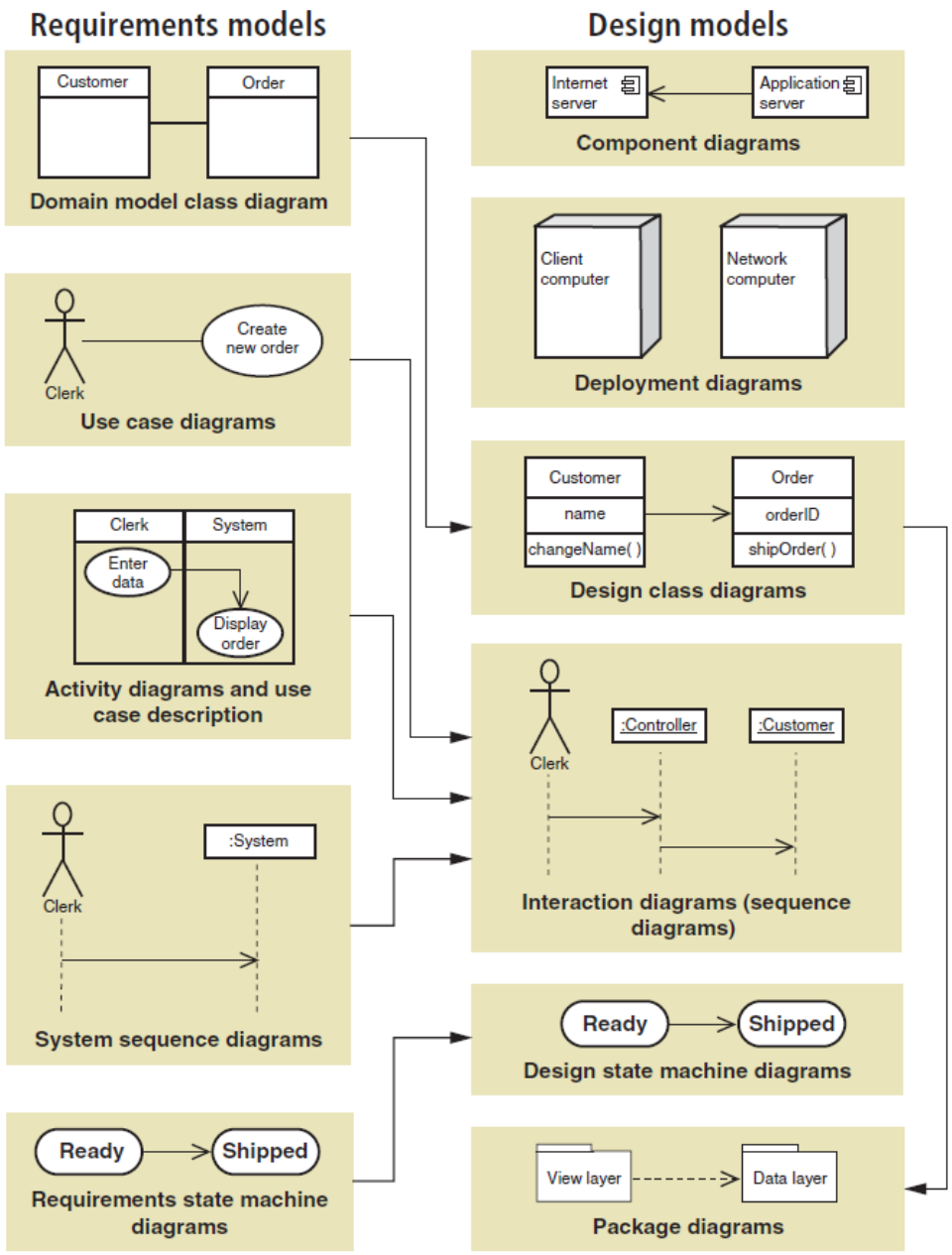
- OO Design: Process by which a set of detailed OO design models are built to be used for coding
- Strength of OO is requirements models from Chapters 3, 4, and 5 are extended to design models. No reinventing the wheel
- Design models are created in parallel to actual coding/implementation with iterative SDLC
- Agile approache says create models only if they are necessary. Simple detailed aspects don't need a design model before coding

Object-Oriented Program Flow
Three Layer Architecture

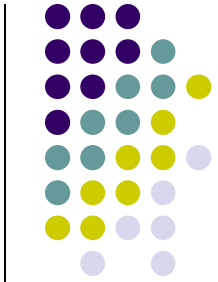


UML Requirements vs. Design Models

Diagrams are enhanced and extended



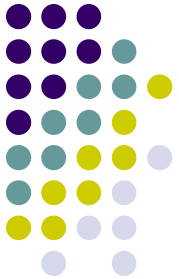
Architectural Design



- Enterprise-level system
  - a system that has shared resources among multiple people or groups in an organization
- Options are Client-Server or Internet Based
  - Each presents different issues

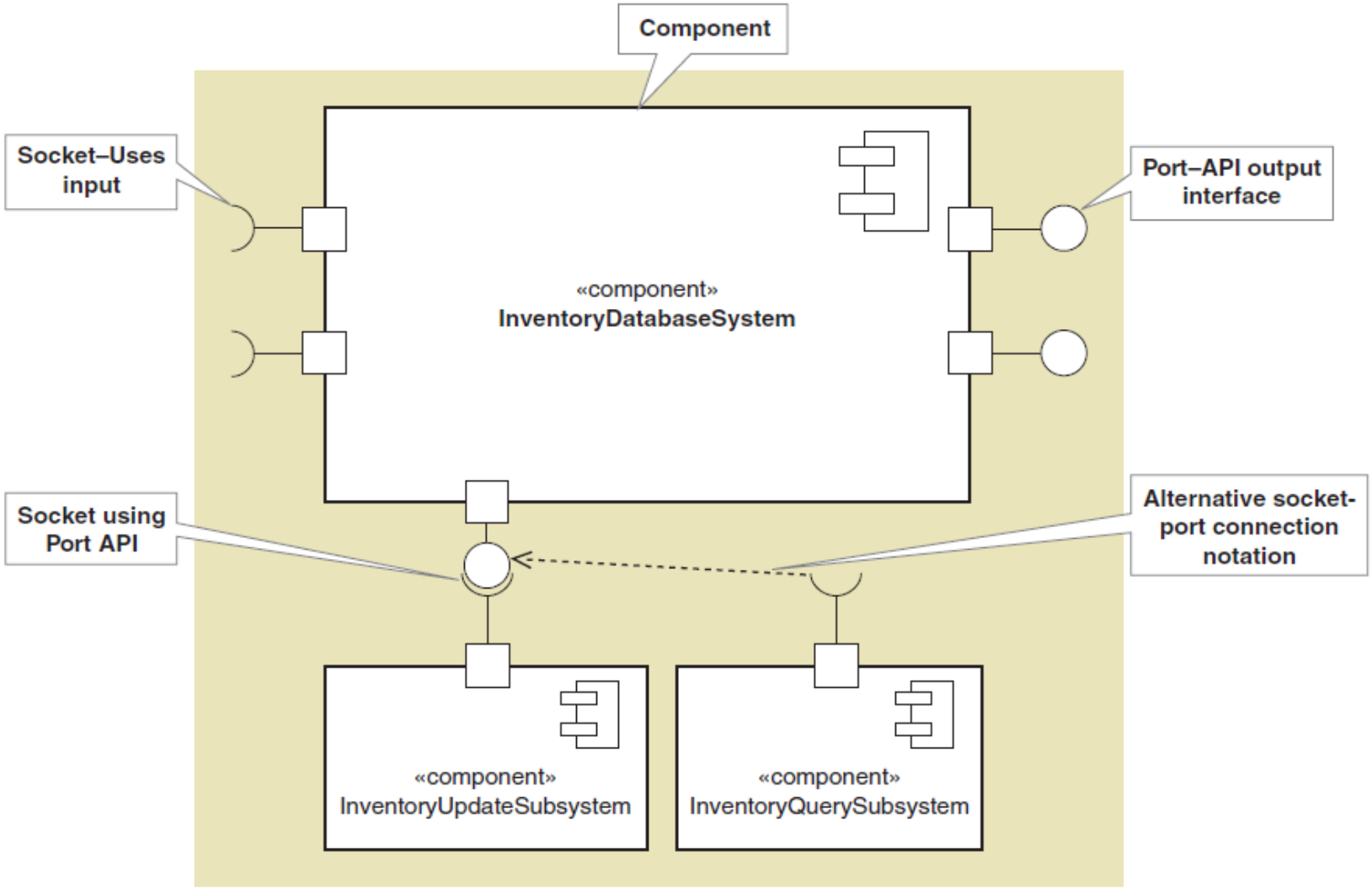
Design Issue	Client/Server Network System	Internet System
State	"Stateful" or state-based system—e.g., client/server connection is long term.	Stateless system—e.g., client/server connection is not long term and has no inherent memory.
Client configuration	Screens and forms that are programmed are displayed directly. Domain layer is often on the client or split between client and server machines.	Screens and forms are displayed only through a browser. They must conform to browser technology.
Server configuration	Application or data server directly connects to client tier.	Client tier connects indirectly to the application server through a Web server.

Component Diagram
for Architectural Design

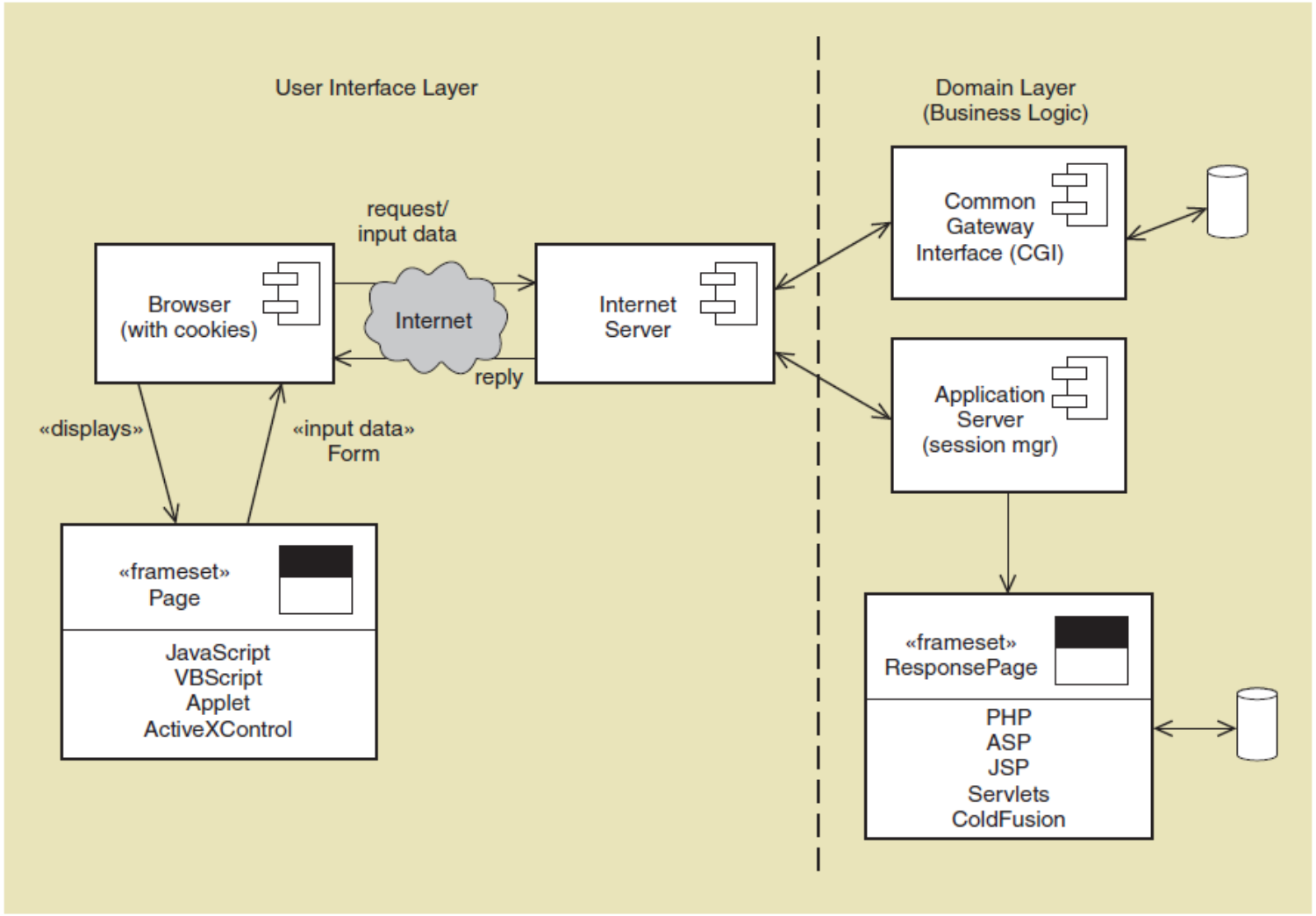


- Component diagram –
  - A type of design diagram that shows the overall system architecture and the logical components within it for how the system will be implemented
  - Identifies the logical, reusable, and transportable system components that define the system architecture
  - The essential element of a component diagram is the component element with its API.
- Application program interface (API) –
  - The set of public methods that are available to the outside world

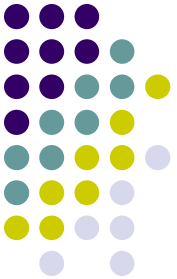
Component Diagram
for Architectural Design



Component Diagram
Two Layer Internet Architecture



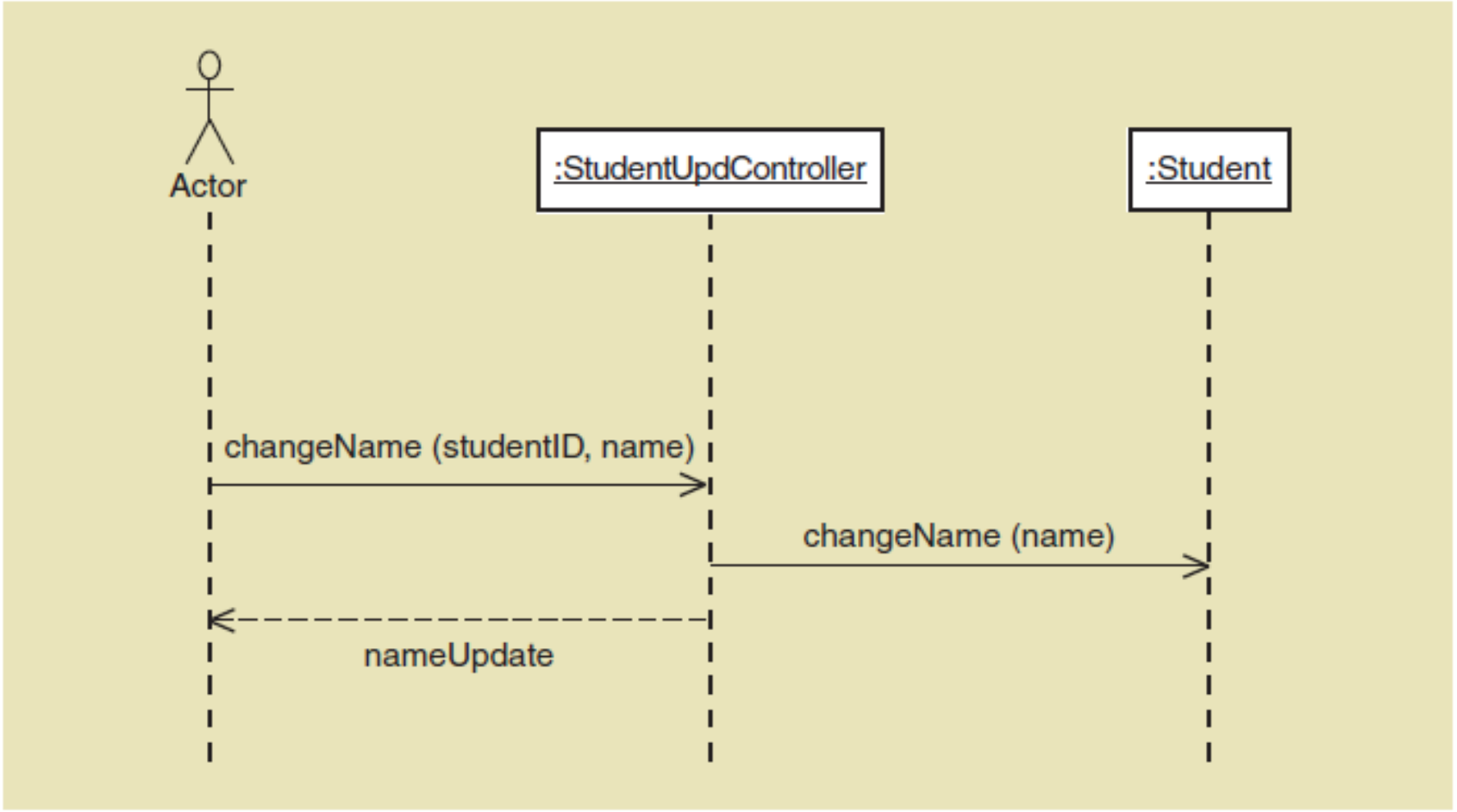
Detailed Design
Use Case Realization



- Design and Implement Use Case by Use Case
  - Sequence Diagram—extended for system sequence diagram adding a controller and the domain classes
  - Design Class Diagram—extended from the domain model class diagram and updated from sequence diagram
    - Messages to an object become methods of the design class
  - Class Definition—written in the chosen code for the controller and the design classes
  - UI Classes—forms or pages are added to handle user interface between actor and the controller
  - Data Access Classes—are added to handle domain layer requests to get or save data to the database

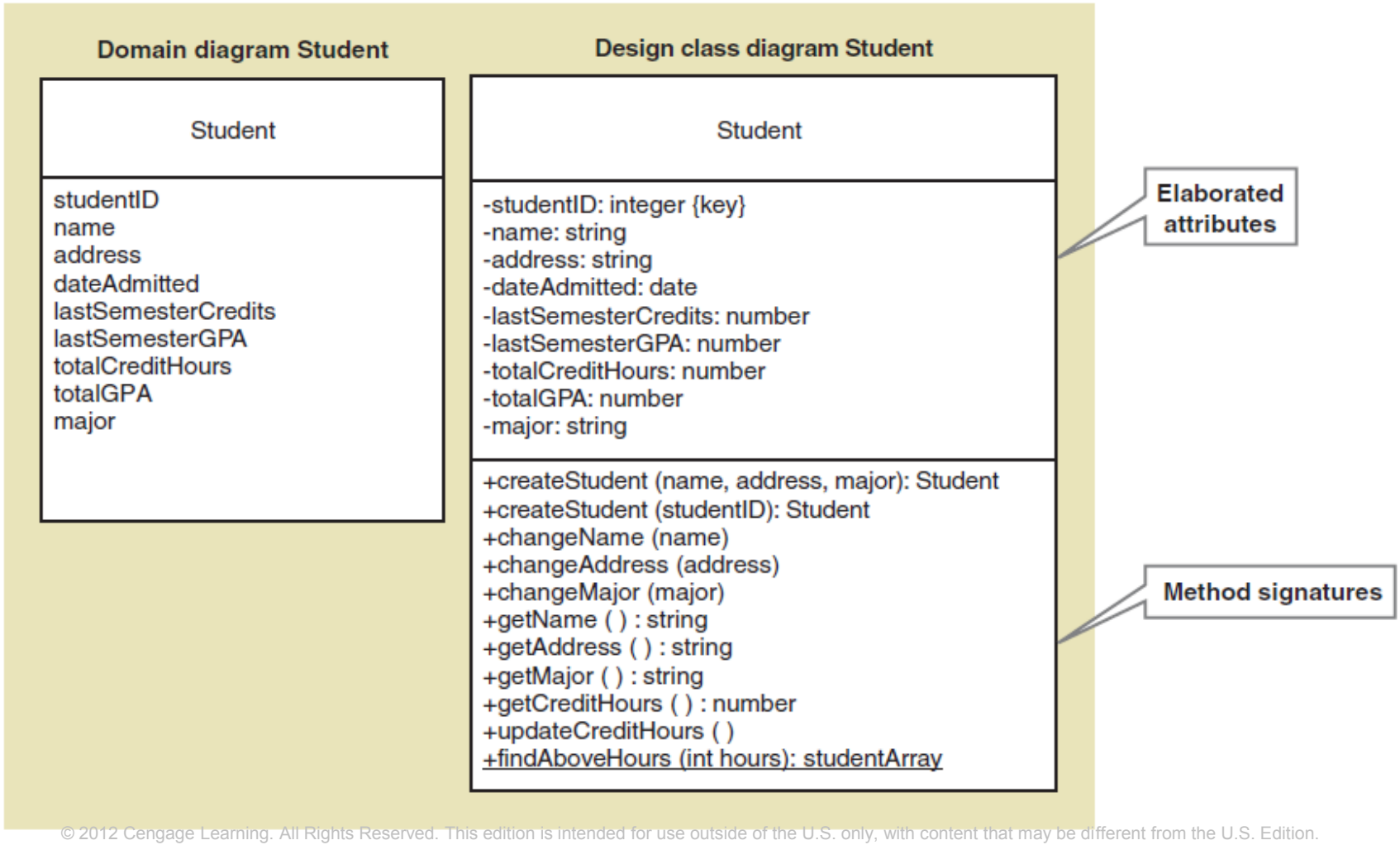
Detailed Design
Sequence Diagram Example

- Use case *Update student name*



Design Classes in Detailed Design

- Elaborate attributes—visibility, type, properties
- Add methods and complete signatures

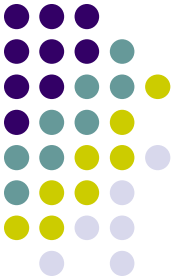


Write the Code for the Design Class to Implement

```
public class Student
{
	//attributes
	private int studentID;
	private String firstName;
	private String lastName;
	private String street;
	private String city;
	private String state;
	private String zipCode;
	private Date dateAdmitted;
	private float numberCredits;
	private String lastActiveSemester;
	private float lastActiveSemesterGPA;
	private float gradePointAverage;
	private String major;

	//constructors
	public Student (String inFirstName, String inLastName, String inStreet,
		String inCity, String inState, String inZip, Date inDate)
	{
		firstName = inFirstName;
		lastName = inLastName;
		...
	}
	public Student (int inStudentID)
	{
		//read database to get values
	}

	//get and set methods
	public String getFullName ( )
	{
		return firstName + " " + lastName;
	}
	public void setFirstName (String inFirstName)
	{
		firstName = inFirstName;
	}
	public float getGPA ( )
	{
		return gradePointAverage;
	}
	//and so on

	//processing methods
	public void updateGPA ( )
	{
		//access course records and update lastActiveSemester and
		//to-date credits and GPA
	}
}
```

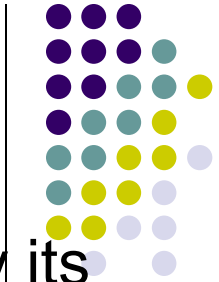
OO Detailed Design Steps

Chapters 10 and 11



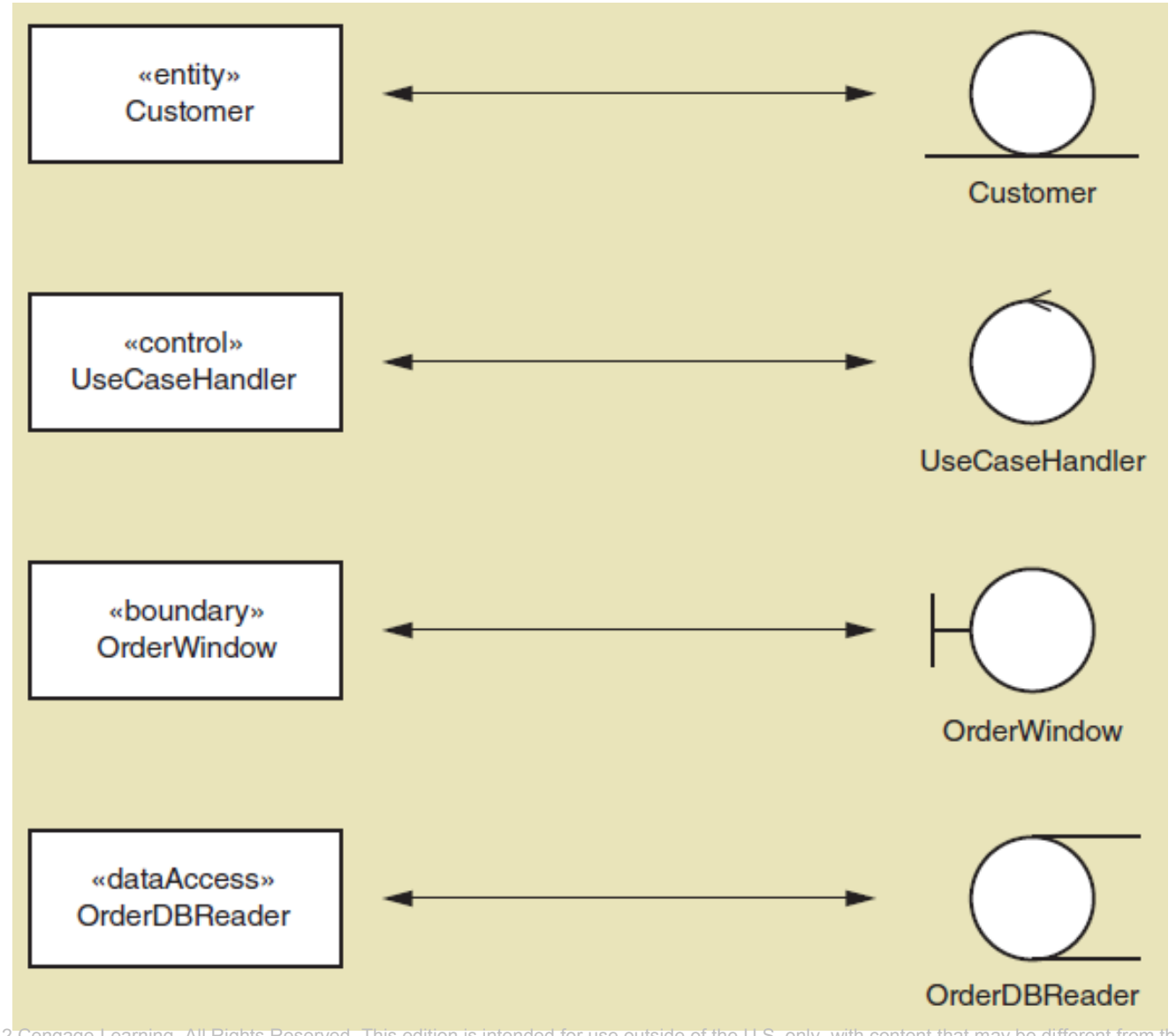
Design Step	Chapter
1. Develop the first-cut design class diagram showing navigation visibility.	10
2. Determine class responsibilities and class collaborations for each use case using class-responsibility-collaboration (CRC) cards.	10
3. Develop detailed sequence diagrams for each use case. (a) Develop the first-cut sequence diagrams. (b) Develop the multilayer sequence diagrams.	11
4. Update the design class diagram by adding method signatures and navigation information using CRC cards and/or sequence diagrams.	11
5. Partition the solution into packages as appropriate.	11

Design Class Diagrams



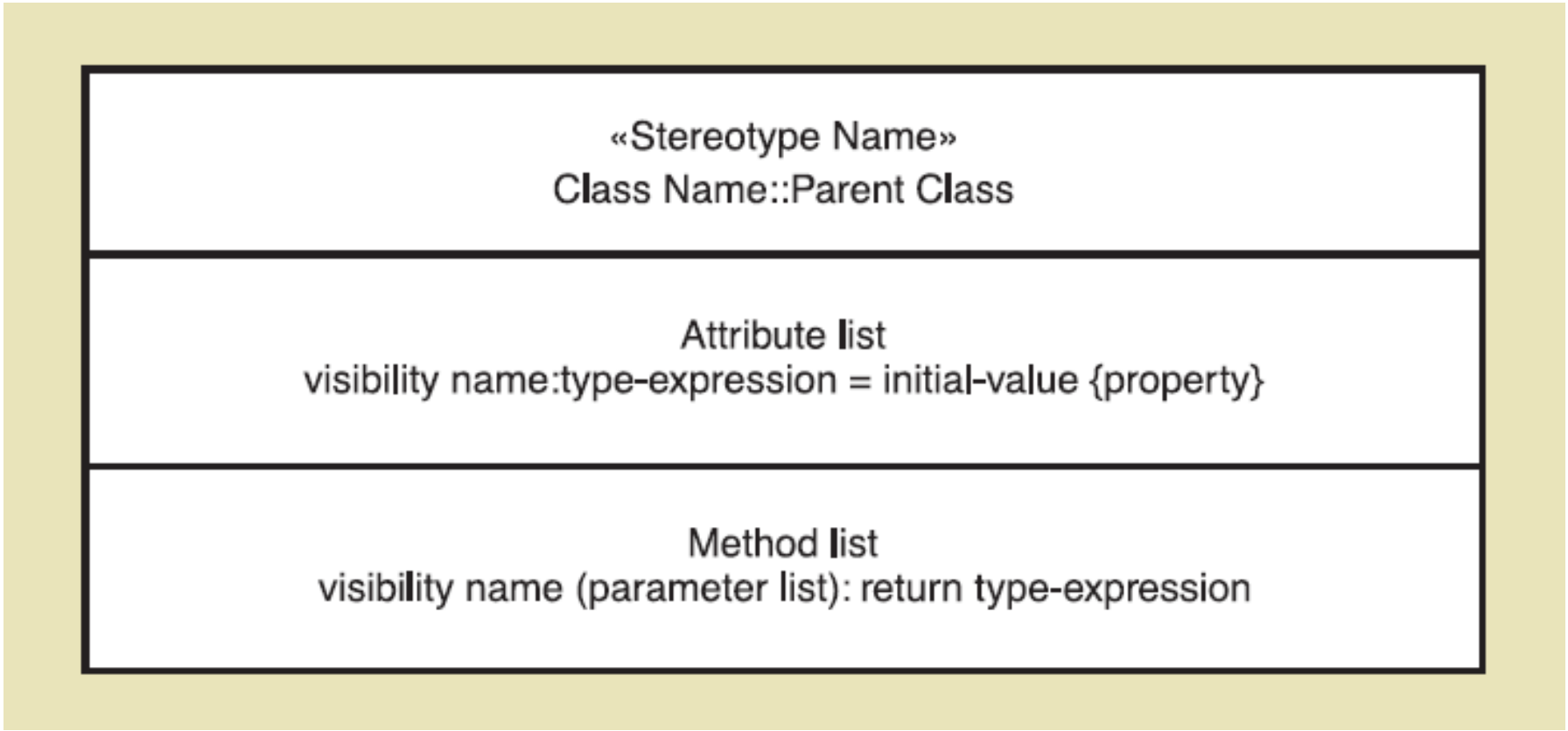
- **stereotype** a way of categorizing a model element by its characteristics, indicated by guillemots (<< >>)
- **persistent class** an class whose objects exist after a system is shut down (data remembered)
- **entity class** a design identifier for a problem domain class (usually persistent)
- **boundary class or view class** a class that exists on a system's automation boundary, such as an input window form or Web page
- **control class** a class that mediates between boundary classes and entity classes, acting as a switchboard between the view layer and domain layer
- **data access class** a class that is used to retrieve data from and send data to a database

Class Stereotypes in UML

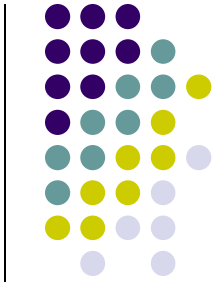


Notation for a Design Class

- Syntax for Name, Attributes, and Methods



Notation for Design Classes

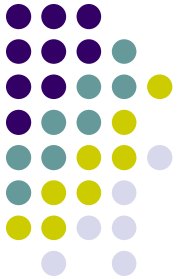


- Attributes
  - Visibility—indicates (+ or -) whether an attribute can be accessed ***directly*** by another object. Usually ***private*** (-) not public (+)
  - Attribute name—Lower case camelback notation
  - Type expression—class, string, integer, double, date
  - Initial value—if applicable the default value
  - Property—if applicable, such as {key}
  - Examples:

    -accountNo: String {key}

    -startingJobCode: integer = 01

Notation for Design Classes



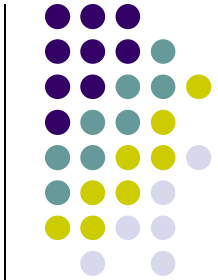
- Methods
  - Visibility—indicates (+ or -) whether an method can be invoked by another object. Usually ***public*** (+), can be private if invoked within class like a subroutine
  - Method name—Lower case camelback, verb-noun
  - Parameters—variables passed to a method
  - Return type—the type of the data returned
  - Examples:

    +setName(fName, lName) : void (void is usually let off)

    +getName(): string (what is returned is a string)

    -checkValidity(date) : int (assuming int is a returned code)

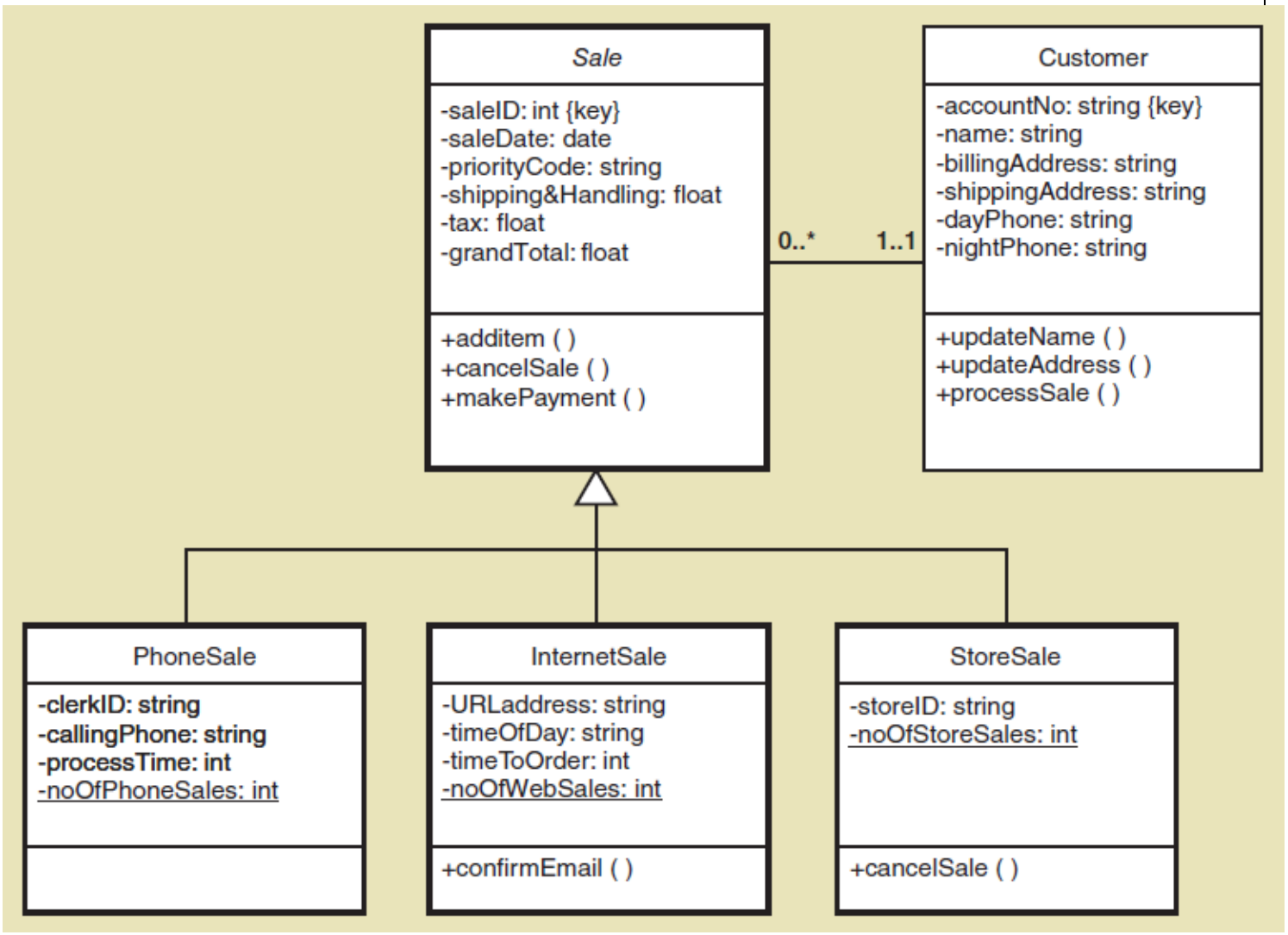
Notation for Design Classes



- Class level method—applies to class rather than objects of class (aka static method). Underline it.
  - +findStudentsAboveHours(hours): Array
  - +getNumberOfCustomers(): Integer
- Class level attribute—applies to the class rather than an object (aka static attribute). Underline it.
  - -noOfPhoneSales: int
- Abstract class– class that can't be instantiated.
  - Only for inheritance. Name in *Italics*.
- Concrete class—class that can be instantiated.

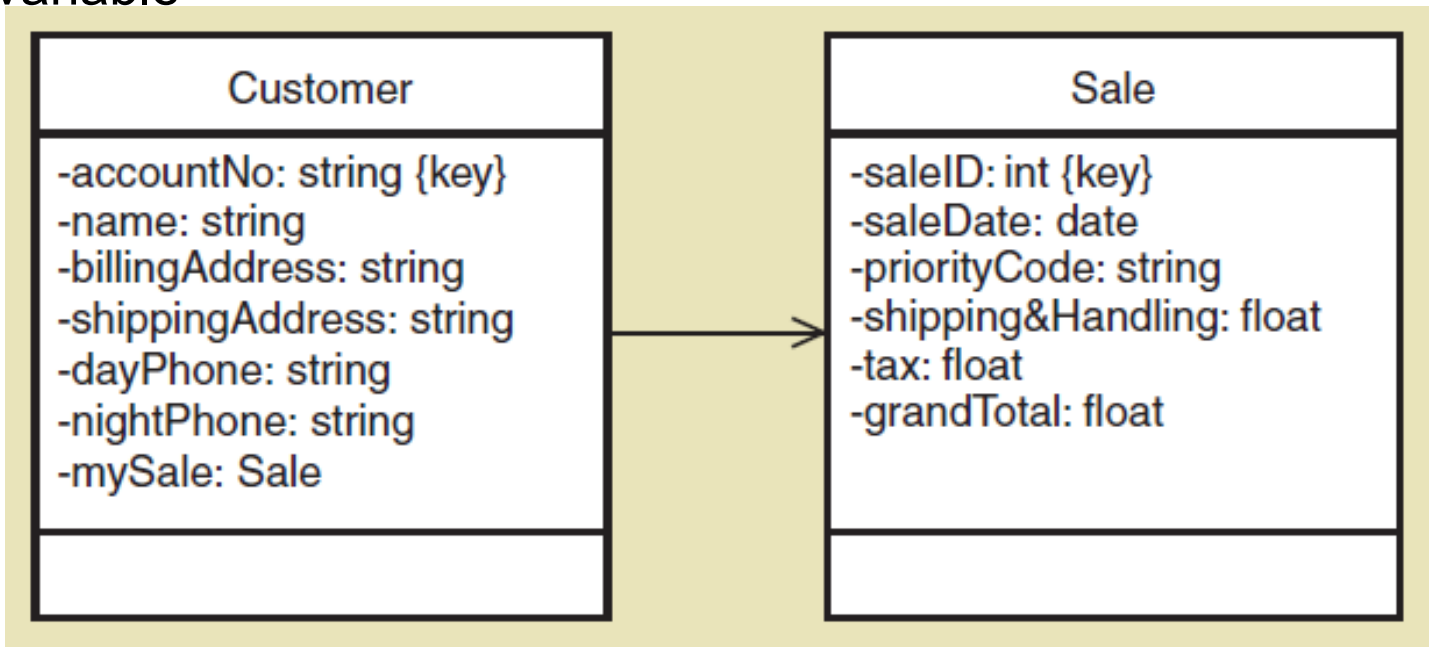
Notation for Design Classes

method arguments and return types not shown

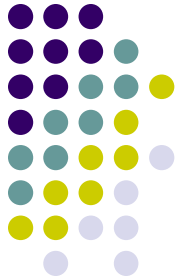


Notation for Design Classes

- Navigation Visibility
  - The ability of one object to view and interact with another object
  - Accomplished by adding an object reference variable to a class.
  - Shown as an arrow head on the association line—customer can find and interact with sale because it has mySale reference variable



Navigation Visibility Guidelines



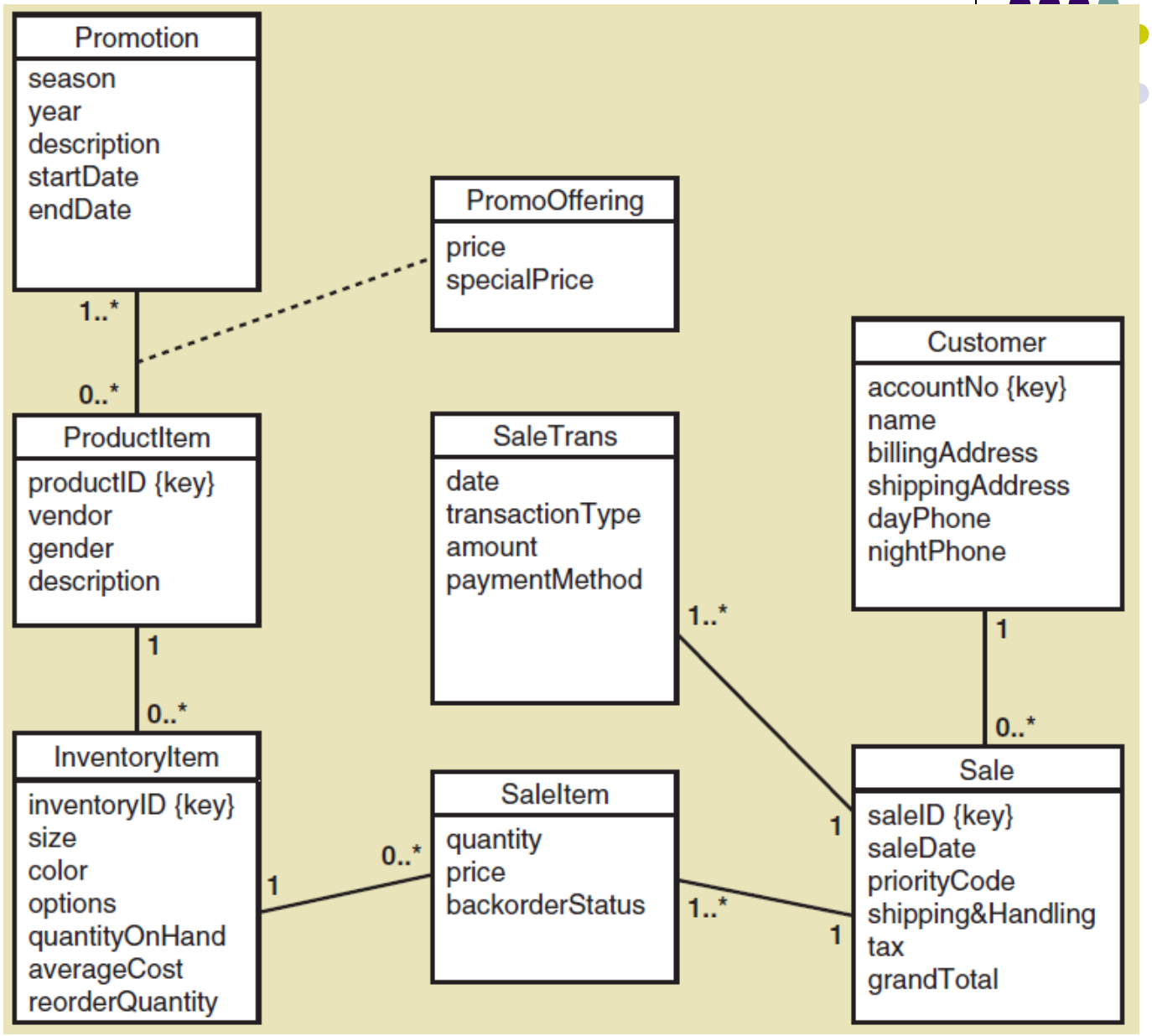
- One-to-many associations that indicate a superior/subordinate relationship are usually navigated from the superior to the subordinate
- Mandatory associations, in which objects in one class can't exist without objects of another class, are usually navigated from the more independent class to the dependent
- When an object needs information from another object, a navigation arrow might be required
- Navigation arrows may be bidirectional.

First Cut Design Class Diagram

- Proceed use case by use case, adding to the diagram
- Pick the domain classes that are involved in the use case (see preconditions and post conditions for ideas)
- Add a controller class to be in charge of the use case
- Determine the initial navigation visibility requirements using the guidelines and add to diagram
- Elaborate the attributes of each class with visibility and type
- Note that often the associations and multiplicity are removed from the design class diagram as in text to emphasize navigation, but they are often left on

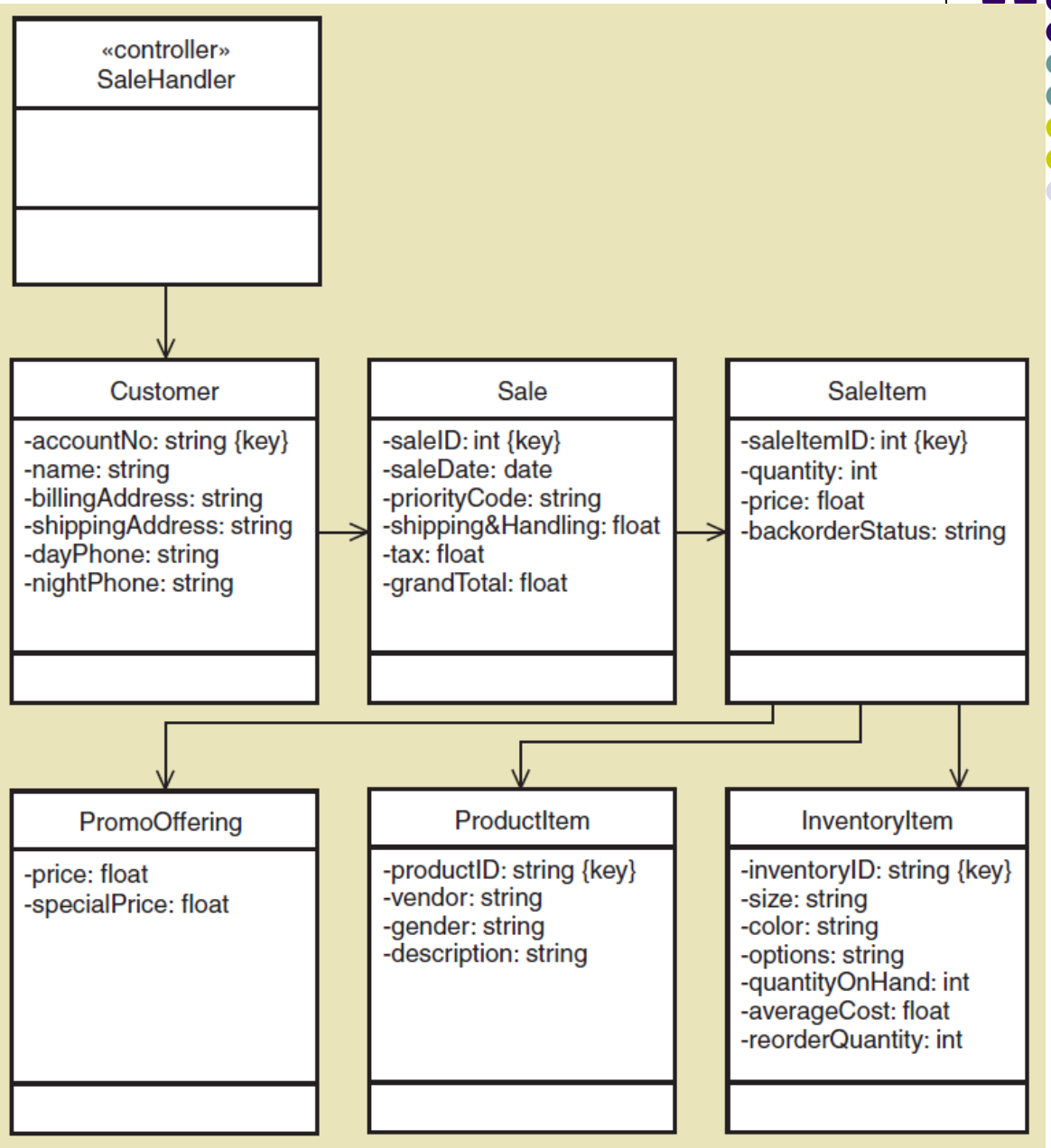
Start with Domain Class Diagram

RMO Sales Subsystem



Create First Cut Design Class Diagram

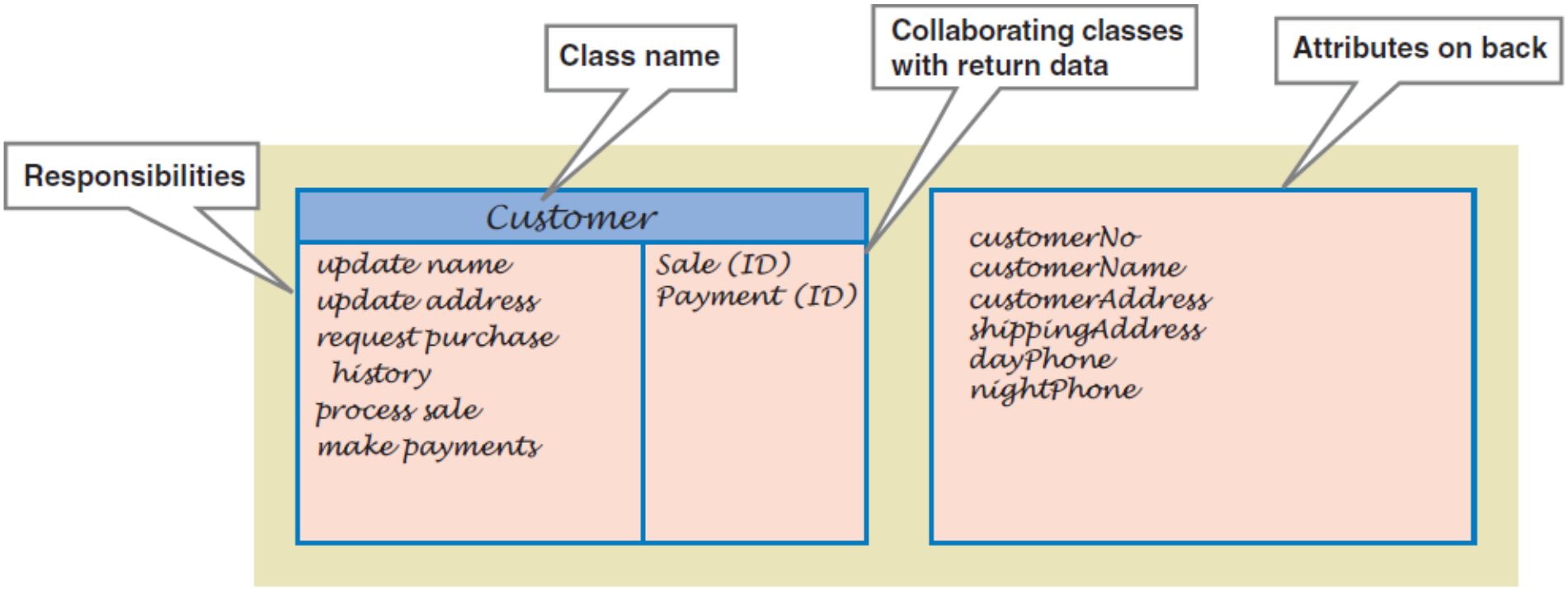
Use Case *Create phone sale* with controller added



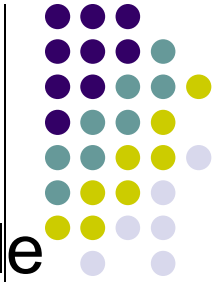
Designing With CRC Cards

- CRC Cards—Classes, Responsibilities, Collaboration Cards
- OO design is about assigning Responsibilities to Classes for how they Collaborate to accomplish a use case
- Usually a manual process done in a brainstorming session
  - 3 X 5 note cards
  - One card per class
  - Front has responsibilities and collaborations
  - Back has attributes needed

Example of CRC Card



CRC Cards Procedure



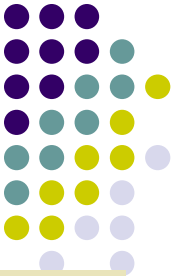
- Because the process is to design, or realize, a single use case, start with a set of unused CRC cards. Add a controller class (Controller design pattern).
- Identify a problem domain class that has primary responsibility for this use case that will receive the first message from the use case controller. For example, a Customer object for new sale.
- Use the first cut design class diagram to identify other classes that must collaborate with the primary object class to complete the use case.
- Have use case descriptions and SSDs handy

CRC Cards Procedure (continued)

- Start with the class that gets the first message from the controller. Name the responsibility and write it on card.
- Now ask what this first class needs to carry out the responsibility. Assign other classes responsibilities to satisfy each need. Write responsibilities on those cards.
- Sometimes different designers play the role of each class, acting out the use case by verbally sending messages to each other demonstrating responsibilities
- Add collaborators to cards showing which collaborate with which. Add attributes to back when data is used
- Eventually, user interface classes or even data access classes can be added

CRC Cards Results

Several Use Cases



SaleHandler	
handle new sale	Customer Sale SaleItem

Customer	
update name update address process sale request history	Sale Transaction

Sale	
update information request shipping update status cancel sale add items to sale take payment	Sale Item Transaction

SaleItem	
updateinformation cancel item request backorder	PromoOffering Product InventoryItem

SaleTransaction	
process payment	Customer Sale

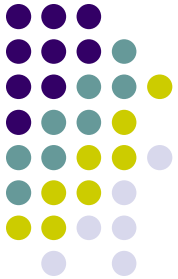
PromoOffering	
provide price	

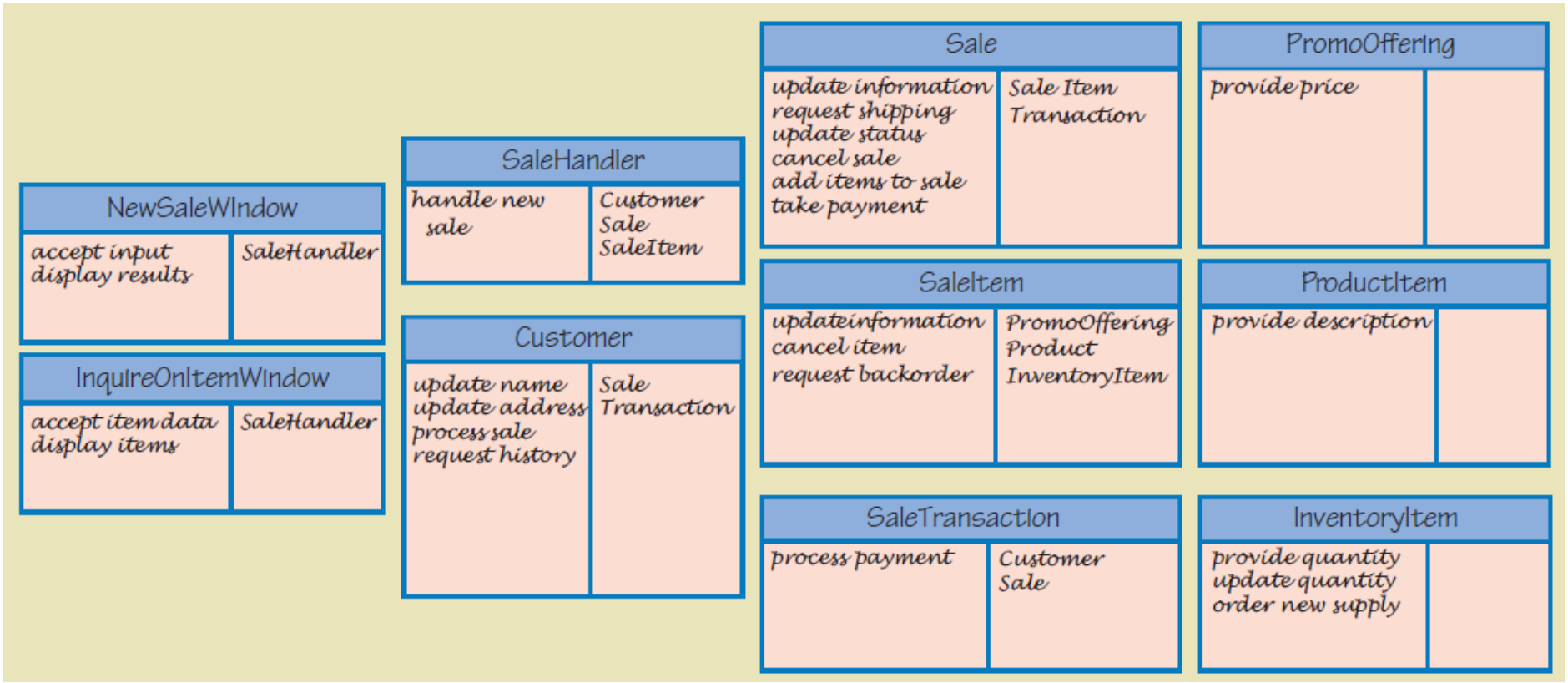
ProductItem	
provide description	

InventoryItem	
provide quantity update quantity order new supply	

CRC Cards Results

Adding In User Interface Layer



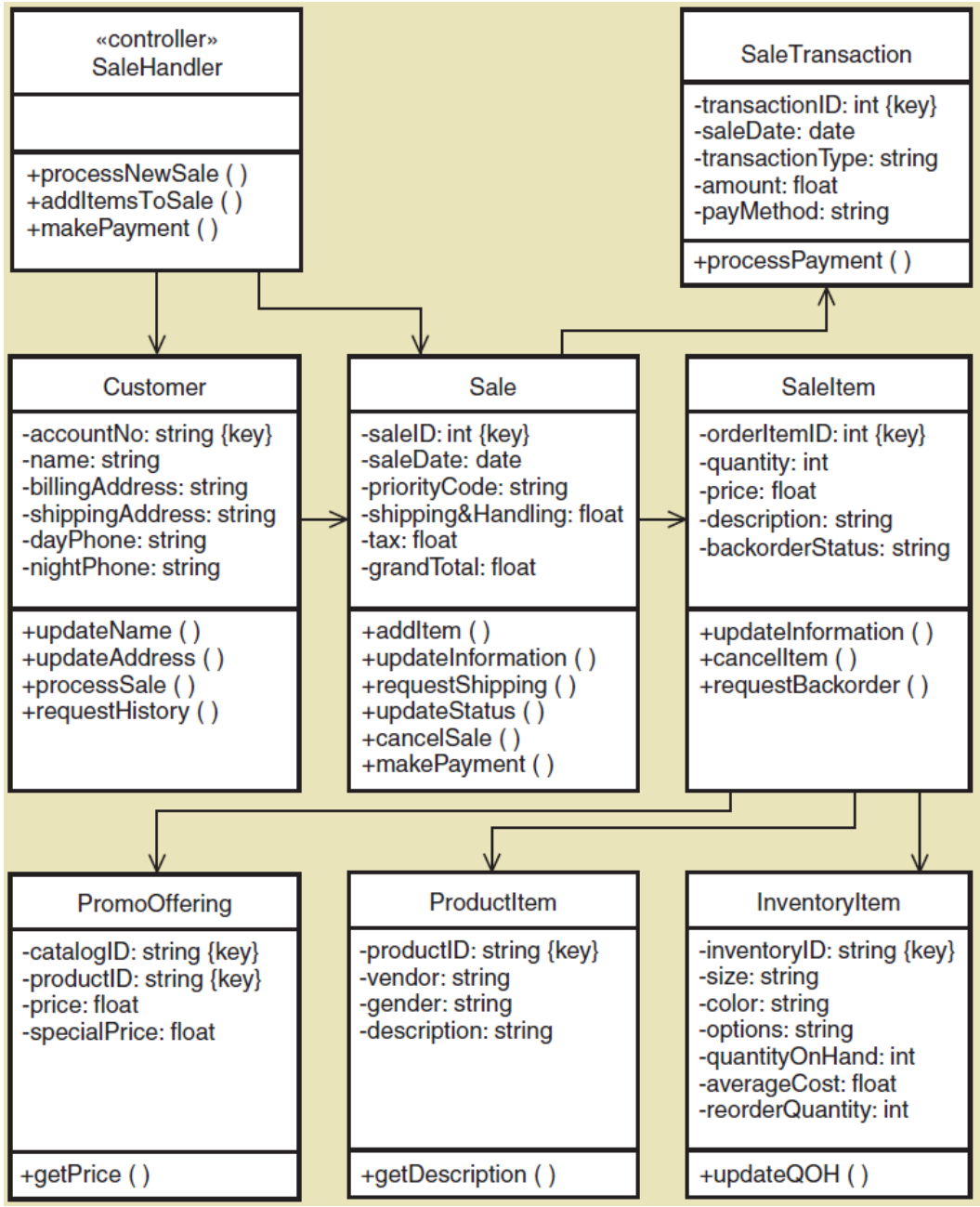


CRC Cards

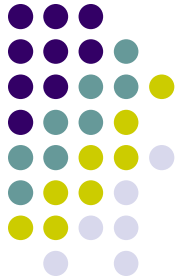
Update design class diagram based on CRC results

Responsibilities become methods

Arguments and return types not yet added

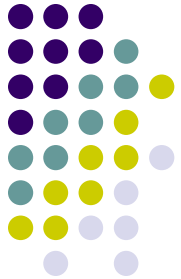


Fundamental Design Principles



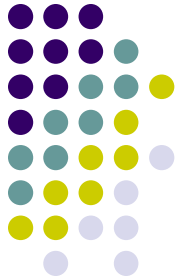
- Coupling
  - A quantitative measure of how closely related classes are linked (tightly or loosely coupled)
  - Two classes are tightly coupled of there are lots of associations with another class
  - Two classes are tightly coupled if there are lots of messages to another class
  - It is best to have classes that are **loosely coupled**
  - If deciding between two alternative designs, choose the one where overall coupling is less

Fundamental Design Principles



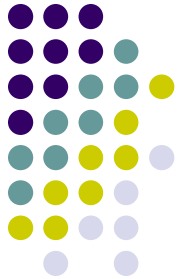
- Cohesion
  - A quantitative measure of the focus or unity of purpose within a single class (high or low cohesiveness
  - One class has high cohesiveness if all of its responsibilities are consistent and make sense for purpose of the class (a customer carries out responsibilities that naturally apply to customers)
  - One class has low cohesiveness if its responsibilities are broad or makeshift
  - It is best to have classes that are **highly cohesive**
  - If deciding between two alternative designs, choose the one where overall cohesiveness is high

Fundamental Design Principles



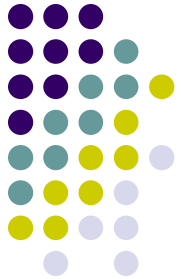
- Protection from Variations
  - A design principle that states parts of a system unlikely to change are separated (protected) from those that will surely change
  - Separate user interface forms and pages that are likely to change from application logic
  - Put database connection and SQL logic that is likely to change in a separate classes from application logic
  - Use adaptor classes that are likely to change when interfacing with other systems
  - If deciding between two alternative designs, choose the one where there is protection from variations

Fundamental Design Principles



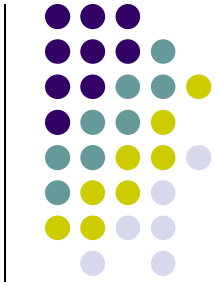
- Indirection
  - A design principle that states an intermediate class is placed between two classes to decouple them but still link them
  - A controller class between UI classes and problem domain classes is an example
  - Supports low coupling
  - Indirection is used to support security by directing messages to an intermediate class as in a firewall
  - If deciding between two alternative designs, choose the one where indirection reduces coupling or provides greater security

Fundamental Design Principles



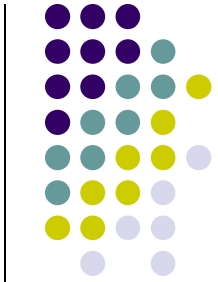
- Object Responsibility
  - A design principle that states objects are responsible for carrying out system processing
  - A fundamental assumption of OO design and programming
  - Responsibilities include “knowing” and “doing”
  - Objects know about other objects (associations) and they know about their attribute values. Objects know how to carry out methods, do what they are asked to do.
  - Note that CRC cards and the design in the next chapter involve assigning responsibilities to classes to carry out a use case.
  - If deciding between two alternative designs, choose the one where objects are assigned responsibilities to collaborate to complete tasks (don’t think procedurally).

Summary



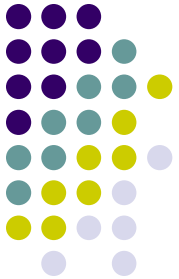
- This chapter focused on designing software that solves business problems by bridging the gap between analysis and implementation.
- Architectural design is the first step, and the UML component diagram is used to model the main components and application program interfaces (API)
- Detail design of software proceeds use case by use case, sometimes called “use case driven” and the design of each use case is called use case realization.
- Detailed design models used are design class diagrams (DCDs) and sequence diagrams.
- The design class diagram is developed is two steps: The first cut diagram is based on the domain model class diagram, but then it is expanded as responsibilities are assigned and sequence diagrams are developed.

Summary (continued)



- Design class diagrams include additional notation because design classes are now software classes, not just work concepts.
- Key issues are attribute elaboration and adding methods. Method signatures include visibility, method name, arguments, and return types.
- Other key terms are abstract vs. concrete classes, navigation visibility, and class level attributes and methods,
- CRC Cards technique can be used to design how the classes collaborate to complete each use case. CRC stands for Classes, Responsibilities, and Collaborations.
- Sometimes the CRC cards approach is used for the initial design of a use case that is further developed using sequence diagrams (as in the next chapter).

Summary (continued)



- Once responsibilities are assigned to classes, the design class diagram is updated by adding methods to classes and updating navigation visibility.
- Decisions about design options are guided by some fundamental design principles. Some of these are coupling, cohesion, protection from variations, indirection, and object responsibility.