Week 8

Object Oriented Design

(Chapter 12)

Chapter Goals

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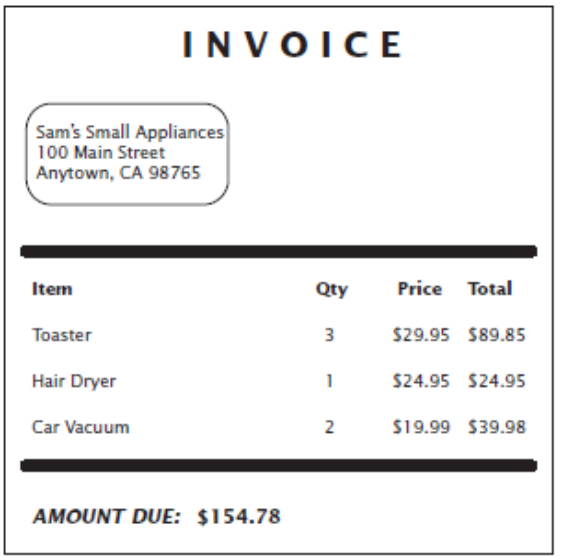
- To learn how to discover new classes and methods
- To use CRC cards for class discovery
- To identify inheritance, aggregation, and dependency relationships between classes
- To describe class relationships using UML class diagrams
- To apply object-oriented design techniques to building complex programs

Discovering Classes

- When designing a program, you work from a requirements specification
  - The designer's task is to discover structures that make it possible to implement the requirements
- To discover classes, look for nouns in the problem description.
- Find methods by looking for verbs in the task description.

Example: Invoice



INVOICE

Sam's Small Appliances
100 Main Street
Anytown, CA 98765

Item	Qty	Price	Total
Toaster	3	$29.95	$89.85
Hair Dryer	1	$24.95	$24.95
Car Vacuum	2	$19.99	$39.98

AMOUNT DUE: **$154.78**

Figure 1 An Invoice

Example: Invoice

- Classes that come to mind:
  - `Invoice`
  - `LineItem`
  - `Customer`
- Good idea to keep a list of candidate classes.
- Brainstorm: put all ideas for classes onto the list.
- Cross out the ones not useful later.
- Concepts from the problem domain are good candidates for classes.
- Not all classes can be discovered from the program requirements:
  - Most programs need tactical classes

The CRC Card Method

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In a class scheduling system, potential classes from the problem domain include Class, LectureHall, Instructor, and Student.

The CRC Card Method

- After you have a set of classes
  - Define the behavior (methods) of each class
- Look for verbs in the task description
  - Match the verbs to the appropriate objects
- The invoice program needs to compute the amount due
  - Which class is responsible for this method?
    - Invoice class

https://www.youtube.com/watch?v=V3n8qtOW7gM&list=PLG8tpvGEaewKkRUlwWiO6xJIvvD9E1FZc&index=2

The CRC Card Method

- To find the class responsibilities, use the CRC card method.
- A CRC card describes a class, its responsibilities, and its collaborating classes.
  - CRC - stands for “classes”, “responsibilities”, “collaborators”
- Use an index card for each class.
- Pick the class that should be responsible for each method (verb).
- Write the responsibility onto the class card.
- Indicate what other classes are needed to fulfill responsibility (collaborators).

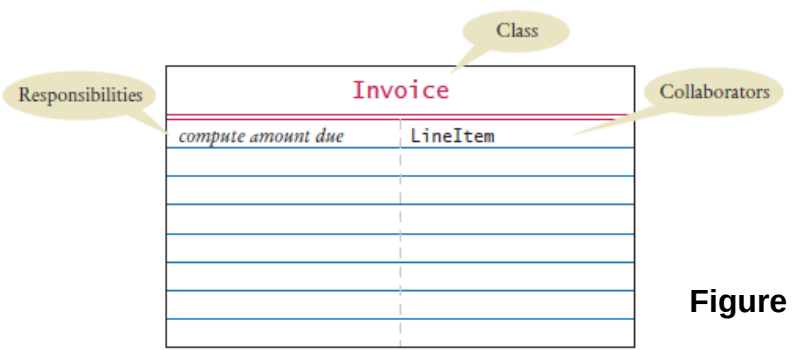


Figure 2 A CRC Card

Relationships Between Classes

The most common types of relationships:

- Dependency
- Aggregation
- Inheritance

Dependency

- A class depends on another class if it uses objects of that class.

  The "knows about" relationship.

- Example: `CashRegister` depends on `Coin`

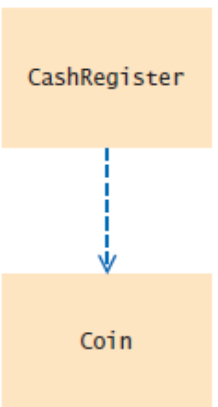


Figure 3 Dependency Relationship Between the `CashRegiste` and `Coin` Classes

Dependency

- It is a good practice to minimize the coupling (i.e., dependency) between classes.

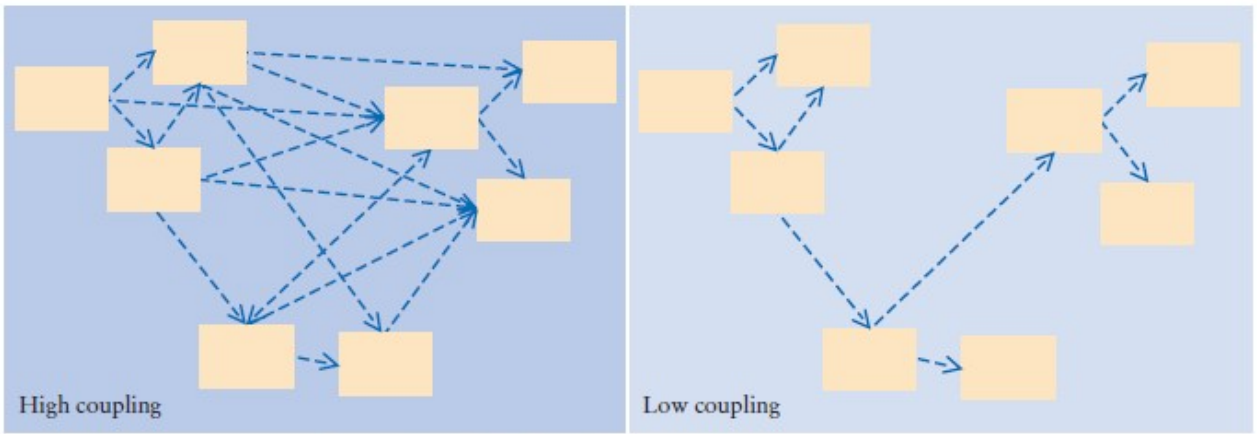


Figure 4 High and Low Coupling Between Classes

- When a class changes, coupled classes may also need updating.

Aggregation

- A class aggregates another if its objects contain objects of the other class.
  - *Has-a* relationship
- Example: a `Quiz` class aggregates a `Question` class. The UML for aggregation:

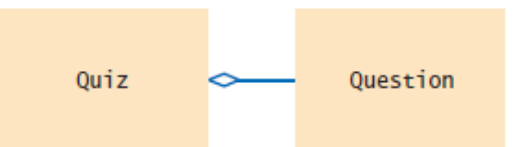


Figure 5
Class Diagram
Showing Aggregation

- Aggregation is a stronger form of dependency.
- Use aggregation to remember another object between method calls.
- Use an instance variable

```
public class Quiz
{
   private ArrayList<Question> questions;
   . . .
}
```

Aggregation

© bojan fatur/iStockphoto.

A car has a motor and tires. In object-oriented design, this “has-a” relationship is called aggregation.

- A class may use the `Scanner` class without ever declaring an instance variable of class `Scanner`.
  - This is dependency NOT aggregation

Inheritance

- Inheritance is a relationship between a more general class (the superclass) and a more specialized class (the subclass).
  - The "is-a" relationship.
  - Example: Every truck is a vehicle.
- Inheritance is sometimes inappropriately used when the has-a relationship would be more appropriate.
  - Should the class `Tire` be a subclass of a class `Circle`? No
    - A tire has a circle as its boundary
    - Use aggregation

```
public class Tire
{
    private String rating;
    private Circle boundary;
    . . .
}
```

Inheritance

- Every car is a vehicle. (Inheritance)
- Every car has a tire (or four). (Aggregation)

```
class Car extends Vehicle
{
   private Tire[] tires;
   . . .
}
```

- Aggregation denotes that objects of one class contain references to objects of another class.

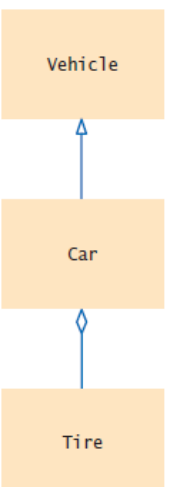
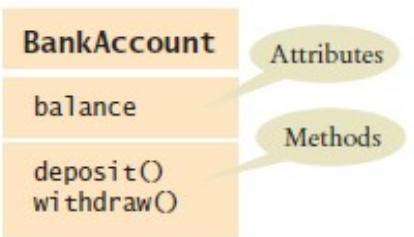


Figure 6 UML Notation for Inheritance and Aggregation

UML Relationship Symbols

Relationship	Symbol	Line Style	Arrow Tip
Inheritance		Solid	Triangle
Interface Implementation		Dotted	Triangle
Aggregation		Solid	Diamond
Dependency		Dotted	Open

Attributes and Methods in UML Diagrams



Multiplicities

- any number (zero or more):
- * one or more: 1..*
- zero or one:
- 0..1 exactly
- one: 1

An Aggregation Relationship with Multiplicities

Aggregation and Association, and Composition

- Association: More general relationship between classes. Use early in the design phase.
- A class is associated with another if you can navigate from objects of one class to objects of the other.
- Given a `Bank` object, you can navigate to `Customer` objects.

An Association Relationship

- Composition: one of the classes can not exist without the other.

A Composition Relationship

Application: Printing an Invoice

Five-part program development process

1. Gather requirements
2. Use CRC cards to find classes, responsibilities, and collaborators
3. Use UML diagrams to record class relationships
4. Use `javadoc` to document method behavior
5. Implement your program

Application: Printing an Invoice — Requirements

- Start the development process by gathering and documenting program requirements.
- Task: Print out an invoice
- Invoice: Describes the charges for a set of products in certain quantities.
- Omit complexities
  - Dates, taxes, and invoice and customer numbers
- Print invoice
  - Billing address, all line items, amount due
- Line item
  - Description, unit price, quantity ordered, total price
- For simplicity, do not provide a user interface.
- Test program: Adds line items to the invoice and then prints it.

Application: Printing an Invoice

- Sample Invoice

```
                  I N V O I C E

Sam's Small Appliances
100 Main Street
Anytown, CA  98765

Description                     Price Qty  Total
Toaster                         29.95   3  89.85
Hair dryer                      24.95   1  24.95
Car vacuum                      19.99   2  39.98

AMOUNT DUE:  $154.78
```

- An invoice lists the charges for each item and the amount due.

Application: Printing an Invoice — CRC Cards

- Use CRC cards to find classes, responsibilities, and collaborators.
- Discover classes
- Nouns are possible classes:

```
Invoice
Address
LineItem
Product
Description
Price
Quantity
Total
Amount Due
```

Application: Printing an Invoice — CRC Cards

- Analyze classes:

```
Invoice
Address
LineItem    // Records the product and the quantity
Product
 Description // Field of the Product class
 Price       // Field of the Product class
 Quantity    // Not an attribute of a Product
 Total       // Computed — not stored anywhere
 Amount  Due // Computed — not stored anywhere
```

- Classes after a process of elimination:

```
Invoice
Address
LineItem
Product
```

CRC Cards for Printing Invoice

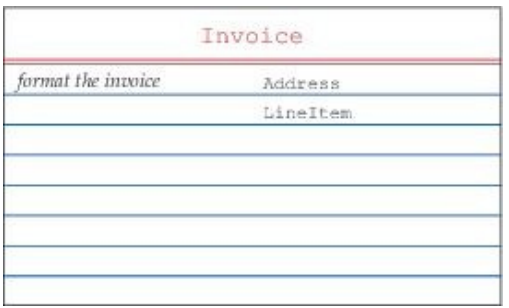
- `Invoice` and `Address` must be able to format themselves:

Invoice
format the invoice

Address
format the address

CRC Cards for Printing Invoice

- Add collaborators to `Invoice` card:



CRC Cards for Printing Invoice

- `Product` and `LineItem` CRC cards:

CRC Cards for Printing Invoice

- `Invoice` must be populated with products and quantities:

Application: Printing an Invoice — UML Diagrams

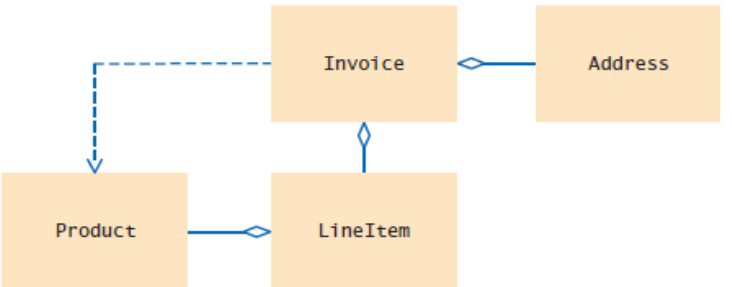


Figure 7 The Relationships Between the Invoice Classes

Printing an Invoice — Method Documentation

- Use `javadoc` comments (with the method bodies left blank) to record the behavior of the classes.
- Write a Java source file for each class:
  - Write the method comments for those methods that you have discovered,
  - Leave the body of the methods blank
- Run `javadoc` to obtain formatted version of documentation in HTML format.
- Advantages:
  - Share HTML documentation with other team members
  - Format is immediately useful: Java source files
  - Supply the comments of the key methods

Method Documentation — Invoice Class

```
/**
   Describes an invoice for a set of purchased products.
*/
public class Invoice
{
   /**
      Adds a charge for a product to this invoice.
      @param aProduct the product that the customer ordered
      @param quantity the quantity of the product
   */
   public void add(Product aProduct, int quantity)
   {
   }
   /**
      Formats the invoice.
      @return the formatted invoice
   */
   public String format()
   {
   }
}
```

Method Documentation — LineItem Class

```
/**
   Describes a quantity of an article to purchase and its price.
*/
public class LineItem
{
   /**
      Computes the total cost of this line item.
      @return the total price
   */
   public double getTotalPrice()
   {
   }
   /**
      Formats this item.
      @return a formatted string of this line item
   */
   public String format()
   {
   }
}
```

Method Documentation — Product Class

```
/**
   Describes a product with a description and a price.
*/
public class Product
{
   /**
      Gets the product description.
      @return the description
   */
   public String getDescription()
   {
   }
   /**
      Gets the product price.
      @return the unit price
   */
   public double getPrice()
   {
   }
}
```

Method Documentation — Address Class

```
/**
   Describes a mailing address.
*/
public class Address
{
   /**
      Formats the address.
      @return the address as a string with three lines
   */
   public String format()
   {
   }
}
```

The Class Documentation in the HTML Format

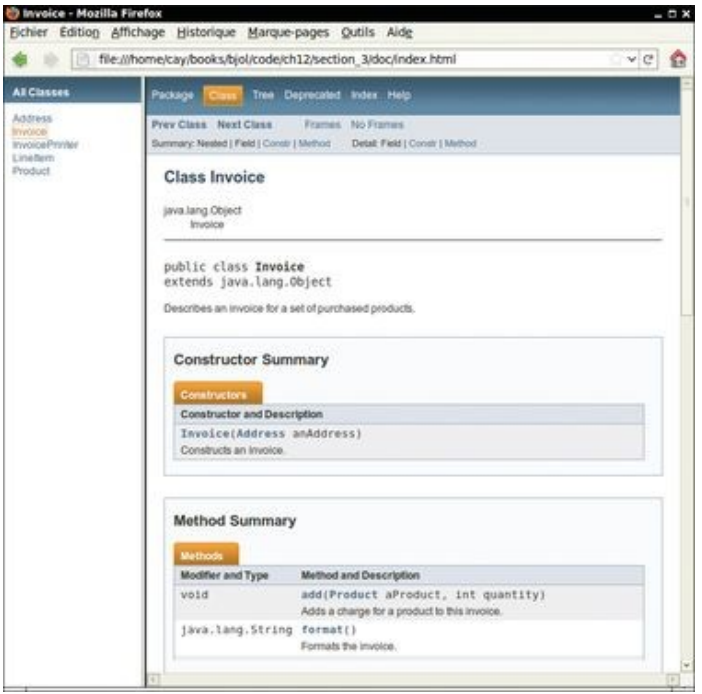


Figure 8 Class Documentation in HTML Format

Printing an Invoice — Implementation

- After completing the design, implement your classes.
- The UML diagram will give instance variables:
  - Look for aggregated classes
  - They yield instance variables

Implementation

- `Invoice` aggregates `Address` and `LineItem`.
- Every invoice has one billing address.
- An invoice can have many line items:

```
public class Invoice
{
   . . .
   private Address billingAddress;
   private ArrayList<LineItem> items;
}
```

Implementation

- A line item needs to store a `Product` object and quantity:

```
public class LineItem
{
   . . .
   private int quantity;
   private Product theProduct;
}
```

Implementation

- The methods themselves are now very easy.

Example:

`getTotalPrice` of `LineItem` gets the unit price of the product and multiplies it with the quantity

```
/**
   Computes the total cost of this line item.
   @return the total price
*/
public double getTotalPrice()
{
   return theProduct.getPrice() * quantity;
}
```

- Also supply constructors

section_3/InvoicePrinter.java

```
1  /**
2     This program demonstrates the invoice classes by printing
3     a sample invoice.
4  */
5  public class InvoicePrinter
6  {
7     public static void main(String[] args)
8     {
9        Address samsAddress
```

section_3/Invoice.java

```
1  import java.util.ArrayList;
2
3  /**
4     Describes an invoice for a set of purchased products.
5  */
6  public class Invoice
7  {
8     private Address billingAddress;
9     private ArrayList<LineItem> items;
```

section_3/LineItem.java

```
1  /**
2     Describes a quantity of an article to purchase.
3  */
4  public class LineItem
5  {
6     private int quantity;
7     private Product theProduct;
8     /**
9
```

section_3/Product.java

```
1  /**
2     Describes a product with a description and a price.
3  */
4  public class Product
5  {
6     private String description;
7     private double price;
8     /**
9
```

section_3/Address.java

```
1  /**
2     Describes a mailing address.
3  */
4  public class Address
5  {
6     private String name;
7     private String street;
8     private String city;
9     private String state;
```