

Appendix 1

■ Introduction to UML

Slide Set to accompany

Software Engineering: A Practitioner's Approach, 8/e

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UML

- The Unified Modeling Language (UML)
 - a standard language for writing software blueprints.
 - used to visualize, specify, construct, and document the artifacts of a software-intensive system
 - developed by Grady Booch, Jim Rumbaugh, and Ivar Jacobson in the mid-1990s with much feedback from the software development community.
- In 1997, UML 1.0 was submitted to the Object Management Group
- The current standard is UML 2.3 and is now an ISO standard.

UML

- UML 2.3 provides 13 different diagrams for use in software modeling.
- What we cover here
 - *class diagram*
 - *deployment diagram*
 - *use case diagram*
 - *Sequence diagram*
 - *Communication diagram*
 - *Activity diagram*
 - *State diagram*

Class Diagram

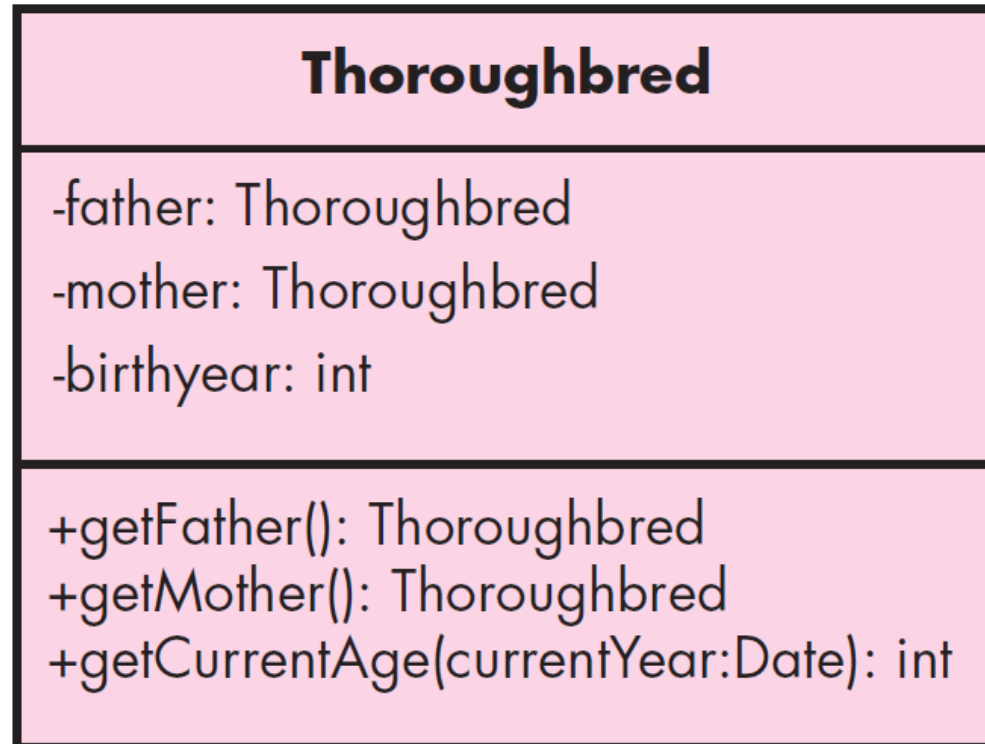
- Model classes, including their attributes, operations, and their relationships and associations with other classes
- A class diagram provides **a static or structural view** of a system.
- It does not show the dynamic nature of the communications between the objects of the classes in the diagram.

Class Diagram

- The top part contains the name of the class.
- The middle section lists the attributes of the class.
 - An *attribute* refers to something that an object of that class knows or can provide all the time.
- The third section contains the operations or behaviors of the class.
 - An *operation* refers to what objects of the class can do. It is usually implemented as a method of the class.

Example

- **Thoroughbred** class that models thoroughbred horses.



Class Diagram: Attribute & Operation

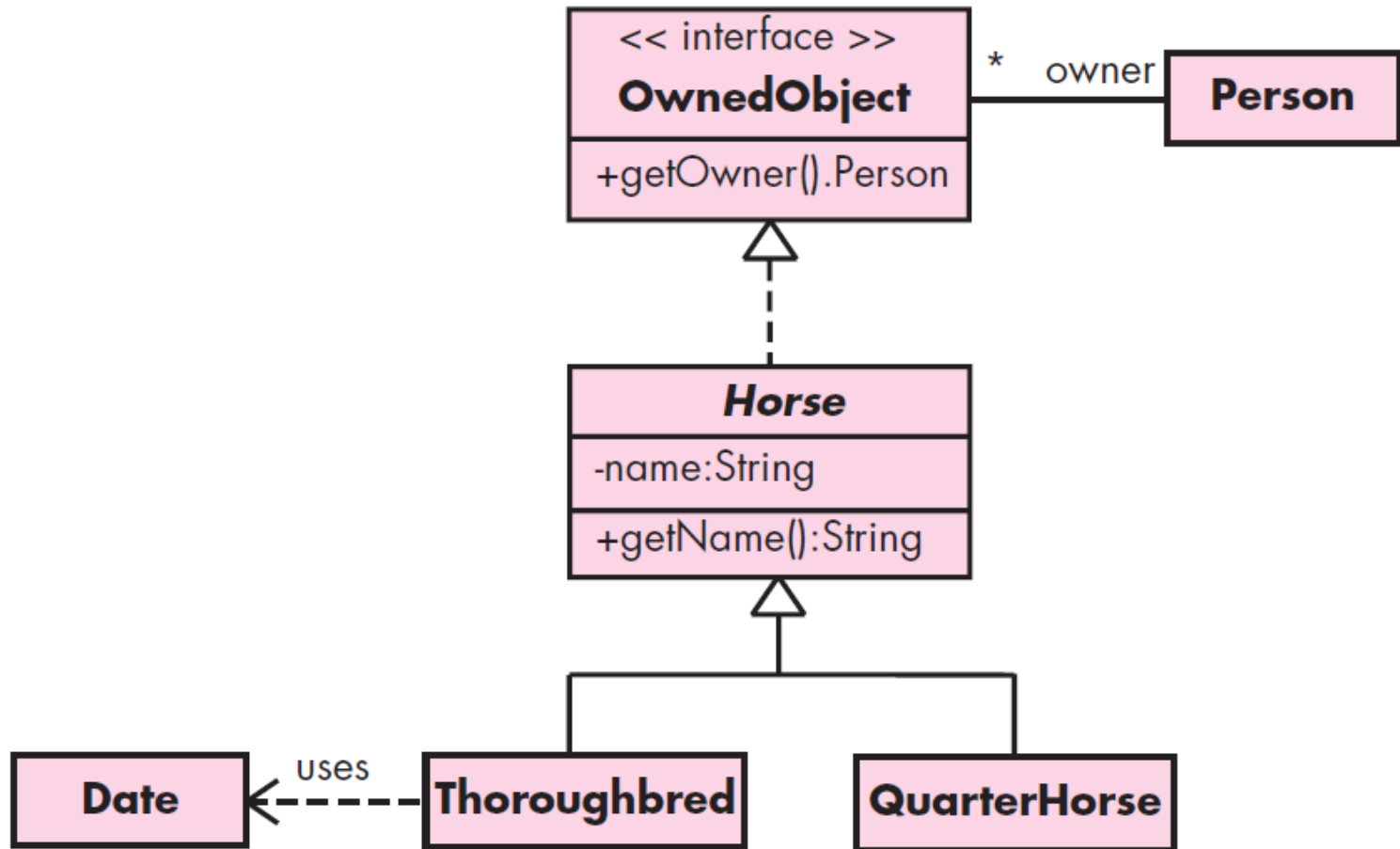
- Each attribute can have a name, a type, and a level of visibility. The type and visibility are optional
- The visibility is indicated by a preceding **–**, **#**, **~**, or **+**, indicating, respectively, *private*, *protected*, *package*, or *public* visibility
- You can also specify that an attribute is a **static or class attribute by underlining it**
- Each operation can also be displayed with a level of visibility, parameters with names and types, and a return type

Class Diagram: Abstract class & method

- An abstract class or abstract method is indicated by the use of italics for the name in the class diagram.
- An interface is indicated by adding the phrase “«interface»” (called a *stereotype*) above the name.
 - An interface can also be represented graphically by a hollow circle.

Class Diagram: Relationship b/w Classes

- A class that is a subclass of another class is **connected to it by an arrow with a solid line** for its shaft and with a triangular hollow arrowhead. The arrow points from the subclass to the superclass.
- **An arrow with a dashed line** for the arrow shaft indicates implementation of an interface. In UML, such a relationship is called a *realization*.



- the **Thoroughbred** and **QuarterHorse** classes are shown to be subclasses of the **Horse** abstract class.
- **Horse** class implements or realizes the **OwnedObject** interface.
- there is an association between **OwnedObject** and **Person** in which the **Person** plays the role of owner.

Class Diagram: Association

- An *association* between two classes means that there is a structural relationship between them. **Associations are represented by solid lines.** An association has many optional parts. **It can be labeled, as can each of its ends, to indicate the role of each class in the association.**
- Arrows on either or both ends of an association line indicate **navigability**. Also, each end of the association line can have a **multiplicity** value displayed.

Class Diagram: Association

- An association with an arrow at one end indicates **one-way navigability**.
 - The arrow means that from one class you can easily access the second associated class to which the association points, but from the second class, you cannot necessarily easily access the first class.
- An association with **no arrows** usually indicates a **two-way association**
 - It could just mean that the navigability is not important and so was left off.

Class Diagram: Attribute of a class

- An attribute of a class is very much the same thing as an association of the class with the class type of the attribute.
- **Attribute approach**: To indicate that a class has a property called “name” of type String, one could display that property as an attribute
- **Association approach**: one could create a one-way association from the **Horse** class to the **String** class with the role of the **String** class being “name.”

Class Diagram: Dependency relationship

- A *dependency* relationship represents another connection between classes and is indicated by a dashed line (with optional arrows at the ends and with optional labels)
 - One class depends on another if changes to the second class might require changes to the first class.
 - An association from one class to another automatically indicates a dependency. No dashed line is needed between classes if there is already an association between them.
 - For a transient relationship, we should draw a dashed line from the first class to the second.
 - E.g.) the **Thoroughbred** class uses the **Date** class whenever its *getCurrentAge()* method is invoked, and so the dependency is labeled “uses.”

Class Diagram: Multiplicity

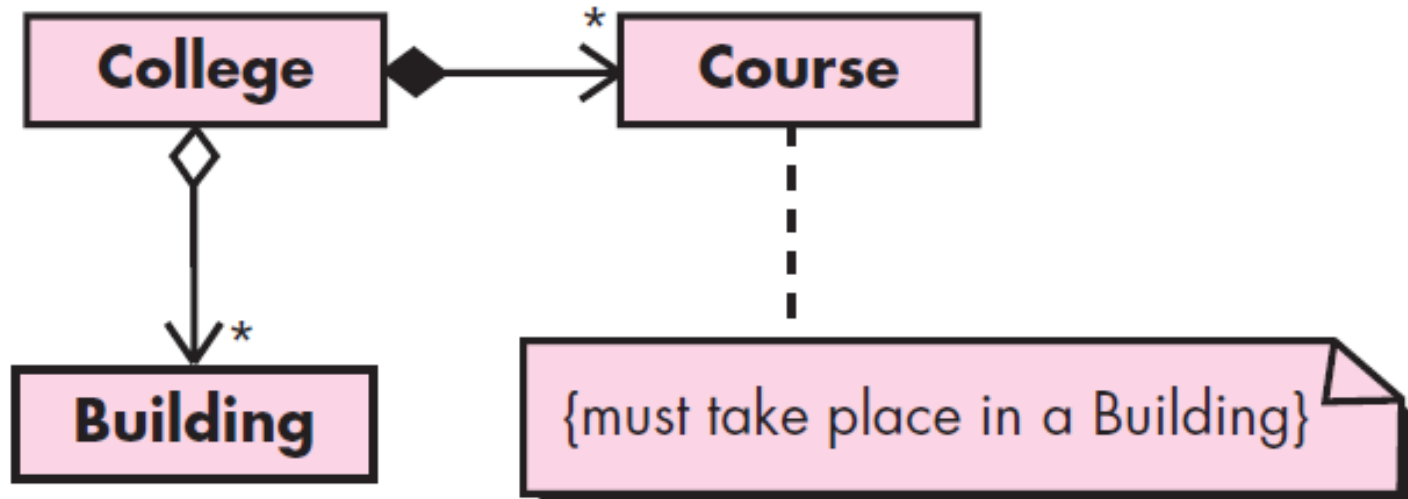
- The *multiplicity* of one end of an association means the number of objects of that class associated with the other class.
- A multiplicity is specified by a nonnegative integer or by a range of integers.
- A multiplicity specified by “0..1” means that there are 0 or 1 objects on that end of the association.
- A multiplicity specified by “1..*” means one or more, and a multiplicity specified by “0..*” or just “*” means zero or more.
- E.g.) An * was used as the multiplicity on the **OwnedObject** end of the association with class **Person** in Figure A1.2 because a **Person** can own zero or more objects

Class Diagram: Aggregation & composition

- An *aggregation* is a special kind of association indicated by a hollow diamond on one end of the icon.
- It indicates a “whole/part” relationship, in that the class to which the arrow points is considered a “part” of the class at the diamond end of the association.
- A *composition* is an aggregation indicating strong ownership of the parts. In a composition, the parts live and die with the owner because they have no role in the software system independent of the owner.

Class Diagram: Note

- a *note* is represented by a box with a dog-eared corner and is connected to other icons by a dashed line. It can have arbitrary content (text and graphics) and is similar to comments in programming languages



- A **College** has an **aggregation** of **Building** objects
- A **College** has a **composition** of **Course** objects
- Note the constraint attached to the **Course** class

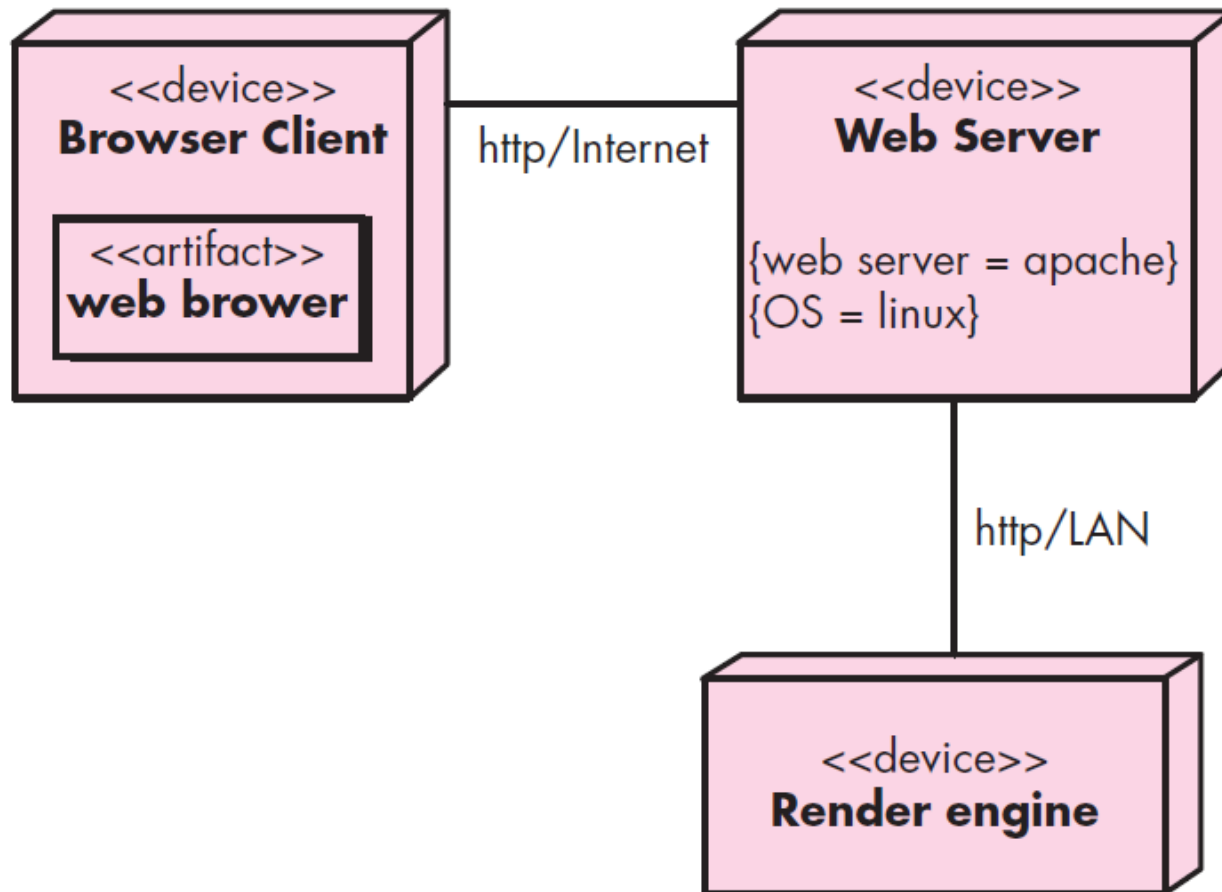
Deployment Diagram

- *Deployment diagram* focuses on the structure of a software system and is useful for showing the physical distribution of a software system among hardware platforms and execution environments

Deployment Diagram: Example

- Suppose, for example, you are developing a [Web-based graphics-rendering package](#).
- Users of your package will use their Web browser to go to your website and enter rendering information.
- Your website would render a graphical image according to the user's specification and send it back to the user.
- Because graphics rendering can be computationally expensive, you decide to move the rendering itself off the Web server and onto a separate platform.
- Therefore, there will be three hardware devices involved in your system: the Web client (the users' computer running a browser), the computer hosting the Web server, and the computer hosting the rendering engine.

Deployment Diagram: Example



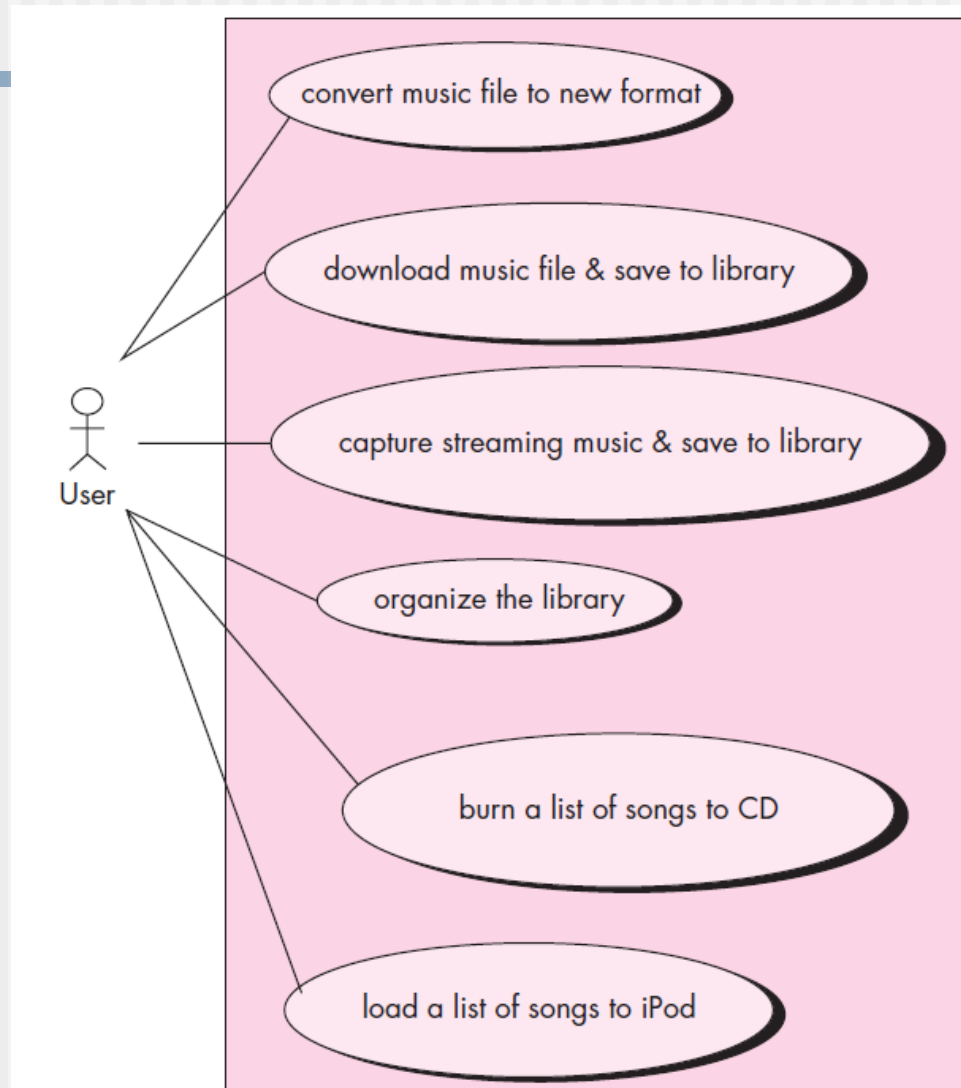
Deployment Diagram

- Deployment diagrams can also display execution environment nodes, which are drawn as boxes containing the label “«execution environment»”.
- These nodes represent systems, such as operating systems, that can host other software.

Use-Case Diagram

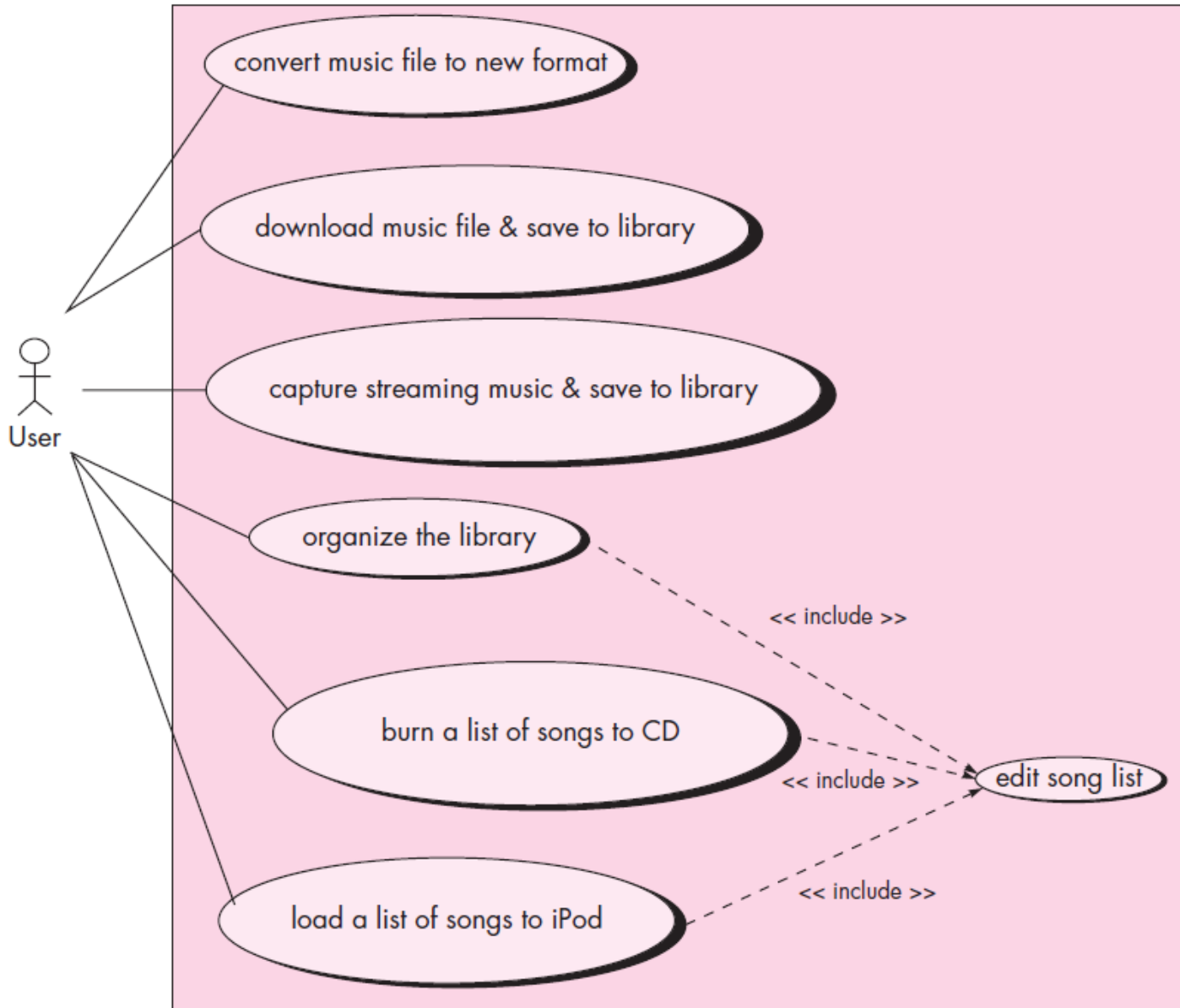
- The UML *use-case diagram* help you determine the functionality and features of the software from the user's perspective.
- E.g.) a software application for managing digital music files, similar to Apple's iTunes software
 - Download an MP3 music file and store it in the application's library.
 - Capture streaming music and store it in the application's library.
 - Manage the application's library (e.g., delete songs or organize them in playlists).
 - Burn a list of the songs in the library onto a CD.
 - Load a list of the songs in the library onto an iPod or MP3 player.
 - Convert a song from MP3 format to AAC format and vice versa.

Use-Case Diagram: Example



Use-Case Diagram

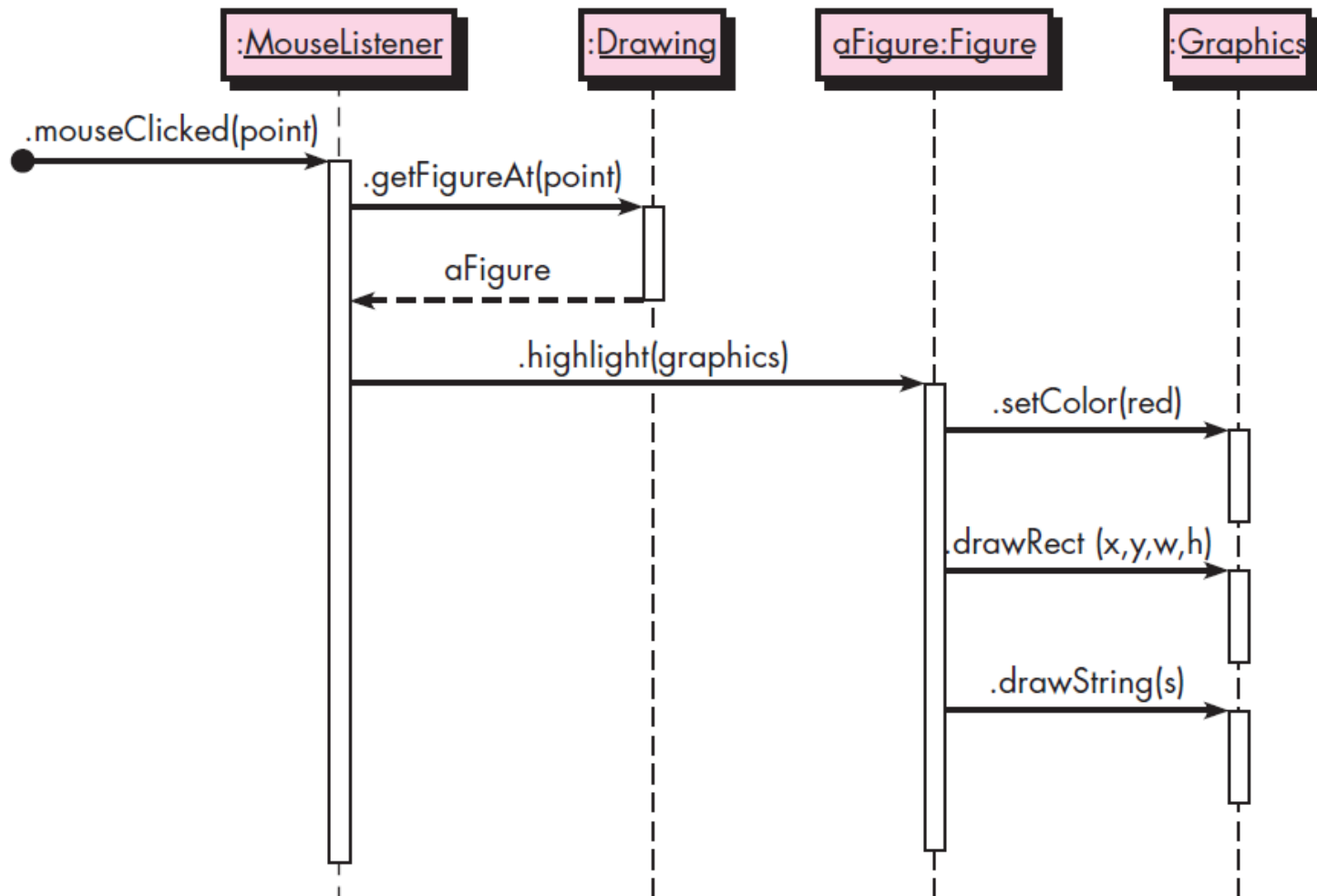
- The stick figure represents an *actor* (Chapter 5) that is associated with one category of user (or other interaction element).
- Some use cases in a system might be related to each other.
- To avoid duplication in use cases, it is usually better to create a new use case representing the duplicated activity, and then **let the other uses cases include this new use case as one of their steps.**



Sequence Diagram

- A *sequence diagram* is used to show the **dynamic communications** between objects during execution of a task.
 - In contrast to class diagrams and deployment diagrams, which show **the static structure of a software component**,
- It shows **the temporal order** in which messages are sent between the objects to accomplish that task.
- It can be used to show **the interactions in one use case or in one scenario** of a software system.

Sequence Diagram

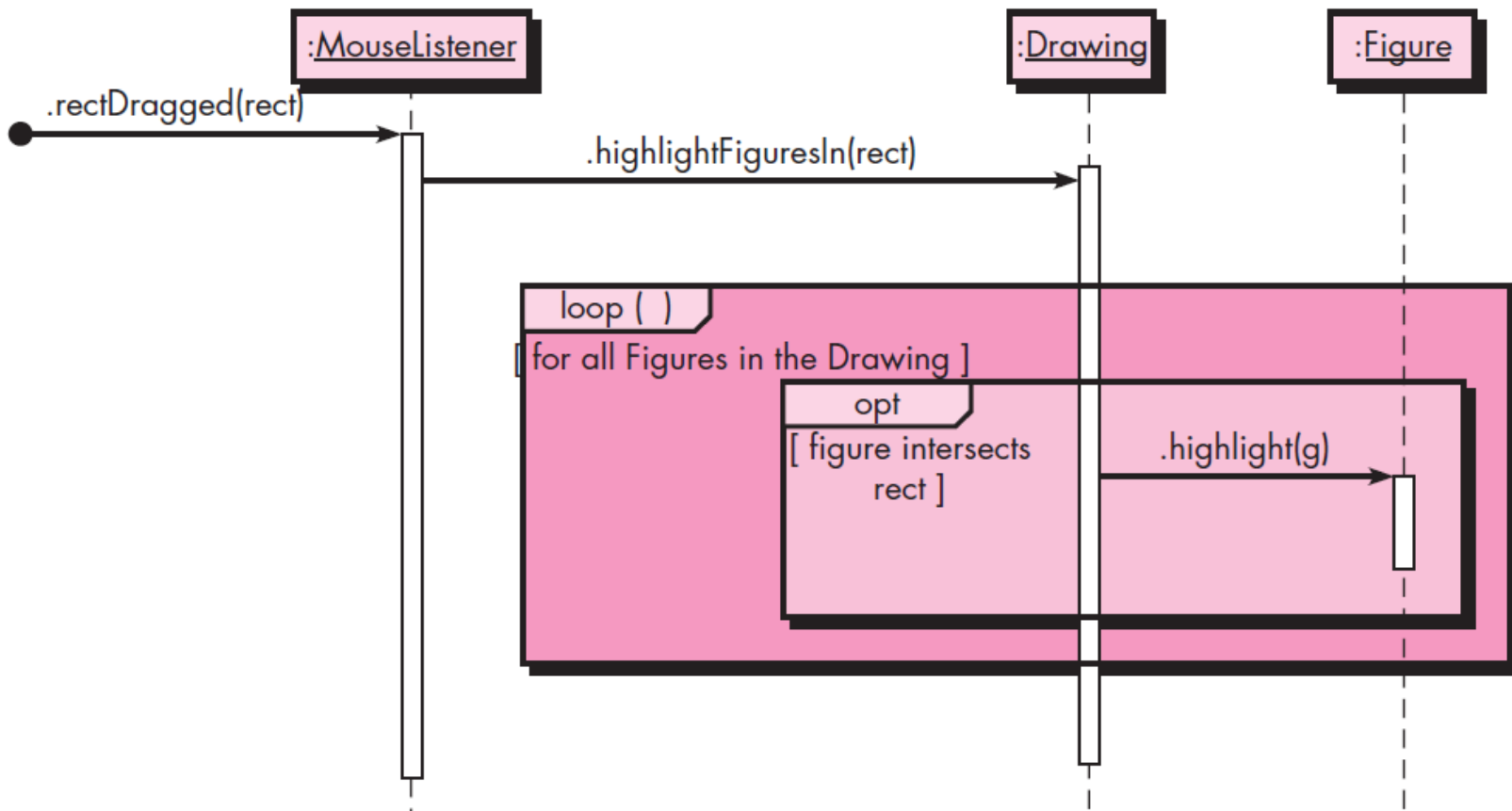


Sequence Diagram

- Each box in the row at the top of the diagram usually corresponds to **an object**
- Below each box there is a dashed line called the **lifeline** of the object
- A sequence diagram shows method calls using horizontal arrows from the **caller** to the **callee**,
- When an object is executing a method (that is, when it has an activation frame on the stack), you can optionally display a white bar, called an **activation bar**,
- The diagram can also optionally **show the return from a method call with a dashed arrow and an optional label**.
 - We can leave off the return arrow when a void method has been called
 - A black circle with an arrow coming from it indicates a **found message** whose source is unknown or irrelevant

Sequence Diagram

- If you insist on including **loops, conditionals, and other control structures** in a sequence diagram, you can use *interaction frames*, which are **rectangles that surround parts** of the diagram and that are labeled with the type of control structures they represent.
- The phrases in square brackets are called *guards*, which are Boolean conditions that must be true if the action inside the interaction frame is to continue.

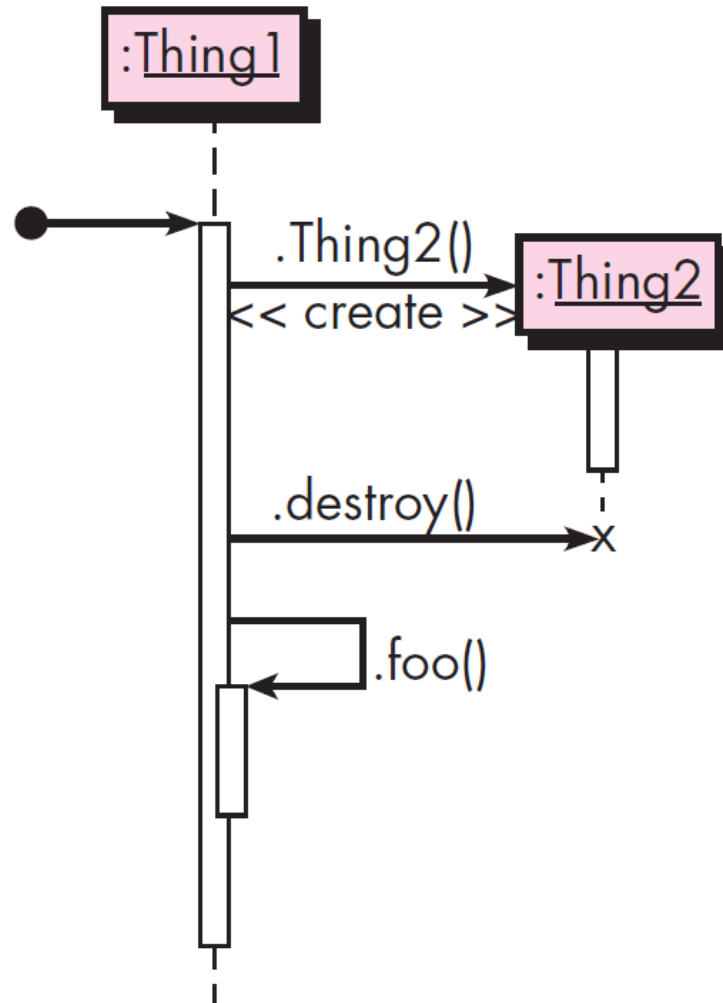


The **MouseListener** is sent the `rectDragged` message. The **MouseListener** then tells the drawing to highlight all figures in the rectangle by calling the method `highlightFiguresIn()`, passing the rectangle as the argument. The method loops through all **Figure** objects in the **Drawing** object and, **Figure** intersects the rectangle, the **Figure** is asked to highlight itself. The phrases in square brackets are called *guards*, which are Boolean conditions that must be true if the action inside the interaction frame is to continue.

Sequence Diagram

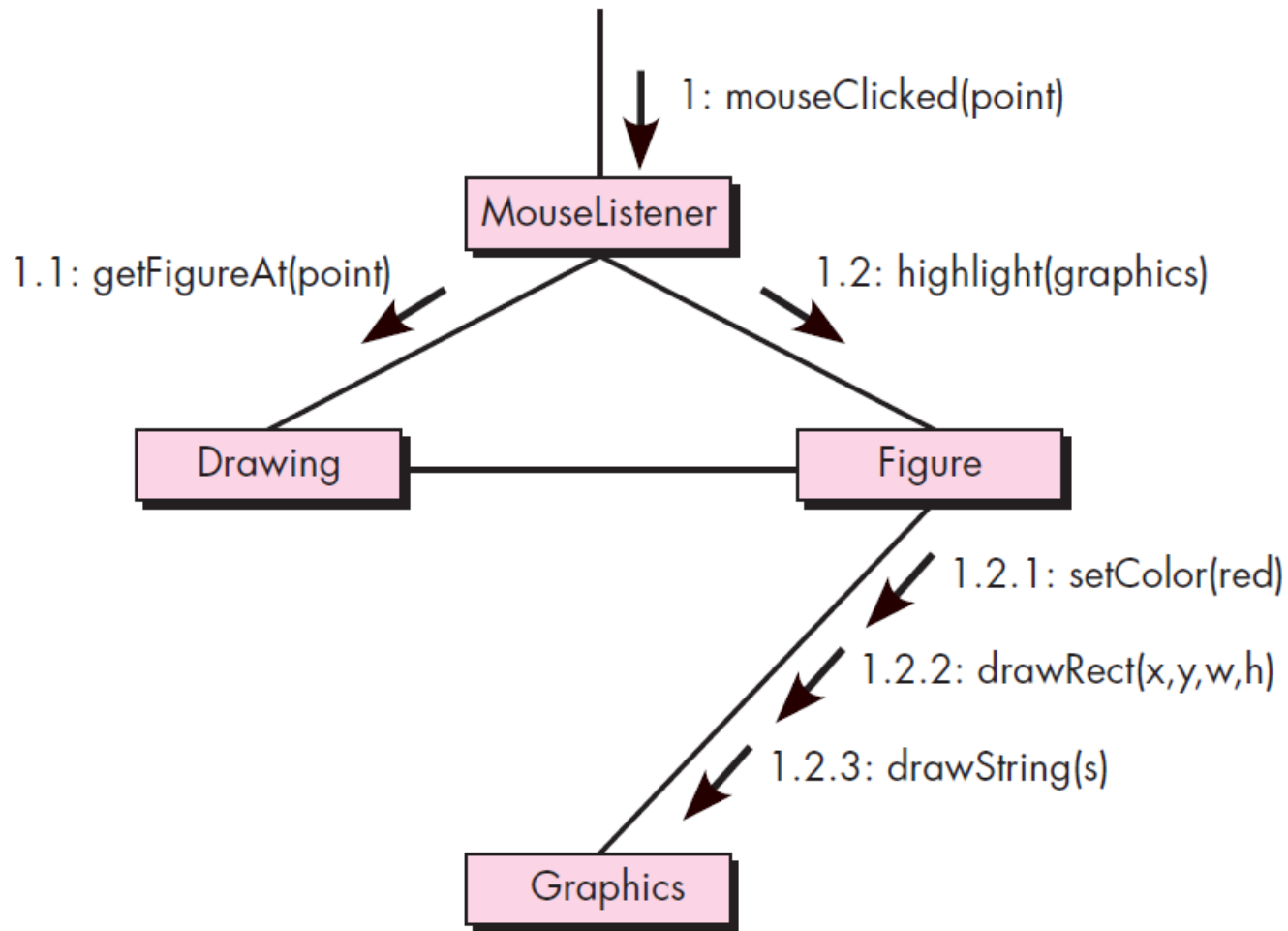
- **1.** You can distinguish between synchronous and asynchronous messages. Synchronous messages are shown with solid arrowheads while asynchronous messages are shown with stick arrowheads.
- **2.** You can show **an object sending itself a message with an arrow going out from the object, turning downward, and then pointing back to the same object.**
- **3.** You can show **object creation by drawing an arrow appropriately labeled (for example, with a «create» label) to an object's box.** In this case, the box will appear lower in the diagram than the boxes corresponding to objects already in existence when the action begins.
- **4.** You can show **object destruction by a big X at the end of the object's lifeline.** Other objects can destroy an object, in which case an arrow points from the other object to the X. An X is also useful for indicating that an object is no longer usable and so is ready for garbage collection.

Sequence Diagram



Communication Diagram

- The UML *communication diagram* (called a “collaboration diagram” in UML 1.X) provides another indication of the temporal order of the communications but **emphasizes the relationships among the objects and classes** instead of the temporal order.



The `highlight()` message invokes three other messages: `setColor()`, `drawRect()`, and `drawstring()`. The numbering in each label shows the nesting as well as the sequential nature of each message.

Communication Diagram

- The interacting objects are represented by **rectangles**.
- **Associations between objects** are represented by **lines connecting the rectangles**.
- There is **typically an incoming arrow** to one object in the diagram that starts the sequence of message passing. That arrow is labeled with a number and a message name.
- If the incoming message is **labeled with the number 1** and if it causes the receiving object to invoke other messages on other objects, **then those messages are represented by arrows from the sender to the receiver along an association line and are given numbers 1.1, 1.2, and so forth, in the order they are called**.

Activity Diagrams

- A UML *activity diagram* depicts the dynamic behavior of a system or part of a system through the flow of control between actions that the system performs.
- It is similar to a flowchart except that an activity diagram can show concurrent flows.

Activity Diagrams

■ *Action node*

- The main component of an activity diagram
- represented by a rounded rectangle
- corresponds to a task performed by the software system
- Arrows from one action node to another indicate the flow of control

■ *Initial node*

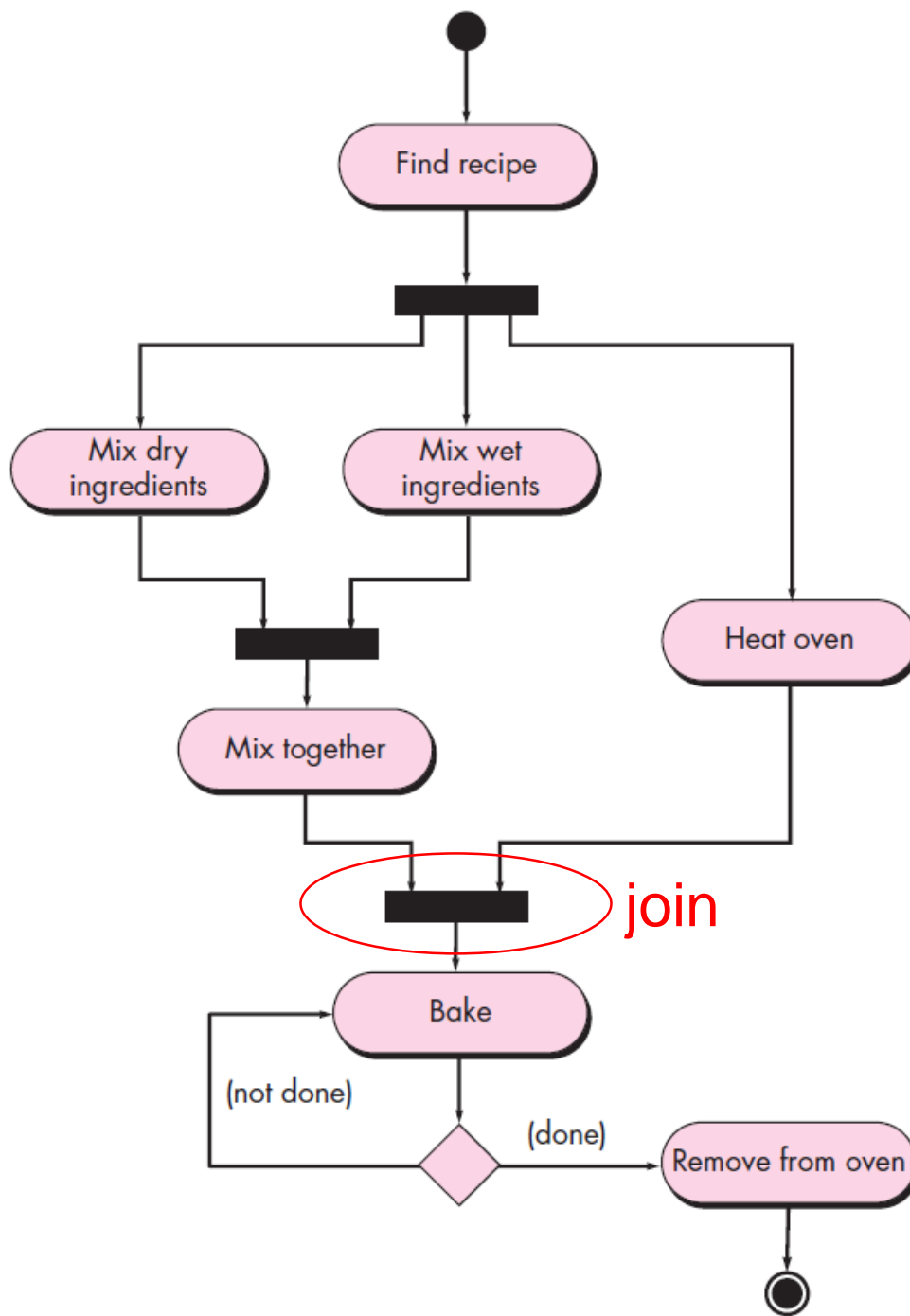
- Represented by a solid black dot,
- Indicates the starting point of the activity

■ *Final node*

- Represented by a black dot surrounded by a black circle
- Indicates the end of the activity

■ *Fork*

- Drawn as a horizontal black bar with one arrow pointing to it and two or more arrows pointing out from it
- Represents the separation of activities into two or more concurrent activities



Activity Diagrams

■ *Join*

- **A way of synchronizing concurrent flows** of control.
- represented by a horizontal black bar with two or more incoming arrows and one outgoing arrow.
- The flow of control represented by the outgoing arrow cannot begin execution until all flows represented by incoming arrows have been completed.

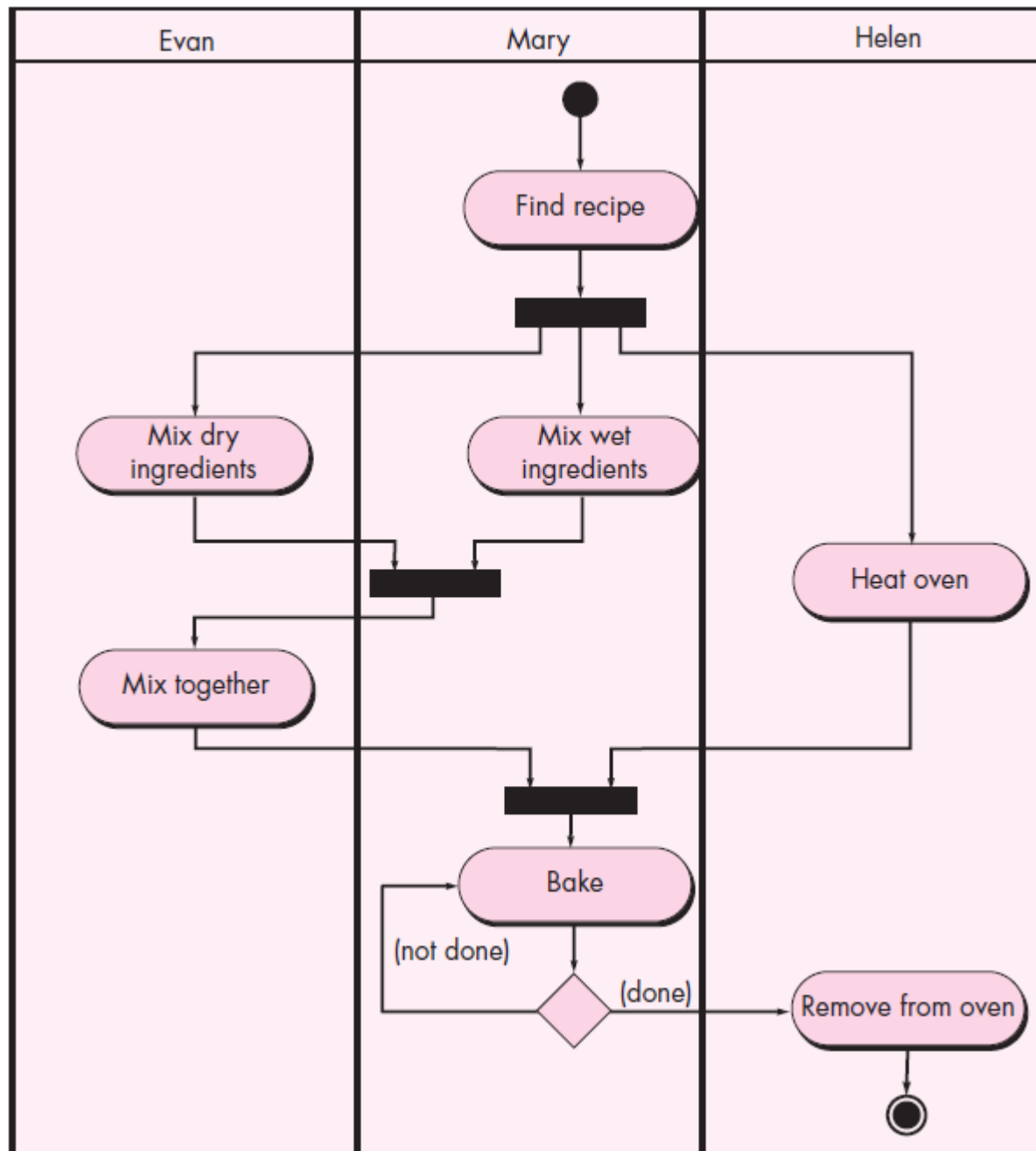
■ *Decision node*

- Corresponds to a branch in the flow of control based on a condition.
- Displayed as a white triangle with an incoming arrow and two or more outgoing arrows

Activity Diagrams

- *Swimlane diagram*
 - To represent how the actions are divided among the participants
 - Formed by **dividing the diagram into strips or “lanes,”** each of which **corresponds to one of the participants.**

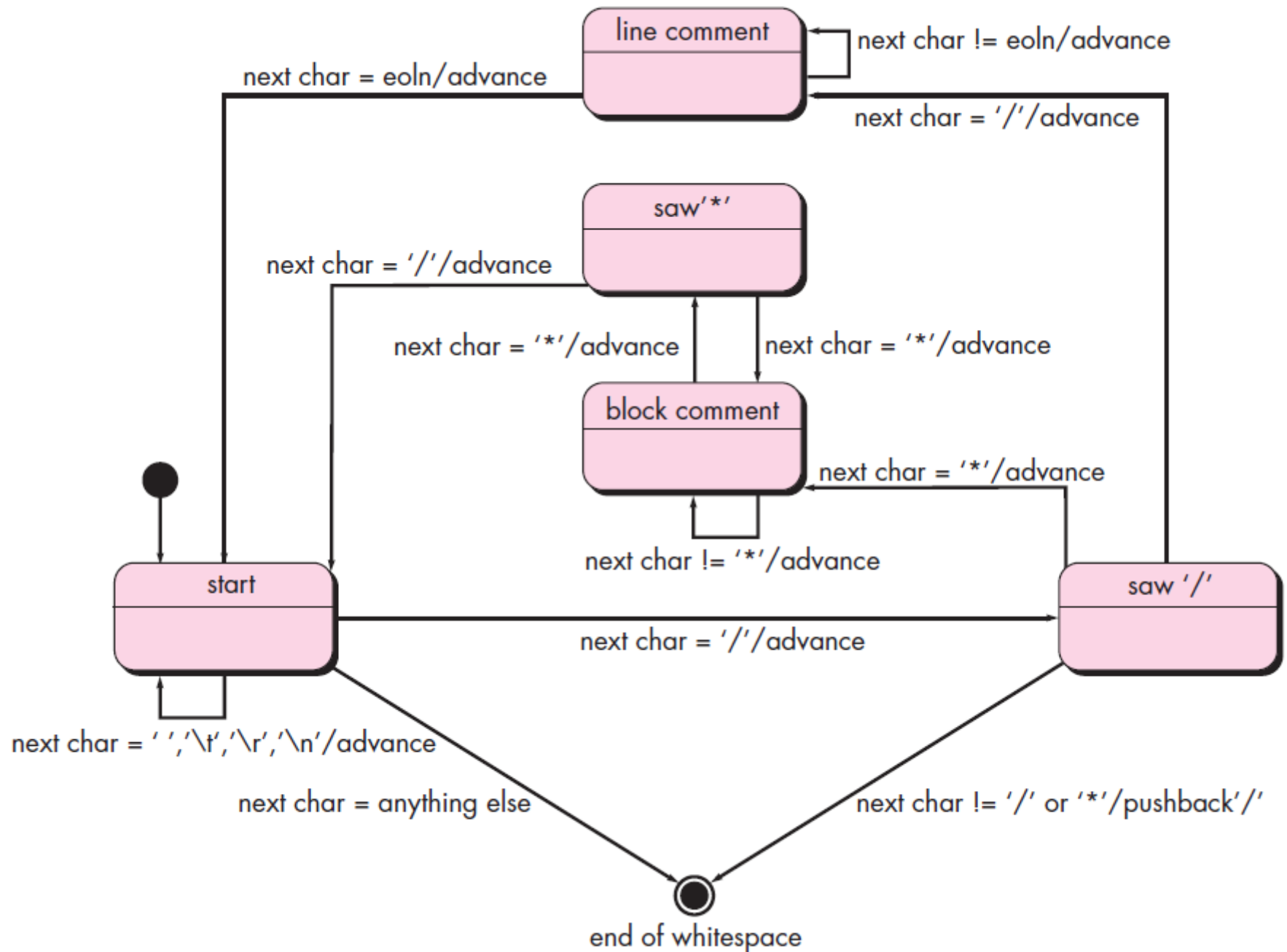
Activity diagram with swimlanes added



State Diagrams

- *A UML State diagram*
 - models an object's states, the actions that are performed depending on those states, and the transitions between the states of the object.
- Example: The state diagram for a part of a Java compiler
 - The input to the compiler is a text file as a long string of characters
 - The compiler reads characters one at a time and from them determines the structure of the program

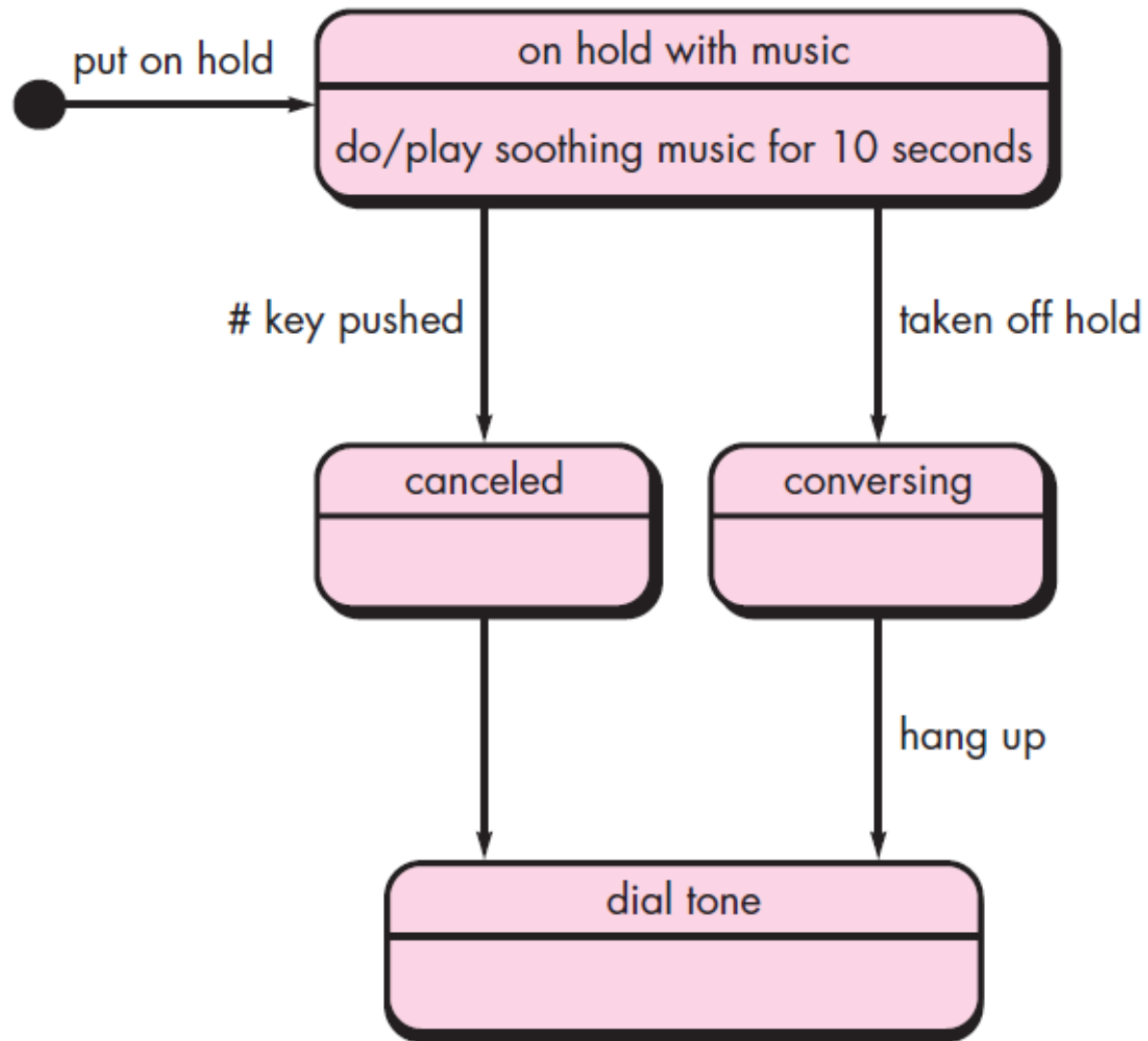
State diagram



State Diagrams

- **Activity state**

- The state in which an object performs some activity, called a *do-activity*,
- Non-activity state (normal case)
 - when an object is in a state, it usually does nothing but sit and wait for a trigger event to occur.
- Represented by **the bottom half of the state's rounded rectangle the phrase "do/"** followed by the activity that is to be done while in that state.



Object Constraint Language

- Often, graphical representations are not enough

- The *Object Constraint Language* (OCL)

- Complements UML by allowing you to use **a formal grammar and syntax to construct unambiguous statements** about various design model elements

- OCL is constructed in four parts

- (1) a *context* that defines the limited situation in which the statement is valid,
- (2) a *property* that represents some characteristics of the context
- (3) an *operation* (e.g., arithmetic, set-oriented) that manipulates or qualifies a property
- (4) **keywords** (e.g., **if, then, else, and, or, not, implies**) that are used to specify conditional expressions.

OCL: Example

customer

self.authorizationAuthority 'yes'

authorization can only occur if the customer is authorized to approve the cost of the job.

Object Constraint Language

- As the design model is created, there are often instances in which pre- or postconditions must be satisfied prior to completion of some action specified by the design.
- OCL provides a powerful tool for specifying pre- and postconditions in a formal manner.

OCL: Example

```
context PrintJob::validate(upperCostBound : Integer, custDeliveryReq : Integer)
  pre: upperCostBound > 0 and custDeliveryReq > 0 and self.jobAuthorization = 'no'

  post: if self.totalJobCost < upperCostBound and self.deliveryDate < custDeliveryReq
    then
      self.jobAuthorization = 'yes'
    endif
```

the customer provides an upper cost bound for the print job and a “drop-dead” delivery date at the same time as other print job characteristics are specified.

If cost and delivery estimates exceed these bounds, the job is not submitted and the customer must be notified.