Object-Oriented Software Engineering

Practical Software Development using UML and Java

Chapter 8:

Modelling Interactions and Behaviour

8.1 Interaction Diagrams

Interaction diagrams are used to model the dynamic aspects of a software system

- They help you to visualize how the system runs.
- An interaction diagram is often built from a use case and a class diagram.
  - —The objective is to show how a set of objects accomplish the required interactions with an actor.

Interactions and messages

Interaction diagrams show how a set of actors and objects communicate with each other to perform:

- —The steps of a use case, or
- —The steps of some other piece of functionality.

The set of steps, taken together, is called an *interaction*.

Interaction diagrams can show several different types of communication.

- —E.g. method calls, messages send over the network
- —These are all referred to as *messages*.

Elements found in interaction diagrams

Instances of classes

- —Shown as boxes with the class and object identifier underlined

Actors

- —Use the stick-person symbol as in use case diagrams

Messages

- —Shown as arrows from actor to object, or from object to object

Creating instances diagrams

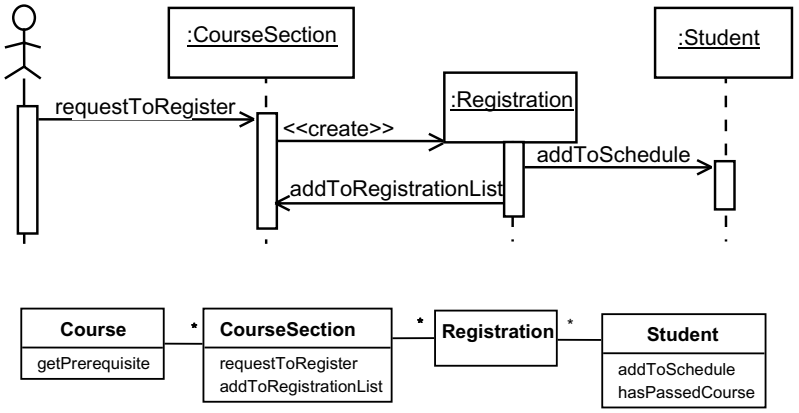
You should develop a class diagram and a use case model before starting to create an interaction diagram.

There are two kinds of interaction diagrams:

—*Sequence diagrams*

—*Collaboration diagrams*

Sequence diagrams – an example



Sequence diagrams

A sequence diagram shows the sequence of messages exchanged by the set of objects performing a certain task

The objects are arranged horizontally across the diagram.

An actor that initiates the interaction is often shown on the left.

The vertical dimension represents time.

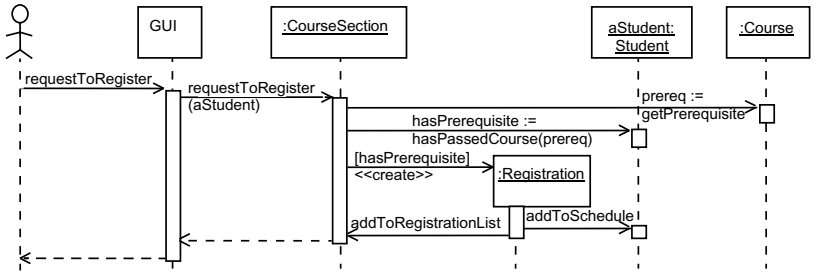
A vertical line, called a *lifeline*, is attached to each object or actor.

The lifeline becomes a broad box, called an *activation box* during the *live activation* period.

A message is represented as an arrow between activation boxes of the sender and receiver.

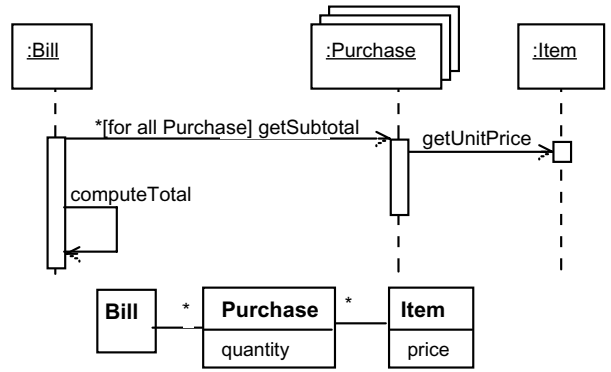
—A message is labelled and can have an argument list and a return value.

Sequence diagrams – same example, more details



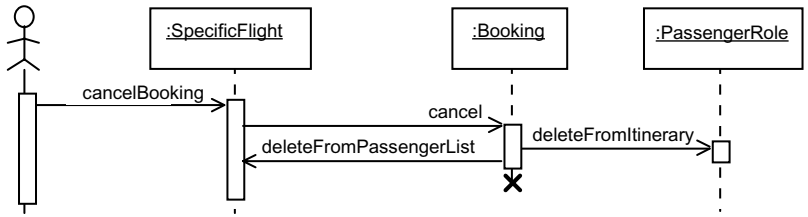
Sequence diagrams – an example with replicated messages

An *iteration* over objects is indicated by an asterisk preceding the message name

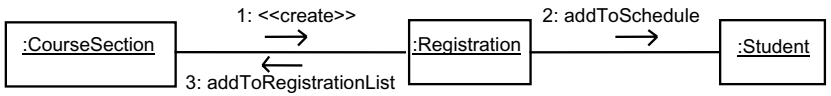


Sequence diagrams – an example with object deletion

If an object's life ends, this is shown with an X at the end of the lifeline



Collaboration diagrams – an example

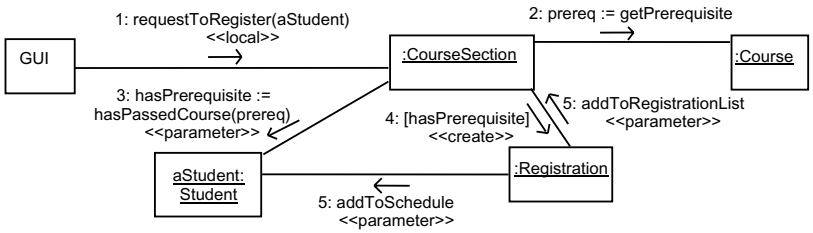


Collaboration diagrams

Collaboration diagrams emphasise how the objects collaborate in order to realize an interaction

- A collaboration diagram is a graph with the objects as the vertices.
- Communication links are added between objects
- Messages are attached to these links.
  - —Shown as arrows labelled with the message name
- Time ordering is indicated by prefixing the message with some numbering scheme.

Collaboration diagrams – same example, more details



Communication links

A communication link can exist between two objects whenever it is possible for one object to send a message to the other one.

Several situations can make this message exchange possible:

1. The classes of the two objects have an *association* between them.
   - This is the most common case.
   - If all messages are sent in the same direction, then probably the association can be made unidirectional.

Other communication links

2. The receiving object is stored in a *local* variable of the sending method.
   - This often happens when the object is created in the sending method or when some computation returns an object .
   - The stereotype to be used is «local» or [L].

3. A reference to the receiving object has been received as a *parameter* of the sending method.
   - The stereotype is «parameter» or [P].

Other communication links

4. The receiving object is global.
   - This is the case when a reference to an object can be obtained using a static method.
   - The stereotype «global», or a [G] symbol is used in this case.

5. The objects communicate over a network.
   - We suggest to write «network».

How to choose between using a sequence or collaboration diagram

Sequence diagrams

Make explicit the time ordering of the interaction.

—Use cases make time ordering explicit too

—So sequence diagrams are a natural choice when you build an interaction model from a use case.

Make it easy to add details to messages.

—Collaboration diagrams have less space for this

How to choose between using a sequence or collaboration diagram

Collaboration diagrams

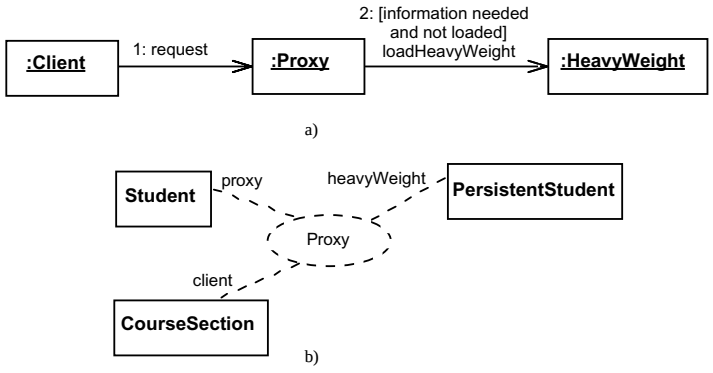
Can be seen as a projection of the class diagram

—Might be preferred when you are *deriving* an interaction diagram from a class diagram.

—Are also useful for *validating* class diagrams.

Collaboration diagrams and patterns

A collaboration diagram can be used to represent aspects of a *design pattern*



8.2 State Diagrams

A state diagram describes the behaviour of a *system*, some *part* of a system, or an *individual object*.

At any given point in time, the system or object is in a certain state.

—Being in a state means that it is will behave in a *specific way* in response to any events that occur.

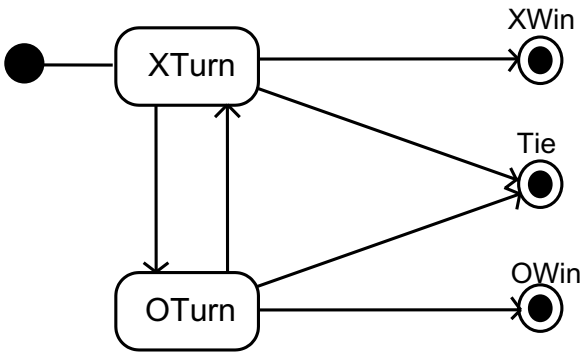
Some events will cause the system to change state.

—In the new state, the system will behave in a different way to events.

A state diagram is a directed graph where the nodes are states and the arcs are transitions.

State diagrams – an example

tic-tac-toe game



States

At any given point in time, the system is in one state.

It will remain in this state until an event occurs that causes it to change state.

A state is represented by a rounded rectangle containing the name of the state.

Special states:

—A black circle represents the *start state*

—A circle with a ring around it represents an *end state*

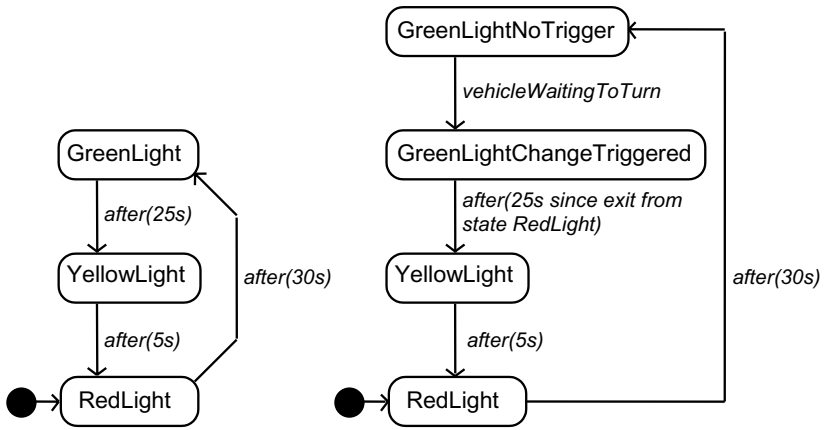
Transitions

A transition represents a change of state in response to an event.

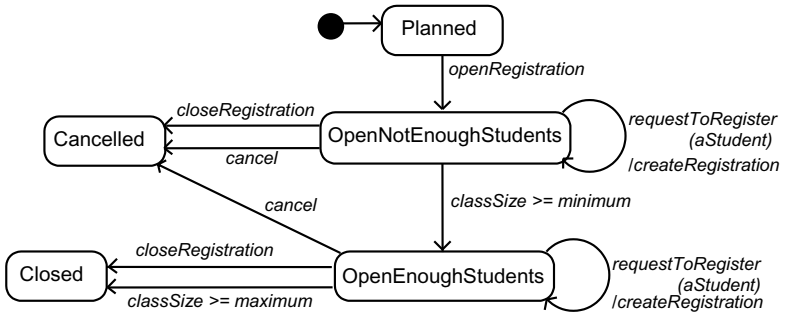
—It is considered to occur instantaneously.

The label on each transition is the event that causes the change of state.

State diagrams – an example of transitions with time-outs and conditions



State diagrams – an example with conditional transitions



Activities in state diagrams

An *activity* is something that takes place while the system is *in* a state.

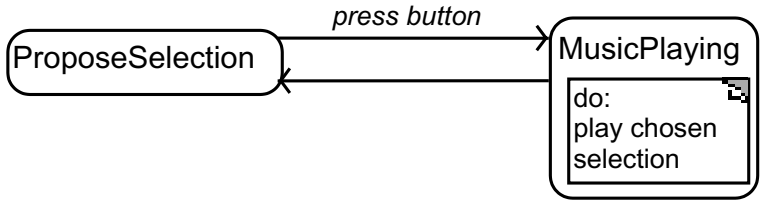
—It takes a period of time.

—The system may take a transition out of the state in response to completion of the activity,

—Some other outgoing transition may result in:

- The interruption of the activity, and
- An early exit from the state.

State diagram – an example with activity



Actions in state diagrams

An *action* is something that takes place effectively *instantaneously*

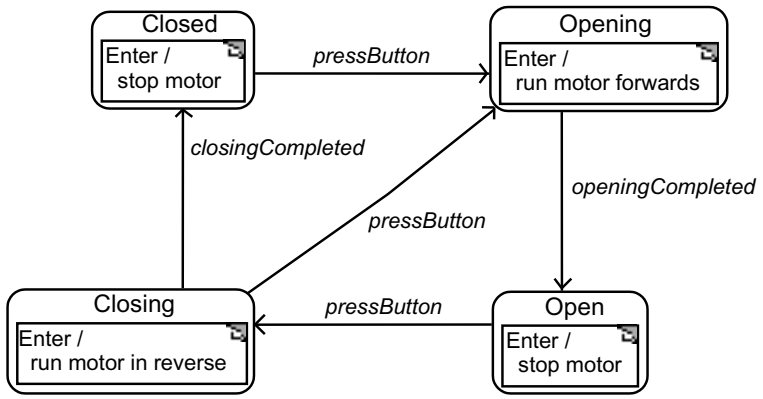
—When a particular transition is taken,

—Upon entry into a particular state, or

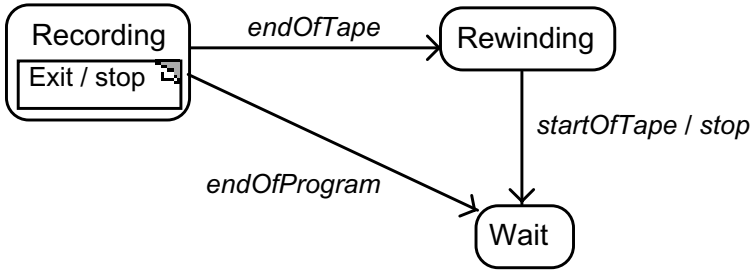
—Upon exit from a particular state

An action should consume no noticeable amount of time

State diagram – an example with actions



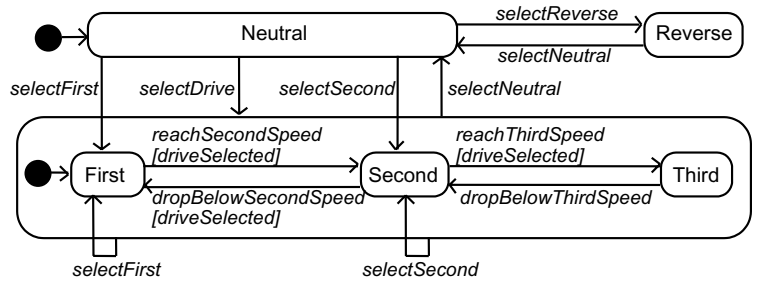
State diagrams – another example



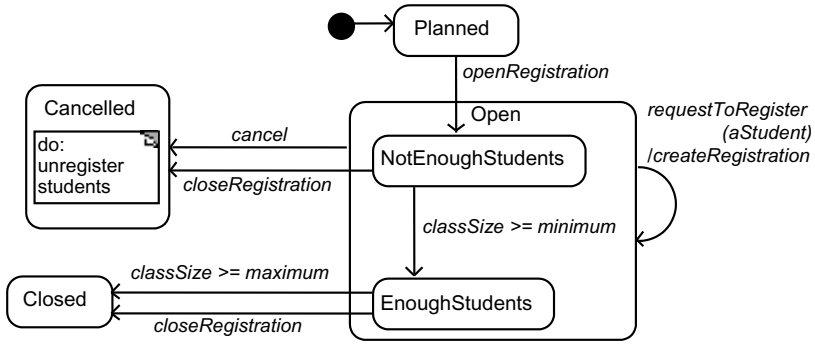
Nested substates and guard conditions

A state diagram can be nested inside a state.

The states of the inner diagram are called *substates*.



State diagram – an example with substates



8.3 Activity Diagrams

An *activity diagram* is like a state diagram.

—Except most transitions are caused by *internal* events, such as the completion of a computation.

An activity diagram

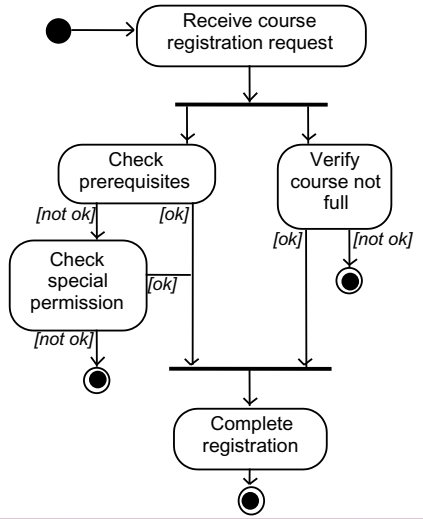
—Can be used to understand the flow of work that an object or component performs.

—Can also be used to visualize the interrelation and interaction between different use cases.

—Is most often associated with several classes.

One of the strengths of activity diagrams is the representation of *concurrent* activities.

Activity diagrams – an example



Representing concurrency

Concurrency is shown using forks, joins and rendezvous.

—A *fork* has one incoming transition and multiple outgoing transitions.

- The execution splits into two concurrent threads.

—A *rendezvous* has multiple incoming and multiple outgoing transitions.

- Once all the incoming transitions occur all the outgoing transitions may occur.

Representing concurrency

—A *join* has multiple incoming transitions and one outgoing transition.

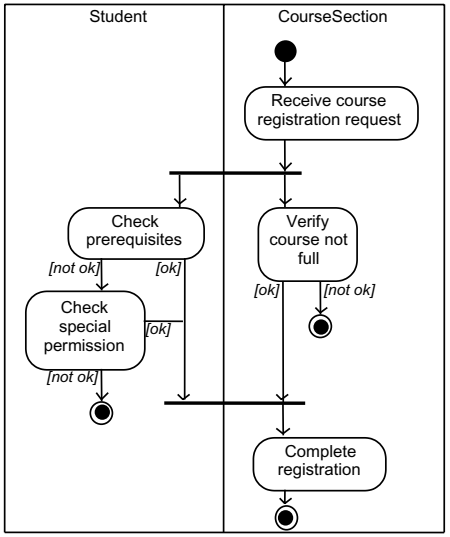
- The outgoing transition will be taken when all incoming transitions have occurred.
- The incoming transitions must be triggered in separate threads.
- If one incoming transition occurs, a wait condition occurs at the join until the other transitions occur.

Swimlanes

Activity diagrams are most often associated with several classes.

The partition of activities among the existing classes can be explicitly shown using *swimlanes*.

Activity diagrams – an example with swimlanes



8.4 Implementing Classes Based on Interaction and State Diagrams

You should use these diagrams for the parts of your system that you find most complex.

—I.e. not for every class

Interaction, activity and state diagrams help you create a correct implementation.

This is particularly true when behaviour is *distributed* across several use cases.

—E.g. a state diagram is useful when different conditions cause instances to respond differently to the same event.

Example: The **`CourseSection`** class

States:

'Planned':

- **`closedOrCancelled == false && open == false`**

'Cancelled':

- **`closedOrCancelled == true && registrationList.size() == 0`**

'Closed' (course section is too full, or being taught):

- **`closedOrCancelled == true && registrationList.size() > 0`**

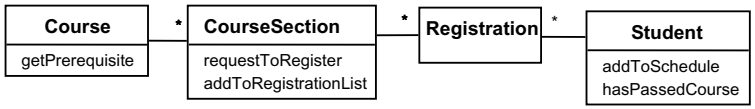
Example: The **CourseSection** class

States:

- 'Open' (accepting registrations):
  - **open == true**
- 'NotEnoughStudents' (substate of 'Open'):
  - **open == true && registrationList.size() < course.getMinimum()**
- 'EnoughStudents' (substate of 'Open'):
  - **open == true && registrationList.size() >= course.getMinimum()**

Example: The **CourseSection** class

Class diagram



Example: The **CourseSection** class

```
public class CourseSection
{
 // The many-1 abstraction-occurence association
 private Course course;

 // The 1-many association to class Registration
 private List registationList;

 // The following are present only to determine
 // the state
 // The initial state is 'Planned'
 private boolean open = false;
 private boolean closedOrCancelled = false;
 ...
}
```


Example: The **CourseSection** class

```
public CourseSection(Course course)
{
 this.course = course;
 RegistrationList = new LinkedList();
}

public void cancel()
{
 // to 'Cancelled' state
 open = false;
 closedOrCancelled = true;
 unregisterStudents();
}
```

Example: The **CourseSection** class

```
public void openRegistration()
{
 if(!closedOrCancelled)
 // must be in 'Planned' state
 {
   open = true;
  //to 'OpenNotEnoughStudents' state
 }
}
```


Example: The **CourseSection** class

```
public void closeRegistration()
{
 //to 'Cancelled' or 'Closed' state
 open = false;
 closedOrCancelled = true;
 if (registrationList.size() <
   course.getMinimum())
 {
   unregisterStudents();
  //to 'Cancelled' state
 }
}
```


Example: The **CourseSection** class

```
public void requestToRegister(Student student)
 {
  if (open)  // must be in one of the two 'Open' states
  {
   // The interaction specified in the sequence diagram
    Course prereq = course.getPrerequisite();
   if (student.hasPassedCourse(prereq))
   {
     //Indirectly calls addToRegistrationList
     new Registration(this, student);
   }

   // Check for automatic transition to 'Closed' state
   if (registrationList.size() >= course.getMaximum())
   {
    //to 'Closed' state
    open = false;
    closedOrCancelled = true;
   }
  }
 }
```


Example: The **CourseSection** class

```
// Activity associated with 'Cancelled' state.
private void unregisterStudents()
{
 Iterator it = registrationList.iterator();
 while (it.hasNext())
 {
   Registration r = (Registration)it.next();
  r.unregisterStudent();
  it.remove();
 }
}

// Called within this package only, by the
// constructor of Registration
 void addToRegistrationList(
   Registration newRegistration)
 {
  registrationList.add(newRegistration);
 }
}
```

8.5 Difficulties and Risks in Modelling Interactions and Behaviour

Dynamic modelling is a difficult skill

In a large system there are a very large number of possible paths a system can take.

It is hard to choose the classes to which to allocate each behaviour:

—*Ensure that skilled developers lead the process, and ensure that all aspects of your models are properly reviewed.*

—*Work iteratively:*

- *Develop initial class diagrams, use cases, responsibilities, interaction diagrams and state diagrams;*
- *Then go back and verify that all of these are consistent, modifying them as necessary.*

—*Drawing different diagrams that capture related, but distinct, information will often highlight problems.*