

Chapter 10

- **Requirements Modeling: Class-based methods**

Slide Set to accompany

Software Engineering: A Practitioner's Approach, 7/e
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Identifying Analysis Classes

- Perform a grammatical parse on the use cases
 - nouns are underlined, verbs italicized
- Classes are determined by underlining each noun or noun phrase and entering it into a simple table.
- Synonyms should be noted.
- If the class (noun) is required to implement a solution, then it is part of the solution space
- Otherwise, if a class is necessary only to describe a solution, it is part of the problem space.

Identifying Analysis Classes

- What should we look for once all of the nouns have been isolated?
 - *External entities* (e.g., other systems, devices, people) that produce or consume information to be used by a computer-based system.
 - *Things* (e.g., reports, displays, letters, signals) that are part of the information domain for the problem.
 - *Occurrences or events* (e.g., a property transfer or the completion of a series of robot movements) that occur within the context of system operation.
 - *Roles* (e.g., manager, engineer, salesperson) played by people who interact with the system.
 - *Organizational units* (e.g., division, group, team) that are relevant to an application.
 - *Places* (e.g., manufacturing floor or loading dock) that establish the context of the problem and the overall function of the system.
 - *Structures* (e.g., sensors, four-wheeled vehicles, or computers) that define a class of objects or related classes of objects.

Class-Based Modeling

- Class-based modeling represents:
 - **objects** that the system will manipulate
 - **operations** (also called methods or services) that will be applied to the objects to effect the manipulation
 - **relationships** (some hierarchical) between the objects
 - **collaborations** that occur between the classes that are defined.
- The elements of a class-based model include classes and objects, attributes, operations, CRC models, collaboration diagrams and packages.

Identifying Analysis Classes

- Examining the usage scenarios developed as part of the requirements model and perform a "grammatical parse" [Abb83]
 - Classes are determined by underlining each noun or noun phrase and entering it into a simple table.
 - Synonyms should be noted.
 - If the class (noun) is required to implement a solution, then it is part of the solution space; otherwise, if a class is necessary only to describe a solution, it is part of the problem space.
- But what should we look for once all of the nouns have been isolated?

Class

- It is also important to note what classes or objects are not.
- In general, a class should never have an “imperative procedural name” [Cas89].
 - E.g.) an object with the name **InvertImage** or even **ImageInversion**, they would be making a subtle mistake.
- It is likely that inversion would be defined as an operation for the object **Image**

Manifestations of Analysis Classes

- *Analysis classes* manifest themselves in one of the following ways:
 - *External entities* (e.g., other systems, devices, people) that produce or consume information
 - *Things* (e.g, reports, displays, letters, signals) that are part of the information domain for the problem
 - *Occurrences or events* (e.g., a property transfer or the completion of a series of robot movements) that occur within the context of system operation
 - *Roles* (e.g., manager, engineer, salesperson) played by people who interact with the system
 - *Organizational units* (e.g., division, group, team) that are relevant to an application
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Example: Performing “Grammatical Parse”

The SafeHome security function *enables* the homeowner to *configure* the security system when it is *installed*, *monitors* all sensors *connected* to the security system, and *interacts* with the homeowner through the Internet, a PC, or a control panel.

During installation, the SafeHome PC is used to *program* and *configure* the system. Each sensor is assigned a number and type, a master password is programmed for *arming* and *disarming* the system, and telephone number(s) are *input* for *dialing* when a sensor event occurs.

When a sensor event is *recognized*, the software *invokes* an audible alarm attached to the system. After a delay time that is *specified* by the homeowner during system configuration activities, the software dials a telephone number of a monitoring service, *provides* information about the location, *reporting* the nature of the event that has been detected. The telephone number will be *redialed* every 20 seconds until telephone connection is *obtained*.

The homeowner *receives* security information via a control panel, the PC, or a browser, collectively called an interface. The interface *displays* prompting messages and system status information on the control panel, the PC, or the browser window. Homeowner interaction takes the following form . . .

Example: Potential Classes

Potential Class

homeowner

sensor

control panel

installation

system (alias security system)

number, type

master password

telephone number

sensor event

audible alarm

monitoring service

General Classification

role or external entity

external entity

external entity

occurrence

thing

not objects, attributes of sensor

thing

thing

occurrence

external entity

organizational unit or external entity

Potential Classes

- *Retained information.* The potential class will be useful during analysis only if information about it must be remembered so that the system can function.
- *Needed services.* The potential class must have a set of identifiable operations that can change the value of its attributes in some way.
- *Multiple attributes.* During requirement analysis, the focus should be on "major" information; a class with a single attribute may, in fact, be useful during design, but is probably better represented as an attribute of another class during the analysis activity.
- *Common attributes.* A set of attributes can be defined for the potential class and these attributes apply to all instances of the class.
- *Common operations.* A set of operations can be defined for the potential class and these operations apply to all instances of the class.
- *Essential requirements.* External entities that appear in the problem space and produce or consume information essential to the operation of any solution for the system will almost always be defined as classes in the requirements model.

Example: Potential SafeHome Classes

Potential Class

homeowner

sensor

control panel

installation

system (alias security function)

number, type

master password

telephone number

sensor event

audible alarm

monitoring service

Characteristic Number That Applies

rejected: 1, 2 fail even though 6 applies

accepted: all apply

accepted: all apply

rejected

accepted: all apply

rejected: 3 fails, attributes of sensor

rejected: 3 fails

rejected: 3 fails

accepted: all apply

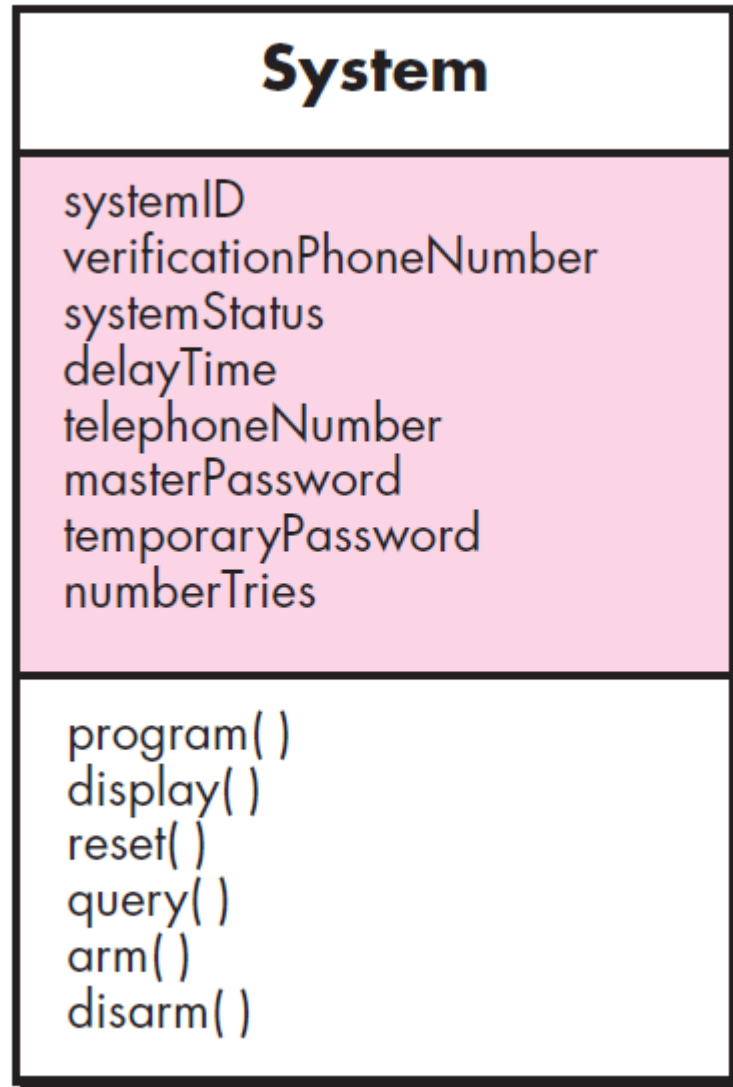
accepted: 2, 3, 4, 5, 6 apply

rejected: 1, 2 fail even though 6 applies

Specifying Attributes

- *Attributes* describe a class that has been selected for inclusion in the analysis model.
 - build two different classes for professional baseball players
 - **For Playing Statistics software:** name, position, batting average, fielding percentage, years played, and games played might be relevant
 - **For Pension Fund software:** average salary, credit toward full vesting, pension plan options chosen, mailing address, and the like.

Attributes: Example in System class for SafeHome



Defining Operations

- Do a grammatical parse of a processing narrative and look at the verbs
- Operations can be divided into four broad categories:
 - (1) operations that manipulate data in some way (e.g., adding, deleting, reformatting, selecting)
 - (2) operations that perform a computation
 - (3) operations that inquire about the state of an object, and
 - (4) operations that monitor an object for the occurrence of a controlling event.

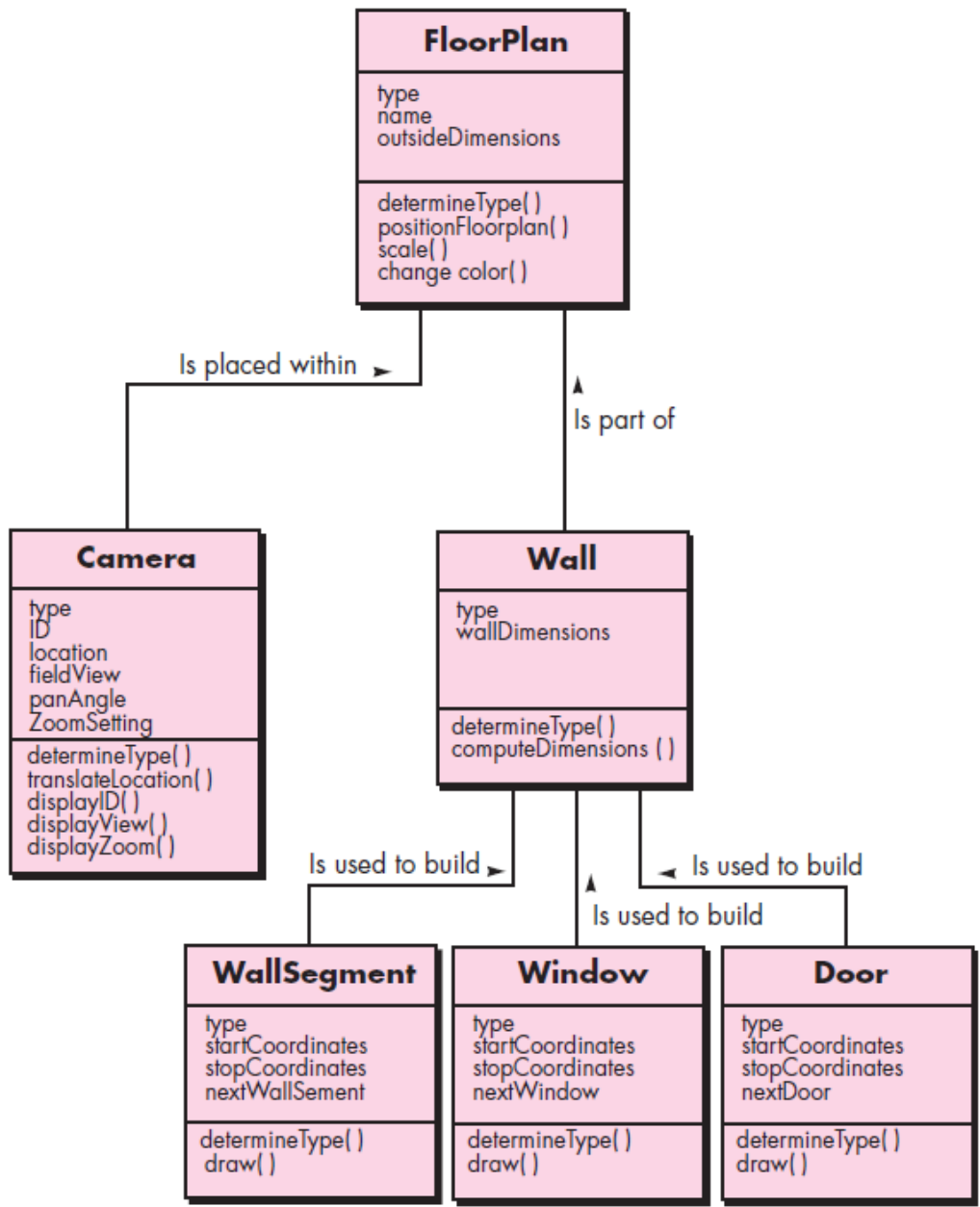
Example: SafeHome Processing Narrative

- Some of the verbs will be legitimate operations
 - They can be easily connected to a specific class
- **SafeHome** Processing Narrative
 - “sensor is *assigned* a number and type” or
 - “a master password is *programmed* for arming and disarming the system.”
- That an *assign()* operation is relevant for the **Sensor** class.
- That a *program()* operation will be applied to the **System** class.
- That *arm()* and *disarm()* are operations that apply to **System** class.

Communication b/w Objects

- We can gain additional insight into other operations by considering the communication that occurs between objects
- Objects communicate by passing messages to one another
- Described using CRC model

Example: Class Diagram for FloorPlan



These (McG)

CRC Models

- *Class-responsibility-collaborator (CRC) modeling* [Wir90] provides a simple means for identifying and organizing the classes that are relevant to system or product requirements. Ambler [Amb95] describes CRC modeling in the following way:
 - A CRC model is really a collection of standard index cards that represent classes. The cards are divided into three sections. Along the top of the card you write the name of the class. In the body of the card you list the class responsibilities on the left and the collaborators on the right.

CRC Modeling

- *Responsibilities* are the **attributes and operations** that are relevant for the class.
 - Stated simply, a responsibility is “anything the class knows or does” [Amb95].
- *Collaborators* are those classes that are required to provide a class with the information needed to complete a responsibility
- *Collaboration* implies either a request for information or a request for some action.

Example: CRF index card for FloorPlan

Class: FloorPlan	
Description	
Responsibility:	Collaborator:
Defines floor plan name/type	
Manages floor plan positioning	
Scales floor plan for display	
Scales floor plan for display	
Incorporates walls, doors, and windows	Wall
Shows position of video cameras	Camera

Class Types

- *Entity classes*, also called *model* or *business classes*, are extracted directly from the statement of the problem (e.g., FloorPlan and Sensor).
- *Boundary classes* are used to create the *interface* (e.g., interactive screen or printed reports) that the user sees and interacts with as the software is used.
- *Controller classes* manage a “*unit of work*” [UML03] from start to finish. That is, controller classes can be designed to manage
 - the *creation or update* of entity objects;
 - the *instantiation* of boundary objects as they obtain information from entity objects;
 - complex *communication* between sets of objects;
 - *validation of data communicated* between objects or between the user and the application.

Responsibilities

Guidelines for allocating responsibilities to classes

- System intelligence should be distributed across classes to best address the needs of the problem
- Each responsibility should be stated as generally as possible
- Information and the behavior related to it should reside within the same class
- Information about one thing should be localized with a single class, not distributed across multiple classes.
- Responsibilities should be shared among related classes, when appropriate.

Collaborations

- Classes fulfill their responsibilities in one of two ways:
 - A class can use its own operations to manipulate its own attributes, thereby fulfilling a particular responsibility, or
 - a class can collaborate with other classes.
- Collaborations identify relationships between classes
- Collaborations are identified by determining whether a class can fulfill each responsibility itself
 - If it cannot, then it needs to interact with another class. Hence, a collaboration

Example: SafeHome Security Function

the **ControlPanel** object must determine whether any sensors are open.



A responsibility named *determine-sensor-status()* is defined.



If sensors are open, **ControlPanel** must set a status attribute to “not ready.”



Sensor information can be acquired from each **Sensor** object.



the responsibility *determine-sensor-status()* can be fulfilled only if **ControlPanel** works in collaboration with **Sensor**.

Three different generic relationships b/w classes

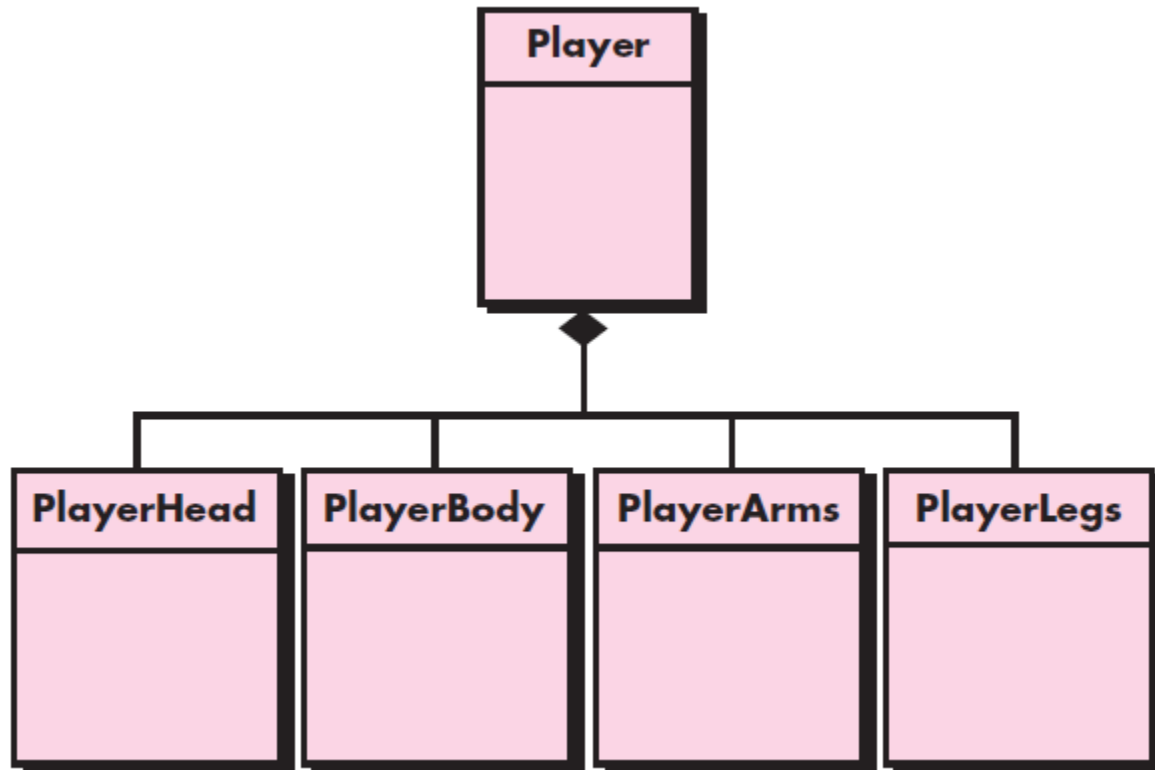
- Three general relationships [WIR90]
 - the *is-part-of* relationship
 - the *has-knowledge-of* relationship
 - the *depends-upon* relationship

Is-part-of relationship

- All classes that are part of an aggregate class are connected to the aggregate class
- Consider the classes defined for the video game,
- the class **PlayerBody** *is-part-of* **Player**, as are **PlayerArms**, **PlayerLegs**, and **PlayerHead**.

Is-part-of relationship: Example in Player

- URM representation



Has-knowledge-of relationship

- When one class must acquire information from another class
- Example
 - The *determine-sensor-status()* responsibility in ControlPanel class is an example of a *has-knowledge-of* relationship.

Depends-upon relationship

- two classes have a dependency that is not achieved by *has-knowledge-of* or *is-part-of*.
- Example:
 - **PlayerHead** *depends-upon* **PlayerBody**
 - **PlayerHead** must always be connected to **PlayerBody** yet each object could exist without direct knowledge of the other.
 - An attribute of the **PlayerHead** object called center-position is determined from the center position of **PlayerBody**. This information is obtained via a third object, **Player**, that acquires it from **PlayerBody**.

CRC model index card

- The index card contains a list of responsibilities and the corresponding collaborations that enable the responsibilities to be fulfilled
 - the collaborator class name is recorded on the CRC model index card next to the responsibility

Reviewing the CRC Model

- All participants in the review (of the CRC model) are given a subset of the CRC model index cards.
 - Cards that collaborate should be separated (i.e., no reviewer should have two cards that collaborate).
- All use-case scenarios (and corresponding use-case diagrams) should be organized into categories.
- The review leader reads the use-case deliberately.
 - As the review leader comes to a named object, she passes a token to the person holding the corresponding class index card.
- When the token is passed, the holder of the class card is asked to describe the responsibilities noted on the card.
 - The group determines whether one (or more) of the responsibilities satisfies the use-case requirement.
- If the responsibilities and collaborations noted on the index cards cannot accommodate the use-case, modifications are made to the cards.
 - This may include the definition of new classes (and corresponding CRC index cards) or the specification of new or revised responsibilities or collaborations on existing cards.

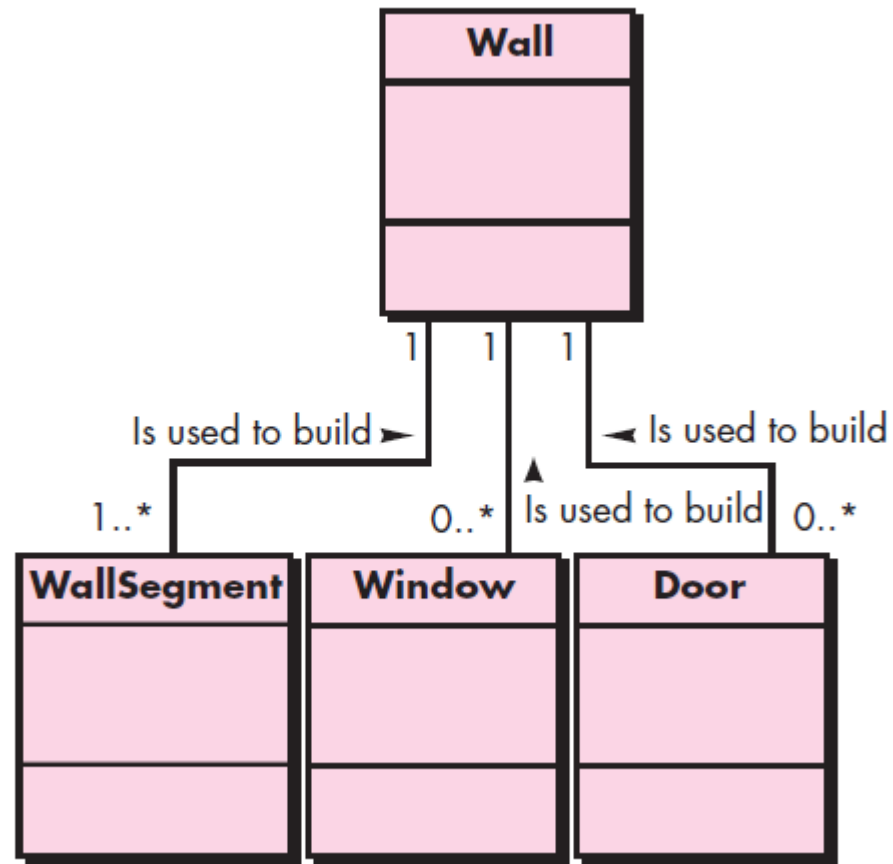
Associations and Dependencies

- Two analysis classes are often related to one another in some fashion
 - In UML these relationships are called *associations*
 - Associations can be refined by indicating *multiplicity* (the term *cardinality* is used in data modeling)
- In many instances, a client-server relationship exists between two analysis classes.
 - In such cases, a client-class depends on the server-class in some way and a *dependency relationship* is established

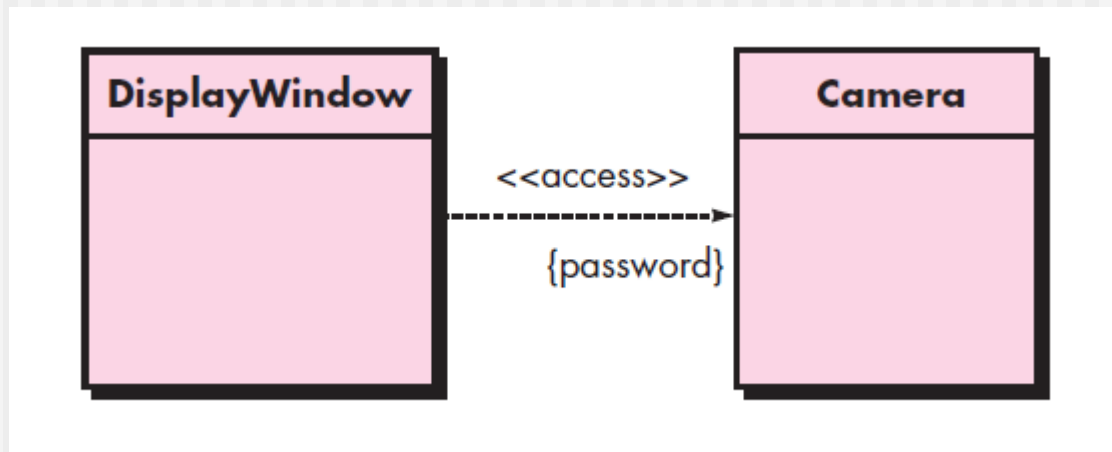
Associations and Dependencies

- **Association** defines a relationship between classes.
- **Multiplicity** defines how many of one class are related to how many of another class
- Dependencies are defined by **a stereotype**.
 - A *stereotype* is an “**extensibility mechanism**” [Arl02] within UML that allows you to define a special modeling element whose semantics are custom defined.
 - In **UML stereotypes** are represented in double angle brackets (e.g., <<stereotype>>).

Multiplicity



Dependencies



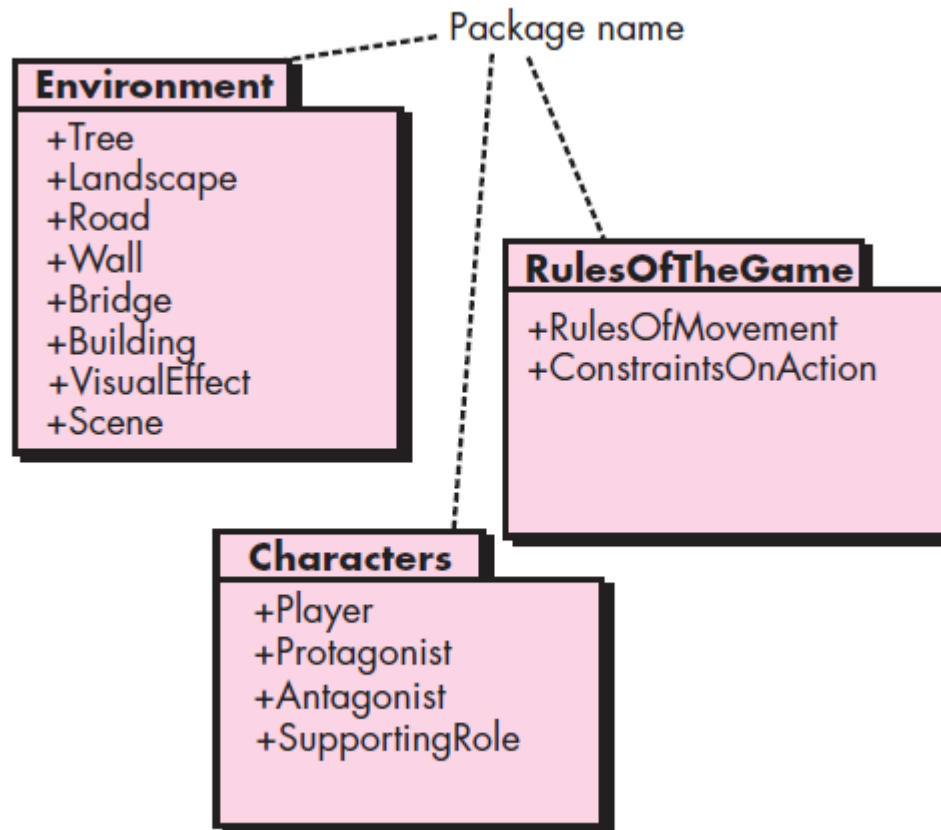
Analysis Packages

- A package is used to assemble a collection of related classes
- Various elements of the analysis model (e.g., use-cases, analysis classes) are categorized in a manner that packages them as a grouping
- **The plus sign preceding the analysis class name in each package** indicates that the classes have public visibility and are therefore accessible from other packages.
- Other symbols can precede an element within a package. **A minus sign indicates that an element is hidden** from all other packages and a # symbol indicates that an element is accessible only to packages contained within a given package.

Analysis Packages: Example

- Game environment
 - The visual scenes that the user sees as the game is played.
 - Classes such as **Tree**, **Landscape**, **Road**, **Wall**, **Bridge**, **Building**, and **VisualEffect**
- Characters within the game
 - Describing their physical features, actions, and constraints
 - Classes such as **Player** (described earlier), **Protagonist**, **Antagonist**, and **SupportingRoles**
- Rules of the game
 - How a player navigates through the environment
 - **RulesOfMovement** and **ConstraintsOnAction**

Analysis Packages: Example



Summary

- Class-based modeling
 - Use information derived from use cases and other written application descriptions to identify analysis classes
 - A grammatical parse may be used to extract candidate classes, attributes, and operations from text-based narratives
- A set of class-responsibility-collaborator index cards
 - Can be used to define relationships b/w classes
 - A variety of ML modeling notation can be applied to define hierarchies, relationships, associations, aggregations and dependencies among classes
- Analysis packages can be used to categorize and group classes in a manner that makes them more manageable for large systems