Unit II

Advanced Structural Modeling

- A relationship is a connection among things. In object-oriented modeling, the four most important relationships are dependencies, generalizations, associations, and realizations.
- Graphically, a relationship is rendered as a path, with different kinds of lines used to distinguish the different relationships.

Dependency

- A dependency is a using relationship, specifying that a change in the specification of one thing may affect another thing that uses it, but not necessarily the reverse. Graphically, a dependency is rendered as a dashed line
- A plain, unadorned dependency relationship is sufficient for most of the using relationships you'll encounter. However, if you want to specify a shade of meaning, the UML defines a number of stereotypes that may be applied to dependency relationships.
- There are 17 such stereotypes, all of which can be organized into six groups.

- First, there are eight stereotypes that apply to dependency relationships among classes and objects in class diagrams.

1	**bind**	Specifies that the source instantiates the target template using the given actual parameters
2	**derive**	Specifies that the source may be computed from the target
3	**friend**	Specifies that the source is given special visibility into the target
4	**instanceOf**	Specifies that the source object is an instance of the target classifier
5	**instantiate**	Specifies that the source creates instances of the target
6	**powertype**	Specifies that the target is a powertype of the source; a powertype is a classifier whose objects are all the children of a given parent
7	**refine**	Specifies that the source is at a finer degree of abstraction than the target
8	**use**	Specifies that the semantics of the source element depends on the semantics of the public part of the target

bind:
bind includes a list of actual arguments that map to the formal arguments of the template.

derive
When you want to model the relationship between two attributes or two associations, one of which is concrete and the other is conceptual.

friend
When you want to model relationships such as found with C++ friend classes.

instanceOf
When you want to model the relationship between a class and an object in the same diagram, or between a class and its metaclass.

instantiate
when you want to specify which element creates objects of another.

powertype
when you want to model classes that cover other classes, such as you'll find when modeling databases

refine
when you want to model classes that are essentially the same but at different levels of abstraction.

use
when you want to explicitly mark a dependency as a using relationship

* There are two stereotypes that apply to dependency relationships among packages.

9	**access**	Specifies that the source package is granted the right to reference the elements of the target package
10	**import**	A kind of access that specifies that the public contents of the target package enter the flat namespace of the source, as if they had been declared in the source

* Two stereotypes apply to dependency relationships among use cases:

11	**extend**	Specifies that the target use case extends the behavior of the source
12	**include**	Specifies that the source use case explicitly incorporates the behavior of another use case at a location specified by the source

* There are three stereotypes when modeling interactions among objects.

13	**become**	Specifies that the target is the same object as the source but at a later point in time and with possibly different values, state, or roles
14	**call**	Specifies that the source operation invokes the target operation
15	**copy**	Specifies that the target object is an exact, but independent, copy of the source

* We'll use become and copy when you want to show the role, state, or attribute value of one object at
different points in time or space

* You'll use call when you want to model the calling dependencies among operations.

* One stereotype you'll encounter in the context of state machines is

16	**send**	Specifies that the source operation sends the target event

* We'll use send when you want to model an operation dispatching a given event to a target object.
* The send dependency in effect lets you tie independent state machines together.

Finally, one stereotype that you'll encounter in the context of organizing the elements of your system into subsystems and models is

17	**trace**	Specifies that the target is an historical ancestor of the source

* We'll use trace when you want to model the relationships among elements in different models

<u>Generalization</u>

A generalization is a relationship between a general thing (called the superclass or parent) and a more specific kind of that thing(called the subclass or child).

In a generalization relationship, instances of the child may be used anywhere instances of the parent apply—meaning that the child is substitutable for the parent.

A plain, unadorned generalization relationship is sufficient for most of the inheritance relationships you'll encounter. However, if you want to specify a shade of meaning,

The UML defines one stereotype and four constraints that may be applied to generalization relationships.

1	**implementation**	Specifies that the child inherits the implementation of the parent but does not make public nor support its interfaces, thereby violating substitutability

<u>implementation</u>

- We'll use implementation when you want to model private inheritance, such as found in C++.

Next, there are four standard constraints that apply to generalization relationships

1	**complete**	Specifies that all children in the generalization have been specified in the model and that no additional children are permitted
2	**incomplete**	Specifies that not all children in the generalization have been specified (even if some are elided) and that additional children are permitted
3	**disjoint**	Specifies that objects of the parent may have no more than one of the children as a type
4	**overlapping**	Specifies that objects of the parent may have more than one of the children as a type

complete

- We'll use the complete constraint when you want to show explicitly that you've fully specified a hierarchy in the model (although no one diagram may show that hierarchy);

incomplete

- We'll use incomplete to show explicitly that you have not stated the full specification of the hierarchy in the model (although one diagram may show everything in the model).

Disjoint & overlapping

- These two constraints apply only in the context of multiple inheritance.
- We'll use disjoint and overlapping when you want to distinguish between static classification (disjoint) and dynamic classification (overlapping).

Association

An association is a structural relationship, specifying that objects of one thing are connected to objects of another.

We use associations when you want to show structural relationships.

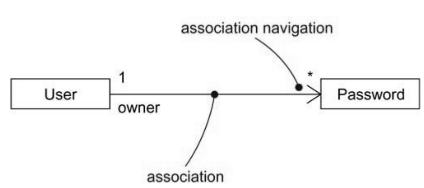
There are four basic adornments that apply to an association: a name, the role at each end of the association, the multiplicity at each end of the association, and aggregation.

For advanced uses, there are a number of other properties you can use to model subtle details, such as

Navigation
Vision
Qualification
various flavors of aggregation.

Navigation

- unadorned association between two classes, such as Book and Library, it's possible to navigate from objects of one kind to objects of the other kind. Unless otherwise specified, navigation across an association is bidirectional.
- However, there are some circumstances in which you'll want to limit navigation to just one direction.

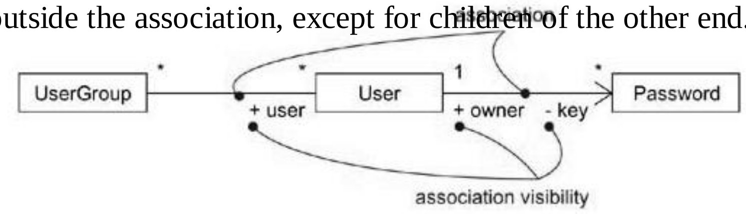


Navigation

Visibility

- Given an association between two classes, objects of one class can see and navigate to objects of the other, unless otherwise restricted by an explicit statement of navigation.
- However, there are circumstances in which you'll want to limit the visibility across that association relative to objects outside the association.
- In the UML, you can specify three levels of visibility for an association end, just as you can for a class's features by appending a visibility symbol to a role name the visibility of a role is public.

- Private visibility indicates that objects at that end are not accessible to any objects outside the association.
- Protected visibility indicates that objects at that end are not accessible to any objects outside the association, except for children of the other end.



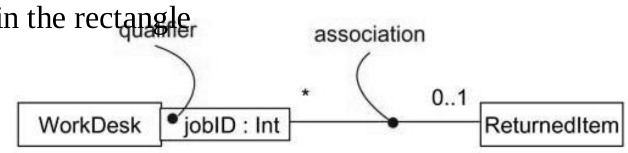
Visibility

Qualification

In the context of an association, one of the most common modeling idioms you'll encounter is the problem of lookup. Given an object at one end of an association, how do you identify an object or set of objects at the other end?

In the UML, you'd model this idiom using a qualifier, which is an association attribute whose values partition the set of objects related to an object across an association.

You render a qualifier as a small rectangle attached to the end of an association, placing the attributes in the rectangle.



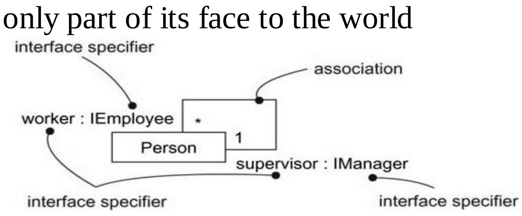
Qualification

Interface Specifier

An interface is a collection of operations that are used to specify a service of a class or a component

Collectively, the interfaces realized by a class represent a complete specification of the behavior of that class.

However, in the context of an association with another target class, a source class may choose to present only part of its face to the world



a Person class may realize many interfaces: IManager, IEmployee, IOfficer, and so on

you can model the relationship between a supervisor and her workers with a one-to-many

association, explicitly labeling the roles of this association as supervisor and worker

- In the context of this association, a Person in the role of supervisor presents only the IManager face to the worker; a Person in the role of worker presents only the IEmployee face to the supervisor. As the figure shows, you can explicitly show the type of role using the syntax rolename : iname, where iname is some interface of the other classifier.

Composition

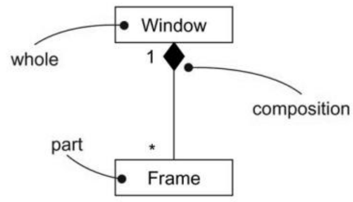
* Simple aggregation is entirely conceptual and does nothing more than distinguish a "whole" from a "part."

* Composition is a form of aggregation, with strong ownership and coincident lifetime as part of the whole.

* Parts with non-fixed multiplicity may be created after the composite itself, but once created they live and die with it. Such parts can also be explicitly removed before the death of the composite.

* This means that, in a composite aggregation, an object may be a part of only one composite at a time

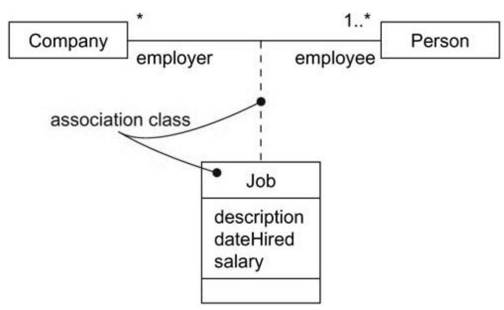
* In addition, in a composite aggregation, the whole is responsible for the disposition of its parts, which
means that the composite must manage the creation and destruction of its parts



Composition

Association Classes

* In an association between two classes, the association itself might have properties.
* An association class can be seen as an association that also has class properties, or as a class that also has
association properties.
* We render an association class as a class symbol attached by a dashed line to an association



Association Classes

Constraints

* UML defines five constraints that may be applied to association relationships.

1	**implicit**	Specifies that the relationship is not manifest but, rather, is only conceptual
2	**ordered**	Specifies that the set of objects at one end of an association are in an explicit order
3	**changeable**	Links between objects may be added, removed, and changed freely
4	**addOnly**	New links may be added from an object on the opposite end of the association
5	**frozen**	A link, once added from an object on the opposite end of the association, may not be modified or deleted

implicit

* if you have an association between two base classes, you can specify that same association between two
children of those base classes

* you can specify that the objects at one end of an association (with a multiplicity greater than one) are
ordered or unordered.

ordered

* For example, in a User/Password association, the Passwords associated with the User might be kept in a
least-recently used order, and would be marked as ordered.

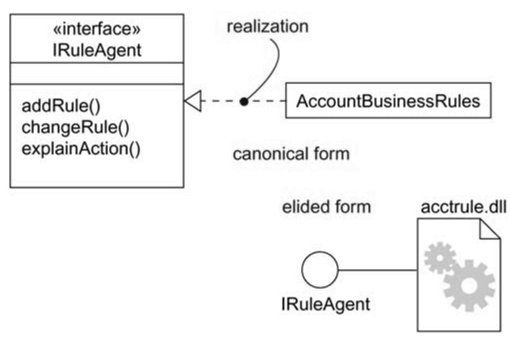
Finally, there is one constraint for managing related sets of associations:

1	**xor**	Specifies that, over a set of associations, exactly one is manfest for each

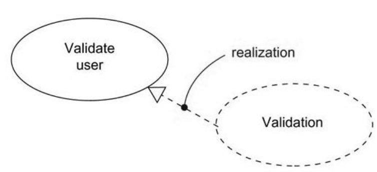
		associated object

Realization

1. Realization is sufficiently different from dependency, generalization, and association relationships that it is treated as a separate kind of relationship.
2. A realizationis a semantic relationship between classifiers in which one classifier specifies a contract that another classifier guarantees to carry out.
3. Graphically, a realization is rendered as a dashed directed line with a large open arrowhead pointing to the classifier that specifies the contract.
4. You'll use realization in two circumstances: in the context of interfaces and in the context of collaborations
5. Most of the time, you'll use realization to specify the relationship between an interface and the class or component that provides an operation or service for it
6. You'll also use realization to specify the relationship between a use case and the collaboration that realizes that use case



Realization of an Interface



Realization of a Use Case

Common Modeling Techniques

Modeling Webs of Relationships

1. When you model the vocabulary of a complex system, you may encounter dozens, if not hundreds or thousands, of classes, interfaces, components, nodes, and use cases.
2. Establishing a crisp boundary around each of these abstractions is hard
3. This requires you to form a balanced distribution of responsibilities in the system as a whole, with individual abstractions that are tightly cohesive and with relationships that are expressive, yet loosely coupled
4. When you model these webs of relationships,
    - Don't begin in isolation. Apply use cases and scenarios to drive your discovery of the relationships among a set of abstractions.
    - In general, start by modeling the structural relationships that are present. These reflect the static view of the system and are therefore fairly tangible.
    - Next, identify opportunities for generalization/specialization relationships; use multiple inheritance sparingly.
    - Only after completing the preceding steps should you look for dependencies; they generally represent more-subtle forms of semantic connection.
    - For each kind of relationship, start with its basic form and apply advanced features only as absolutely necessary to express your intent.

- Remember that it is both undesirable and unnecessary to model all relationships among a set of abstractions in a single diagram or view. Rather, build up your system's relationships by considering different views on the system. Highlight interesting sets of relationships in individual diagrams.

Interfaces, type and roles

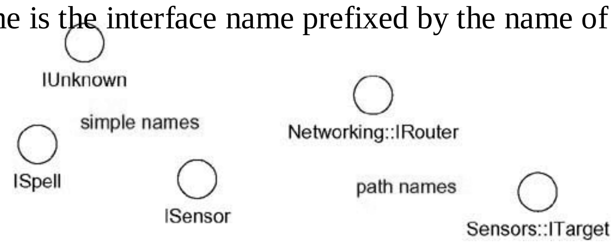
Interface
- An interface is a collection of operations that are used to specify a service of a class or a component

type
- A type is a stereotype of a class used to specify a domain of objects, together with the operations (but not the methods) applicable to the object.

role
- A role is the behavior of an entity participating in a particular context.

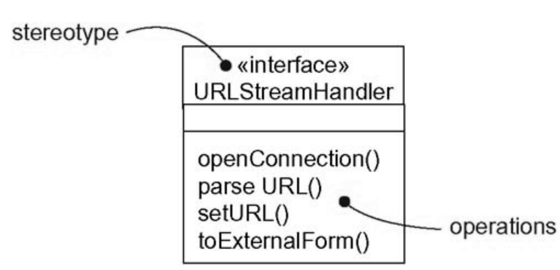
an interface may be rendered as a stereotyped class in order to expose its operations and other properties.

Names
- Every interface must have a name that distinguishes it from other interfaces.
- A name is a textual string. That name alone is known as a simple name;
- A path name is the interface name prefixed by the name of the package



Simple and Path Names

Operations
- An interface is a named collection of operations used to specify a service of a class or of a component.
- Unlike classes or types, interfaces do not specify any structure (so they may not include any attributes), nor do they specify any implementation
- These operations may be adorned with visibility properties, concurrency properties, stereotypes, tagged values, and constraints.
- you can render an interface as a stereotyped class, listing its operations in the appropriate compartment. Operations may be drawn showing only their name, or they may be augmented to show their full signature and other properties



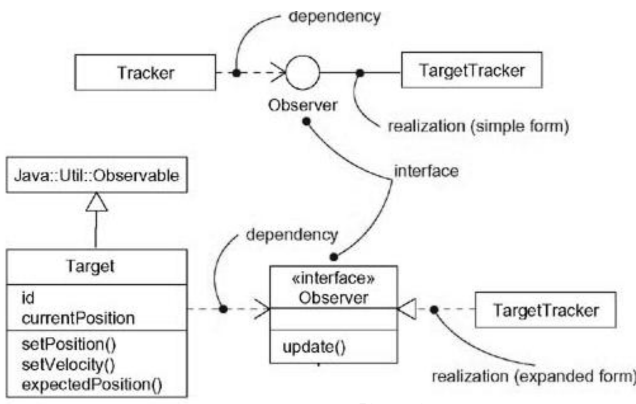
Operations

Relationships

- Like a class, an interface may participate in generalization, association, and dependency relationships. In addition, an interface may participate in realization relationships.
- An interface specifies a contract for a class or a component without dictating its implementation. A class or component may realize many interfaces

- We can show that an element realizes an interface in two ways.
  - First, you can use the simple form in which the interface and its realization relationship are rendered as a lollipop sticking off to one side of a class or component.

  - Second, you can use the expanded form in which you render an interface as a stereotyped class, which allows you to visualize its operations and other properties, and then draw a realization relationship from the classifier or component to the interface.



Realizations

Understanding an Interface

- In the UML, you can supply much more information to an interface in order to make it understandable and approachable.

- First, you may attach pre- and postconditions to each operation and invariants to the class or component as a whole. By doing this, a client who needs to use an interface will be able to understand what the interface does and how to use it, without having to dive into an implementation.

- We can attach a state machine to the interface. You can use this state machine to specify the legal partial ordering of an interface's operations.

- We can attach collaborations to the interface. You can use collaborations to specify the expected behavior of the interface through a series of interaction diagrams.

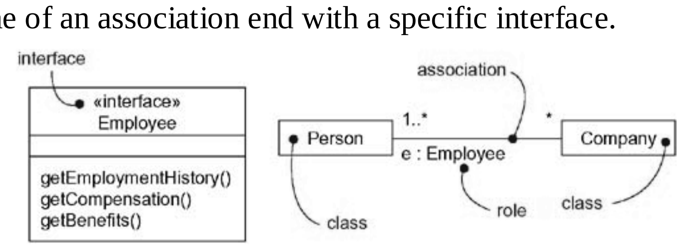
Types and Roles

A role names a behavior of an entity participating in a particular context. Stated another way, a role is the face that an abstraction presents to the world.

For example, consider an instance of the class Person. Depending on the context, that Person instance may play the role of Mother, Comforter, PayerOfBills, Employee, Customer, Manager, Pilot, Singer, and so on. When an object plays a particular role, it presents a face to the world, and clients that interact with it expect a certain behavior depending on the role that it plays at the time.

an instance of Person in the role of Manager would present a different set of properties than if the instance were playing the role of Mother.

In the UML, you can specify a role an abstraction presents to another abstraction by adorning the name of an association end with a specific interface.



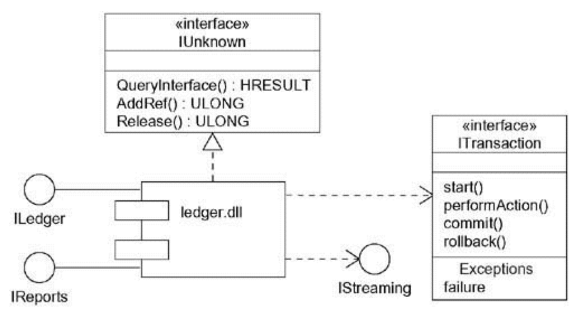
Roles

- A class diagram like this one is useful for modeling the static binding of an abstraction to its interface. You can model the dynamic binding of an abstraction to its interface by using the become stereotype in an interaction diagram, showing an object changing from one role to another.
- If you want to formally model the semantics of an abstraction and its conformance to a specific interface, you'll want to use the defined stereotype type
- Type is a stereotype of class, and you use it to specify a domain of objects, together with the operations (but not the methods) applicable to the objects of that type. The concept of type is closely related to that of interface, except that a type's definition may include attributes while an interface may not.

Common Modeling Techniques

➢ Modeling the Seams in a Systemeling the Seams in a System

- The most common purpose for which you'll use interfaces is to model the seams in a system composed of software components, such as COM+ or Java Beans.
- Identifying the seams in a system involves identifying clear lines of demarcation in your architecture. On either side of those lines, you'll find components that may change independently, without affecting the components on the other side,



Modeling the Seams in a System

- The above Figure shows the seams surrounding a component (the library ledger.dll) drawn from a financial system. This component realizes three interfaces: IUnknown, ILedger, and IReports. In this diagram, IUnknown is shown in its expanded form; the other two are shown in their simple form, as lollipops. These three interfaces are realized by ledger.dll and are exported to other components for them to build on.
- As this diagram also shows, ledger.dll imports two interfaces, IStreaming and ITransaction, the latter of which is shown in its expanded form. These two interfaces are required by the ledger.dll component for its proper operation. Therefore, in a running system, you must supply components that realize these two interfaces.
- By identifying interfaces such as ITransaction, you've effectively decoupled the components on either side of the interface, permitting you to employ any component that conforms to that interface.

➢ Modeling Static and Dynamic Typeseling Static and Dynamic Types

- Most object-oriented programming languages are statically typed, which means that the type of an object is bound at the time the object is created.
- Even so, that object will likely play different roles over time.
- Modeling the static nature of an object can be visualized in a class diagram. However, when you are modeling things like business objects, which naturally change their roles throughout a workflow,
- To model a dynamic type
    - o Specify the different possible types of that object by rendering each type as a class stereotyped as
      type (if the abstraction requires structure and behavior) or as interface (if the
  abstraction requires

only behavior).

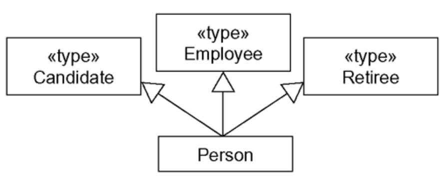
- Model all the roles the of the object may take on at any point in time. You can do so in two ways:

1.) First, in a class diagram, explicitly type each role that the class plays in its association with
Other classes. Doing this specifies the face instances of that class put on in the context of the
associated object.

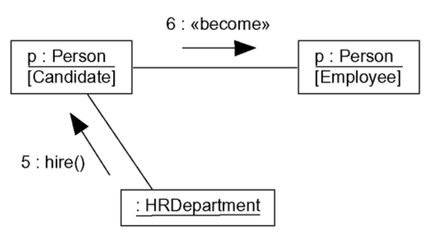
2.) Second, also in a class diagram, specify the class-to-type relationships using generalization.

- In an interaction diagram, properly render each instance of the dynamically typed class. Display
the role of the instance in brackets below the object's name.

- To show the change in role of an object, render the object once for each role it plays in the
interaction, and connect these objects with a message stereotyped as become.



Modeling Static Types



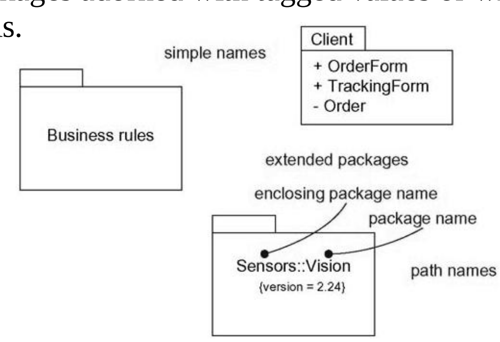
Modeling Dynamic Types

Package

"A package is a general-purpose mechanism for organizing elements into groups." Graphically, a package is rendered as a tabbed folder.

Names

- Every package must have a name that distinguishes it from other packages. A name is a textual string.
- That name alone is known as a simple name; a path name is the package name prefixed by the name of the package in which that package lives
- We may draw packages adorned with tagged values or with additional compartments to expose their details.



Simple and Extended Package

Owned Elements

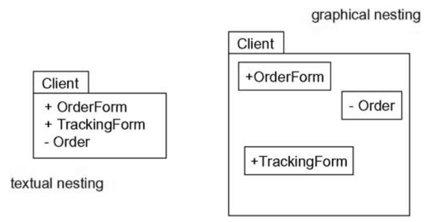
A package may own other elements, including classes, interfaces, components, nodes, collaborations, use cases, diagrams, and even other packages.

Owning is a composite relationship, which means that the element is declared in the package. If the package is destroyed, the element is destroyed. Every element is uniquely owned by exactly one package.

Elements of different kinds may have the same name within a package. Thus, you can have a class named Timer, as well as a component named Timer, within the same package.

Packages may own other packages. This means that it's possible to decompose your models hierarchically.

We can explicitly show the contents of a package either textually or graphically.



Owned Elements

<u>Visibility</u>

You can control the visibility of the elements owned by a package just as you can control the visibility of the attributes and operations owned by a class.

Typically, an element owned by a package is public, which means that it is visible to the contents of any package that imports the element's enclosing package.

Conversely, protected elements can only be seen by children, and private elements cannot be seen outside the package in which they are declared.

We specify the visibility of an element owned by a package by prefixing the element's name with an appropriate visibility symbol.

<u>Importing and Exporting</u>

In the UML, you model an import relationship as a dependency adorned with the stereotype import

Actually, two stereotypes apply here—import and access— and both specify that the source package has access to the contents of the target.

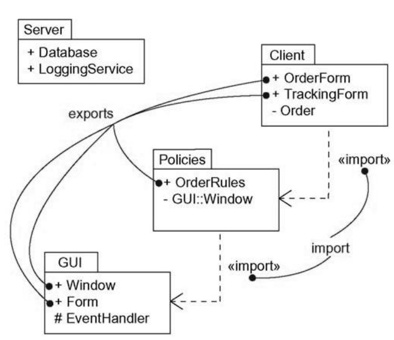
Import adds the contents of the target to the source's namespace

Access does not add the contents of the target

The public parts of a package are called its exports.

The parts that one package exports are visible only to the contents of those packages that explicitly import the package.

Import and access dependencies are not transitive



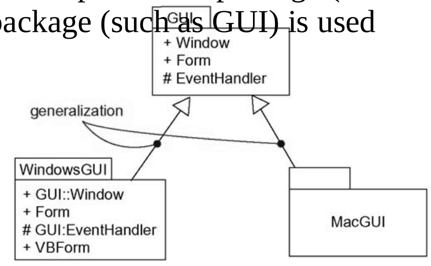
Importing and Exporting

<u>Generalization</u>

There are two kinds of relationships you can have between packages: import and access dependencies used to import into one package elements exported from another and generalizations, used to specify families of packages

Generalization among packages is very much like generalization among classes

Packages involved in generalization relationships follow the same principle of substitutability as do classes. A specialized package (such as WindowsGUI) can be used anywhere a more general package (such as GUI) is used



Generalization Among Packages

Standard Elements

- All of the UML's extensibility mechanisms apply to packages. Most often, you'll use tagged values to add new package properties (such as specifying the author of a package) and stereotypes to specify new kinds of packages (such as packages that encapsulate operating system services).
- The UML defines five standard stereotypes that apply to packages

1. facade	Specifies a package that is only a view on some other package
2. framework	Specifies a package consisting mainly of patterns
3. stub	Specifies a package that serves as a proxy for the public contents of another package
4. subsystem	Specifies a package representing an independent part of the entire system being modeled
5. system	Specifies a package representing the entire system being modeled

The UML does not specify icons for any of these stereotypes

Common Modeling Techniques

Modeling Groups of Elements

The most common purpose for which you'll use packages is to organize modeling elements into groups that you can name and manipulate as a set.

There is one important distinction between classes and packages:

Packages have no identity (meaning that you can't have instances of packages, so they are invisible in the running system);

classes do have identity (classes have instances, which are elements of a running system).

To model groups of elements,

Scan the modeling elements in a particular architectural view and look for clumps defined by elements that are conceptually or semantically close to one another.

Surround each of these clumps in a package.

For each package, distinguish which elements should be accessible outside the package. Mark them public, and all others protected or private. When in doubt, hide the element.

Explicitly connect packages that build on others via import dependencies

In the case of families of packages, connect specialized packages to their more general part via generalizations

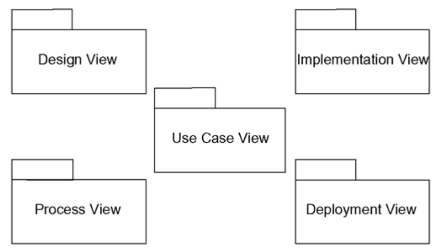
Modeling Architectural Views

- We can use packages to model the views of an architecture.
- Remember that a view is a projection into the organization and structure of a system, focused on a particular aspect of that system.
- This definition has two implications. First, you can decompose a system into almost orthogonal packages, each of which addresses a set of architecturally significant decisions.(design view, a process view, an implementation view, a deployment view, and a use case view)
- Second, these packages own all the abstractions germane to that view.(Implementation view)
- To model architectural views,
  - Identify the set of architectural views that are significant in the context of your problem. In practice, this typically includes a design view, a process view, an implementation view, a deployment view, and a use case view.

- Place the elements (and diagrams) that are necessary and sufficient to visualize, specify, construct,
  and document the semantics of each view into the appropriate package.

- As necessary, further group these elements into their own packages.

- There will typically be dependencies across the elements in different views. So, in general, let each
  view at the top of a system be open to all others at that level.



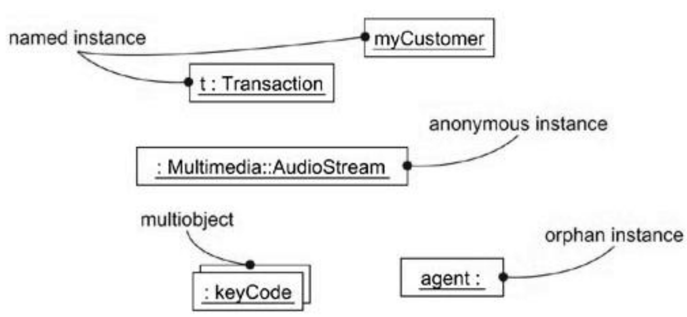
Modeling Architectural Views

Instances

- An instance is a concrete manifestation of an abstraction to which a set of operations can be applied and which has a state that stores the effects of the operations.
- Graphically, an instance is rendered by underlining its name.

Abstractions and Instances

- Most instances you'll model with the UML will be instances of classes although you can have instances of other things, such as components, nodes, use cases, and associations
- In the UML, an instance is easily distinguishable from an abstraction. To indicate an instance, you underline its name.
- We can use the UML to model these physical instances, but you can also model things that are not so concrete.



Named, Anonymous, Multiple, and Orphan Instances

Names

- Every instance must have a name that distinguishes it from other instances within its context.
- Typically, an object lives within the context of an operation, a component, or a node.
- A name is a textual string. That name alone is known as a simple name. or it may be a path name

Operations

- The operations you can perform on an object are declared in the object's abstraction
- For example, if the class Transaction defines the operation commit, then given the instance t : Transaction, you can write expressions such as t.commit()

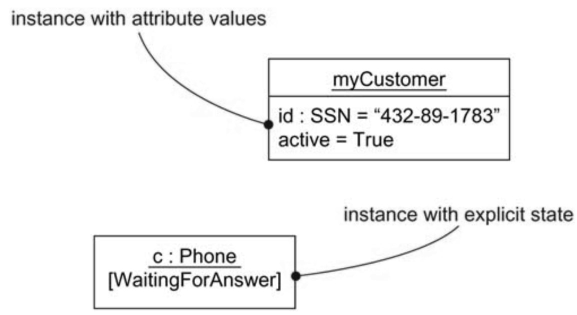
State

An object also has state. An object's state is therefore dynamic. So when you visualize its state, you are really specifying the value of its state at a given moment in time and space.

It's possible to show the changing state of an object by showing it multiple times in the same interaction diagram, but with each occurrence representing a different state.

When you operate on an object, you typically change its state;

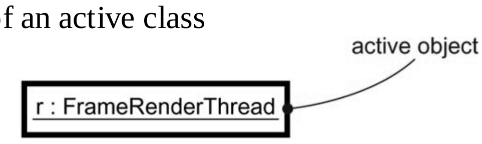
when you query an object, you don't change its state



Other Features

Processes and threads are an important element of a system's process view, so the UML provides a visual cue to distinguish elements that are active from those that are passive.

You can declare active classes that reify a process or thread, and in turn you can distinguish an instance of an active class

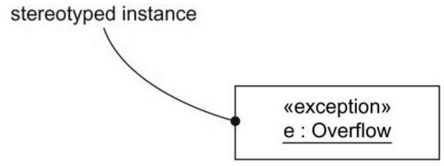


Active Objects

- There are two other elements in the UML that may have instances
- The first is a link. A link is a semantic connection among objects. An instance of an association is therefore a link. A link is rendered as a line
- The second is a class-scoped attribute and operation. A class-scoped feature is in effect an object in the class that is shared by all instances of the class.

Standard Elements

- All of the UML's extensibility mechanisms apply to objects. Usually, however, you don't stereotype an instance directly, nor do you give it its own tagged values. Instead, an object's stereotype and tagged values derive from the stereotype and tagged values of its associated abstraction.



Stereotyped Objects

The UML defines two standard stereotypes that apply to the dependency relationships among objects and among classes:

1. instanceOf	Specifies that the client object is an instance of the supplier classifier
2. instantiate	Specifies that the client class creates instances of the supplier class

There are also two stereotypes related to objects that apply to messages and transitions:

1. become	Specifies that the client is the same object as the supplier, but at a later time and with possibly different values, state, or roles
2. copy	Specifies that the client object is an exact but independent copy of the supplier

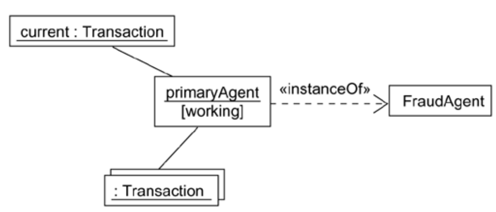
The UML defines a standard constraint that applies to objects:

transient	Specifies that an instance of the role is created during execution of the enclosing interaction but is destroyed before completion of execution

Common Modeling Techniques

Modeling Concrete Instances

- When you model concrete instances, you are in effect visualizing things that live in the real world
- One of the things for which you'll use objects is to model concrete instances that exist in the real world
- To model concrete instances,
    - Identify those instances necessary and sufficient to visualize, specify, construct, or document the problem you are modeling.
    - Render these objects in the UML as instances. Where possible, give each object a name. If there is no meaningful name for the object, render it as an anonymous object.
    - Expose the stereotype, tagged values, and attributes (with their values) of each instance necessary and sufficient to model your problem.
    - Render these instances and their relationships in an object diagram or other diagram appropriate to the kind of the instance.

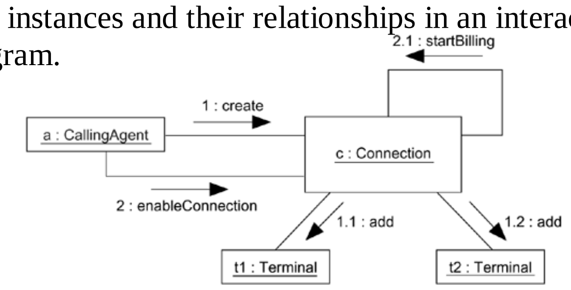


Modeling Concrete Instances

Modeling Prototypical Instances

- Perhaps the most important thing for which you'll use instances is to model the dynamic interactions among objects. When you model such interactions, you are generally not modeling concrete instances that exist in the real world.
- These are prototypical objects and, therefore, are roles to which concrete instances conform.
- Concrete objects appear in static places, such as object diagrams, component diagrams, and deployment diagrams.
- Prototypical objects appear in such places as interaction diagrams and activity diagrams.
- To model prototypical instances,
    - Identify those prototypical instances necessary and sufficient to visualize, specify, construct, or document the problem you are modeling.
    - Render these objects in the UML as instances. Where possible, give each object a name. If there is no meaningful name for the object, render it as an anonymous object.
    - Expose the properties of each instance necessary and sufficient to model your problem.

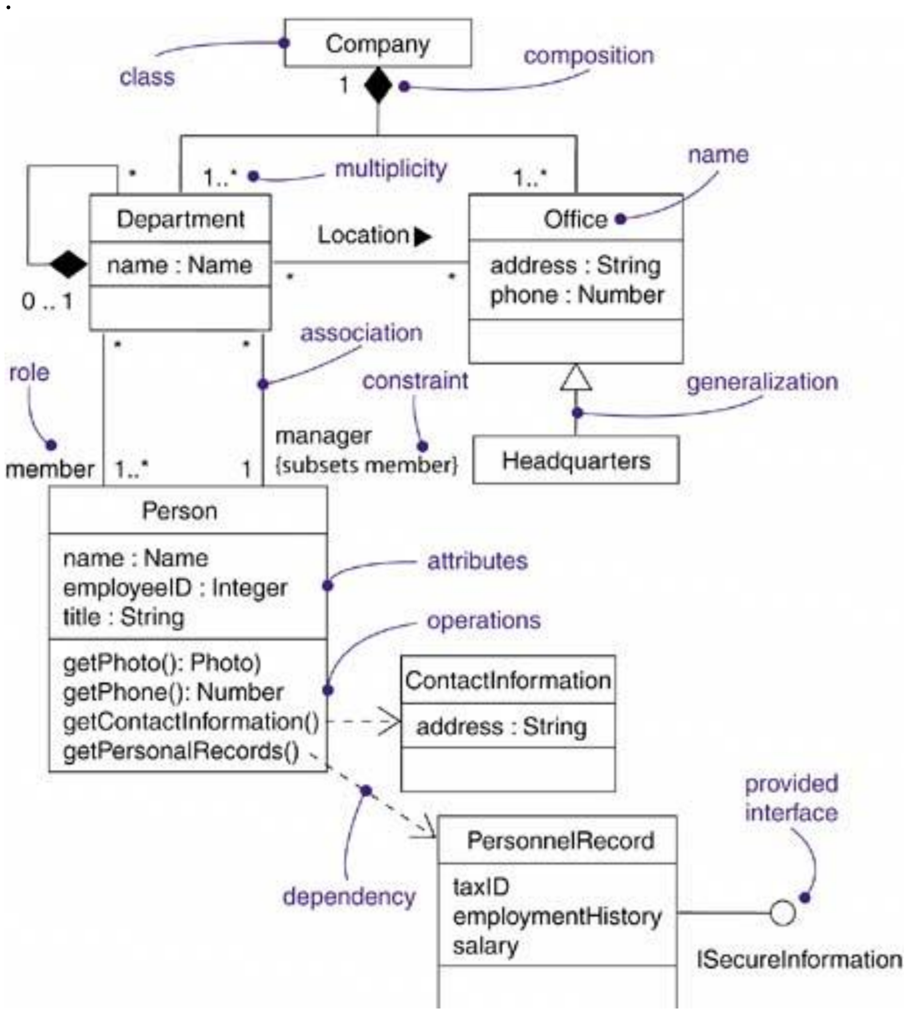
- Render these instances and their relationships in an interaction diagram or an activity diagram.



CLASS DIAGRAMS

Class diagrams are the most common diagram found in modeling object-oriented systems. A class diagram shows a set of classes, interfaces, and collaborations and their relationships.
Class diagrams are important not only for visualizing, specifying, and documenting structural models, but also for constructing executable systems through forward and reverse engineering.

Building software has much the same characteristics except that, given the fluidity of software, we have the ability to define your own basic building blocks from scratch. With the UML, you use class diagrams to visualize the static aspects of these building blocks and their relationships and to specify their details for construction, as you can see in Figure .



Common Properties
A class diagram is just a special kind of diagram and shares the same common properties as do all other diagrams name and graphical content that are a projection into a model. What distinguishes a class diagram from other kinds of diagrams is its particular content.

Class diagrams commonly contain the following things:
• Classes
• Interfaces
• Collaborations

• Dependency, generalization, and association relationships
Like all other diagrams, class diagrams may contain notes and constraints.

Class diagrams may also contain packages or subsystems, both of which are used to group elements of your model into larger chunks. Sometimes you'll want to place instances in class diagrams as well, especially when we want to visualize the (possibly dynamic) type of an instance.

Common Uses

Use class diagrams to model the static design view of a system. This view primarily supports the functional requirements of a system the services the system should provide to its end users.

When you model the static design view of a system, you'll typically use class diagrams in one of three ways.

1. To model the vocabulary of a system

Modeling the vocabulary of a system involves making a decision about which abstractions are a part of the system under consideration and which fall outside its boundaries. You use class
diagrams to specify these abstractions and their responsibilities.

2. To model simple collaborations

A collaboration is a society of classes, interfaces, and other elements that work together to provide some cooperative behavior that's bigger than the sum of all the elements. For example,
when you re modeling the semantics of a transaction in a distributed system, you can't just stare
at a single class to understand what's going on. Rather, these semantics are carried out by a set of
classes that work together. You use class diagrams to visualize and specify this set of classes and
their relationships.

3. To model a logical database schema

Think of a schema as the blueprint for the conceptual design of a database. In many domains, we want to store persistent information in a relational database or in an object-oriented database. We can model schemas for these databases using class diagrams.

COMMON MODELING TECHNIQUES

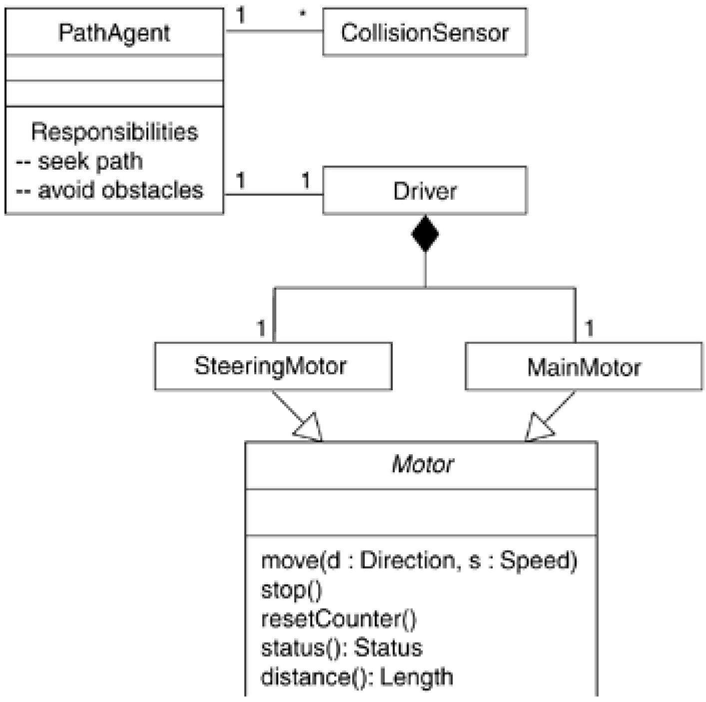
Modeling Simple Collaborations

No class stands alone. Rather, each works in collaboration with others to carry out some semantics greater than each individual. Therefore, in addition to capturing the vocabulary of your system, you'll also need to turn your attention to visualizing, specifying, constructing, and documenting the various ways these things in your vocabulary work together. Weuse class diagrams to represent such collaborations.

To model a collaboration,

• Identify the mechanism you'd like to model. A mechanism represents some function or behavior of the part of the system you are modeling that results from the interaction of a society of classes, interfaces, and other things.
• For each mechanism, identify the classes, interfaces, and other collaborations that participate in this collaboration. Identify the relationships among these things as well.
• Use scenarios to walk through these things. Along the way, you'll discover parts of your model that were missing and parts that were just plain semantically wrong.
• Be sure to populate these elements with their contents. For classes, start with getting a good balance of responsibilities. Then, over time, turn these into concrete attributes and operations.

For example, Figure shows a set of classes drawn from the implementation of an autonomous robot. The figure focuses on the classes involved in the mechanism for moving the robot along a path. You'll find one abstract class (Motor) with two concrete children, SteeringMotor and MainMotor. Both of these classes inherit the five operations of their parent, Motor. The two classes are, in turn, shown as parts of another class, Driver. The class PathAgent has a one-to-one association to Driver and a one-to-many association to CollisionSensor. No attributes or operations are shown for PathAgent, although its responsibilities are given.



MODELING A LOGICAL DATABASE SCHEMA

Many of the systems you'll model will have persistent objects, which means that they can be stored in a database for later retrieval. Most often, you'll use a relational database, an objectoriented database, or a hybrid object/relational database for persistent storage. The UML is wellsuited to modeling logical database schemas, as well as physical databases themselves.

The UML's class diagrams are a superset of entity-relationship (E-R) diagrams, a common modeling tool for logical database design. Whereas classical E-R diagrams focus only on data, class diagrams go a step further by permitting the modeling of behavior as well. In the physical database, these logical operations are generally turned into triggers or stored procedures.

To model a schema,

Identify those classes in your model whose state must transcend the lifetime of their applications.

• Create a class diagram that contains these classes. You can define your own set of stereotypes and tagged values to address database-specific details.

• Expand the structural details of these classes. In general, this means specifying the details of their attributes and focusing on the associations and their multiplicities that relate these classes.

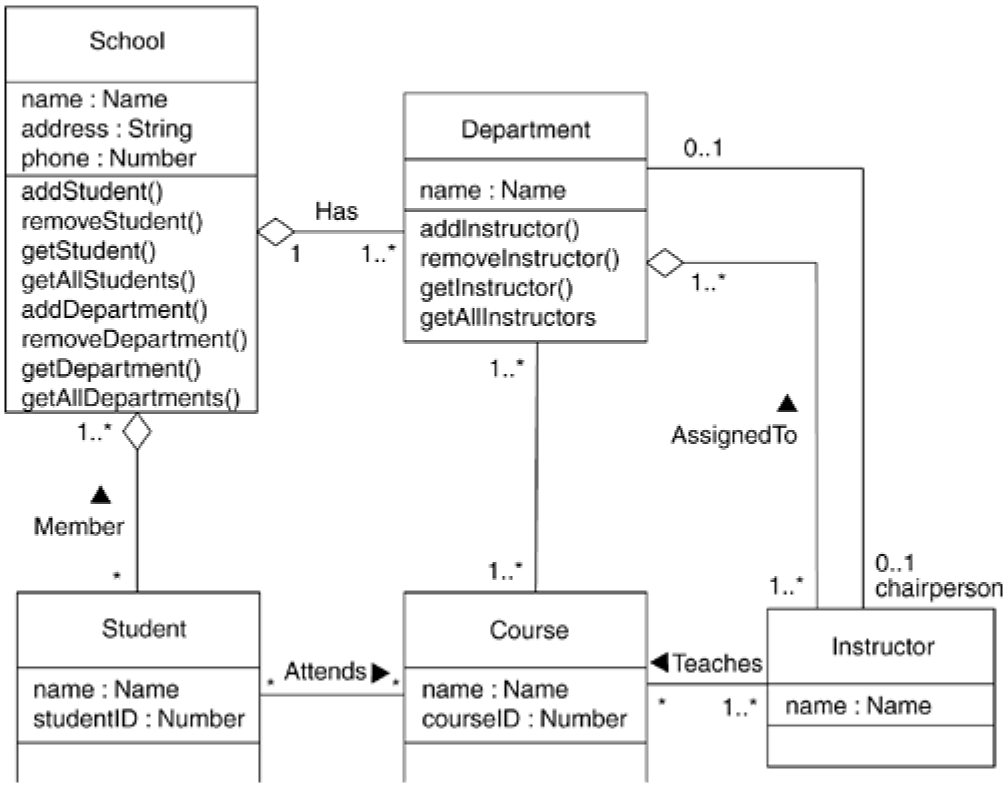
• Watch for common patterns that complicate physical database design, such as cyclic associations and one-to-one associations. Where necessary, create intermediate abstractions to simplify your logical structure.

• Consider also the behavior of these classes by expanding operations that are important for data access and data integrity.

The Figure shows a set of classes drawn from an information system for a school.

We find the classes named Student, Course, and Instructor. There's an association between Student and Course, specifying that students attend courses. Furthermore, every student may attend any number of courses, and every course may have any number of students.

Figure: Modeling a Schema



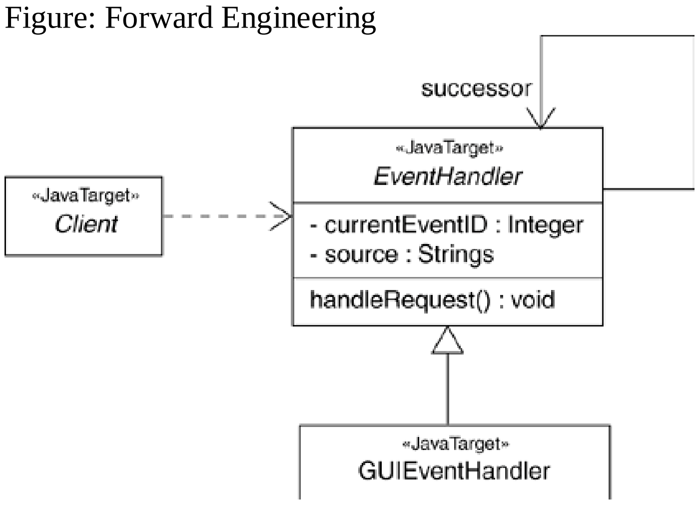
FORWARD AND REVERSE ENGINEERING
For some uses of the UML, the models we create will never map to code. For example, if you are modeling a business process using activity diagrams, many of the activities we model will involve people, not computers. In other cases, you'll want to model systems whose parts are, from your level of abstraction, just a piece of hardware.
Forward engineering is the process of transforming a model into code through a mapping to an implementation language. Forward engineering results in a loss of information, because models written in the UML are semantically richer than any current object-oriented programming language. In fact, this is a major reason why you need models in addition to code.

Structural features, such as collaborations, and behavioral features, such as interactions, can be visualized clearly in the UML, but not so clearly from raw code.

To forward engineer a class diagram,

• Identify the rules for mapping to your implementation language or languages of choice. This is something you'll want to do for your project or your organization as a whole.
• Depending on the semantics of the languages you choose, you may want to constrain your use of certain UML features. For example, the UML permits you to model multiple inheritance, but Smalltalk permits only single inheritance.
• Use tagged values to guide implementation choices in your target language. You can do this at the level of individual classes if you need precise control. You can also do so at a higher level, such as with collaborations or packages.
• Use tools to generate code.

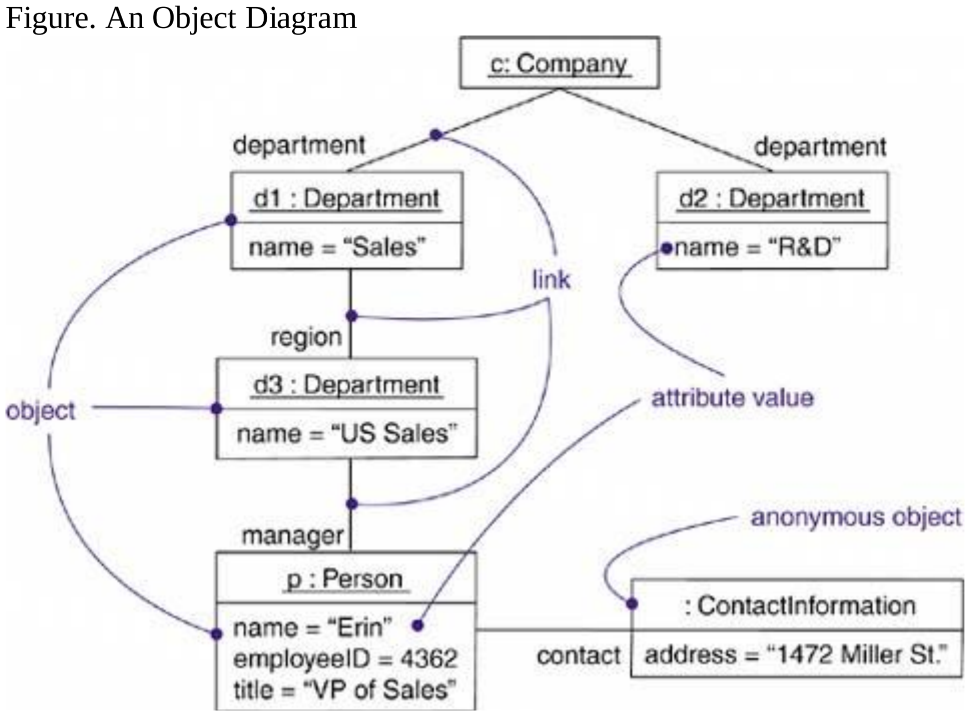
Figure: Forward Engineering



Reverse engineering is the process of transforming code into a model through a mapping from a specific implementation language. Reverse engineering results in a flood of information, some of which is at a lower level of detail than you'll need to build useful models. At the same time, reverse engineering is incomplete.
To reverse engineer a class diagram,
• Identify the rules for mapping from your implementation language or languages of choice. This is something you'll want to do for your project or your organization as a whole.
• Using a tool, point to the code you'd like to reverse engineer. Use your tool to generate a new model or modify an existing one that was previously forward engineered. It is unreasonable to expect to reverse engineer a single concise model from a large body of code. You need to select portion of the code and build the model from the bottom.
• Using your tool, create a class diagram by querying the model. For example, you might start with one or more classes, then expand the diagram by following specific relationships or other neighboring classes. Expose or hide details of the contents of this class diagram as necessary to communicate your intent.
• Manually add design information to the model to express the intent of the design that is missing or hidden in the code.

OBJECT DIAGRAMS

Object diagrams model the instances of things contained in class diagrams. An object diagram shows a set of objects and their relationships at a point in time.
We use object diagrams to model the static design view or static process view of a system. This involves modeling a snapshot of the system at a moment in time and rendering a set of objects, their state, and their relationships.
Object diagrams are not only important for visualizing, specifying, and documenting structural models, but also for constructing the static aspects of systems through forward and reverse engineering.
An object diagram covers a set of instances of the things found in a class diagram. An object diagram,
therefore, expresses the static part of an interaction, consisting of the objects that collaborate but without any of the messages passed among them. In both cases, an object diagram freezes a moment in time, as in Figure .
Figure. An Object Diagram



An *object diagram* is a diagram that shows a set of objects and their relationships at a point in time. Graphically, an object diagram is a collection of vertices and arcs.
Common Properties
An object diagram is a special kind of diagram and shares the same common properties as all other diagrams that is, a name and graphical contents that are a projection into a model.

What distinguishes an object diagram from all other kinds of diagrams is its particular content.
Contents
Object diagrams commonly contain
• Objects
• Links
Like all other diagrams, object diagrams may contain notes and constraints.
COMMON MODELING TECHNIQUES
Modeling Object Structures
When you construct a class diagram, a component diagram, or a deployment diagram, what we are doing is capturing a set of abstractions that are interesting to you as a group and, in that context, exposing their semantics and their relationships to other abstractions in the group.
If class A has a one-to-many association to class B, then for one instance of A there might be five instances of B; for another instance of A there might be only one instance of B. Furthermore, at a given moment in time, that instance of A, along with the related instances of B, will each have certain values for their attributes and state machines.
To model an object structure,
Identify the mechanism you'd like to model. A mechanism represents some function or behavior of the part of the system you are modeling that results from the interaction of a society of classes, interfaces, and other things.
• Create a collaboration to describe a mechanism.
• For each mechanism, identify the classes, interfaces, and other elements that participate in this collaboration; identify the relationships among these things as well.
• Consider one scenario that walks through this mechanism. Freeze that scenario at a moment in time, and render each object that participates in the mechanism.
• Expose the state and attribute values of each such object, as necessary, to understand the scenario.
• Similarly, expose the links among these objects, representing instances of associations among them.

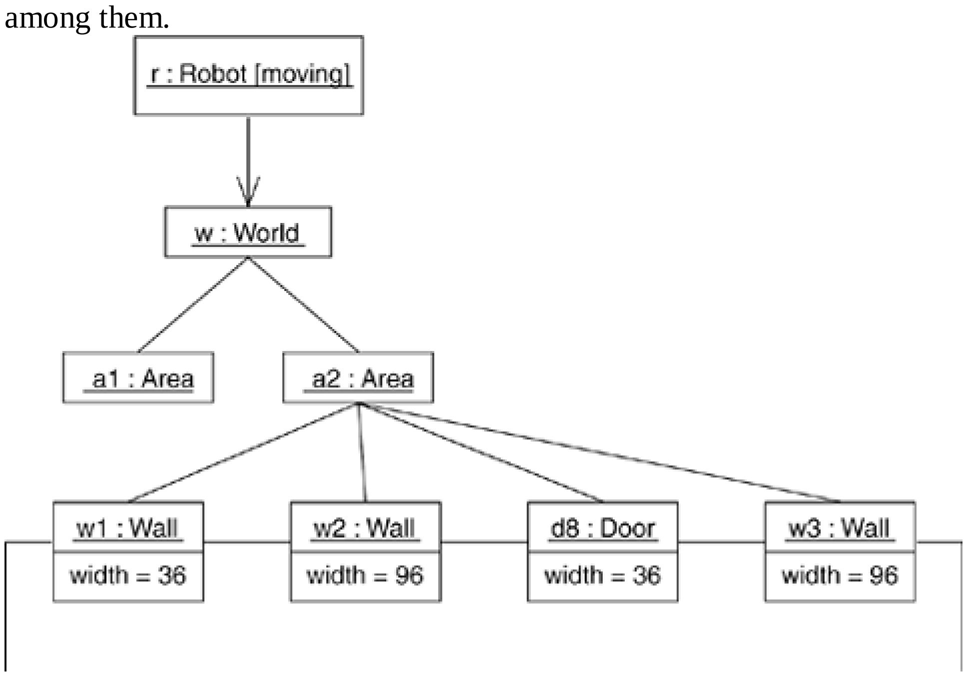


Figure : Modeling Object Structures

FORWARD AND REVERSE ENGINEERING
Forward engineering (the creation of code from a model) an object diagram is theoretically possible but pragmatically of limited value. In an object-oriented system, instances are things that are created and destroyed by the application during run time. Therefore, you cannot exactly instantiate these objects from the outside.
Reverse engineering (the creation of a model from code) an object diagram can be useful.In fact, while you are debugging your system, this is something that you or your tools will do all the time.
To reverse engineer an object diagram,

• Chose the target you want to reverse engineer. Typically, you'll set your context inside an operation or relative to an instance of one particular class.
• Using a tool or simply walking through a scenario, stop execution at a certain moment in time.
• Identify the set of interesting objects that collaborate in that context and render them in an object diagram.
• As necessary to understand their semantics, expose these object's states.
• As necessary to understand their semantics, identify the links that exist among these objects.
• If your diagram ends up overly complicated, prune it by eliminating objects that are not germane to the questions about the scenario you need answered. If your diagram is too simplistic, expand the neighbors of certain interesting objects and expose each object's state more deeply.