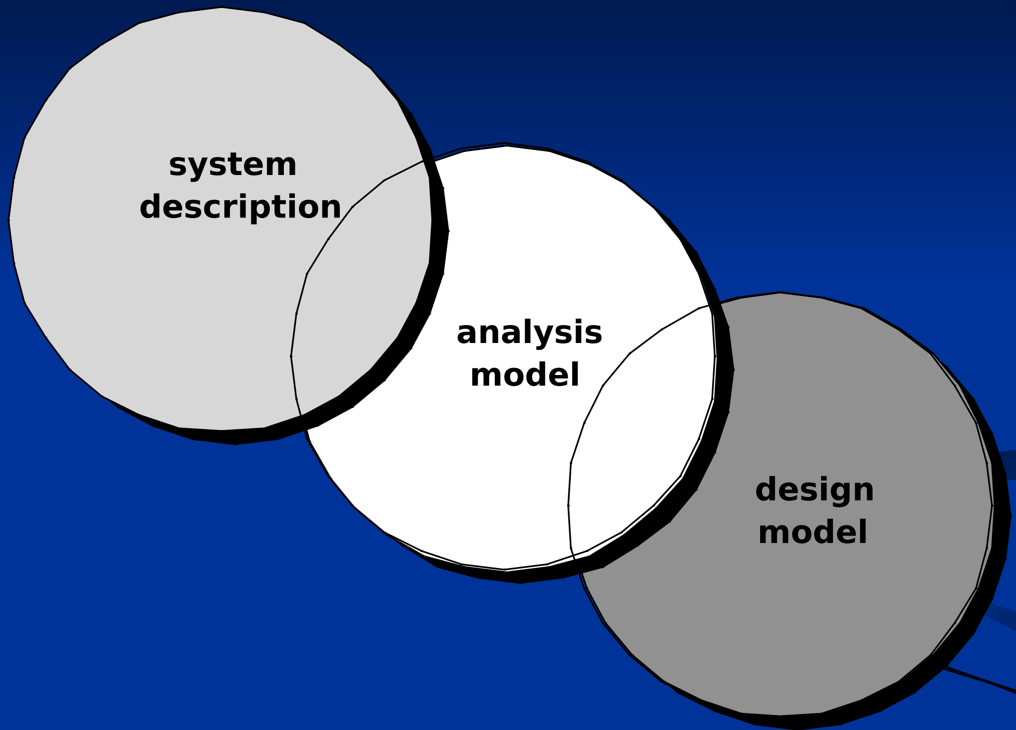
Software Engineering: A Practitioner's Approach, 6/e

Chapter 8
Analysis Modeling

Requirements Analysis

- Requirements analysis
  - specifies software's operational characteristics
  - indicates software's interface with other system elements
  - establishes constraints that software must meet
- Requirements analysis allows the software engineer (called an *analyst* or *modeler* in this role) to:
  - elaborate on basic requirements established during earlier requirement engineering tasks
  - build models that depict user scenarios, functional activities, problem classes and their relationships, system and class behavior, and the flow of data as it is transformed.

A Bridge



Rules of Thumb

- The model should focus on requirements that are visible within the problem or business domain. The level of abstraction should be relatively high.
- Each element of the analysis model should add to an overall understanding of software requirements and provide insight into the information domain, function and behavior of the system.
- Delay consideration of infrastructure and other non-functional models until design.
- Minimize coupling throughout the system.
- Be certain that the analysis model provides value to all stakeholders.
- Keep the model as simple as it can be.

Domain Analysis

Software domain analysis is the identification, analysis, and specification of common requirements from a specific application domain, typically for reuse on multiple projects within that application domain . . . [Object-oriented domain analysis is] the identification, analysis, and specification of common, reusable capabilities within a specific application domain, in terms of common objects, classes, subassemblies, and frameworks . . .

Donald Firesmith

Domain Analysis

- Define the domain to be investigated.
- Collect a representative sample of applications in the domain.
- Analyze each application in the sample.
- Develop an analysis model for the objects.

Data Modeling

- examines data objects independently of processing
- focuses attention on the data domain
- creates a model at the customer's level of abstraction
- indicates how data objects relate to one another

What is a Data Object?

Object—something that is described by a set of attributes (data items) and that will be manipulated within the software (system)

- each instance of an object (e.g., a book) can be identified uniquely (e.g., ISBN #)
- each plays a necessary role in the system i.e., the system could not function without access to instances of the object
- each is described by attributes that are themselves data items

Typical Objects

- *external entities* (printer, user, sensor)
- *things* (e.g, reports, displays, signals)
- *occurrences or events* (e.g., interrupt, alarm)
- *roles* (e.g., manager, engineer, salesperson)
- *organizational units* (e.g., division, team)
- *places* (e.g., manufacturing floor)
- *structures* (e.g., employee record)

Data Objects and Attributes

A data object contains a set of attributes that act as an aspect, quality, characteristic, or descriptor of the object

object: automobile

attributes:

- **make**
- **model**
- **body type**
- **price**
- **options code**

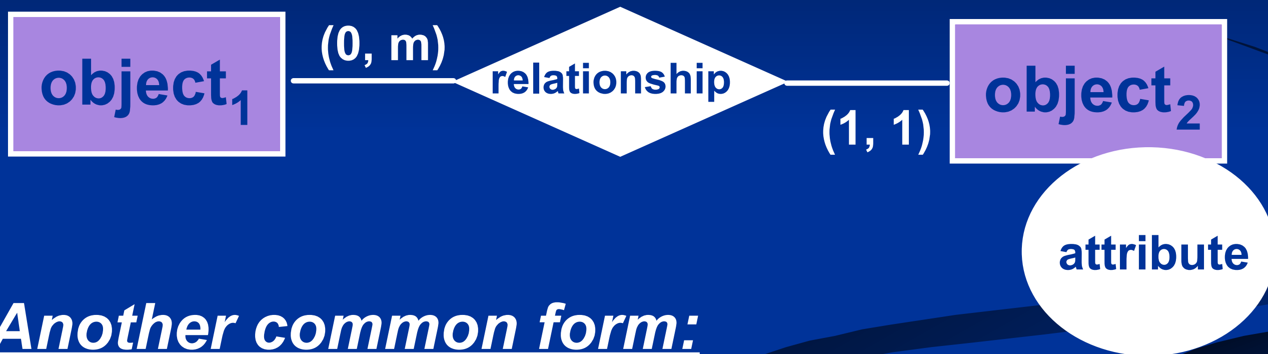
What is a Relationship?

relationship —indicates "connectedness"; a "fact" that must be "remembered" by the system and cannot or is not computed or derived mechanically

- several instances of a relationship can exist
- objects can be related in many different ways

ERD Notation

One common form:

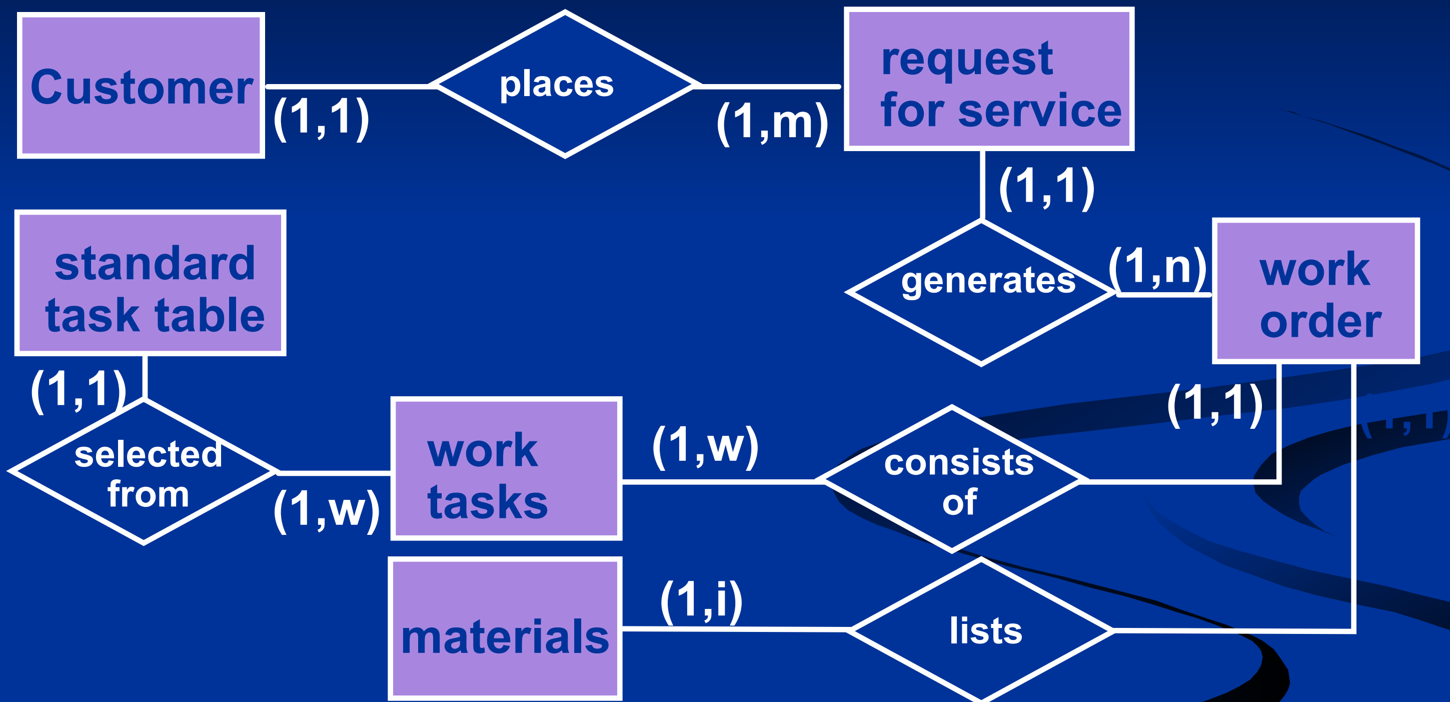


Another common form:

Building an ERD

- Level 1—model all data objects (entities) and their "connections" to one another
- Level 2—model all entities and relationships
- Level 3—model all entities, relationships, and the attributes that provide further depth

The ERD: An Example



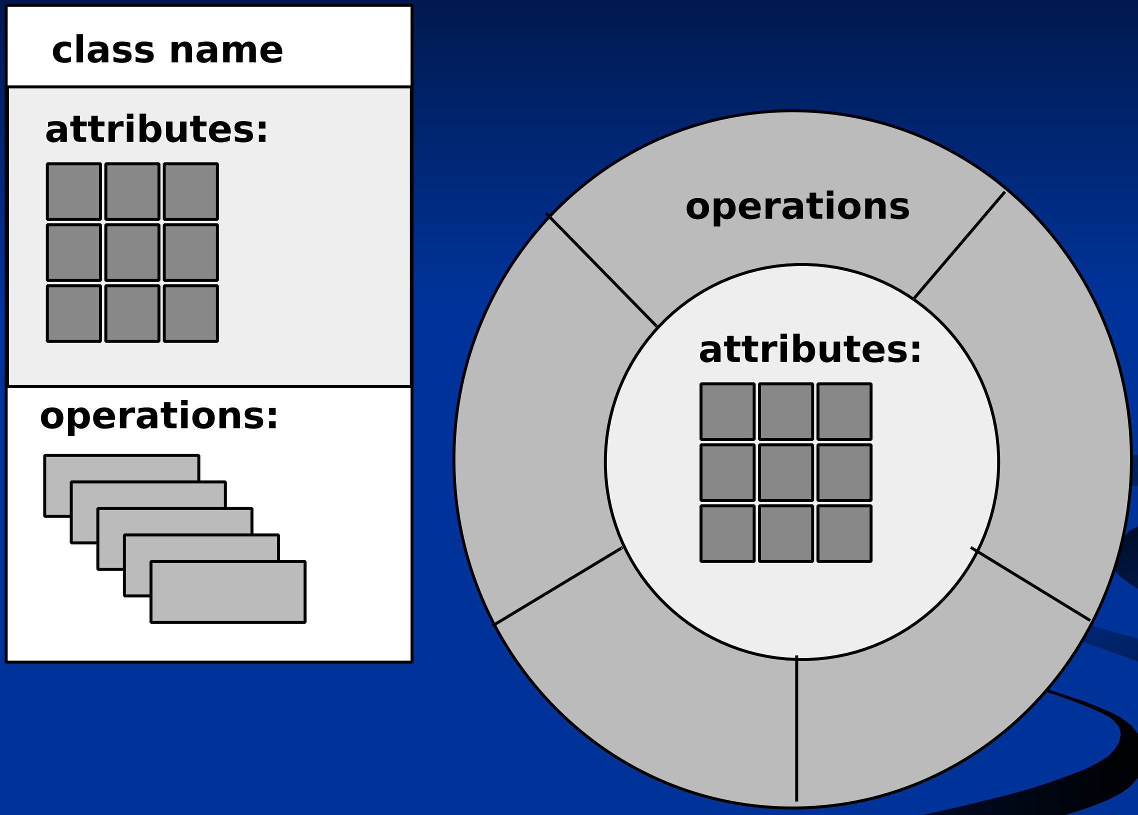
Object-Oriented Concepts

- Must be understood to apply class-based elements of the analysis model
- Key concepts:
  - Classes and objects
  - Attributes and operations
  - Encapsulation and instantiation
  - Inheritance

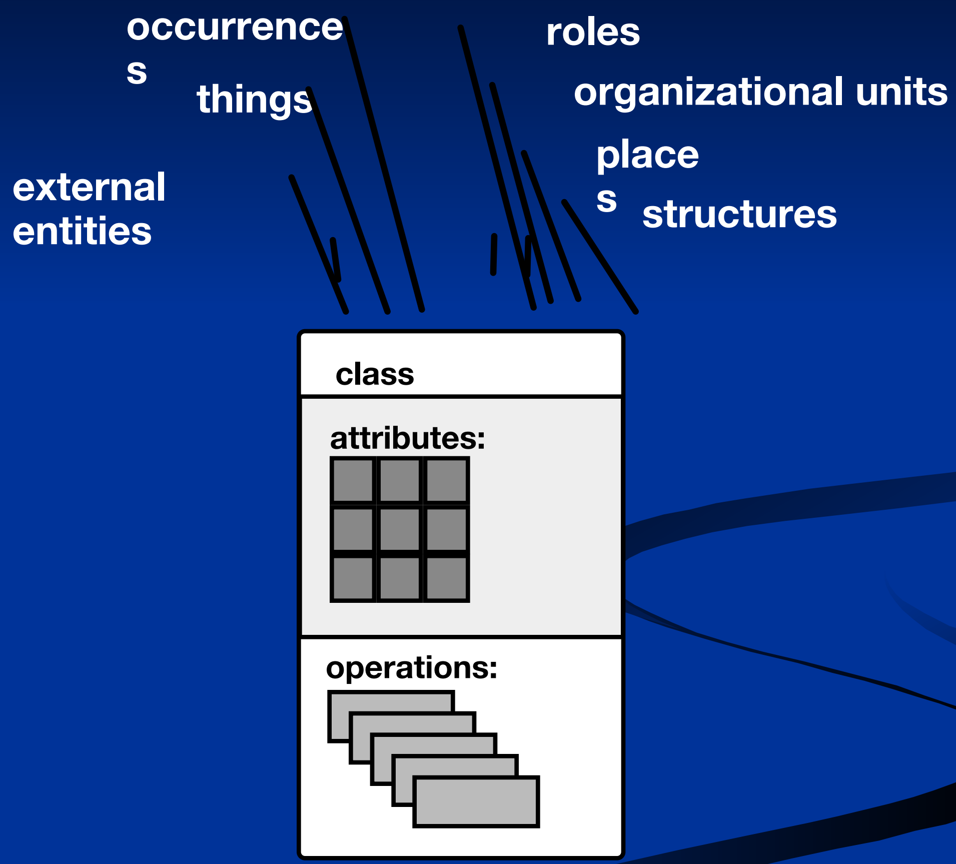
Classes

- object-oriented thinking begins with the definition of a class, often defined as:
  - template
  - generalized description
  - "blueprint" ... describing a collection of similar items
- a metaclass (also called a superclass) establishes a hierarchy of classes
- once a class of items is defined, a specific instance of the class can be identified

Building a Class

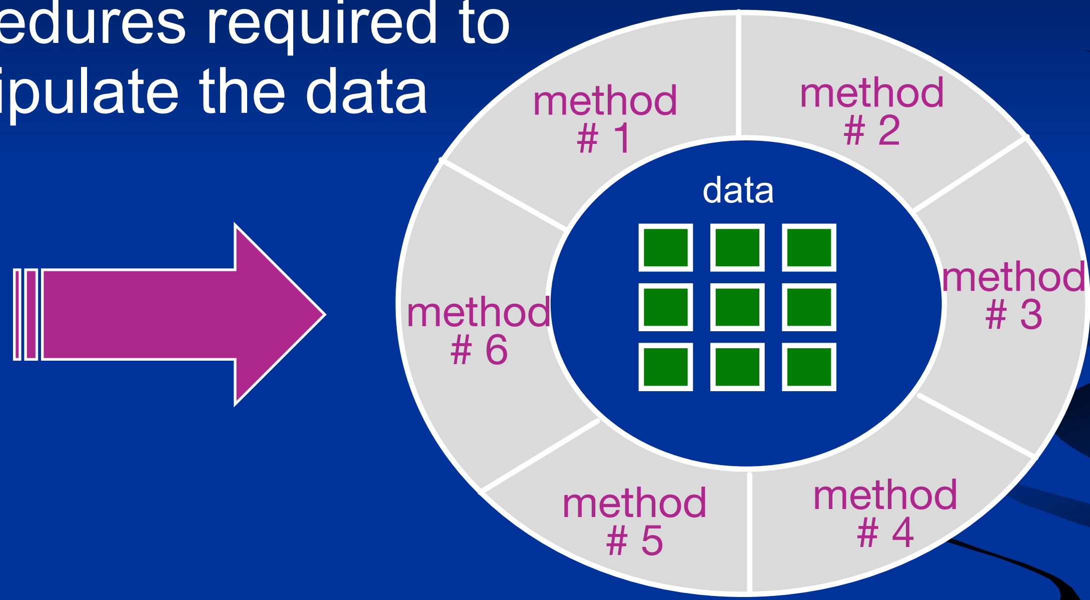


What is a Class?

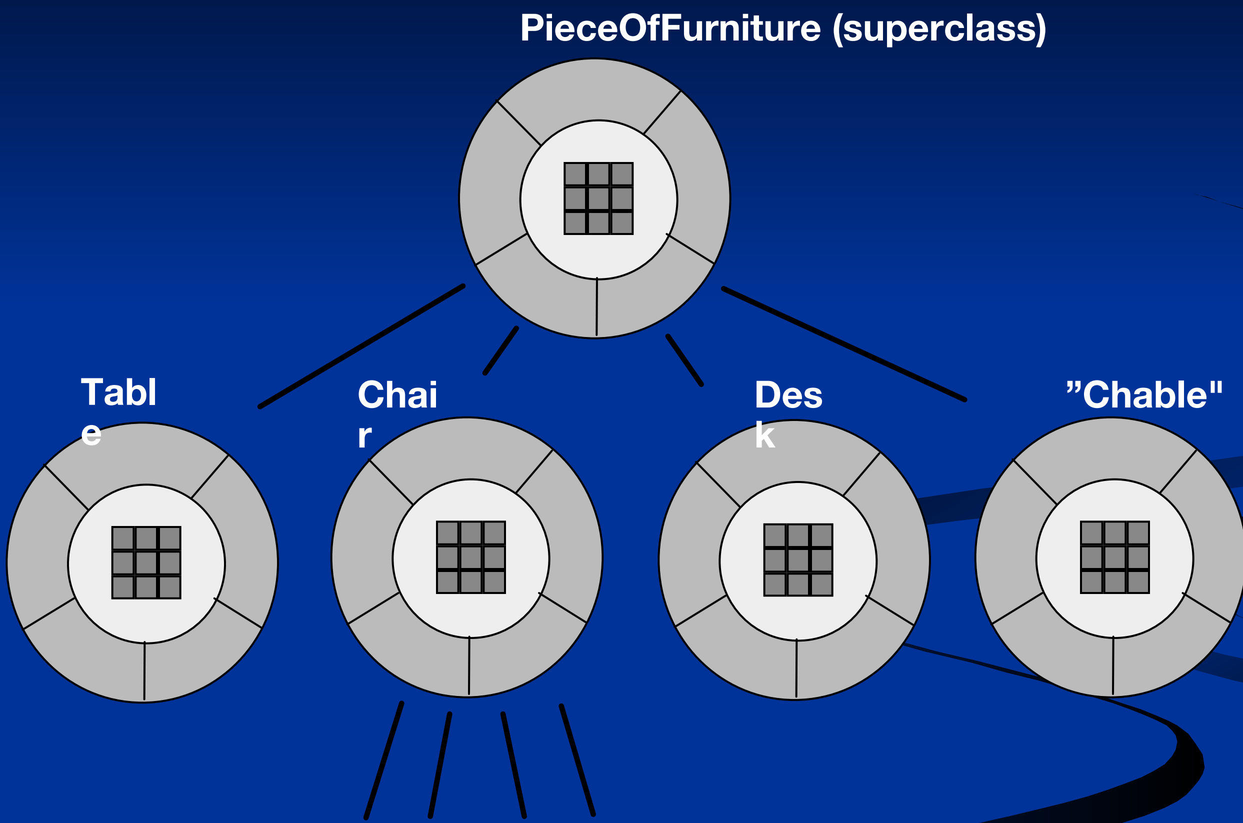


Encapsulation/Hiding

The object encapsulates both data and the logical procedures required to manipulate the data



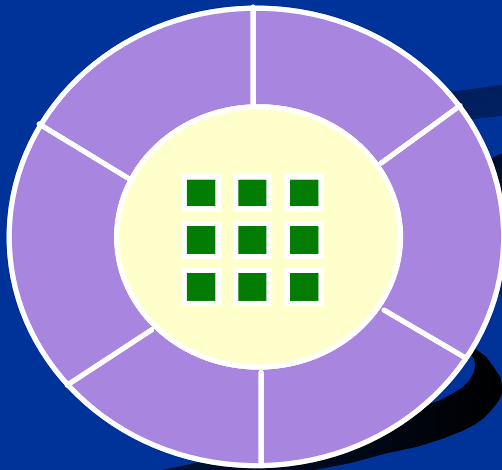
Class Hierarchy



Methods
(a.k.a. Operations, Services)

An executable procedure that is encapsulated in a class and is designed to operate on one or more data attributes that are defined as part of the class.

A method is invoked via message passing.



Scenario-Based Modeling

"[Use-cases] are simply an aid to defining what exists outside the system (actors) and what should be performed by the system (use-cases)." Ivar Jacobson

(1) What should we write about?

(2) How much should we write about it?

(3) How detailed should we make our description?

(4) How should we organize the description?

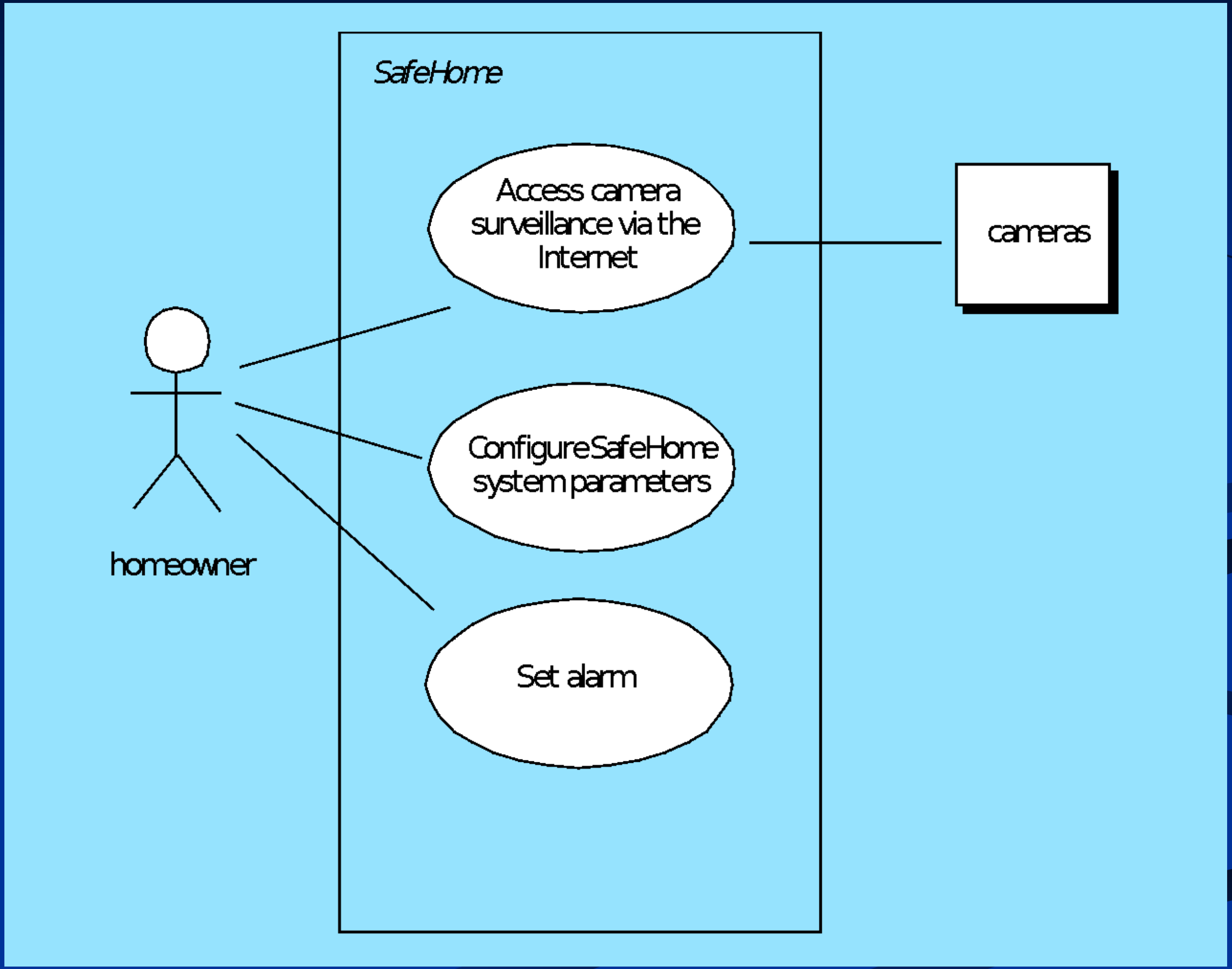
Use-Cases

- a scenario that describes a "thread of usage" for a system
- *actors* represent roles people or devices play as the system functions
- *users* can play a number of different roles for a given scenario

Developing a Use-Case

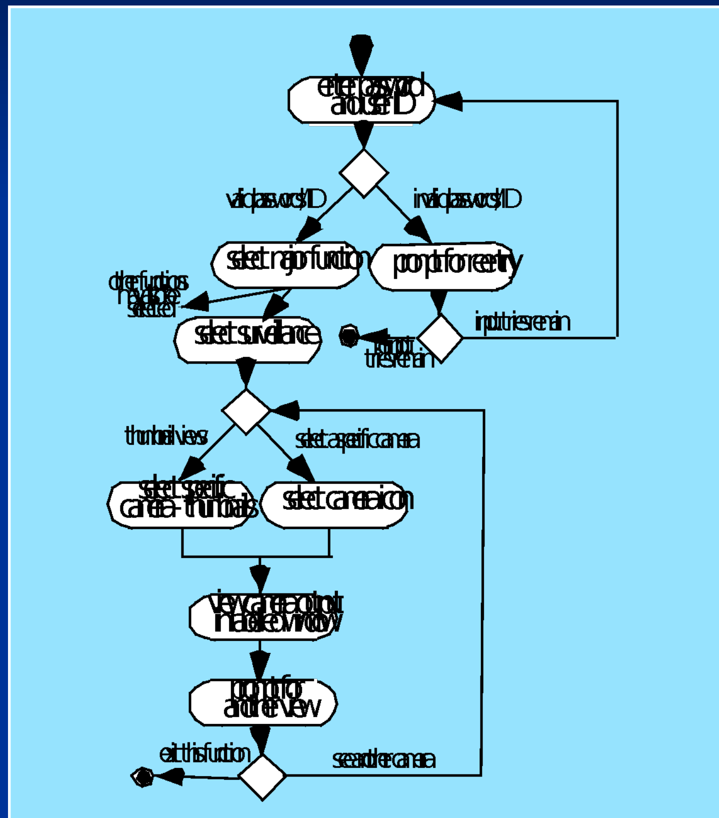
- What are the main tasks or functions that are performed by the actor?
- What system information will the the actor acquire, produce or change?
- Will the actor have to inform the system about changes in the external environment?
- What information does the actor desire from the system?
- Does the actor wish to be informed about unexpected changes?

Use-Case Diagram



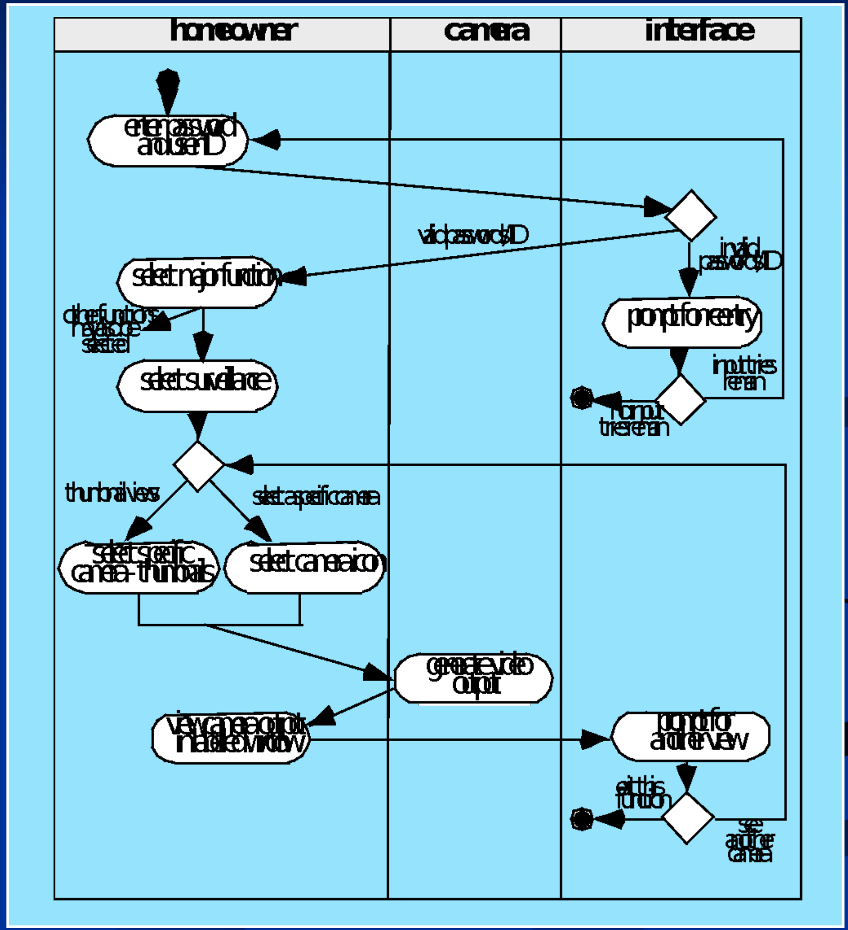
Activity Diagram

Supplements the use-case by providing a diagrammatic representation of procedural flow



Swimlane Diagrams

Allows the modeler to represent the flow of activities described by the use-case and at the same time indicate which actor (if there are multiple actors involved in a specific use-case) or analysis class has responsibility for the action described by an activity rectangle

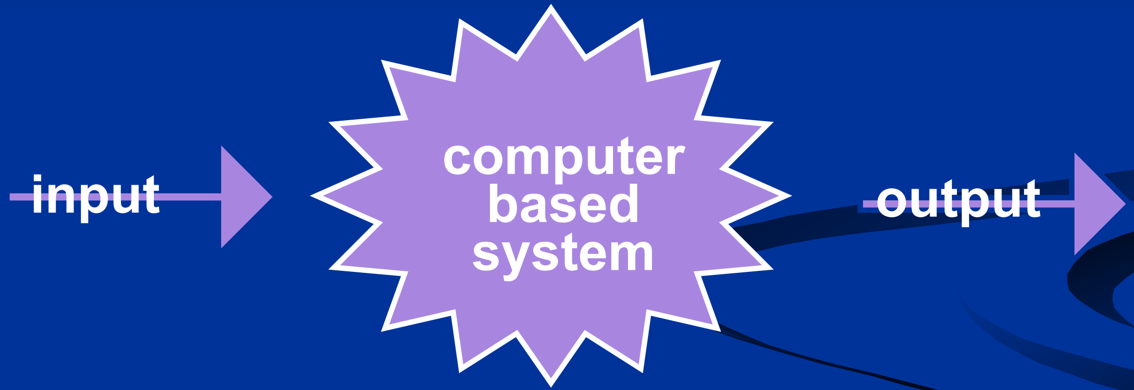


Flow-Oriented Modeling

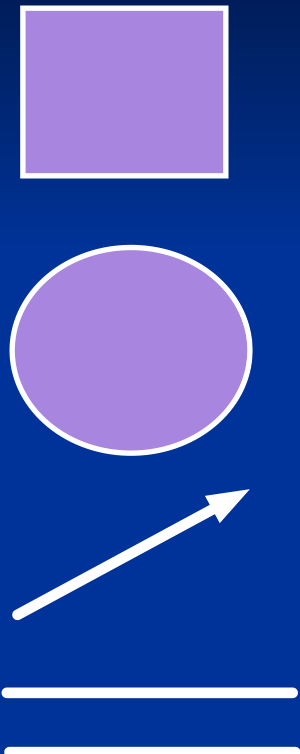
- Represents how data objects are transformed at they move through the system
- A data flow diagram (DFD) is the diagrammatic form that is used
- Considered by many to be an ‘old school’ approach, flow-oriented modeling continues to provide a view of the system that is unique—it should be used to supplement other analysis model elements

The Flow Model

Every computer-based system is
an
information transform ....



Flow Modeling Notation



external entity

process

data flow

data store

External Entity

A producer or consumer of data

Examples: a person, a device, a sensor

Another example: computer-based system

Data must always originate somewhere and must always be sent to something

Process

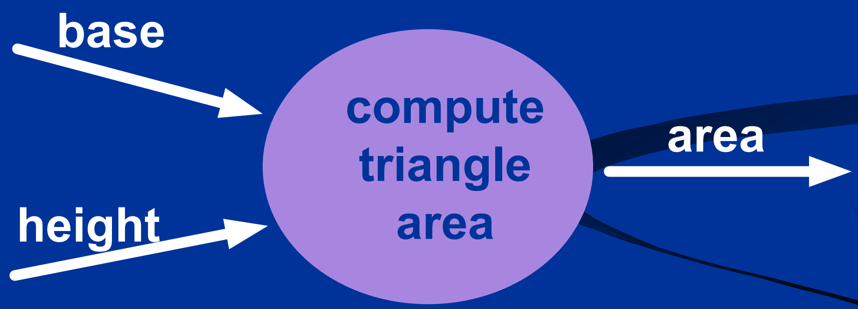
- **A data transformer (changes input to output)**

Examples: compute taxes, determine area,
format report, display graph

Data must always be processed in some
way to achieve system function

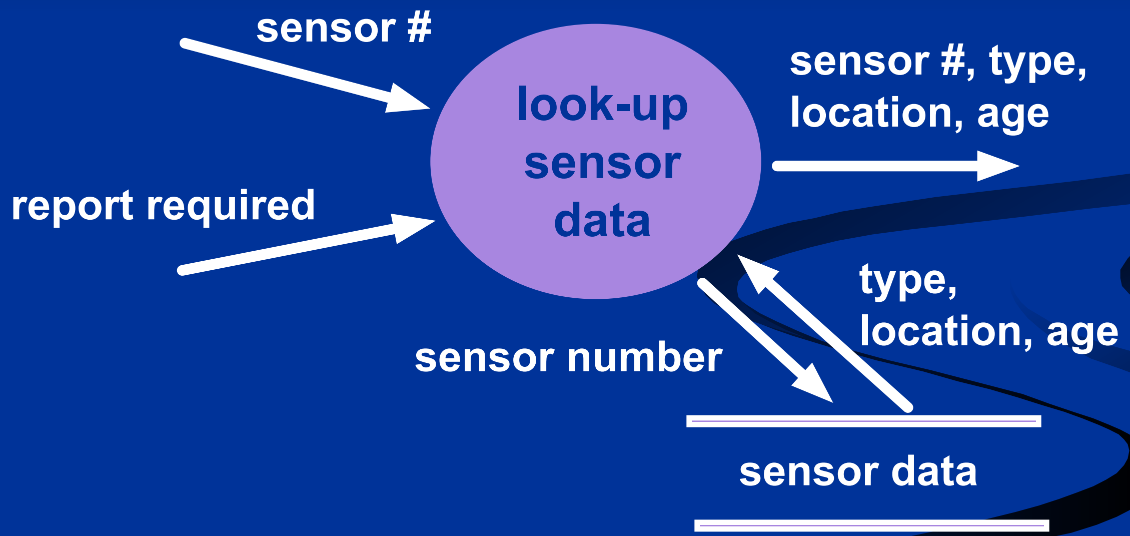
Data Flow

Data flows through a system, beginning as input and be transformed into output.



Data Stores

Data is often stored for later use.



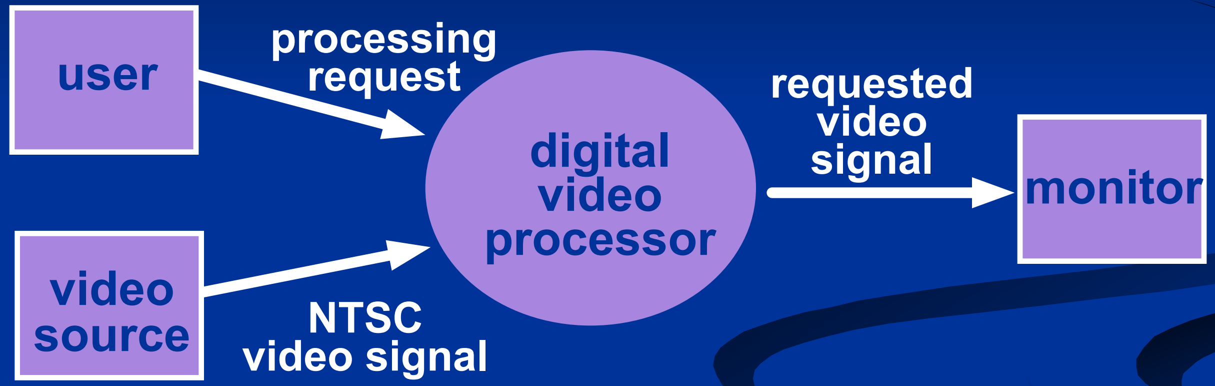
Data Flow Diagramming: Guidelines

- all icons must be labeled with meaningful names
- the DFD evolves through a number of levels of detail
- always begin with a context level diagram (also called level 0)
- always show external entities at level 0
- always label data flow arrows
- do not represent procedural logic

Constructing a DFD—I

- review the data model to isolate data objects and use a grammatical parse to determine "operations"
- determine external entities (producers and consumers of data)
- create a level 0 DFD

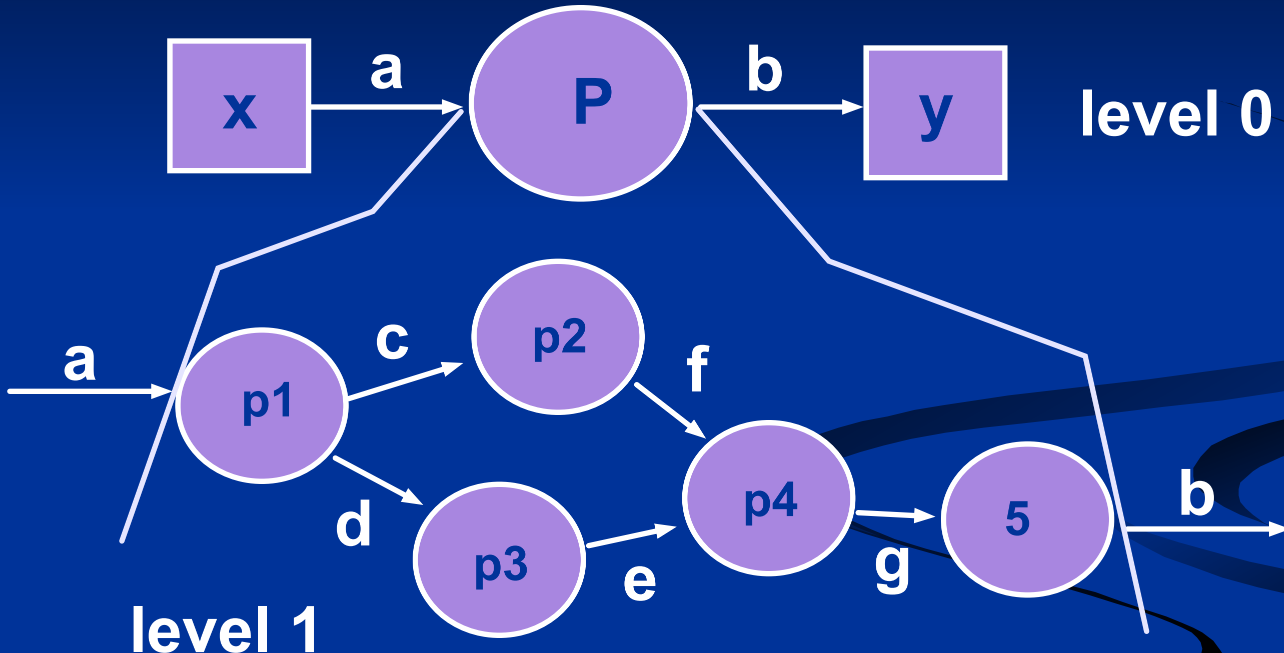
Level 0 DFD Example



Constructing a DFD—II

- write a narrative describing the transform
- parse to determine next level transforms
- “balance” the flow to maintain data flow continuity
- develop a level 1 DFD
- use a 1:5 (approx.) expansion ratio

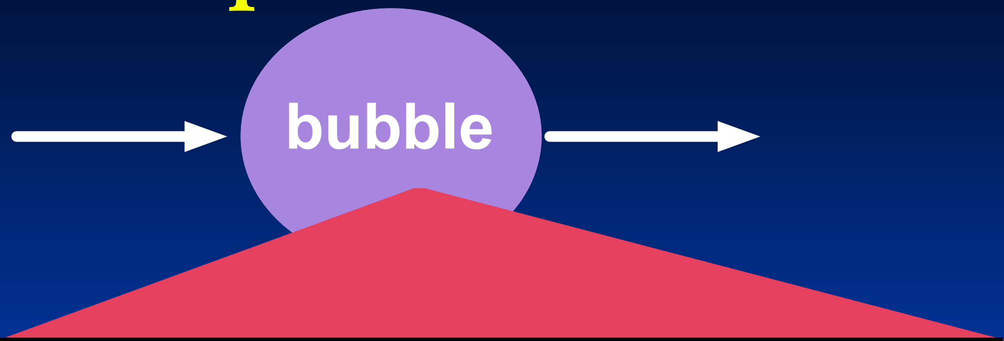
The Data Flow Hierarchy



Flow Modeling Notes

- each bubble is refined until it does just one thing
- the expansion ratio decreases as the number of levels increase
- most systems require between 3 and 7 levels for an adequate flow model
- a single data flow item (arrow) may be expanded as levels increase (data dictionary provides information)

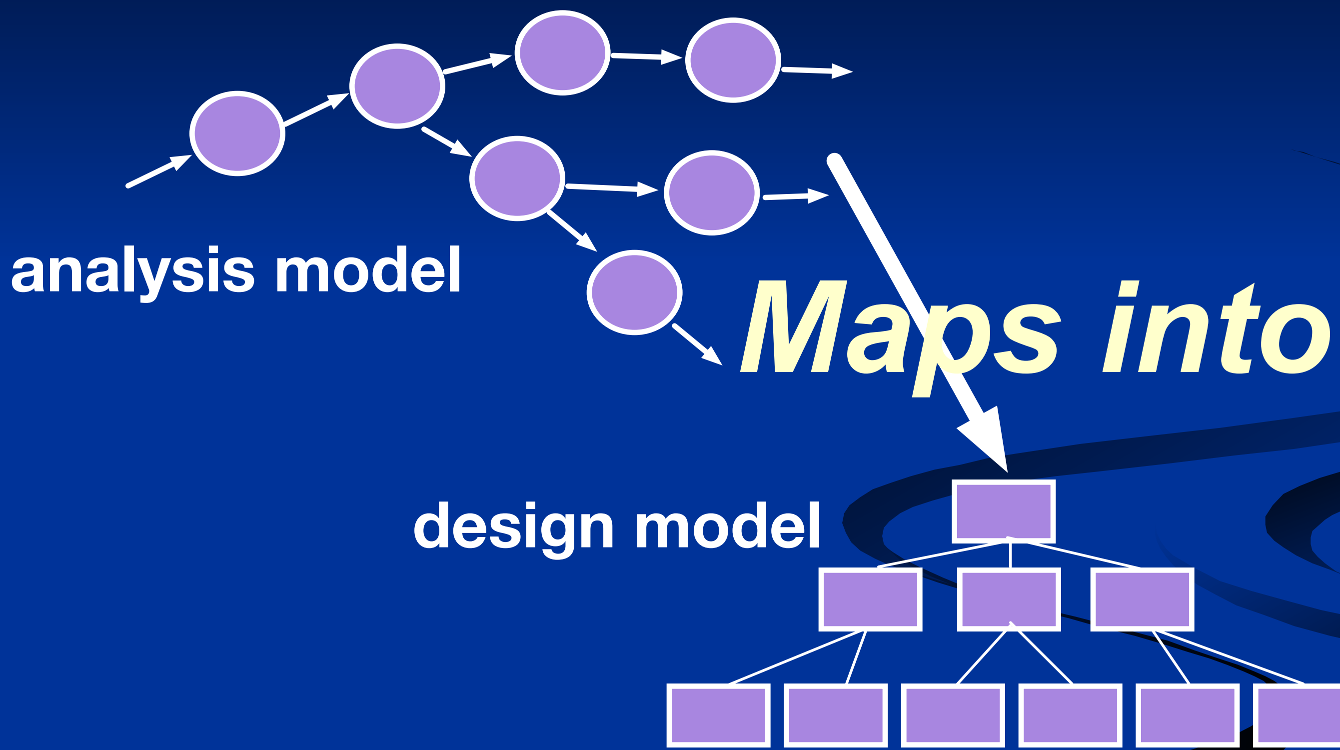
Process Specification (PSPEC)



PSPEC

- narrative
- pseudocode (PDL)
- equations
- tables
- diagrams and/or charts

DFDs: A Look Ahead



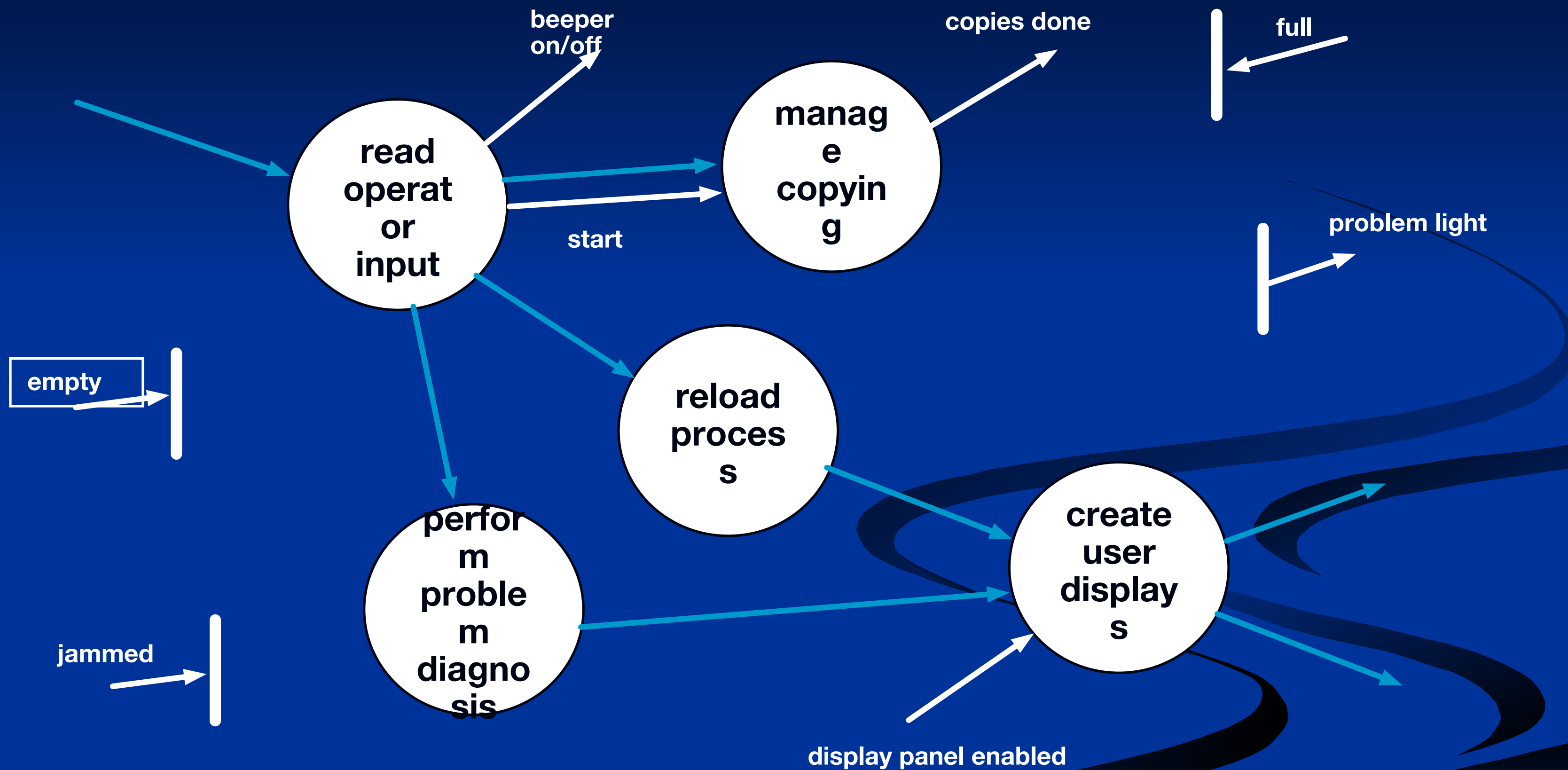
Control Flow Diagrams

- Represents "events" and the processes that manage events
- An "event" is a Boolean condition that can be ascertained by:
    - listing all sensors that are "read" by the software.
    - listing all interrupt conditions.
    - listing all "switches" that are actuated by an operator.
    - listing all data conditions.
    - recalling the noun/verb parse that was applied to the processing narrative, review all "control items" as possible CSPEC inputs/outputs.

The Control Model

- the control flow diagram is "superimposed" on the DFD and shows events that control the processes noted in the DFD
- control flows—events and control items—are noted by dashed arrows
- a vertical bar implies an input to or output from a control spec (CSPEC) — a separate specification that describes how control is handled
- a dashed arrow entering a vertical bar is an input to the CSPEC
- a dashed arrow leaving a process implies a data condition
- a dashed arrow entering a process implies a control input read directly by the process
- control flows do not physically activate/deactivate the processes—this is done via the CSPEC

Control Flow Diagram



Control Specification (CSPEC)

The CSPEC can be

- state diagram (sequential spec)
- state transition table
- decision tables
- activation tables

combinatorial spec

Guidelines for Building a CSPEC

- list all sensors that are "read" by the software
- list all interrupt conditions
- list all "switches" that are actuated by the operator
- list all data conditions
- recalling the noun-verb parse that was applied to the software statement of scope, review all "control items" as possible CSPEC inputs/outputs
- describe the behavior of a system by identifying its states; identify how each state is reach and defines the transitions between states
- focus on possible omissions ... a very common error in specifying control, e.g., ask: "Is there any other way I can get to this state or exit from it?"

Class-Based Modeling

- Identify analysis classes by examining the problem statement
- Use a “grammatical parse” to isolate potential classes
- Identify the attributes of each class
- Identify operations that manipulate the attributes

Analysis Classes

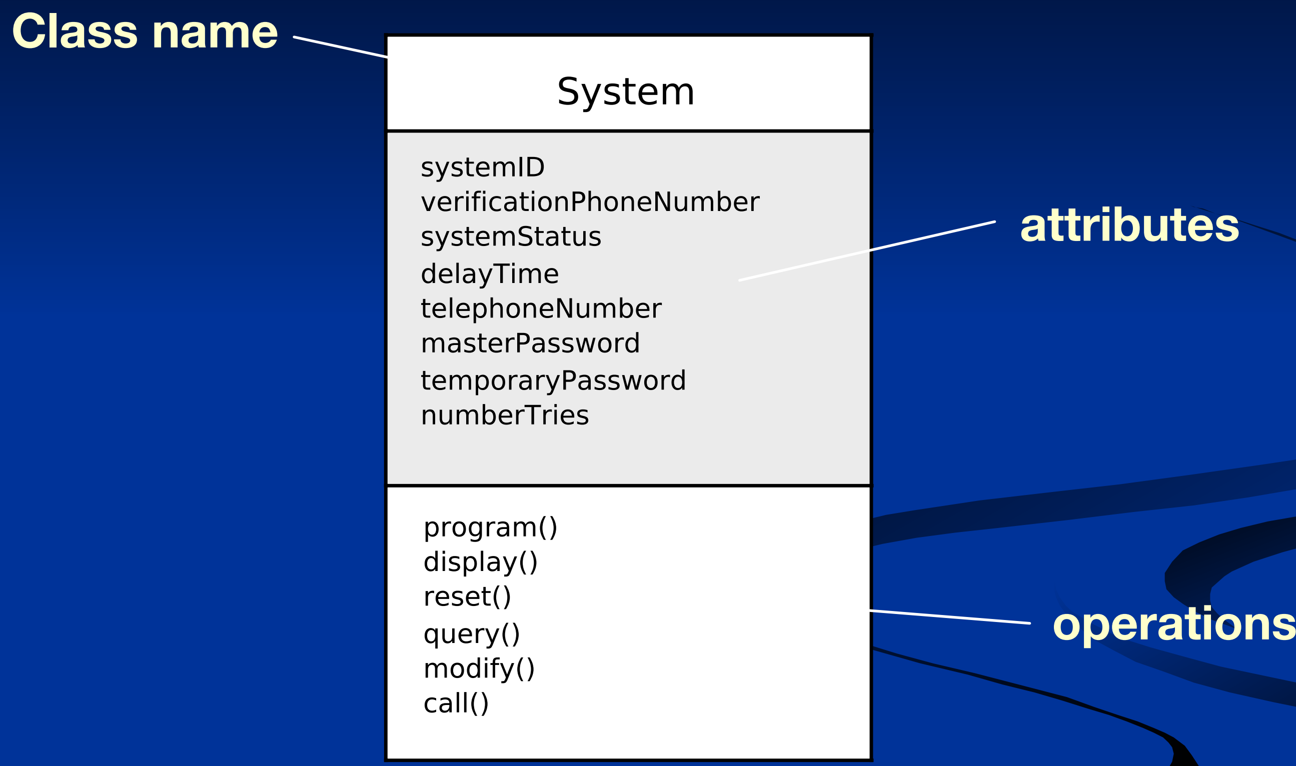
- *External entities* (e.g., other systems, devices, people) that produce or consume information to be used by a computer-based system.
- *Things* (e.g, reports, displays, letters, signals) that are part of the information domain for the problem.
- *Occurrences or events* (e.g., a property transfer or 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.

Selecting Classes—Criteria

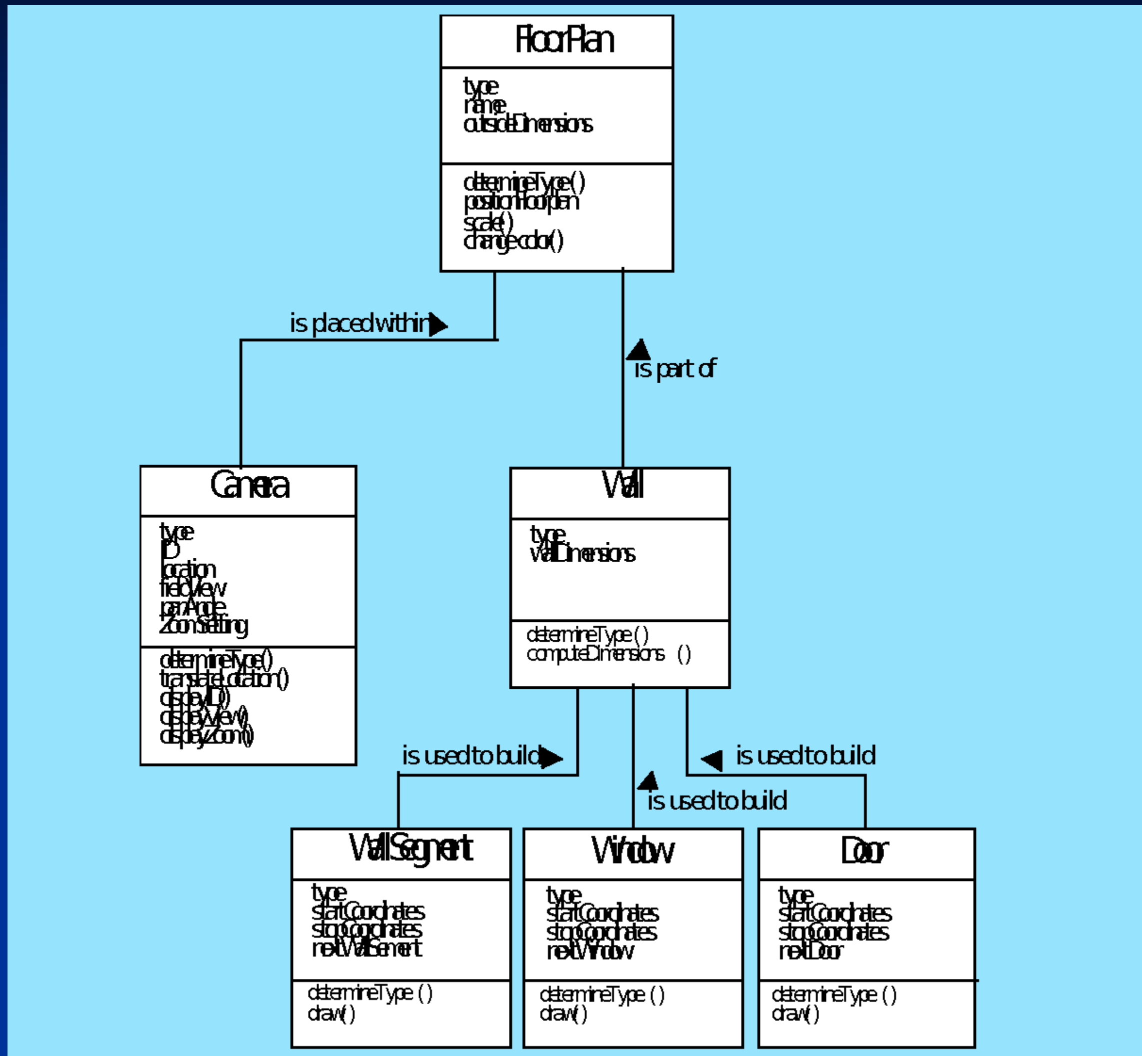
- retained
- information needed
- services multiple
- attributes common
- attributes common
- operations essential

requirements

Class Diagram



Class Diagram



CRC Modeling

- Analysis classes have “responsibilities”
  - *Responsibilities* are the attributes and operations encapsulated by the class
- Analysis classes collaborate with one another
  - *Collaborators* are those classes that are required to provide a class with the information needed to complete a responsibility.
  - In general, a collaboration implies either a request for information or a request for some action.

CRC Modeling

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.

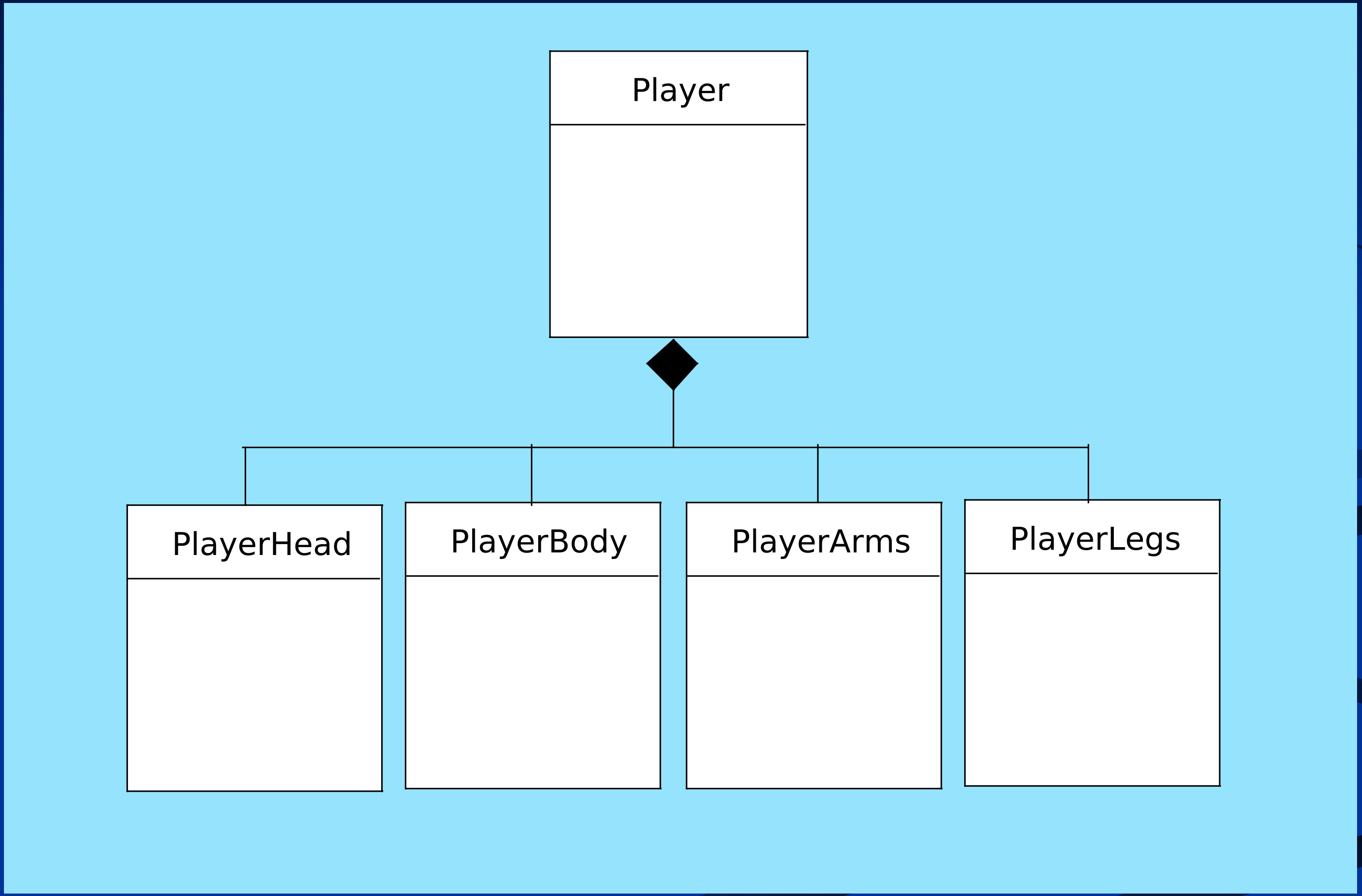
Responsibilities

- 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
- three different generic relationships between classes [WIR90]:
  - the *is-part-of* relationship
  - the *has-knowledge-of* relationship
  - the *depends-upon* relationship

Composite Aggregate Class



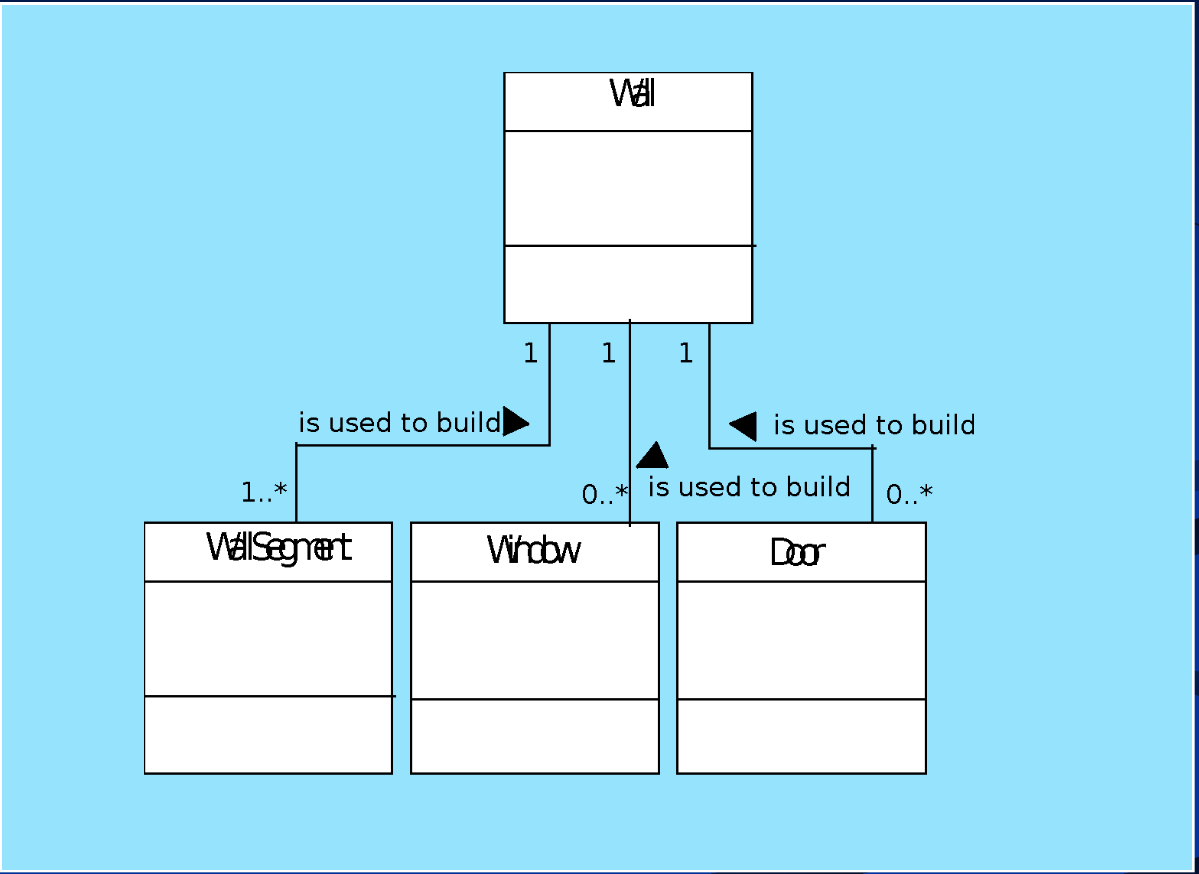
Reviewing the CRC Model

- 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.

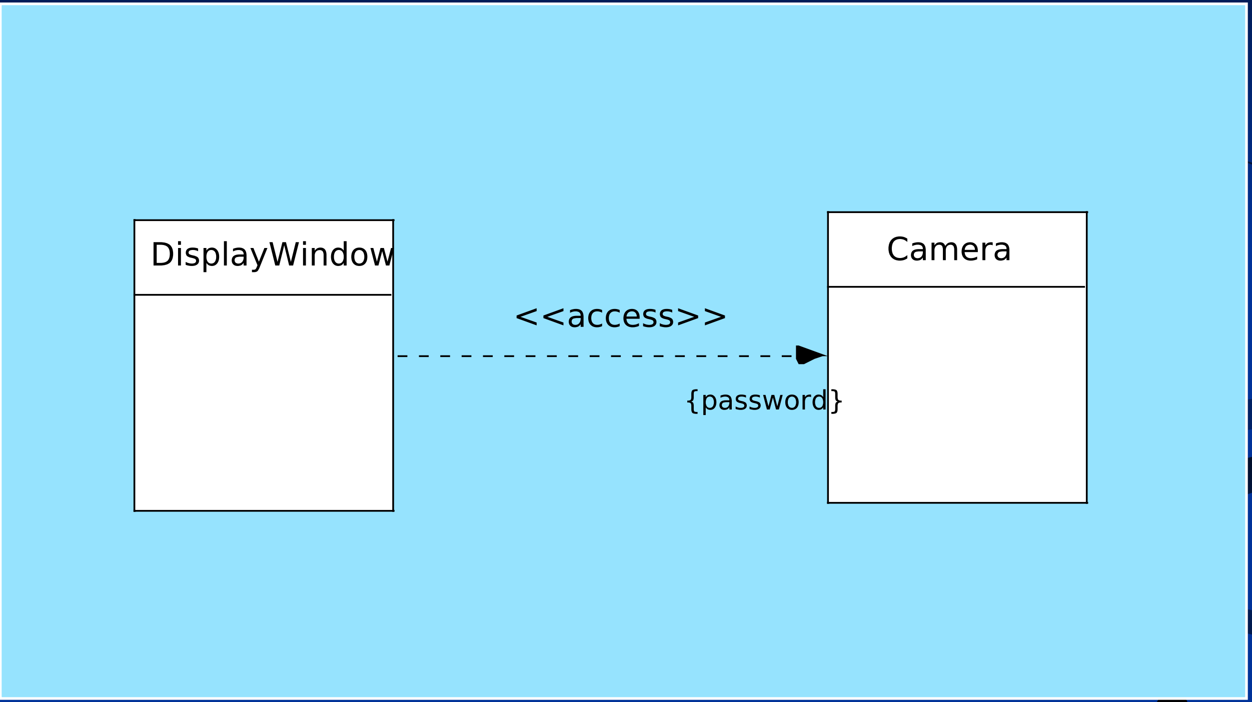
Associations and Dependencies

- 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

Multiplicity



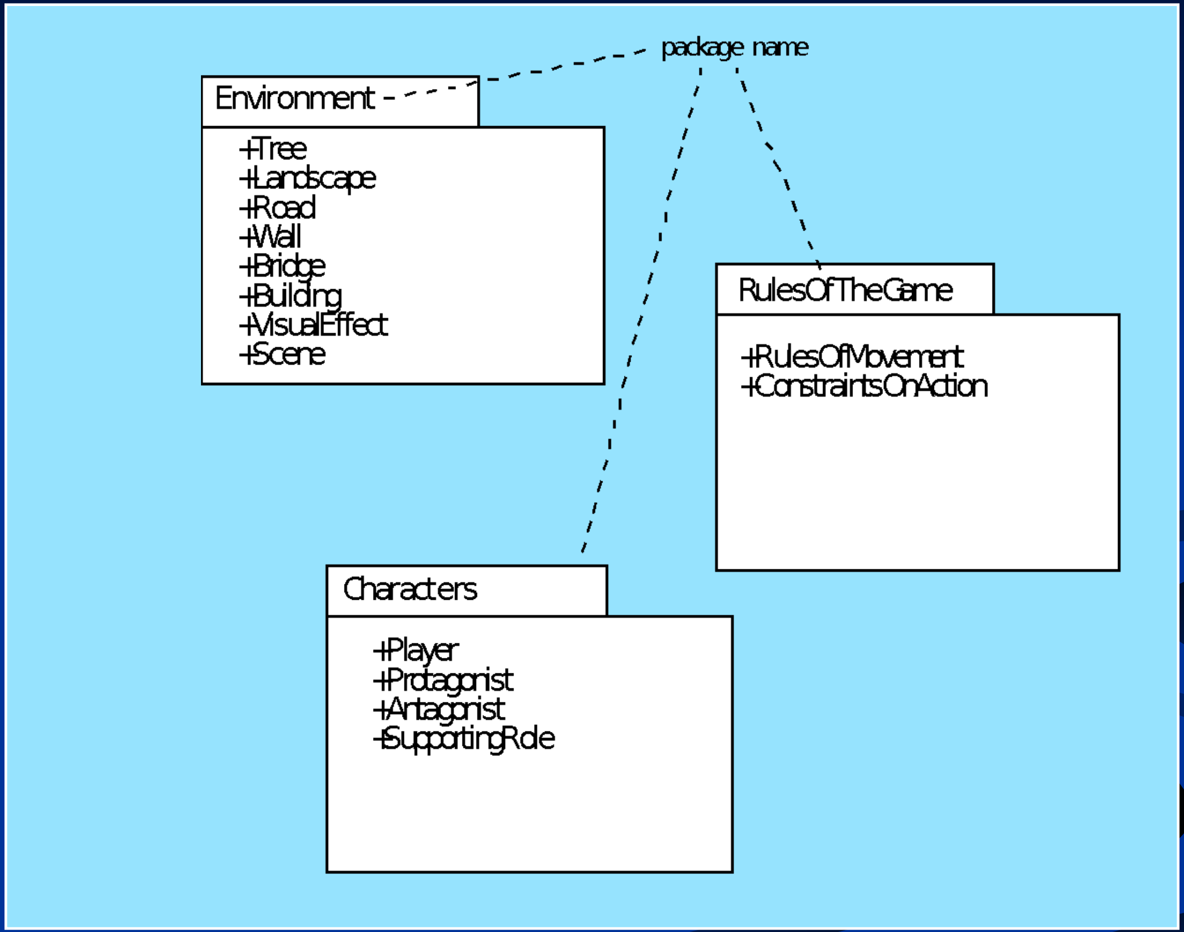
Dependencies



Analysis Packages

- 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



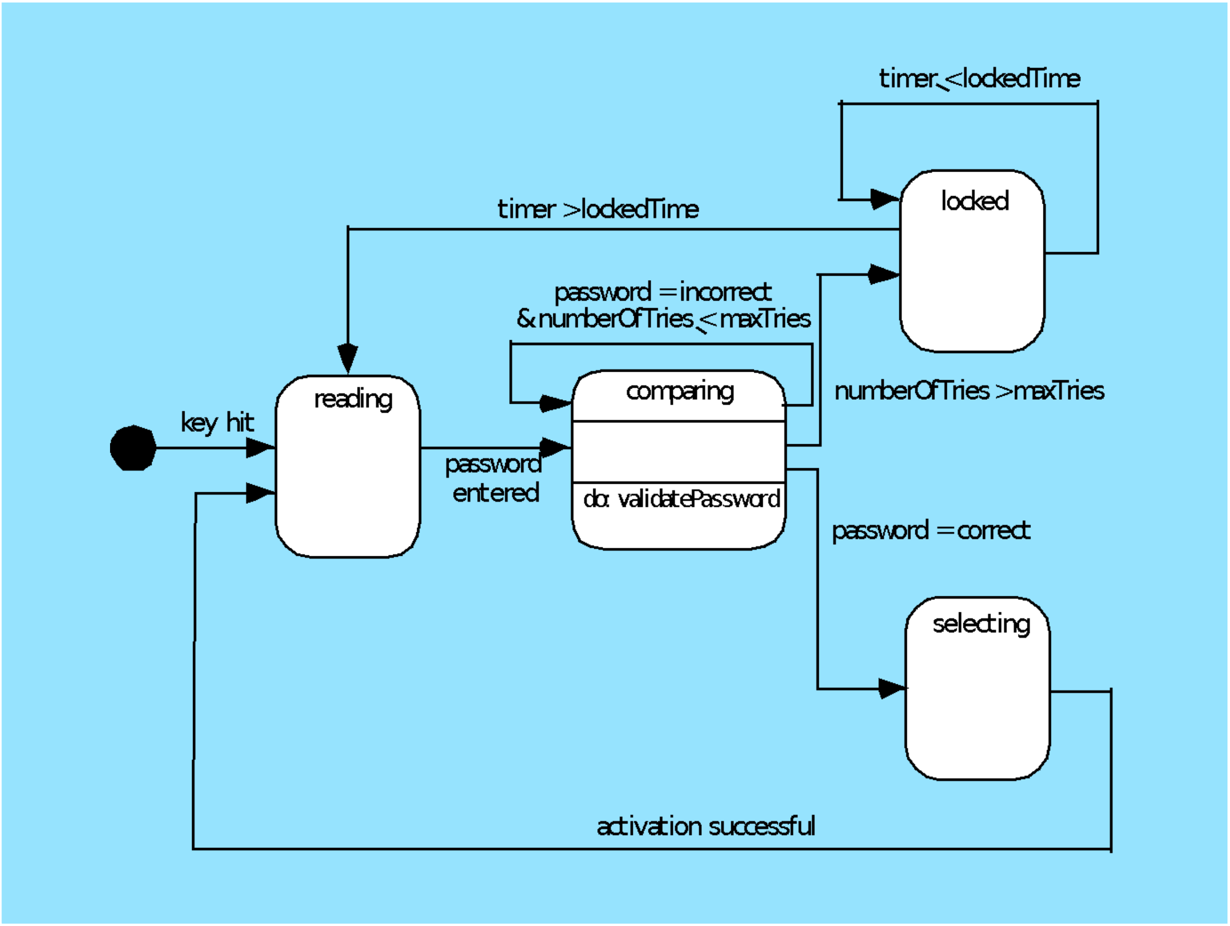
Behavioral Modeling

- The behavioral model indicates how software will respond to external events or stimuli. To create the model, the analyst must perform the following steps:
  - Evaluate all use-cases to fully understand the sequence of interaction within the system.
  - Identify events that drive the interaction sequence and understand how these events relate to specific objects.
  - Create a sequence for each use-case.
  - Build a state diagram for the system.
  - Review the behavioral model to verify accuracy and consistency.

State Representations

- In the context of behavioral modeling, two different characterizations of states must be considered:
  - the state of each class as the system performs its function and
  - the state of the system as observed from the outside as the system performs its function
- The state of a class takes on both passive and active characteristics [CHA93].
  - A *passive state* is simply the current status of all of an object's attributes.
  - The *active state* of an object indicates the current status of the object as it undergoes a continuing transformation or processing.

State Diagram for the ControlPanel Class



The States of a System

- state—a set of observable circum-stances that characterizes the behavior of a system at a given time
- state transition—the movement from one state to another
- event—an occurrence that causes the system to exhibit some predictable form of behavior
- action—process that occurs as a consequence of making a transition

Behavioral Modeling

- make a list of the different states of a system (How does the system behave?)
- indicate how the system makes a transition from one state to another (How does the system change state?)
  - indicate event
  - indicate action
- draw a state diagram or a sequence diagram

Sequence Diagram

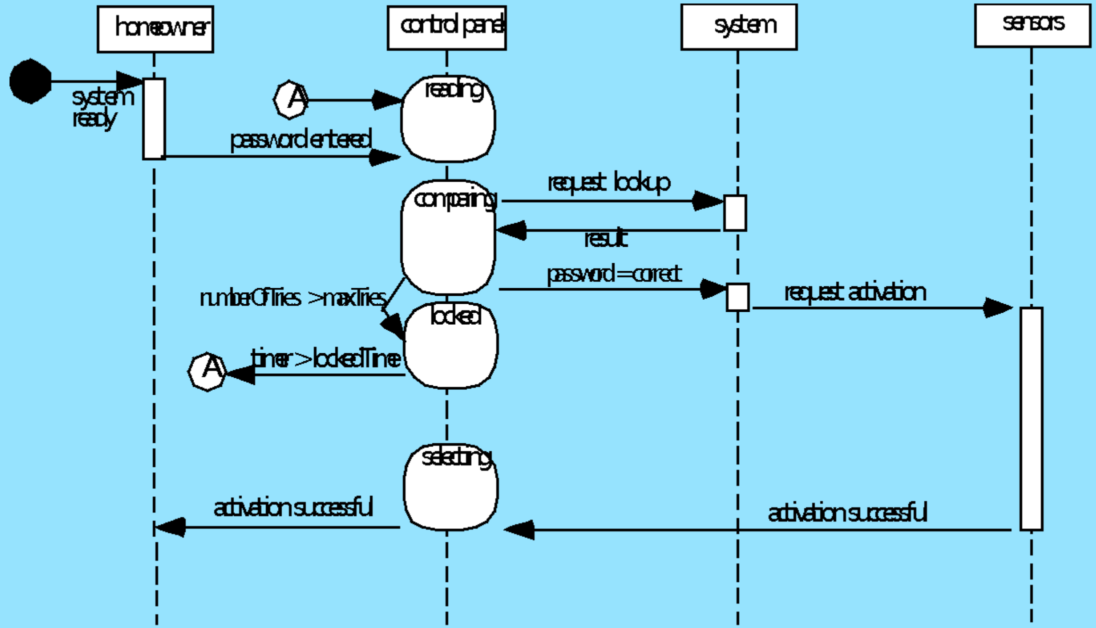


Figure 8.27 Sequence diagram (partial) for *SafeHome* security function

Writing the Software Specification

Specification Guidelines

- use a layered format that provides increasing detail as the "layers" deepen
- use consistent graphical notation and apply textual terms consistently (stay away from aliases)
- be sure to define all acronyms
- be sure to include a table of contents; ideally, include an index and/or a glossary
- write in a simple, unambiguous style (see "editing suggestions" on the following pages)
- always put yourself in the reader's position, "Would I be able to understand this if I wasn't intimately familiar with the system?"

Specification Guidelines

Be on the lookout for persuasive connectors, ask why?
keys: *certainly, therefore, clearly, obviously, it follows that ...*

Watch out for vague terms
keys: *some, sometimes, often, usually, ordinarily, most, mostly ...*

When lists are given, but not completed, be sure all items are understood
keys: *etc., and so forth, and so on, such as*

Be sure stated ranges don't contain unstated assumptions
e.g., *Valid codes range from 10 to 100.* Integer? Real? Hex?

Beware of vague verbs such as *handled, rejected, processed, ...*

Beware "passive voice" statements
e.g., *The parameters are initialized.* By what?

Beware "dangling" pronouns
e.g., *The I/O module communicated with the data validation module and its contol flag is set.* Whose control flag?

Specification Guidelines

When a term is explicitly defined in one place, try substituting the definition forother occurrences of the term

When a structure is described in words, draw a picture

When a structure is described with a picture, try to redraw the picture to emphasize different elements of the structure

When symbolic equations are used, try expressing their meaning in words

When a calculation is specified, work at least two examples

Look for statements that imply certainty, then ask for proof
keys; always, every, all, none, never

Search behind certainty statements—be sure restrictions or limitations are realistic