Requirements Modeling

BOOK REFERRED: ROGER PRESSMAN 7TH EDITION CHAPTER 6 & 7

Requirements Modeling

- What is it? – uses a combination of text and diagrammatic forms to depict requirements in a way that is relatively easy to understand and to review for correctness, completeness and consistency.
- Why is it important? – to validate software requirements from different points of view. [scenario based, data, class oriented, flow oriented, behavioral model]

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.

Requirements Modeling

- The requirements modeling action results in one or more of the following types of models:
  - *Scenario-based models* of requirements from the point of view of various system “actors”
  - *Data models* that depict the information domain for the problem
  - *Class-oriented models* that represent object-oriented classes (attributes and operations) and the manner in which classes collaborate to achieve system requirements
  - *Flow-oriented models* that represent the functional elements of the system and how they transform data as it moves through the system
  - *Behavioral models* that depict how the software behaves as a consequence of external “events”

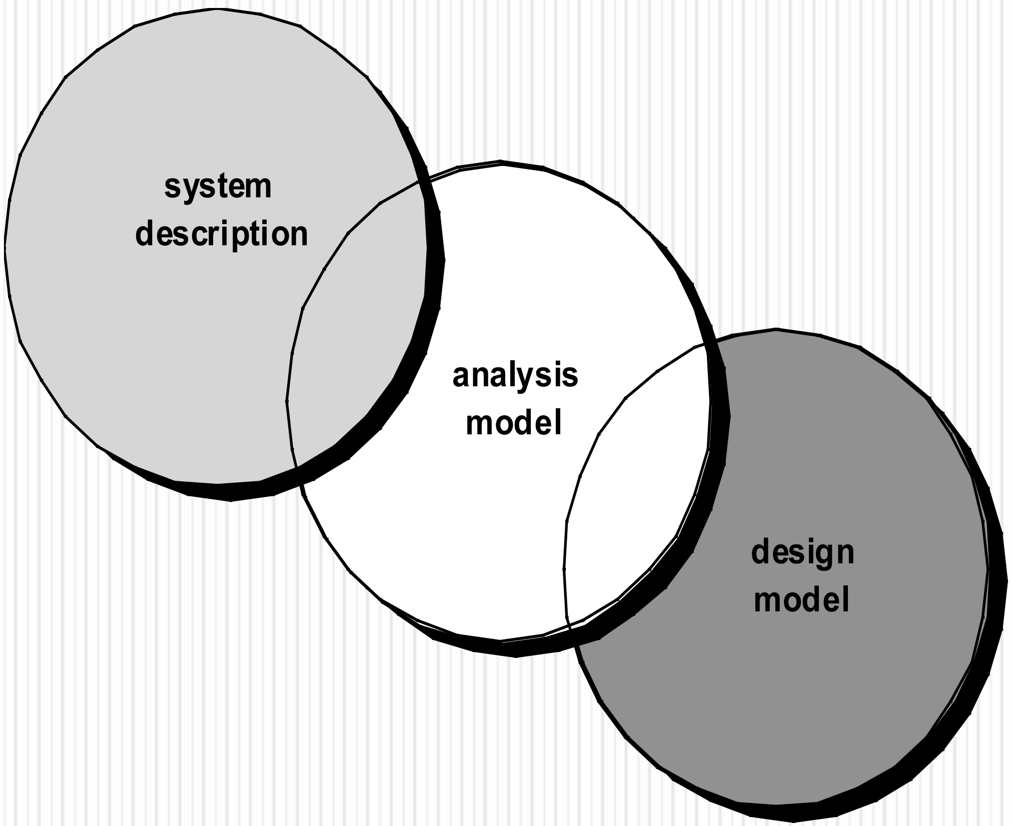
Requirements Modeling

- The primary focus is *what* and not *how*.
  - what user interaction occurs in a particular circumstance.
  - What objects does system manipulate.
  - What functions must the system perform.
  - What behaviors does the system exhibit.
  - What constraints apply and so on.
- *Requirements are not architecture, Requirements are not design, nor are they the user interface. Requirements are need."*

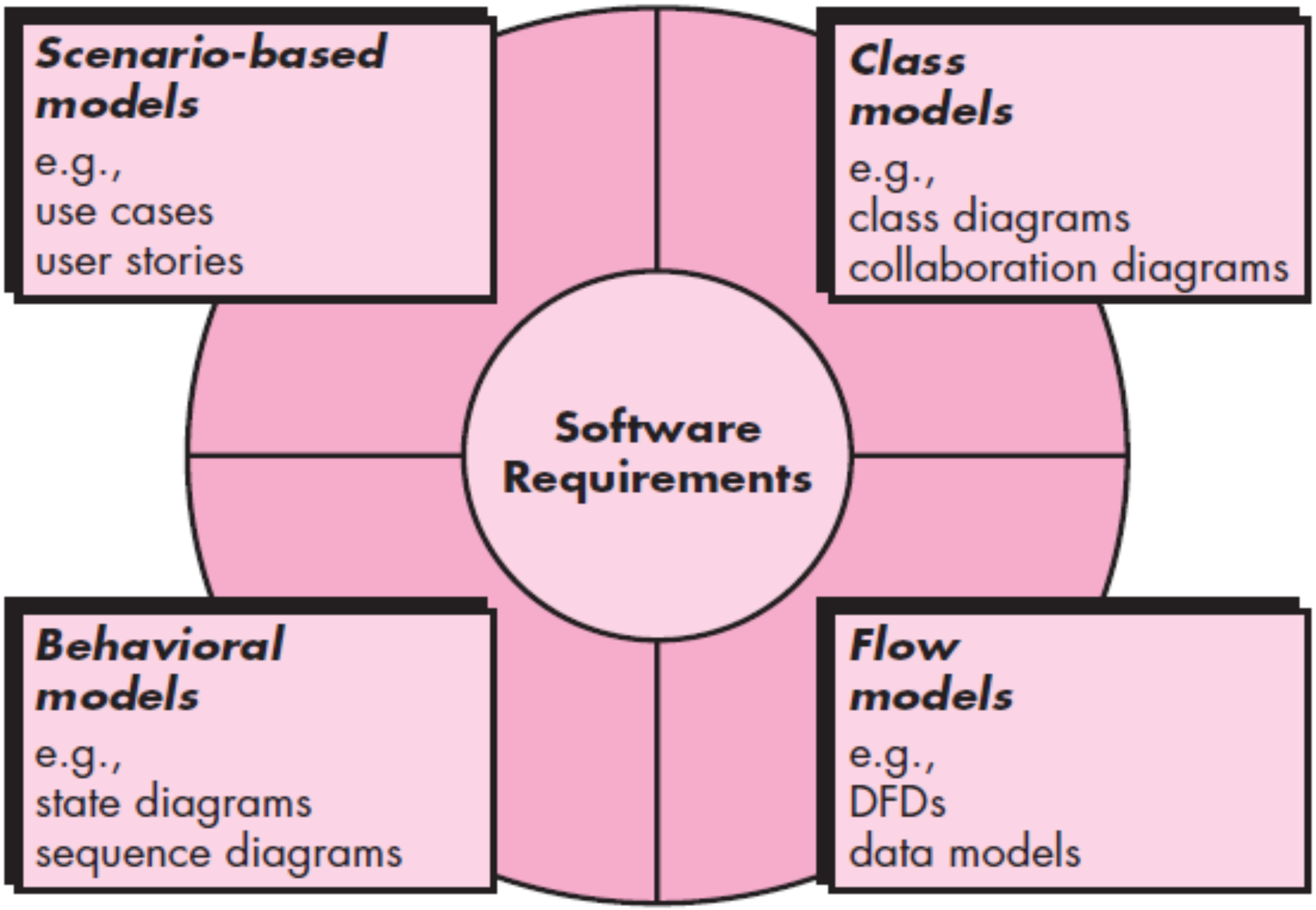
Requirements Modeling

- The requirements model must achieve three primary objectives:
- (1) to describe what the customer requires,
- (2) to establish a basis for the creation of a software design,
- (3) to define a set of requirements that can be validated once the software is built.

A Bridge



Elements of Requirements Analysis



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)."

(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?

What to Write About?

- Inception and elicitation - provide you with the information you'll need to begin writing use cases.
- Requirements gathering meetings and other requirements engineering mechanisms are used to
  - identify stakeholders
  - define the scope of the problem
  - specify overall operational goals
  - establish priorities
  - outline all known functional requirements, and
  - describe the things (objects) that will be manipulated by the system.
- To begin developing a set of use cases, list the functions or activities performed by a specific actor.

How Much to Write About?

- As further conversations with the stakeholders progress, the requirements gathering team develops use cases for each of the functions noted.
- In general, use cases are written first in an informal narrative fashion.
- If more formality is required, the same use case is rewritten using a structured format similar to the one proposed.

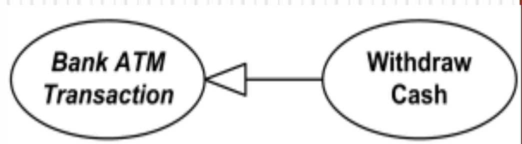
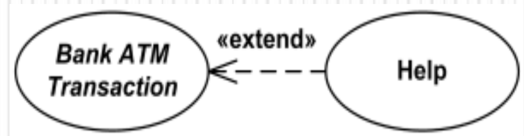
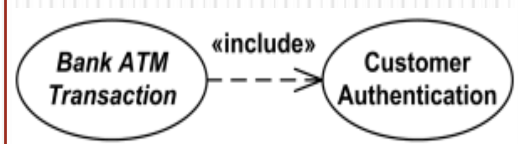
Use-Cases

- a *scenario* that describes a “thread of usage” for a system
- *actors* represent roles people or devices play as the system functions
- *Relationships*
- *System boundary*

Developing a Use-Case

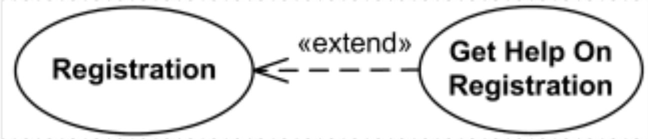
- What are the main tasks or functions that are performed by the actor?
- What system information will the actor acquire, produce or change?
- Will the actor have to inform the system about changes in the external environment?
- What information does the actor desire from the system?
- Does the actor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

Relationships

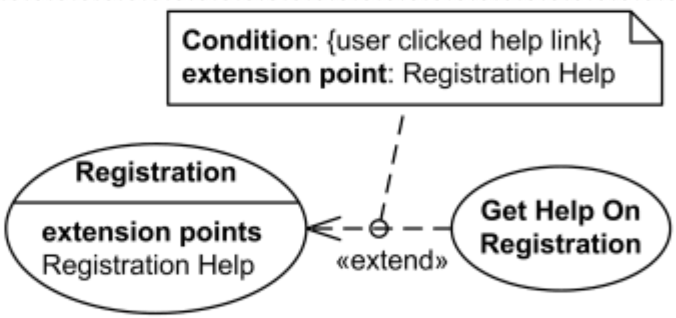
Generalization	Extend	Include
		
Base use case could be abstract use case (incomplete) or concrete (complete).	Base use case is complete (concrete) by itself, defined independently.	Base use case is incomplete (abstract use case).
Specialized use case is required, not optional, if base use case is abstract.	Extending use case is optional, supplementary.	Included use case required, not optional.
No explicit location to use specialization.	Has at least one explicit extension location.	No explicit inclusion location but is included at some location.
No explicit condition to use specialization.	Could have optional extension condition.	No explicit inclusion condition.

Extension points when using <<extend>> relationship

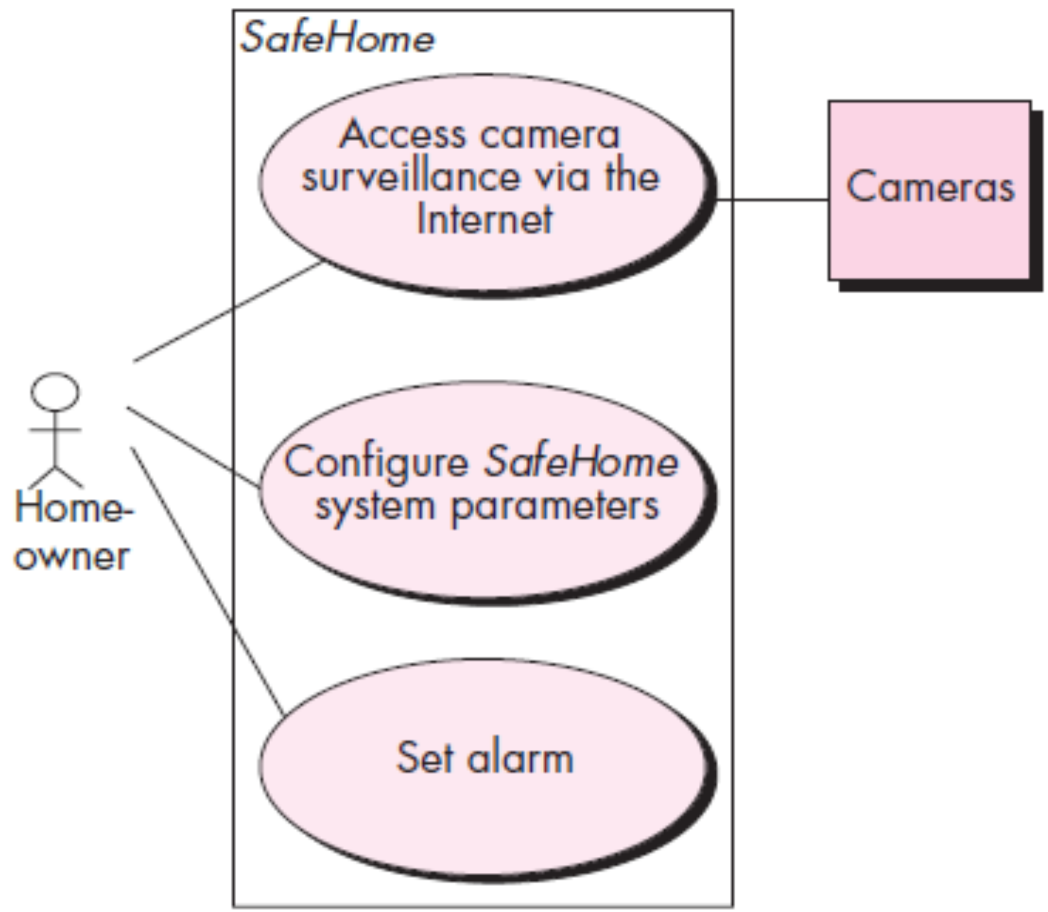
- **Extend** relationship is shown as a dashed line with an open arrowhead directed from the **extending use case** to the **extended (base) use case**. The arrow is labeled with the keyword **«extend»**.

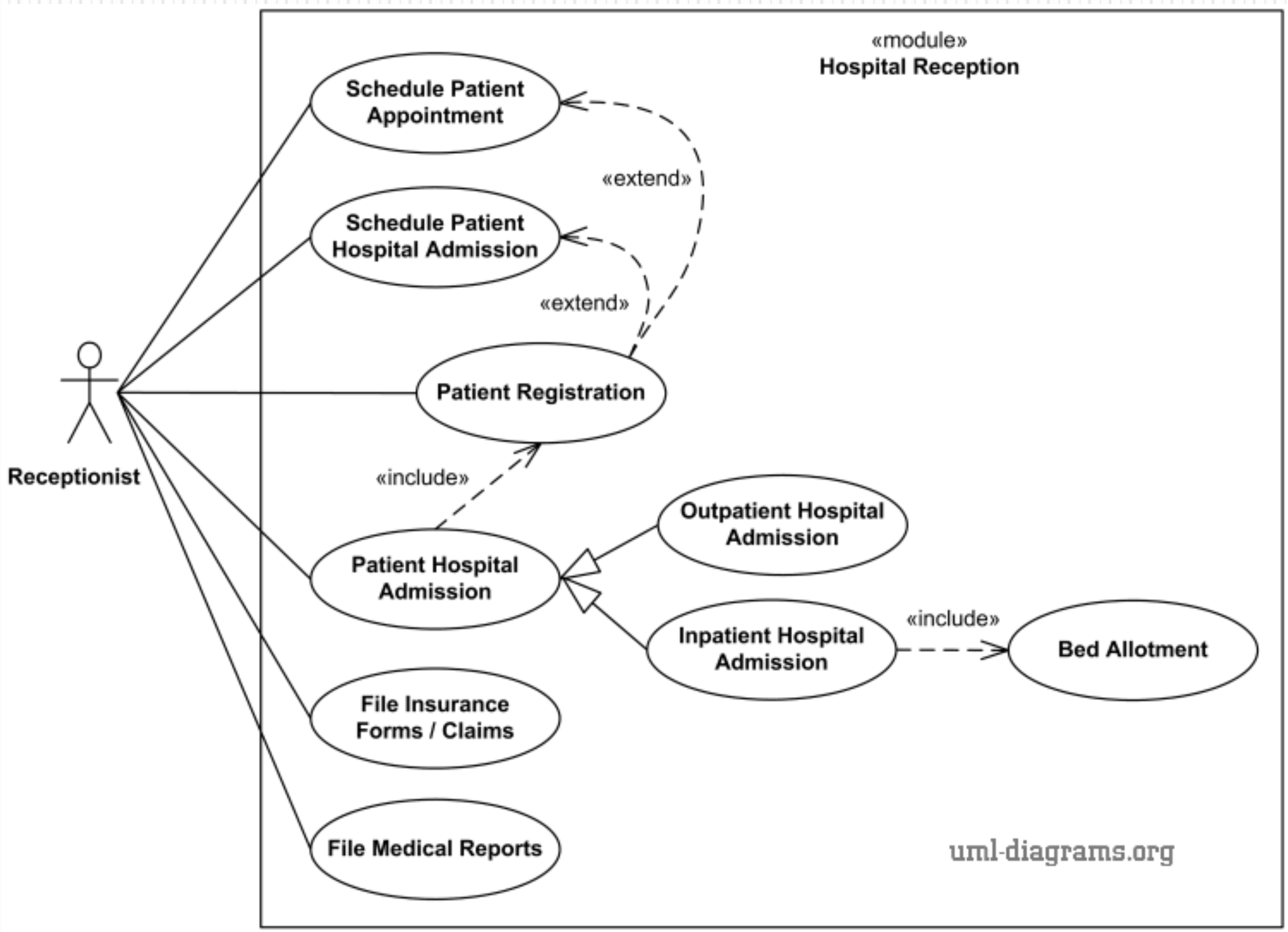


- The **condition** of the extend relationship as well as the references to the **extension points** are optionally shown in a **comment** note attached to the corresponding extend relationship.



Use-Case Diagram




«module»
Hospital Reception
Schedule Patient Appointment
Schedule Patient Hospital Admission
«extend»
«extend»
Patient Registration
Receptionist
«include»
Outpatient Hospital Admission
Patient Hospital Admission
Inpatient Hospital Admission
«include»
Bed Allotment
File Insurance Forms / Claims
File Medical Reports
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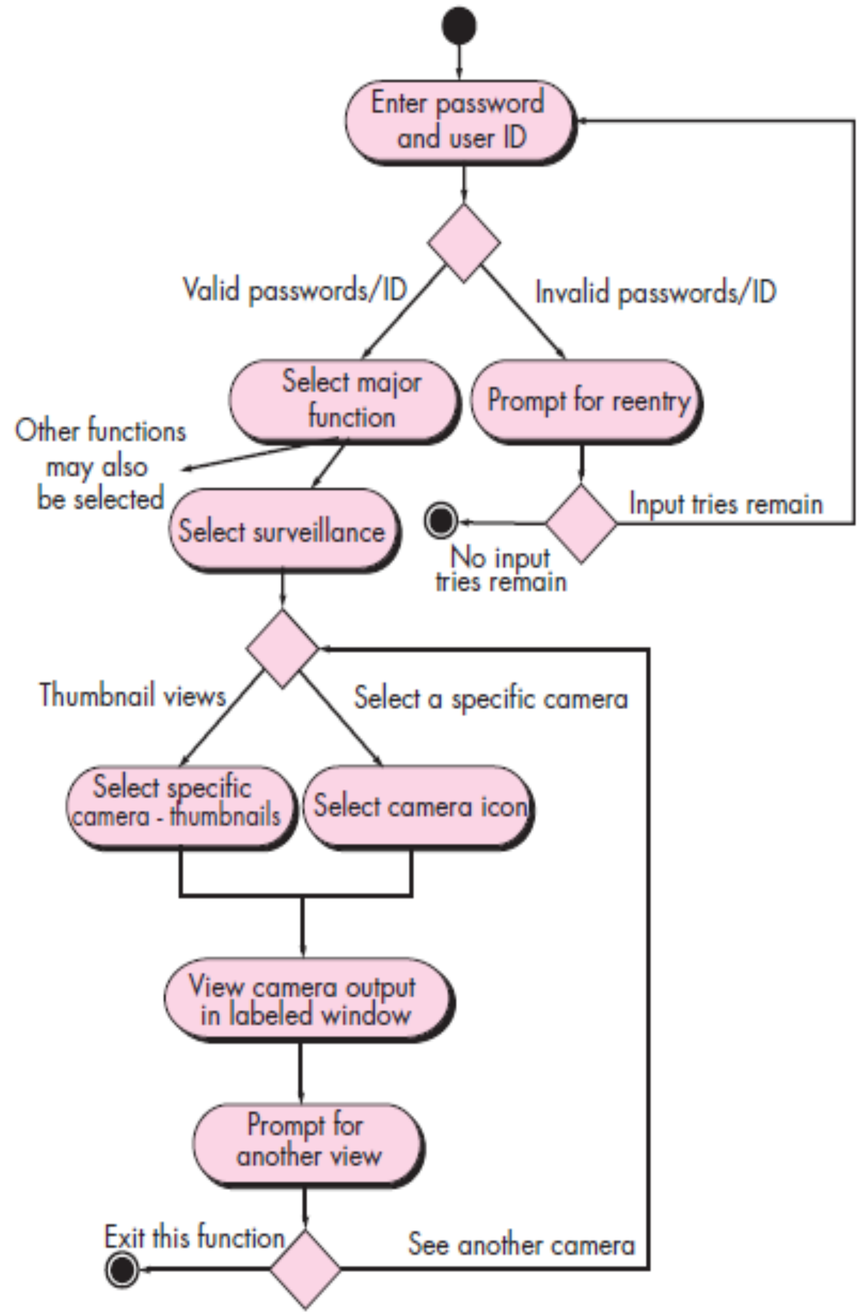
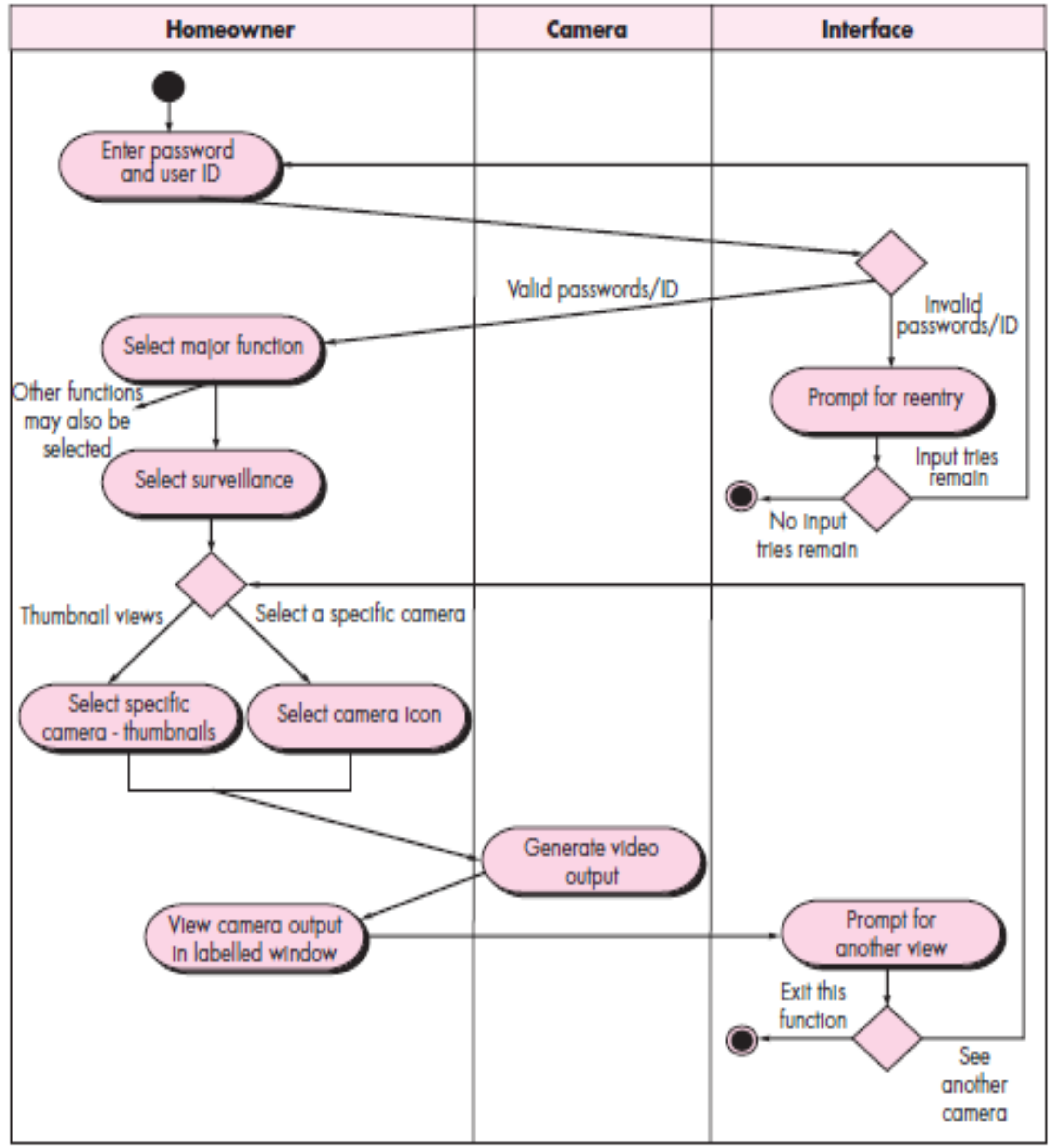
Activity Diagram

Supplements the use case by providing a graphical representation of the flow of interaction within a specific scenario



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



Data Modeling

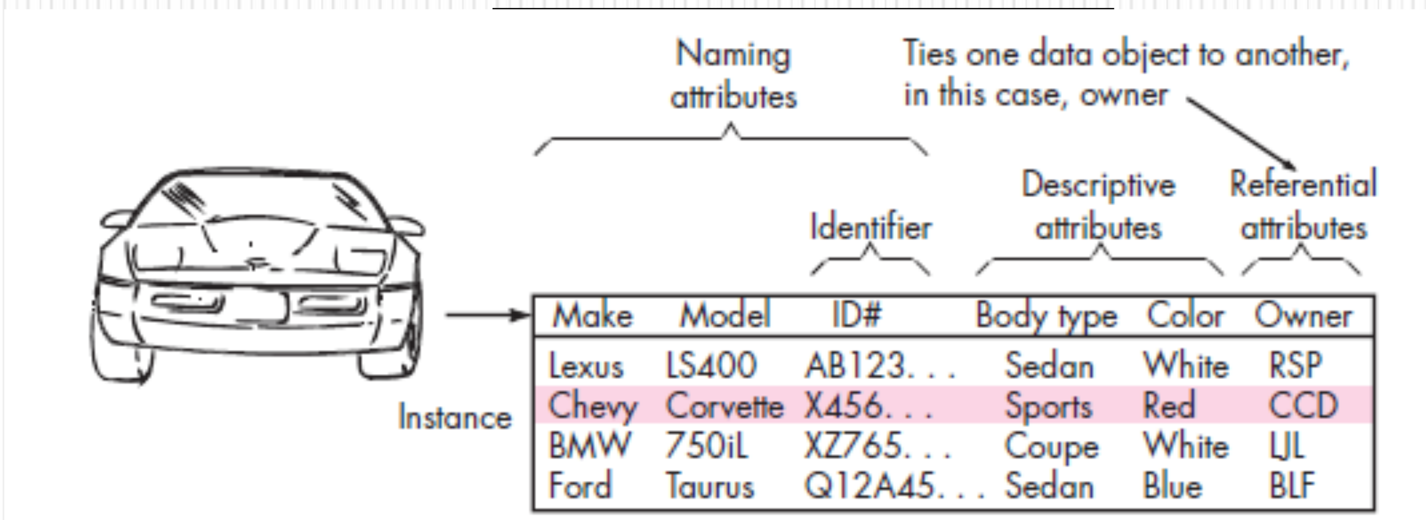
- Examines data objects independently of processing
- Focuses attention on the data domain
- Creates a model at the customer's level of abstraction
- Indicates how data objects relate to one another

What is a Data Object?

- a representation of almost any composite information that must be understood by software.
  - *composite information*—something that has a number of different properties or attributes
- can be an external entity (e.g., anything that produces or consumes information), a thing (e.g., a report or a display), an occurrence (e.g., a telephone call) or event (e.g., an alarm), a role (e.g., salesperson), an organizational unit (e.g., accounting department), a place (e.g., a warehouse), or a structure (e.g., a file).
- The description of the data object incorporates the data object and all of its attributes.
- A data object encapsulates data only—there is no reference within a data object to operations that act on the data.

Data Objects and Attributes

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



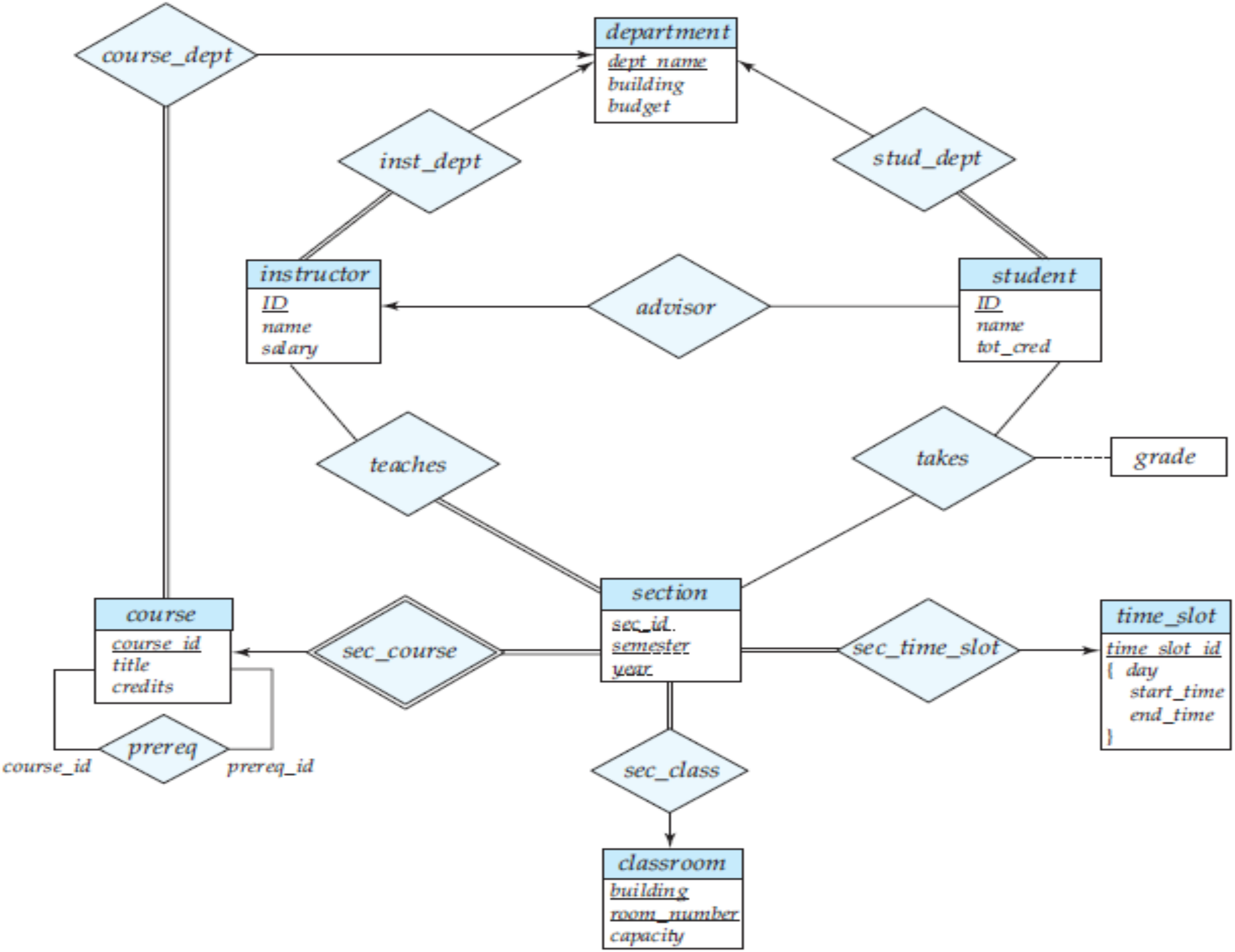
Make	Model	ID#	Body type	Color	Owner
Lexus	LS400	AB123. . .	Sedan	White	RSP
Chevy	Corvette	X456. . .	Sports	Red	CCD
BMW	750iL	XZ765. . .	Coupe	White	LJL
Ford	Taurus	Q12A45. . .	Sedan	Blue	BLF

What is a Relationship?

- Data objects are connected to one another in different ways.
  - A connection is established between **person** and **car** because the two objects are related.
    - A person *owns* a car
    - A person *is insured to drive* a car
- The relationships *owns* and *insured to drive* define the relevant connections between **person** and **car**.
- Several instances of a relationship can exist
- Objects can be related in many different ways

Building an Entity Relationship Diagram

- *Step 1* : model all data objects (entities) and their “connections” to one another
- *Step 2* : model all entities and relationships
- *Step 3* : model all entities, relationships, and the attributes that provide further depth



course_dept
department
dept_name
building
budget
inst_dept
stud_dept
instructor
ID
name
salary
advisor
student
ID
name
tot_cred
teaches
takes
grade
section
sec_id
semester
year
course
course_id
title
credits
sec_course
sec_time_slot
time_slot
time_slot_id
{ day
start_time
end_time
}
prereq
course_id
prereq_id
sec_class
classroom
building
room_number
capacity

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 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 (class responsibility collaborator) models, collaboration diagrams and packages.

Manifestation 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
  - *Places* (e.g., manufacturing floor or loading dock) that establish the context of the problem and the overall function
  - *Structures* (e.g., sensors, four-wheeled vehicles, or computers) that define a class of objects or related classes of objects

Potential Classes

- *Retained information: I*nformation about it must be remembered so that the system can function.
- *Needed services.* Operations that an change the value of its attributes in some way.
- *Multiple attributes:* That define the characteristics of the potential class.
- *Common attributes:* These attributes apply to all instances of the class.
- *Common operations: T*hese operations apply to all instances of the class.
- *Essential requirements:* Finally, defines the requirements of the potential class.

Defining 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.

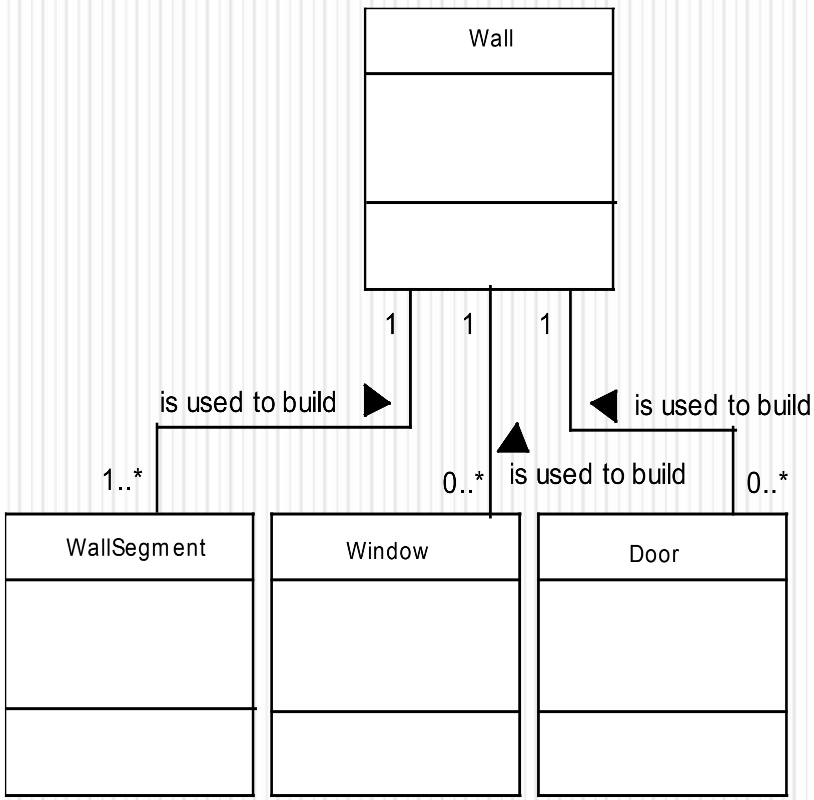
Defining Operations

- 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.

Associations and Dependencies

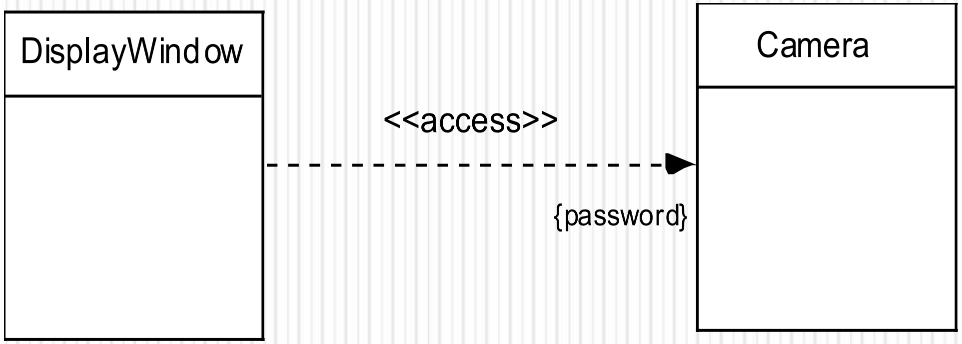
- Two analysis classes are often related to one another in some fashion
  - In UML these relationships are called *associations*
  - Associations can be refined by indicating *multiplicity* (the term *cardinality* is used in data modeling
- In many instances, a client-server relationship exists between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

Multiplicity



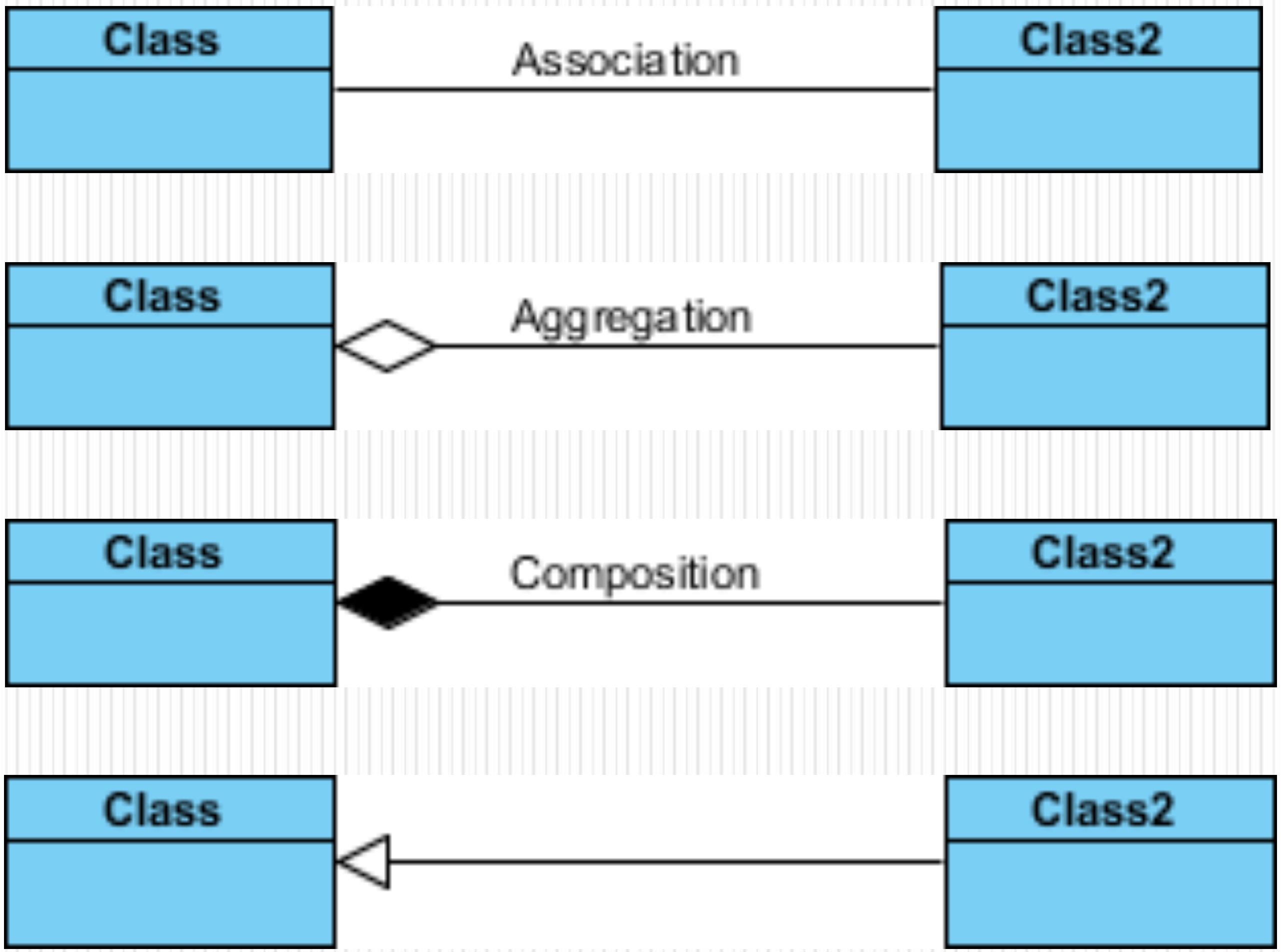
Indicator	Meaning
0..1	Zero or one
1	One only
0..*	Zero or more
1..*	One or more
n	Only *n* (where *n* > 1)
0..n	Zero to *n* (where *n* > 1)
1..n	One to *n* (where *n* > 1)

Dependencies

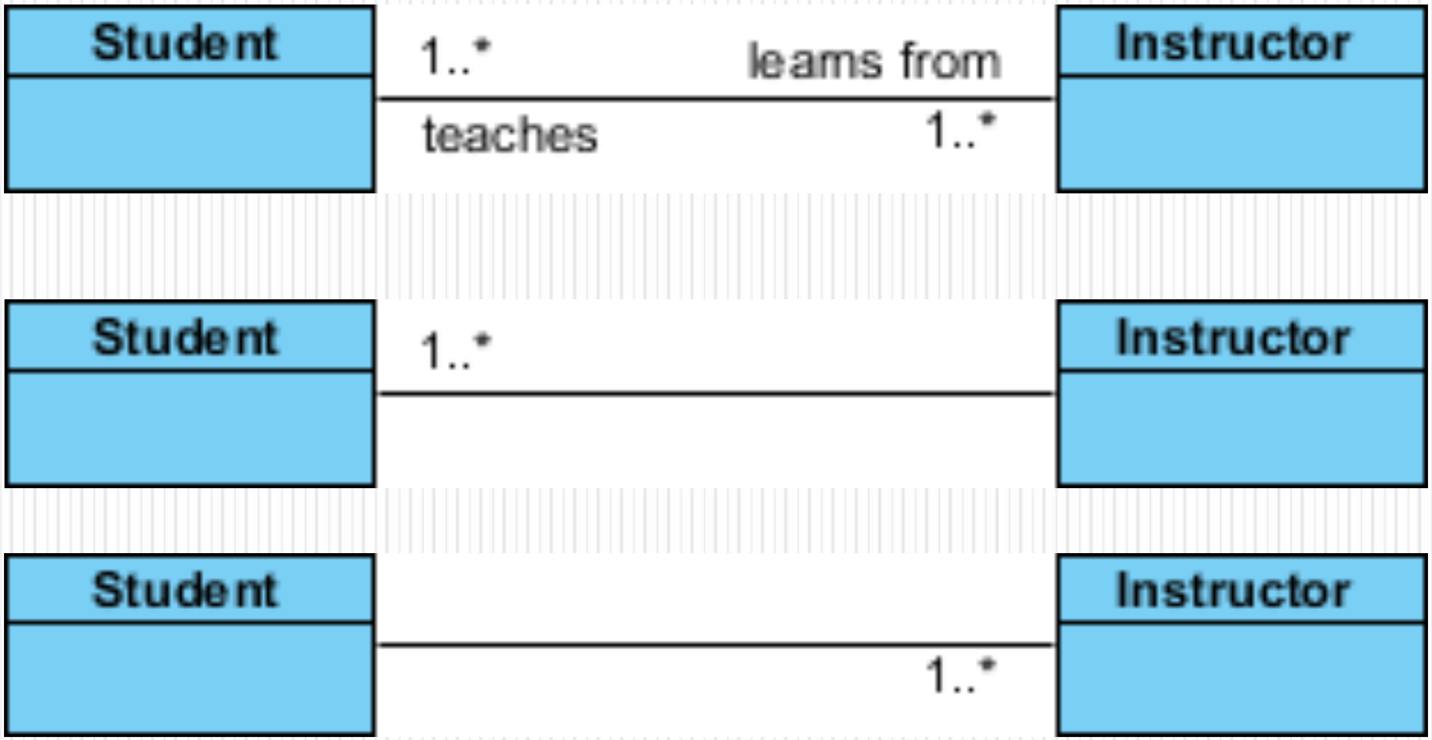


Usage is a dependency in which one **named element** (client) requires another named element (supplier) for its full **definition** or **implementation**.

Relationships

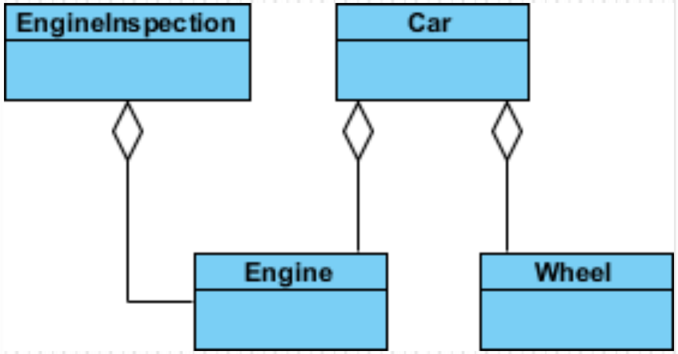


Association

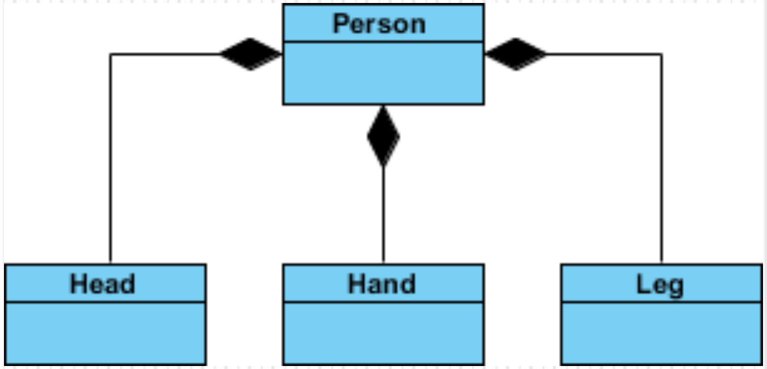


Aggregation vs. Composition

- **Aggregation** implies a relationship where the child can exist independently of the parent. Example: Class (parent) and Student (child). Delete the Class and the Students still exist.

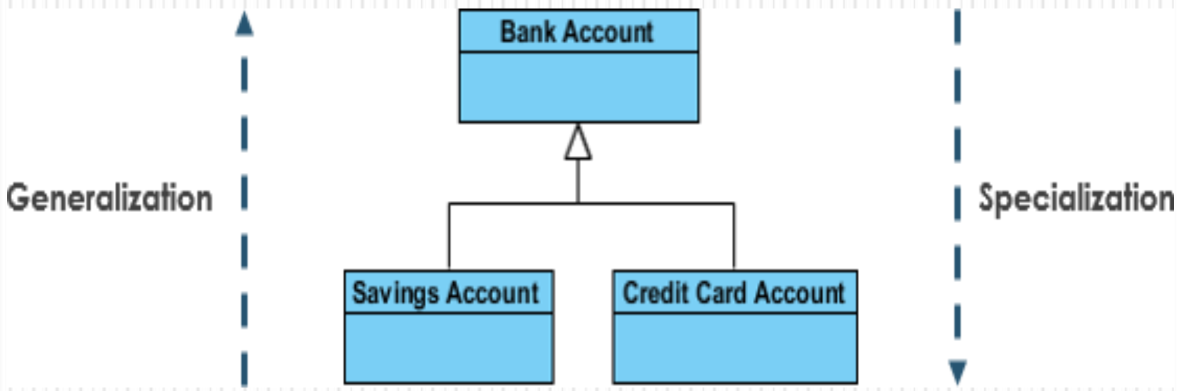


- **Composition** implies a relationship where the child cannot exist independent of the parent. Example: House (parent) and Room (child). Rooms don't exist separate to a House.



Generalization vs. Specialization

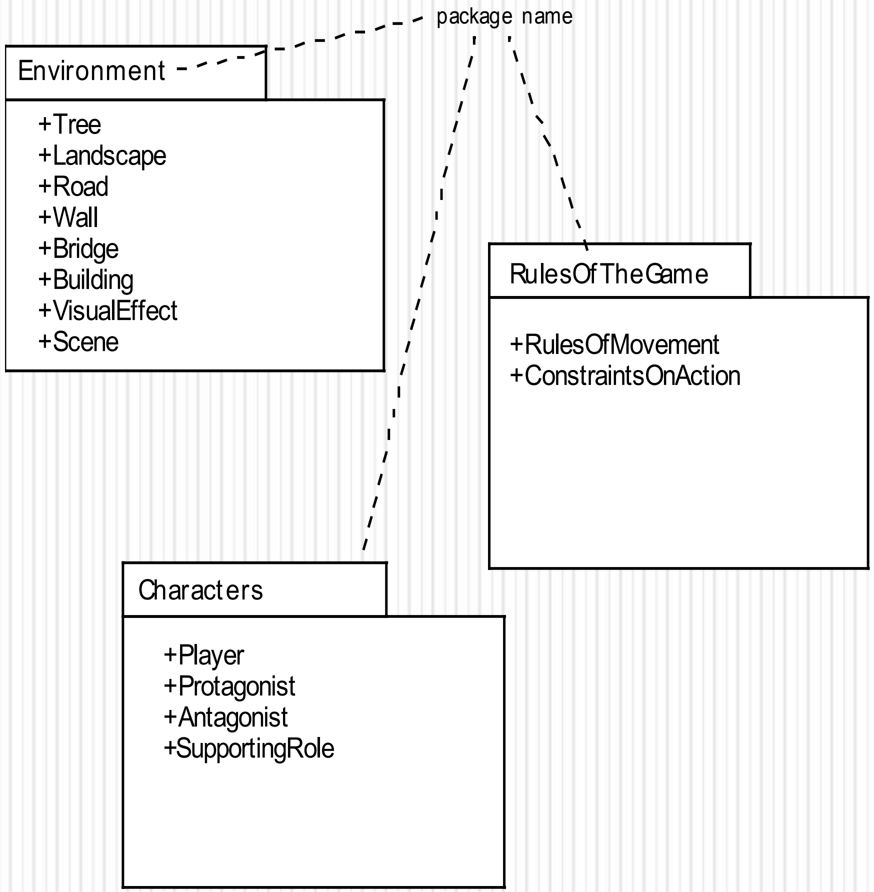
- **Generalization** identifies commonalities among a set of entities. The commonality may be of attributes, behavior, or both. A subclass may have more specialized attributes and operations.
- **Specialization** is the reverse process of Generalization means creating new sub classes from an existing class.
- For Example, a Bank Account is of two types - Savings Account and Credit Card Account. Savings Account and Credit Card Account inherit the common/ generalized properties like Account Number, Account Balance etc. from a Bank Account and also have their own specialized properties like unsettled payment etc.



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.

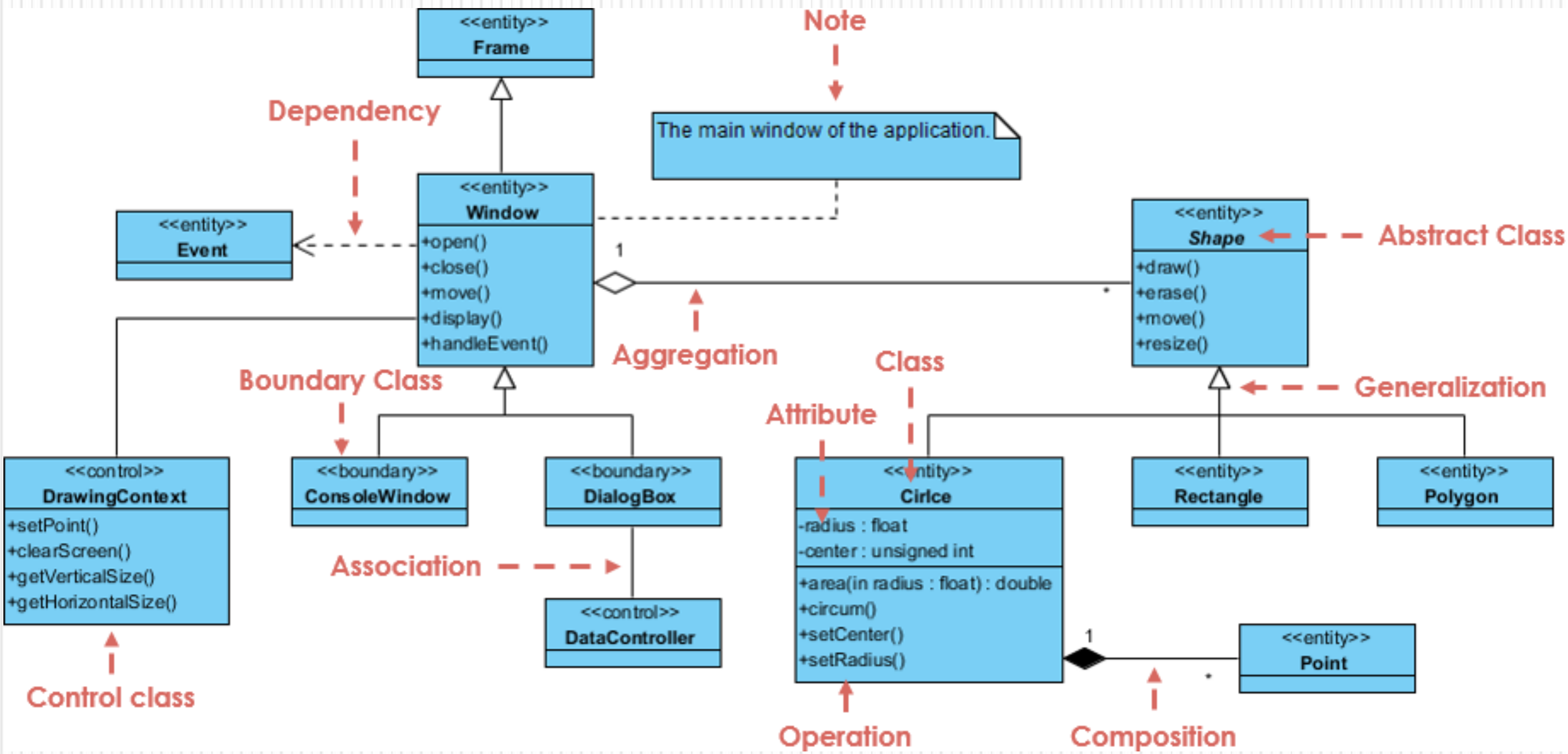
Analysis Packages

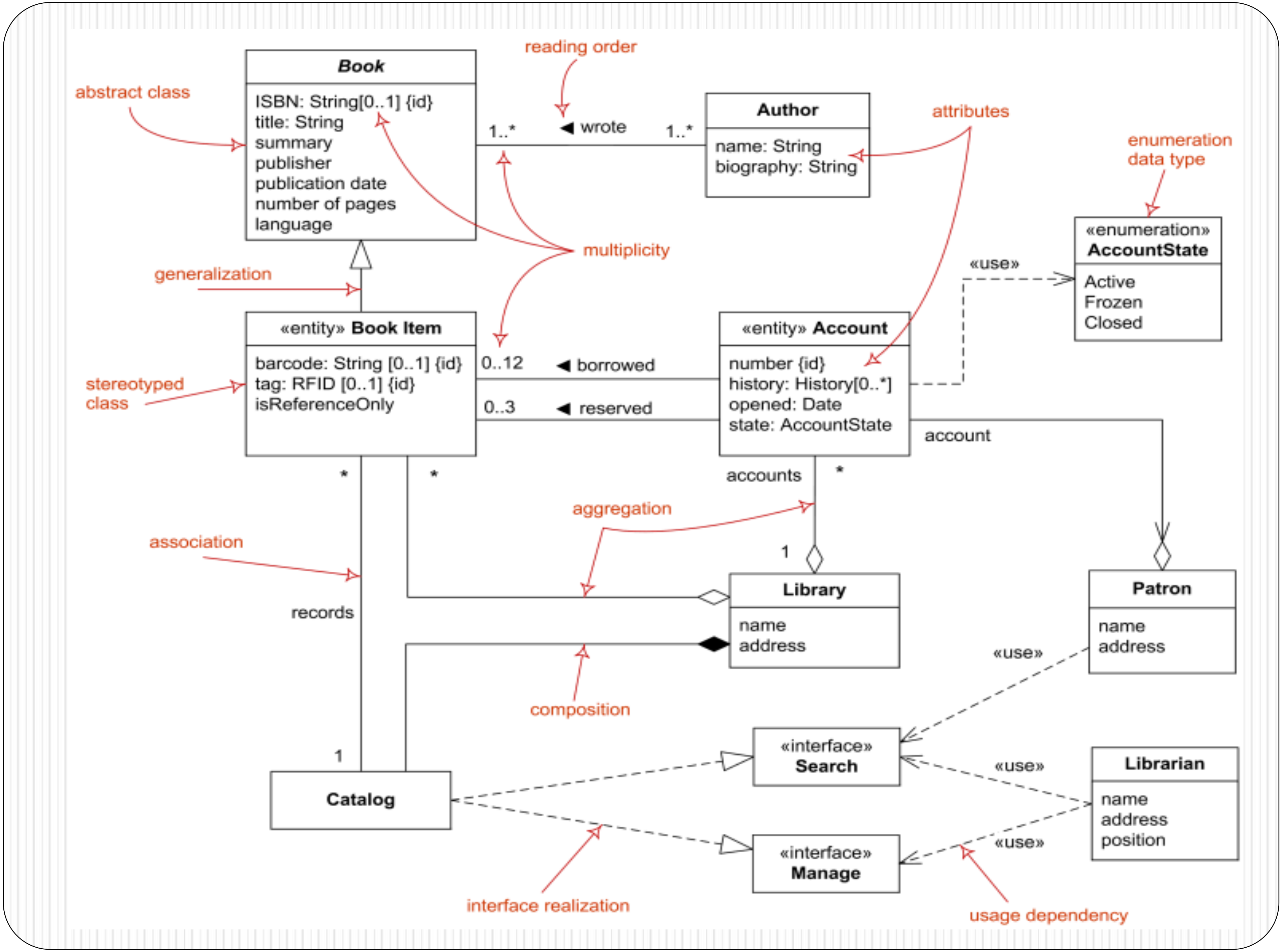


Class Types

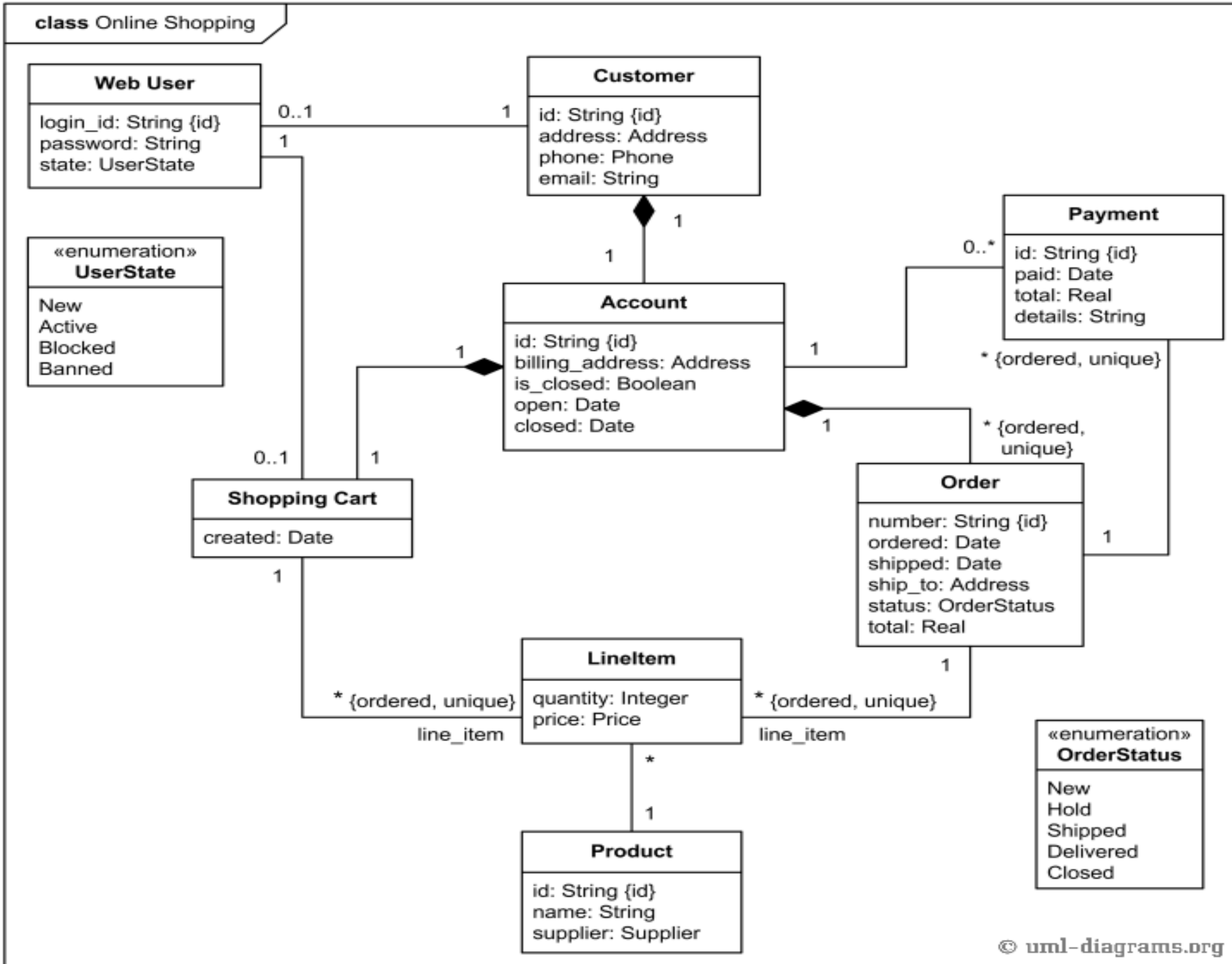
- *Entity classes*, also called *model* or *business classes*, are extracted directly from the statement of the problem (e.g., FloorPlan and Sensor).
- *Boundary classes* are used to create the interface (e.g., interactive screen or printed reports) that the user sees and interacts with as the software is used.
- *Controller classes* represent coordination, sequencing, transactions, and control of other objects and are often used to encapsulate control related to a specific use case.
  - Control classes are also used to represent complex derivations and calculations, such as business logic, that cannot be related to any specific, long-lived information stored by the system (ie. a specific entity class).

All notations of Class Diagram





reading order
abstract class
Book
ISBN: String[0..1] {id}
title: String
summary
publisher
publication date
number of pages
language
1..*
◀ wrote
1..*
Author
name: String
biography: String
attributes
enumeration data type
«enumeration»
AccountState
Active
Frozen
Closed
multiplicity
generalization
«use»
«entity» Book Item
barcode: String [0..1] {id}
tag: RFID [0..1] {id}
isReferenceOnly
stereotyped class
0..12
◀ borrowed
0..3
◀ reserved
«entity» Account
number {id}
history: History[0..*]
opened: Date
state: AccountState
account
*
*
accounts
*
aggregation
association
1
Library
name
address
Patron
name
address
records
«use»
composition
1
«interface»
Search
«use»
Librarian
name
address
position
Catalog
«interface»
Manage
«use»
interface realization
usage dependency



class Online Shopping
Web User
login_id: String {id}
password: String
state: UserState
0..1
1
1
Customer
id: String {id}
address: Address
phone: Phone
email: String
1
1
«enumeration»
UserState
New
Active
Blocked
Banned
Payment
0..*
id: String {id}
paid: Date
total: Real
details: String
Account
id: String {id}
billing_address: Address
is_closed: Boolean
open: Date
closed: Date
1
1
* {ordered, unique}
1
* {ordered, unique}
0..1
1
Shopping Cart
created: Date
Order
number: String {id}
ordered: Date
shipped: Date
ship_to: Address
status: OrderStatus
total: Real
1
1
1
LineItem
quantity: Integer
price: Price
* {ordered, unique}
* {ordered, unique}
line_item
line_item
*
1
«enumeration»
OrderStatus
New
Hold
Shipped
Delivered
Closed
Product
id: String {id}
name: String
supplier: Supplier
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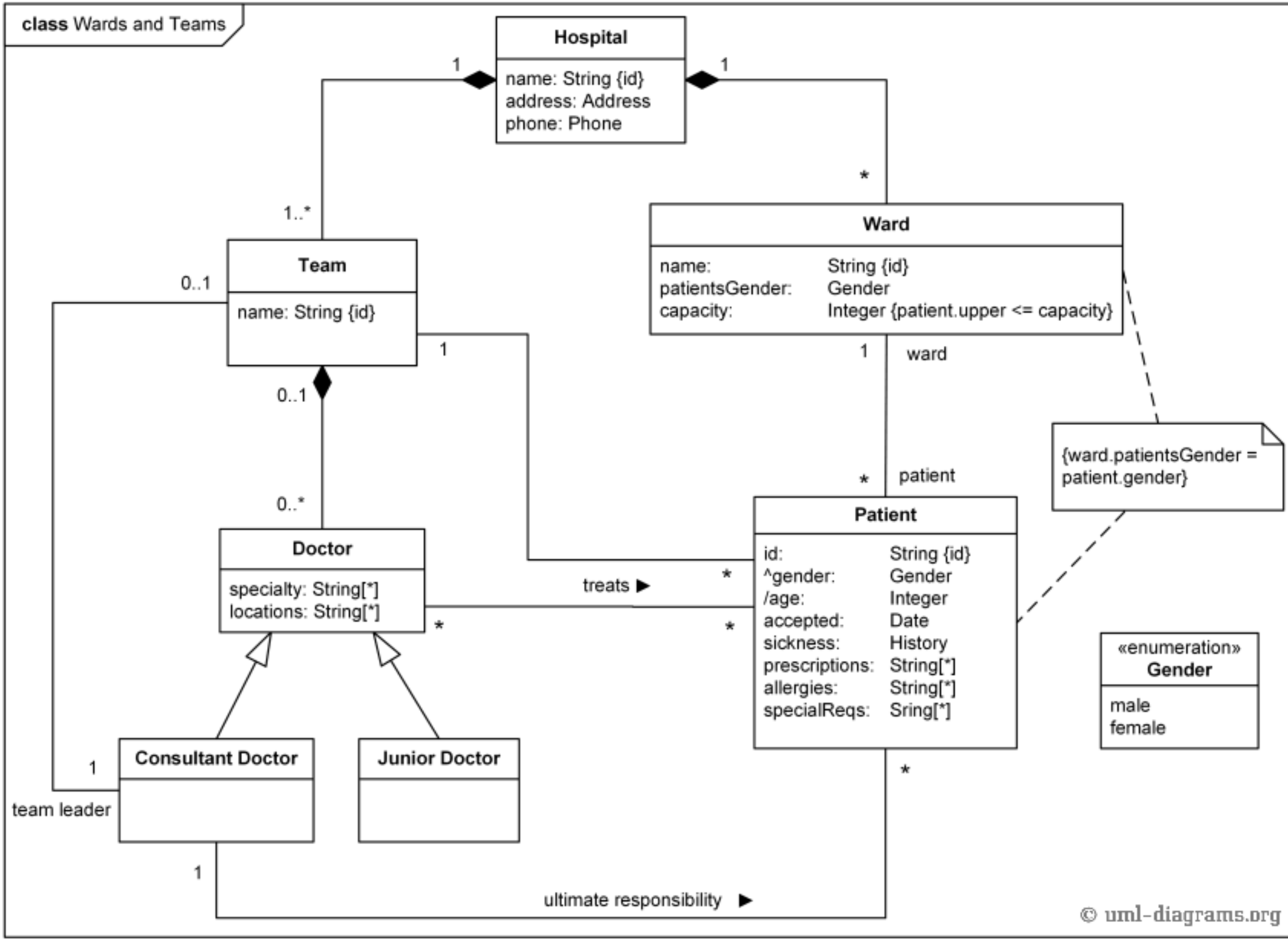

class Wards and Teams
Hospital
name: String {id}
address: Address
phone: Phone
1
1
1..*
*
Ward
name: String {id}
patientsGender: Gender
capacity: Integer {patient.upper <= capacity}
Team
name: String {id}
0..1
1
1
ward
0..1
{ward.patientsGender = patient.gender}
0..*
*
patient
Doctor
specialty: String[*]
locations: String[*]
Patient
id: String {id}
^gender: Gender
/age: Integer
accepted: Date
sickness: History
prescriptions: String[*]
allergies: String[*]
specialReqs: Sring[*]
treats ▶
*
*
*
«enumeration»
Gender
male
female
Consultant Doctor
Junior Doctor
1
team leader
*
1
ultimate responsibility ▶
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Example

- Saturn Int. management wants to improve their security measures, both for their building and on site. They would like to prevent people who are not part of the company to use their car park.
- Saturn Int. has decided to issue identity cards to all employees. Each card records the name, department and number of a company staff, and give them access to the company car park. Employees are asked to wear the cards while on the site.
- There is a barrier and a card reader placed at the entrance to the car park. When a driver drives his car into the car park, he/she inserts his or her identity card into the card reader. The card reader then verify the card number to see if it is known to the system. If the number is recognized, the reader sends a signal to trigger the barrier to rise. The driver can then drive his/her car into the car park.
- There is another barrier at the exit of the car park, which is automatically raised when a car wishes to leave the car park.
- A sign at the entrance display "Full" when there are no spaces in the car park. It is only switched off when a car leaves.
- There is another type of card for guests, which also permits access to the car park. The card records a number and the current date. Such cards may be sent out in advance, or collected from reception. All guest cards must be returned to reception when the visitor leaves Saturn Int.

Analysis Class/Candidate Class Identification

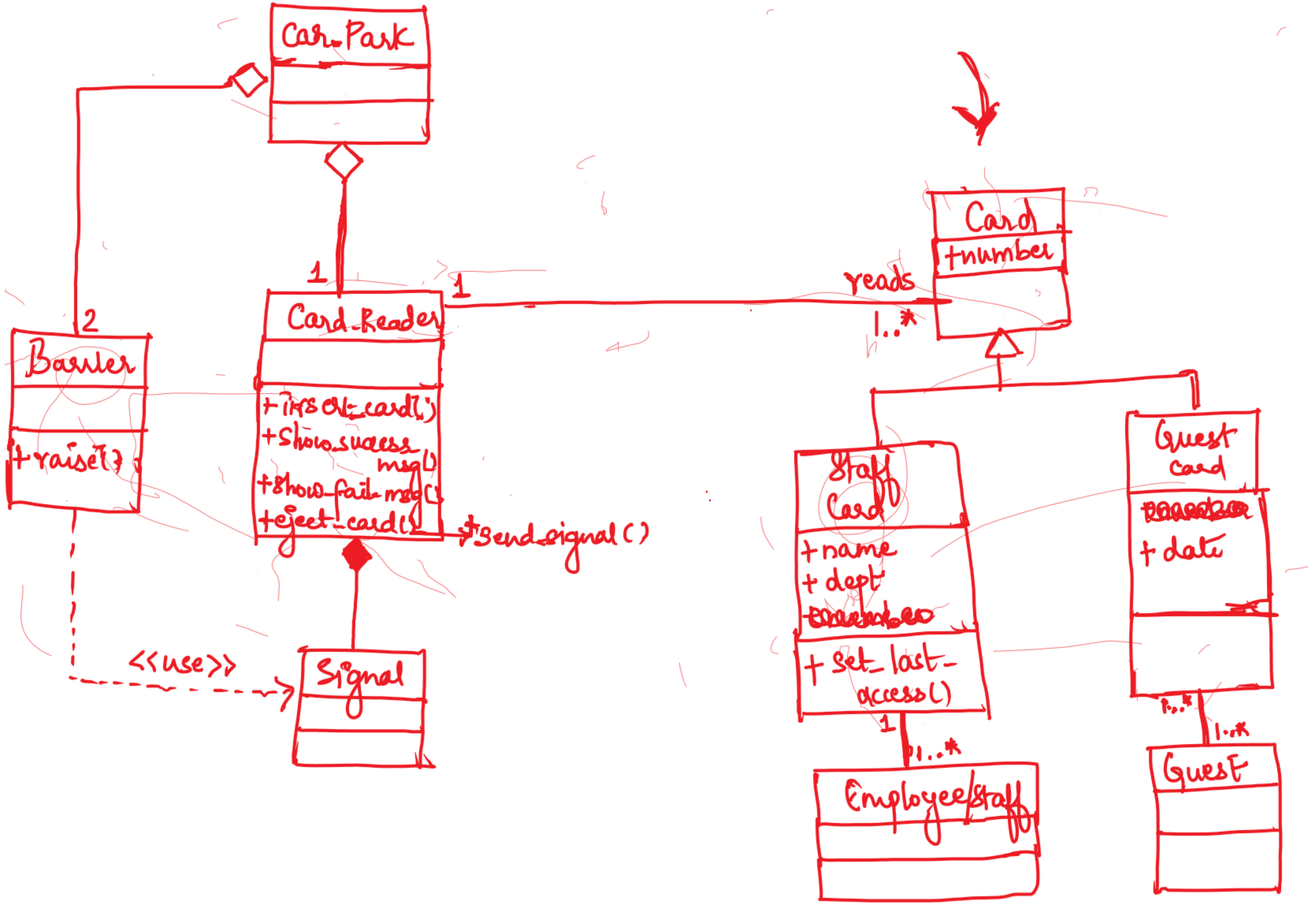
- **Saturn Int.** management wants to improve their **security measures**, both for their **building** and on **site**. They would like to prevent **people** who are not part of the **company** to use their **car park**.
- Saturn Int. has decided to issue **identity cards** to all **employees**. Each card records the name, department and number of a **company staff**, and give them **access** to the company car park. Employees are asked to wear the cards while on the site.
- There is a **barrier** and a **card reader** placed at the entrance to the car park. When a **driver** drives his car into the car park, he/she inserts his or her identity card into the card reader. The card reader then verify the card number to see if it is known to the **system**. If the number is recognized, the reader sends a **signal** to trigger the barrier to rise. The driver can then drive his/her car into the car park.
- There is another barrier at the **exit** of the car park, which is automatically raised when a car wishes to leave the car park.
- A **sign** at the entrance display "Full" when there are no spaces in the car park. It is only switched off when a car leaves.
- There is another type of card for **guests**, which also permits access to the car park. The card records a number and the current date. Such cards may be sent out in advance, or collected from reception. All guest cards must be returned to **reception** when the **visitor** leaves Saturn Int.

Bold coloured are analysis classes.
Red coloured are attributes.

Potential Classes

- Car Park
- Employee
- Barrier
- Card Reader
- Signal
- Staff Card
- Guest Card

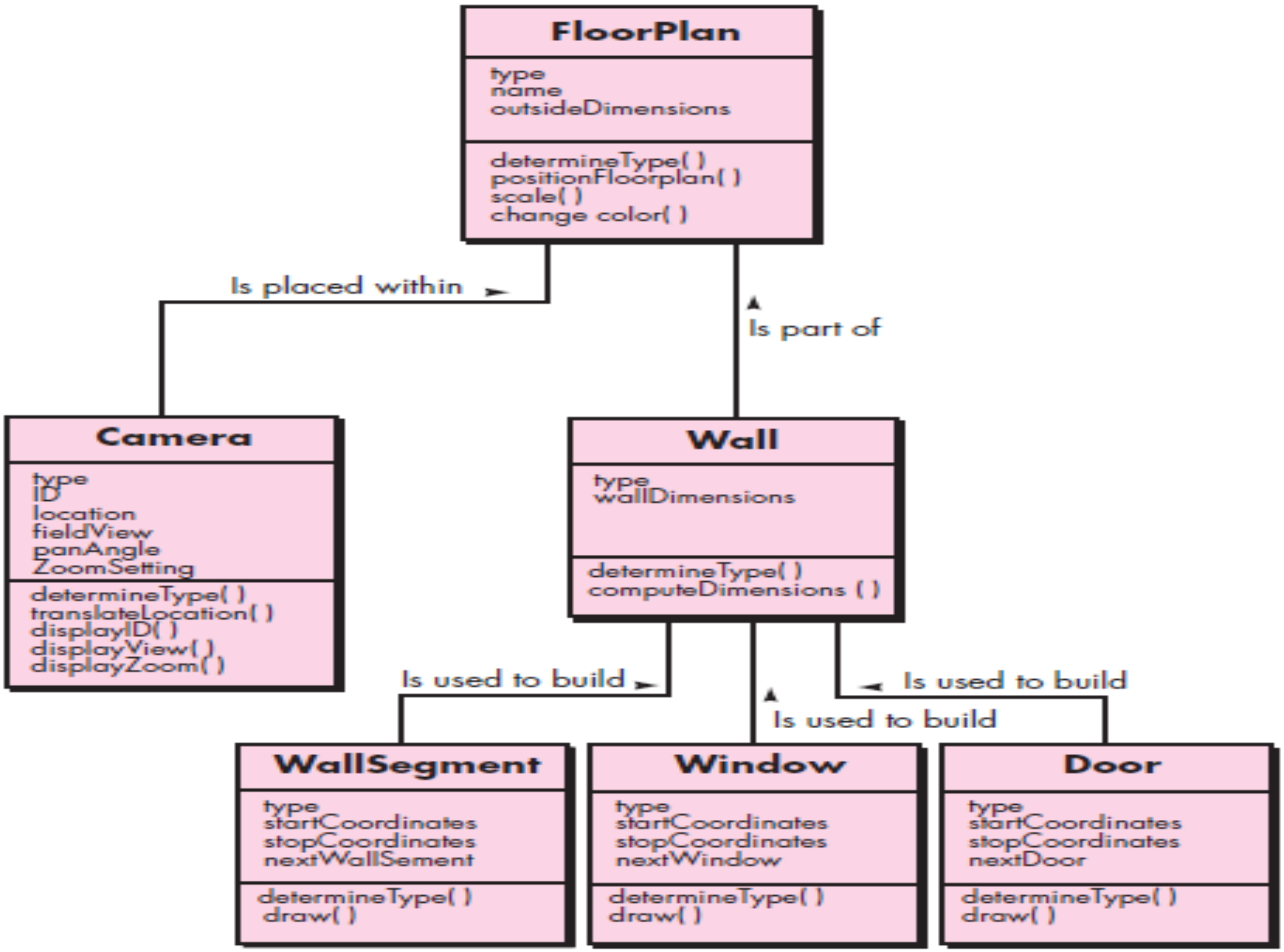
Class Diagram



CRC Models

- *Class-responsibility-collaborator (CRC) modeling* provides a simple means for identifying and organizing the classes that are relevant to system or product requirements. 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.
- Refer : http://agilemodeling.com/artifacts/crcModel.htm

Class diagram



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

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

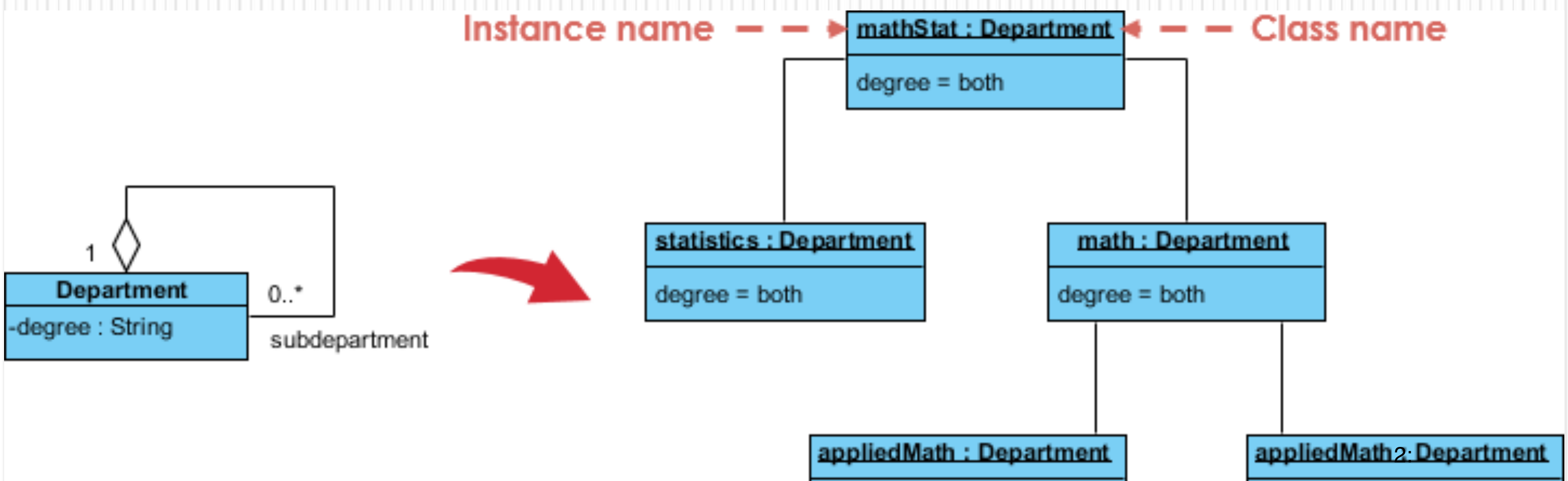
- Classes fulfill their responsibilities in one of two ways:
  - A class can use its own operations to manipulate its own attributes, thereby fulfilling a particular responsibility, or
  - A class can collaborate with other classes.
- Collaborations identify relationships between classes
- Collaborations are identified by determining whether a class can fulfill each responsibility itself
- Three different generic relationships between classes:
  - the *is-part-of* relationship
  - the *has-knowledge-of* relationship
  - the *depends-upon* relationship

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.

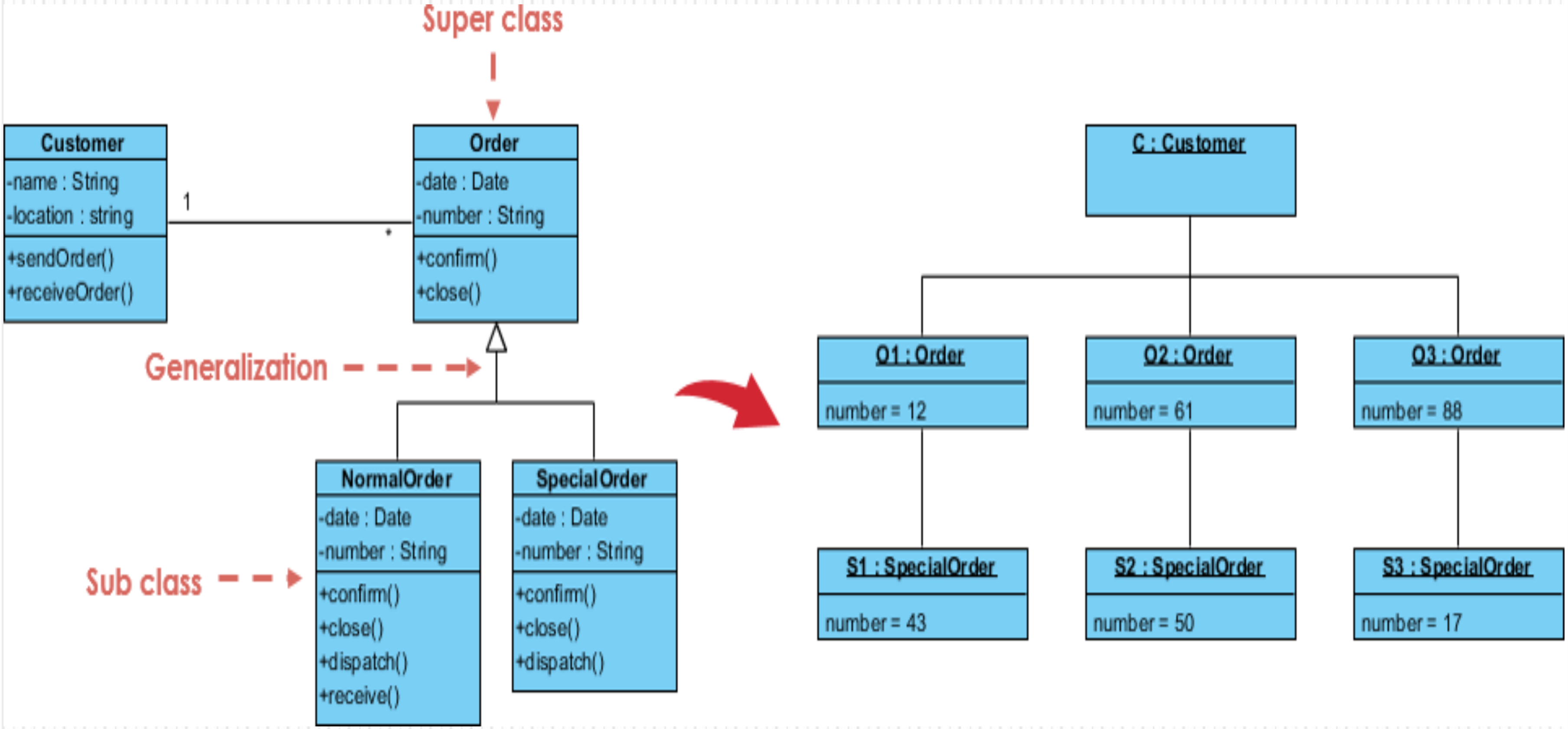
Object Diagram

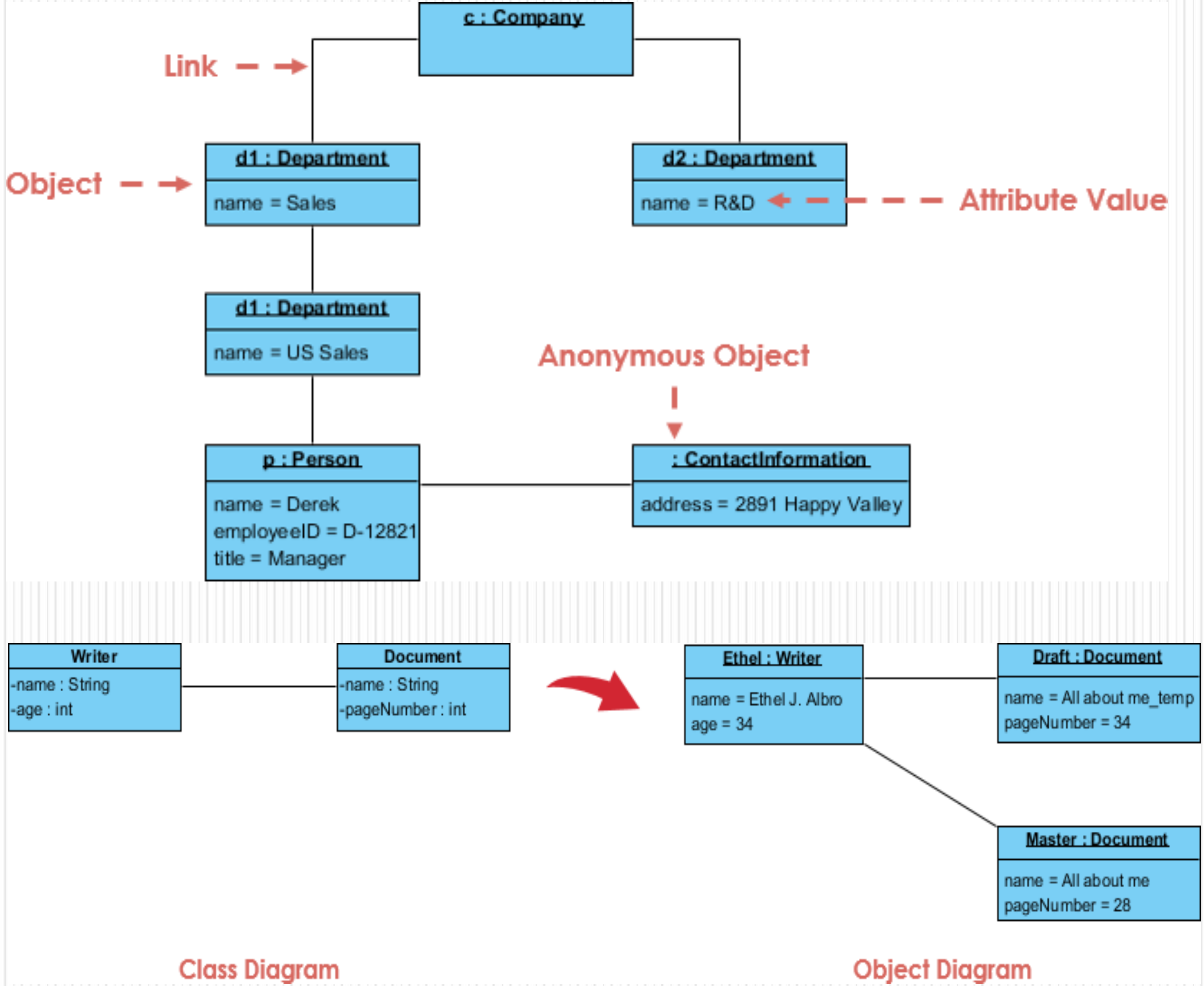
- An object diagram shows this relation between the instantiated classes and the defined class, and the relation between these objects in the system.
- The best way to illustrate what an object diagram look like is to show the object diagram derived from the corresponding class diagram.



Every instance/object name should be different from eachother.

Object Diagram




c : Company
Link
Object
d1 : Department
name = Sales
d2 : Department
name = R&D
Attribute Value
d1 : Department
name = US Sales
Anonymous Object
p : Person
name = Derek
employeeID = D-12821
title = Manager
: ContactInformation
address = 2891 Happy Valley
Writer
-name : String
-age : int
Document
-name : String
-pageNumber : int
Ethel : Writer
name = Ethel J. Albro
age = 34
Draft : Document
name = All about me_temp
pageNumber = 34
Master : Document
name = All about me
pageNumber = 28
Class Diagram
Object Diagram

Requirements Modeling Strategies

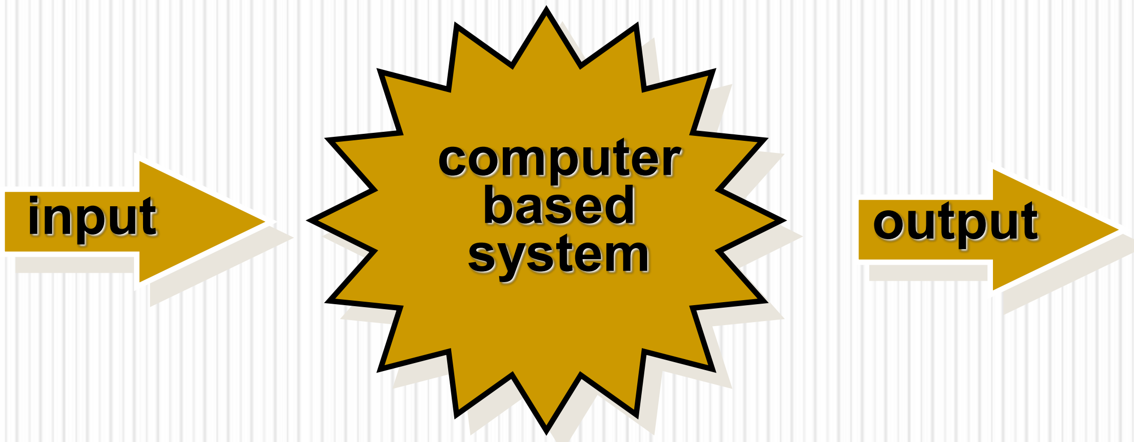
- One view of requirements modeling, called *structured analysis,* considers data and the processes that transform the data as separate entities.
  - Data objects are modeled in a way that defines their attributes and relationships.
  - Processes that manipulate data objects are modeled in a manner that shows how they transform data as data objects flow through the system.
- A second approach to analysis modeled, called *object-oriented analysis,* focuses on
  - the definition of classes and
  - the manner in which they collaborate with one another to effect customer requirements.

Flow-Oriented Modeling

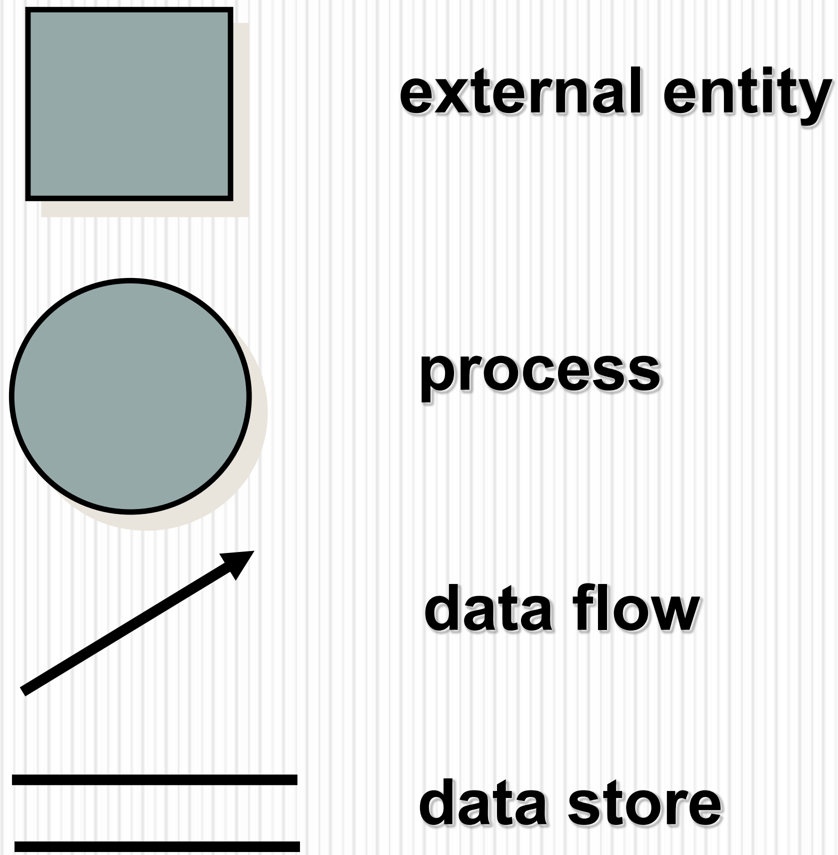
- Represents how data objects are transformed at they move through the system
- **Data flow diagram (DFD)** is the diagrammatic form that is used
- Considered by many to be an “old school” approach, but continues to provide a view of the system that is unique—it should be used to supplement other analysis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

The Flow Model

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



Flow Modeling Notation



External Entity

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

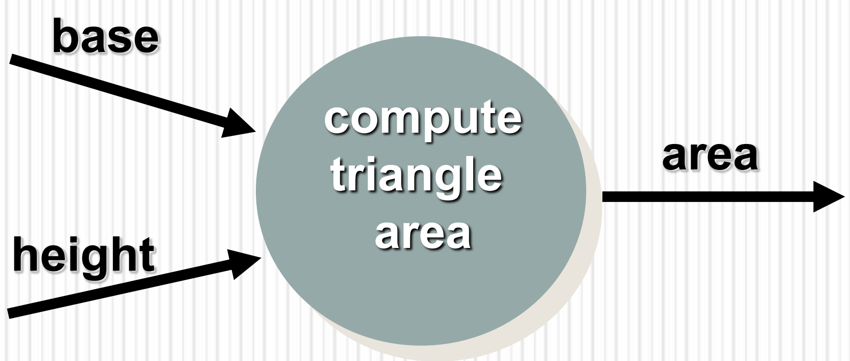
A data transformer (changes input to output)

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

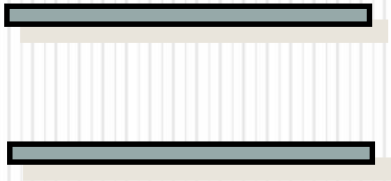
Data must always be processed in some way to achieve system function

Data Flow

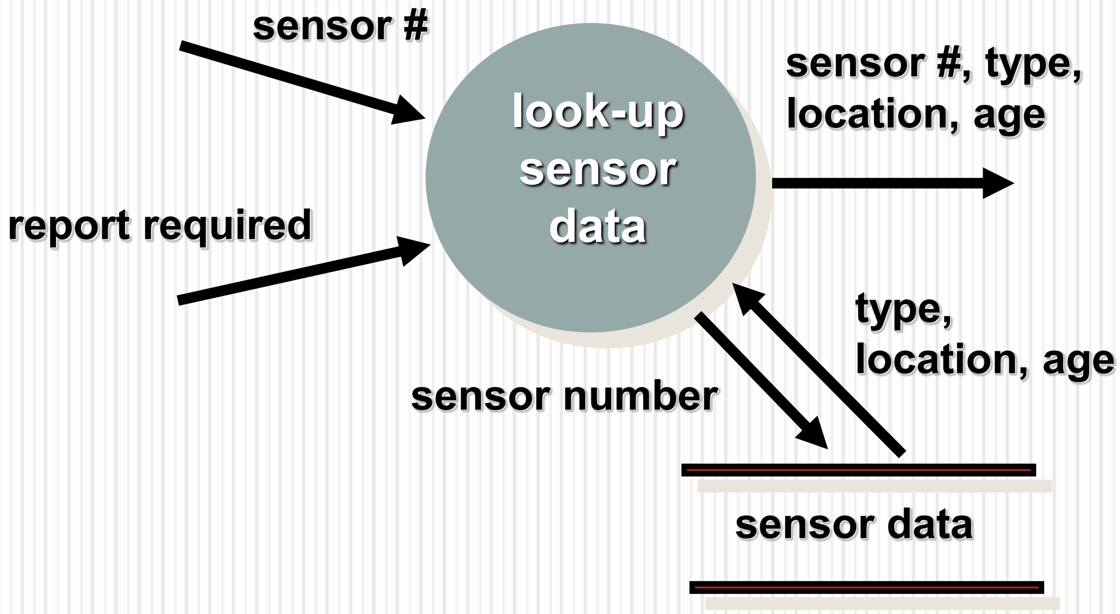
Data flows through a system, beginning as input and transformed into output.



Data Stores



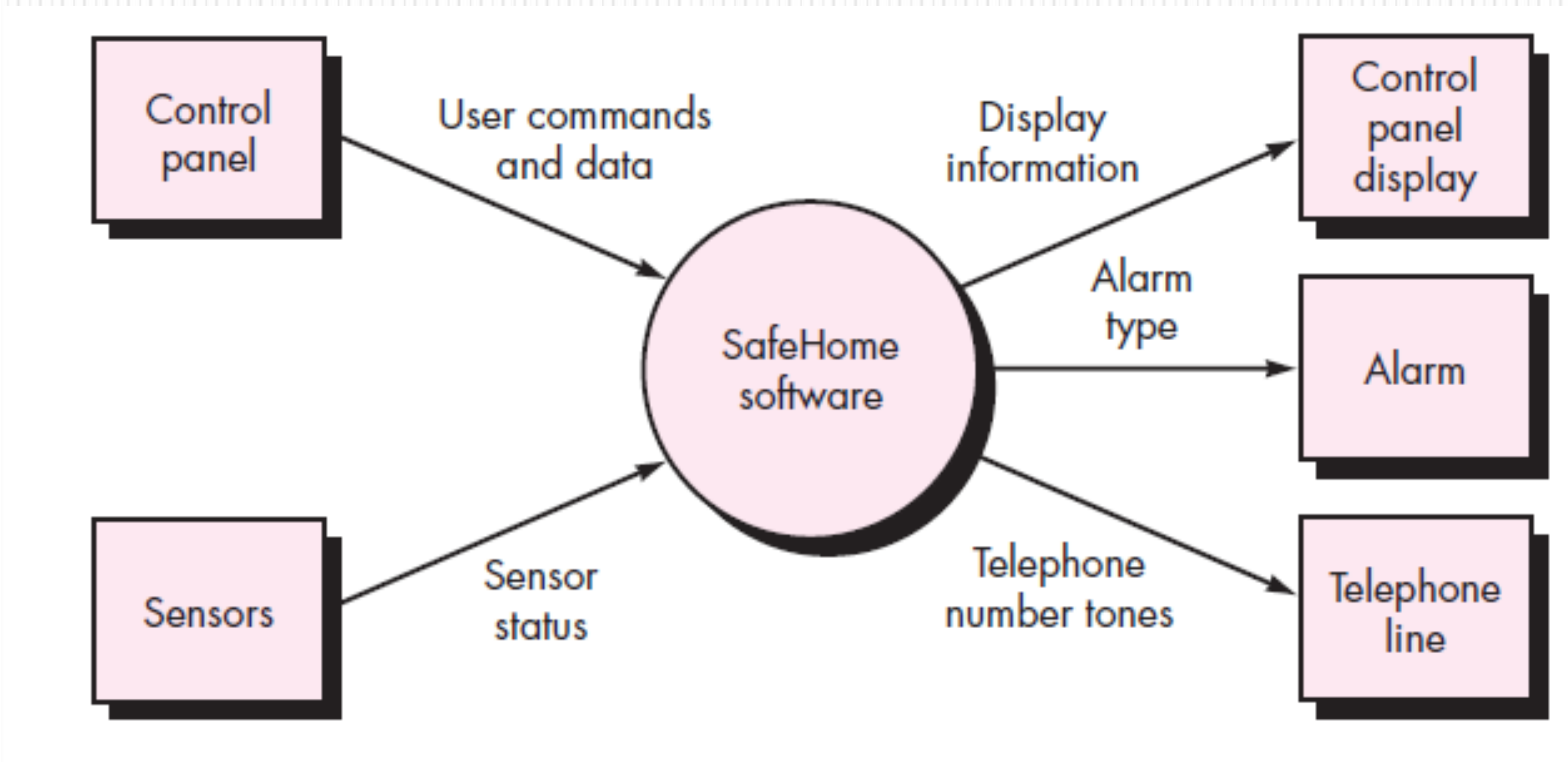
Data is often stored for later use.



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
- *information flow continuity* must be maintained from level to level

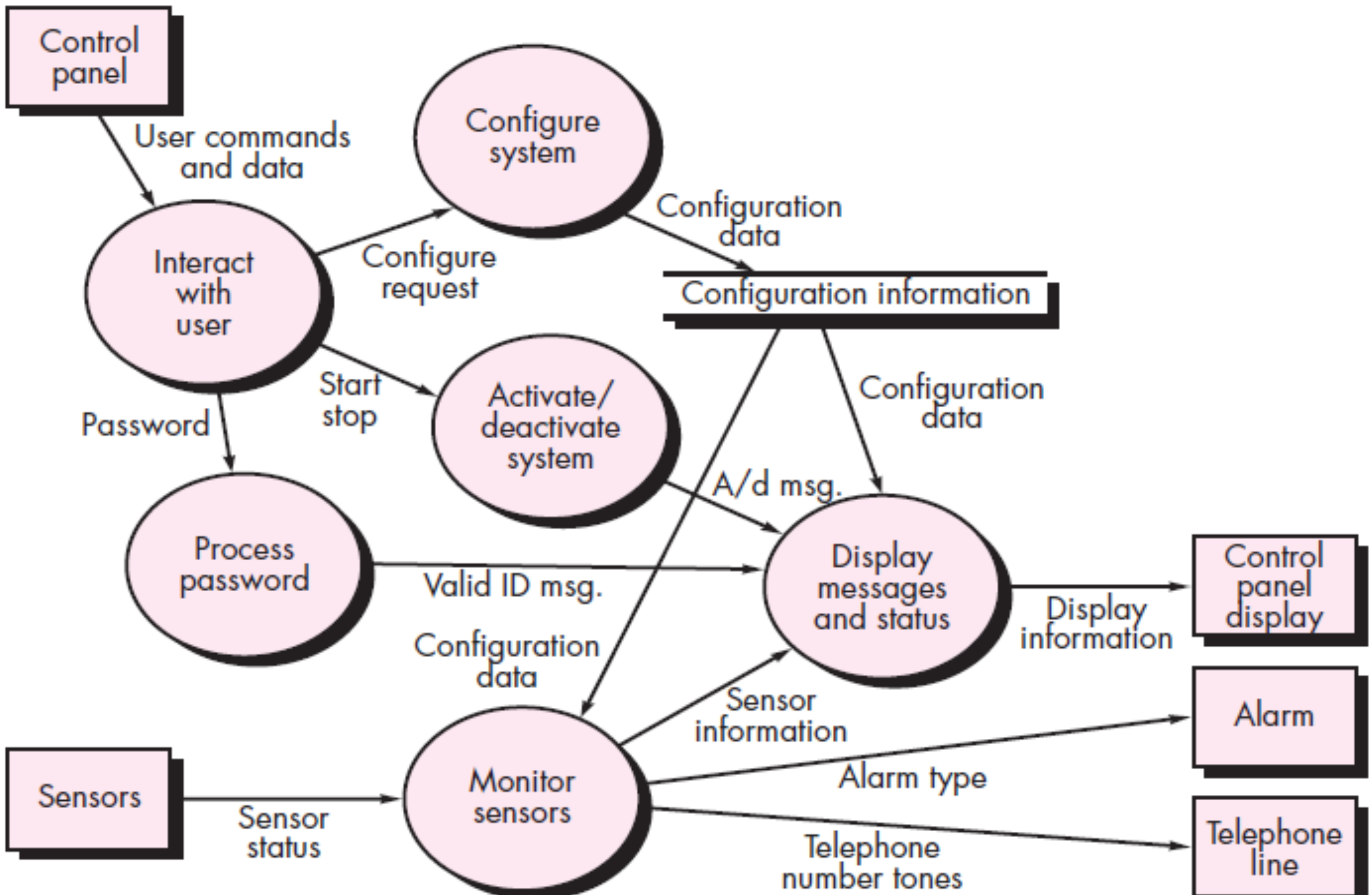
Level – 0 DFD / context level diagram



Constructing a DFD - I

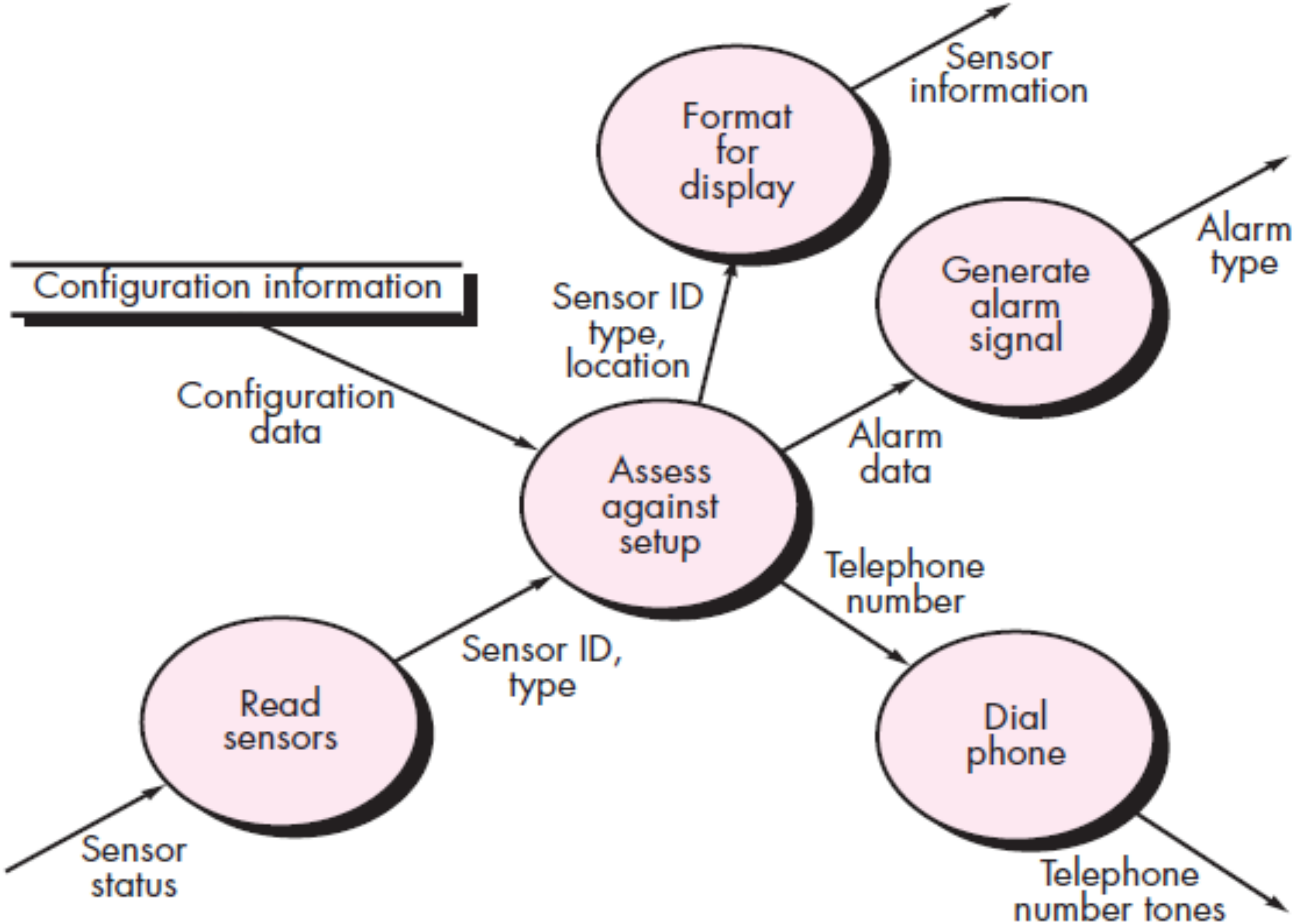
- Review user scenarios and/or the data model to isolate data objects and use a grammatical parse to determine “operations”
- Determine external entities (producers and consumers of data)
- Nouns are either external entities (boxes), data or control objects (arrows), or data stores (double lines).
- Verbs are processes and can be represented as bubbles in subsequent DFD.

LEVEL – 1 DFD



Control panel
User commands and data
Configure system
Configuration data
Interact with user
Configure request
Configuration information
Start stop
Activate/ deactivate system
Configuration data
Password
A/d msg.
Process password
Display messages and status
Control panel display
Valid ID msg.
Display information
Configuration data
Sensor information
Alarm
Sensors
Monitor sensors
Alarm type
Sensor status
Telephone number tones
Telephone line

LEVEL – 2 DFD



Format for display
Sensor information
Generate alarm signal
Alarm type
Configuration information
Sensor ID type, location
Configuration data
Assess against setup
Alarm data
Telephone number
Read sensors
Sensor ID, type
Dial phone
Sensor status
Telephone number tones

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.

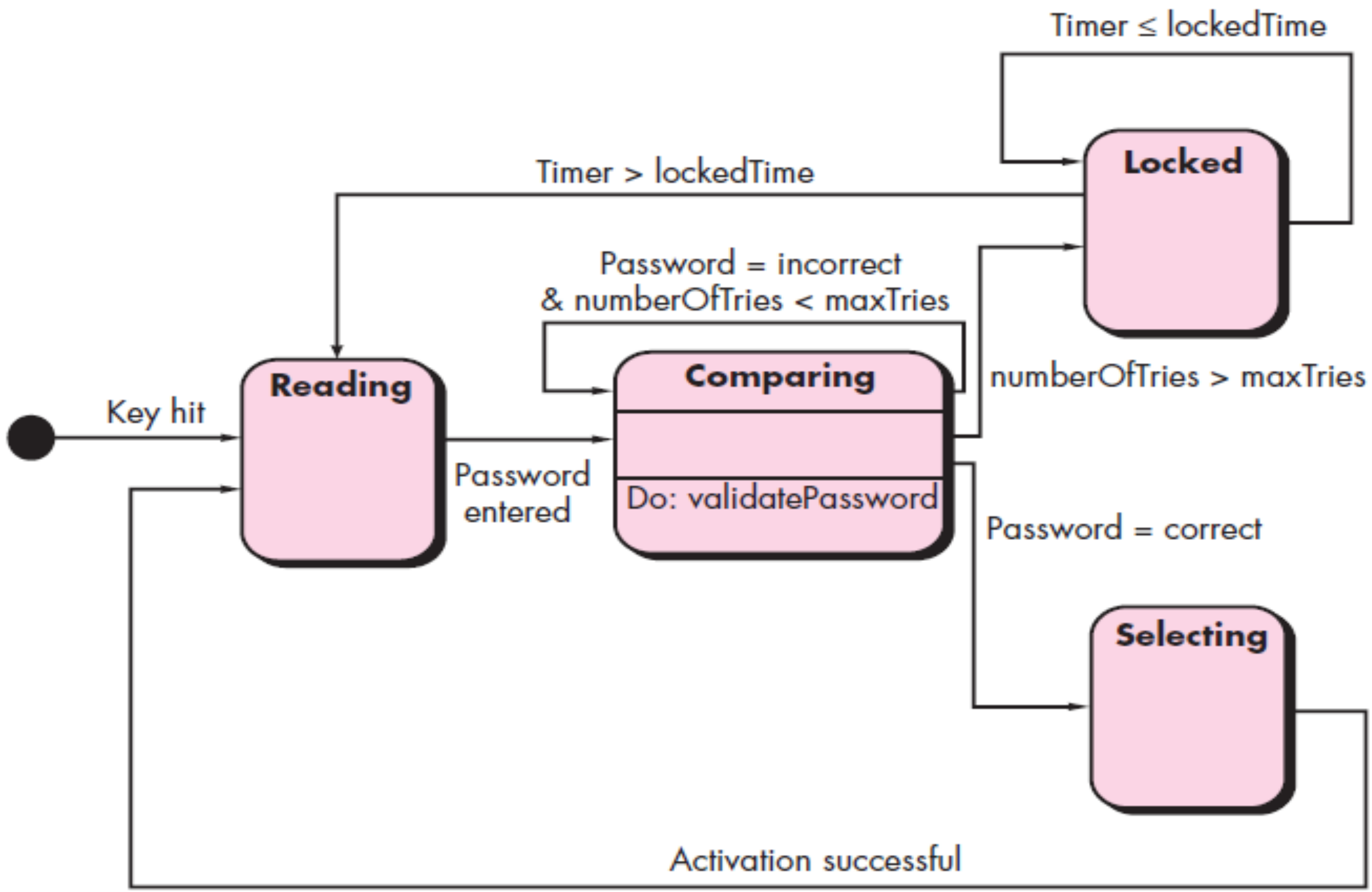
State Representations

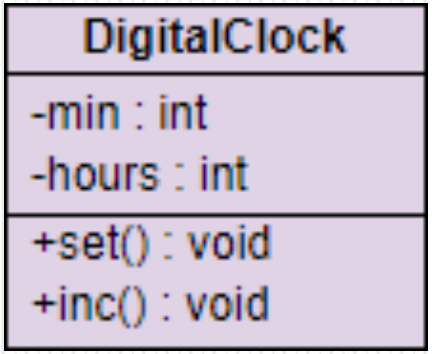
- In the context of behavioral modeling, two different characterizations of states must be considered:
  - the state of each class as the system performs its function and
  - the state of the system as observed from the outside as the system performs its function
- The state of a class takes on both passive and active characteristics.
  - 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.

The States of a System

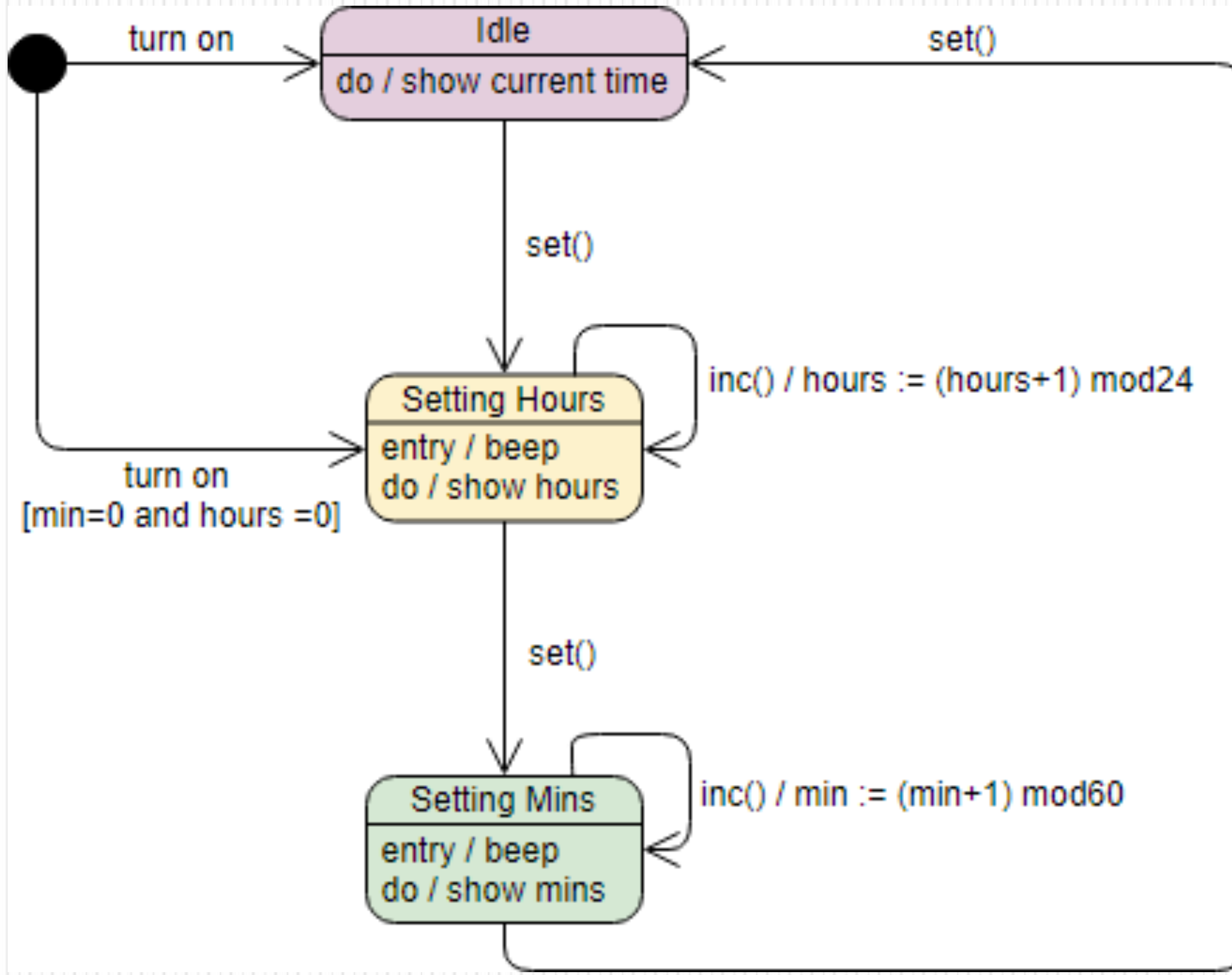
- state—a set of observable circumstances that characterizes the behavior of a system at a given time
- state transition—the movement from one state to another
- event—an occurrence that causes the system to exhibit some predictable form of behavior
- action—process that occurs as a consequence of making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

State diagram

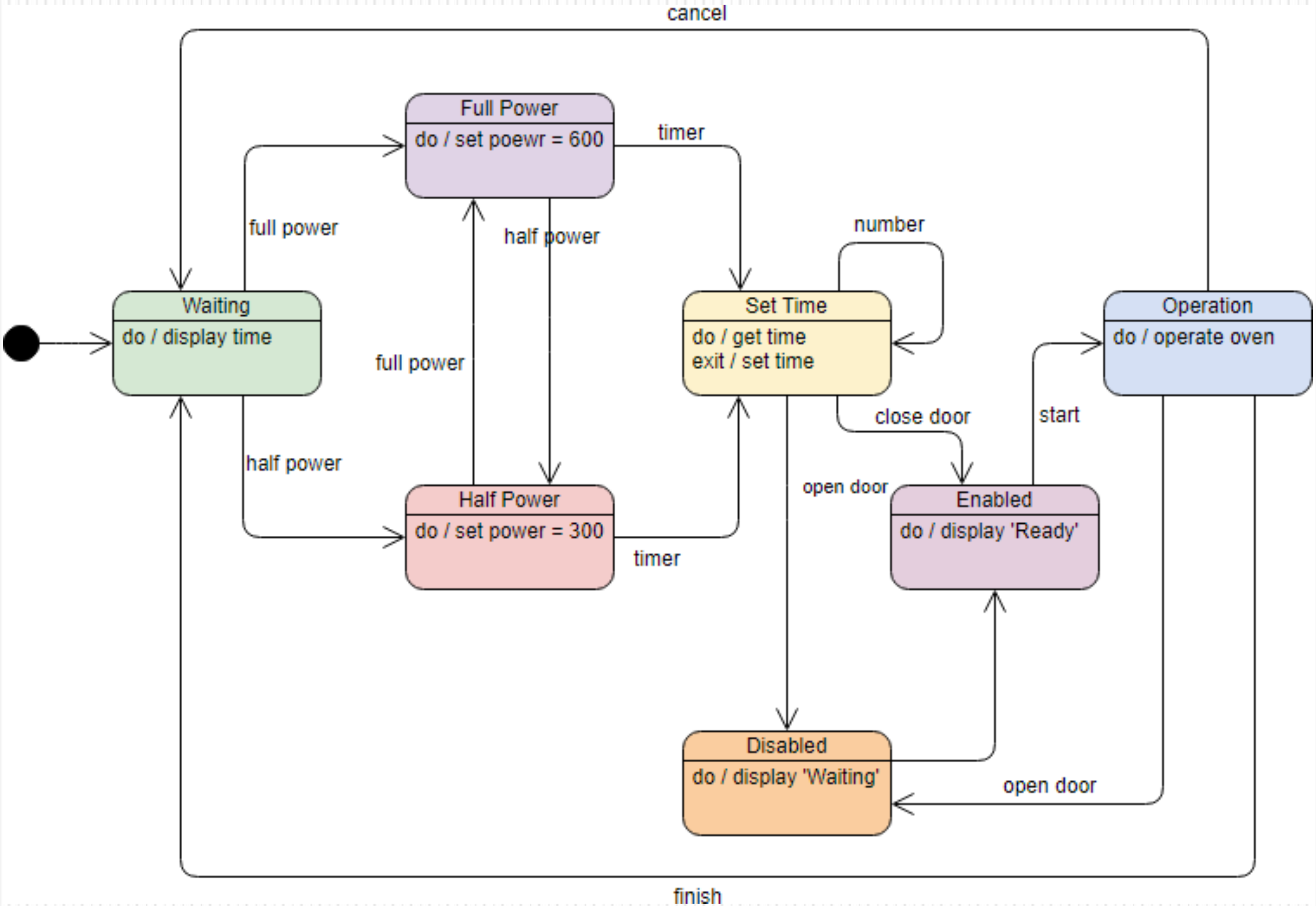




State Diagram for Digital Clock



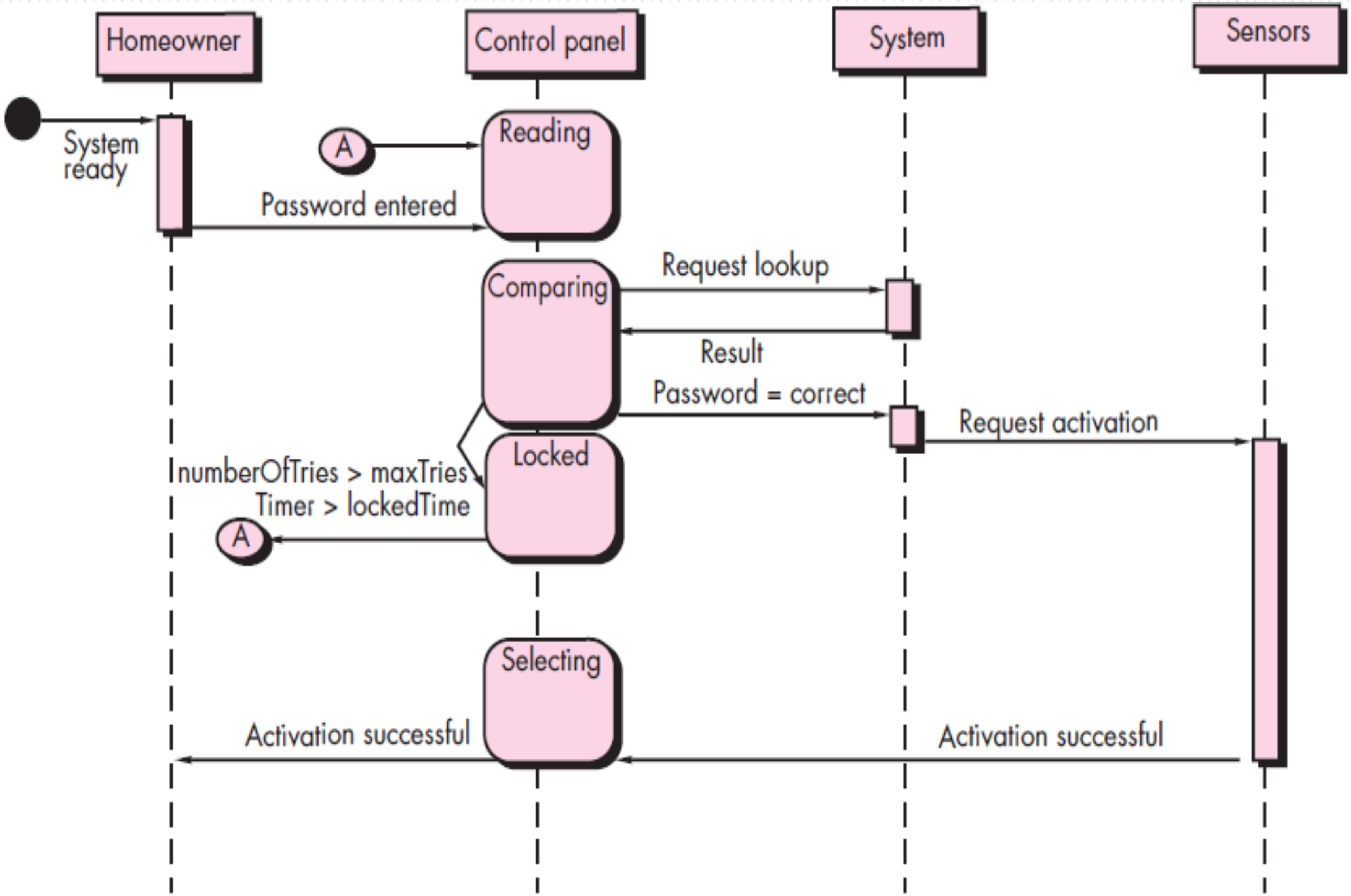
State Diagram for Oven



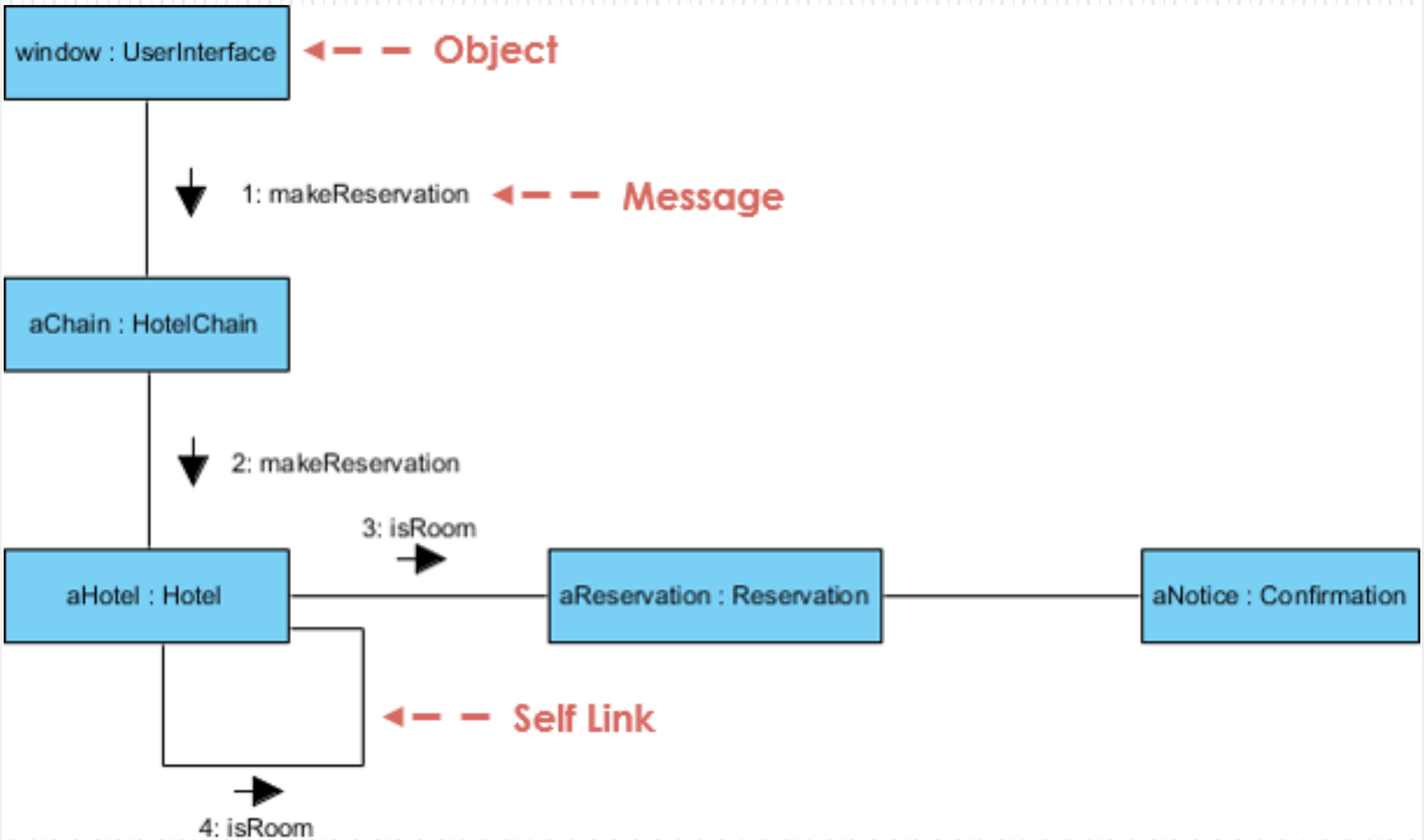
Behavioral Modeling

- 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



Collaboration/Communication Diagram



Thank you!!!

Any Questions???