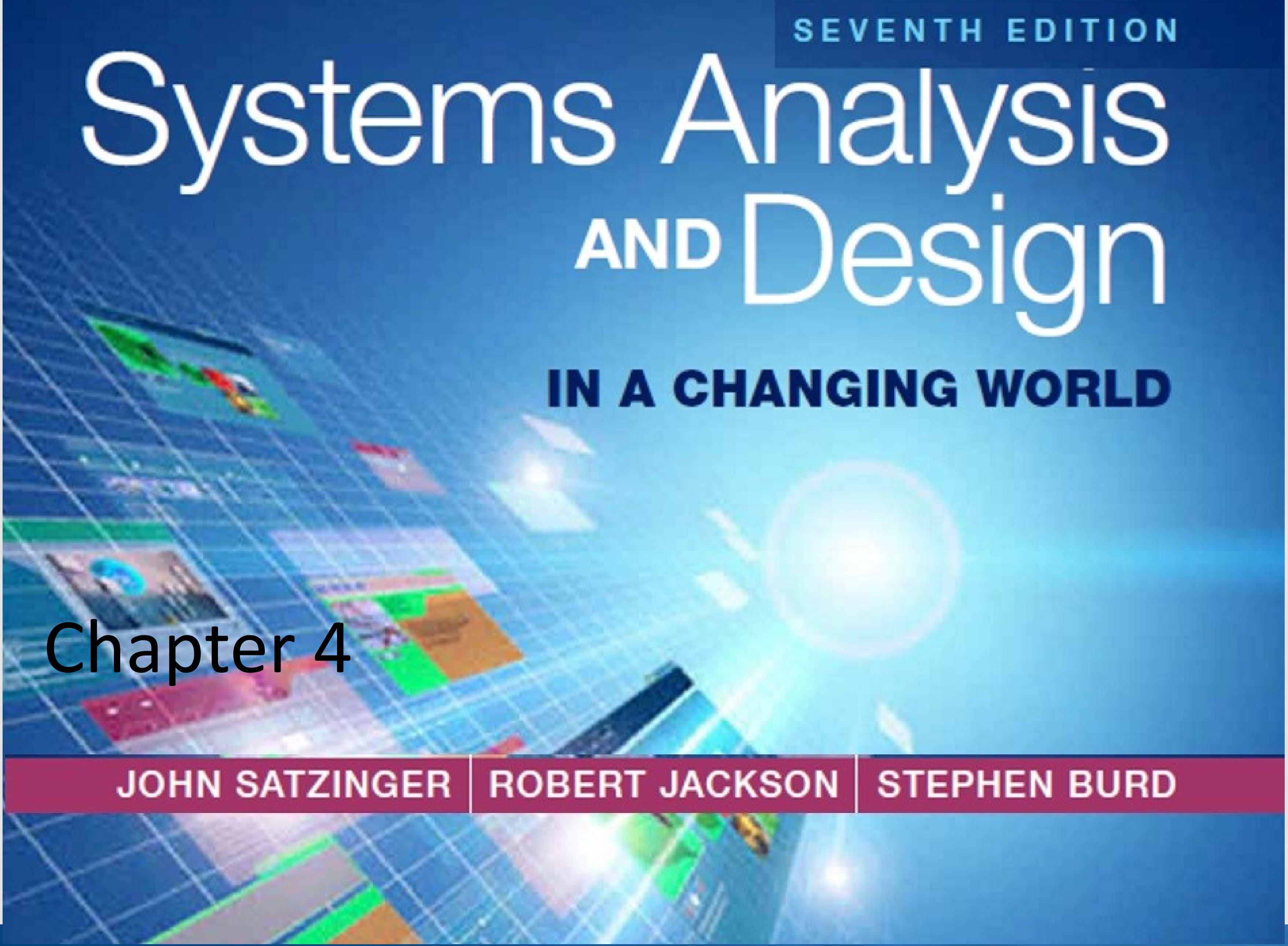


SEVENTH EDITION

# Systems Analysis AND Design IN A CHANGING WORLD

JOHN SATZINGER | ROBERT JACKSON | STEPHEN BURD

# Chapter 4

# Domain Modeling

# Chapter 4

Systems Analysis and Design in a Changing World 7th Ed
Satzinger, Jackson & Burd

# Chapter 4: Outline

- “Things” in the Problem Domain
- The Entity-Relationship Diagram
- The Domain Model Class Diagram
- The State Machine Diagram – Identifying Object Behavior

## Learning Objectives

- Explain how the concept of “things” in the problem domain also define requirements
- Identify and analyze data entities and domain classes needed in the system
- Read, interpret, and create an entity-relationship diagram
- Read, interpret, and create a domain model class diagram
- Understand the domain model class diagram for the RMO Consolidated Sales and Marketing System
- Read, interpret, and create a state machine diagram that models object behavior

## Overview

- This chapter focuses on another key concept for defining requirements— data entities or domain classes
- In the RMO Tradeshow System from Chapter 1, some domain classes are Supplier, Product, and Contact
- In this chapter's opening case Waiters on Call, examples of domain classes are Restaurants, Menu Items, Customers, Orders, Drivers, Routes, and Payments

## Things in the Problem Domain

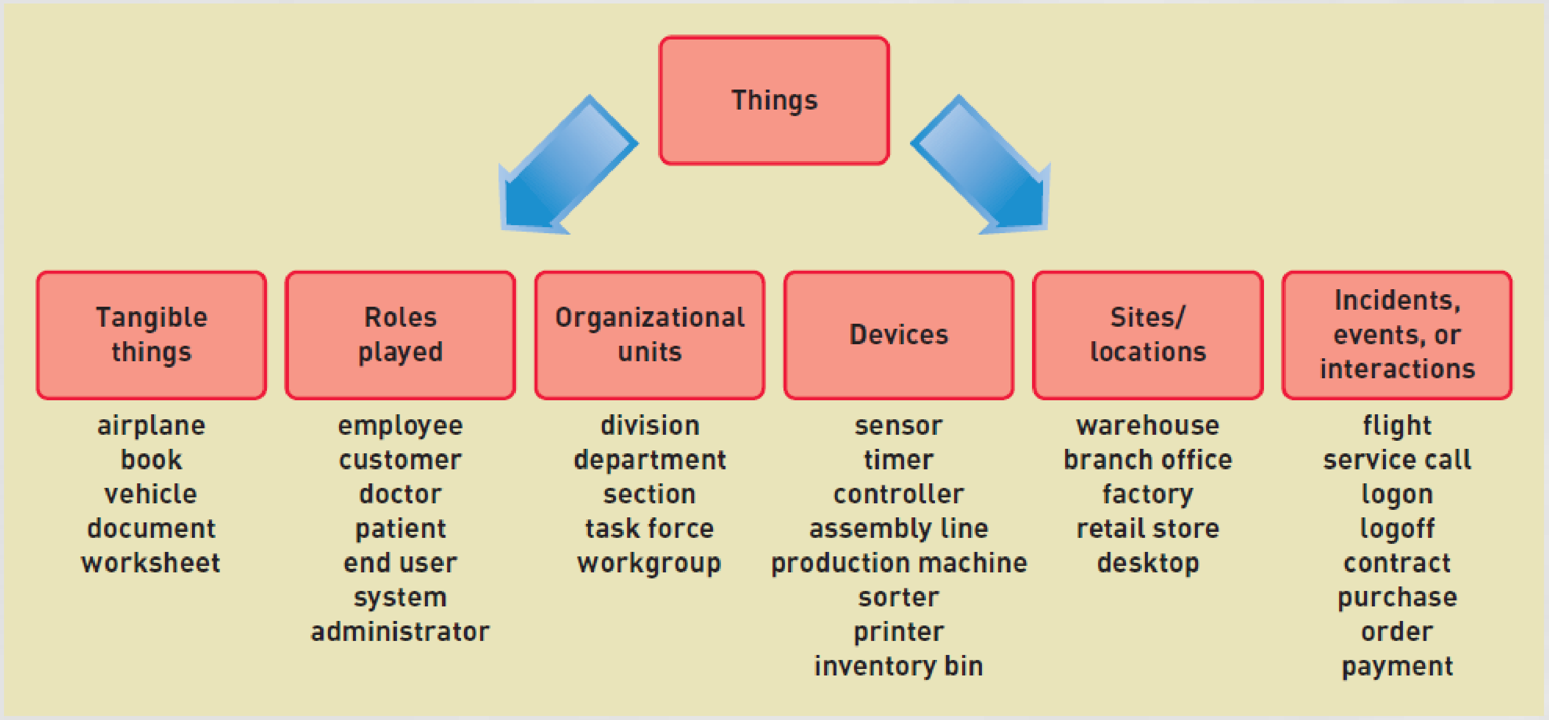
- Problem domain—the specific area (or domain) of the users’ business need that is within the scope of the new system.
- “Things” are those items users work with when accomplishing tasks that need to be remembered
- Examples of “Things” are products, sales, shippers, customers, invoices, payments, etc.
- These “Things” are modeled as domain classes or data entities
- In this course, we will call them domain classes. In database class you may call them data entities

## Things in the Problem Domain: Two Techniques for Identifying Them

- Brainstorming Technique
  - Use a checklist of all of the usual types of things typically found and brainstorm to identify domain classes of each type
- Noun Technique
  - Identify all of the nouns that come up when the system is described and determine if each is a domain class, an attribute, or not something we need to remember

# Brainstorming Technique

- Are there any tangible things? Are there any organizational units? Sites/locations? Are there incidents or events that need to be recorded?



## Brainstorming Technique: Steps

1. Identify a user and a set of use cases
2. Brainstorm with the user to identify things involved when carrying out the use case—that is, things about which information should be captured by the system.
3. Use the types of things (categories) to systematically ask questions about potential things, such as the following: Are there any tangible things you store information about? Are there any locations involved? Are there roles played by people that you need to remember?
4. Continue to work with all types of users and stakeholders to expand the brainstorming list
5. Merge the results, eliminate any duplicates, and compile an initial list

## The Noun Technique

- A technique to identify problem domain classes (things) by finding, classifying, and refining a list of nouns that come up in in discussions or documents
- Popular technique. Systematic.
- Does end up with long lists and many nouns that are not things that need to be stored by the system
- Difficulty identifying synonyms and things that are really attributes
- Good place to start when there are no users available to help brainstorm

## The Noun Technique: Steps (1 of 3)

1. Using the use cases, actors, and other information about the system— including inputs and outputs—identify all nouns.
   - For the RMO CSMS, the nouns might include customer, product item, sale, confirmation, transaction, shipping, bank, change request, summary report, management, transaction report, accounting, back order, back order notification, return, return confirmation…
2. Using other information from existing systems, current procedures, and current reports or forms, add items or categories of information needed.
   - For the RMO CSMS, these might include price, size, color, style, season, inventory quantity, payment method, and shipping address.

## The Noun Technique: Steps (2 of 3)

3. As this list of nouns builds, refine it. Ask these questions about each noun to help you decide whether you should include it:
   - Is it a unique thing the system needs to know about?
   - Is it inside the scope of the system I am working on?
   - Does the system need to remember more than one of these items?

   Ask these questions to decide to exclude it:
   - Is it really a synonym for some other thing I have identified?
   - Is it really just an output of the system produced from other information I have identified?
   - Is it really just an input that results in recording some other information I have identified?

   Ask these questions to research it:
   - Is it likely to be a specific piece of information (attribute) about some other thing I have identified?
   - Is it something I might need if assumptions change?

## The Noun Technique: Steps (3 of 3)

4. Create a master list of all nouns identified and then note whether each one should be included, excluded, or researched further.
5. Review the list with users, stakeholders, and team members and then define the list of things in the problem domain.

# Partial List of Nouns for RMO (1 of 2)

- With notes on whether to include as domain class

| Identified noun | Notes on including noun as a thing to store |
|---|---|
| Accounting | We know who they are. No need to store it. |
| Back order | A special type of order? Or a value of order status? Research. |
| Back-order information | An output that can be produced from other information. |
| Bank | Only one of them. No need to store. |
| Catalog | Yes, need to recall them, for different seasons and years, Include. |
| Catalog activity reports | An output that can be produced from other information, Not stored. |
| Catalog details | Same as catalog? Or the same as product items in the catalog? Research. |
| Change request | An input resulting in remembering changes to an order. |
| Charge adjustment | An input resulting in a transaction. |

# Partial List of Nouns for RMO (2 of 2)

| **Identified noun** | **Notes on including noun as a thing to store** |
|---|---|
| Color | One piece of information about a product item. |
| Confirmation | An output produced from other information, Not stored. |
| Credit card information | Part of an order? Or part of customer information? Research. |
| Customer | Yes, a key thing with lots of details required. Include. |
| Customer account | Possibly required if an RMO payment plan is included. Research. |
| Fulfillment reports | An output produced from information about shipments. Not stored. |
| Inventory quantity | One piece of information about a product item. Research. |
| Management | We know who they are. No need to store. |
| Marketing | We know who they are. No need to store. |
| Merchandising | We know who they are. No need to store. |

## Details about Domain Classes

- Attribute— describes one piece of information about each instance of the class
  - Customer has first name, last name, phone number
- Identifier or key
  - One attribute uniquely identifies an instance of the class. Required for data entities, optional for domain classes. Customer ID identifies a customer
- Compound attribute
  - Two or more attributes combined into one structure to simplify the model. (E.g., address rather than including number, street, city, state, zip separately). Sometimes an identifier or key is a compound attribute.

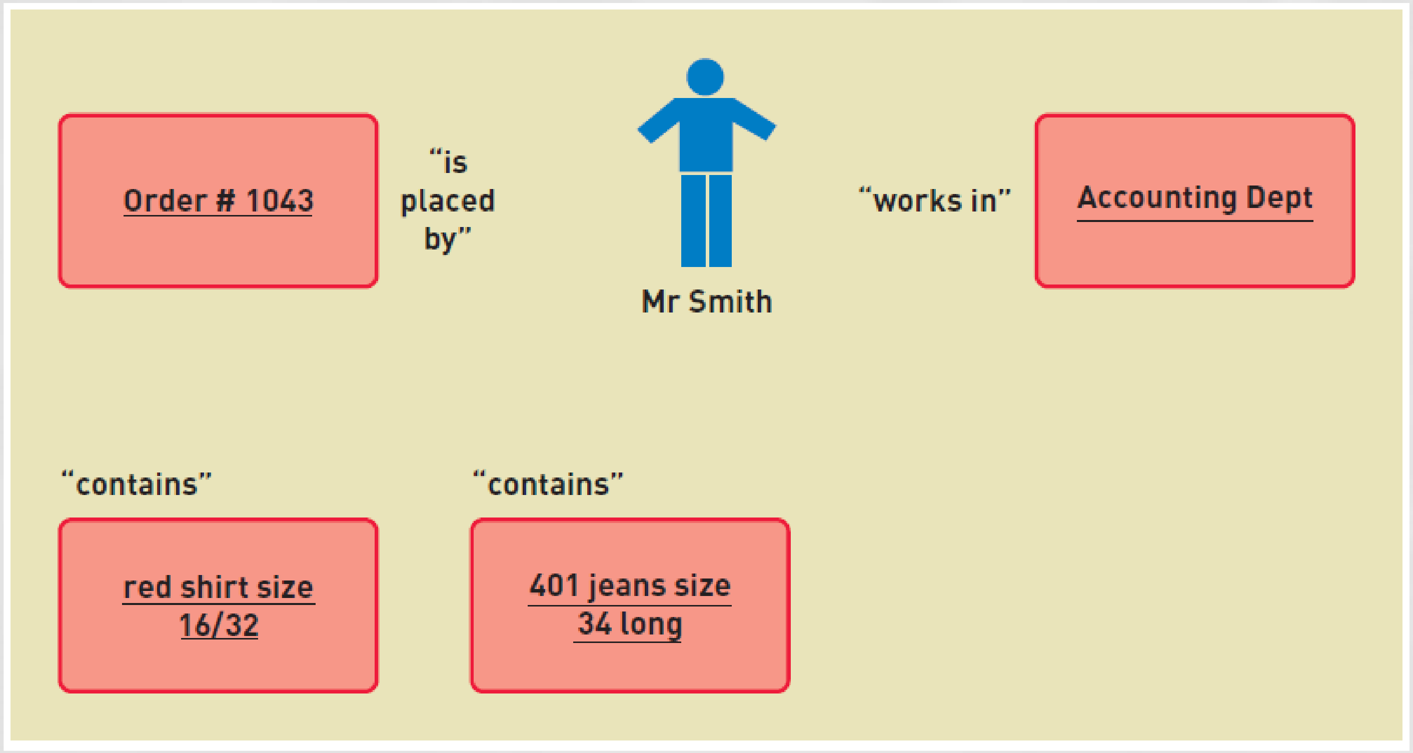
## Attributes and Values

- Class is a type of thing. Object is a specific instance of the class. Each instance has its own values for an attribute

| **All customers have these attributes:** | **Each customer has a value for each attribute:** | | |
|---|---|---|---|
| Customer ID | 101 | 102 | 103 |
| First name | John | Mary | Bill |
| Last name | Smith | Jones | Casper |
| Home phone | 555-9182 | 423-1298 | 874-1297 |
| Work phone | 555-3425 | 423-3419 | 874-8546 |

# Associations Among Things

- Association— a naturally occurring relationship between classes (UML term)

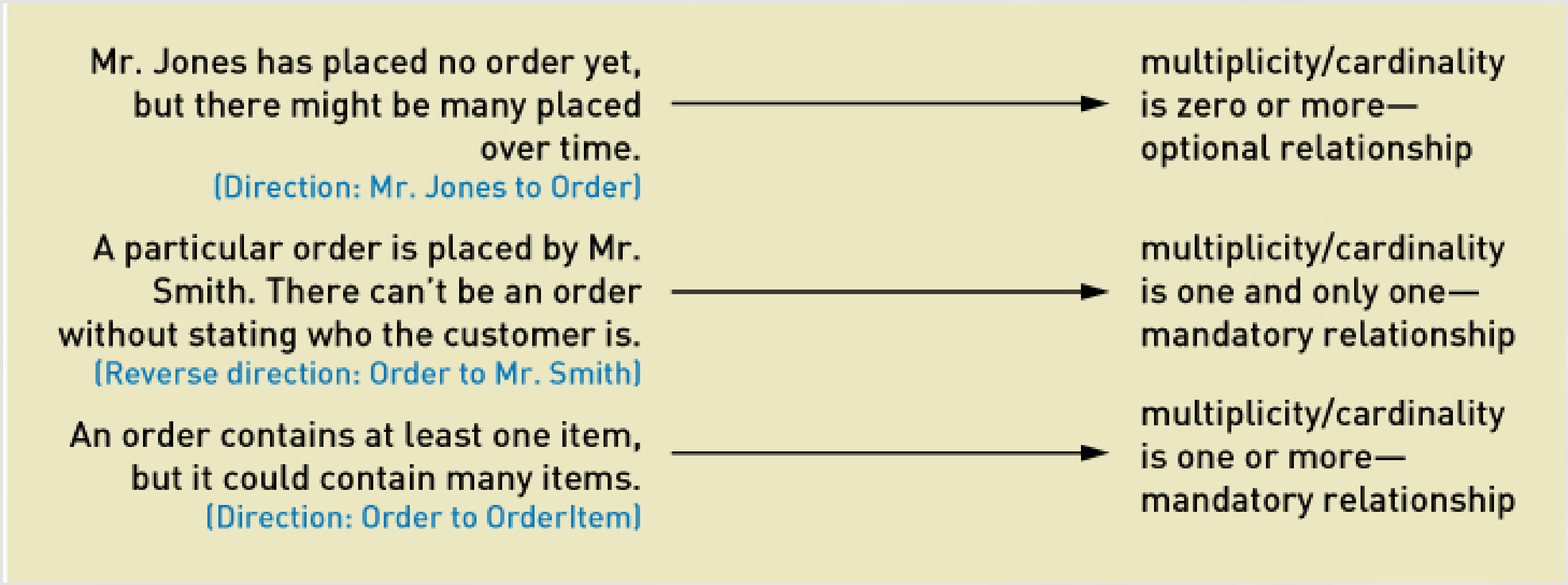


## Just to Clarify…

- Called ***association*** on class diagram in UML
  - **Multiplicity** is term for the number of associations between classes: 1 to 1 or 1 to many (synonym to cardinality)
  - UML is the primary emphasis of this text
- Called ***relationship*** on ERD in database class
  - **Cardinality** is term for number of relationships in entity relationship diagrams: 1 to 1 or 1 to many (synonym to multiplicity)
- Associations and Relationships apply in two directions
  - Read them separately each way
  - A customer places an order
  - An order is placed by a customer

## Minimum and Maximum Multiplicity

- Associations have minimum and maximum constraints
  - minimum is zero, the association is optional
  - If minimum is at least one, the association is mandatory



Mr. Jones has placed no order yet, but there might be many placed over time. (Direction: Mr. Jones to Order) → multiplicity/cardinality is zero or more—optional relationship

A particular order is placed by Mr. Smith. There can't be an order without stating who the customer is. (Reverse direction: Order to Mr. Smith) → multiplicity/cardinality is one and only one—mandatory relationship

An order contains at least one item, but it could contain many items. (Direction: Order to OrderItem) → multiplicity/cardinality is one or more—mandatory relationship

## Types of Associations

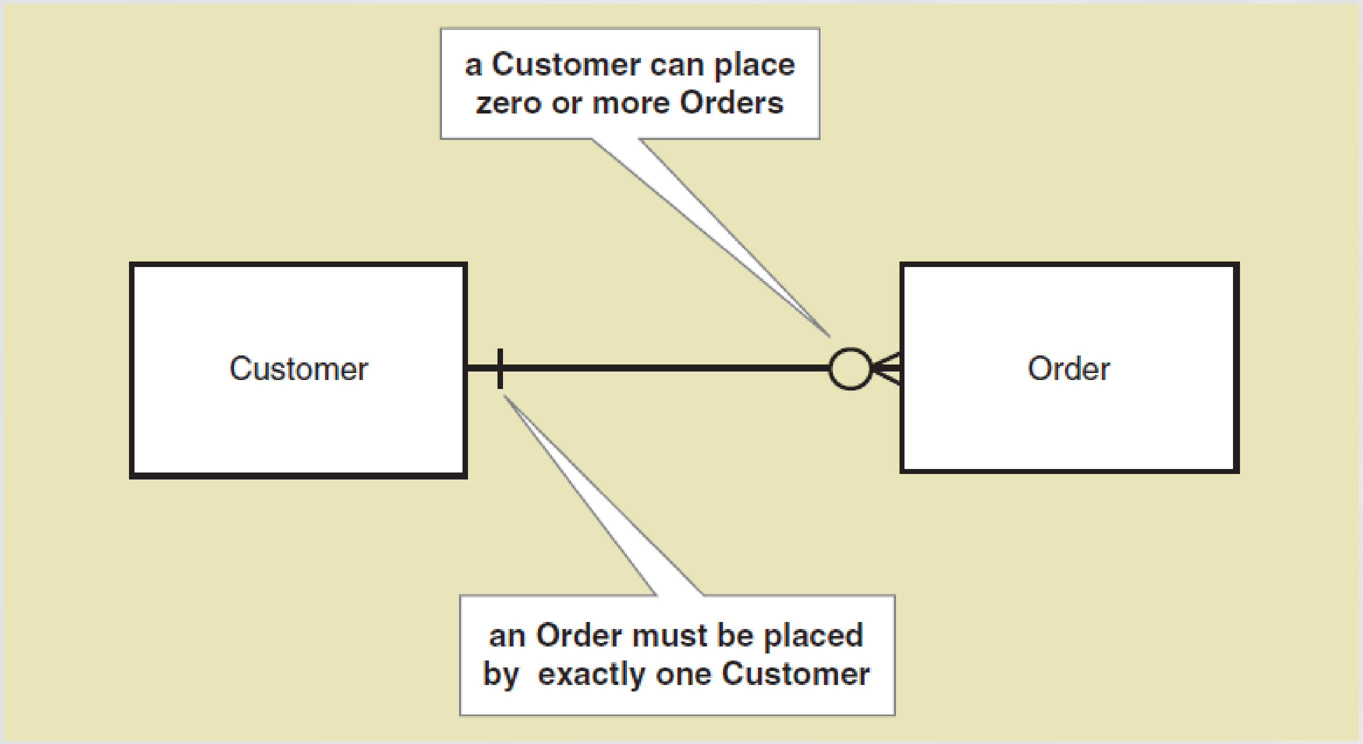
- Binary Association
  - Associations between exactly two different classes
    - Course Section includes Students
    - Members join Club
- Unary Association (recursive)
  - Associations between two instances of the same class
    - Person married to person
    - Part is made using parts
- Ternary Association (three)
- N-ary Association (between n)

## Entity-Relationship Diagrams: ERD

- ERD s have been used for many years to develop data models that are used in database development
- The term for “things” in ERD models is **data entities**
- ERD models are not UML models and do not use standard UML notation
- ERD models are not as expressive as UML models
  - They do not model generalization/specialization well
  - They do not model whole/part well

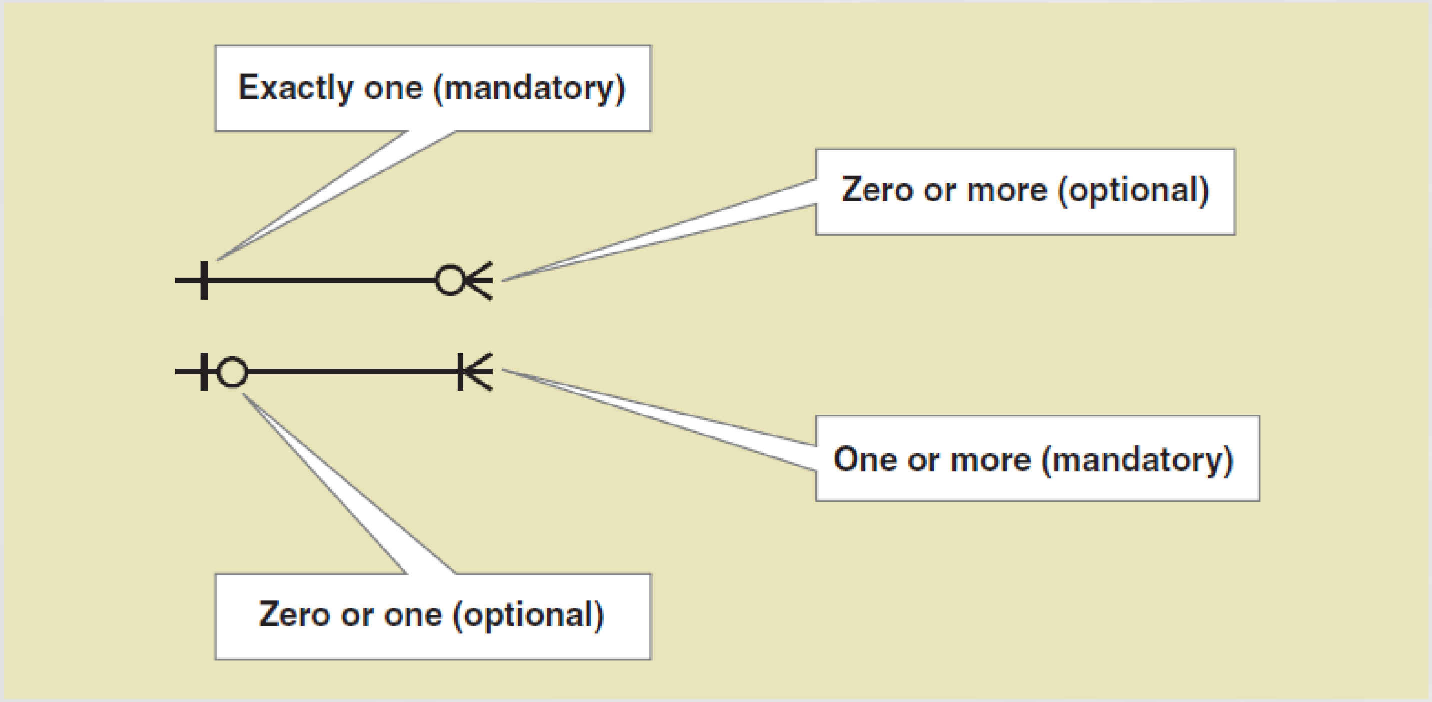
## Example of ERD Notation

- ERD Models normally use “crows feet” notation to show cardinality


a Customer can place zero or more Orders
Customer
Order
an Order must be placed by exactly one Customer

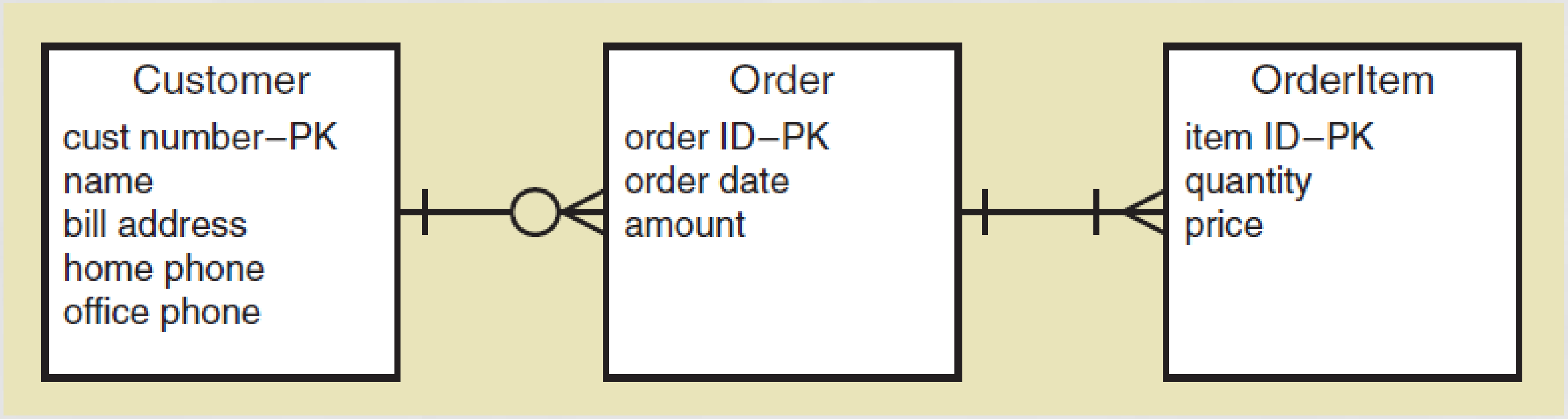
## ERD Cardinality Symbols

- Examples of crows feet notation for various cardinalities



## Expanded ERD with Attributes

- ERD with cardinalities and attributes
- There are several different notation methods for attributes in ERD models
- This notation places attributes within data entities

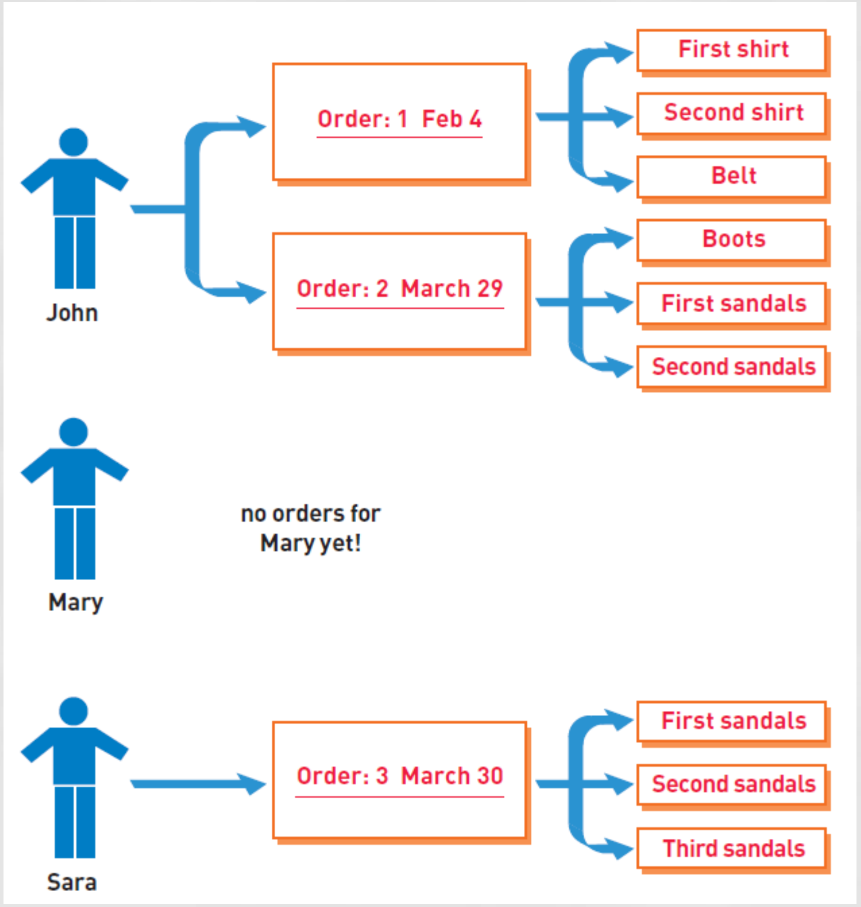


## Semantic Net (1 of 2)

- A **semantic net** is a graphical representation of an individual data entity and its relationship with other individual entities
- It is often used to help understand and then develop an ERD model

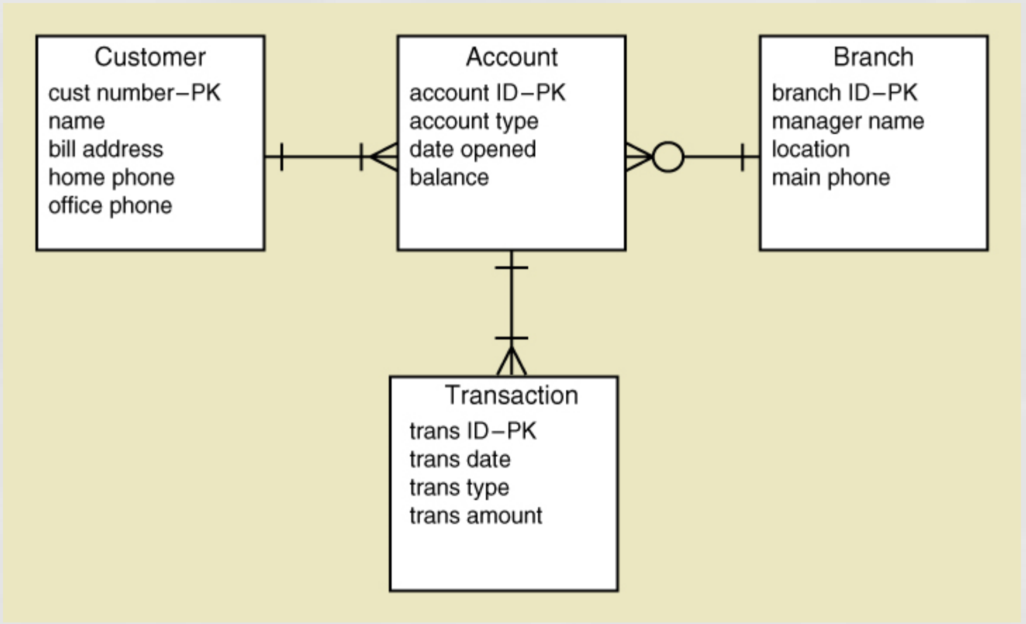
## Semantic Net (2 of 2)

- This example shows three classes.
- Quick quiz
  - What are the classes?
  - How many relationships?
  - What are min and max cardinalities?
  - What type of relationships are they?



# An ERD for a Bank

- Quick Quiz
  - What are the key fields?
  - How many accounts can a customer have?
  - How many branches can a customer be assigned to?
  - How many customers can a branch have?

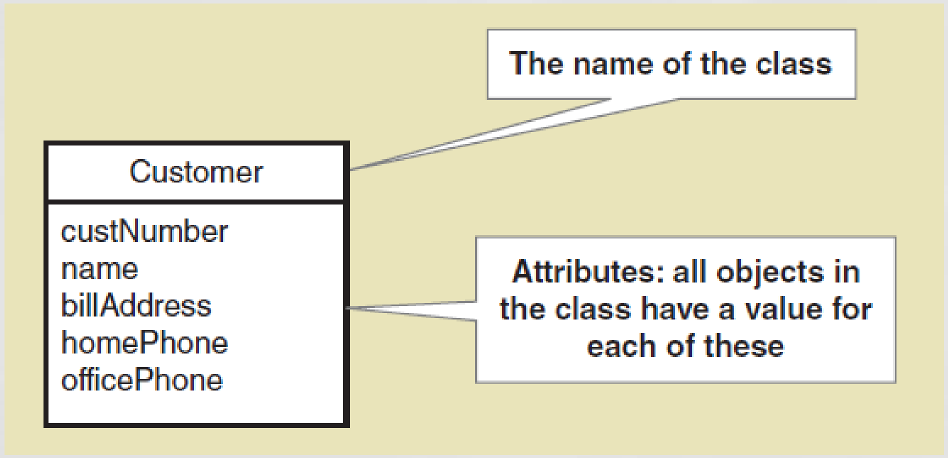


## The Domain Model Class Diagram

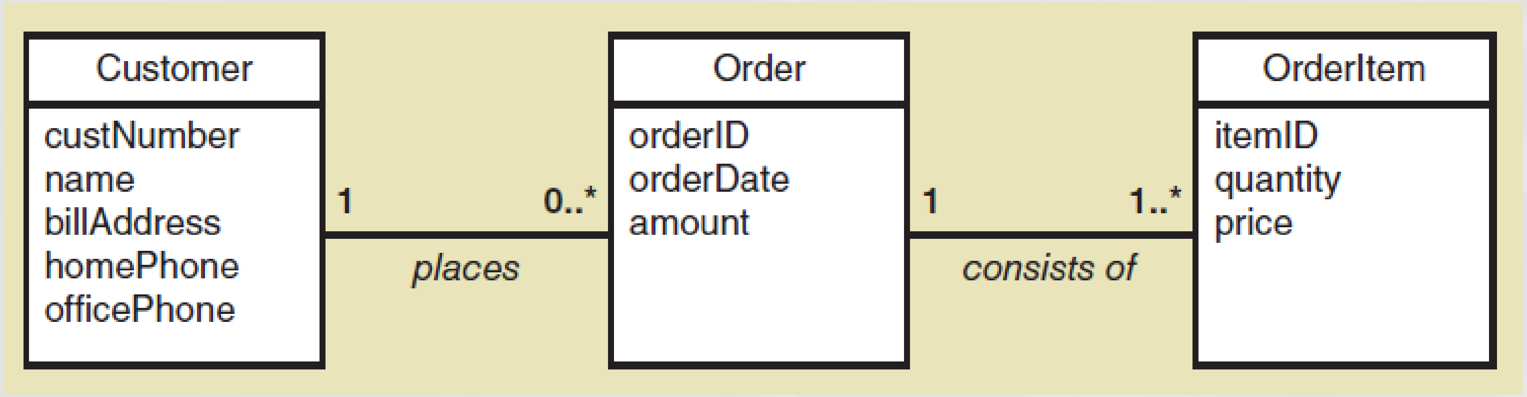
- Class
  - A type of classification used to describe a collection of objects
- Domain Class
  - Classes that describe objects in the problem domain
- Class Diagram
  - A UML diagram that shows classes with attributes and associations (plus methods if it models software classes)
- Domain Model Class Diagram
  - A class diagram that only includes classes from the problem domain, not software classes so no methods

# UML Domain Class Notation

- Domain class a name and attributes (no methods)
- Class name is always capitalized
- Attribute names are not capitalized and use **camelback notation** (words run together and second word is capitalized)
- Compound class names also use camelback notation

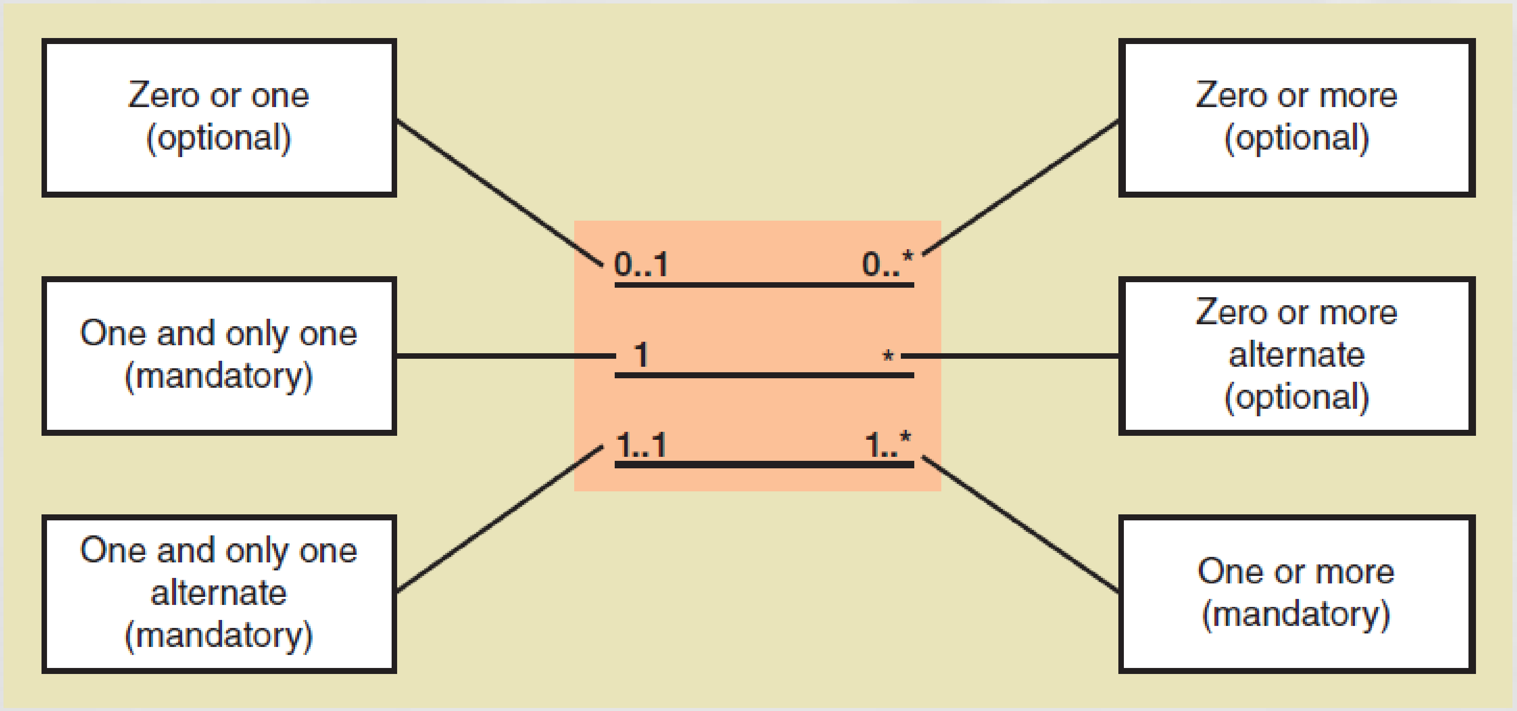


# A Simple Domain Model Class Diagram



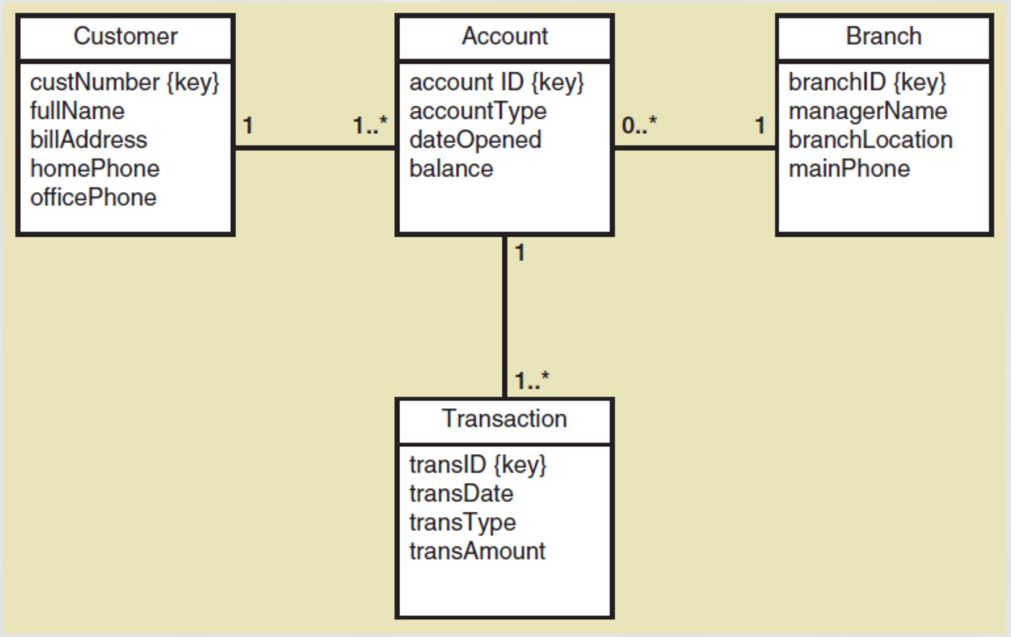
- Note: This diagram matches the semantic net shown previously
  - A customer places zero or more orders
  - An order is placed by exactly one customer
  - An order consists of one or more order items
  - An order item is part of exactly one order

# UML Notation for Multiplicity


Zero or one (optional)
One and only one (mandatory)
One and only one alternate (mandatory)
0..1
1
1..1
0..*
*
1..*
Zero or more (optional)
Zero or more alternate (optional)
One or more (mandatory)

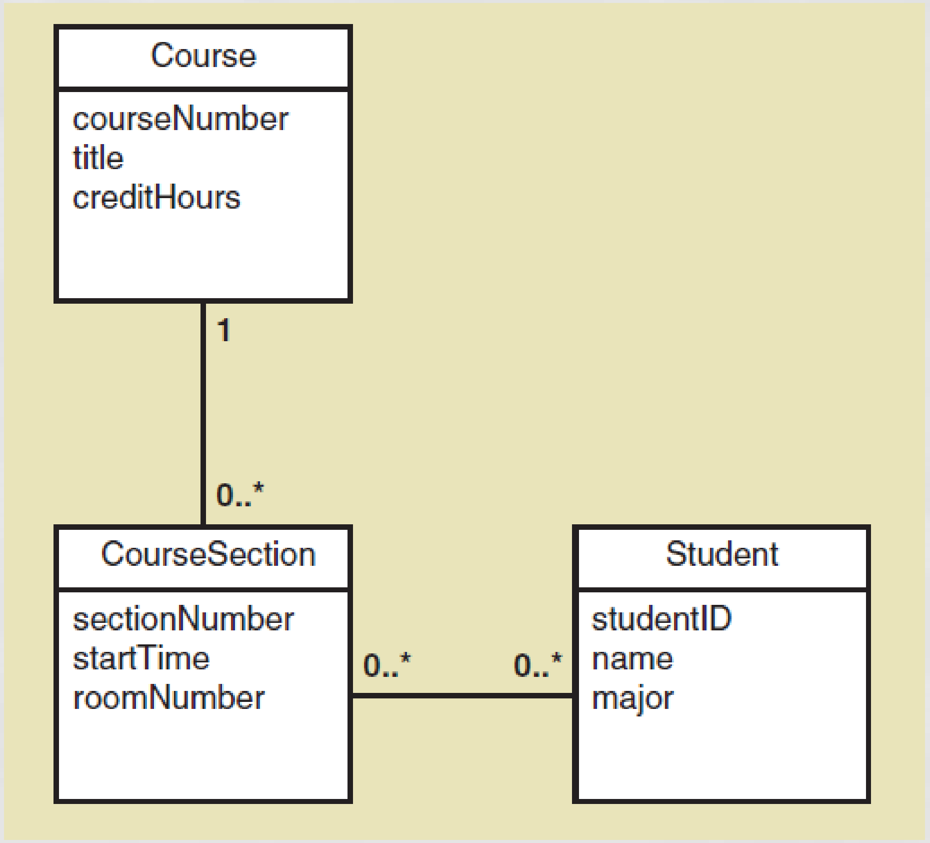
# Domain Model Class Diagram (1 of 2)

- Bank with many branches as show previously in ERD
  - Note notation for the key
  - Note the precise notation for the attributes (camelback)
  - Note the multiplicity notation



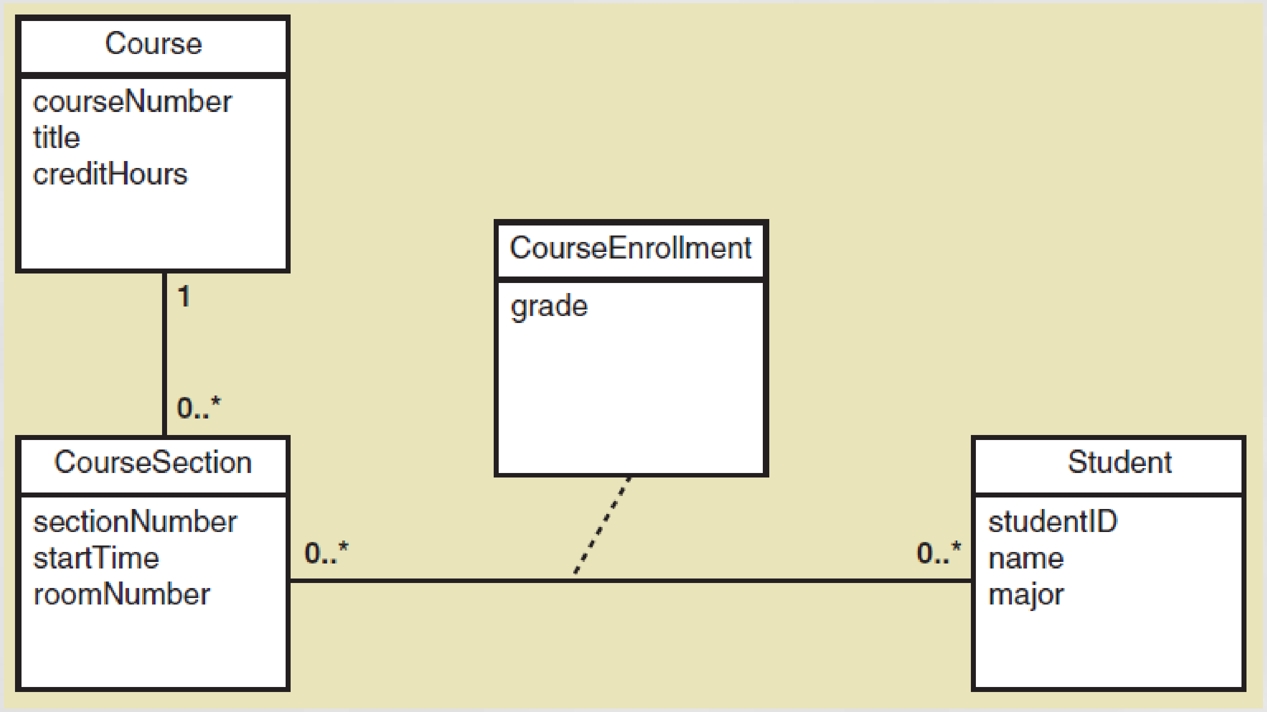
## Domain Model Class Diagram (2 of 2)

- Course Enrollment at a University
- A Course has many CourseSections
- A CourseSection has many Students and a Student is registered in many CourseSections
- Problem
  - How/where to capture student grades?



## Refined Course Enrollment Model with an Association Class CourseEnrollment

- **Association class**— an association that is treated as a class in a many to many association because it has attributes that need to be remembered (such as grade)

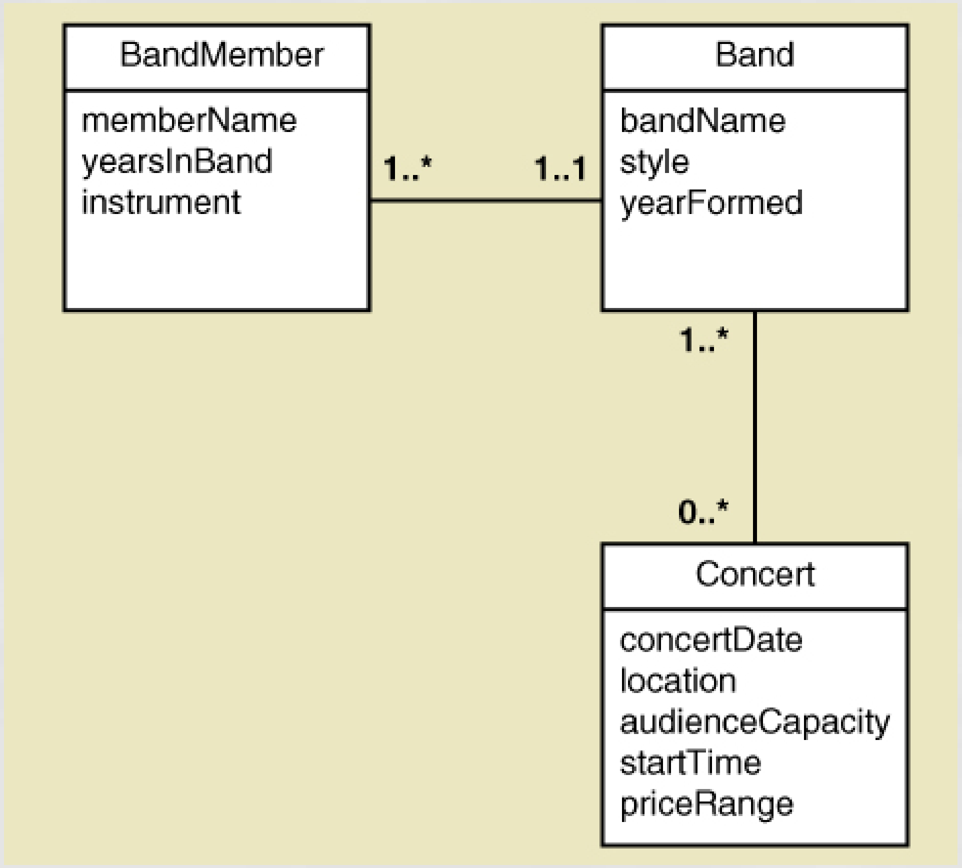


# Association Class Properties

- The association class **is** the same “thing” as the association itself
- The unique identifier (key) for the association class is the concatenation of the keys of the attached classes
  - In the previous example the key for CourseSection is CourseNumber+SectionNumber
  - Hence the key for CourseEnrollment is CourseNumber+SectionNumber+StudentID
  - Note: If more information is required to uniquely identify instances of the association class, then the model is incorrect, i.e., if the key cannot be formed by the concatenation of the endpoint keys, it is in error.

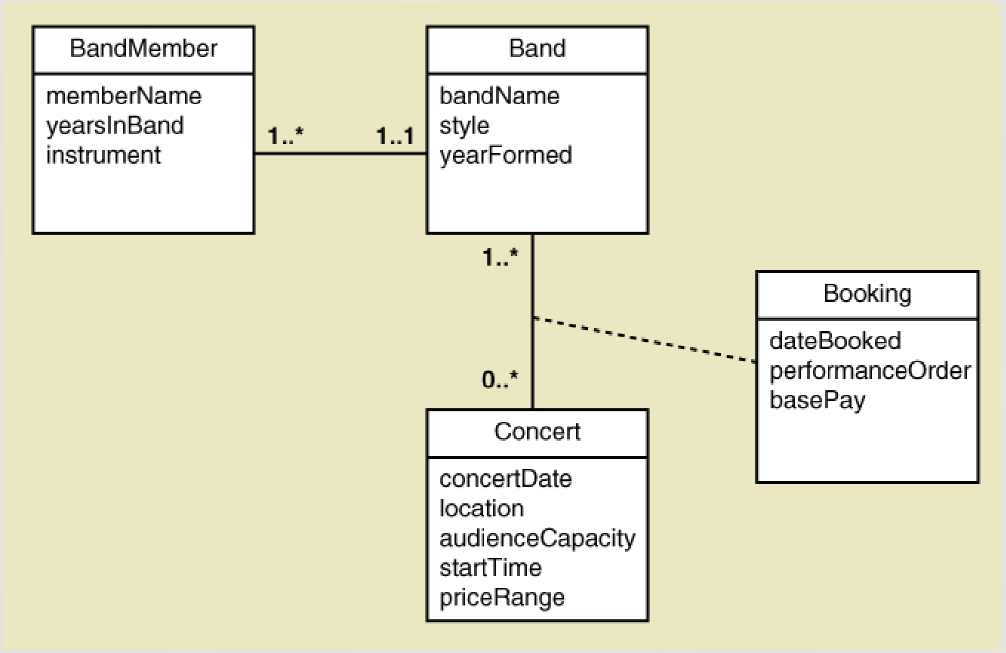
## Band with members and concerts

- Quick Quiz
  - How many bands can a person play in?
  - For a band, how many concerts can it play in?
  - For a concert, how many bands may be playing?
  - What attributes can you use for keys? Do you need to add "key" attributes?



# Band with Concert Booking Information

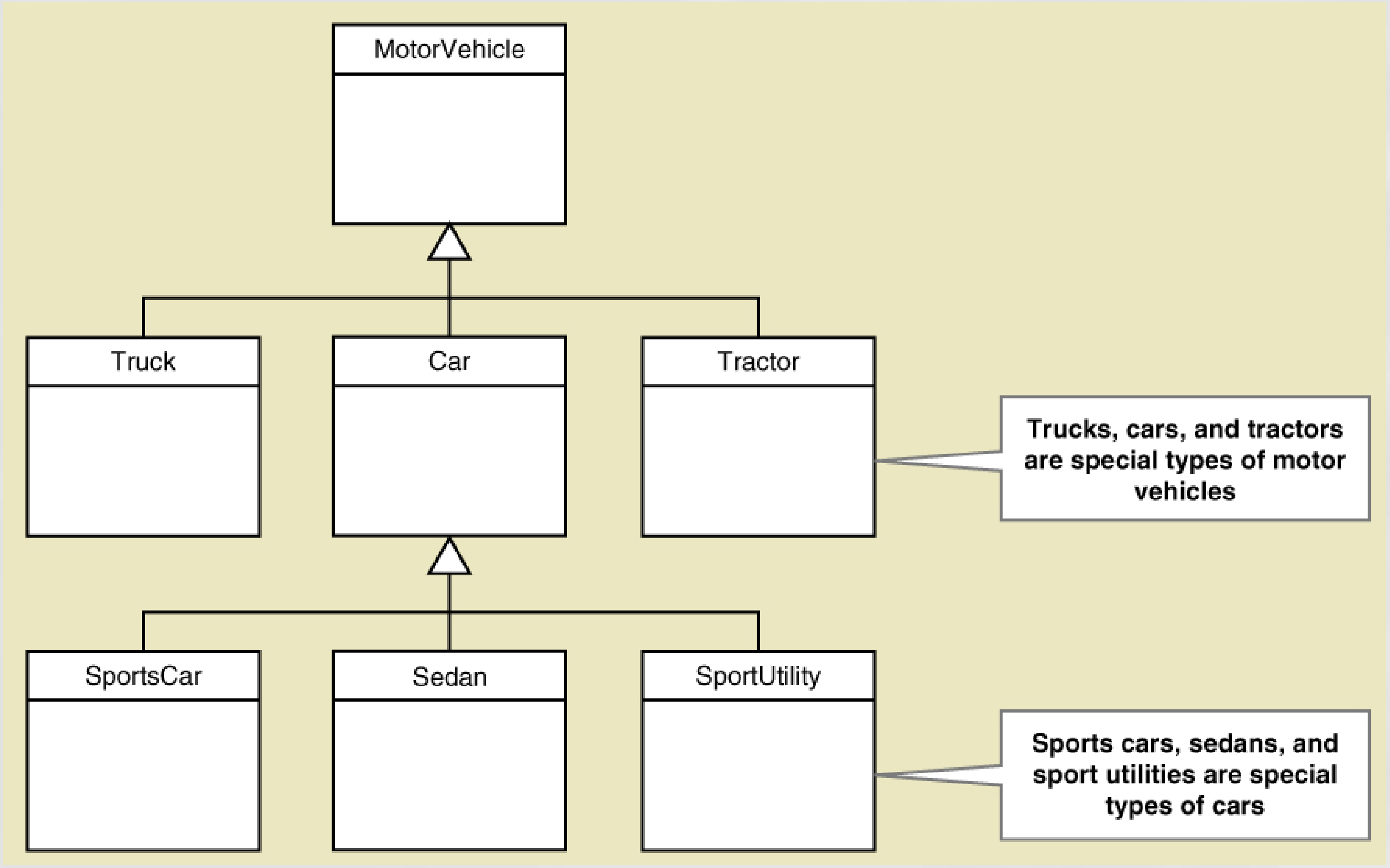
- Note: The association class (Booking) also provides a name and meaning for the association
- Given the keys you identified, what is the key for the Booking class? Does it uniquely identify instances?



## More Complex Issues about Classes:
### Generalization/Specialization Relationships

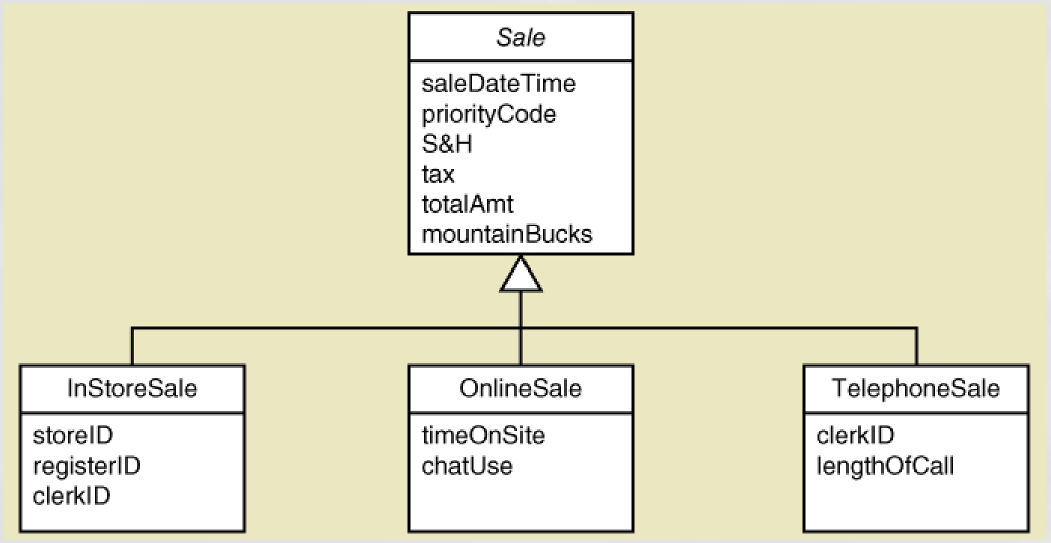
- Generalization/Specialization
  - A hierarchical relationship where subordinate classes are special types of the superior classes. Often called an Inheritance Hierarchy
- Superclass
  - the superior or more general class in a generalization/specialization hierarchy
- Subclass
  - the subordinate or more specialized class in a generalization/specialization hierarchy
- Inheritance
  - the concept that subclasses classes inherit characteristics of the more general superclass

# Generalization/Specialization


MotorVehicle
Truck
Car
Tractor
Trucks, cars, and tractors are special types of motor vehicles
SportsCar
Sedan
SportUtility
Sports cars, sedans, and sport utilities are special types of cars

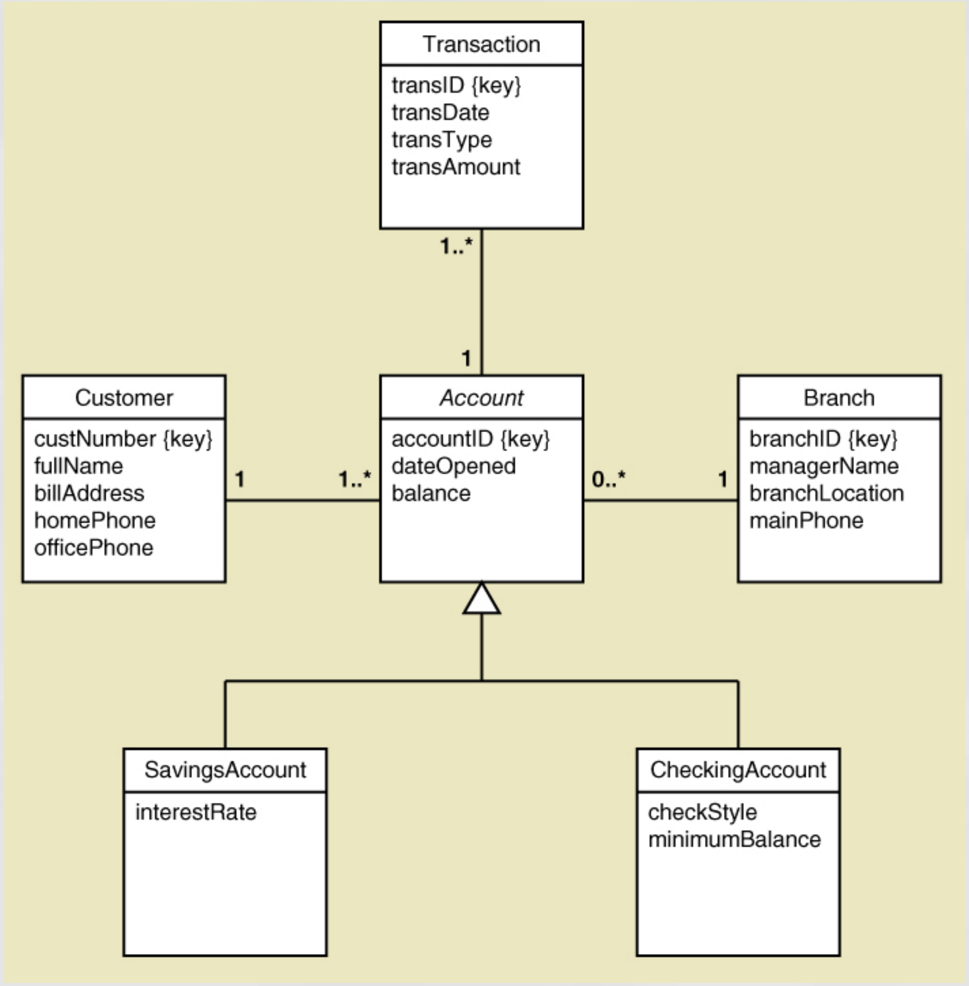
## Generalization/Specialization: Inheritance for RMO Three Types of Sales

- Abstract class— a class that allow subclasses to inherit characteristics but never gets instantiated. In Italics (*Sale*)
- Concrete class— a class that can have instances
- Inheritance – Attributes of OnlineSale are:
    - timeOnSite, chatUse, saleDateTime, priorityCode, S&H, tax, totalAmt…



## Generalization/Specialization: Inheritance for the Bank with Special Types of Accounts

- A SavingsAccount has 4 attributes
- A CheckingAccount has 5 attributes
- Note: the subclasses inherit the associations too

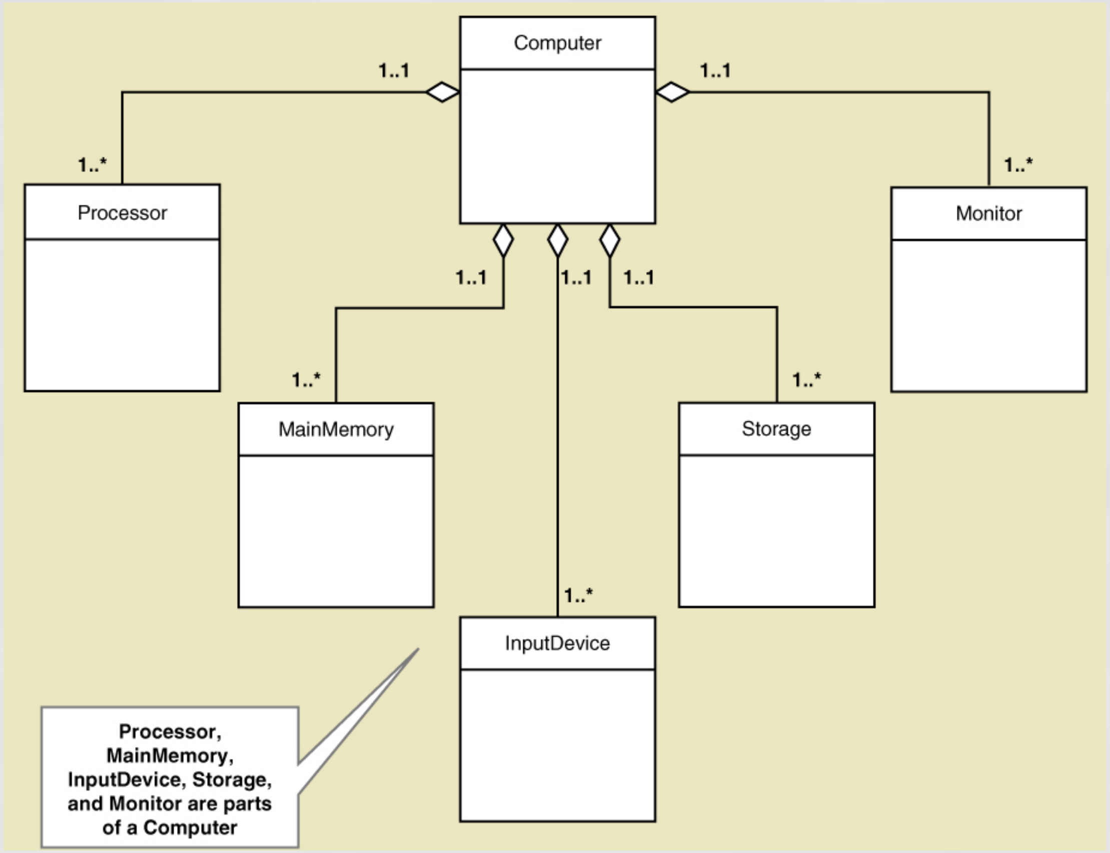


## More Complex Issues about Classes: Whole Part Relationships

- Whole-part relationship— a relationship between classes where one class is part of or a component portion of another class
- Aggregation— a whole part relationship where the component part exists separately and can be removed and replaced (UML diamond symbol on next slide)
  - Computer has disk storage devices (storage devices exist apart from computer)
  - Car has wheels (wheels can be removed and still be wheels)
- Composition— a whole part relationship where the parts cannot be removed (filled in diamond symbol)
  - OrderItem on an Order (without the Order, there are no OrderIterms)
  - Chip has circuits (without the chip, there are no circuits)

## Whole Part Relationships: Computer and its Parts

- Note: this is composition, with diamond symbol.
- Whole part can have multiplicity symbols, too (not shown)\



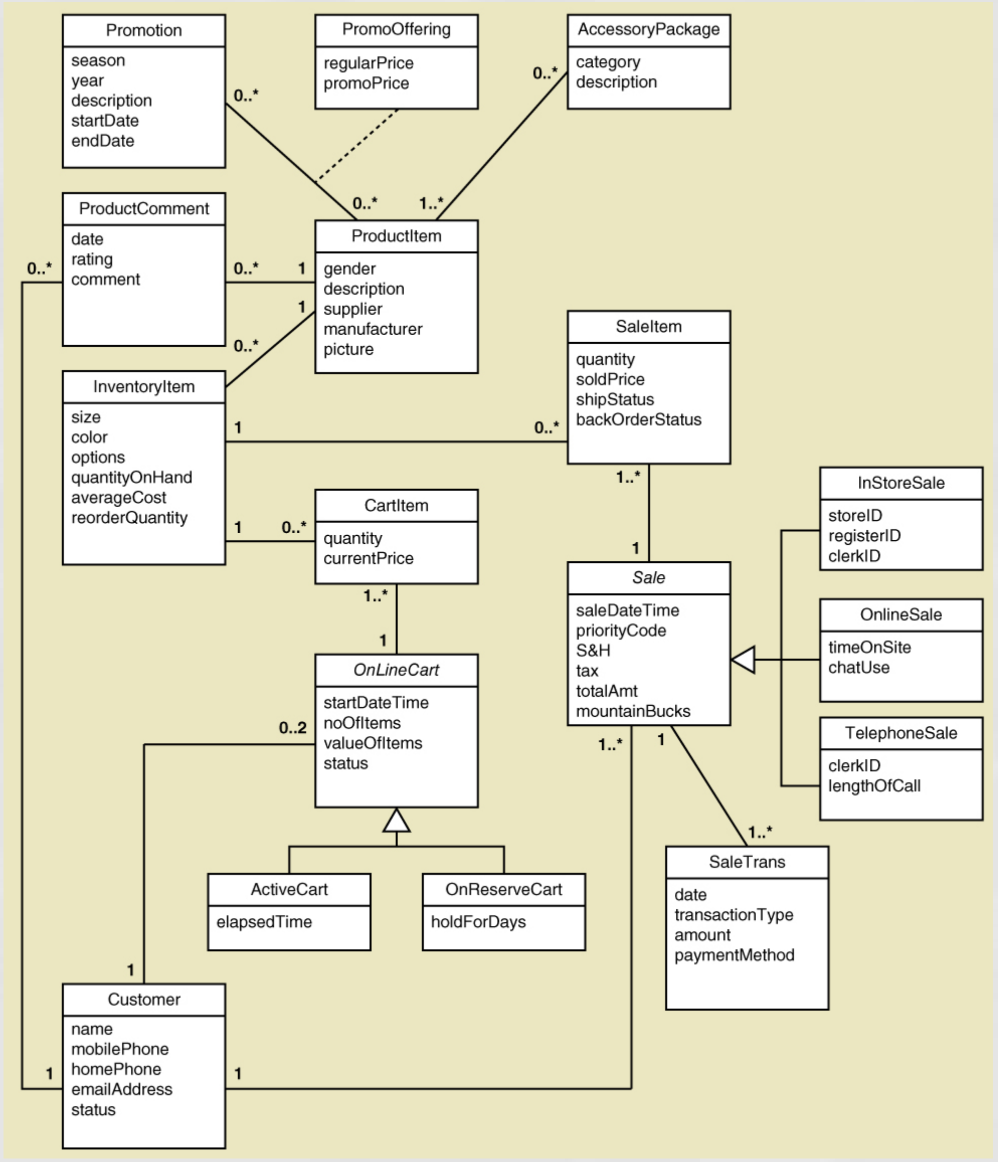
## More on UML Relationships

- There are actually three types of ***relationships*** in class diagrams
  - Association Relationships
    - These are associations discussed previously, just like ERD relationships
  - Whole Part Relationships
    - One class is a component or part of another class
  - Generalizations/Specialization Relationships
    - Inheritance
- Try not to confuse relationship with association

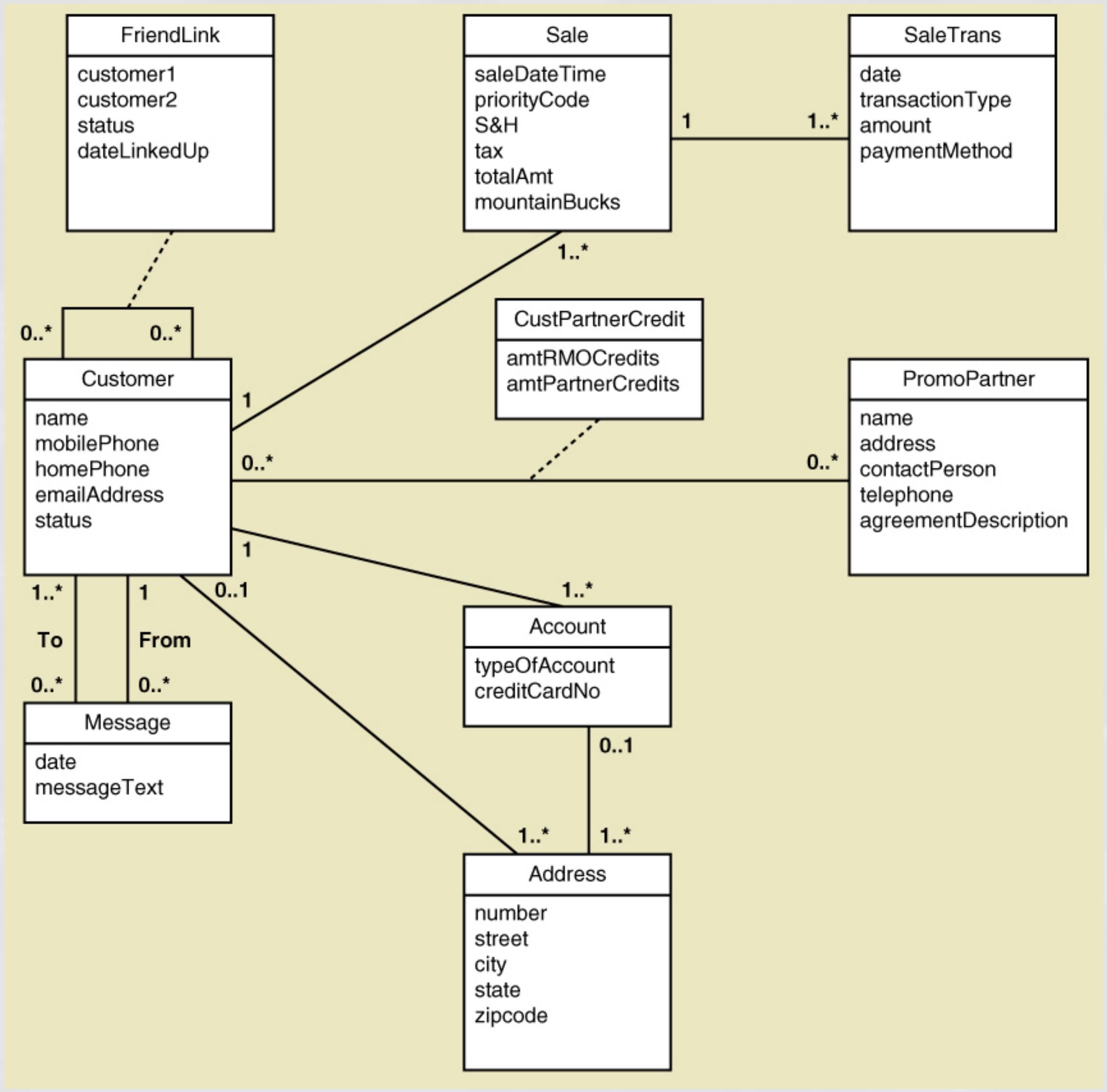
## RMO CSMS Project: Domain Model Class Diagrams

- There are several ways to create the domain model class diagram for a project
- RMO CSMS has 27 domain classes overall
- Can create one domain model class diagram per subsystem for those working on a subsystem
- Can create one overall domain model class diagram to provide an overview of the whole system
- Usually in early iterations, an initial draft of the domain model class diagram is completed and kept up to date. It is used to guide development.

# RMO CSMS Project: Sales Subsystem Domain Model Class Diagrams

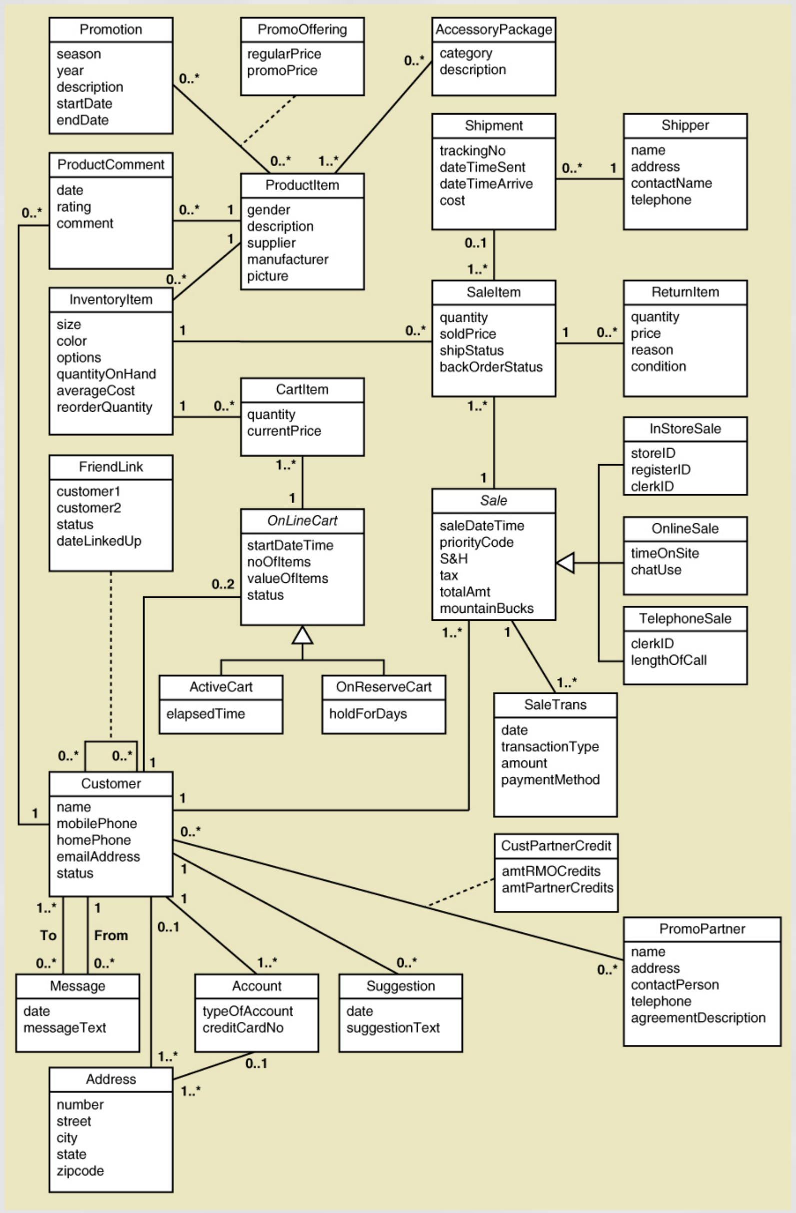


# RMO CSMS Project: Customer Account Subsystem Domain Model Class Diagram



# RMO CSMS Project:

## Complete Domain Model Class Diagram



## RMO CSMS Project: Domain Model Class Diagrams (2 of 2)

- Given the complete RMO CSMS Domain Model Class Diagram and Sales and Customer Account subsystem examples:
  - Try completing the Order Fulfilment Subsystem Domain Model Class Diagram
  - Try Completing the Marketing Subsystem Domain Model Class Diagram
  - Try Completing the Reporting Subsystem Domain Model Class Diagram
- Review the use cases from Chapter 3 and decide what classes and associations from the complete model are required for each subsystem
  - Classes and associations might be duplicated in more than one subsystem model

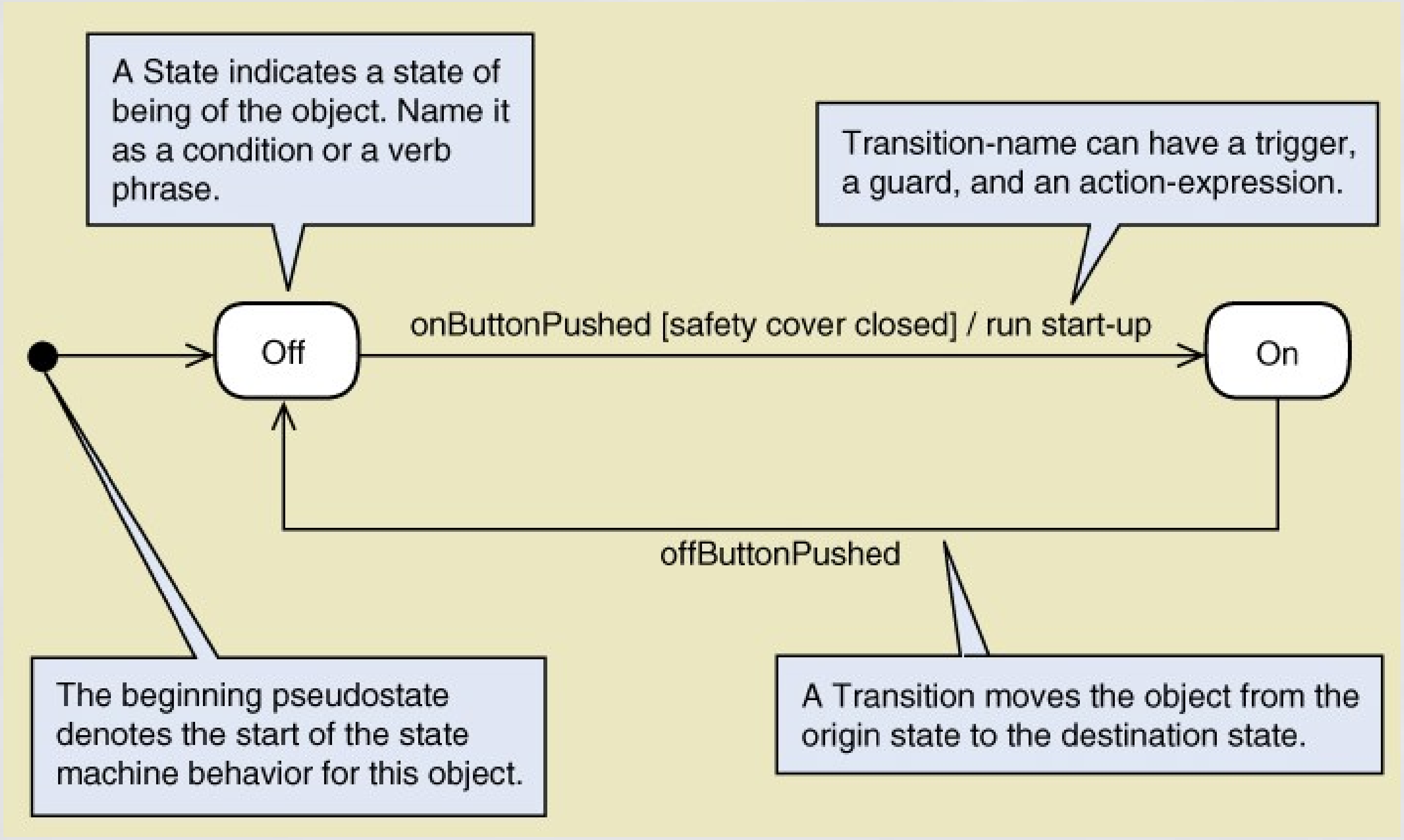
## Object Behavior – State Machine Diagram

- Each class has objects that may have status conditions or “states”
- Object behavior consists of the various states and the movement between these states
- **State** – a condition during an object’s life when it satisfies some criterion, performs an action, or waits for an event
- **Transition** – the movement of an object from one state to another

## State Machine Diagram

- **State Machine Diagram** – a diagram which shows the life of an object in states and transitions
- **Origin state** – the original state of an object before it begins a transition
- **Destination state** – the state to which an object moves after completing a transition
- **pseudostate** – the starting point in a state machine diagram. Noted by a black circle.
- **action-expression** – some activity that must be completed as part of a transition
- **guard-condition** – a true/false test to see whether a transition can fire

# State Machine for a Printer

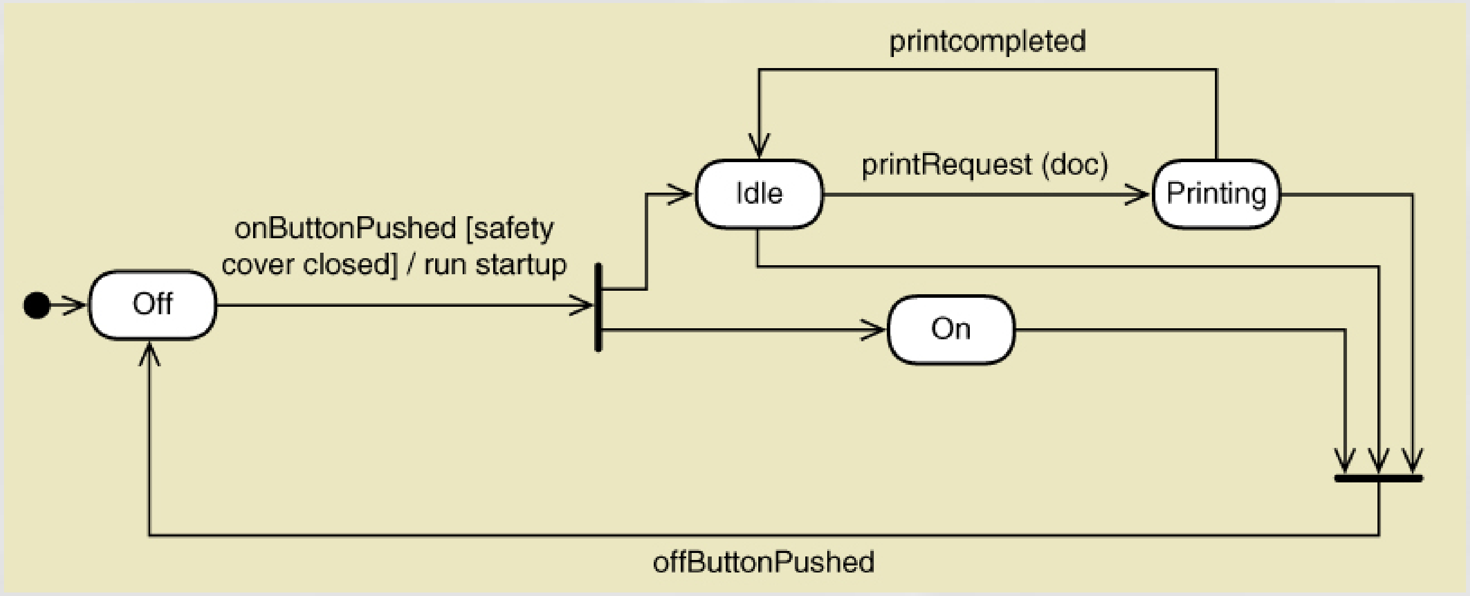

A State indicates a state of being of the object. Name it as a condition or a verb phrase.
Transition-name can have a trigger, a guard, and an action-expression.
Off
onButtonPushed [safety cover closed] / run start-up
On
offButtonPushed
The beginning pseudostate denotes the start of the state machine behavior for this object.
A Transition moves the object from the origin state to the destination state.

- Syntax of transition statement
  - *transition-name (parameters, …) [guard-condition] / action-expression*

## Concurrency in a State Machine Diagram

- **Concurrent states** – when an object is in one or more states at the same time
- **Path** – a sequential set of connected states and transitions
- **Concurrent paths** – when multiple paths are being followed concurrently, i.e. when one or more states in one path are parallel to states in another path

# Printer with Concurrent Paths



- Concurrent paths often shown by synchronization bars (same as Activity Diagram)
- Multiple exits from a state is an "OR" condition.
- Multiple exits from a synchronization bar is an "AND" condition.

## Creating a State Machine Diagram: Steps (1 of 2)

1. Review the class diagram and select classes that might require state machine diagrams
2. For each class, make a list of status conditions (states) you can identify
3. Begin building diagram fragments by identifying transitions that cause an object to leave the identified state
4. Sequence these states in the correct order and aggregate combinations into larger fragments
5. Review paths and look for independent, concurrent paths

## Creating a State Machine Diagram: Steps (2 of 2)

6. Look for additional transitions and test both directions
7. Expand each transition with appropriate message event, guard condition, and action expression
8. Review and test the state machine diagram for the class
   - Make sure state are really state for the object in the class
   - Follow the life cycle of an object coming into existence and being deleted
   - Be sure the diagram covers all exception condition
   - Look again for concurrent paths and composite states

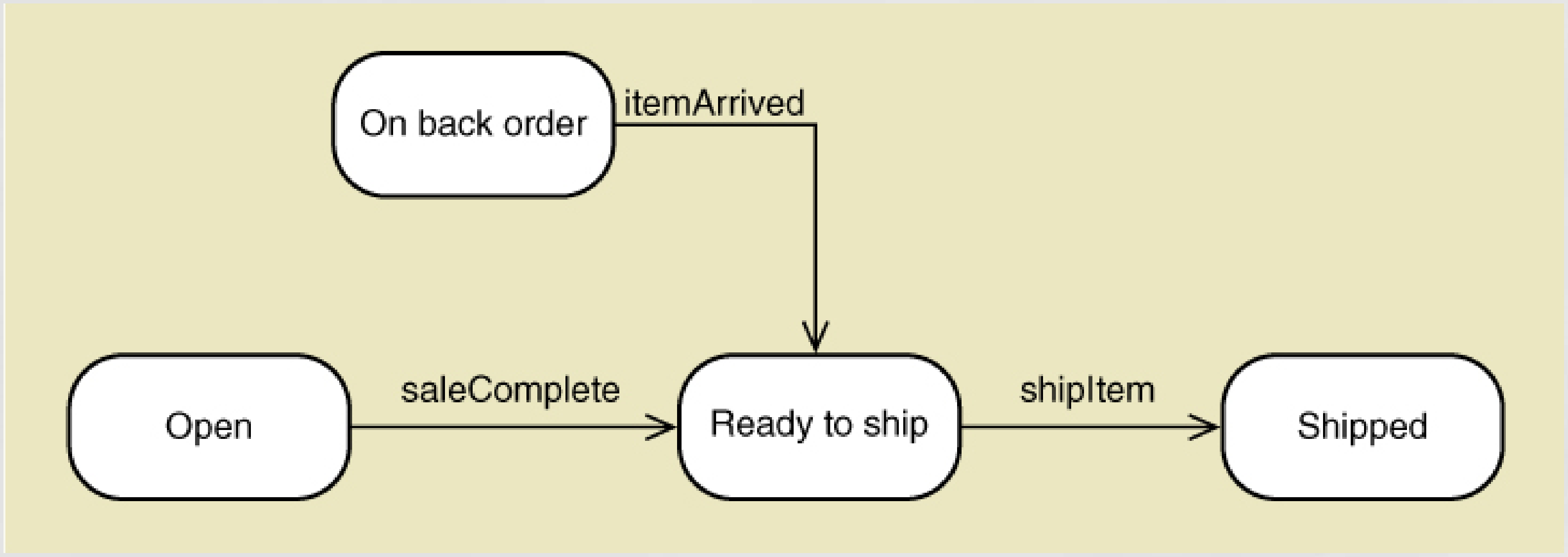
## RMO – Creating a State Machine Diagram: Steps – SaleItem (1 of 3)

1. Choose SaleItem. It has status conditions that need to be tracked
2. List the states and exit transitions

| State | Transition causing exit |
|---|---|
| Open | saleComplete |
| Ready to Ship | shipItem |
| On back order | itemArrived |
| Shipped | No exit transition defined |

## RMO – Creating a State Machine Diagram: Steps – SaleItem (2 of 3)

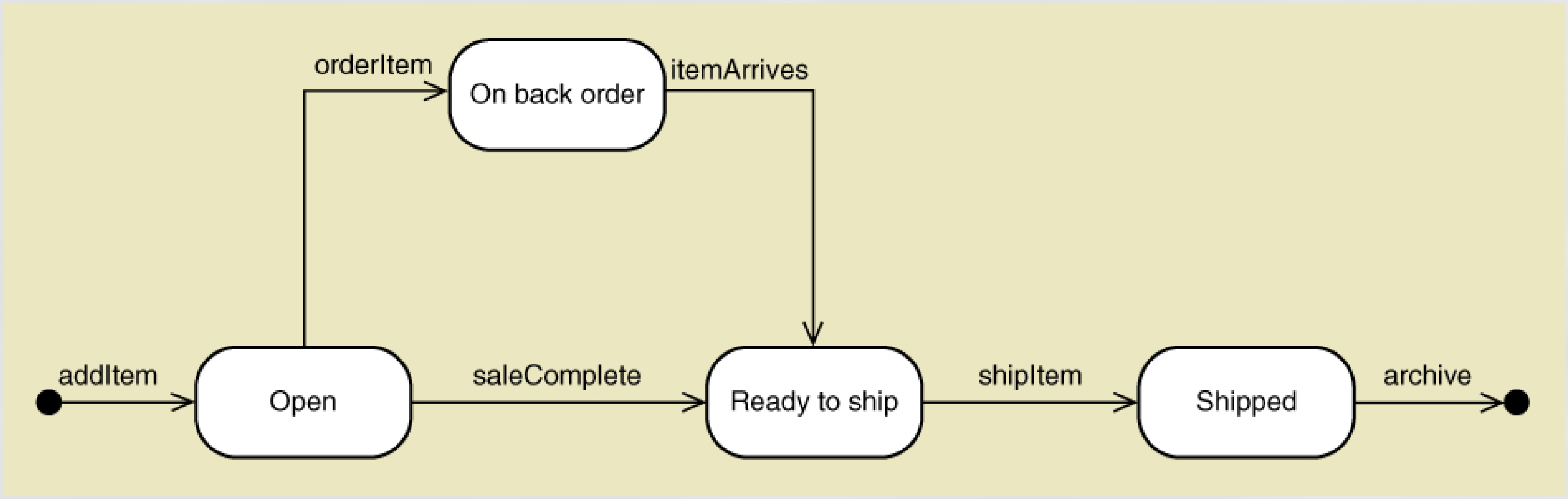
3. Build fragments – see figure below
4. Sequence in correct order – see figure below
5. Look for concurrent paths – none



## RMO – Creating a State Machine Diagram: Steps – SaleItem (3 of 3)

6. Add other required transitions
7. Expand with guard, action-expressions etc.
8. Review and test

Below is the final State Machine Diagram



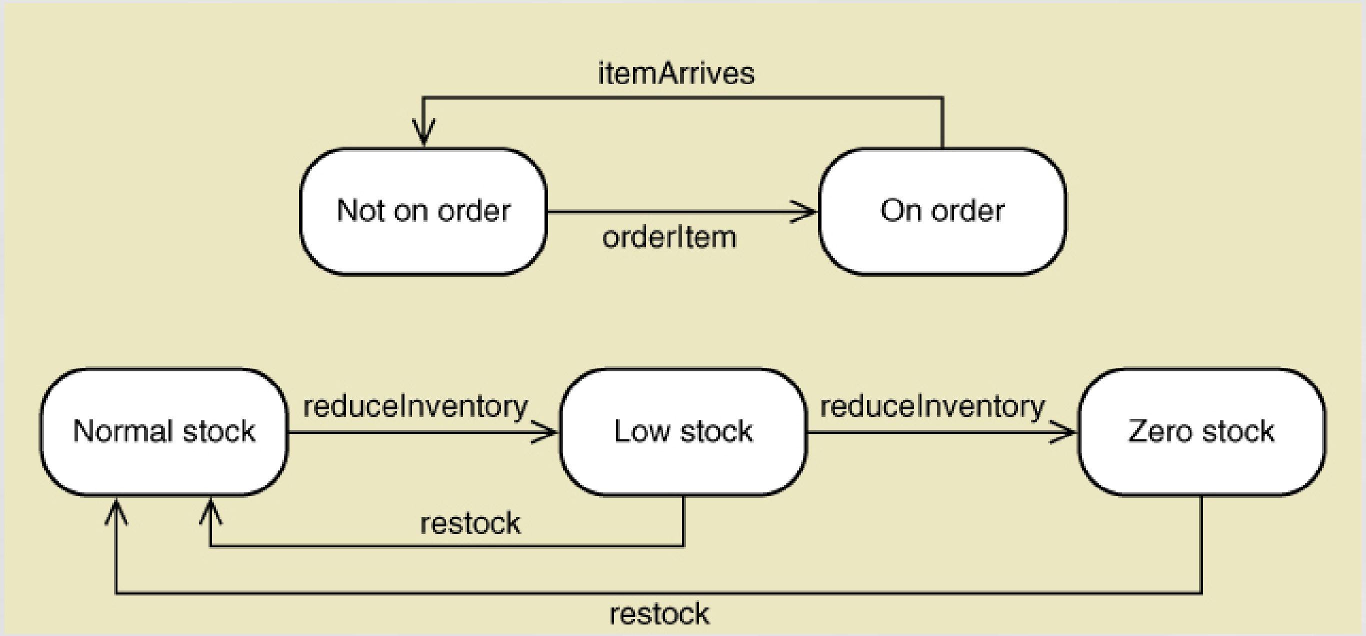
## RMO – Creating a State Machine Diagram: Steps – InventoryItem (1 of 3)

1. Choose InventoryItem. It has status conditions that need to be tracked
2. List the states and exit transitions

| **State** | **Transition causing exit** |
|---|---|
| Normal stock | reduceInventory |
| Low stock | reduceInventory OR restock |
| Zero stock | removeItem OR restock |
| On order | itemArrives |
| Not on order | orderItem |

# RMO – Creating a State Machine Diagram: Steps – InventoryItem (2 of 3)

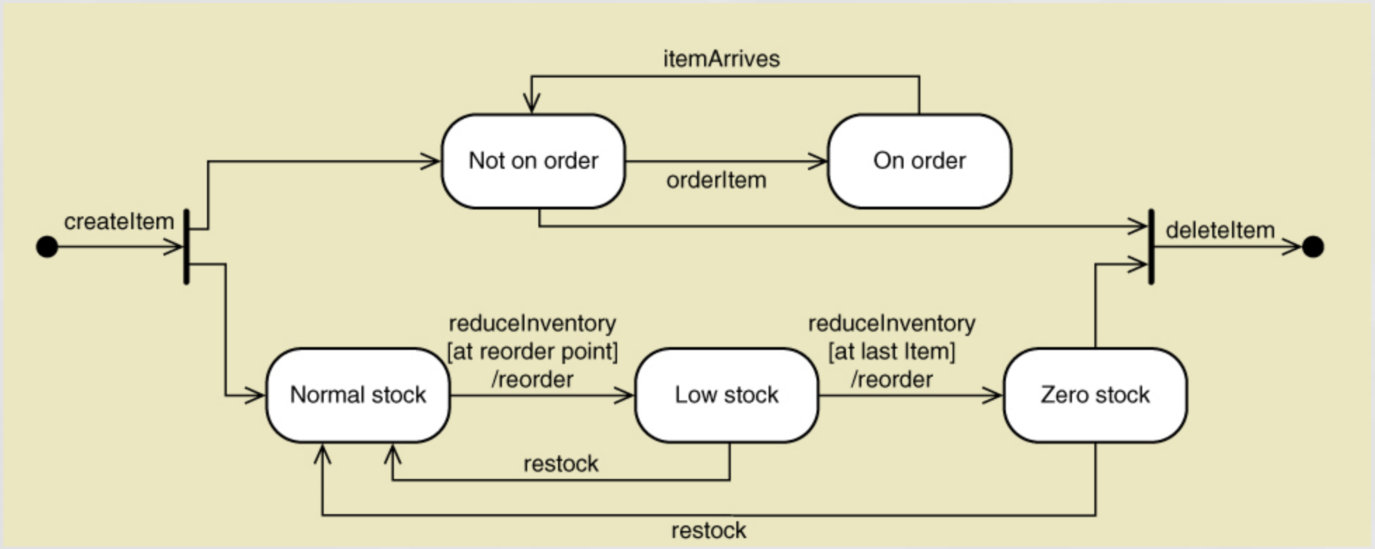
3. Build fragments – see figure below
4. Sequence in correct order – see figure below
5. Look for concurrent paths – see figure below



# RMO – Creating a State Machine Diagram: Steps – InventoryItem (3 of 3)

6. Add other required transitions
7. Expand with guard, action-expressions etc.
8. Review and test

Below is the final State Machine Diagram



## Summary (1 of 4)

- This chapter focuses on modeling functional requirements as a part of systems analysis
- “Things” in the problem domain are identified and modeled, called domain classes or data entities
- Two techniques for identifying domain classes/data entities are the brainstorming technique and the noun technique
- Domain classes have attributes and associations
- Associations are naturally occurring relationships among classes, and associations have minimum and maximum multiplicity

## Summary (2 of 4)

- Entity-relationship diagrams (ERDs) show the information about data entities
- ERD s are often preferred by database analysts and are widely used
- ERD s are not UML diagrams, and an association is called a relationship, multiplicity is called cardinality, and generalization/specialization (inheritance) and whole part relationships are usually not shown

## Summary (3 of 4)

- The UML class diagram notation is used to create a domain model class diagram for a system. The domain model classes do not have methods because they are not yet software classes.
- There are actually three UML class diagram relationships: association relationships, generalization/specialization (inheritance) relationships, and whole part relationships
- Other class diagram concepts are abstract versus concrete classes, compound attributes, composition and aggregation, association classes, super classes and subclasses

## Summary (4 of 4)

- Some objects have a life cycle with status conditions that change and should be tracked
- A State Machine Diagram tracks the behavior of these objects with states and transitions
- To develop a State Machine Diagram
  - Choose a single object class.
  - Identify the states and exit transitions
  - Identify concurrent paths
  - Identify additional paths
  - Build the State Machine Diagram