Domain Modeling

- A representation of the conceptual classes in problem domain
  - UML (conceptual) class diagrams
    - What's a conceptual class?
      - What are its attributes?
      - What are description classes?
    - What are inter-class associations?
    - Implementation issues

Domain Modeling

- Idea: identify the important concepts in the problem domain
  - These concepts later will serve as basis for the design and the implementation
- Domain modeling (domain analysis)
  - We will consider object-oriented domain modeling in the context of the Unified Process

The Domain Model

- Representation of real-world conceptual classes in the problem domain
  - With class attributes
- Representation of relationships between conceptual classes
  - Associations between classes
  - Generalization relationships
- Represented by a UML class diagram
  - But it could also be described in text

Models of Domain Concepts

Store
address
name

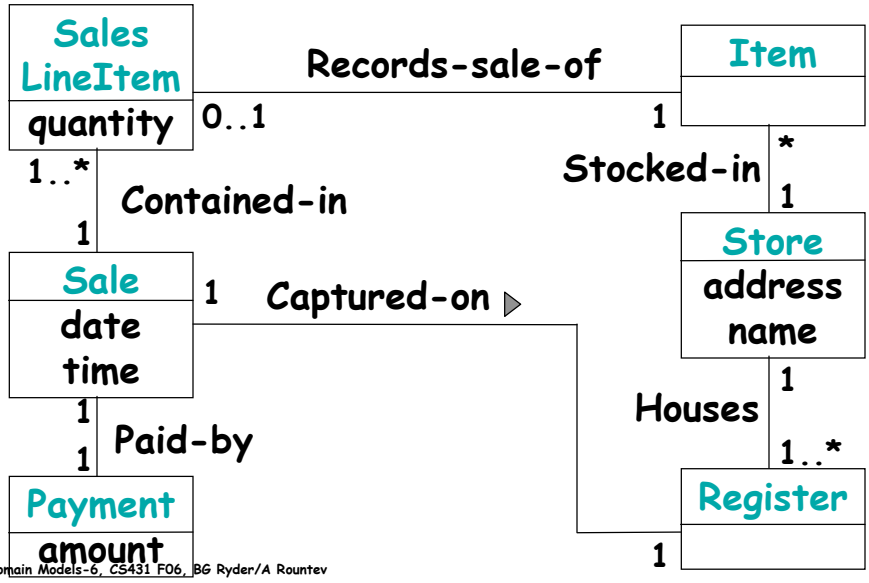
```
class Store {
  String address;
  String name;
  addRegister()…
}
```

Conceptual class:
No operations; part of domain model

Implementation class: created during design; not part of domain model

Of course, it is not always this simple …

A Conceptual Class Diagram

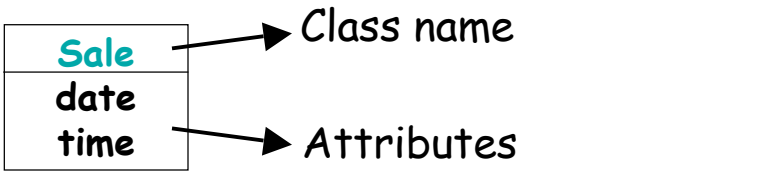


UML Diagrams

- UML is just notation
- Different diagrams mean different things in different contexts
  - Conceptual perspective: description of the problem domain
  - Specification perspective: description of software abstractions or components
    - e.g., no commitment to a particular language
  - Implementation perspective: description of Java classes
- Can have UML class diagrams in each perspective; used for different purposes

Conceptual Classes

- Abstractions of concepts from the problem domain
  - Concepts such as Sale, Register, Item, ..
- UML representation



- only attributes relevant to the problem

Building the Domain Model

- Over several iterations during elaboration
- Driven by the use cases
  - In each iteration, the use case model is enriched, and the domain model is extended accordingly
- How to identify conceptual classes?
  - Consider common categories (see next slide)
  - Identify nouns and noun phrases from the fully dressed use case
  - Use analysis patterns: existing partial domain models created by experts
    - "recipes" for well-known problems and domains (e.g. accounting, stock market, …)

Common Categories

Category	Examples
Physical objects	Register, Airplane
Places	Store, Airport
Transactions	Sale, Payment, Reservation
Roles of people	Cashier, Manager
Scheduled Events	Meeting, Flight
Records	Receipt, Ledger
Specifications and descriptions	FlightDescription, ProductSpecification
Catalogs of descriptions	ProductCatalog

Example: Simplified "Process Sale"

Simplified scenario in **Process Sale**.
No credit cards, no taxes, no external accounting system, no external inventory system, …

- **Customer arrives with goods**
- **Cashier starts a new sale**

Possible conceptual classes: **Customer**, **Cashier**, **Item** (i.e., goods), **Sale**

Simplified "Process Sale", cont.

- **Cashier enters item ID**
- **System records sale line item and presents item description, price, and running total**
- **At the end, Cashier tells Customer the total and asks for payment**

Possible conceptual classes: SalesLineItem, ProductSpecification (description + price + item ID), Payment

- item ID, description, price, total: probably too simple to be classes but will be class attributes

Simplified "Process Sale", cont.

- **Cashier enters amount tendered (cash)**
- **System presents change due, and releases cash drawer**
- **Cashier deposits cash and returns change**
- **System presents receipt**

Possible conceptual classes:
Register (implied by cash drawer), Receipt

- amount, change: probably too simple

Example (cont)

- Want a completely integrated system
  - Store: has the items and the registers
  - ProductCatalog: stores the product specifications for all items
  - Manager: starts all the registers in the morning
    - Need this for the initial implementation: to be able to start up the system
- There is no "correct solution"
  - Somewhat arbitrary collection of concepts

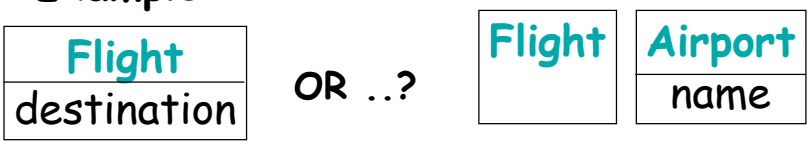
Possible Initial Domain Model

- Just the conceptual classes
  - Attributes and associations later
- For this particular simplified scenario
  - Will evolve as more scenarios are explored

Register	Store	Item	Sale
Customer	Cashier	Manager	Payment
Product Specification	Product Catalog	Sales LineItem	

A Common Mistake

- Example



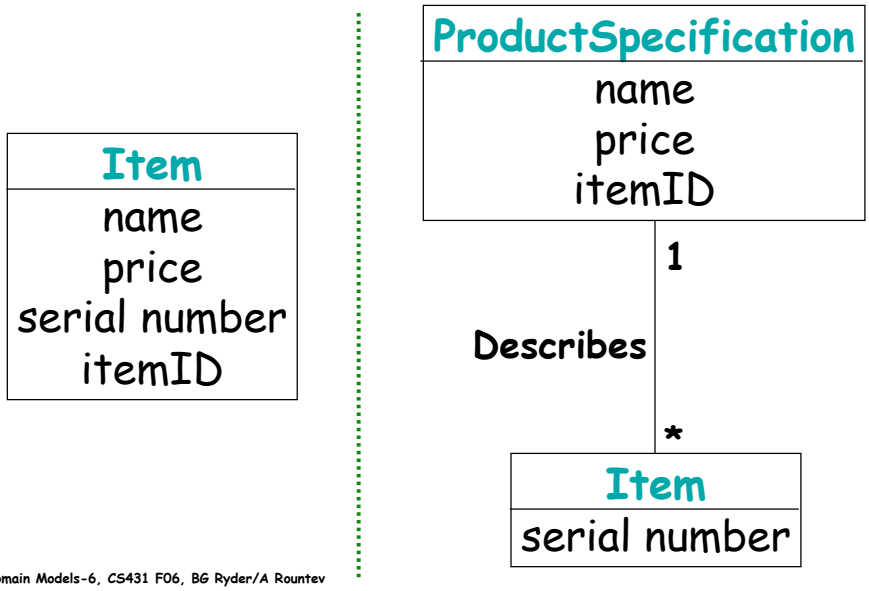
- If in doubt, make it a conceptual class
  - Attributes should be fairly rare in a domain model and should be relevant to a use case.

"If we do not think of some conceptual class X as a number or text in the real world, X is probably a contextual class, not an attribute.", Larman Ch 9, p 146.

Description Classes

- Class Item represents a physical item in a store
  - unique serial number, but same ID and price as all items of same kind (e.g., JVC XV-S40 DVD player)
- Could represent ID and price as attributes of Item
  - Suppose we sell all items of a particular kind; we lose all price info
  - Unnecessary duplication of data
- Need a separate conceptual class that is a description of items e.g., class ProductSpecification
- An instance of this class represents a description of information about items
  - Even if we sell all JVC XV-S400 DVD players, we still have information about their price/item ID

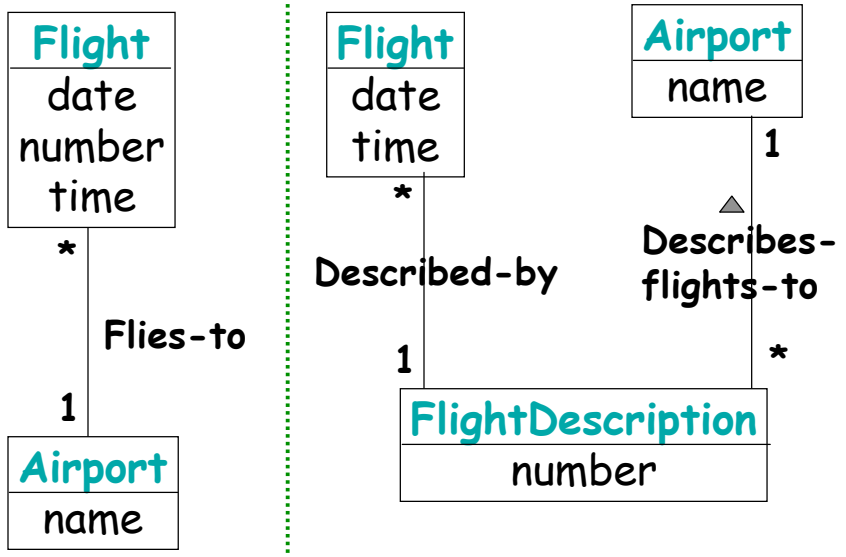
The Two Alternatives



When Do We Need This?

- When need description of an item or a service
  - Independent of the current existence of any instances of those items or services
- When description classes would reduce amount of redundant info in model
  - e.g., many instances of the class have the same values for some attributes
- If the description alone can be in interesting relationships
  - e.g., all JVC XV-S400 DVD players are on sale until Dec 26th

Another Example



Associations in the Domain Model

- Relationship between instances of conceptual classes
  - "connectedness" between instances
  - e.g. an order is related to the customer that placed that order
- Think of it as a mathematical relation
  - Typically a binary relation: $R \subseteq S1 \times S2$
  - S1 = set of instances of the first class
  - S2 = set of instances of the second class

Associations in the Domain Model

- Usually, the relation changes with time
  - For any pair (o1,o2) $\in$ S1 $\times$ S2: at some moments of time the link exists, other times it does not
- An association typically represents a relatively permanent relationship
  - Often holds for the duration of the entire lifetime of the instance(s)
  - e.g. a sale is permanently associated with the register that captures it

UML Notation

- Named to enhance understanding of the relationship
- Multiplicity: what number of instances can be associated?
- Direction arrow: just helps the reader
  - No meaning for the model; often omitted

Multiplicity

- One instance of Store can be associated with zero or more Item instances

- Intuition
  - A person may be married to many spouses during their lifetime, but at any particular moment the person is married to zero or one other person
  - Think of R $\subseteq$ S1 $\times$ S2 at a particular moment

Representing Multiplicity

- Range: x..y
- Common notation for ranges
  - x..x -> x
  - x..infinity -> x..*
  - 0..infinity -> *
- Combination of ranges
  - x..y, z..w
  - e.g. "2,4" -> number of doors in a car
- Most common multiplicities: *, 1..*, 0..1, 1

Interpretation of Multiplicity

Why 1 and not 0..1?

- E.g., an item may be sold or discontinued and then no store stocks it
- Multiplicities may encode relevant domain constraints
  - But: it is not always clear

Typical Associations

- *A is a physical/logical part of B*
  - Wing-Airplane, SalesLineItem-Sale, FlightLeg-FlightRoute, Finger-Hand
- *A is physically/logically contained in B*
  - Item-Shelf, Passenger-Airplane, Flight-FlightSchedule
- *A is recorded/reported/captured in B*
  - Sale-Register, Reservation-FlightManifest
- *A is a description of B*
  - ProductSpecification-Item

Typical Associations

- A is a member of B
  - Cashier-Store, Pilot-Airline
- A uses or manages B
  - Cashier-Register, Pilot-Airplane
- A is related to a transaction B
  - Customer-Payment, Payment-Sale, Reservation-Cancellation
- A is owned by B
  - Airplane-Airline

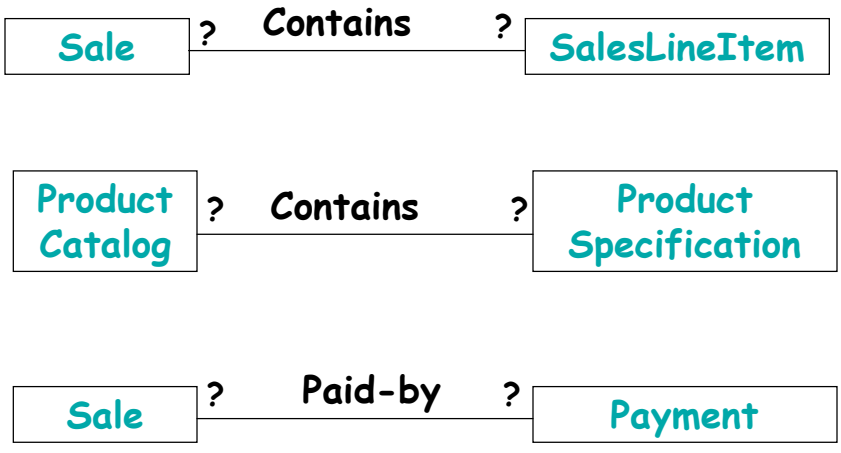
Finding Associations

- Consider the typical categories
  - Larman, Ch 9 p 155
- Focus on associations that are relevant with respect to the use cases
- SalesLineItem-Sale
  - A sale contains a set of line items
    - Permanent "whole-part" relationship
  - Needed in the context of the Process Sale use case (for the total and receipt)

Examples

- ProductSpecification-ProductCatalog
  - "contained-in" relationship
  - Given an item id, the system needs to look up the item description in the catalog
- Payment-Sale
  - Two related transactions: the payment is with respect to a particular sale
  - The payment info is needed to compute the change due

Examples



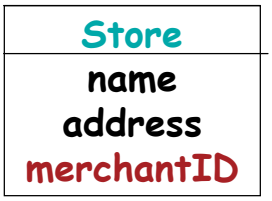
A Complicated Example

- A store uses a set of external authorization services for payments

- Each service associates merchant ID with the store (different for each store)
  - The ID is provided by the store as part of the request for authorization
- A store has different merchant IDs for each service

Stores and Services

- A software system at headquarters: many stores, many services
  - Where should the merchantID be located?

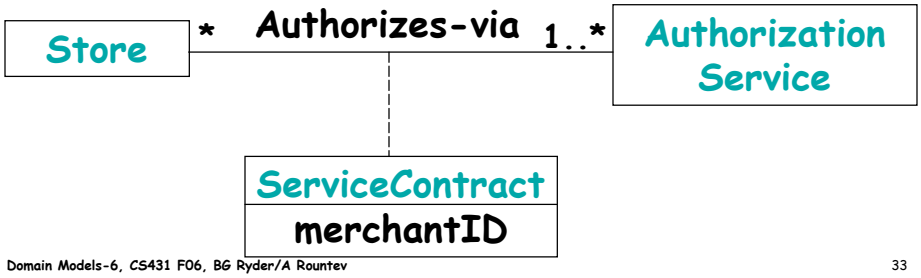


Option 1

Option 2

Association Class

- Attribute merchantID is conceptually related to the association, not to the individual classes
- Solution: association class
  - Represents attributes of the association



Association Classes

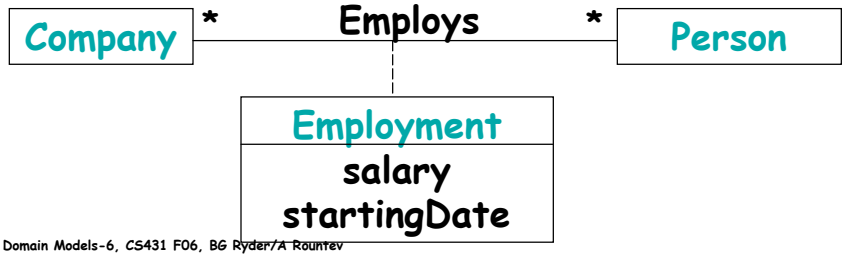
- An association class is a generalized form of an association
  - *Association:* set of pairs (o1,o2) $\in$ S1 $\times$ S2
  - *Association class:* set of pairs (o1,o2) $\in$ S1 $\times$ S2, where each pair has some attached info (attributes)
- The attributes of a pair may change with time (e.g., the merchant ID may change)
- Association classes may be associated with other classes (e.g., ternary relation)

When to Use Association Classes?

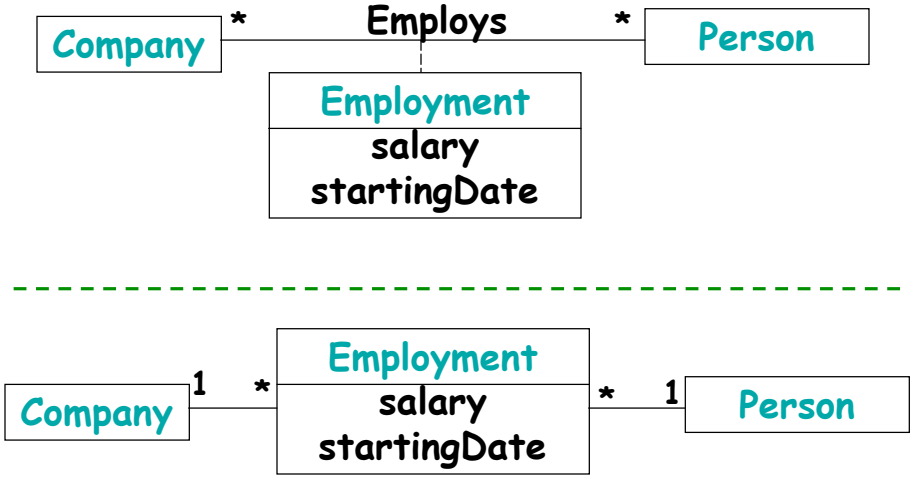
- When an attribute "doesn't fit" in the classes participating in an association
- When the lifetime of the attribute depends on the lifetime of the association
- Often used with many-to-many associations

Many-to-Many Association

- A company may employ several persons
- A person may be employed by several companies
  - Many people work two or even three jobs
- Attributes: salary, starting date, …



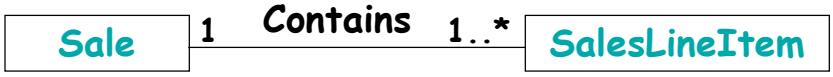
What is the Difference?



Associations and Their Implementation

- In the domain model: an association is conceptual and does not imply that a particular implementation will be used
  - Some domain-level associations may never be implemented
- In design and coding: there are standard mechanisms to implement the associations

Implementation Examples




```
class Sale {
   // set of references
   // to S.L.I. objects
   private Set items;
}
class SalesLineItem {
}
```

```
class Sale {
}
class SalesLineItem {
   private Sale encl_sale;
}
```

Could even be bi-directional: fields in both classes

Domain Model vs. Implementation

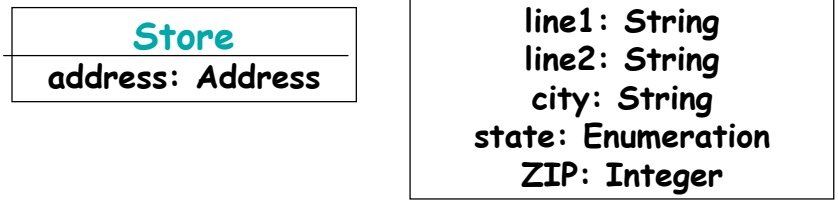
- Key principle: in the domain model, complex concepts should be related through associations, not through attributes
- In design/code, the implementation of the association may be through attributes of software classes
  - e.g. class Flight may have a field (attribute) that refers to an instance of Airport
  - But other implementations are also possible

Common Types of Attributes

- Primitive types: Number, String, Boolean
- Other simple types: Date, Time, Name, Address, Color, Phone Number, SSN, UPC (universal product code = barcode), ZIP, enumeration types, …
- Some simple attribute types (e.g., SSN) may need to be represented as separate conceptual classes

When Attribute Types are Classes?

- The type has separate sections
  - e.g. address, phone number, name, item id



- The type has associated operations
  - e.g. parsing and validation for SSN

When Attribute Types are Classes?

- Quantity with a unit
  - Most quantities have units neede for conversions: price, velocity, weight, etc.
  - Represent different quantities as separate conceptual classes: Money, Weight, etc.

Payment
amount:Number

Not useful

Payment
amount:Money

Better

"Process Sale" Use Case

Store
address:Address name:String

Sales LineItem
quantity:Integer

Payment
amount:Money

Sale
date:Date time:Time

Product Specification
descr:String price:Money id:ItemID

- Store name/address: for receipt
- item ID in Product Spec: for lookups
- Description/price in ProductSpec: for amount due and for display/receipt

Summary

- Conceptual classes
  - Special case: specification classes
- Attributes
  - Should be simple
- Associations: relationships that are relevant for the use cases
  - Multiplicity at a particular moment
  - Association classes