Steps in Using COMET/UML

1 Develop Software Requirements Model
   - Develop Use Case Model (Chapter 6)
2 Develop Software Analysis Model
   - Develop static model of problem domain (Chapter 7)
   - Structure system into objects (Chapter 8)
   - Develop statecharts for state dependent objects (Chapter 10)
   - Develop object interaction diagrams for each use case (Chapter 9, 11)
3 Develop Software Design Model
Static Modeling

Section 4

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Static Modeling

- Originated with Rumbaugh Object Modeling Technique (OMT)
- Represents static structure of system
- Based on information (Entity-Relationship) modeling
- Static Modeling
  - In OO Analysis Modeling
    - Define classes in system
    - Defines attributes of classes
    - Defines relationships between classes
  - In OO Design Modeling
    - Defines operations of each class
Design Concepts
Objects and Classes

- Objects represent “things” in real world
  - Provide understanding of real world
  - Form basis for a computer solution
- An Object (object instance) is a single “thing”
  - E.g., an account, an employee
- A Class (object class) is a collection of objects with the same characteristics
  - E.g., account, employee
- Attribute
  - Data value held by object in class
  - E.g., account number, balance

Figure 2.2 UML notation for objects & classes

```
Class
attributes

Class
attributes
operations

Class
Class with attributes
Class with attributes and operations

anObject
anotherObject
:Class

Objects
```
**Figure 4.1** Example of classes and objects

Class

- Customer
- Account

Objects

- aCustomer: Customer
- anotherCustomer: Customer
- anAccount
- anotherAccount: Account

**Figure 4.2** Example of class with attributes

Class with attributes

<table>
<thead>
<tr>
<th>Account</th>
</tr>
</thead>
<tbody>
<tr>
<td>accountNumber: Integer</td>
</tr>
<tr>
<td>balance: Real</td>
</tr>
</tbody>
</table>

Objects with values

<table>
<thead>
<tr>
<th>anAccount: Account</th>
</tr>
</thead>
<tbody>
<tr>
<td>accountNumber = 1234</td>
</tr>
<tr>
<td>balance = 525.36</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>anotherAccount: Account</th>
</tr>
</thead>
<tbody>
<tr>
<td>accountNumber = 5678</td>
</tr>
<tr>
<td>balance = 1,897.44</td>
</tr>
</tbody>
</table>
Static Modeling

- Define structural relationships between classes
  - Depict classes and their relationships on class diagrams

- Relationships between classes
  - Associations
  - Composition / Aggregation
  - Generalization / Specialization

- Static Modeling during Analysis

- System Context Class Diagram
  - Depict external classes and system boundary

- Static Modeling of Entity classes
  - Persistent classes that store data

Figure 2.3 UML notation for relationship on class diagram

ClassA
  \[1 \text{ Association} \rightarrow \star \text{ ClassB} \]
  Association
  \[0..1 \text{ Association} \rightleftharpoons \text{ ClassC} \]

ClassWhole
  Superclass
  Subclass1
  SubclassA2
  Generalization/specialization

ClassWhole
  ClassWhole
  ClassWhole
  ClassPart1
  ClassPart2
  ClassPart1
  ClassPart2
  Aggregation hierarchy
  Composition hierarchy
Associations

• Association is
  – static, structural relationship between classes
  – E.g, Employee works in Department
• Multiplicity of Associations
  – Specifies how many instances of one class may relate to a single instance of another class

Multiplicity of Associations

• 1-to-1 association
  – Company has President
• 1-to-many association
  – Bank manages Account
• Numerically specified association
  – Car has 2,4 Door
• Optional association (0 or 1)
  – Customer owns Debit Card
• Optional association (0, 1, or many)
  – Customer owns Credit Card
• Many-to-Many association
  – Course has Student
  – Student attends Course
Figure 7.1 Example of one-to-one association

Company

name: String
address: String
businessSector: String

1
Is led by
▼
1

CEO

name: String
employeeId: String
address: String
phoneNumber: Integer

▼ Direction of Association

Figure 7.2 Example of one-to-many association

Bank

bankName: String
bankAddress: String

1
Administers
▼
1..*

Account

accountNumber: Integer
balance: Real

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Figure 7.3 Numerically specified association

```
Car
modelName: String
manufacture: String
modelYear: Date

1
Is entered through
▼

2,4

Door
height: Real
width: Real
depth: Real
windowArea: Real
material: String
```

Figure 7.4 Optional (zero-or-one) association

```
Customer

1
▼ Owns

0..1

DebitCard

cardId: Integer
PIN: String
startDate: Date
expirationDate: Date
status: Integer
limit: Real
total: Real
```

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Figure 7.5 Optional (zero, one, or many) association

Customer

- customerName: String
- customerId: String
- customerAddress: String

1

\[\text{Owns} \quad \nabla \quad 0..*\]

CreditCard

- cardType: String
- cardId: Integer
- startDate: Date
- expirationDate: Date
- status: Integer

Figure 7.6 Many-to-many association

Course

- courseId: String
- courseName: String
- section#: Integer
- semester: String

* \[\text{Enrolls in} \quad \nabla \quad 1..*\]

Student

- studentName: String
- studentId: String
- studentAddress: String
- studentType: String
Association Class

- Class to model association between two or more classes
  - Usually for many-to-many associations
  - Attributes of Association Class
    - Attributes of association
  - E.g., Many-to-many association between
    - Project and Employee classes
      - Project has Employee
      - Employee works on project
    - Association Class - Hours
      - Attribute - Hours Worked

Figure 7.11 Example of association class
Composition/Aggregation Hierarchy

- Whole/Part Relationships
  - Show parts of more complex class
  - Composition is stronger relationship than aggregation
- IS PART OF Relationship
  - Between part classes and whole (composite or aggregate) class
- Composition is stronger relationship than aggregation

Composition Hierarchy

- Composition Hierarchy
  - Whole and part objects are created, live, die together
  - Often also has a physical association
  - Association between instances
- E.g., Composite class
  - ATM
  - Part classes
Composition/Aggregation Hierarchy

- Aggregation Hierarchy
  - Part objects of aggregate object may be created and deleted independently of aggregate object
  - E.g., Aggregate class
    - College
  - Part classes
    - Admin Office IS PART OF College
    - Department IS PART OF College
    - Research Center IS PART OF College
Generalization / Specialization Hierarchy

- Some classes are similar but not identical
  - Have some attributes in common, others different
- Common attributes abstracted into generalized class (superclass)
  - E.g., Account (Account number, Balance)
- Different attributes are properties of specialized class (subclass)
  - E.g., Savings Account (Interest)
- IS A relationship between subclass and superclass
  - Savings Account IS A Account
Static Modeling of Problem Domain

• During Analysis Modeling
  – Conceptual static model
  – Emphasizes real-world classes in the problem domain
  – Does not initially address software classes
  – Emphasis on
    • Physical classes
      – Have physical characteristics (can see, touch)
    • Entity classes
      – Data intensive classes
Figure 7.18 Conceptual static model for Banking System

Software System Context Class Diagram

- Defines boundary between system and external environment
  - May be depicted on Software System Context Class Diagram
- System
  - Depicted as one aggregate «software system» class
- External environment
  - External classes that software system interfaces to
- Categories of external classes
  - «external I/O device»
  - «external user»
  - «external system»
  - «external timer»
Associations on Software System Context Class Diagram

- Software System Context Class Diagram shows
  - Association between software system and external class
  - Multiplicity of association (1 to 1, 1..* to 1, etc.)
- Associations have standard names
  - «external input device» Inputs to «software system»
  - «software system» Outputs to «external output device»
  - «external user» Interacts with «software system»
  - «external system» Communicates with «software system»
  - «external timer» Signals «software system»
Static Modeling of Entity Classes

- Entity classes
  - Data intensive classes
  - Store long-living (persistent) data
  - Especially important for Information Systems
    - Many are database intensive
    - Also important for many real-time and distributed applications
- During analysis modeling
  - Model entity classes in the problem domain
  - Attributes
  - Relationships
Figure 21.4 Conceptual static model for Banking System - entity classes

![Diagram of Banking System - entity classes]

- **Bank**
  - bankName: String
  - bankAddress: String
- **Customer**
  - customerName: String
  - customerId: String
  - customerAddress: String
- **DebitCard**
  - cardId: String
  - PIN: String
  - startDate: Date
  - expirationDate: Date
  - status: Integer
  - limit: Real
  - total: Real
- **Account**
  - accountNumber: String
  - accountType: String
  - balance: Real
- **CheckingAccount**
  - lastDepositAmount: Real
- **SavingsAccount**
  - interest: Real

Figure 21.5 Conceptual static model for Banking System

![Diagram of Banking System - static model]

- **Bank**
  - Provides service for
- **Customer**
  - Owns
  - Administers
- **DebitCard**
  - Owns
  - Provides access to
- **CardAccount**
  - Provides service for
- **SavingsAccount**
  - Provides service for
- **CheckingAccount**
  - Provides service for
- **Withdrawal Transaction**
  - Modifies
- **Query Transaction**
  - Identifies
- **Transfer Transaction**
  - Identifies
- **PINValidation Transaction**
  - Identifies

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Figure 21.6 Conceptual static model for Banking System

- **ATMTransaction**
  - bankId: String
  - ATMId: String
  - date: Date
  - time: Time
  - transactionType: String
  - cardId: String
  - PIN: String
  - status: Integer

- **PINValidationTransaction**
  - startDate: Date
  - expirationDate: Date

- **WithdrawalTransaction**
  - accountNumber: String
  - amount: Real
  - balance: Real

- **QueryTransaction**
  - accountNumber: String
  - balance: Real
  - lastDepositAmount: Real

- **TransferTransaction**
  - fromAccountNumber: String
  - toAccountNumber: String
  - amount: Real

Figure 21.7 Conceptual static model for Banking System

- **CardAccount**
  - cardId: String
  - accountNumber: String
  - accountType: String

- **ATMInfo**
  - bankId: String
  - ATMId: String
  - ATMLocation: String
  - ATMAddress: String

- **ATMCash**
  - cashAvailable: Integer
  - fives: Integer
  - tens: Integer
  - twenties: Integer

- **ATMCard**
  - cardId: String
  - startDate: Date
  - expirationDate: Date
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