SWE 621:
Software Modeling and Architectural Design

Lecture Notes on Software Design

Lecture 13 - Relational Database Design

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Relational Database Design

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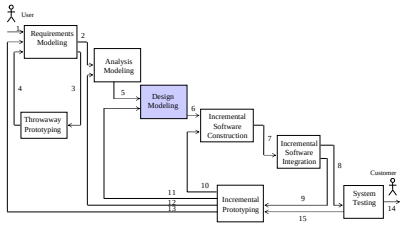
Reference: H. Gomaa, Chapters 15 - *Software Modeling and Design*, Cambridge University Press, February 2011

Steps in Using COMET/UML

1 Develop Software Requirements Model
2 Develop Software Analysis Model
3 **Develop Software Design Model**
- Design Overall Software Architecture (Chapter 12, 13)
- Design Distributed Component-based Subsystems (Chapter 12-13,15)
- Structure Subsystems into Concurrent Tasks (Chapter 18)
- Design Information Hiding Classes (Chapter 14)
- **Design relational database (Chapter 15)**

Figure 6.1 COMET object-oriented software life cycle model

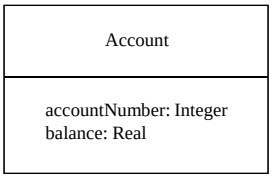


Relational Database Design

- Objective: Map static model to relational database
- Each entity class from static model that needs to be stored in relational database
  - Entity class maps to one (or more) relation(s) (table)
  - Attributes mapped to columns of table
  - Each object instance maps to a row of table
- Relational Database Design
  - Primary keys
  - Foreign keys for associations
  - Association classes
  - Aggregation/Composition Hierarchy
  - Generalization/Specialization hierarchy

Entity Classes and Relational Tables

Account entity class



Account relational table

Account Number	Balance
1234	398.07
5678	439.72
1287	851.65

Primary Keys

- Each relation must have a primary key
- Primary Key
  - Combination of one or more attributes
  - Uniquely locates a row in relation
    - E.g., Account Number is primary key of Account relation
    - Account (Account number, Balance)
      - (underline = primary key)

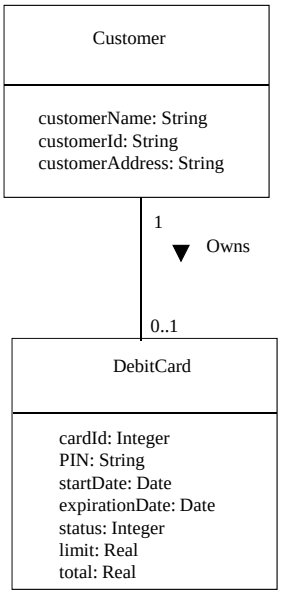
Relational Database Design
Foreign Keys

- Associations in relational databases
  - Many-to-many association in static model
    - Maps to a relation
  - One-to-one and one-to-many associations
    - Use Foreign keys
- Foreign key
  - Primary key of one table that is embedded in another table
  - Represents mapping of association between relations into a table
  - Allows navigation between tables

One-to-one or Zero-or-one Association

- One-to-one association maps to
  - Foreign key in one of relations
- Zero-or-one association maps to
  - Foreign key in optional relation
- E.g., Customer Owns Debit Card
- Static model (Figure 15.16)
  - Customer (Customer Name, Customer Id, Customer Address)
  - Debit Card (Card Id, PIN, Expiration date, Status, Limit, Total)

Figure 15.16 Optional (zero-or-one) association



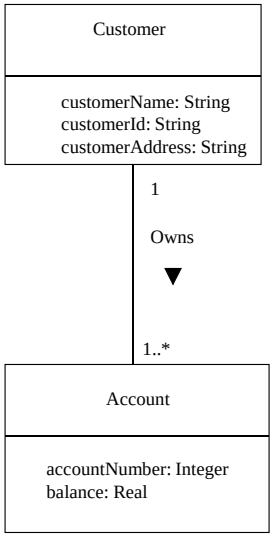
One-to-one or Zero-or-one Association

- Relational Database Design
  - Customer Id chosen as primary key of **Customer**
    - Customer (Customer Name, Customer Id, Customer Address)
  - Card id chosen as primary key of **Debit Card** relation
- *Customer Id* chosen as foreign key in **Debit Card**
- Represents association between **Customer** and **Debit Card** relations
    - Debit Card (Card Id, PIN, Expiration date, Status, *Customer Id*)
  - (underline = primary key, italic = *foreign key*)

One-to-Many Association

- One-to-many association maps to
  - Foreign key in “many” relation
  - E.g., Customer Owns Account
- Static Model (Figure 15.15)
  - Customer (Customer Name, Customer Id, Customer Address)
  - Account (Account number, Balance)
- Relational Database Design
  - Primary key of “one” relation (Customer) is chosen as foreign key in “many” relation (Account)

Figure 15.15 Example of one-to-many association



One-to-Many Association

- Relational Database Design
  - Customer Id is chosen as primary key of Customer relation
    - Customer (Customer Name, Customer Id, Customer Address)
  - Account Number is chosen as primary key of Account relation
  - *Customer Id* is foreign key in Account relation
    - Account (Account Number, Balance, *Customer Id*)

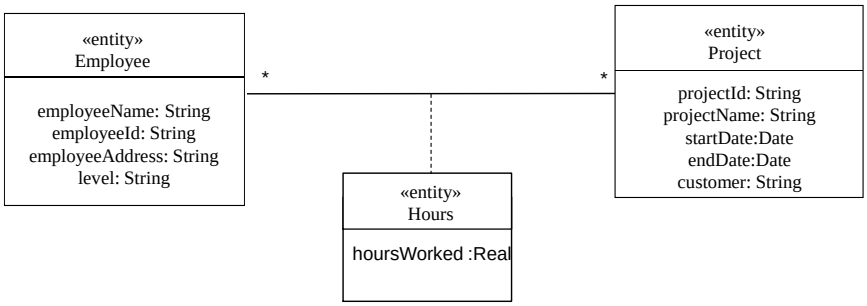
Static Model
Association Class

- Class models association between two or more classes
  - Usually for many-to-many associations
- Association class is mapped to associative relation
- Associative relation
  - Relation to represent association between two or more relations
  - Primary key of associative relation
    - Concatenated key
    - Formed from primary key of each relation that participates in association

Static Model
Association Class

- E.g., Hours association class
  - Represents association between Project and Employee classes
  - Mapped to Associative relation Hours
- Static Model (Figure 15.17)
  - Project (Project id, Project name)
  - Employee (Employee id, Employee name, Employee address)
  - Hours (Hours Worked)
    - Hours Worked is attribute of association

Figure 15.17 Example of association class



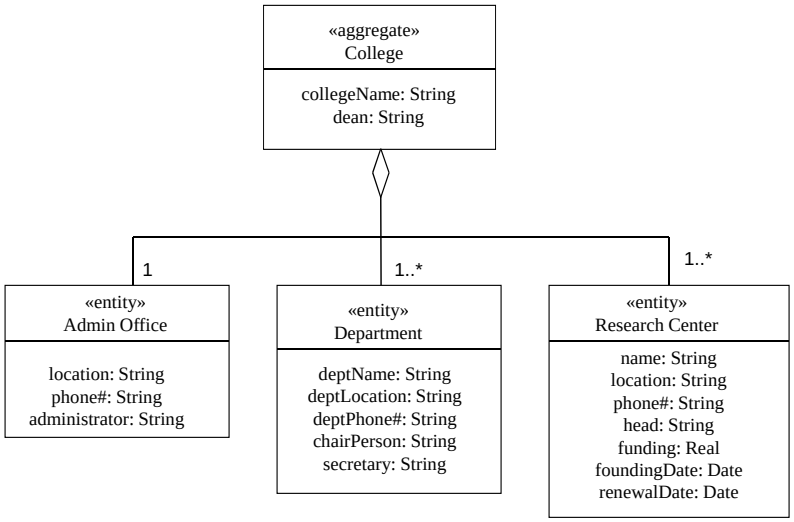
Relational Database Design
Associative Relation

- Relational Database Design
  - Project (Project id, Project name)
  - Employee (Employee id, Employee name, Employee address)
- Project id and Employee id
  - Form concatenated primary key of Hours relation
  - Also foreign keys
    - Hours (*Project id*, *Employee id*, Hours worked)

Static Model
Aggregation/Composition Hierarchy

- Whole/part relationship
  - Aggregate/Composite (whole) class is mapped to relation
  - Each part class is mapped to relation
  - Primary key of composite/aggregate relation
    - All of primary key of component relation
      - 1-1 aggregation
    - Part of primary key of component relation
      - 1-n aggregation
    - Foreign key
      - If not needed to uniquely identify component relation

Figure 15.18 Example of aggregation hierarchy



Relational Database Design Aggregation/Composition Hierarchy

- E.g., Static Model (Figure 15.18)
  - Department IS PART OF College
  - Admin Office IS PART OF College
  - College (College name)
  - Admin Office (Location)
  - Department (Department name, Location)
- Relational Database Design
  - Primary key of aggregate relation = College name
  - College (College name)
  - Admin Office (College name, Location)
  - Department (Department name, *College name*, Location)

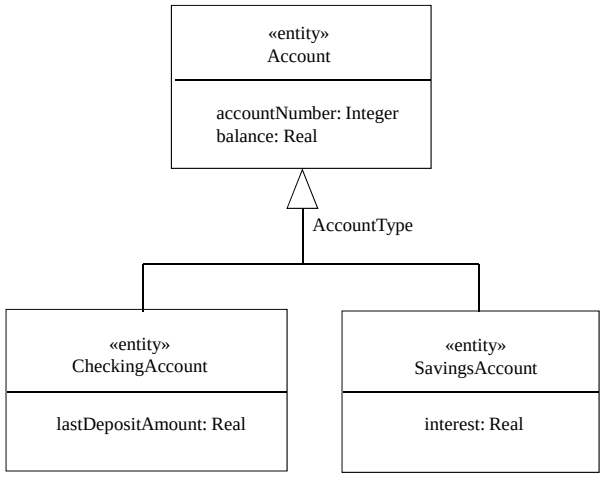
Static Model
Generalization / Specialization Hierarchy

- Three alternative mappings from Generalization / Specialization Hierarchy to relational database
  - Superclass & subclasses mapped to relations
  - Subclasses only mapped to relations
  - Superclass only mapped to relation

Relational Database Design
Generalization / Specialization Hierarchy

- Superclass & subclasses mapped to relations
  - Superclass mapped to table
    - Discriminator is attribute of superclass table
  - Each subclass mapped to table
  - Shared id for primary key
    - Same primary key in superclass and subclass tables
  - Clean and extensible
  - However, superclass / subclass navigation may be slow

Figure 15.19 Generalization / specialization



Relational Database Design
Generalization / Specialization Hierarchy

- Superclass & subclasses mapped to relations
- E.g.: Account Generalization / Specialization Hierarchy
- Static Model (Figure 15.19)
  - Superclass: Account (Account number, Balance)
  - Subclass: Checking Account (Last Deposit Amount)
  - Subclass: Savings Account (Interest)
- Relational Database Design
  - Account (Account number, Account Type, Balance)
  - Checking Account (Account Number, Last Deposit Amount)
  - Savings Account (Account Number, Interest)

Relational Database Design
Generalization / Specialization Hierarchy

- Subclasses only mapped to relations
  - Map each subclass to relation
  - No superclass relation
  - Superclass attributes replicated for each subclass table
- Can use if
  - Subclass has many attributes
  - Superclass has few attributes
  - Application knows what subclass to search

Relational Database Design
Generalization / Specialization Hierarchy

- Subclasses only mapped to relations
- Example of Account Generalization / Specialization Hierarchy
- Static Model (Figure 15.19)
  - Superclass: Account (Account number, Balance)
  - Subclass: Checking Account (Last Deposit Amount)
  - Subclass: Savings Account (Interest)
- Relational Database Design
  - Checking Account (Account Number, Balance, Last Deposit Amount)
  - Savings Account (Account Number, Balance, Interest)

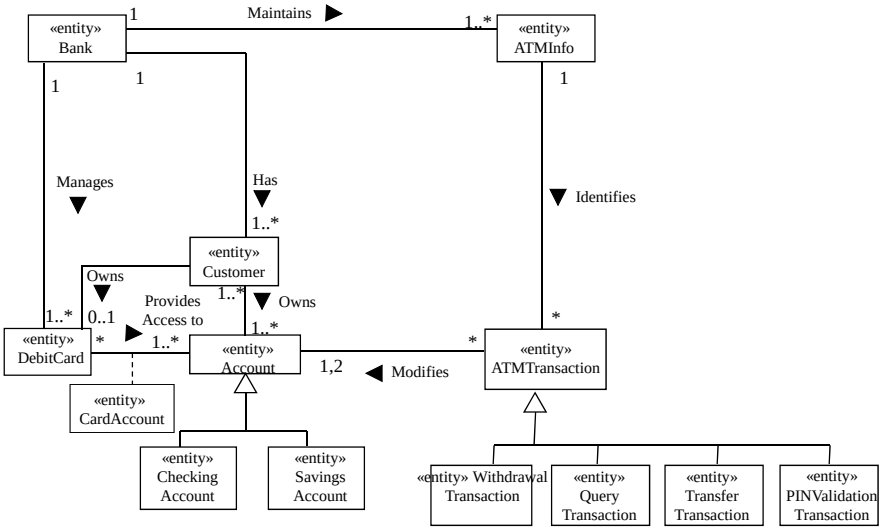
Relational Database Design
Generalization / Specialization Hierarchy

- Superclass only mapped to relation
- All subclass attributes brought up to superclass table
  - Discriminator is attribute of superclass table
  - Each record in superclass table uses attributes relevant to one subclass
  - Other attribute values are null
- Can use if
  - Superclass has many attributes
  - Subclass has few attributes
  - Only two or three subclasses

Relational Database Design
Generalization / Specialization Hierarchy

- Superclass only mapped to relation
- Example of Account Generalization / Specialization Hierarchy
- Static Model (Figure 15.19)
  - Superclass: Account (Account number, Balance)
  - Subclass: Checking Account (Last Deposit Amount)
  - Subclass: Savings Account (Interest)
- Relational Database Design
  - Account (Account Number, Account Type, Balance, Last Deposit Amount, Interest)

Figure 21.4 Conceptual static model for Banking System - entity classes



Example of Relational Database Design

- Banking System static mode (Figure 21.4)
- Bank Information (underline = primary key, italic = *foreign key*):

Bank (bankName, Bank Address, bankId)
ATM Info (*bankId*, ATMId, ATM Location, ATM Address)
Customer (customerName, customerId, customerAddress)
Debit Card (cardId, PIN, startDate, expirationDate, status, limit, total, *customerId*)
Checking Account (accountNumber, accountType, balance, lastDepositAmount)
Savings Account (accountNumber, accountType, balance, interest)
Card Account (*cardId*, *accountNumber*)
Customer Account (*customerId*, *accountNumber*)

Assumption: Account type is determined from account number

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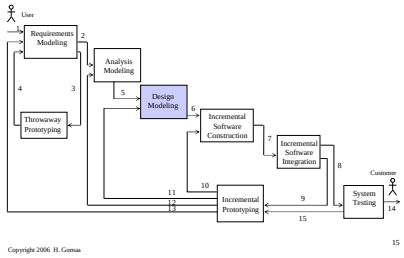

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