Lecture Plan

• Part 1
  • Operations on the object model:
    • Optimizations to address performance requirements
    • Implementation of class model components:
      • Realization of associations
      • Realization of operation contracts

• Part 2
  • Realizing entity objects based on selected storage strategy
  • Mapping the object model to a storage schema
  • Mapping class diagrams to tables
Problems with implementing an Object Design Model

• Programming languages do not support the concept of UML associations
  • The associations of the object model must be transformed into collections of object references

• Many programming languages do not support contracts (invariants, pre and post conditions)
  • Developers must therefore manually transform contract specification into source code for detecting and handling contract violations

• The client changes the requirements during object design
  • The developer must change the contracts in which the classes are involved

• All these object design activities cause problems, because they need to be done manually.
4 Different Types of Transformations

- **Model space**
  - System Model (in UML)
  - Model transformation
  - Another System Model

- **Source code space**
  - Program (in Java)
  - Refactoring
  - Another Program

- **Forward engineering**
- **Reverse engineering**
Model Transformation

• Takes as input a model conforming to a meta model (for example the MOF metamodel) and produces as output another model conforming to the metamodel

• Model transformations are used in MDA (Model Driven Architecture).
Model Transformation Example

Object design model before transformation:

<table>
<thead>
<tr>
<th>LeagueOwner</th>
<th>Advertiser</th>
<th>Player</th>
</tr>
</thead>
<tbody>
<tr>
<td>+email:Address</td>
<td>+email:Address</td>
<td>+email:Address</td>
</tr>
</tbody>
</table>

Object design model after transformation:

```
User
+email:Address
```

LeagueOwner

Advertiser

Player
Source code space

Forward engineering

Reverse engineering

Refactoring

Model space

Another System Model

Yet Another System Model

Model transformation

System Model (in UML)

Program (in Java)

Another Program

Yet Another System Model

Another System Model

Source code space
Refactoring: Pull Up Field

```java
public class Player {
    private String email;
    //...
}

public class LeagueOwner {
    private String eMail;
    //...
}

public class Advertiser {
    private String email_address;
    //...
}

public class User {
    private String email;
}

public class Player extends User {
    //...
}

public class LeagueOwner extends User {
    User {
        //...
    }
}

public class Advertiser extends User {
    User {
        //...
    }
}
```
Refactoring Example: Pull Up Constructor Body

```java
public class User {
    private String email;
}

public class Player extends User {
    public Player(String email) {
        this.email = email;
    }
}

public class LeagueOwner extends User {
    public LeagueOwner(String email) {
        this.email = email;
    }
}

public class Advertiser extends User {
    public Advertiser(String email) {
        this.email = email;
    }
}
```

```java
public class User {
    public User(String email) {
        this.email = email;
    }
}

public class Player extends User {
    public Player(String email) {
        super(email);
    }
}

public class LeagueOwner extends User {
    public LeagueOwner(String email) {
        super(email);
    }
}

public class Advertiser extends User {
    public Advertiser(String email) {
        super(email);
    }
}
```
4 Different Types of Transformations

Source code space

Model space

Forward engineering

Reverse engineering

Refactoring

Another System Model

Yet Another System Model

Model transformation

System Model (in UML)

Program (in Java)

Another Program

Another System Model

Yet Another System Model
Forward Engineering Example

Object design model before transformation:

<table>
<thead>
<tr>
<th>User</th>
<th>LeagueOwner</th>
</tr>
</thead>
<tbody>
<tr>
<td>-email:String</td>
<td>-maxNumLeagues:int</td>
</tr>
<tr>
<td>+getEmail():String</td>
<td>+getMaxNumLeagues():int</td>
</tr>
<tr>
<td>+setEmail(e:String)</td>
<td>+setMaxNumLeagues(n:int)</td>
</tr>
<tr>
<td>+notify(msg:String)</td>
<td></td>
</tr>
</tbody>
</table>

Source code after transformation:

```java
public class User {
    private String email;
    public String getEmail() {
        return email;
    }
    public void setEmail(String e) {
        email = e;
    }
    public void notify(String msg) {
        // ....
    }
}

public class LeagueOwner extends User {
    private int maxNumLeagues;
    public int getMaxNumLeagues() {
        return maxNumLeagues;
    }
    public void setMaxNumLeagues(int n) {
        maxNumLeagues = n;
    }
}
```
More Forward Engineering Examples

• Model Transformations
  • Goal: Optimizing the object design model
    Collapsing objects
    • Delaying expensive computations

• Forward Engineering
  • Goal: Implementing the object design model in a programming language
  • Mapping inheritance
  • Mapping associations
  • Mapping contracts to exceptions
  • Mapping object models to tables
Collapsing Objects

Object design model before transformation:

```
Person

SocialSecurity

number: String
```

Object design model after transformation:

```
Person

SSN: String
```

Turning an object into an attribute of another object is usually done, if the object does not have any interesting dynamic behavior (only get and set operations).
Examples of Model Transformations and Forward Engineering

• Model Transformations
  • Goal: Optimizing the object design model
    • Collapsing objects
    • Delaying expensive computations

• Forward Engineering
  • Goal: Implementing the object design model in a programming language
    Mapping inheritance
    • Mapping associations
    • Mapping contracts to exceptions
    • Mapping object models to tables
Forward Engineering: Mapping a UML Model into Source Code

• **Goal**: We have a UML-Model with inheritance. We want to translate it into source code

• **Question**: Which mechanisms in the programming language can be used?
  • Let’s focus on Java

• Java provides the following mechanisms:
  • Overwriting of methods (default in Java)
  • Final classes
  • Final methods
  • Abstract methods
  • Abstract classes
  • Interfaces.
Realizing Inheritance in Java

- **Realisation of specialization and generalization**
  - Definition of subclasses
  - Java keyword: `extends`
- **Realisation of simple inheritance**
  - Overwriting of methods is not allowed
  - Java keyword: `final`
- **Realisation of implementation inheritance**
  - Overwriting of methods
  - No keyword necessary:
    - Overwriting of methods is default in Java
- **Realisation of specification inheritance**
  - Specification of an interface
  - Java keywords: `abstract`, `interface`. 
Examples of Model Transformations and Forward Engineering

• Model Transformations
  • Goal: Optimizing the object design model
    ✓ Collapsing objects
    ✓ Delaying expensive computations

• Forward Engineering
  • Goal: Implementing the object design model in a programming language
    ✓ Mapping inheritance
    ➡ Mapping associations
    • Mapping contracts to exceptions
    • Mapping object models to tables
Mapping Associations

1. Unidirectional one-to-one association
2. Bidirectional one-to-one association
3. Bidirectional one-to-many association
4. Bidirectional many-to-many association
5. Bidirectional qualified association.
Unidirectional one-to-one association

Object design model before transformation:

```
Advertiser -> 1 -> Account
```

Source code after transformation:

```java
public class Advertiser {
    private Account account;
    public Advertiser() {
        account = new Account();
    }
}
```
Bidirectional one-to-one association

Object design model before transformation:

<table>
<thead>
<tr>
<th>Advertiser</th>
<th>1</th>
<th>1</th>
<th>Account</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ getAccount(): Account</td>
<td></td>
<td>+ getOwner(): Advertiser</td>
<td></td>
</tr>
</tbody>
</table>

Source code after transformation:

```java
public class Advertiser {
    /* account is initialized * in the constructor and never * modified. */
    private Account account;
    public Advertiser() {
        account = new Account(this);
    }
    public Account getAccount() {
        return account;
    }
}
```

```java
public class Account {
    /* owner is initialized * in the constructor and * never modified. */
    private Advertiser owner;
    public Account(owner: Advertiser) {
        this.owner = owner;
    }
    public Advertiser getOwner() {
        return owner;
    }
}
```
Bidirectional one-to-many association

Object design model before transformation:

<table>
<thead>
<tr>
<th>Advertiser</th>
<th>1</th>
<th>Account</th>
</tr>
</thead>
</table>
| + addAccount (a: Account)  
+ removeAccount (a: Account) | | + setOwner (Advertiser: NewOwner) |

Source code after transformation:

```java
public class Advertiser {
    private Set accounts;
    public Advertiser() {
        accounts = new HashSet();
    }
    public void addAccount(Account a) {
        accounts.add(a);
        a.setOwner(this);
    }
    public void removeAccount(Account a) {
        accounts.remove(a);
        a.setOwner(null);
    }
}

public class Account {
    private Advertiser owner;
    public void setOwner(Advertiser newOwner) {
        Advertiser old = owner;
        owner = newOwner;
        if (newOwner != null) {
            newOwner.addAccount(this);
        }
        if (oldOwner != null) {
            oldOwner.removeAccount(this);
        }
    }
}
```
Bidirectional many-to-many association

Object design model before transformation

<table>
<thead>
<tr>
<th>Tournament</th>
<th>* {ordered}</th>
<th>Player</th>
</tr>
</thead>
<tbody>
<tr>
<td>+ addPlayer(p: Player)</td>
<td></td>
<td>+ addTournament(t: Tournament)</td>
</tr>
</tbody>
</table>

Source code after transformation

```java
public class Tournament {
    private List players;
    public Tournament() {
        players = new ArrayList();
    }
    public void addPlayer(Player p) {
        if (!players.contains(p)) {
            players.add(p);
            p.addTournament(this);
        }
    }
}

public class Player {
    private List tournaments;
    public Player() {
        tournaments = new ArrayList();
    }
    public void addTournament(Tournament t) {
        if (!tournaments.contains(t)) {
            tournaments.add(t);
            t.addPlayer(this);
        }
    }
}
```
Examples of Model Transformations and Forward Engineering

• Model Transformations
  • Goal: Optimizing the object design model
    ✓ Collapsing objects
    ✓ Delaying expensive computations

• Forward Engineering
  • Goal: Implementing the object design model in a programming language
    ✓ Mapping inheritance
    ✓ Mapping associations

Next!  Mapping contracts to exceptions
• Mapping object models to tables
Implementing Contract Violations

• Many object-oriented languages do not have built-in support for contracts
• However, if they support exceptions, we can use their exception mechanisms for signaling and handling contract violations
• In Java we use the try-throw-catch mechanism
• Example:
  • Let us assume the acceptPlayer() operation of TournamentControl is invoked with a player who is already part of the Tournament
    • UML model
  • In this case acceptPlayer() in TournamentControl should throw an exception of type KnownPlayer
    • Java Source code.
The Try-throw-catch mechanism

- The first step in constructing an exception handler is to enclose the code that might throw an exception within a try block. In general, a try block looks like the following:

```java
try {
    code
} catch (ExceptionType name) {
    ...
} catch (ExceptionType name) {
    ...
}
```

From: Catching and Handling Exceptions
http://docs.oracle.com/javase/tutorial/essential/exceptions/handling.html
The Try-throw-catch mechanism/2

• Each catch block is an exception handler and handles the type of exception indicated by its argument.
  • The argument type, ExceptionType, declares the type of exception that the handler can handle and must be the name of a class that inherits from the `Throwable` class. The handler can refer to the exception with name.

```java
try {
    code
}
catch (ExceptionType name) {
    ...
}
catch (ExceptionType name) {
    ...
}
```
The Try-throw-catch mechanism/3

- The catch block contains code that is executed if and when the exception handler is invoked.

```java
try {
    code
}

catch (ExceptionType name) {
    ...
}

catch (ExceptionType name) {
    ...
}
```
The Try-throw-catch mechanism

- The following are examples of exception handlers
- The first handler, in addition to printing a message, throws a user-defined exception: SampleException(e).

```java
try {
    } catch (FileNotFoundException e) {
        System.err.println("FileNotFoundException: "+
                           e.getMessage());
        throw new SampleException(e);
    } catch (IOException e) {
        System.err.println("Caught IOException: " +
                           e.getMessage());
    }
```
The Try-throw-catch mechanism

• The **finally** block always executes when the try block exits. This ensures that the finally block is executed even if an unexpected exception occurs.

```java
try {
    } catch (FileNotFoundException e) {
        System.err.println("FileNotFoundException: " +
                           e.getMessage());
        throw new SampleException(e);
    } catch (IOException e) {
        System.err.println("Caught IOException: " +
                           e.getMessage());
    }
    finally {
        if (out != null) {
            System.out.println("Closing PrintWriter");
            out.close();
        } else {
            System.out.println("PrintWriter not open");
        }
    }
```
UML Model for Contract Violation Example

```
TournamentControl
+applyForTournament()
+selectSponsors(advertisers):List
+advertizeTournament()
+acceptPlayer(p)
+announceTournament()
+isPlayerOverbooked():boolean

Tournament
-players
+start:Date
+end:Date
+matches
+acceptPlayer(p)
+removePlayer(p)
+isPlayerAccepted(p)

Player
+matches

Match
+start:Date
+status:MatchStatus
+playMove(p,m)
+getScore():Map

TournamentForm
+applyForTournament()

Advertiser
+sponsors

matches
```

Bernd Bruegge & Allen H. Dutoit
Object-Oriented Software Engineering: Using UML, Patterns, and Java
30
public class TournamentForm {
    private TournamentControl control;
    private ArrayList players;
    public void processPlayerApplications() {
        for (Iteration i = players.iterator(); i.hasNext();)
            try {
                control.acceptPlayer((Player)i.next());
            } catch (KnownPlayerException e) {
                // If exception was caught, log it to console
                ErrorConsole.log(e.getMessage());
            }
    }
}
The try-throw-catch Mechanism in Java

```java
public class TournamentControl {
    private Tournament tournament;
    public void addPlayer(Player p) throws KnownPlayerException {
        if (!tournament.isPlayerAccepted(p)) {
            throw new KnownPlayerException(p);
        }
        //... Normal addPlayer behavior
    }
}

public class TournamentForm {
    private TournamentControl control;
    private ArrayList players;
    public void processPlayerApplications() {
        for (Iteration i = players.iterator(); i.hasNext();) {
            try {
                control.acceptPlayer((Player)i.next());
            } catch (KnownPlayerException e) {
                // If exception was caught, log it to console
                ErrorConsole.log(e.getMessage());
            }
        }
    }
}
```
Implementing a Contract

• **Check each precondition:**
  • Before the beginning of the method with a test to check the precondition for that method
  • Raise an exception if the precondition evaluates to false

• **Check each postcondition:**
  • At the end of the method write a test to check the postcondition
  • Raise an exception if the postcondition evaluates to false. If more than one postcondition is not satisfied, raise an exception only for the first violation.

• **Check each invariant:**
  • Check invariants at the same time when checking preconditions and when checking postconditions

• **Deal with inheritance:**
  • Add the checking code for preconditions and postconditions also into methods that can be called from the class.
Summary

• Strategy for implementing associations:
  • Be as uniform as possible
  • Individual decision for each association

• Example of uniform implementation
  • 1-to-1 association:
    • Role names are treated like attributes in the classes and translate to references
  • 1-to-many association:
    • "Ordered many" : Translate to Vector
    • "Unordered many" : Translate to Set
  • Qualified association:
    • Translate to Hash table
Additional Slides
A complete implementation of the Tournament.addPlayer() contract

```
Tournament
  -maxNumPlayers: int
  +getNumPlayers():int
  +getMaxNumPlayers():int
  +isPlayerAccepted(p:Player):boolean
  +addPlayer(p:Player)
```

«precondition»

!isPlayerAccepted(p)

«invariant»

getMaxNumPlayers() > 0

«precondition»

getNumPlayers() < getMaxNumPlayers()

«postcondition»

isPlayerAccepted(p)