Software Engineering
G22.2440-001

Session 7 – Sub-Topic 1
UML and the SDLC

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Bibliographie

- UML Distilled *Fowler&Scott*
- UML Toolkit *Eriksson&Penker*
- Applying UML and Patterns *Larman*
- Design pattern *GOF*
- System of patterns *Buschman&al*
- Penser objet avec UML&Java *Lai*
- Object oriented Analysis *Spadounakis*
- UML Specification *www.rational.com*
Introduction and Big Picture

- Requirements Analysis
  - Analysis
  - Design
  - Programming
  - Test

- UML: artifact production
- Relevant
- Coherent
- Understandable
- Easy to exchange
- Complete SDLC coverage

Why UML?

- Produce artifacts to communicate as a team
- Understand the « big picture »
- Keep learning about OO
Methodology War

- Booch, OMT, Coad/Yourdon, Fusion, SADT, OOSE, Schlaer/Mellor, HOOD…
- UML: a modeling meta-language to unify models used in various methodologies
- Grady Booch, Ivar Jacobson, James Rumbaugh.
- OMG standardization

Requirements Analysis

- Capture User Needs
- UML « Use-Case » Diagram
Analysis

• Implementation independent
• Identify classes and inter-relationships
• Describe collaboration between objects that are instances of the various classes
• Class, Collaboration, Activity, and State Diagrams

Design

• Takes computer architecture into account
• Relies on class techniques to manage GUIs, distribution, persistence, concurrency
• Class, Sequence, Component, Deployment, and State diagrams
Programming

• Convert design classes into target languages: Java, SQL, C++, IDL
• Convert persistent classes to match persistence models (DBMS, ODS, persistent languages, etc.)
• etc ...

Test

• Unit testing: class diagrams
• Integration testing: component and collaboration diagrams
• System test: use-case diagram(s)
First Example

- A die
- The player throws die 10 x 2
- When total is 7, player scores 10 points
- At the end of the game, the score is collected in a score map

Requirements Analysis

- First Use Case
- Identify Actors?
- Identify possible System use cases
- External functionality!
First Use Case

- **Play:**
  - Actor: Player
  - Descr: Player rolls the dices 10 times, whenever total is 7, +10pts

- **View High Score**
  - Actor: Player
  - Descr: Player looks up highest score in read-only mode

Use Case

- Very important diagram!
- A must for requirements analysis
- A must to present an application!
- MUST BE formally commented
- Used as a reference for all remaining modeling stages
Activity Diagram

- Looks awfully close to a flow diagram
- Identify activities based on a use case
- Identify transitions between activities
Activity Diagram

- Requirements analysis or analysis phase?
- More business process than object
- Provide message calling sequence and detail
  Use-cases
- Very useful for tests...

Analysis

- Model the real world
- Implementation independent
- Determine real world classes: first class diagram
- Model system’s dynamics: collaboration diagram
Collaboration Diagram

- Identify the Objects
- Identify relationships between Objects (objects graph)
- Identify messages and message calling sequence between objects

Collaboration Diagram

- Display the objects
- Display relationships between objects
- Display message calling sequence on individual objects
Collaboration Diagram

Class Diagram

- Identify classes
- Identify **static** and **dynamic** relationships between classes
- Identify relationships’ cardinality
- Identify class attributes
- Identify methods and their **parameters**
Sequence Diagram

- Dynamic modeling (~same as collaboration)
- Focuses on message sequencing
- Identify objects, their messages, and the message calling sequence
Sequence Diagram

The player is only created at the beginning of the game!
State Diagram

- Identify the states of an object
- Identify state transitions

State Diagram for a « game » object
Modify Schemas?

End of Analysis?

- Verify coverage for use-case and activity diagrams…
- Use case « view highscores »?
- Use case « play » partially handled
Diagram Coverage

Sequence Diagram
Sequence Diagram

Class Diagram
End of Analysis?

- Coverage is « pretty » good
- Consistency across schemas is correct
- 14/20
  - Dynamic model lacks detail (dynamic model for cancel?)
  - Schemas are not described in enough detail…
  - Sequence diagrams for the game are not detailed enough: a few methods are missing…

Design

- Take implementation into account
  - Handle the GUI portion
  - Handle highscores persistence
- Define a logical architecture
- Define a physical architecture
- Add technical classes allowing the implementation of such architecture!
Architecture Design

Layered Architecture...

- One possible architecture, others exist (seeo « A system of patterns » Bushmann »)
- Layers must be as independent as possible
- « Separate » layers by relying on interfaces + abstract classes (design patterns)
Logical « packaging »

- Map the architecture on « layered » packages
- Express dependencies

« core » Layer

- Classes representing the application logic
- In fact, these are the analysis classes which are being revisited for realization purpose
Core « Layer »: First Diagram

Design

Analyis

Graphical Interface Layering: MVC
Views?

Attention...
MVC in action: 1 Setup

MVC in action: 2 state change
MVC

- Java AWT Java: Delegation Model
  - Event propagation from user interface to core application classes
- MVC:
  - State change propagation to graphical objects

Put the views in the « forms »

- Implement graphical interfaces containing views as needed…
- The UI « layer » ...
UI « Layer »

UI Mapping Class, UI
UI/Core Separation...

```
Singleton...
```

```
HighScore
HighScore = new HighScore();
addObserver(Observer);
addObserver(Observer);
return component;
display();
```

```
Entry(name: String, score: int);
```

```
Entry.name: String = initval;
Entry.score: int = initval;
```

```
Player
name : String
score : int = 0;
```

```
Die
faceValue : int = 1;
roll();
display();
setValue();
```

```
DiceGame
getInstance();
start();
```

```
Displayable
```

```
<<Interface>>
```

```
UI/Core Separation...
```
Layered Architecture...

Technical classes
UI

UI

Interface and abstract classes handling decoupling

Core

Analysis classes

Util « subsystem »

- Need for random numbers
- Use java.util « random » functionality…
- The random number generator is shared by the die…
- Another singleton…
Subsystem « util »

Random

serialVersionUID : long = 3905348978240126619L
seed : long
multiplier : long = 0x5DEECE66DL
addend : long = 0xBL
mask : long = (1L << 48) - 1
BITS_PER_BYTE : int = 8
BYTES_PER_INT : int = 4
nextNextGaussian : double
haveNextNextGaussian : boolean = false

nextNextGaussian : double
nextDouble()
nextFloat()
nextBoolean()
nextInt(int)
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« Persist » Layer

- Technical classes used for persistence
- Ensures Core/Persist independence
  - Ability to switch « persistent engine »
- For example:
  - Persistence by « Serialization »
  - Persistence via a relational DBMS (JDBC)

Isolation : Pattern Fabrication

Abstract product

Concrete product

Concrete factory

Abstract factory
Using Serialization

• Persistence propagation...

```
> High Score
 e1 : Entry
  e2 : Entry
  e3 : Entry
  e4 : Entry
```
A little bit of code…that’s all folks

class HighScoreSr extends HighScore implements Serializable {

   public void save() throws Exception {
      FileOutputStream ostream = new FileOutputStream(filename);
      ObjectOutputStream p = new ObjectOutputStream(ostream);

      p.writeObject(this); // Write the tree to the stream.
      p.flush();
      ostream.close();    // close the file.
   }

   public void load() throws Exception {
      FileInputStream istream = new FileInputStream(filename);
      ObjectInputStream q = new ObjectInputStream(istream);

      HighScoreSr hsr = (HighScoreSr)q.readObject();
   }
}

JdbPersist... Dynamic Model

- A table must be created in a relational DBMS
- Upon creation of HighScoreJDBC: Connection to DBMS via JDBC
- **save:**
  - Perform « inserts » for each « entry »
- **load:**
  - Select * from ...
  - Follow the result,
  - create « entry » objects
public class HighScoreJDBC extends HighScore {
    public static final String url="jdbc:odbc:dice";
    Connection con=null;

    public HighScoreJDBC() {
        try {
            //loads the driver
            Class.forName("sun.jdbc.odbc.JdbcOdbcDriver");
            con=DriverManager.getConnection(url, 
            "molli","");
        } catch (Exception e) {
            e.printStackTrace();
            new Error("Cannot access Database at"+url);
        }
        hs=this; // register unique instance !
        this.load();
    }
}

public void load() {
    try {
        Statement select=con.createStatement();
        ResultSet result=select.executeQuery
        ("SELECT Name,Score FROM HighScore");
        while (result.next()) {
            this.add(new Entry(result.getString(1),
            result.getInt(2)));
        }
    } catch (Exception e) {
        e.printStackTrace();
    }
}
Jdbc Save

```java
public void save() {
    try {
        for (Enumeration e = this.elements();
             e.hasMoreElements() ;) {
            Entry entry=(Entry)e.nextElement();
            Statement s=con.createStatement();
            s.executeUpdate("INSERT INTO HighScore (Name,Score)"
                           +"VALUES('"+entry.getName()+"',"+
                           entry.getScore()+")");
        }
    } catch (Exception e) {
        e.printStackTrace();
    }
}
```

Component diagram...

- A component is a « non-trivial, nearly independent, and replaceable part of a system that fulfills a clear function in the context of a well-defined architecture »
- A component conforms to and provides the physical realization of a set of interfaces.
Component diagram

- « Realize » : implement interfaces
- « Depend » : Use interfaces
- Interfaces isolate components
Deployment Diagrams

- Display the physical architecture
- Associer execution units to associated handlers
- Identify connections between execution units
Design Complete?

- Functionality coverage: compare Use-case and activity diagrams...
- Consistency between diagrams??
  - Some inconsistencies… UI vs Core
  - Core/Persist independence partially modeled...

Generate code: code mapping

- Map into any programming language!
- OO languages: java, C++, smalltalk
- Or: VB, C, Fortran
- As well as: SQL, Cobol...
package Core;
import Util.Randomizer;
import UI.DieView;
import java.util.*;
import java.awt.Component;
public class Die extends Observable implements Displayable {
  private int faceValue = 1;
  public int roll() {
    setValue(Randomizer.getInstance().getValue());
    return getValue();
  }
  public Component display() {
    Component c = new DieView(this);
    addObserver((Observer)c);
    return c;
  }
  public void setValue(int value) {
    faceValue = value;
    setChanged();
    notifyObservers();
  }
  public int getValue() { return faceValue; }
}

package Core;
import java.util.*;
import java.awt.Component;
import UI.HighScoreView;
public abstract class HighScore extends Observable implements java.io.Serializable, Displayable {
  protected static HighScore hs = null;
  public Vector entries = new Vector();
  public void add(Entry entry) {
    entries.addElement(entry);
    setChanged();
    notifyObservers();
  }
  public Enumeration elements() {
    return entries.elements();
  }
  public abstract void load();
  public abstract void save();
  public Component display() { return entries.elements(); }
  public static HighScore getInstance() {
    if (hs == null) {
      new Error("No Persist Kit declared");
    }
    return hs;
  }
  public abstract void load();
  public abstract void save();
  public Component display() { return entries.elements(); }
  public static HighScore getInstance() {
    if (hs == null) {
      new Error("No Persist Kit declared");
    }
    return hs;
  }
}
Programming...

- Use « forward engineering » functionality provided by tools
- Then « reverse engineering »
- To achieve « round trip engineering » ;-D
- Ensure Programming/Design/Analysis consistency...

Forward engineering

```java
// Source file: c:/prout/Core/DiceGame.java
package Core;
public class DiceGame {
  private static int dg = null;
  private Die dies[];
  private Player thePlayer;
  DiceGame() {
  }
  /**
   * @roseuid 37F877B3027B
   */
  private DiceGame() {
  }
  /**
   * @roseuid 3802F61403A0
   */
  public void getInstance() {
  }
  /**
   * @roseuid 37F8781A014D
   */
  public void start() {
  }
  /**
   * @roseuid 38074E7F0158
   */
  public void quit() {
  }
}
```
package Core;
import UI.MainForm;
import Persist.*;
import java.awt.*
class Main {
    public static void main(String args[]) {
        // SrKit srk=new SrKit();
        JdbcKit srk=new JdbcKit();
        DiceGame dg=DiceGame.getInstance();
        Frame f=MainForm.getInstance();
        f.setSize(300,300);
        f.show();
    }
Reverse engineering

- Does not apply to the dynamic model!
- Handle forward+modification+reverse issues
- Nothing miraculous!
Problems Found

- Dynamic model to handle turns is not designed properly!
- Who really tests for the end of the game?
- Design flaw!

Here! Analysis Diagram!!
Problem!

- Not formal enough!
- This analysis diagram was not reviewed at design time!!!
- (-4)

Redo!
Finally!

Does it work? Testing

- Unit testing: test each class and each method at a time
  - Class diagram
- Integration tests:
  - Component diagram
- System test:
  - Use Case + Activity diagram
Ok, functionality is there ...  
And conforms to the description of the use case!  
>8->
System Test

- Test all possible paths!
- Ex:
  - 1/Start
  - 2/ roll
  - 3/ cancel
  - 4/ highscore
  - 5/ exit

Problems Found

- Scenario 1:
  - start, roll*, highscore, quit : OK
- Scenario 2:
  - highscore, : ko ! Bug
  - Design bug:
    - DiceGame creates Highscore (start)
    - If Highscore before start : bug
Solution

```java
package Core;

import UI.MainForm;
import Persist.*;
import java.awt.*;

class Main {
    public static void main(String args[]) {
        // SrKit srk=new SrKit();
        JdbcKit srk=new JdbcKit();
        DiceGame dg=DiceGame.getInstance();
        Frame f=MainForm.getInstance();
        f.setSize(300,300);
        f.show();
    }
}
```

Integration Test

![Diagram of the integration test with classes and their relationships]

MVC Test

![Diagram of the MVC test with classes and their relationships]
Test Scenario

- Highscore, start, roll*
- If the MVC works properly, entry of a new highscore leads to redisplaying the list which is already opened !!
- Ok, it works…
- It is good to design well ...

Summary of this Application Design

- Requirements Analysis
  – Use-case + description
  – Activity diagram
  – UI prototyping
- Analysis
  – Dynamic Model : Collaboration, Sequence, state diagrams
  – Static Model : Class Diagram
Design

- Architecture design (layer)
  - Package diagram, component diagram, deployment diagram
- Technical classes used to ensure isolation:
  - MVC pattern,
  - Factory pattern
- Technical classes UI and persistence
  - *Forms, Highscore*

Programming

- Simple conversion of design to Java
- For each UML model, it is possible to build a translation towards any target language
- Use « round-trip engineering » tools
- Programming PB: Need to update the analysis/design artifacts !!!
Feedback Problems Found at Coding!

- « auto-critique » to find the reason behind the problem.
- Improve process for next time!
- Here: analysis diagrams have not been redone!
- A software process must emphasize quality!

Testing

- Functionality control: Use-case diagram
- Conformance control: Activity diagram
- Integration tests: Component diagram
- Unit tests: not done
Paying Attention to Testing!

- Current vision is too simplistic!
- Must integrate testing as part of a quality management process (change management)
- Regression testing, automated testing (test suites, test generation, tools!!)

Conclusion for this Application

- Phase:
  - Requirements analysis, analysis, design, implementation, etc.
- For each phase:
  - Put together views for the same problem
  - Static, dynamic, functional, architectural views
Consistency/Coverage

- Use-cases/Activity Diagrams
  - An activity must always be assigned to a use-case
  - All use cases must be implemented in the activity diagrams
Use-case/Activity

Activity/Collaboration

- All possible paths in the activity diagrams may be represented using collaboration diagrams!
- Beware of over-analysis!
- Only represent the most relevant scenarios!
Collaboration/Class diagram

- All the objects in a collaboration diagram have a type: the class diagram Class
- All the relationships in a collaboration diagram must exist or may be derived from the class diagram!
- Messages exchanged are methods in the class diagram!
Collaboration/Class Diagram

Class diagram / collab / sequence

- The complete dynamic model for relations must appear in at least one sequence or activity diagram
- Any attribute change must be represented in at least one activity or sequence diagram
- Object creation or destruction must appear in at least one dynamic diagram!
Class/Sequence

KO!

Class/Sequence

• A « good » solution:
  – Follow the activity diagram to generate scenarios
  – Follow the possible paths in the activity diagram
  – If the activity diagram is not covered:
    • Granularity is not fine enough (it is the case here)
    • Class diagram over-specified
Class/State diagram...

- For each class, ask yourself if its state evolves with time?
- If so, put together a state diagram…
- Every transition in the state diagram must be verified!
Class/Packaage/Component diagram (Design)

- Each class must be allocated to one package, which is itself part of the overall architecture.
- Every class must also be part of a component that implements a set of functionalities in that architecture !!
- Otherwise the class is not part of the architecture !
Class/Component

Component/Deployment

- Each component must be allocated to one execution unit in the deployment diagram!
- In general, a component cannot be part of two execution units...
- Every execution unit must have at least one component...
Component Deployment!

General Conclusion on Dice

• How different is it from a « directly coded » application ??
Analysis and Design

• Dice is documented: decisions occuring during analysis and design are visible and justified!
  – Dice can be taken over by somebody else! Maintenance costs are reduced! Dice is maintainable!
  – Dice may also be controlled (integrated in a software process) throughout the requirements analysis/test process …

Analysis and Design

• Dice is conforming: I said what I was going to do (before I did it) and I have done what I said I would do!
  – I could also have produced time to delivery and costs…
Analysis and Design

• Dice is evolving
  – It is possible to change the user interface
  – Additional persistence support may be provided (OO Mapping, Web server backup…)
  – And I can come up with a process to handle this evolution!

Analysis and Design

• Dice is robust:
  – Test suites campaign
  – Natural justification for MVC…
• Dice is portable:
  – Java + JDBC… (but not tested !)
Analysis and Design

• Dice is therefore maintainable, conforming, robust, and portable…

• The cost of Dice is therefore less than that of the same application developed using a « Quick and Dirty » approach
  – Maintenance costs are much higher than development costs (50% of the overall programming effort of a large company)

---

Analysis and Design

• Typical System Development Costs:

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<th>System type</th>
<th>Phase Costs (%)</th>
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Working with Tools...

- Drawing diagrams: must follow diagrams semantics
- Tool is used as a point of reference: all the elements created in the diagrams are stored in a single database
- Navigation: can « browser » through UML documents

Working with Tools...

- Multi-users support: Several users are able to work in parallel on the same model (configuration management)
- Code generation: Skeletons may be generated for several target languages
Working with Tools...

• Reverse engineering: Read the existing code and generate or update existing diagrams
• Integration with other tools: Editor, compiler, debugger, configuration management tool

Working with Tools...

• Model coverage at all abstraction levels: from packages to code
• Import/export: The tool must allow design import/export from/to other design tools (i.e., XMI)
A Tool...

Working with Tools

• A point of reference for:
  – Consistency control
  – Critical analysis (metrics)
  – Reporting
• Basically, DBMS scripts...
Scripts...

Function GetSubclasses (theSuperClass As Class, AllClasses As ClassCollection) As CClass
Dim theSuperclasses As ClassCollection
Dim theSubclass As Class
Dim theSubClasses As New ClassCollection

'Print '"Checking subclasses for": theSuperClass.Name"
For i = 1 To AllClasses.Count
Set theSubclass = AllClasses.GetAt (i)
Print '"theSubclass": theSubclass.Name"
Set theSuperclasses = theSubclass.GetSuperclasses ()
For j = 1 to theSuperclasses.Count
Print '"has superclass": theSuperclasses.GetAt (j).Name"
Next j
If theSuperclasses.Exists (theSuperClass) Then
'Print '"Found one"
theSubClasses.Add theSubclass
End If
Next i
'Print '"Found ": theSubClasses.Count "classes"

Integration...

Modeling tool

Requirements and Specification tools
Profiler and metrics
Compiler/Debugger
Gui Builder
Test Administration Tool
Process Support
Testing tools
Configuration Management
Documentation Tool
Project Management Tool