2IS55 Software Evolution

Architecture Evolution

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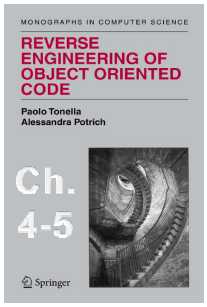
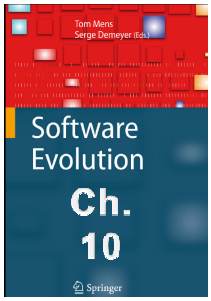
Where innovation starts

Assignment 3: Reminder

- Deadline: Next Monday, 23:59
- Individual or pair
- Questions?

Sources





Part 1: Where are we now?

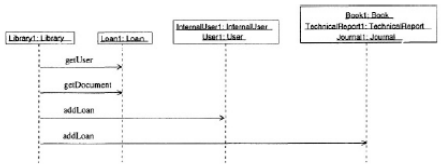
- Last week: architecture
  - Structure (class and package diagrams)
  - Where have we been in the table?
- This week: behaviour
  - Sequence diagrams
  - State diagrams (State machines)

Static vs. Dynamic Analysis

- Dynamic (execution)
  - \+ More precise
  - \- Requires the system to be executable
  - \- Limited to test-cases
- Static (no execution required)
  - \- Less precise (approximate but conservative)
  - \+ The system may be incomplete
  - \+ All possible executions can be considered

		Object of the analysis	
		Structure	Behaviour
Analysis technique	Static	Last week	Today
	Dynamic		

Static analysis of behavioural models



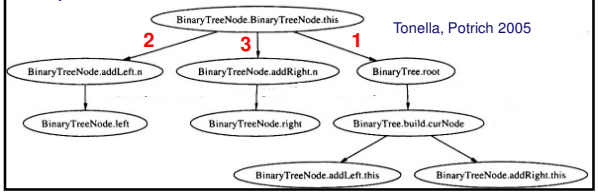
- Columns
  - Containers
  - Objects vs. classes
- Method invocations
  - Resolving the calls
  - Invocation order

Objects vs. Classes

```
class BT {
    BTNode root;
    public void build() {
 1  root = new BTNode();
    BTNode curNode = root;
    while(…) {
      …
      curNode.addLeft(new BTNode());   2
      …
      curNode.addRight(new BTNode());  3
    }
```

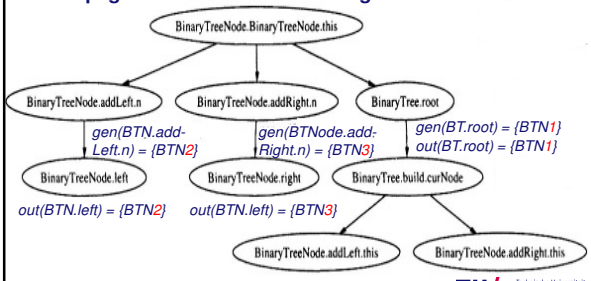
```
class BTNode {
    BTNode left, right;
    public void addLeft(BTNode n) {
        left = n;
    }
    public void addRight(BTNode n) {
        right = n;
    }
}
```

Tonella, Potrich 2005



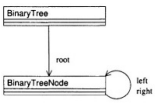
Solution

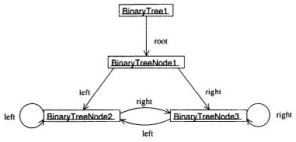
- **Generate**
  - **Increment the counter for every "new BTNode"**
- **Propagate this information through the OFG**



Objects vs. Classes

Tonella, Potrich 2005



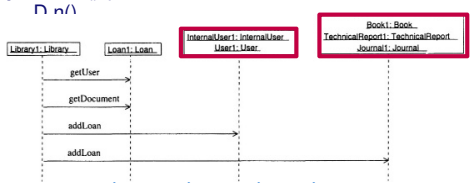


- **We can use the same technique for sequence diagrams!**

Next step: resolving method calls

```
class C {
    public m() {
      D n()
}
```

- **Intuitively, C.m() ⇒ D**



- **But**
  - **If**
  - **O**
- **NB: out are sets (polymorphism)**

Invocation order

- **Traditional approach**
  - **Follow the code**
  - **UML 1.x: SD represents one execution path**
    - **Decide arbitrarily on if/while choices**
  - **UML 2.x: SD contains alterations, options and loops**
    - **Follow the code**
- **Can you think on Java programs that cannot be analysed in this way?**
  - **Limitations of the approach**
    - **"Hidden" control flow rules: EJB interceptors**
  - **Limitations of the UML**
    - **Java/UML mismatches**

Interceptor

Logging, security, performance, …

```
public class importantClass {
    public String importantMethod() {
        …
    }
    …
}
```

Flexibility:

- **How?**
  - *XML file*
  - *Annotation*
- **At what level?**
  - *Bean class*
  - *Method*
- **Where?**
  - *Bean class*
  - *Superclass*
  - *Separate class*
  - *Injected bean*

Order of invocation

- **9 complex and interwined laws**
- **Spec is inconsistent with *GlassFish***

Code Example: Enterprise Java Bean

```
package ejb;
import ...

@Stateless
@Interceptors({Logger.class})
public class ProductFacade
extends EJBObject /* it may have an
interceptor */
implements ProductFacadeRemote {
  @PersistenceContext
  private EntityManager em;
    ...
  public Product find(Object id) {
    return em.find(Product.class, id);
  }

  @Interceptors({Profiler.class})
  public String productInfo(int id) {
    Product product = find(new Integer(id));
    if (product != null) {
      return " Description: "
        + product.getDescription();
    } else {
      return null;
    }
  }
  @AroundInvoke
  @Override
  protected Object logMethods(
    InvocationContext ctx)
     throws Exception {...}
}
```


Example (cont.): XML deployment descriptor

```
<assembly-descriptor>
<!-- Default interceptor -->
  <interceptor-binding>
    <ejb-name> * </ejb-name>
    <interceptor-class> interceptor.Login </interceptor-class>
  </interceptor-binding>
<!-- Method interceptor -->
  <interceptor-binding>
    <ejb-name> ProductFacade </ejb-name>
    <interceptor-class> interceptor.Auditor </interceptor-class>
   <exclude-class-interceptors> true
   </exclude-class-interceptors>
    <method>
      <method-name> productInfo </method-name>
    </method>
  </interceptor-binding>
</assembly-descriptor>
```


Reverse engineered sequence diagram

Sounds interesting?

Talk to me!

Opportunity for a Capita Selecta assignment.

Limitations of UML: Java/UML mismatches

- **Java semantics does not match UML semantics**
- **UML break**
  - **if the selected interaction occurs, the enclosing interaction is abandoned**
- **Java break**

```
for (j = 0; j < arrayOfInts.length; j++) {
  if (arrayOfInts[j] == searchfor) {
    foundIt = true;
    break;
  }
}
```

Rountev, Volgin, Reddoch
PASTE'05

Java/UML mismatches

- **Java semantics does not match UML semantics**
- **UML break**
  - **if the selected interaction occurs, the enclosing interaction is abandoned**
- **Java break**

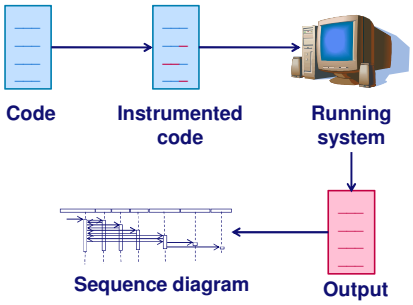
```
search:
  for (i = 0; i < arrayOfInts.length; i++) {
    for (j = 0; j < arrayOfInts[i].length; j++) {
      if (arrayOfInts[i][j] == searchfor) {
        foundIt = true;
        break search;
      }
    }
  }
```

Rountev, Volgin, Reddoch
PASTE'05

Static analysis so far…

- **Architecture reconstructor has to decide**
  - **Classes or objects**
- **Methods**
  - **Resolve the method calls**
  - **Invocation order**
    - **May be complex (interceptors)**

Dynamic analysis

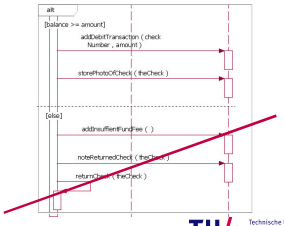


What would you like to instrument?

- Source code
  - Maximal precision
- Compiled code
  - Example:
    - gcc -c -pg myfile.c
    - gcc -pg collatz.o
  - Works for any source code
  - Information is lost
- Execution environment (e.g., Java VM)
  - Idem

How to instrument the code?

- Classes: augment with the object identifier
  - Java: hashCode, rmi.ObjID, etc…
- Add to the trace
<currObject,targetObject,methodName,timeStamp>
- Trace ifs and loops
  - We cannot see the "other way"
  - We can see the constructs



How to store the information?

- XML with special tags
  - MXML, Columbus CAN, …
- Compact Trace Format [Hamou-Lhadj, Lethbridge 2004]
  - Common subtrees are represented only once
    - Similar to Aterms library (ASF+SDF, mCRL2,…)
- XES [Günther 2009]
  - Used for process mining

The Size Explosion problem

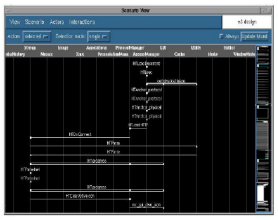
- One process in a printer component
  - 129 calls from the main function
  - 18 objects (1 per class) involved
  - Picture does not fit the slide
- Solutions
  - Smaller scale
    - "interesting" top-level functions
    - "interesting" calls in these functions
    - "interesting" target objects/classes
  - Different visualization

Require a priori knowledge

Better visualization (1)

Jerding, Stasko, Ball 1997

Message-flow diagram

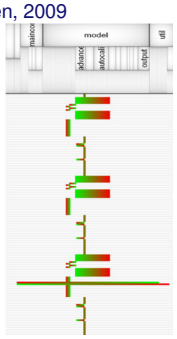


Information mural view: general overview in small

One can define interaction patterns and search for their appearances.

Better visualization (2)

Holten, 2009



Hierarchy of packages and classes

Arrow:
from green
to red

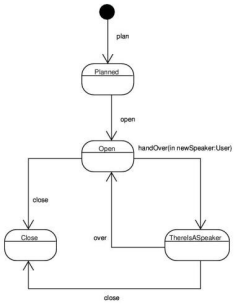
Repeated pattern and exceptional behaviour are clearly visible. Solves the blurring up problem by special visualization technique

Summary so far

- Static and dynamic approaches to sequence diagram reconstruction
  - Static:
    - Objects or classes
    - Resolve the method calls
    - Invocation order
  - Dynamic:
    - What should be instrumented?
    - How should it be instrumented?
    - How should the information be stored?
- Still: size explosion problem
  - Limitation vs. Visualization

State machines

- States and transitions
- Usually describe behaviour within one class
- Either
  - Explicit
    - Developers intentionally encode states and transitions
  - Implicit
- Also useful for model checking.



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Explicit State Machine Patterns

- Nested Choice Patterns
  - Switch/Case – Switch/Case
  - Switch/Case – If/Else
  - If/Else – Switch/Case
  - If/Else – If/Else

```
typedef struct {
  bool initialised;
  OBJ_STATE state;
} OBJ;
...
switch (obj->state) {
  case STATE_A:
    switch (event) {
      case EVENT1:
        obj->state = STATE_B;
        break;
      case EVENT2:
        obj->state = STATE_C;
        break;
    } break;
  case STATE_B:
    switch (event) {
      case EVENT1:
        obj->state = STATE_B;
        break;
      case EVENT2:
        obj->state = STATE_C;
        break;
    } break;
    ...
}
```


Explicit State Machine Patterns

- Nested Choice Patterns
- Jump Tables
  - State = a pointer to a function pointer array (jump table)
  - Transitions = function in the jump table

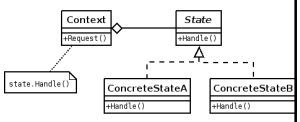
```
typedef int (*Handler)(char *);

/* The functions */
int func0 ( char *event) {
     int state;
     state = …
     return state;
}
…
Handler jt[4] =
    {func0,
     func1,
     func2,
     func3};
…
int main () {
   int state;

   while(true) {
       state = jt[state](event);
   }
}
```


Explicit State Machine Patterns

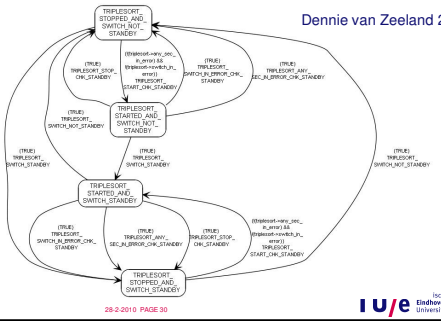
- Nested Choice Patterns
- Jump Tables
- Goto statements
  - States = program locations
  - Transitions = goto
- Long jumps
  - Setjmp: records the environment
  - Longjmp: restores the environment
- Object-oriented: State design pattern



Explicit State Machines: Architecture Reconstr.

- Recognize a pattern
- And create the state machine

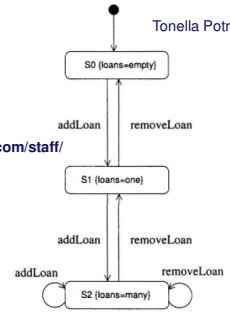
Dennie van Zeeland 2008



Implicit State Machines

- States determined by field values
- Transitions – modification of the field values by methods

Tonella Potrich



http://Tapulous.com/staff/

```
class Document {
   …
   Loan loan = null;

   public void addLoan(Loan ln) {
      loan = ln;
   }
   public void removeLoan() {
      loan = null;
   }
}
```


States

- "States determined by field values"
  - Which fields to chose?

```
class Document {
   int documentCode;
   String title;
   String authors;
   String ISBNCode;
   Loan loan = null;
   static int nextDocumentCodeAvailable = 0;
   …
}
```

Cannot be changed by the class methods (except for constructor)

Changes but class-level!

States

- "States determined by field values"
  - Which fields to chose?
  - Which values to chose?

`Loan loan`

Objects are pointers: many possible values and not all of them are meaningful

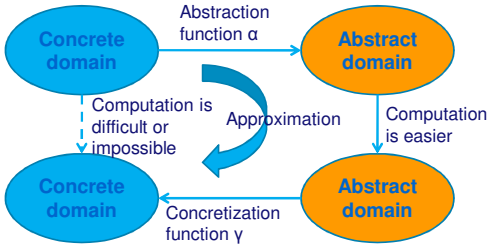
- Often groups (equivalence classes) are more meaningful than individual values:
  - "Pointer is null" vs. "pointer is not null"
  - "temperature is positive and precipitation < 250 mm per year"

Abstract interpretation (Cousot, Cousot)

- Abstract value – representation of group of concrete values
  - "positive" represents {x | x > 0}
  - "woman" represents {x | female(x) /\ adult(x)}
- Abstract domain – set of all possible abstract values
  - Complete semi-lattice
    - Partially ordered (≤)
    - For each two elements there exists a unique lub
- Abstraction – mapping from concrete to abstract val:
  - α(5) = positive

Abstract Interpretation

⟨A, α, C, γ⟩ should form a Galois connection

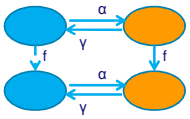


Abstract Interpretation: Example

- $2173 \times 38 = 81574$ or $2173 \times 38 = 82574$?
- Casting out nines:
  - Sum the digits in the multiplicand n_1, multiplier n_2 and the product n to obtain s_1, s_2 and s.
  - Divide s_1, s_2 and s by 9 to compute the remainder, that is, $r_1 = s_1 \bmod 9$, $r_2 = s_2 \bmod 9$ and $r = s \bmod 9$.
  - If $(r_1 \times r_2) \bmod 9 \neq r$ then multiplication is incorrect
- The algorithm returns "incorrect" or "don't know"
- What are the concrete/abstract domains? Abstraction/concretisation functions?

To ensure correctness of the abstraction

- $\langle A, \alpha, C, \gamma \rangle$ should be a Galois connection
  - $\langle A, \leq_A \rangle$ and $\langle C, \leq_C \rangle$ are complete semi-lattices
  - $\alpha: C \to A$ and $\gamma: A \to C$ are monotonic
  - $\gamma \circ \alpha: A \to A$ and $\alpha \circ \gamma: C \to C$ satisfy
    - $c \leq_C (\gamma \circ \alpha)(c)$ for all $c \in C$
    - $(\alpha \circ \gamma)(a) \leq_A a$ for all $a \in A$
- Galois connection guarantees
  - $(\alpha \circ f_C \circ \gamma)(a) = a$
  - $f_C(c) \leq_C (\gamma \circ f_A \circ \alpha)(c)$ (*)



State machines?

- Concrete domain:
  - values of the class fields
  - functions over the concrete domain:
    - methods
    - constructors must be applied first
- Abstract domain:
  - representation of the sets of the values of the class fields
  - which sets?
    - standard techniques (null/not-null, 0-1-many, pos-0-neg)
    - well-studied domains (intervals, octagons)
    - determined by comparisons in the code
  - functions over the abstract domain
    - define to satisfy (*)

State machines reconstruction

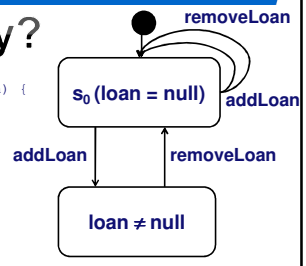
1. Initialization:
   - initStates = ∅
   - $s_0 = \alpha$(initialization values)
   - SM = {<•,'', s_0 >}
2. For every constructor cs:
   - $s = cs_A(s_0)$
   - initStates = initStates U {s}
   - SM = SM U {< s_0,cs,s>}
3. toGoStates = initStates
4. while not empty(toGoStates)
   - r = select(toGoStates)
   - toGoStates = toGoStates \ {r}
   - for each method m
     - $s = m_A(r)$
     - SM = SM U {<r,m,s>}
     - toGoStates = toGoStates U {s}

Example

```
class Document {
   …
   Loan loan = null;

   public void addLoan(Loan ln) {
      loan = ln;
   }
   public void removeLoan() {
      loan = null;
   }
}
```

Why?



Hidden assumptions:

- precondition addLoan: ln ≠ null
- precondition removeLoan: loan ≠ null

State machine reconstruction: Summary

- State machines
  - Popular for object behaviour specification
  - Can be used for model checking
- Explicit state machines
  - Designed by a developer
  - Patterns
- Implicit state machines
  - Abstract interpretation

Part 2: Architecture (last week)

- As intended
- As described
  - Architecture Description Languages
    - Should express different views
- As implemented
  - Code, deployment
  - From code to architecture: reverse engineering
    - Should extract different views

evolution

evolution

Current ADLs target

- Correctness: e.g., Wright [Allen 1997]

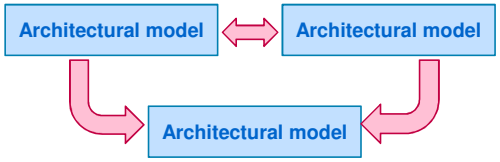
```
public component class Parser {
    public port in {
        provides void setInfo(Token symbol,
                              SymTabEntry e);
        requires Token nextToken()
        throws ScanException;
        }
    public port out {
        provides SymTabEntry getInfo(Token t);
        requires void compile(AST ast);
        }
…
```

- Sy
  - p)
  - …
    - components, ports, commections
    - enforces communication integrity

Major problems with current ADLs

- No support for evolution during the execution
  - Architecture can change during the execution:
    - client connects to a different server
  - Snapshots easily become obsolete
- No support for evolution due to change in requirements
  - Wright
    - model checking: no incremental approach
    - minor property/model modification ⇒ everything should be rechecked
  - ArchJava
    - no real separation of architecture/implementation
    - overtly complex code

First attempts at solutions: Extended Wright



- Event-driven reconfiguration
  - Component description should be adapted to describe when/which reconfigurations are permitted
  - Incomplete separation of the reconfiguration policies
- Can be used to model evolution, but
  - Finite number of models

Architecture Description Languages

- Minimal support for evolution
  - Only run-time
- Use of an ADL can even hinder evolution
- On-going research