2IS55 Software Evolution

Architecture Evolution

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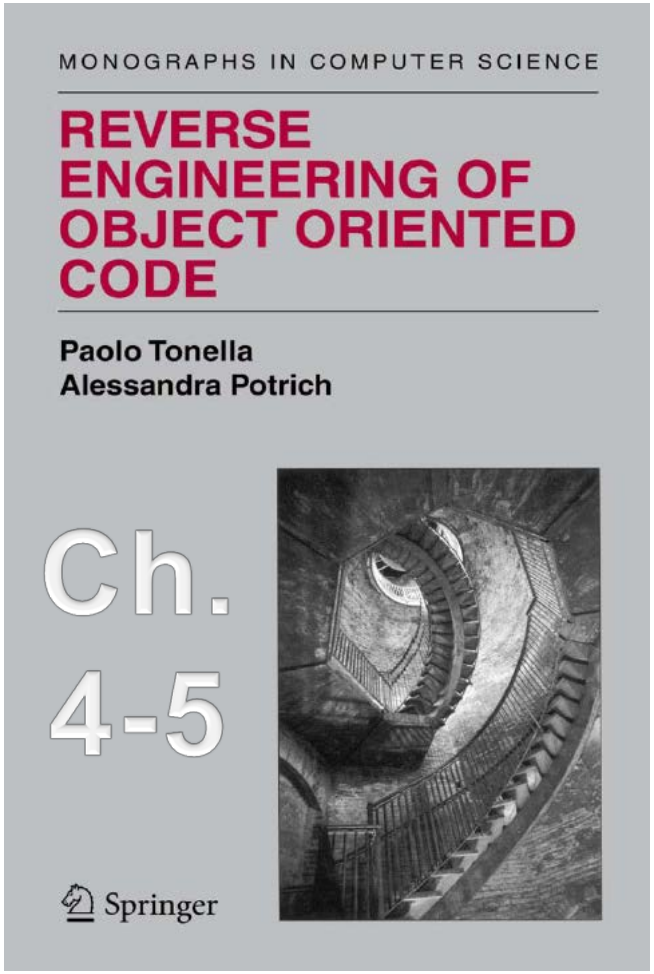
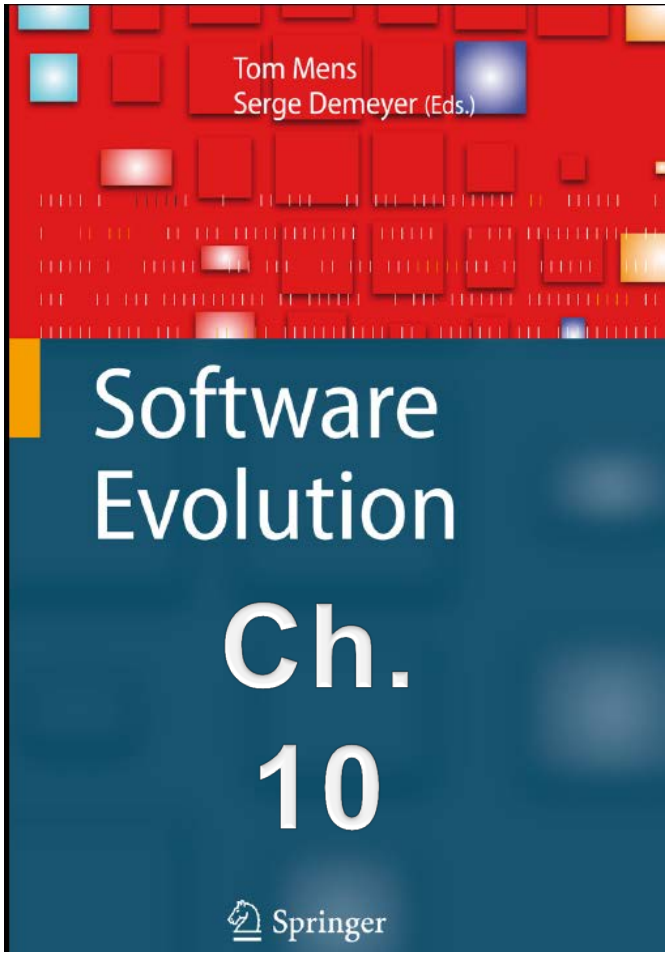
Where innovation starts

Assignments: Reminder

- **Assignment 2:**
  - **Architecture reconstruction**
  - **Deadline: March 27, 2012 23:59**
  - **Work in pairs**

Sources


MONOGRAPHS IN COMPUTER SCIENCE
REVERSE ENGINEERING OF OBJECT ORIENTED CODE
Paolo Tonella
Alessandra Potrich
Ch. 4-5
Springer


Tom Mens
Serge Demeyer (Eds.)
Software Evolution
Ch. 10
Springer

Part 1: Where are we now?

- **Last week: architecture**
  - **Structure (class and package diagrams)**

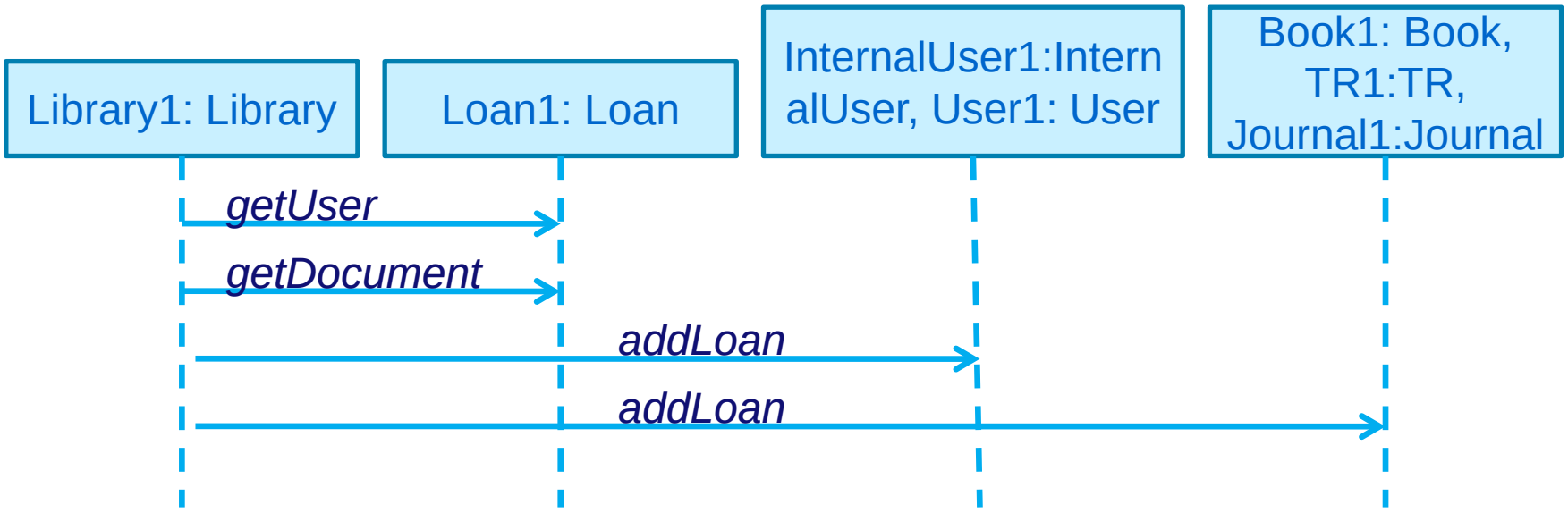
- **This week: behaviour**
  - **Sequence diagrams**
  - **State diagrams (State machines)**

Static vs. Dynamic Analysis

- **Dynamic (execution)**
  - + More precise: at run-time you know everything
  - - 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		

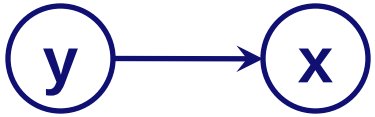
Static analysis of behavioural models



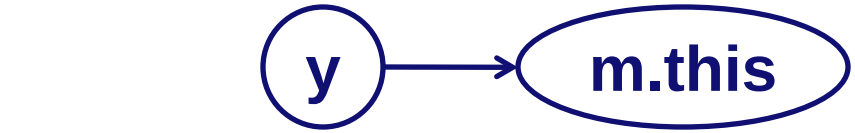
- **Columns**
  - **Containers**
  - **Objects vs. classes**
    - **Objects: more precise**
    - **Objects: Too many/too few?**
- **Method invocations**
  - **Resolving the calls**
  - **Invocation order**

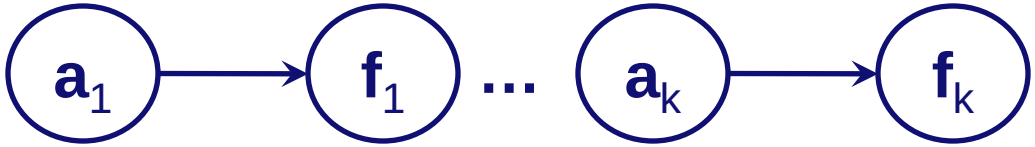
Recapitulation: Object Flow Graph

- Vertices: variables, fields, method parameters
- x = y

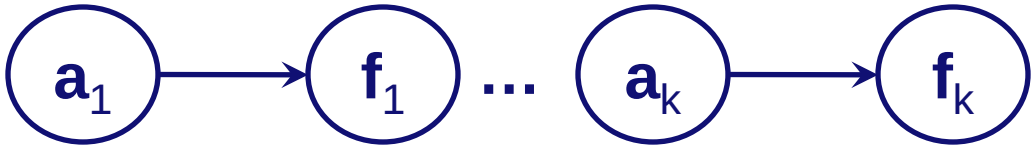


- x = y.m(a_1, …, a_k)
  - Method m(f_1, …, f_k)





- x = new c(a_1, …, a_k)
  - cs – constructor of c

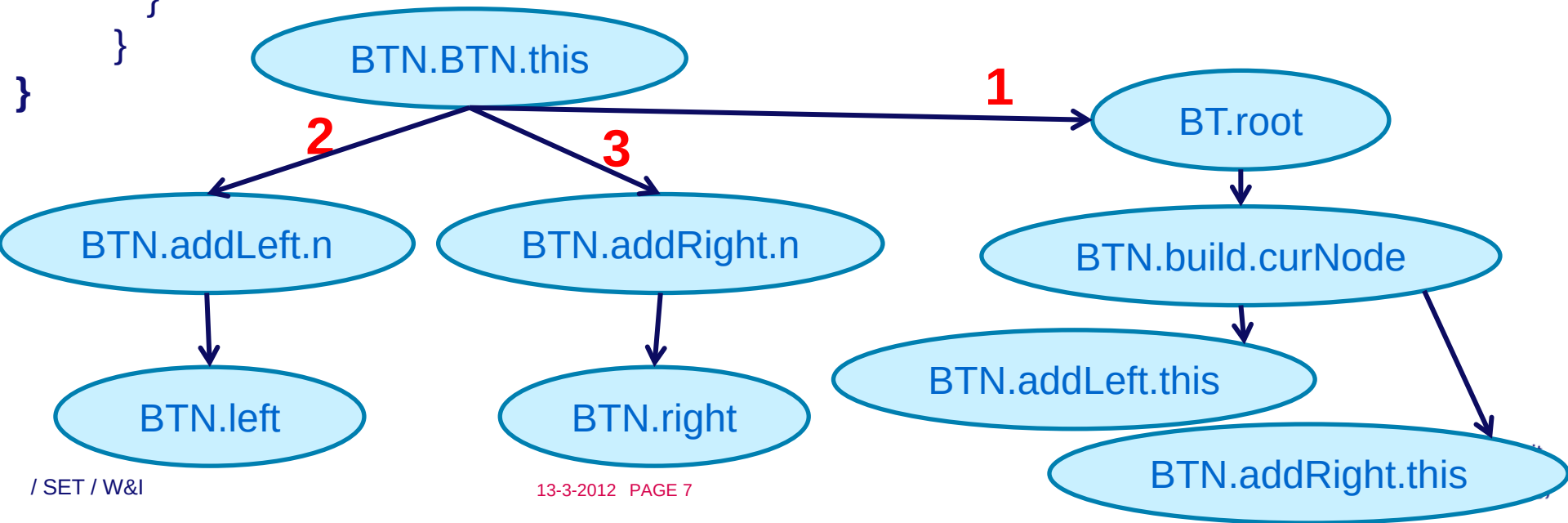


Objects vs. Classes

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

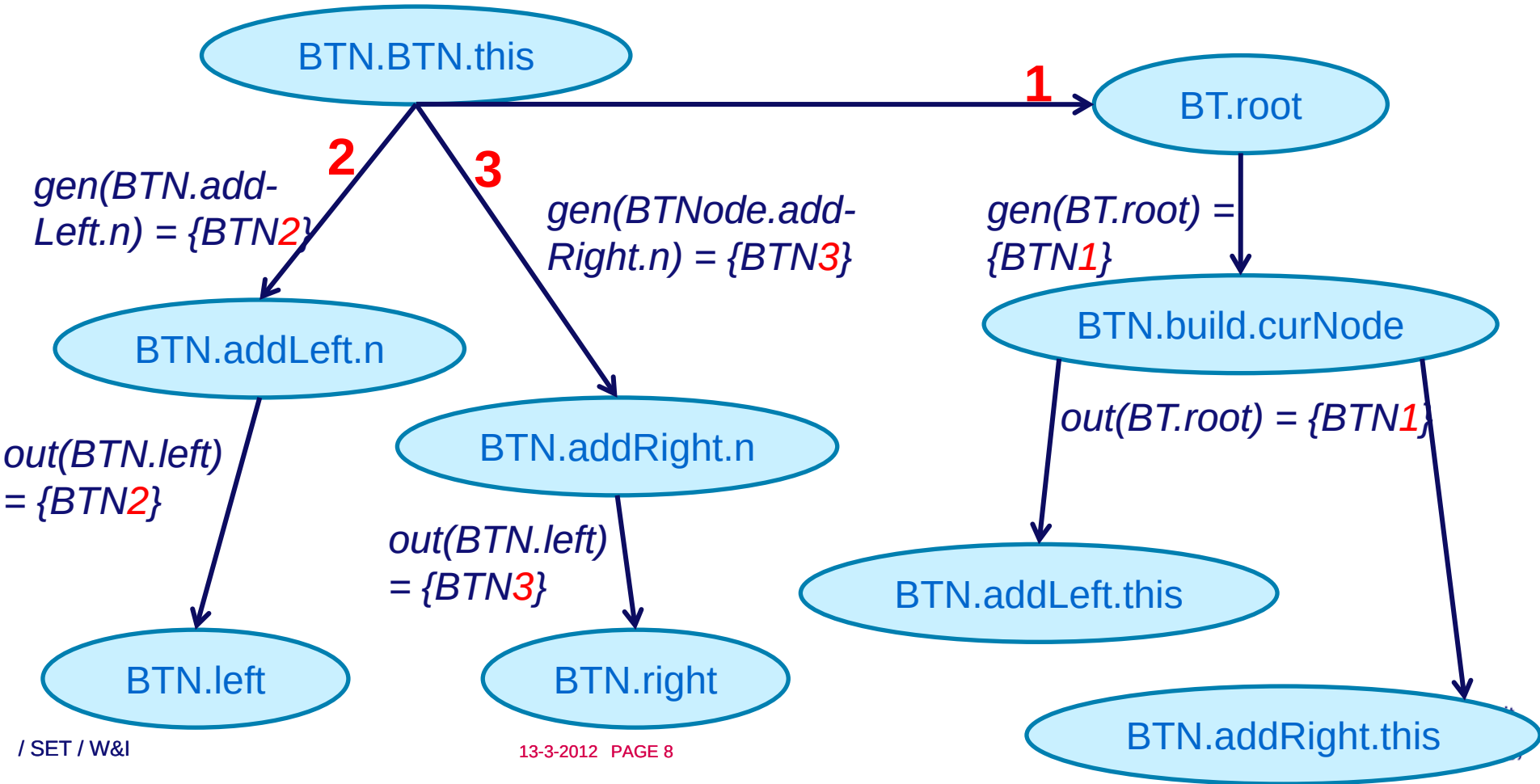
```
class BTNode {
    BTNode left, right;
    public void addLeft(BTNode n) {
        left = n;
    }
    public void addRight(BTNode n) {
        right = n;
    }
}
```

Tonella, Potrich 2005



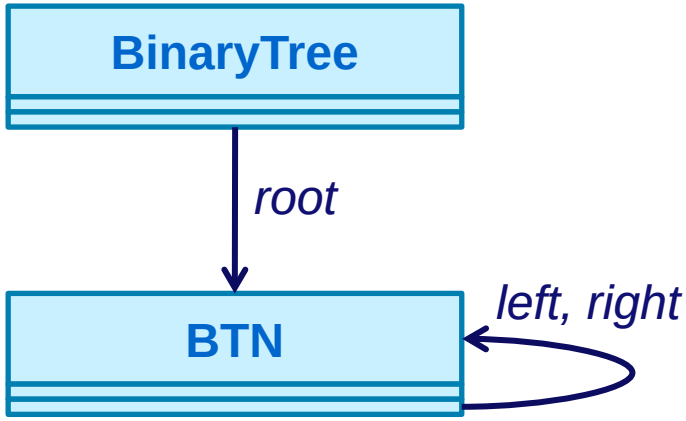
Solution

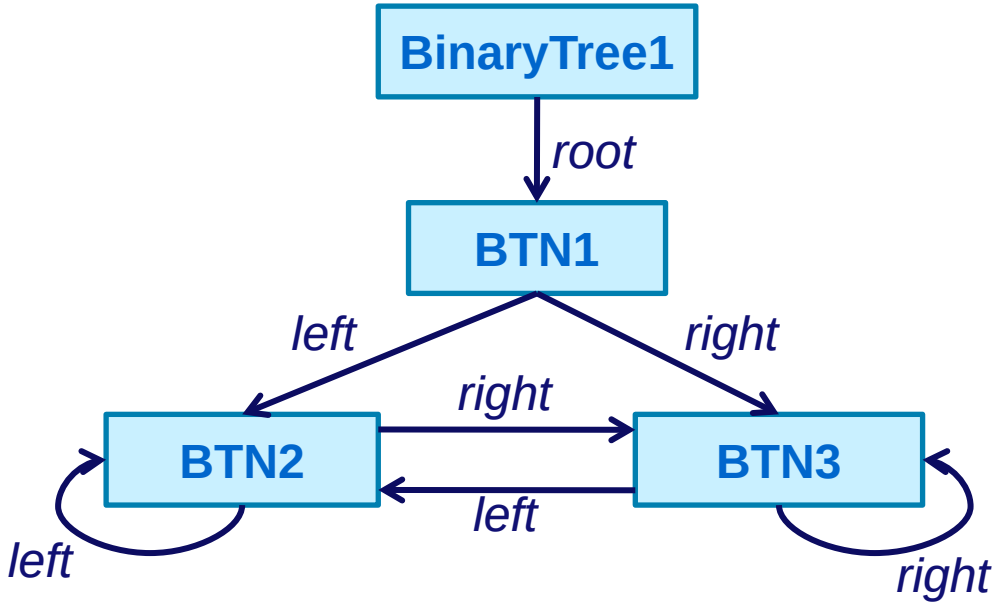
- **Generate**
  - **Increment the counter for every “new BTNode”**
- **Propagate this information through the OFG**



Objects vs. Classes

Tonella, Potrich 2005





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

Next step: resolving method calls

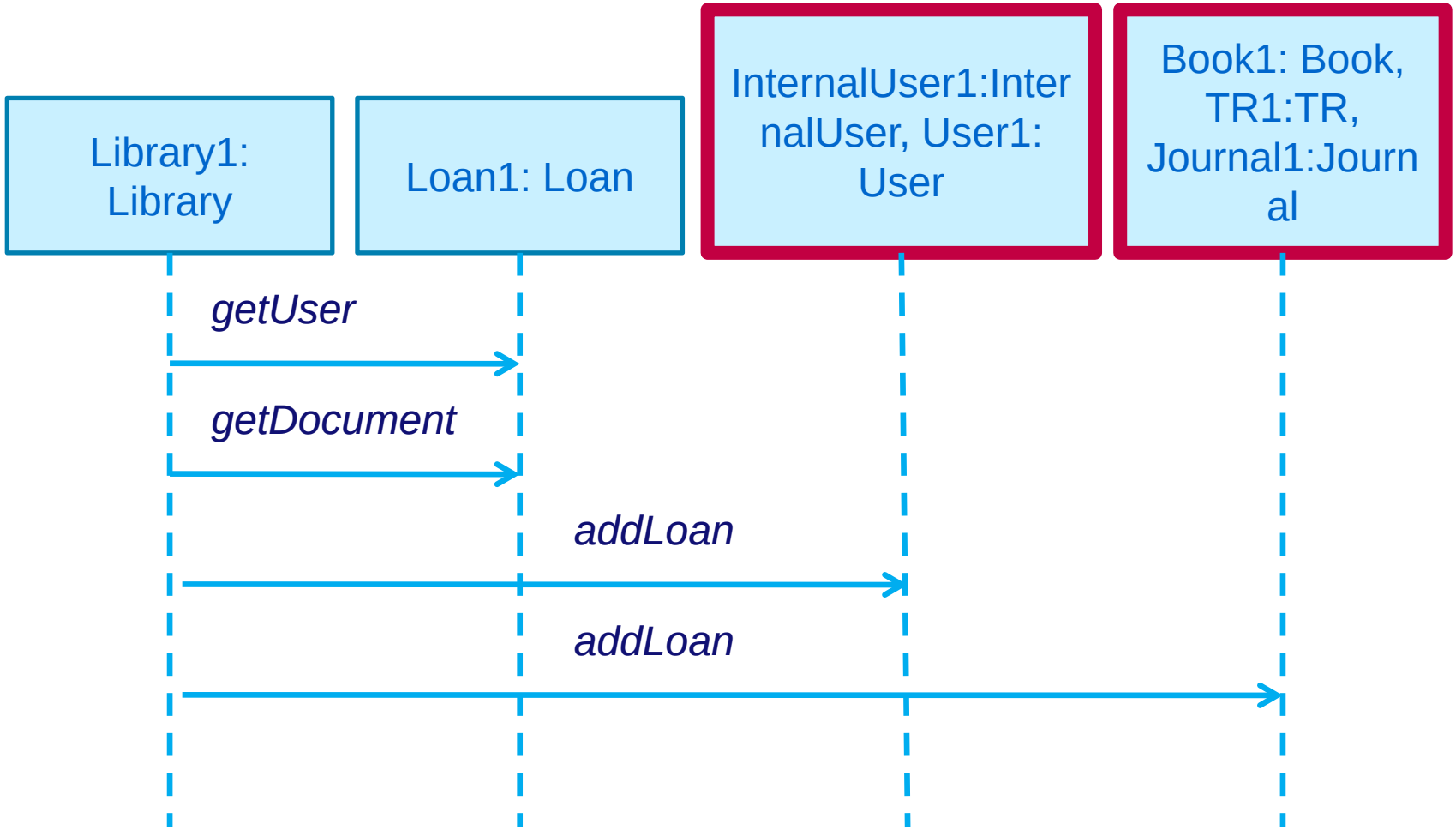
```
class C {
    public m() {
        D.n()
    }
}
```

- Intuitively, C.m() ⇒ D
- In the OFG notation:
  - If D is a field: C.m.this ⇒ C.D
  - Otherwise: C.m.this ⇒ C.m.D

- But these are classes, not objects! And containers…
  - If D is a field: out(C.m.this) ⇒ out(C.D)
  - Otherwise: out(C.m.this) ⇒ out(C.m.D)

- NB: out are sets (polymorphism)

Out is a set!


Library1: Library
Loan1: Loan
InternalUser1:InternalUser, User1: User
Book1: Book, TR1:TR, Journal1:Journal
getUser
getDocument
addLoan
addLoan

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

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;
        }
     }
  }
```

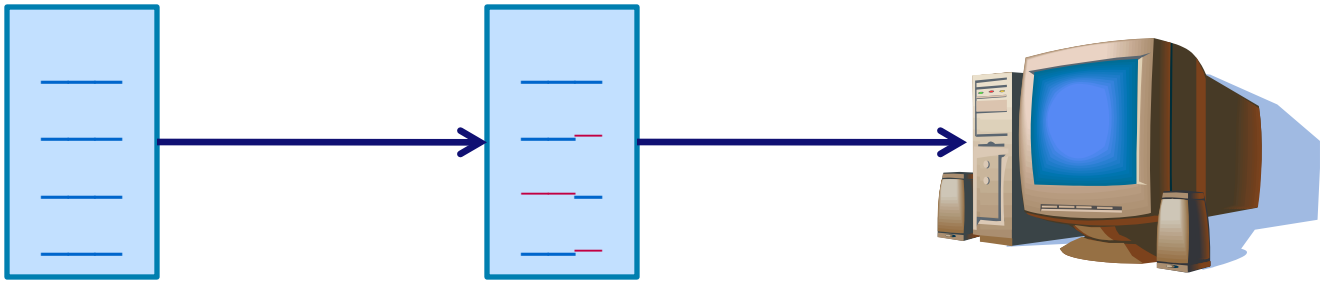
Rountev, Volgin, Reddoch
PASTE'05

Static analysis so far…

- Architecture reconstructor has to decide
  - Classes or objects

- Methods
  - Resolve the method calls
  - Invocation order
    - May be complex (interceptors)

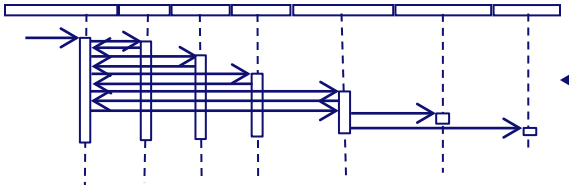
Dynamic analysis



Code

Instrumented code

Running system



Sequence diagram

Output

What would you like to instrument?

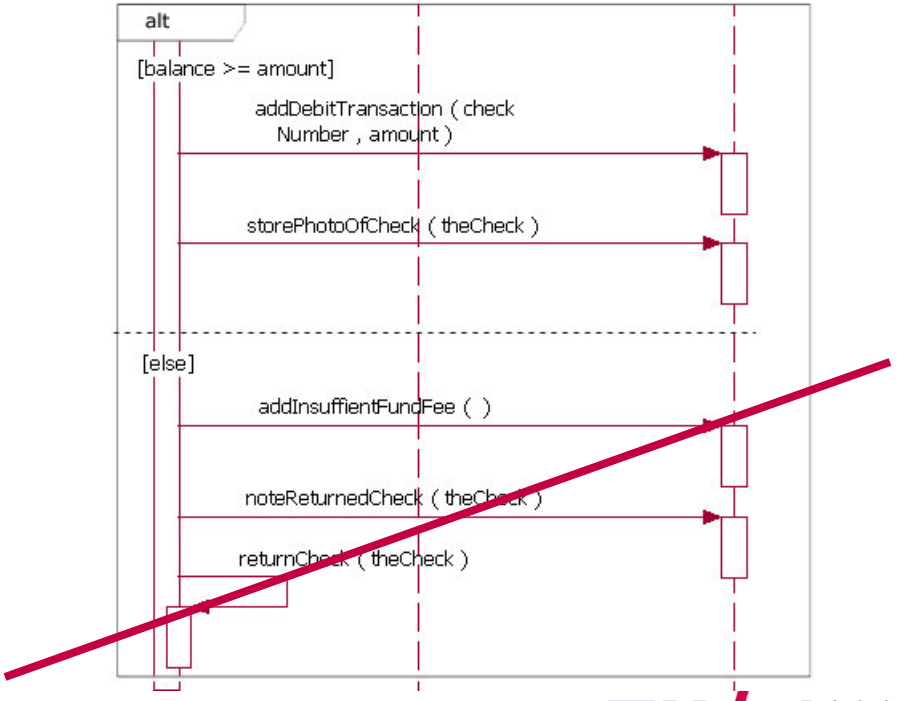
- **Source code**
  - **Maximal precision**
- **Compiled code**
  - **Example:**
    - **gcc -c -pg myfile.c**
    - **gcc -pg collatz.o**
  - **Works for any source code**
  - **Information is lost**
- **Execution environment (e.g., Java VM)**
  - **Idem**

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

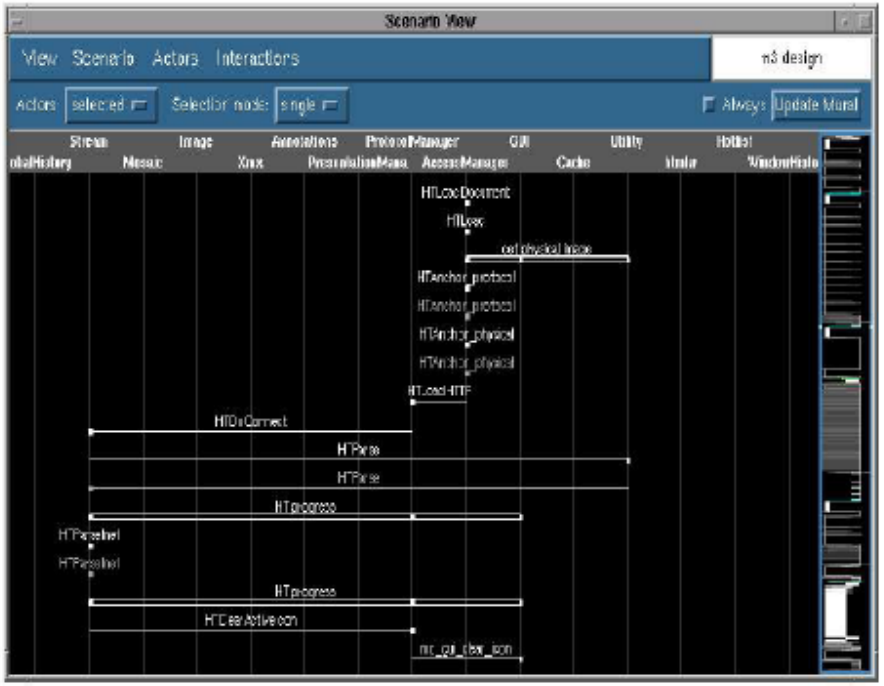
- Solutions
  - Smaller scale
    - “interesting” top-level functions
    - “interesting” calls in these functions
    - “interesting” target objects/classes
  - Different visualization

Require a priori knowledge

Better visualization (1)

Jerding, Stasko, Ball 1997

Message-flow diagram

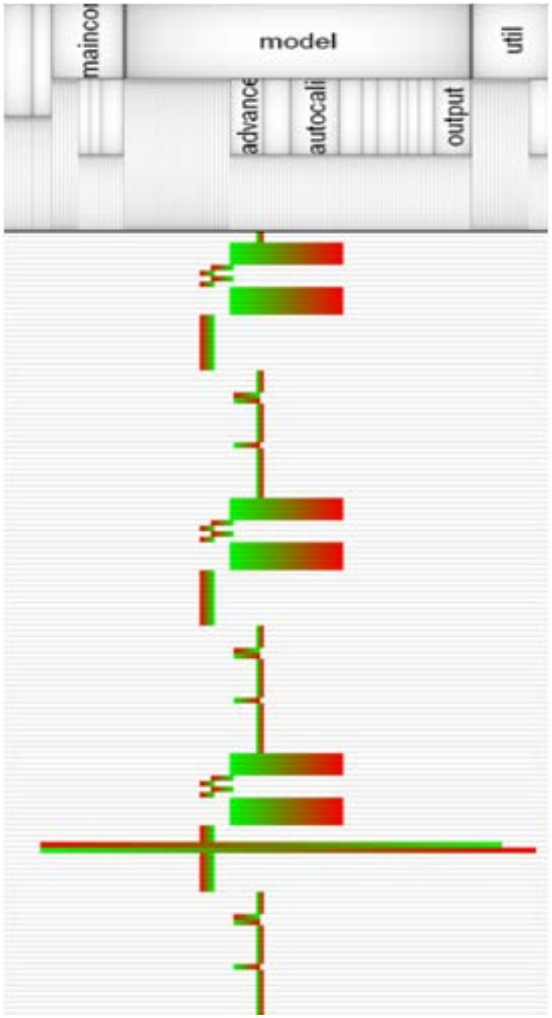


Information mural view: general overview in small

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

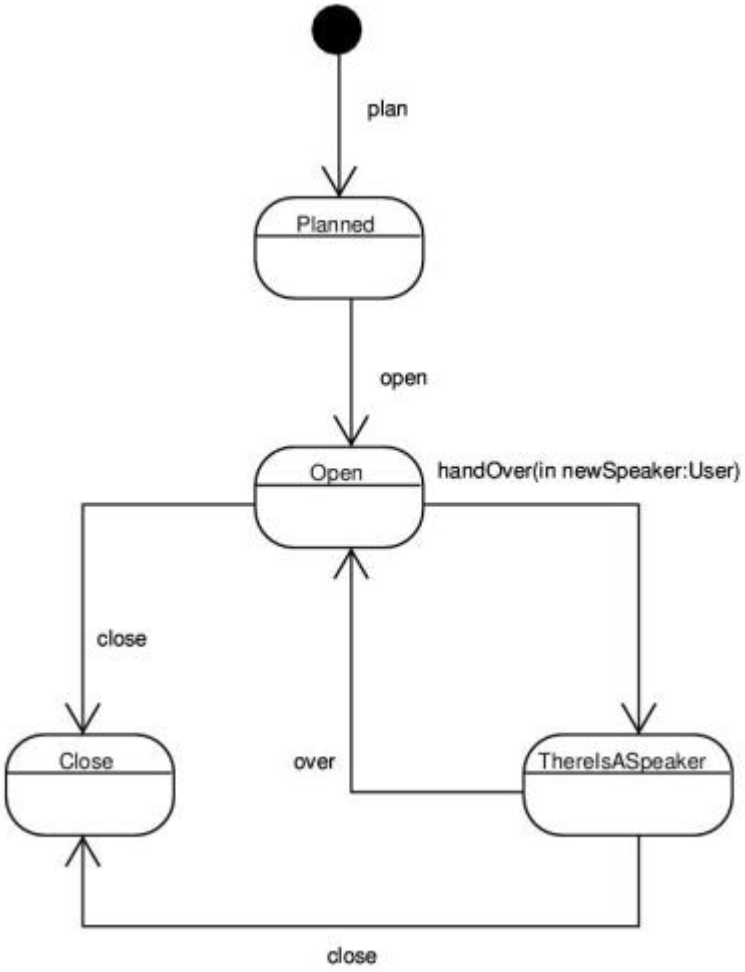
Repeated pattern and exceptional behaviour are clearly visible. Solves the blurring up problem by special visualization technique

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.



http://franck.fleurey.free.fr/VirtualMeeting/index.html

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

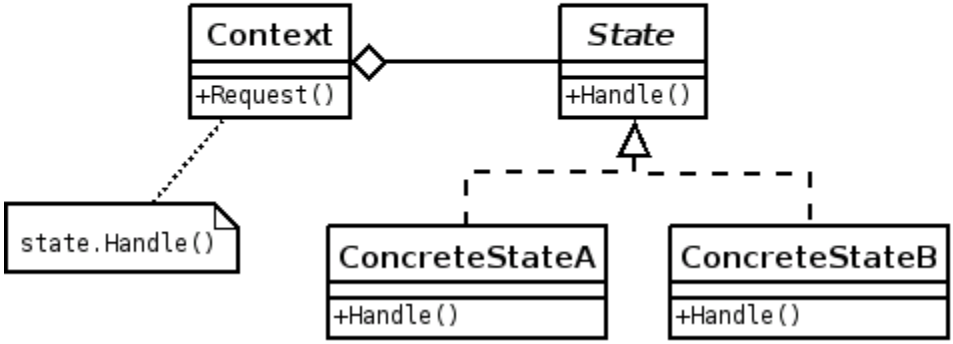
- **Nested Choice Patterns**
- **Jump Tables**
  - **State = a pointer to a function pointer array (jump table)**
  - **Transitions = function in the jump table**

```
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

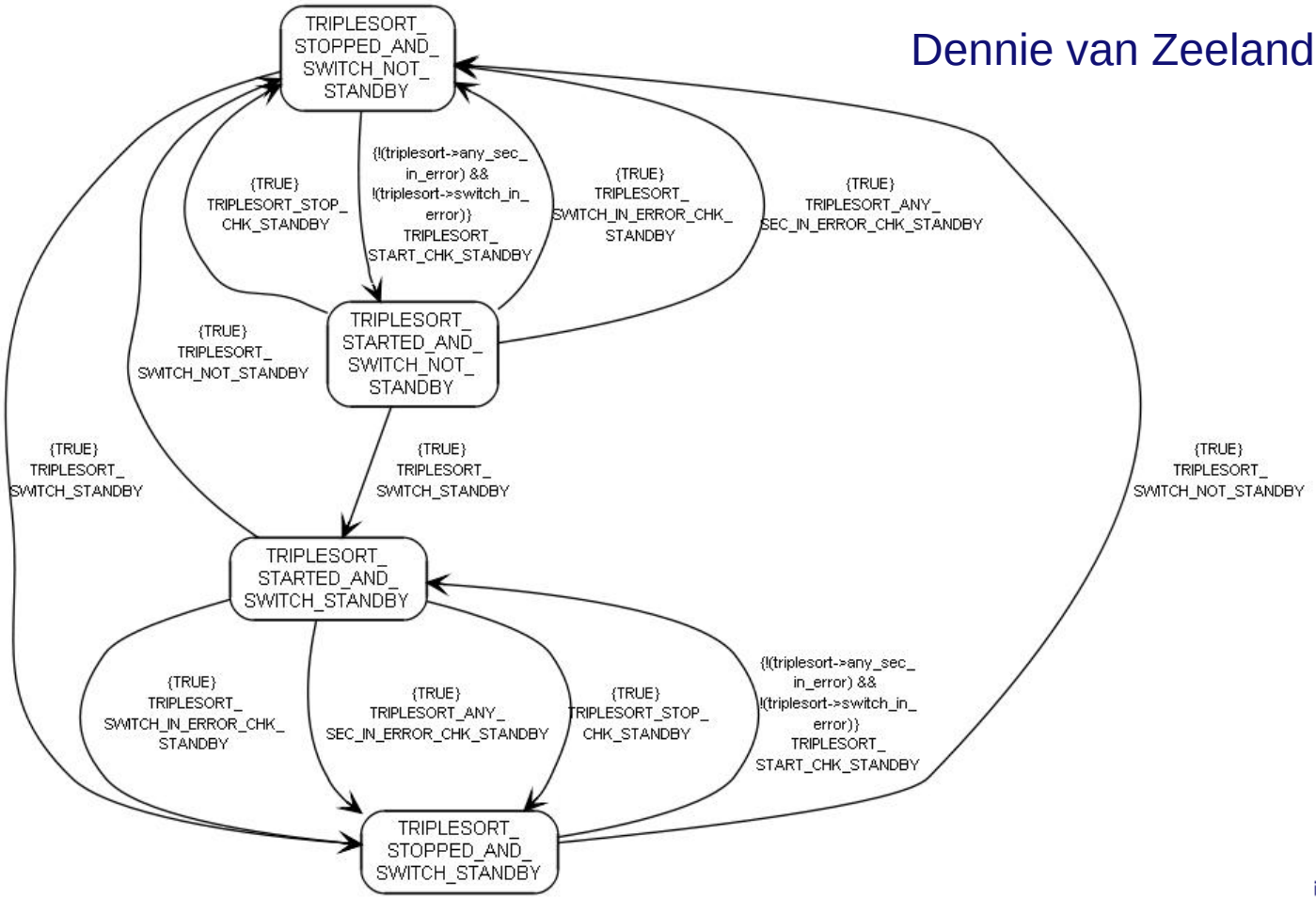
- Object-oriented: State design pattern



Explicit State Machines: Architecture Reconstr.

- **Recognize a pattern**
- **And create the state machine**

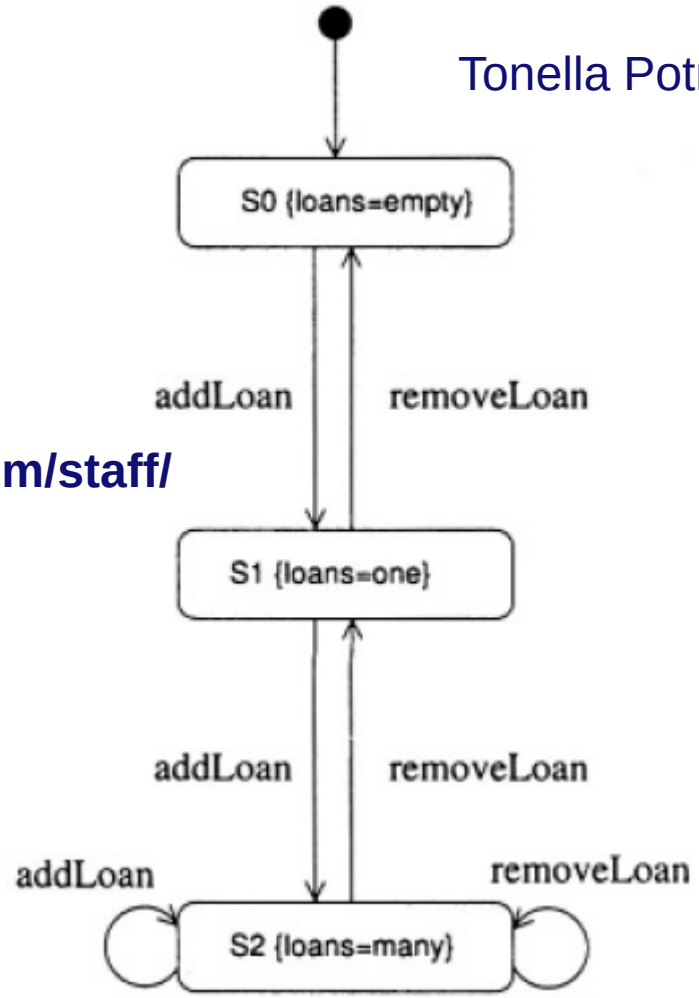
Dennie van Zeeland 2008



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"**
  - **Zero, one or more loans**
  - **"temperature is positive and precipitation < 250 mm per year"**

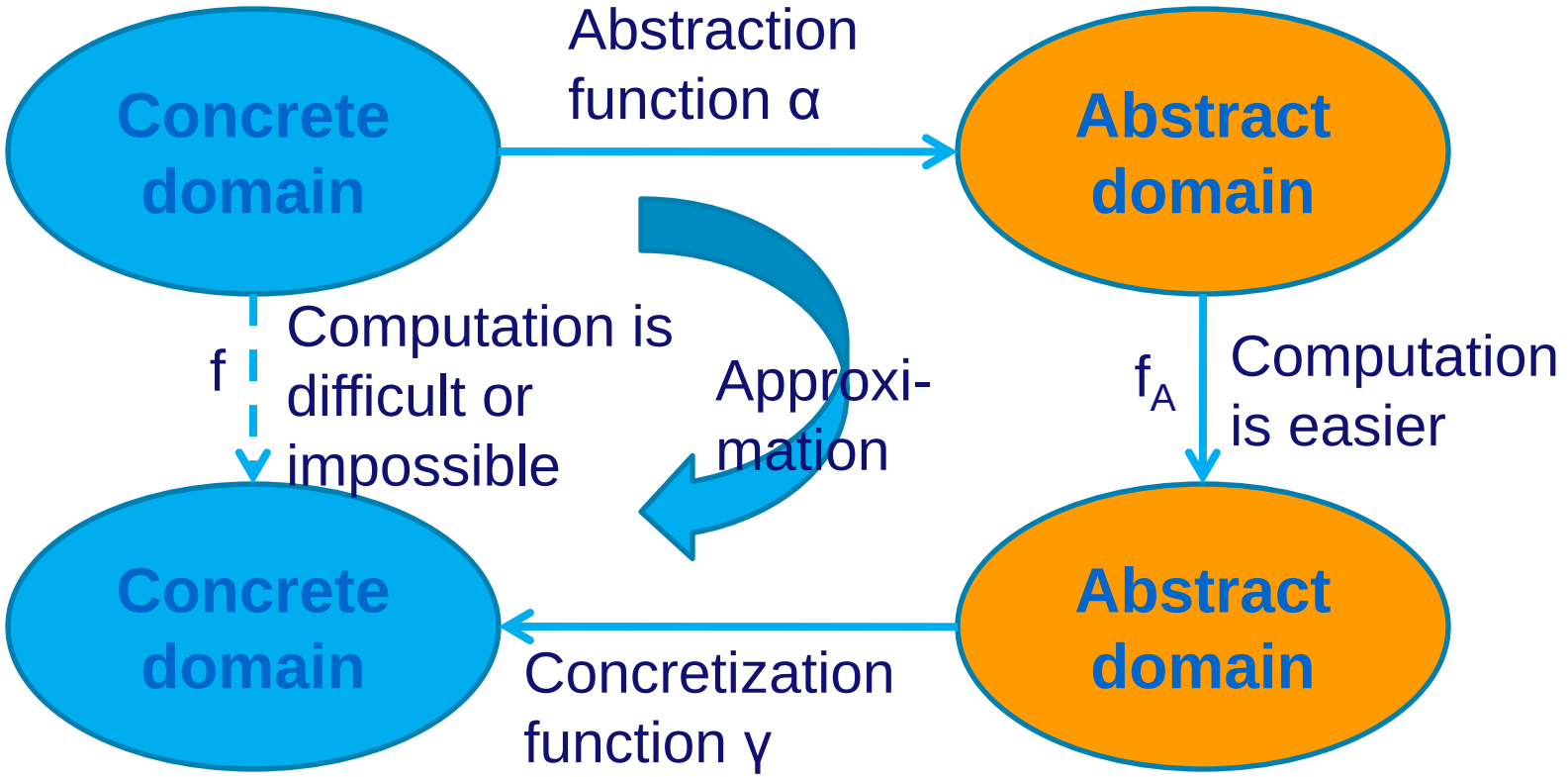
Abstract interpretation (Cousot, Cousot)

- **Abstract value – representation of group of concrete values**
  - **“positive” {x | x > 0}**
  - **“woman” {x | person(x) /\ female(x) /\ adult(x)}**

- **Abstract domain – set of all possible abstract values**
- **Abstraction – mapping from concrete to abstract val:**
  - **α(5) = positive**

Abstract Interpretation

Requirement
$\langle A, \alpha, C, \gamma \rangle$ 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?

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**

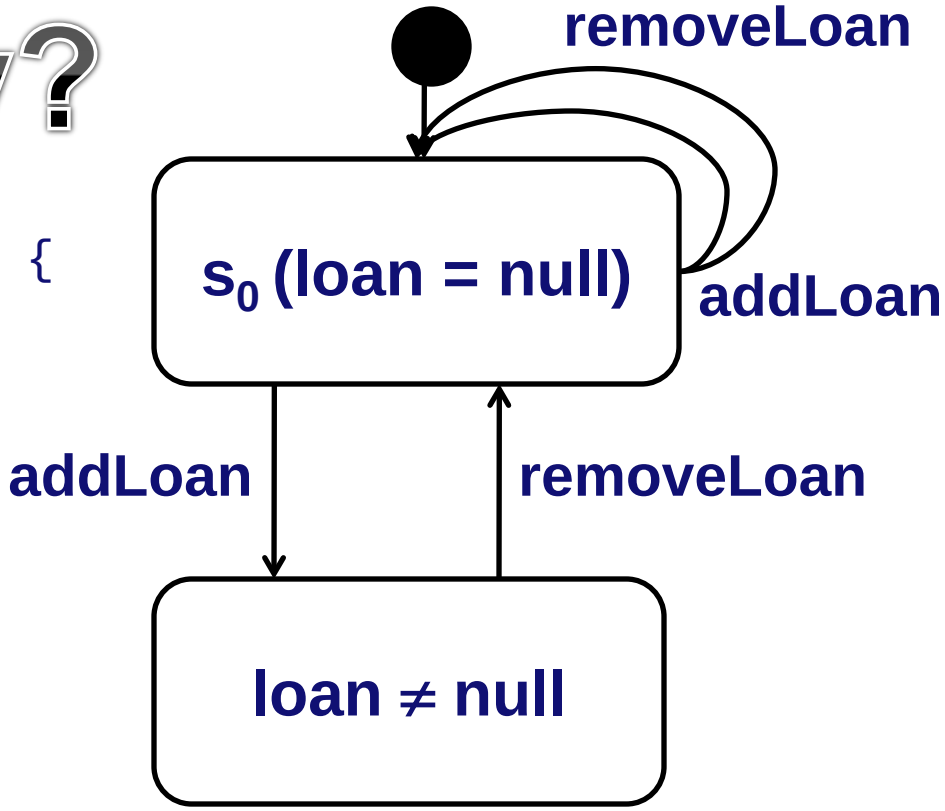
State machines reconstruction

1. **Initialization:**
   - initStates = ∅
   - s_0 = α(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:

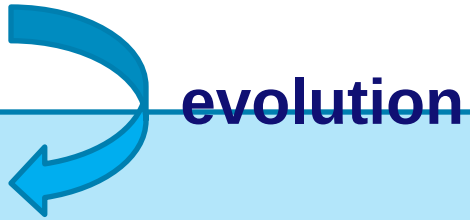
- **precondition addLoan:** **ln ≠ null**
- **precondition removeLoan:** **loan ≠ null**

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

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**
  - **I**
  - **A**

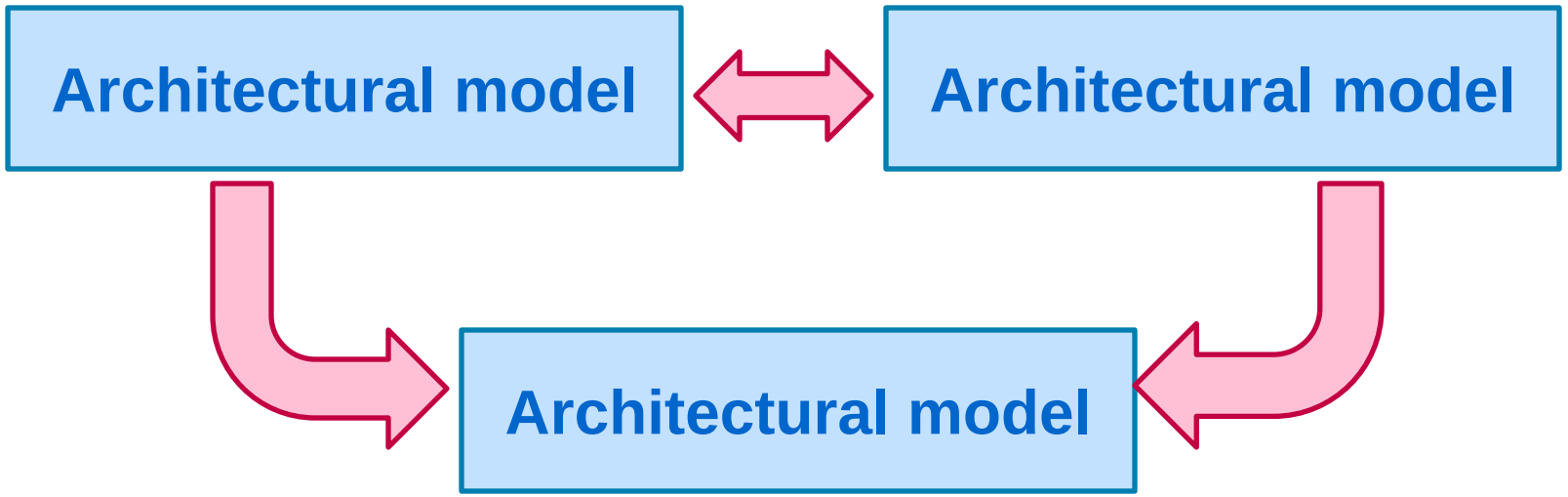
p)

  - **components, ports, connections**
  - **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**

Conclusions

- **Behaviour reconstruction**
  - **Classes or objects**
  - **Sequence diagrams or state machines**
  - **Statically or dynamically**
  - **Visualization**

- **ADL**