Software Transformations: A formalism to trace program modifications

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Typical Problem: Documenting Software Evolution

Many people working at many abstraction levels on the same project at the same time.

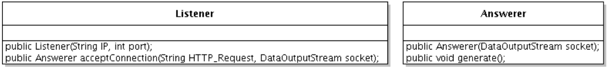
Problem: How to keep track of each modification, in a way readable by every one (Developer, Analyst, Manager)?

Goal: reduce cost, ease communication, trace software evolution.

Current Solutions

- Versionning Control Repositories (CVS, SVN, DARCS, ...)
  $\Longrightarrow$ textual documents, only for developer
- Model Driven/Reverse Engineering Architecture Tools (OMONDO, Ptidej [Gué05], ...)
  $\Longrightarrow$ no simultaneous modifications of code and model.
- post-mortem analysis (detection of refactorings, entity matching [ACPT01])
  $\Longrightarrow$ no live feedback, no rollback capabilities.

Development of a web server - Model



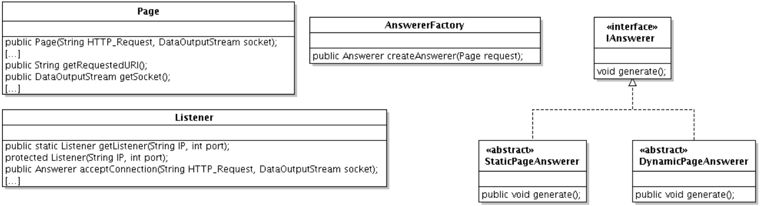
Listener

public Listener(String IP, int port);
public Answerer acceptConnection(String HTTP_Request, DataOutputStream socket);

Answerer

public Answerer(DataOutputStream socket);
public void generate();

First-draft, orignal specification



Page

public Page(String HTTP_Request, DataOutputStream socket);
[...]
public String getRequestedURI();
public DataOutputStream getSocket();
[...]

AnswererFactory

public Answerer createAnswerer(Page request);

«interface»
IAnswerer

void generate();

Listener

public static Listener getListener(String IP, int port);
protected Listener(String IP, int port);
public Answerer acceptConnection(String HTTP_Request, DataOutputStream socket);
[...]

«abstract»
StaticPageAnswerer

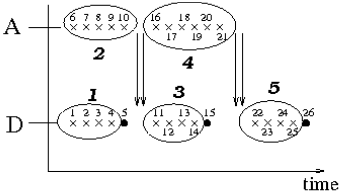
public void generate();

«abstract»
DynamicPageAnswerer

public void generate();

Actually created code modelization

Development of a web server - Time line



A is Analyst, D is Developper, Each little number is a single modification.

1. Modification of Listener constructor (code modifications)
2. Creation of Item class (model modifications)

   Modifications sent to D
3. Renaming of Item to Page and implementation of Page (code modifications)
4. Creation of IAnswerer interface and its Factory (model modifications)

   Modifications sent to D
5. Implementation of the IAnswerer hierarchy (code modifications)

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Hoare Triples [Hoa69]

Representation of action having

- guards (pre-condition)
- effects (post-condition)

Notation:
“{pre-condition}action{post-condition}”

Group and Homomorphism [DF04]

- Group:
  Set of mathematical objects with an intern operation $\circ$.
  Properties:
  - $\circ$ is associative,
  - There is a unique neutral element for $\circ$,
  - Each element has an unique inverse.
- Group Homomorphism:
  Mathematical function from one group to another preserving the group structure: $F(r_1 \circ r_2) = F(r_1) \circ F(r_2)$.

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Vocabulary: What is a transformation?

Transformation :

- Mathematical and reifiable object.
- Modification of a model (software representation).
- Defined under a meta-model (model specification [BP01]).

Notation $\mathbb{T}_{MM}$: set of all transformations under the meta-model MM.

Our goal: Transpose them between meta-models.

Example: Renaming a class could be a transformation.

Transformations as Hoare Triple

Transformation = Modification:

- Is an action,
- Depends on a previous model state,
- Creates a new model state

Example:

$$\{\exists C_0 \wedge \nexists C_1\}\text{Rename } C_0 \text{ in } C_1\{\nexists C_0 \wedge \exists C_1\}$$

Set of Transformations as Groups

$\circ$ is sequencement ("followed by", "then").

- Internal Operation:
  $\forall a, b \in \mathbb{T}_{MM}, a \circ b \in \mathbb{T}_{MM}$
- Associativity:
  $\forall a, b, c \in \mathbb{T}_{MM}, (a \circ b) \circ c = a \circ (b \circ c) \overset{\text{def}}{\equiv} a \circ b \circ c$
- Unique Neutral Element (Identity):
  $\exists! \mathbb{I} \in \mathbb{T}_{MM}$ st $\forall a \in \mathbb{T}_{MM}, a \circ \mathbb{I} = \mathbb{I} \circ a = a$
- Unique Inverse:
  $\forall a \in \mathbb{T}_{MM}, \exists!\ a^{-1} \in \mathbb{T}_{MM}$ st $a \circ a^{-1} = a^{-1} \circ a = \mathbb{I}$
- Inversion of sequence:
  $\forall a, b \in \mathbb{T}_{MM}, (a \circ b)^{-1} = b^{-1} \circ a^{-1}$

Example: The reverse of Renaming a class *FOO* as *BAR*, is to rename the class *BAR* as *FOO*.

Transpositions as Group Homomorphism

Transformations are elements of Groups,
therefore
Transpositions are Group Homomorphisms.

$$F(a \circ b) = F(a) \circ F(b)$$

$$F(\mathbb{I}_{MM1}) = \mathbb{I}_{MM2}$$

$$F(a^{-1}) = F(a)^{-1}$$

Example: There would be a transposition between the code, the developper work on, and the model, the analyst work on.

Commutativity

commuting transformations = change modifications order.

Example: “Renaming *FOO* in *BAR*, then Adding a method *baz* in *BAR*” becomes “Adding a method *baz* in *FOO*, then Renaming *FOO* in *BAR*”.

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Implementation

- PADL [Gué03, AA03, GA08]
  - Meta-model used to represent specification of programs,
  - High-level models.
  - Developed to represent patterns and abstract designs,
- JCT
  - Meta-model used to represent program code source,
  - Low-level models (Bound Abstract Syntax Tree),
  - Developped to represent Java Program, similarly to javac.

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Future Work

Implementation in progress:

- JCT implementation almost finalized,
- PADL and JCT transformations implementation in progress,
- Transposition between JCT and PADL to specify and implement,
- PADL and JCT transformations commutativity implementation in progress.

Conclusion

Our approach provides:

- Mathematical theory, verifiable, formal.
- Live feedback and concurent modifications of the program, at many levels of abstraction.
- Reversibility (Rollback facilities).
- Traceability of each transformations.

But is purely theoritical now. Implementation in progress.

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The End!

Thank You!

Question?