Towards a Framework for Software Design Defects Correction with Refactoring Plans

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Fundamental Aspects of Software Evolution
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Introduction
Software Design Defects

Definition

**Design defects** are “bad” solutions to recurring design problems in object-oriented systems. Design defects are problems resulting from bad design practices. They include problems ranging from high-level and design problems, such as antipatterns, to low-level or local problems, such as code smells. (Mohra, 2008)

- Why is important to deal with design defects?
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Motivation

Software evolution “happens”.

Software design decays:
- changes are applied hastily
- “design debt” appears (Kerievsky, *Refactoring To Patterns*)

Design decay can manifest through design defects, which affect software quality factors:
- maintainability
- reusability
- comprehensibility
- ...
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Techniques to **detect design defects** and to **suggest design changes** are maturing:

- Structural patterns to find defects (Moha, DECOR project)
- Metrics to detect “bad smells” (Marinescu, 2006; Crespo et al., 2005).
- Formal/Relational Concept Analysis to propose reorganisation of OO entities (Moha et al., 2006; Prieto et al., 2003).
- Software inconsistency management (Mens, 2006)

The change suggestions given:

- are not directly applicable over a system,
- are usually given in terms of refactorings.
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Refactorings to Correct Design Defects

- **Refactorings** are structural transformations that can be applied to a software system to perform design changes without modifying its behaviour.
- **Current approaches** to improve a system design with refactoring focus in:
  - Individual refactoring steps.
  - Detecting refactoring opportunities.
  - Assisting the developer in executing the refactoring
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Objective of a Defect Correction Framework

1. Instantiate defect removing suggestions into a correction plan which could be effectively applied.
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**Definition**

A **Refactoring Plan** will be a specification of a refactoring sequence which matches a system redesign proposal, so that it can be automatically executed to modify the system in order to obtain that desirable system redesign without changing the system’s behaviour.
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Goals

Goals of a Framework for Refactoring Plans

1. Support to automatic or assisted generation of refactoring plans

2. To provide very high level (big) refactorings for design improvement, using refactoring plan generation altogether with the defect detection techniques that suggest redesign proposals.
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Design Defect Correction
General Defect Correction Process

Current System

Change Suggestions

Defect Detection

Correction Planification

Refactoring Plan

Defect Correction

Redesigned System
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A Framework sketch

Software System

Software Entity

Class

Interface

Instance Methods

Instance Variables

Detected Defect

Design Defect Definition

Defect Symptom

Defect Correction Strategy

Defect Symptom

Metric Symptom

Structural Symptom

Lexical/Semantic Symptom

Behaviour-Preserving Change

Non Behaviour-Preserving

Refactoring Suggestion

Refactoring Plan

Automated Refactorings

Non-Automated Refactorings

Change

Detected Defect

0..* 1..*

Design Defect Definition

1..*

Defect Symptom

0..*

Detected Defect

0..* 1..*

Design Defect Definition

1..*

Defect Symptom

0..*

Detected Defect

0..* 1..*

Design Defect Definition

1..*

Defect Symptom

0..*
Generating Refactoring Plans
Refactoring Plan Questions

Given a software system as the source of the transformation, a redesign proposal, and a set of refactorings that can be used as transformation operations:

1. Does a refactoring plan, which transforms the source, according to the redesign proposal, using the provided refactorings, exist?
   - additional non-refactoring transformations could be needed

2. When a refactoring plan exists, can it be generated and executed automatically?
   - How to deal with a semi-automated solution, with additional user input?
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Subproblems

- We have divided the problem of **automatic generation of refactoring plans** in:
  - Definition and formalization of the “Refactoring Plan” concept
  - Representation of Software
  - Formalization of Refactorings
  - Elaboration of techniques to obtain refactoring plans
Formalising Refactorings

- Any refactoring formalization method must allow:
  - to deal with **system structure**.
  - to **check** behaviour preserving **conditions**.
- We will use **Graph Transformations** because:
  - Representing and managing structural information is straightforward with graphs.
  - This approach has already been validated (Mens et al., 2005).
- With Graph Transformation:
  - **Software** is represented as **graphs**.
  - **Refactorings** are represented as **graph transformation rules**.

Other refactoring formalization approaches:
- First Order Logic (Kniessel, Köch, 2002).
Example of a Graph Transformation Rule

Left Hand Side

Right Hand Side
A graph representation for Object-Oriented Software is needed. We must represent:
- elements of OO paradigm (classes, fields, methods, ...)
- structural relationships
- method bodies

We have chosen the software representation part from the refactoring formalization of (Mens et al., 2005). This representation:
- uses directed type graphs.
- is language independent, lacking specific language constructions.
- has been simplified to be as flexible as possible.
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Software Representation: Java Program Graphs
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- More detailed representation of method bodies, with new node types, attributes and relationships.
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Software Representation: Java Program Graphs

- **Package**
  - `name : String`

- **Classifier**
  - `name : String`
  - `visibility : String`
  - `isAbstract : boolean`
  - `isStatic : boolean`
  - `isFinal : boolean`
  - `implements 0..* 0..*`

- **MethodBody**
  - `belongsTo 0..* 0..1`
  - `belongsTo 1 0..*`
  - `belongsTo 0..* 0..1`

- **Expression**
  - `belongsTo 0..* 0..1`
  - `{ordered} 0..*`
  - `link 0..1 0..*`
  - `link 0..1 0..*`
  - `link 0..* 0..1`
  - `link 0..* 0..1`

- **Operation**
  - `belongsTo 1 0..*`
  - `belongsTo 1 0..*`

- **ActualParameters**
  - `belongsTo 0..1 0..1`

- **Variable**
  - `belongsTo 0..* 0..1`
  - `belongsTo 0..1 0..1`
  - `belongsTo 1 0..*`

- **Literal**
  - `value : String`

- **Access**
  - `belongsTo 0..* 0..1`
  - `belongsTo 0..* 0..1`

- **Update**
  - `belongsTo 0..* 0..1`
  - `belongsTo 0..* 0..1`

- **Call**
  - `belongsTo 0..* 0..1`
  - `belongsTo 1 0..*`

- **Instantiation**
  - `belongsTo 0..* 0..1`
  - `belongsTo 1 0..*`

- **Operator**
  - `belongsTo 0..* 0..1`

- **Return**
  - `belongsTo 0..* 0..1`

- **Block**
  - `belongsTo 1 0..*`

- **Expression**
  - `belongsTo 0..* 0..1`

- **Link**
  - `{ordered} 0..*`
  - `{incomplete} 0..*`

- **Package**
  - `belongsTo 0..* 1`

- **Class**
  - `belongsTo 0..* 1`
  - `belongsTo 1 0..*`
  - `implements 0..* 0..*`

- **Interface**
  - `belongsTo 0..* 1`

- **Type**
  - `belongsTo 0..* 1`

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Possible Approaches to Obtain Refactoring Plans

- We are exploring two approaches:
  - Searching forwards
  - Searching backwards
Searching forwards

- **approach**
  - Suggested changes are turned into a simplified version of the system’s desirable design.
  - Available refactorings are applied in a state space search way.
  - Refactoring pre and postconditions guide the search.

- **Advantages**
  - Every possible path is being explored
  - Relatively easy to implement

- **Problems**
  - Size of the state space
  - Possible infinite process
Searching Backwards

- **approach**
  - Dependencies between refactorings are computed
  - Iteratively, refactorings which enable the application of the desired change are added to the plan.

- **Advantages**
  - More efficient than searching backwards

- **Problems**
  - More difficult to implement with current Graph Transformation tools
Open questions

- Can complex refactorings be represented and analysed with current GT tools?
- Can searching be reduced to finite process?
Conclusions and Future Work
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- Automatic generation of refactoring plans will provide very high level refactorings to improve the design of existing code.

- The Main subproblems and the research strategy have been introduced.

- Graph transformation can be used as the underlying formalism, specifically the programmed graph rewriting approach.
  - Representing Java programs with Java Program Graphs.
  - The graph transformation formalism could provide support to refactorings formal analysis, enabling searching for refactoring plans.
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Main future tasks will be directed to:

- Further definition of the “Refactoring Plan” concept.
- Explore the expressiveness of GT tools
- Analyse termination and correctness conditions of the searching approaches.
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