Overview of the Refactoring Discovering Problem

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Introduction

Refactoring Plans
- Defining Refactoring Plans
- The Problem of Automatic Generation of Refactoring Plans
- Research Strategy

Problem Formalization
- Rule Driven Systems
- Programmed Graph Rewriting Systems

Software Representation

Refactoring Rules Description

Refactoring Sequences Discovering Algorithm
- Basic Algorithm
- Algorithm Heuristics

Conclusions and Future Work
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 refactorings focus in:

- Individual refactoring steps.
- Detecting refactoring opportunities.
- Executing the refactoring with a tool.

Some techniques can suggest wider design changes:

- Formal Concept Analysis to propose hierarchy reorganization (Prieto et al., 2003).
- Metrics to detect Bad Smells (Crespo et al., 2005).

They require sequences of refactorings to perform the proposed change.
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Main Goals

1. To automatically and dynamically generate refactoring sequences (refactoring plans) that can transform a system, following a redesign proposal, and preserving the system’s behaviour.

2. To provide very high level (big) refactorings for design improvement, using refactoring plan generation altogether with analysis techniques that suggest redesign proposals.

3. To support this “refactoring plan” technique with tool prototypes to provide it as a regular design improving development technique.
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Refactoring Sequences Problem Overview

Current System -> System Analysis

System Analysis -> System Redesign Proposal

System Redesign Proposal -> Refactoring Analysis

Refactoring Analysis -> Refactoring Plan

Refactoring Plan -> Refactoring Plan Execution

Refactoring Plan Execution -> Desirable System
Refactoring Sequences Problem Overview

Current System → System Analysis → System Redesign Proposal

System Analysis

Refactoring Analysis

Refactoring Plan

Refactoring Plan Execution

Desirable System
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- System Redesign Proposal
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Refactoring Sequences Problem Overview

Current System

System Analysis

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Desirable System
Refactoring Plans

We pretend to introduce a new concept: **Refactoring Plans**

**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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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?
2. When a refactoring plan exists, can it be generated and executed automatically?
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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 a “refactoring sequences” discovering algorithm
- Validation of proposed subproblem solutions through existing tools and prototype implementation
Research Strategy

To reduce the problem complexity given by:

- differences between source and redesign proposal representation type, abstraction level, description language, ... 
- uncertainty about what kind of redesign proposal descriptions will we be capable to deal with.

We have planned the research to progress through two stages:

- First, we will apply some restrictions to the problem and propose a restricted solution.
- Then, we will “open up” those restrictions to find a more general solution.
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Research Strategy: First Stage

We apply some **restrictions to reduce complexity:**
- The transformation source is the current system code.
- The redesign proposal is the modified system code.

**Goals** of this stage are:
- To propose a solution to the restricted refactoring plan problem.
- To validate this solution.

**Results** obtained so far can be applied to other problems:
- Testing if an evolved system preserves the behaviour of the original system.
- Documenting refactoring changes performed in a redesigned system.
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Research Strategy: Second Stage

After validating the first stage restricted solution, we will reduce restrictions to generalize the problem:

- The transformation source will still be the current system code.
- The redesign proposal will be allowed to be of different type, abstraction level, description language, . . . , than the source.
- Redesign proposals in the second stage will contain less information than redesign proposal in the first stage (modified system code).

Goals of this stage are:

- To specify which kind of descriptions will we be capable to deal with and would be allowed as redesign proposals.
- To propose a general solution to the problem of automatic elaboration of refactoring plans.
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We are at the first stage of the research, and working on these subproblems:

- Software representation
- Refactoring formalization
- “refactoring sequences discovering” algorithm

This presentation introduces the current progress of each one.
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 (Köch, 2002).
Example of a Graph Transformation Rule

Left Hand Side

Right Hand Side
We have found two main directions within the field of graph transformations, that can be useful:

- Rule Driven Systems
- Programmed Graph Rewriting Systems
Rule Driven Systems are graph rewriting systems where:
- transformation rules are described by a graph grammar
- transformations follow known derivation sequences
- rules are randomly selected to automatically transform a graph

The problem was modeled as a formal language problem:
- Current system $\Rightarrow$ starting node
- Refactorings $\Rightarrow$ production rules
- Desirable system $\Rightarrow$ final node
- Does the plan exist? $\Rightarrow$ membership problem
- Refactoring plan $\Rightarrow$ derivation sequence
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We explored this approach and found some issues:

- This approach deals well with problems for which derivation paths are well defined (e.g. visual language parsing).
- A well known derivation tree for refactoring sequences should be needed.
- The number of refactorings which can be applied for each derivation step is unpredictable.
Programmed Graph Rewriting Systems

**PGR Systems** present a more general graph rewriting approach:

- graph grammars are also used
- they include structured programming
- transformations can be programmed and organized in modules

The problem can be seen as a state space search problem:

- Current system $\Rightarrow$ starting state
- Refactorings $\Rightarrow$ state changing operations
- Desirable System $\Rightarrow$ a desired state
- Does the plan exist? $\Rightarrow$ reachability of the desired state
- Refactoring Plan $\Rightarrow$ path to the final state

Issues found so far:

- the combinatorial explosion
- the need to develop heuristics
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Refactoring Formalization with PGR Systems

We have chosen Programmed Graph Rewriting Systems because:

- they offer **programmable control** over the graph transformation process
- they offer **more expressiveness** than the grammar based systems
- **refactorings which take multiple transformation steps** are very difficult to describe with Rule Driven Systems, and they can be described easily with PGR Systems

In the first stage of the research we are addressing the already mentioned subproblems according to the PGR systems paradigm.
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A graph representation for Object-Oriented Software is needed. We must represent:

- elements of OO paradigm (classes, fields, methods, ...)
- structural relationships
- method bodies

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- uses directed type graphs.
- is language independent, lacking specific language constructions.
- has been simplified to be as flexible as possible.
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We have extended program graphs for Java: Java Program Graphs. Our graph representation format adds:

- Java concepts such as visibility, interfaces, packages, ...
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Refactoring Rules Description

Refactorings will be formalized for PGR, by splitting its descriptions:
- pre and postconditions
- transformation process (the refactoring itself)
- transformation relationships between pre and post conditions.

Programmed Graph Rewritings will allow to:
- Use each refactoring description part when it’s needed.
- Describe structured conditions:
  - if...then...else
- Algorithmically describe refactorings that take multiple transformation steps:
  *Pull Up Method*
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Example: Change Interface Type Parameter

Preconditions:

1) M
2) I
3) C
4) M → P
5) C → i*

Postconditions:

1) M
2) I
3) C
4) M → P
5) C → i*
6) C → i*

Transformation:

<table>
<thead>
<tr>
<th>pre</th>
<th>post</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<tr>
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<td>4</td>
<td>4,5</td>
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<tr>
<td>5</td>
<td>6</td>
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A basic state space search algorithm is being developed.

It needs refactoring descriptions to be expressed in terms of preconditions, transformations and postconditions.

It needs the expressiveness and execution control of programmed graph rewriting.

The algorithm main keys are:

- The Algorithm is **guided by pre and postconditions**.
- **To look for preconditions in the source graph** in order to reveal which refactorings can be applied.
- **To look for postconditions in the target graph** in order to find which refactorings are more likely to be part of the sequence.
- The **source graph gets transformed progressively into the target graph**.
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Refactoring Sequences Discovering Algorithm

Available Refactorings

R1  R2  R3  R4

Refactoring Plan

Source  0

Target
Refactoring Sequences Discovering Algorithm

Available Refactorings
- R1
- R2
- R3
- R4

Refactoring Plan

Source 0
- Pre

Target
- Post
- Post

R1
- Pre

R3
Refactoring Sequences Discovering Algorithm

Available Refactorings
- R1
- R2
- R3
- R4

Refactoring Plan
- R1

Source 1
- Pre

Target
- Post
- Post

Pre

The Refactoring Discovering Problem
Refactoring Sequences Discovering Algorithm

Available Refactorings

R1  R2  R3  R4

Refactoring Plan

R1  →  R1

Source  2

Pre

Pre

Target

Post

R4

R3

Post

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The Refactoring Discovering Problem

ECOOP’06 PhD S. Workshop
Refactoring Sequences Discovering Algorithm

Available Refactorings
R1  R2  R3  R4

Refactoring Plan
R1  →  R1  →  R3

Source
3

Pre

R2

Target

Post

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Refactoring Sequences Discovering Algorithm

Available Refactorings
- R1
- R2
- R3
- R4

Refactoring Plan
- R1 \rightarrow R1 \rightarrow R3 \rightarrow R2

Source 4

Target

The Refactoring Discovering Problem
“Postcondition” Heuristic

Prioritize refactorings whose postconditions hold on the target graph.

Available Refactorings
- R1
- R2
- R3
- R4

Refactoring Plan
- R1 -> R1

Source
- 2
- Pre
- Pre

Target
- Post
- Post

R3
- Pre

R4
- Post
"Postcondition" Heuristic

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Available Refactorings

- R1
- R2
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Refactoring Plan

- R1 → R1 → R3

Source: 3

Target
**“Awaiting Postcondition” Heuristic**

- Prioritize refactorings which make that the previous selected. refactorings can hold their awaiting postconditions.
"Awaiting Postcondition" Heuristic

- Prioritize refactorings which make that the previous selected. refactorings can hold their awaiting postconditions.

Available Refactorings:
- R1
- R2
- R3
- R4

Refactoring Plan:
- R1

Source:
- Pre
- R1

Target:
- Post
“Awaiting Postcondition” Heuristic

- Prioritize refactorings which make that the previous selected refactorings can hold their awaiting postconditions.

Available Refactorings:

- R1
- R2
- R3
- R4

Refactoring Plan:

- R1

Source:

- 2

Target:

Awaiting Post

Javier Pérez (Universidad de Valladolid)
"Awaiting Postcondition" Heuristic

Prioritize refactorings which make that the previous selected. refactorings can hold their awaiting postconditions.

![Diagram](attachment:image.png)
"Awaiting Postcondition" Heuristic

Prioritize refactorings which make that the previous selected. refactorings can hold their awaiting postconditions

Available Refactorings

R1  R2  R3  R4

Refactoring Plan

R1  R1  R3

Source  3

Target
Conclusions

- 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.
  - Describing refactoring rules with programmed graph transformation rules in terms of pre, postconditions and transformations.
- The problem can be modeled as a state space search problem.
  - Using a “refactoring sequences discovering” algorithm guided by pre and postconditions, to find a refactoring plan, .
  - Using heuristics to guide the algorithm.
Conclusions

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Detected Problems

Correction and completeness of the algorithm:

- Heuristics could not be enough to prevent the algorithm getting lost in the search.
- The number of applicable refactorings on each step is expectable to be very big.
- The algorithm can get stuck selecting “wrong” refactorings.
Conclusions and Future Work

Future Work

Main future tasks will be directed to:

- Further definition of the “Refactoring Plan” concept.
- Extend the available set of formalized refactorings.
- Validate proposals implementing the algorithm with a PGR tool.
- Analyse termination and correctness conditions of the refactoring discovering algorithm.
- Analyse, improve and extend heuristics of the state space search algorithm.
Overview of the Refactoring Discovering Problem

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