Exploring a Method to Detect Behaviour-Preserving Evolution Using Graph Transformation

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Introduction: Context

- Refactorings are commonly integrated into development environments and are extensively used.
- Finding and understanding refactorings is important to document and to understand a system's evolution.
- It will be useful to determine automatically when software evolution has been behaviour-preserving.
  - to verify a redesign process
  - to verify a handmade refactoring
  - to find and characterise stages of a system's evolution
  - ...

Introduction: Goals

- To detect whether two versions of a software system are functionally equivalent,
- by checking whether the evolution process between this two versions can be formulated by a refactoring sequence

$$\boxed{\mathbf{n}} \qquad \simeq \qquad \boxed{\mathbf{n+1}}$$

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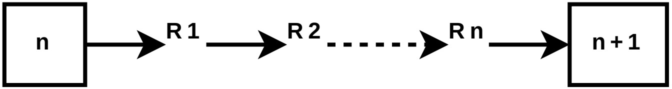

Introduction: Approach

- We are exploring a method which:
  - uses a graph representation format for Java programs and Java refactorings,
  - models the problem as a state space search,
  - searches sequences of ONLY refactorings,
  - uses refactorings' pre and postconditions to guide the search.

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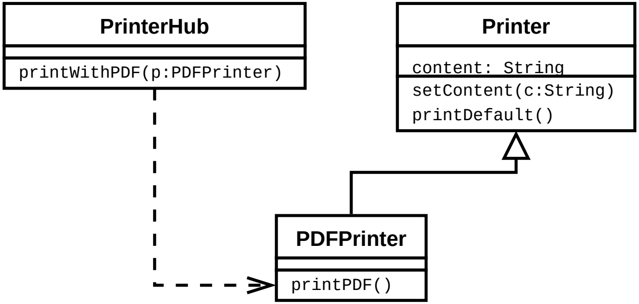
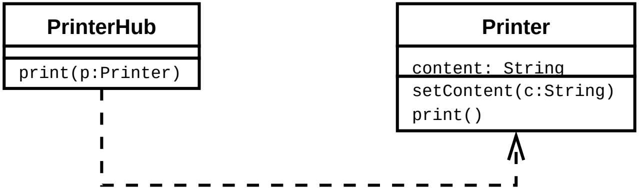
Example: Simulation of a Printing System



Different printers for different document types and a printer hub to connect all the printers. More printers will be added when needed.

Example: Refactored Printing System



The system administrator noticed that only pdf documents were sent.
Rashly modification to simplify the inheritance hierarchy.

Problem!

- A new system administrator arrives. Finds two versions of the system, and no documentation about the changes performed between them.
- **Problems:**
  - documenting the changes performed to the old system
  - is the new system functionally equivalent to the old one?
- We know that a sequence exists (done manually).

Refactoring Sequence Applied

1. ***removeMethod*:**
   printing.Printer.printDefault()
2. ***pullUpMethod*:**
   printing.PDFPrinter.printPDF() $\Longrightarrow$ *printing.Printer.printPDF()*
3. ***renameMethod*:**
   printing.Printer.printPDF() $\Longrightarrow$ *printing.Printer.print()*
4. ***renameMethod*:**
   printing.PrinterHub.printWithPDF() $\Longrightarrow$ *printing.PrinterHub.print()*
5. ***useSuperType*:**
   printing.Printer.print(PDFPrinter p) $\Longrightarrow$
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6. ***removeClass*:**
   printing.PDFPrinter

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Refactorings and Graph Transformation

- We use Graph Transformation as a formal representation for refactorings and OO software
  - GT deals with structure representation and modification
  - refactorings are structural modifications
- We use the work of Mens et al. *“Formalising Refactorings with Graph Transformations”* as our basis, to represent:
  - programs as graphs
  - refactorings as graph transformation rules
- We have made a small extension to this format to represent simple Java programs.

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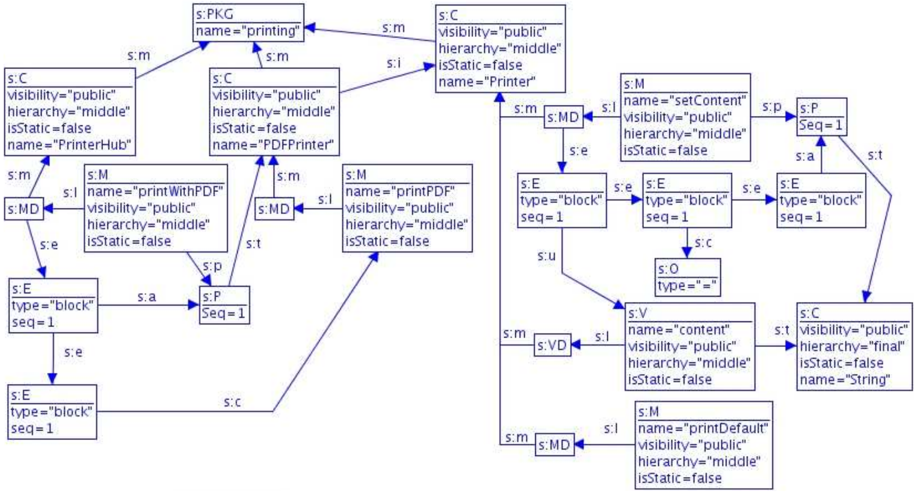
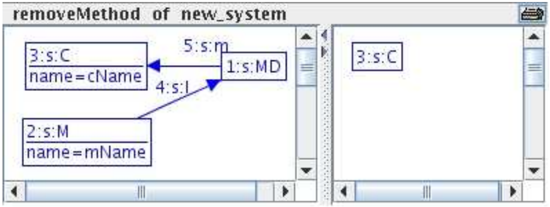
Original Printing System

```
//-----------------------PrinterHub.java
public class PrinterHub {
  public void printWithPDF(PDFPrinter p){
    p.printPDF();
  }
}
//-----------------------PDFPrinter.java
public class PDFPrinter extends Printer{
  public void printPDF(){
    // body of printPDF method
  }
}
//--------------------------Printer.java
public class Printer {
        public String content;
        public void setContent(String c){
                this.content = c;
        }
        public void printDefault(){
          // body of printDefault method
        }
}
```

Original Printing System Graph



Refactorings as Graph Transformation Rules



- **Left-hand side:** Rule precondition.
  - Can be used to express refactorings' pre and postconditions.
- **Rigth-hand side:** Transformation.

Modeling the problem

- We address the problem as a state space search problem:
  - **Original/Old system** $\simeq$ start state.
  - **Refactoring operations** $\simeq$ state changing operations, edges.
  - **Refactored/New system** $\simeq$ goal state.
  - **Does a refactoring sequence exist?** $\simeq$ reachability problem.
  - **Refactoring sequence** $\simeq$ path from the start state to the goal state.
- We apply a graph parsing algorithm to perform depth-first search
- **Main problem:** size of the state space (finite?)
  - With refactoring descriptions expressed in terms of preconditions, transformations and postconditions,
  - preconditions and postconditions can guide the search,
  - we can reduce the size of the state space.

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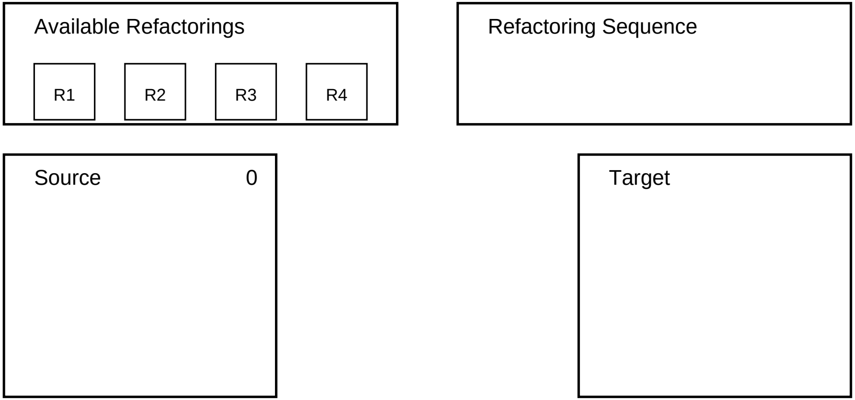
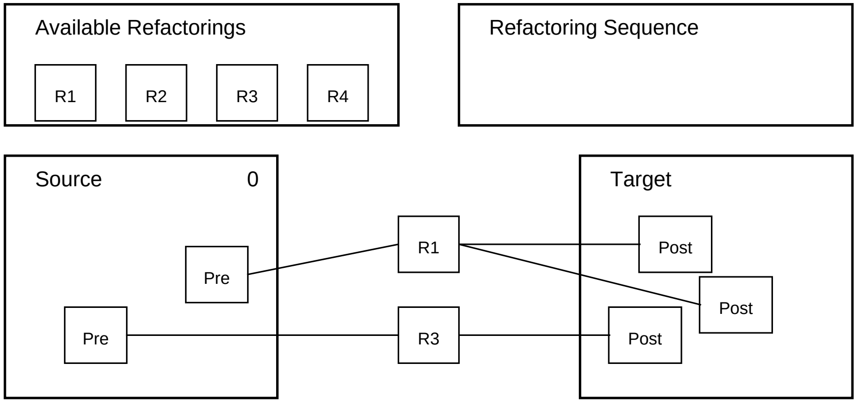
Algorithm

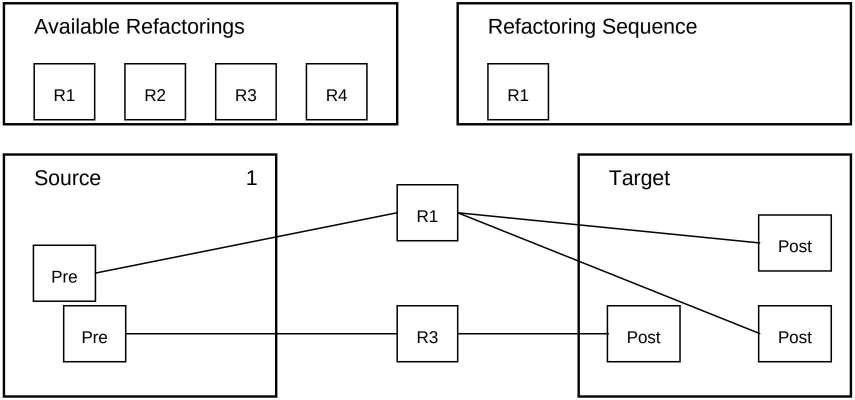

Available Refactorings
R1
R2
R3
R4
Refactoring Sequence
Source
0
Target

Algorithm



- Looks for refactoring preconditions in the start graph.
- Looks for refactoring postconditions in the goal graph.

Algorithm



- Iteratively selects candidate refactorings
- Transforms the current graph with them

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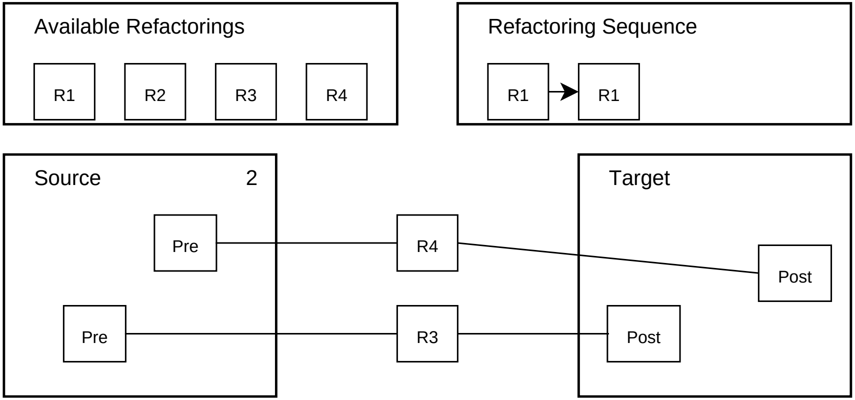

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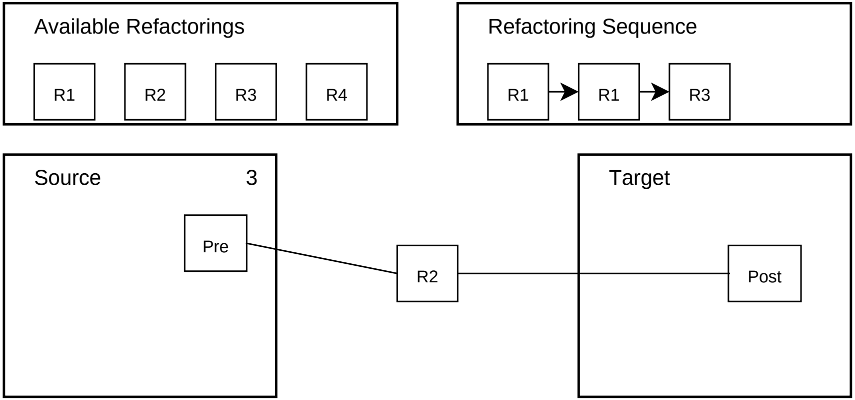
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Pre
R2
Target
Post

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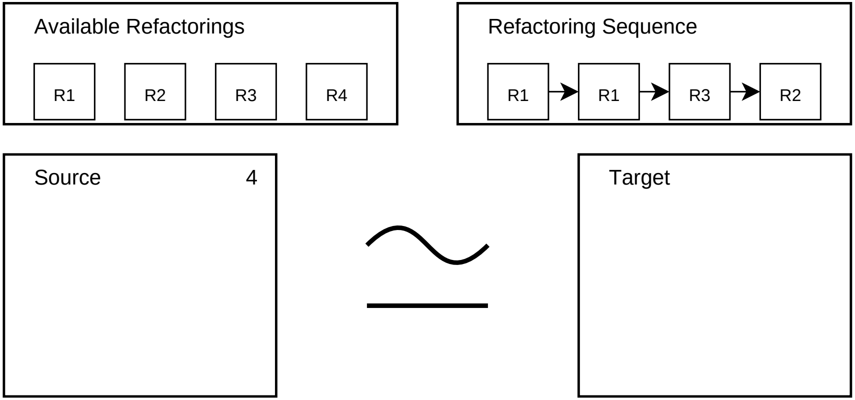

- Success: current graph isomorphic to the goal graph,
- Fail: No more refactorings can be executed, current and goal states are not isomorphic.

Implementation in AGG

- Easy to use graph transformation tool
- AGG allows rapid prototyping of GT systems.
- It supports graph parsing, which can be used to perform the search:
    - The AGG parser randomly applies rules to the start graph
    - until it is isomorphic to the goal graph,
    - or no more rules are available,
    - and backtracking is no longer possible.
- AGG allows to “exercise” our approach easily.
- It present expressiveness and efficiency limitations.

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Running the Example

- Set of rules to search:
  - pullUpMethod, renameMethod, removeMethod, removeClass, removeInterface and useSuperType
- Each iteration, among candidate rules:
  - AGG selects randomly one to apply it.
  - AGG backtracks when needed and possible.
- Output from the AGG parser's debugging information:
  - rules applied
  - when backtracking occurs
  - intermediate graphs
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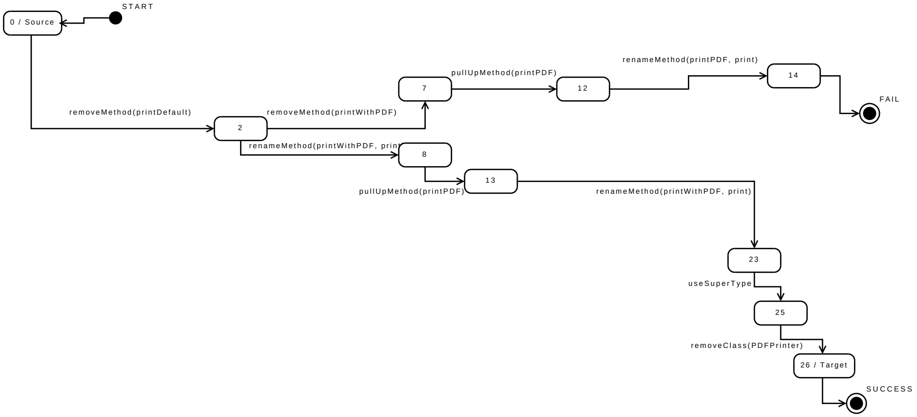
START
0 / Source
removeMethod(printDefault)
2
removeMethod(printWithPDF)
7
pullUpMethod(printPDF)
12
renameMethod(printPDF, print)
14
FAIL
renameMethod(printWithPDF, print)
8
pullUpMethod(printPDF)
13
renameMethod(printWithPDF, print)
23
useSuperType
25
removeClass(PDFPrinter)
26 / Target
SUCCESS

For this experiment, the parsing terminates and finds a sequence.

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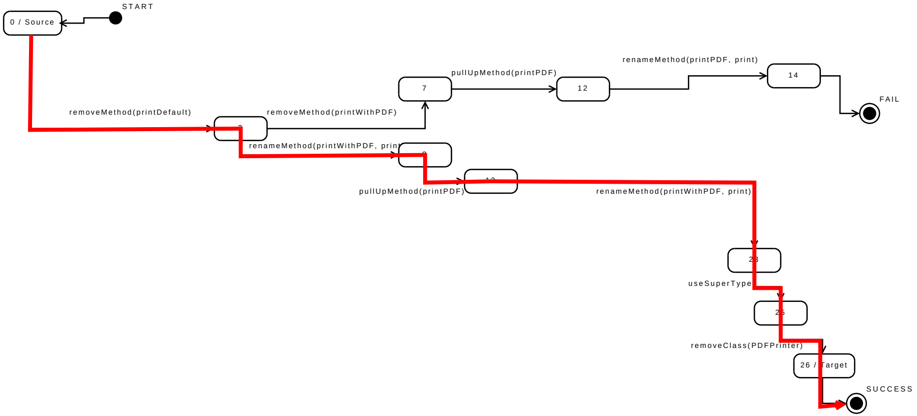
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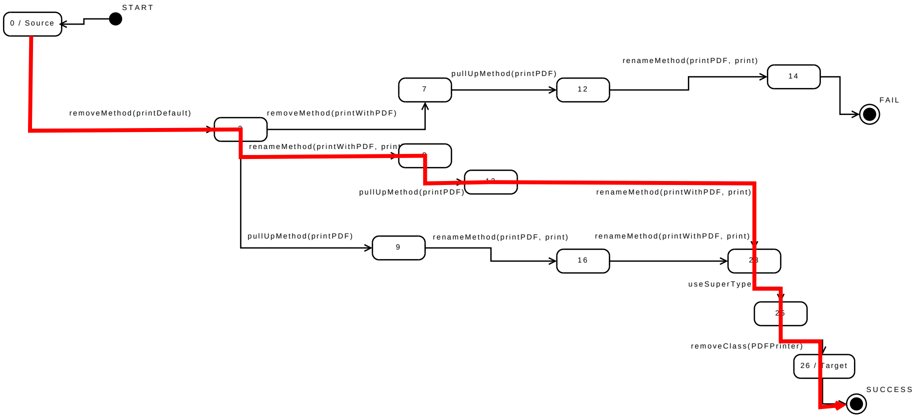
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- The first sequence found differs from the one found manually

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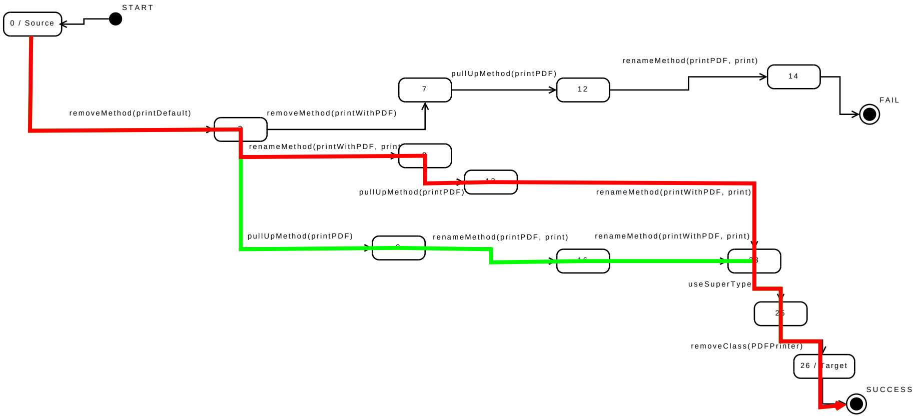
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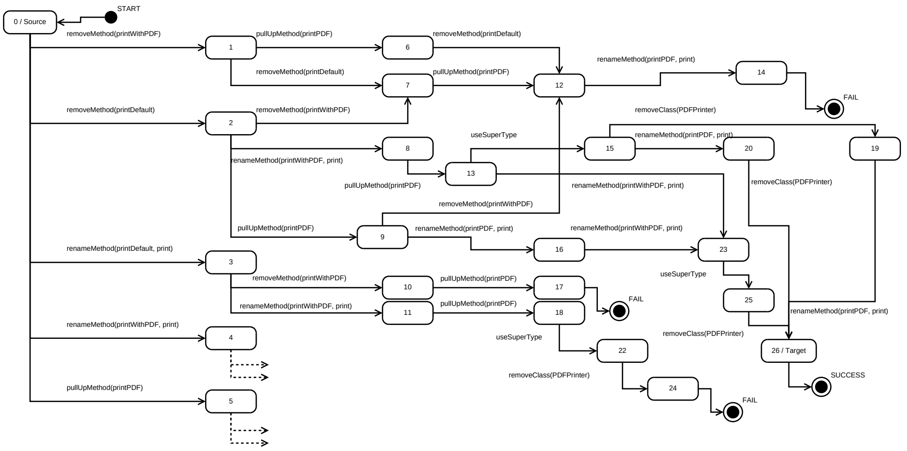
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25

- We can obtain the whole state space. In this case, it is finite.

Our results

- There are not many works dealing with finding refactorings.
- These efforts focus in mining refactorings mixed with other changes.
- We focus on the detection of behaviour-preserving evolution. Changes are only refactorings.

- We can deal with multiple refactoring changes applied to the same piece of code.
- We can deal with renamings.
- The structural representation can be as detailed as needed to support refactorings at any abstraction level.

- We have explored the possibilities of our approach.
- Many ways of improving it to solve the open problems.

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- **Problem:**
  - Our searching algorithm is only partially correct.
  - If the state space is not finite the termination can not be guaranteed.
- **Solutions:**
  - Use of refactorings' pre and postconditions
  - Formulate the searching rules to limit the search space size.
  - Store states to not check the same state twice.
  - More heuristics.

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  - AGG lacks some key features needed, path expressions.
  - Representing context:
    - Limitation to a single, finite context.
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Problems and Limitations: Complex Refactorings

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  - Difficult to represent rules for refactorings which take an undetermined number of steps.
  - Lack of a full transformation control in AGG,
- **Solutions:**
  - Last versions of AGG implement a better execution control.
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Future Work

- **Analysis of the state space:** Can we formulate the refactoring searching rules to restrict the search space to a finite state space?
- **Searching rule catalog:** Improving rules with features in the newest AGG's versions. Implementing rules to search more refactorings.
- **Test other GT tools:** To improve efficiency, expressiveness, . . .
- **Full Java model**: Use another metamodel which can represent full Java programs.
- **Scalability:** Measuring the scalability and reliability of our technique over industrial-size systems.
- **Tool:** Eclipse plugin front-end to translate code to graphs, to launch AGG and to show up the refactoring sequence in a more convenient way.

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