Proof Re-Use in Java Software Verification

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Goal: Proof Re-Use for Java Software Verification

Why Re-Use Proofs?

Typical use case: verification **fails**.
➥ the program (the specification?) has to be amended; user starts verification from scratch...

A re-use facility would recycle unaffected proof parts, saving efforts, user interaction.

The Re-Use Task

Bird’s eye view:

Frontend: Source	Backend: Proof
old source	old proof
new source	?

Some Re-Use Scenarios

What can happen?

- statement insertion
- statement deletion
- change in expression
- ...

Imagine

You want to “add a case”...

Related Efforts

Different approaches to re-use

- Abstraction: proof planning, analogy reasoners
- Construction: KIV
- Incremental fixed: Isabelle
- Incremental similarity-based: us

What we don't want to do

- Learn from proofs in general

The Re-Use Framework

Keep a list of **candidates** $\hat{=}$ marked nodes in template

❶ Match candidates against open goals ➥ possible **re-use units**

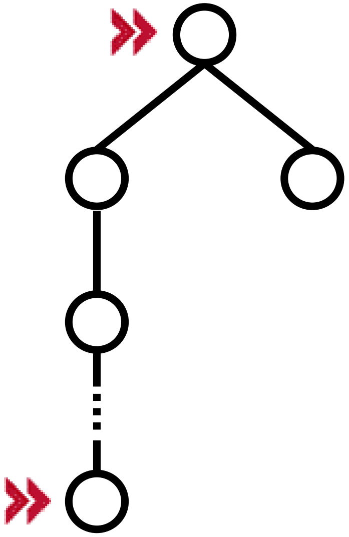
❷ Select re-use unit with best score, apply it

❸ Advance markers in the template proof

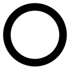
Questions:

Where do the candidates originally come from?
What if nothing works?
Where does the new proof "stuff" come from?

In Action

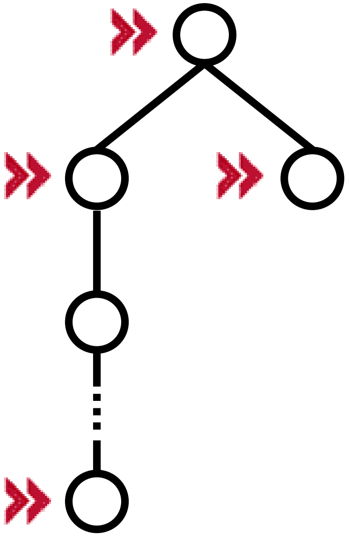


Template

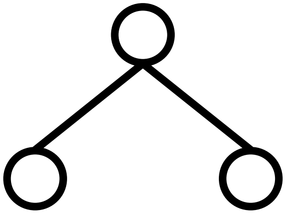


Target

In Action

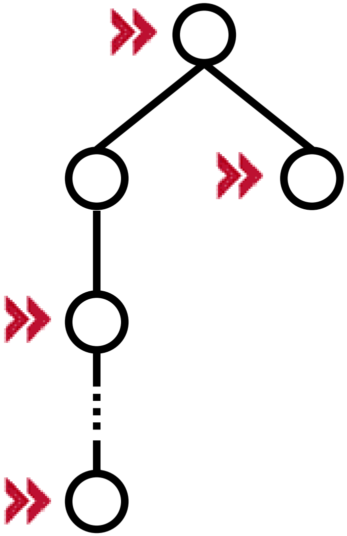


Template



Target

In Action



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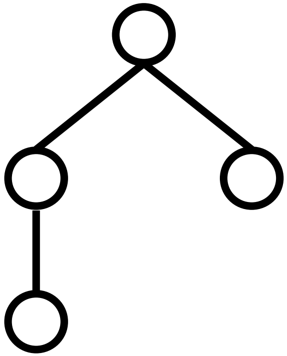

Target

Formula Similarity Function

Beyond copy & paste: Identify similar situations by comparing rule application foci.

Three cases:

- Symbolic execution rules: Eugene Myers **diff** algorithm on the programs in focus
- First-order rules
- Focus-less rules

We install a **cut-off threshold**.

Program Abstractions

From programs

$$\alpha : \left\{ \begin{array}{l} \texttt{int x; int result;} \\ \texttt{result = x/x;} \end{array} \right.$$

$$\beta : \left\{ \begin{array}{l} \texttt{int x; int result;} \\ \texttt{if (x==0) result=1; else result=x/x;} \end{array} \right.$$

To sequences of statement signatures

$$A : \left\{ \begin{array}{l} \texttt{LocalVarDecl}, \texttt{LocalVarDecl}, \\ \texttt{Assignment(int)} \end{array} \right.$$

$$B : \left\{ \begin{array}{l} \texttt{LocalVarDecl}, \texttt{LocalVarDecl}, \\ \underline{\texttt{If}}, \texttt{Assignment(int)}, \underline{\texttt{Assignment(int)}} \end{array} \right.$$

Program Similarity Function

Let $E(A, B) = e_1\, e_2 \cdots e_n$ be the minimal edit script for the abstractions A, B.

The *similarity score* of α, β:

$$\delta(\alpha, \beta) = \delta(A, B) \quad = \quad - \sum_{e_i \in E(A,B)} P(e_i)$$

where the penalty $P(e)$ for an edit command e is

$$P(e) \quad = \quad \begin{cases} \displaystyle\sum_{k=1}^{t} \frac{0.75}{x+k} & \text{if } e = x\; I\; b_1\, b_2 \cdots b_t \\ \displaystyle\frac{1}{x+1} & \text{if } e = x\; D \end{cases}$$

First-Order Formula Similarity

❶ abstraction step

❷ compare foci

❸ difference detection on whole formulas

❹ compare focus position in formula

Augmenting With Connectivity

Introduce parent relationship for formulae. Prefer proof steps that respect it.

Feedback loop: amplifies good decisions... unfortunately bad decisions too.

Prevents related proof steps being torn apart.

On the Frontend

Obtain source code diffs from CVS.

Mark statement after each difference hunk.

```
  int x;
  int result;
+ if(x==0) {
+    result=1;
+ } else {
     result=x/x;
+ }
```

Why This Works

❶ Proof structure follows program structure

❷ Similar situations warrant similar actions

❸ Calculus to a high degree "locally deterministic"

- ② Symbolic execution rules only applicable to the active statement
- ③ No split rule ➥ active statements do not multiply

At Last

DEMO

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