Identifying change patterns in software history

Jason Dagit | Galois, Inc

Motivation

Tools to detect changes exist.

For example, traditional line-based diff:

- Pro: diff is very general and programming language agnostic
- Con: diff is not structurally aware:

```
if( foo ){
  bar;
}
```

```
if( foo )
{
  bar;
}
```

We need tools for interpreting changes.

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Motivation

Common looping pattern with loop counter initialized to zero:

```
for (□ = 0; □ < □; □) {
    □
}
```

We also want to see how source code *changes*.

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Example from Clojure: Related edits

Our tool found these related edits:

PersistentArrayMap.java

```
 public Object kvreduce(IFn f, Object init){
     for(int i=0;i < array.length;i+=2){
         init = f.invoke(init, array[i], array[i+1]);
-            if(RT.isReduced(init))
-                return ((IDeref)init).deref();
         }
     return init;
 }
```

PersistentHashMap.java

```
 public Object kvreduce(IFn f, Object init){
-    for(INode node : array){
-        if(node != null){
+    for(INode node : array)
+        {
+        if(node != null)
             init = node.kvreduce(f,init);
-                if(RT.isReduced(init))
-                    return ((IDeref)init).deref();
-                }
-            }
+        }
     return init;
 }
```

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Approach

Key Idea: We can find *structural patterns* by generalizing *sufficiently similar* difference trees.

- Difference trees computed using structural diff of AST
- Similarity is measured using a tree edit distance score
- Generalization is accomplished through *antiunification*

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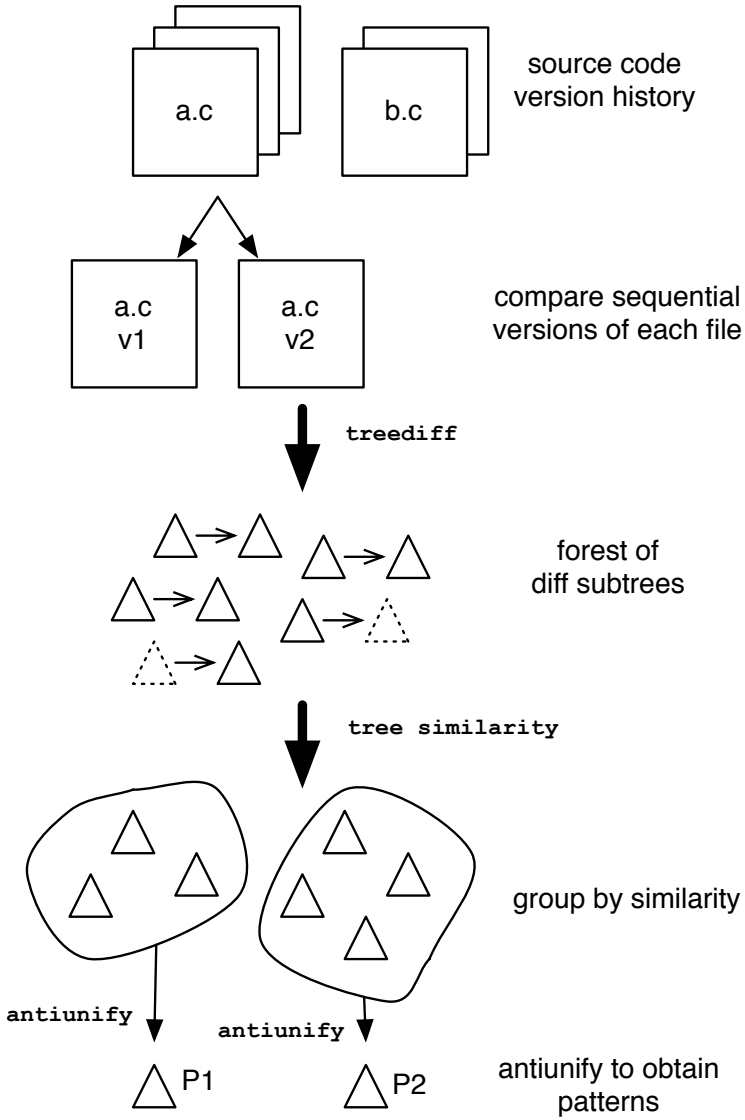
Workflow



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```
i++;
```

```
AAppl "ExpStmt"
  [AAppl "PostIncrement"
    [AAppl "ExpName"
      [AAppl "Name"
        [AList
          [AAppl "Ident" [AAppl "\"i\"" []]]]]]]
```

Generic tree structure—programming language agnostic.

Easy to modify parsers to generate ATerms.

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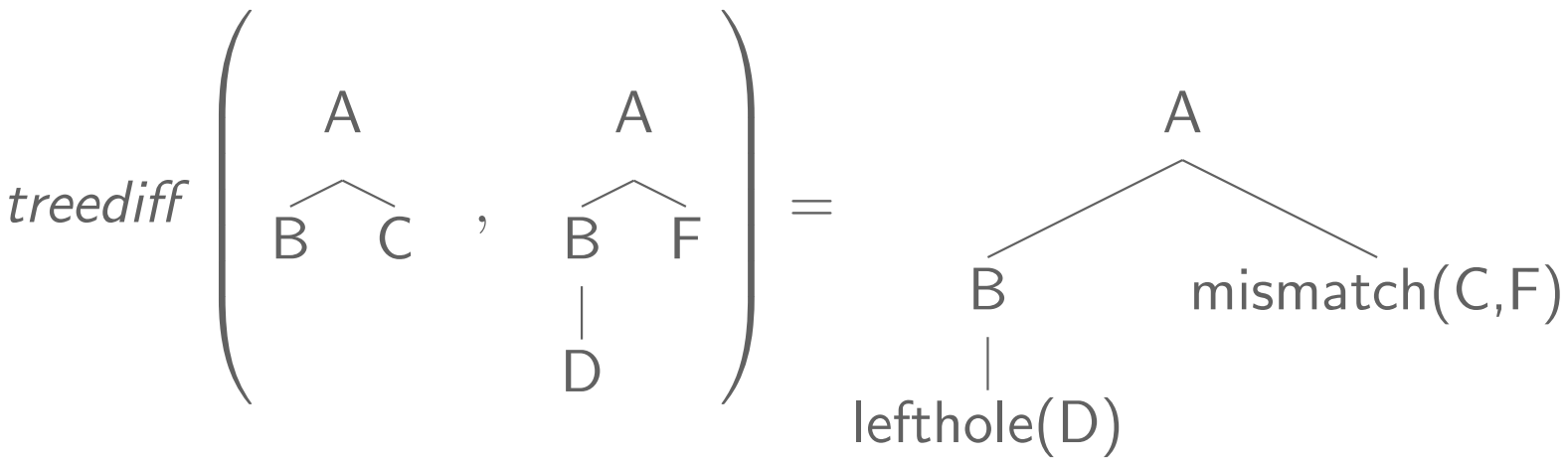
Structural diff



Keep just the differences with a bit of context:

Output also gives us an edit distance.

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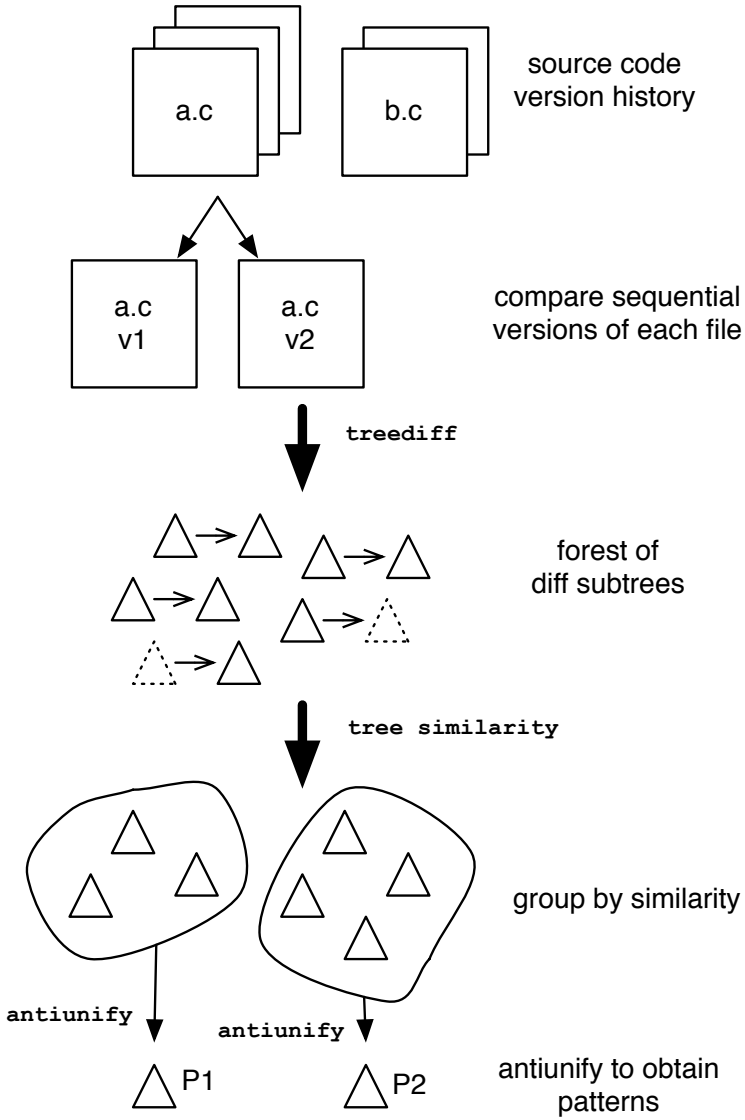
Workflow



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Similarity grouping

We define the similarity score by:

$$\Delta(t_a, t_b) := \frac{min(d(t_a, t_b), d(t_b, t_a))}{max(|t_a|, |t_b|)}$$

where d is the tree edit distance score.

Similarity matrix D given by $D_{ij} = \Delta(t_i, t_j)$.

Given threshold $\tau \in [0, 1]$ we say t_i and t_j are similar if $D_{ij} \geq \tau$.

Group trees such that all elements in the group are within τ.

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ANTLR similarity groups with $\tau = 0.01$

10 similarity groups from ANTLR source, when $\tau = 0.01$:

7 are patterns:

```
□;

if( □ ) □;

if( □ ) { □ } □;

return □;

for( □ □ : □ ) □;

for( □ = □; □ < □; □ ) □;

throw RuntimeException( □ + □ );
```

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ANTLR similarity groups with $\tau = 0.01$

3 are constants (no □s):

```
try {
  walker.grammarSpec();
} catch (RecognitionException re){
  ErrorManager.internalError("bad grammar AST structure",re);
}
```

```
while(sp !=
      StackLimitedNFAToDFAConverter.NFA_EMPTY_STACK_CONTEXT)
{
  n++;
  sp = sp.parent;
}
```

```
switch(gtype) {
  case ANTLRParser.LEXER_GRAMMAR:
    return legalLexerOptions.contains(key);
  case ANTLRParser.PARSER_GRAMMAR:
    return legalParserOptions.contains(key);
  case ANTLRParser.TREE_GRAMMAR:
    return legalTreeParserOptions.contains(key);
  default:
    return legalParserOptions.contains(key);
}
```

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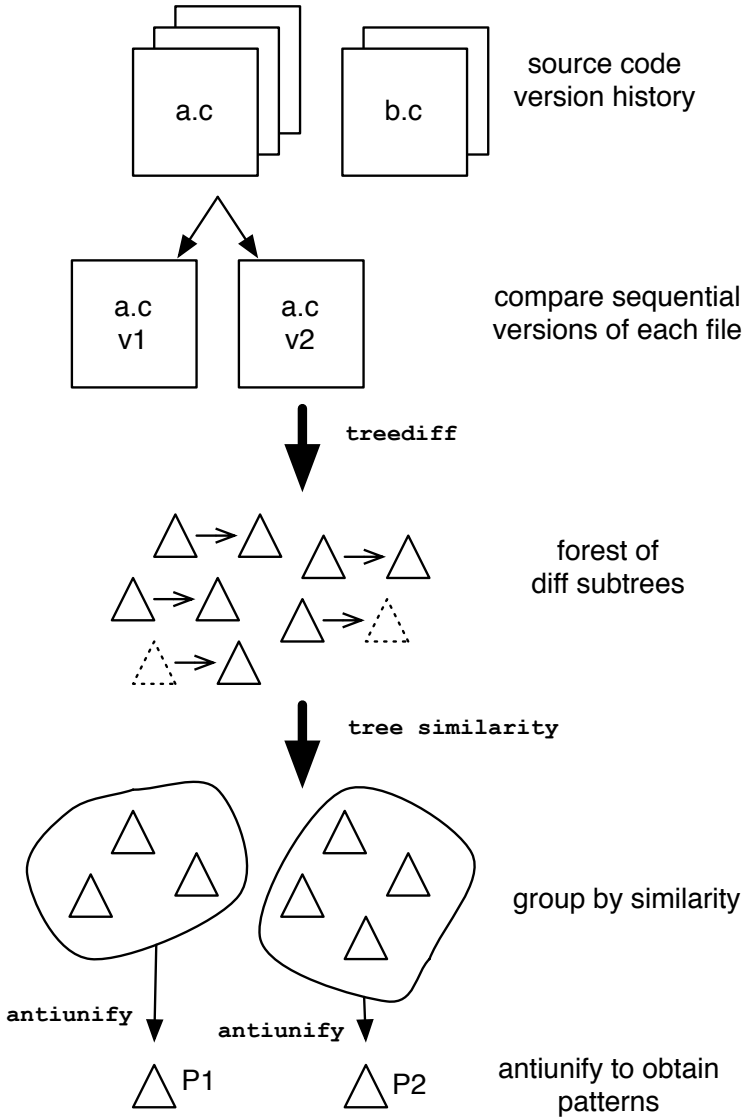
Workflow



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$$au\left(\begin{array}{c} \text{A} \\ \text{B}\quad\text{C} \end{array}\ ,\ \begin{array}{c} \text{A} \\ \text{B}\quad\text{F} \\ \text{D} \end{array}\right) = \left(\begin{array}{c} \text{A} \\ \square_1\quad\square_2 \end{array}\ , subst_l, subst_r\right)$$

where,

$$subst_l = \{\square_1 \mapsto B\ ,\ \square_2 \mapsto C\}$$

$$subst_r = \{\square_1 \mapsto \begin{array}{c} \text{B} \\ \text{D} \end{array}\ ,\ \square_2 \mapsto F\}$$

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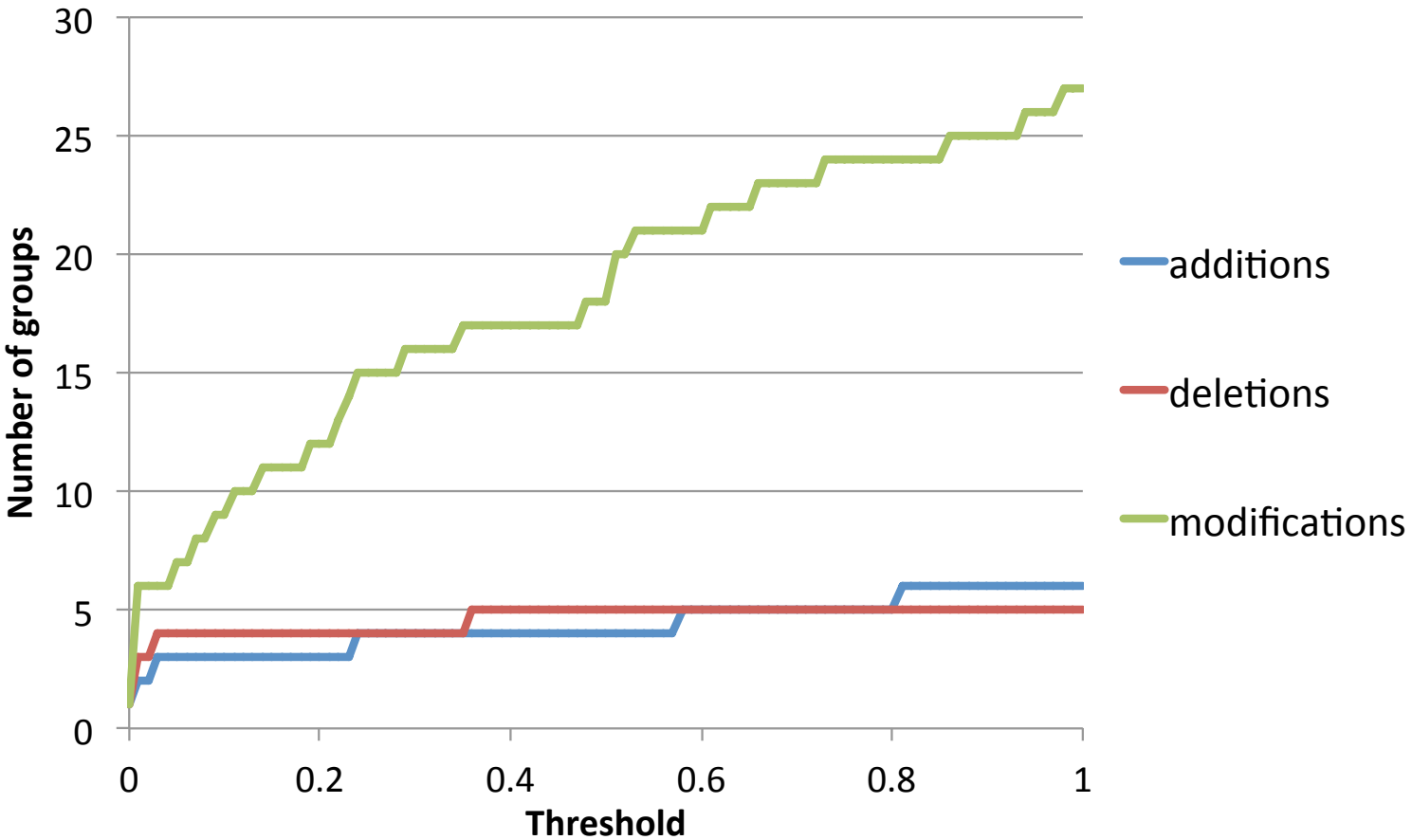
Similarity groups versus threshold

What happens to similarity groups when we vary the threshold?



Number of additions, deletions, and modifications by threshold for the Clojure source.

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Patterns as a function of threshold

Generic Loop pattern, $\tau = 0.15$:

```
for (□ = □; □ < □; □) {
    □
}
```

Loop counter is initialized to zero, $\tau = 0.25$:

```
for (□ = 0; □ < □; □) {
    □
}
```

Loop termination criteria becomes more specific, $\tau = 0.35$:

```
for (□ = 0; □ < □.□; □) {
    □
}
```

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Future work

- We only consider structural patterns
  - Example: We don't detect design patterns
- Not semantically aware
  - Example: changing the name of a loop variable leads to □
- Generate rewrite rules based on before and after patterns
- Use patterns for searching as a structural `grep`-like mechanism
- Correlate patterns with bug fixes

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Thank you!

Questions?

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