Mining Patterns in Source Code using Tree Mining Algorithms

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Outline

Introduction

Frequent tree mining

Constraint-based maximal tree mining

Empirical evaluation

Conclusion and future work

Introduction

Discovering source code patterns: coding idioms, usage protocols

Source code patterns can be used to build intelligent systems to support maintaining and developing big software projects

```
public final class ReturnCountCheck extends AbstractFormatCheck {
   ...
   @Overwrite
   public int[] getDefaultTokens(){
      return new int[] {
         TokenTypes.CTOR_DEF,
         TokenTypes.METHOD_DEF,
         TokenTypes.LITERAL_RETURN,
         };
      }
   ...
   @Overwrite
   public int[] getRequiredTokens() { … }
   ...
   @Overwrite
   public void visitToken(DetailAST aAST){
      switch (aAST.getType()) {
         case TokenTypes.CTOR_DEF:
         case TokenTypes.METHOD_DEF:
         ...
         break;
         ...
         default:
         ...
         }
   }
   ...
   @Overwrite
   public void leaveToken(DetailAST aAST){
      switch (aAST.getType()) {
         case TokenTypes.CTOR_DEF:
         case TokenTypes.METHOD_DEF:
         ...
         default:
         ...
         }
   }
   ...
}
```

Example of pattern in source code

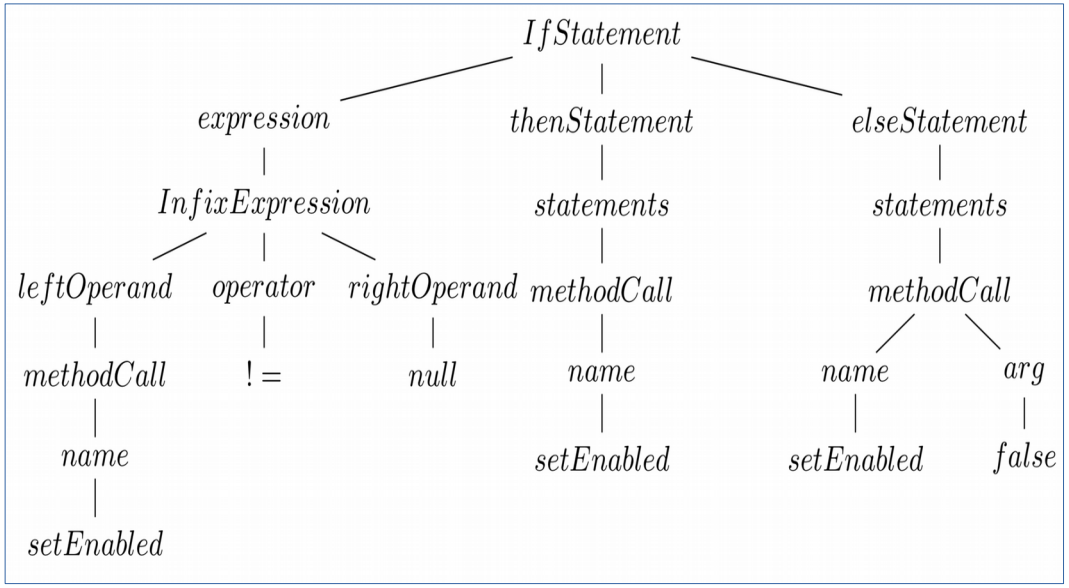
Source code patterns

- Source code are represented by Abstract Syntax Trees (ASTs)
- Source code patterns correspond to fragments that occur frequently
- Discover source code patterns: frequent tree mining algorithms

Source code pattern

```
protected void updateEnabledState() {
    if (getView() != null) {
        setEnabled(...);
    } else {
        setEnabled(false);
    }
}
```

Tree representation



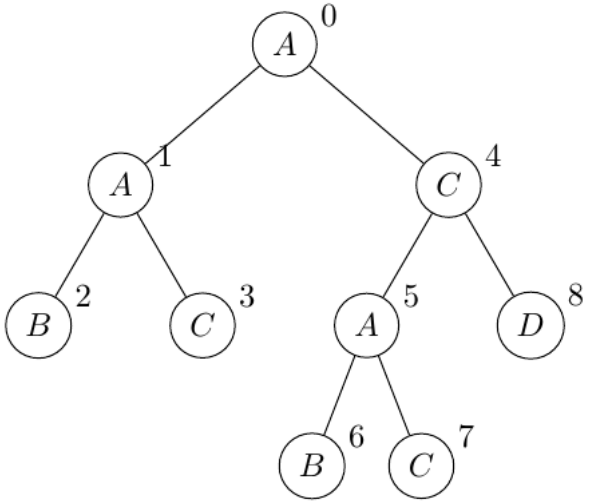
Frequent tree mining

Ordered, rooted tree mining

- FREQT, a depth-first search tree mining algorithm
- Limitation: finds large numbers of patterns

Other approaches:

- Constraint-based pattern mining
- Condensed representations, e.g., closed, maximal frequent tree mining
- Statistically motivated pattern set mining
- → *not designed to work on ASTs*



Example of ordered, rooted tree

Our proposal

Novel constraint-based tree mining algorithm, specifically designed for the analysis of code repositories

Our approach based on FREQT with these extensions:

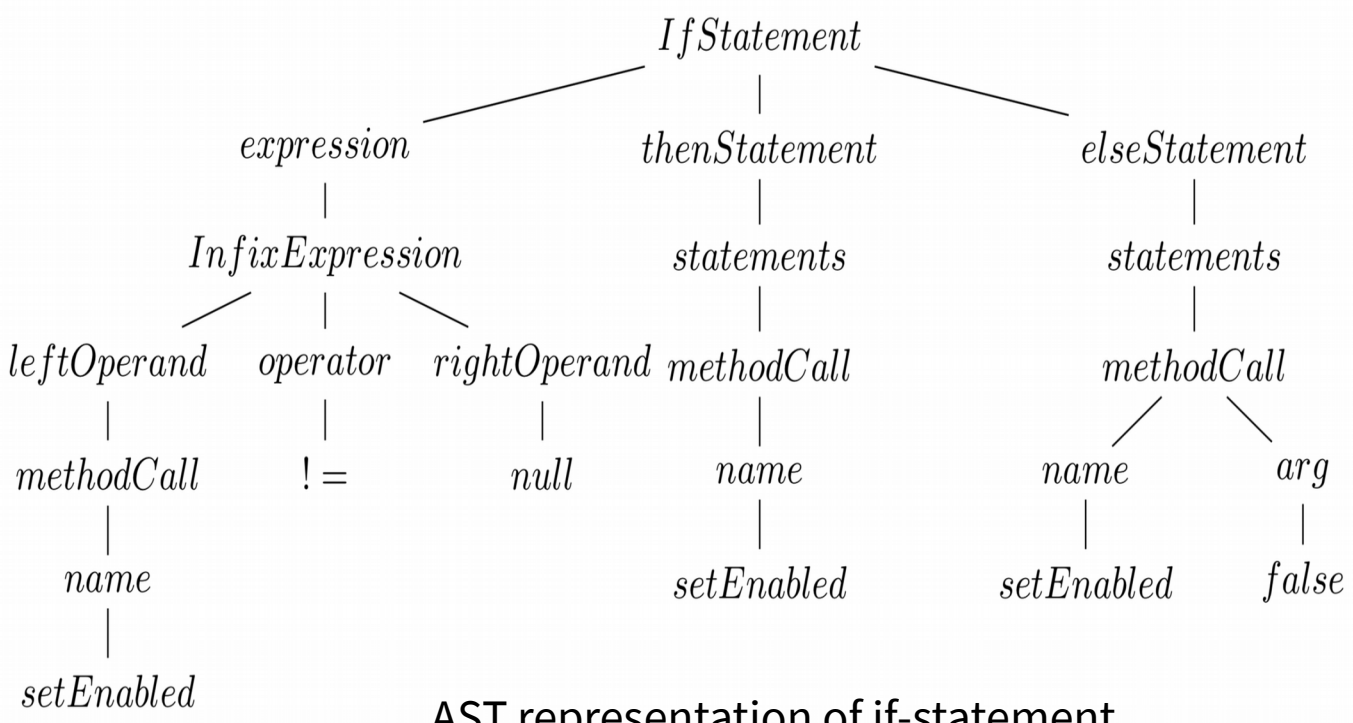
(i) **constraint-based data mining**, in which additional constraints are imposed on the patterns to be found

(ii) **maximal frequent subtree mining** to ensure that a condensed representation of only large patterns is found

Interesting source code patterns

Reflect structure of programming language

Total number of nodes/leafs in a pattern sufficiently large



AST representation of if-statement

Proposed constraints

***C0*: minimum support**

***C1*: maximum size of the pattern**

***C2*: minimum size of the pattern**

***C3*: limit the set of labels allowed to occur in the root of patterns**

***C4*: provide labels forbidden from occurring in the pattern**

***C5*: limit the number of siblings in a pattern that can have the same label**

***C6*: all leaf nodes in a pattern must have a label that is included in leafs of data**

***C7*: do not allow to produce patterns that missing mandatory labels**

Constraint-based maximal tree mining algorithm

FREQTALS algorithm

input: tree data $\mathcal{D}$, constraints C_0-C_5

output: a set of maximal patterns

Step 1: using modified $\mathcal{FREQT}$ to find frequent patterns under the given constraints

Step 2: growing the patterns found under constraint as large as possible, and return the maximal patterns among these large patterns

Empirical evaluation

Dataset:

- Programming language: Java
- Project: CheckStyle (including 270 classes)

Configurations:

Constraint	Variable	Value
C0	Minimum Support Threshold	5
C1	Maximum # of Leaves	4
C2	Minimum # of Leaves	2
C3	Root Labels	TypeDeclaration, Block
C4	Black List Labels	Javadoc, Modifiers, Annotations, ...
C5	Maximum # of Similar Siblings	10

Qualitative Analysis

```
public final class ReturnCountCheck extends AbstractFormatCheck {
   ...
   @Overwrite
   public int[] getDefaultTokens(){
      return new int[] {
         TokenTypes.CTOR_DEF,
         TokenTypes.METHOD_DEF,
         TokenTypes.LITERAL_RETURN,
         };
      }
   ...
   @Overwrite
   public int[] getRequiredTokens() { … }
   ...
   @Overwrite
   public void visitToken(DetailAST aAST){
      switch (aAST.getType()) {
         case TokenTypes.CTOR_DEF:
         case TokenTypes.METHOD_DEF:
         ...
         break;
         ...
         default:
         ...
         }
   }
   ...
   @Overwrite
   public void leaveToken(DetailAST aAST){
      switch (aAST.getType()) {
         case TokenTypes.CTOR_DEF:
         case TokenTypes.METHOD_DEF:
         ...
         default:
         ...
         }
   }
   ...
}
```

Pattern 34: An instance of Checkstyle's Visitor design pattern

```
private void visitMethod(final DetailAST aMethod)
   ...
   DetailAST child = objBlock.getFirstChild();
   while (child != null) {
      if (child.getType() == TokenTypes.METHOD_DEF) {
         ... }
      child = child.getNextSibling();
}
```

Pattern 27: AST traversal.

```
@Override
public void leaveToken(DetailAST aAST) {
   switch(aAST.getType()) {
      case TokenTypes.OBJBLOCK:
      case TokenTypes.SLIST:
      case TokenTypes.LITERAL_FOR:
      ...
}
```

Pattern 9: Check for different blocks.

```
public int[] getDefaultTokens(){
    return new int[] {
       TokenTypes.ASSIGN,            // '='
       TokenTypes.DIV_ASSIGN,        // "/="
       TokenTypes.PLUS_ASSIGN,       // "+="
       …
    };
}
```

Pattern 18: Method structure.

```
private boolean checkParams(DetailAST aMethod){
   ...
   if ((aAST.getType() == TokenTypes.VARIABLE_DEF) ||
       (aAST.getType() == TokenTypes.PARAMETER_DEF))
      {
        …
      }
```

Pattern 140: IF Statement.

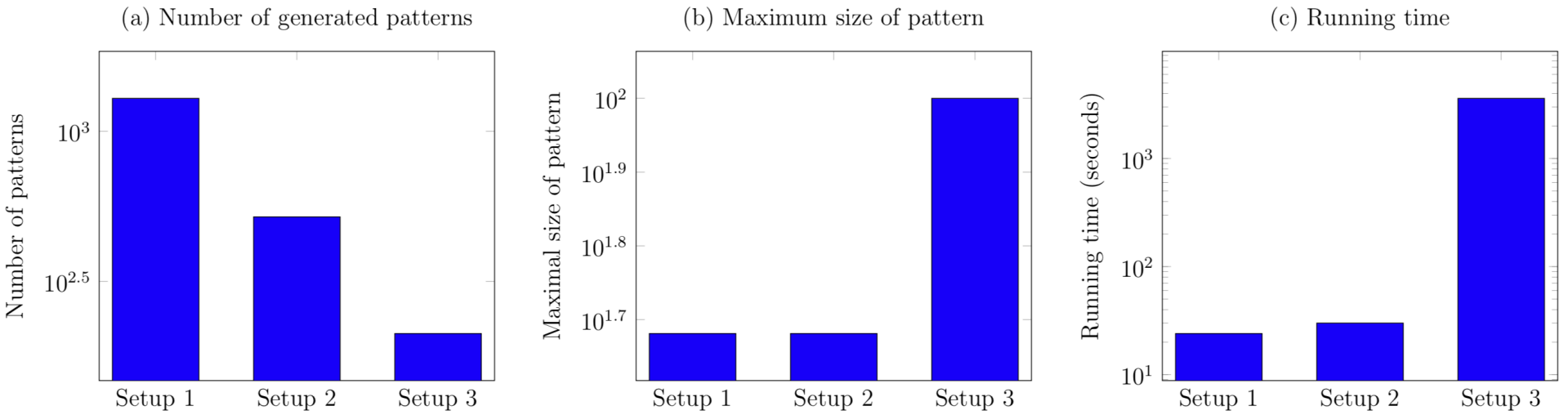
Quantitative analysis

1. Compare to the original FREQT algorithm

   FREQTALS : 1,288 patterns in 23 seconds

   Original FREQT : 717,859 patterns in 60 minutes

2. Evaluate the extensions of FREQTALS



Conclusion and Future work

Conclusion:

- discovered patterns highlight relevant code regularities
- patterns found are significantly larger
- amount of output patterns is significantly smaller
- configurations are easily adapted to other programming languages

Future work:

- employ FREQTALS on legacy programming languages, e.g., COBOL
- explore more details of the quality of patterns
- improve the scalability
- define guidelines to setup configurations

Thank for your attention!