Mapping Features to Automatically Identified Object-Oriented Variability Implementations

The case of ArgoUML-SPL

Johann Mortara [1] , Xhevahire Tërnava [2] , Philippe Collet [1]

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Variability-Rich Systems with a Single Code Base

16.000 options managed
in 25M LoC [Acher2018]

#ifdef

24.000 different platforms in
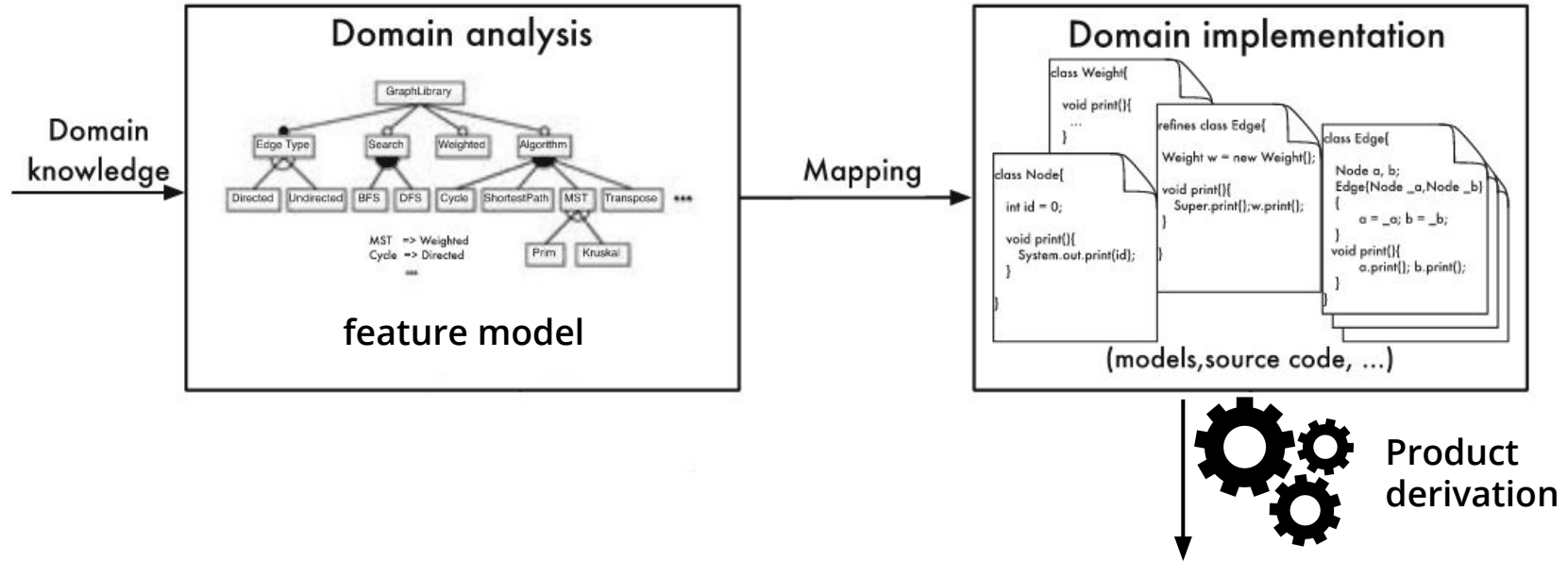2015 [Open2015]

Object-orientation

2.000+ options generating variants for
platforms, security levels... [Acher2018]

Object-orientation

and many variability implementation techniques...

Problem: How to master them as SPL?

How to engineer an SPL?

Forward-engineering:

<p align="center">Feature model → Domain implementation</p>

Mapping between feature model and features is done **during the implementation**

How to engineer an SPL?

Forward-engineering:

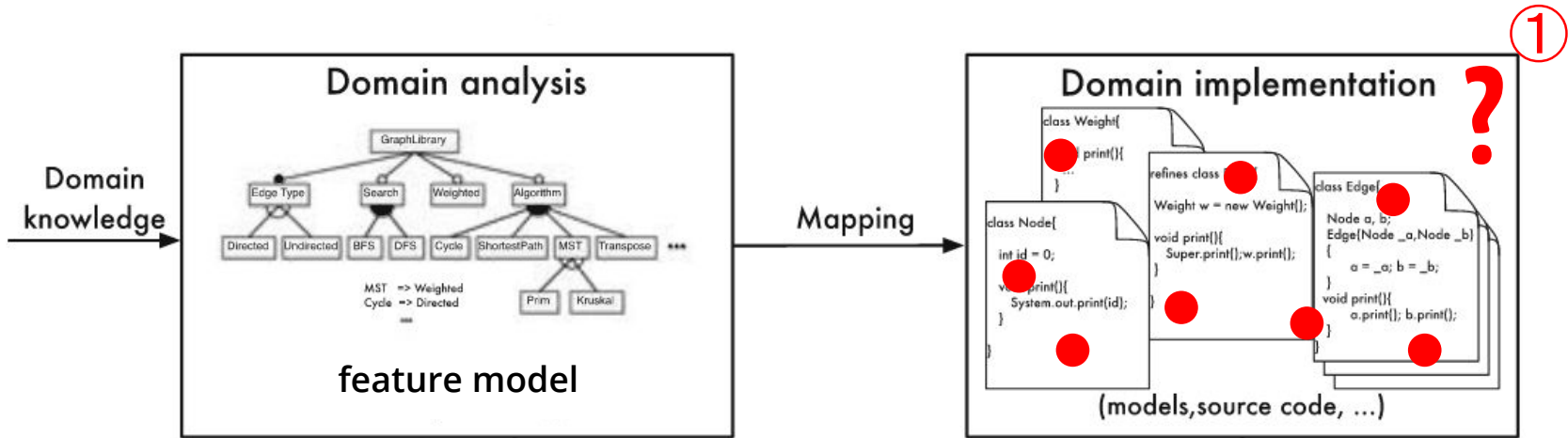Feature model $\rightarrow$ Domain implementation

Mapping between feature model and features is done **during the implementation**

Reverse-engineering:
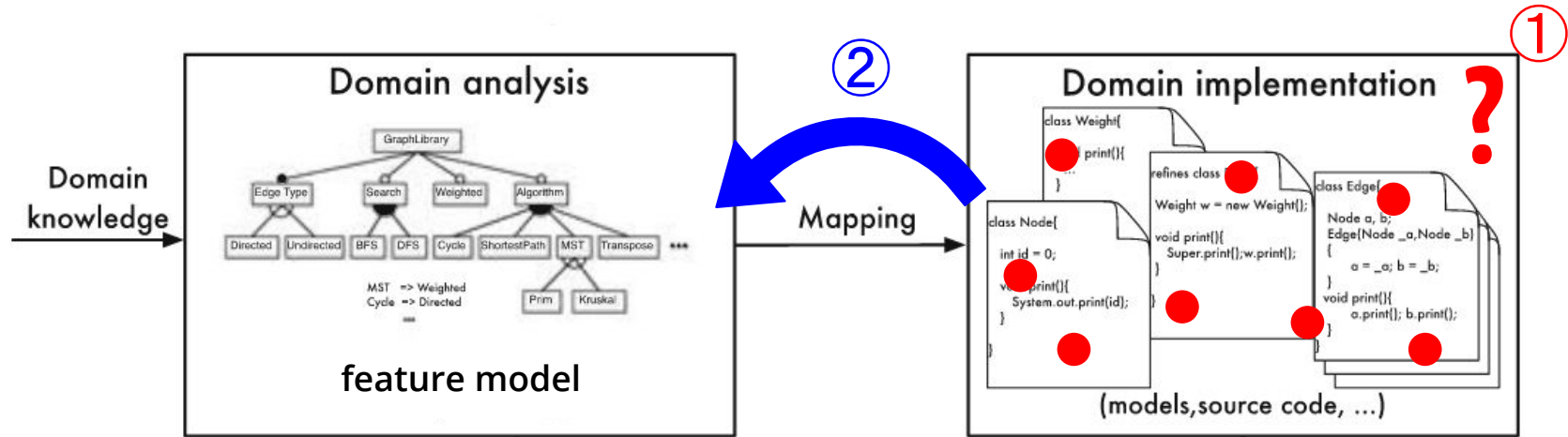
Feature model $\leftarrow$ Domain implementation

Need to extract the features and build a mapping with the feature model, or build it

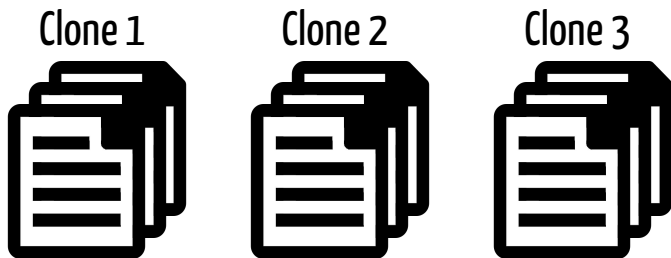# Problem 1: How to identify variability implementations in an existing codebase?

Problem 1: How to identify variability implementations in an existing codebase?

Problem 2: How to map these variability implementations to domain features?

State of the art on variability implementations detection

Context: <u>projects clones</u>

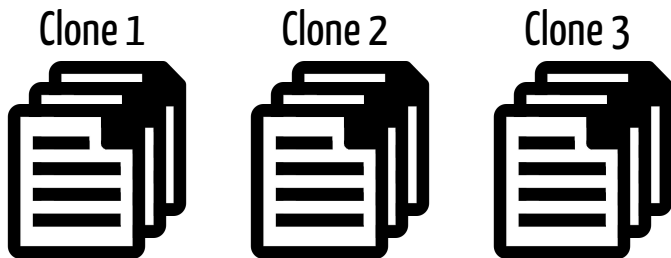Clone 1   Clone 2   Clone 3

<u>Detection method:</u>

Comparison between clones and mapping with
the domain features [Wesley2017]

State of the art on variability implementations detection

Context: projects clones

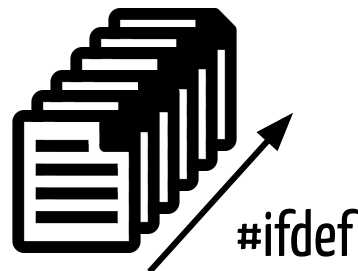Clone 1   Clone 2   Clone 3

Detection method:

Comparison between clones and mapping with the domain features [Wesley2017]

Context: unique codebase and preprocessing directives

#ifdef $\longrightarrow$ variant

#ifdef

Detection method:

Determining the consistency of directives [Liebig2010]

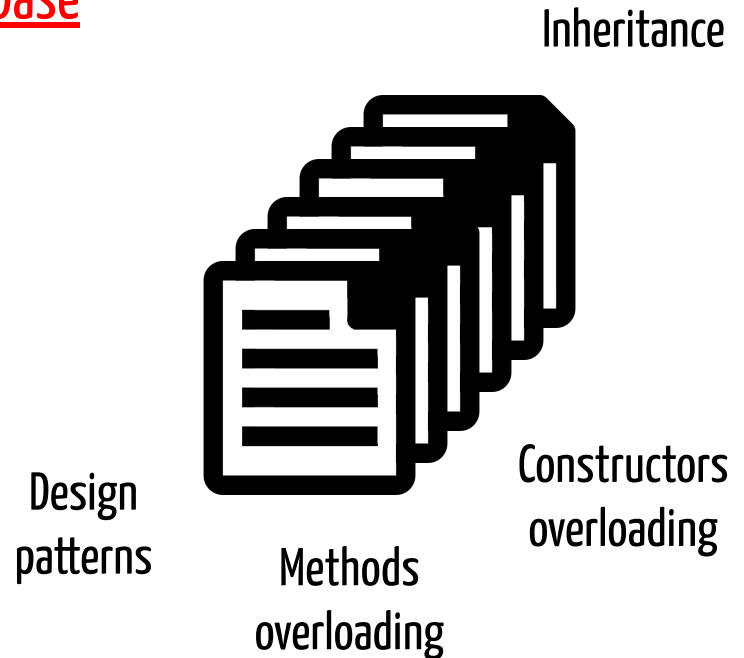# State of the art on variability implementations detection

Our context: large and unique object-oriented codebase

- Several implementation mechanisms
- Variability buried in the code (variation points)

Detection method:

Currently no method

[Lozano2011], [Metzger2014], [Tërnava2017]

Inheritance

Design
patterns

Methods
overloading

Constructors
overloading

Variation points and variants

```java
 1   public abstract class Shape {
 2     public abstract double area();
 3     public abstract double perimeter(); /*...*/
 4   }


 5   public class Circle extends Shape {
 6     private final double radius;
 7     // Constructor omitted
 8     public double area() {
 9       return Math.PI * Math.pow(radius, 2);
10     }
11     public double perimeter() {
12       return 2 * Math.PI * radius;
13     }
14   }
```

```java
15   public class Rectangle extends Shape {
16     private final double width, length;
17     // Constructor omitted
18     public double area() {
19       return width * length;
20     }
21     public double perimeter() {
22       return 2 * (width + length);
23     }
24     public void draw(int x, int y) {
25     // rectangle at (x, y, width, length)
26     }
27     public void draw(Point p) {
28     // rectangle at (p.x, p.y, width, length)
29     }
30   }
```

Variation points and variants

```java
1  public abstract class Shape {
2    public abstract double area();
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4  }
```

```java
5  public class Circle extends Shape {
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12     return 2 * Math.PI * radius;
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```java
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```
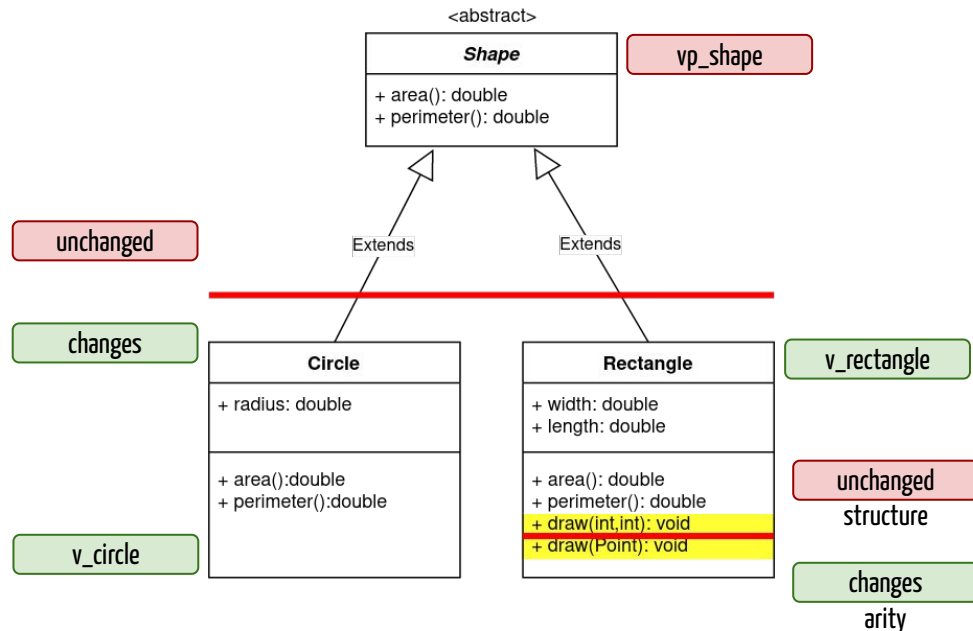
Use of symmetries to detect variability implementations?

Intuition:

- Presence of **symmetries in object-oriented codebases** [Coplien2019] inspired from the theory of centres [Alexander2002]

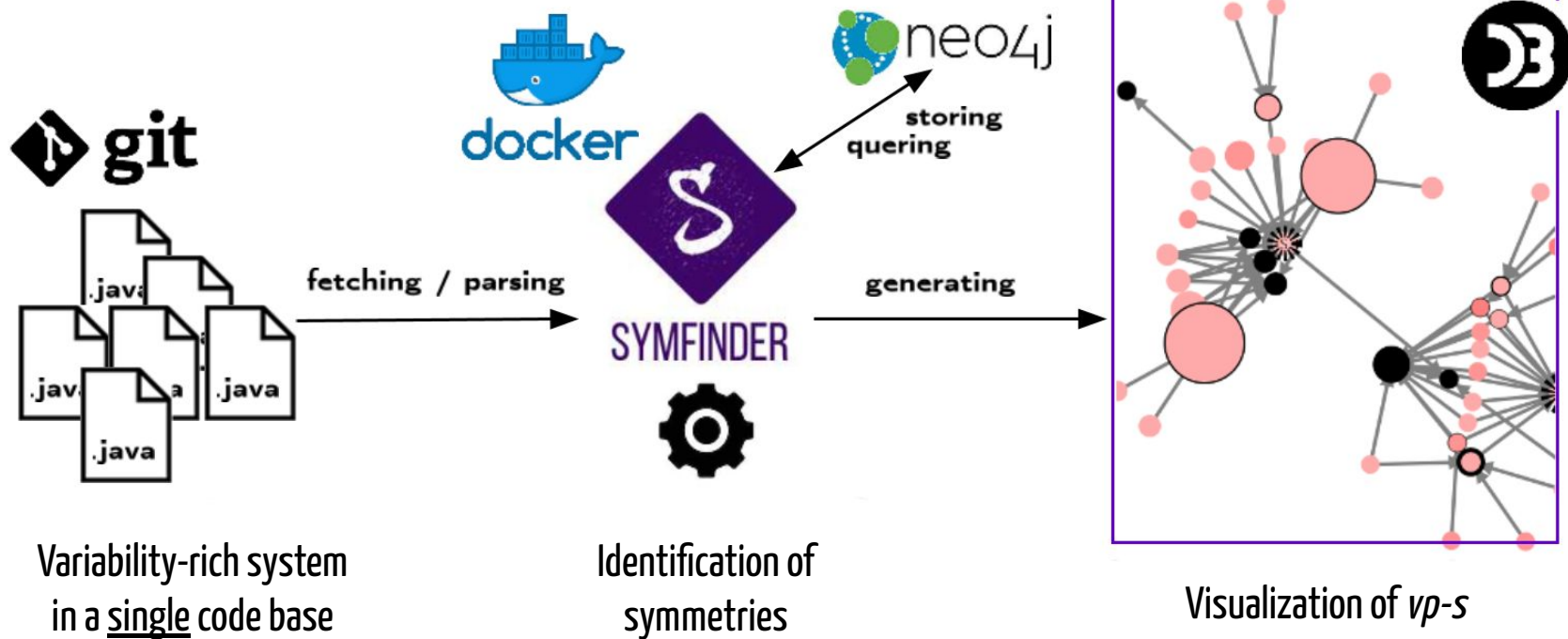- Symmetries present in **mechanisms implementing variability**

Identifying variation points with variants

Variability implementation technique   ⟷   `local symmetry`

-    variation point (commonality)   ⟷   `unchanged`
-    variant (variability)   ⟷   `changes`

Identification through local symmetries in core assets

High density of symmetries ⟶ variability intense places

Xhevahire Tërnava, Johann Mortara, and Philippe Collet. 2019. Identifying and Visualizing Variability in Object-Oriented Variability-Rich Systems. In 23rd International Systems and Software Product Line Conference - Volume A (SPLC '19), September 9–13, 2019, Paris, France. ACM, New York, NY, USA, 12 pages.

symfinder

**Variability-rich system
in a <u>single</u> code base**

**Identification of
symmetries**

Visualization of *vp-s*

Xhevahire Tërnava, Johann Mortara, and Philippe Collet. 2019. Identifying and Visualizing Variability in Object-Oriented Variability-Rich Systems. In 23rd International Systems and Software Product Line Conference - Volume A (SPLC '19), September 9–13, 2019, Paris, France. ACM, New York, NY, USA, 12 pages.

Automatic visualization of *vp-s* with variants
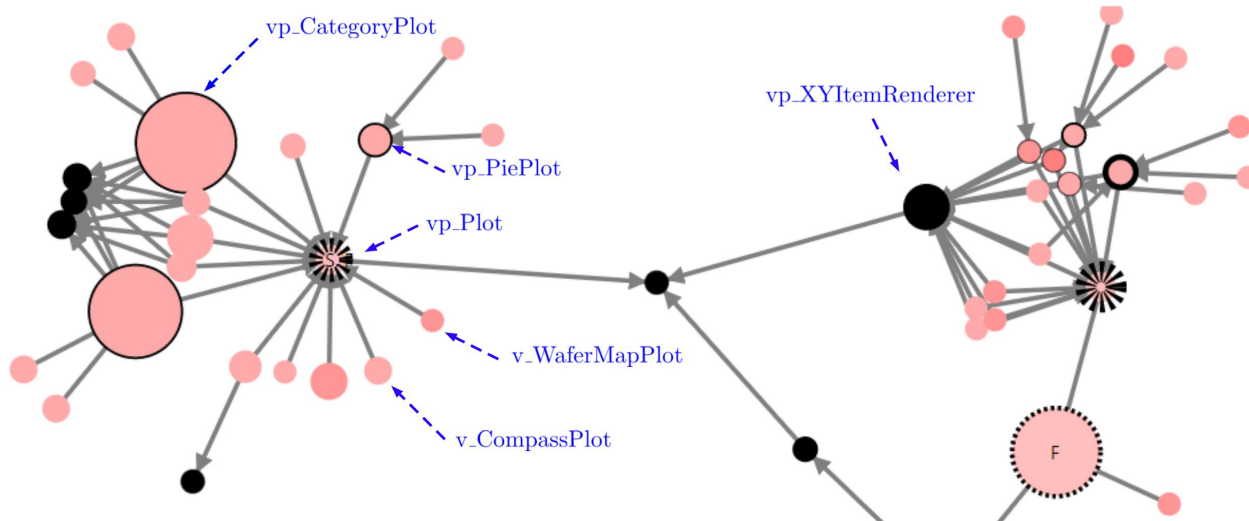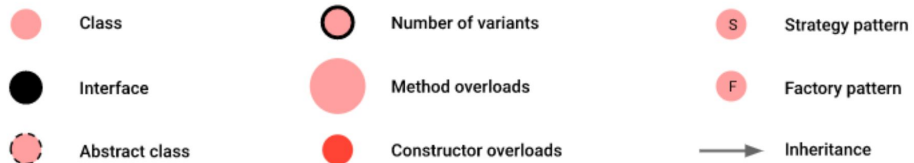
What can be manually found: an example
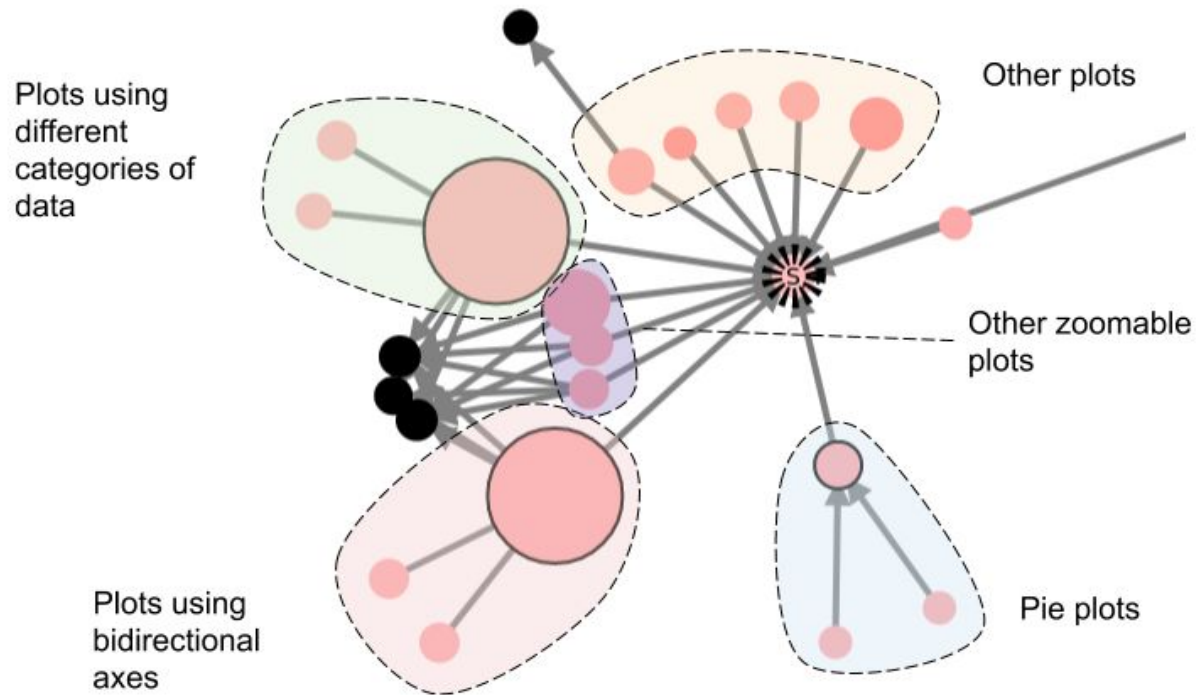
Plots using different categories of data

Other plots

Other zoomable plots

Plots using bidirectional axes

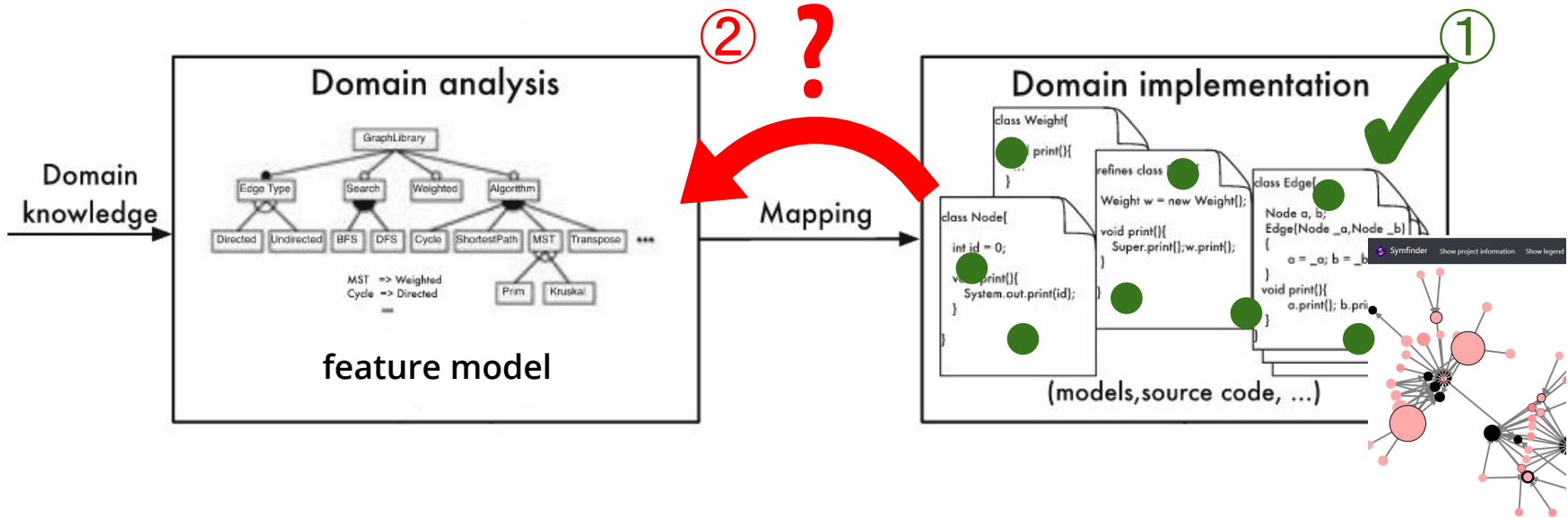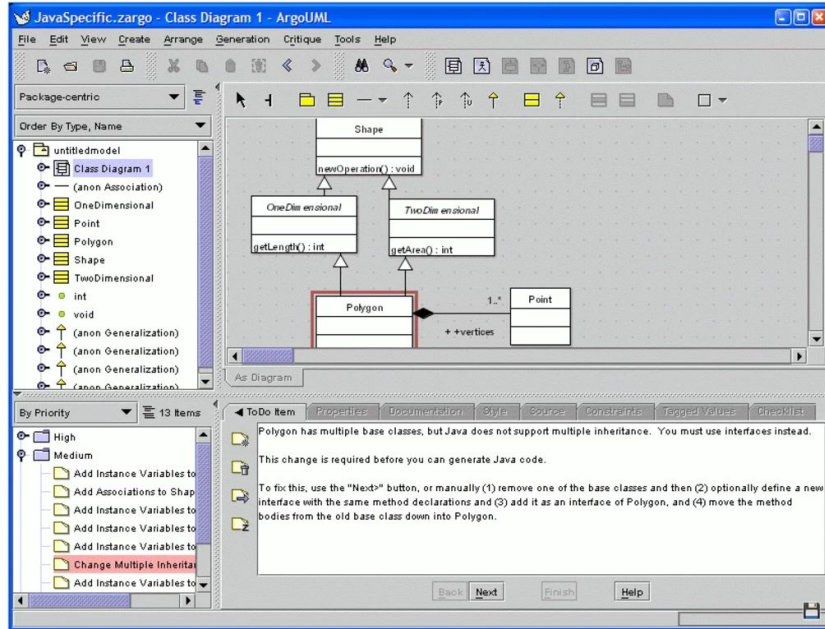Pie plots

Problem 1: How to identify variability implementations in an existing codebase?
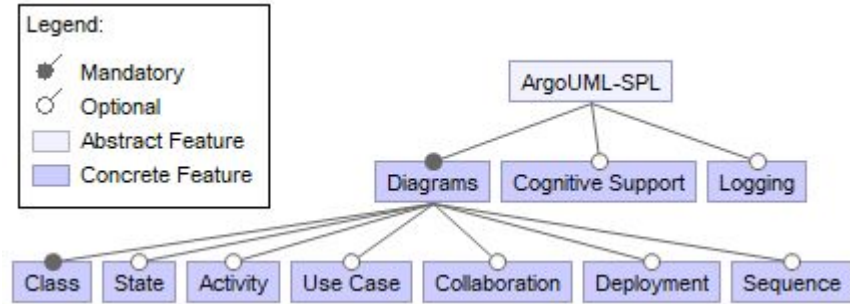
Problem 2: How to map these variability implementations to domain features?
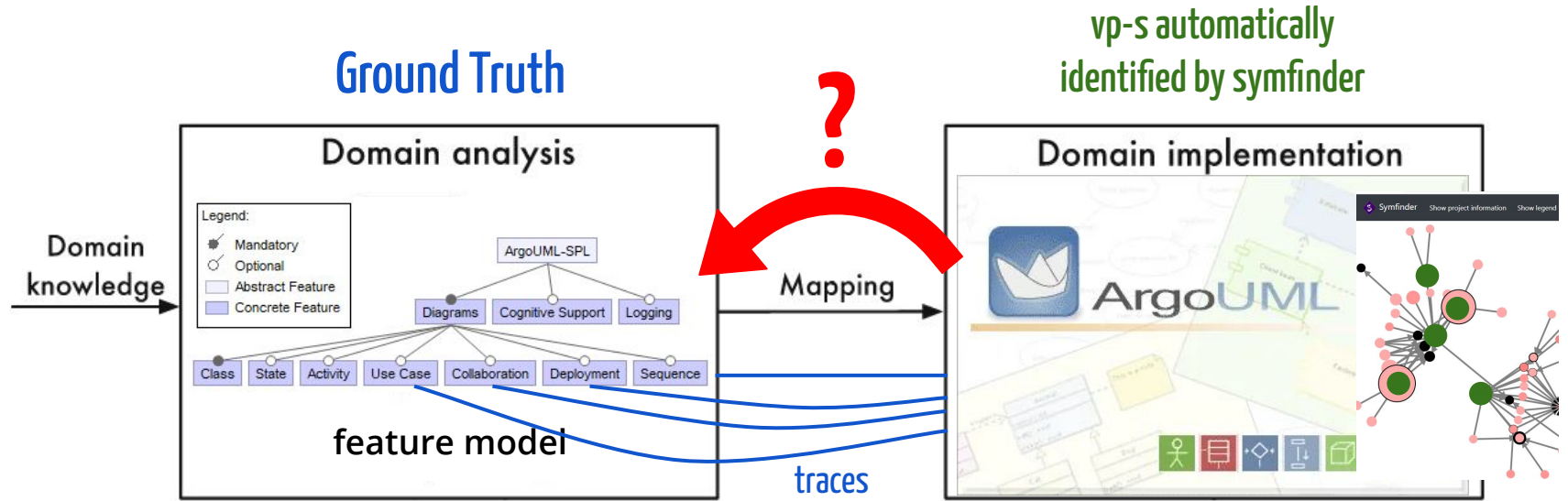
ArgoUML-SPL [Couto2011]

ArgoUML editor

Feature model of ArgoUML-SPL

Question: Are the identified *vp-s* from ArgoUML relevant for a feature mapping?

Ground Truth

vp-s automatically
identified by symfinder

Experimental setup

Ground Truth

Excerpt of traces for USECASE feature

```
org.argouml.uml.diagram.use_case.ui.FigActor
```

```
//#if defined(USECASEDIAGRAM)
//@#$LPS-USECASEDIAGRAM:GranularityType:Package
public class FigActor extends FigNodeModelElement
```

```
org.argouml.uml.diagram.use_case.ui.FigClassifierRole
```

```
//#if defined(SEQUENCEDIAGRAM)
//@#$LPS-SEQUENCEDIAGRAM:GranularityType:Package
public class FigClassifierRole extends FigNodeModelElement
```

.

.

.

Experimental setup

Ground Truth

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//#if defined(USECASEDIAGRAM)
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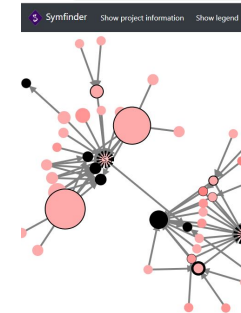
org.argouml.uml.diagram.use_case.ui.FigClassifierRole

```
//#if defined(SEQUENCEDIAGRAM)
//@#$LPS-SEQUENCEDIAGRAM:GranularityType:Package
public class FigClassifierRole extends FigNodeModelElement
```

.
.
.

Excerpt of *symfinder* JSON output

```
{
  "nodes": [
    {
      "types": [
        "CLASS", "METHOD_LEVEL_VP", "VARIANT"
      ],
      "constructorVPs": 1,
      "methodVariants": 0,
      "classVariants": 0,
      "methodVPs": 0,
      "constructorVariants": 3,
      "name":
"org.argouml.uml.diagram.use_case.ui.FigActor"
    },...
  ],
  "links": [
    {
      "type": "EXTENDS",
      "source":
"org.argouml.uml.diagram.ui.FigNodeModelElement",
      "target":
"org.argouml.uml.diagram.use_case.ui.FigActor"
    },...
  ]
}
```

Experimental setup

Ground Truth

Excerpt of traces for USECASE feature

org.argouml.uml.diagram.use_case.ui.FigActor

```
//#if defined(USECASEDIAGRAM)
//@#$LPS-USECASEDIAGRAM:GranularityType:Package
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org.argouml.uml.diagram.use_case.ui.FigClassifierRole

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//#if defined(SEQUENCEDIAGRAM)
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public class FigClassifierRole extends FigNodeModelElement
```

.
.
.

Manual mapping using
Excel formulae

Excerpt of *symfinder* JSON output

```
{
  "nodes": [
    {
      "types": [
        "CLASS", "METHOD_LEVEL_VP", "VARIANT"
      ],
      "constructorVPs": 1,
      "methodVariants": 0,
      "classVariants": 0,
      "methodVPs": 0,
      "constructorVariants": 3,
      "name":
"org.argouml.uml.diagram.use_case.ui.FigActor"
    },...
  ],
  "links": [
    {
      "type": "EXTENDS",
      "source":
"org.argouml.uml.diagram.ui.FigNodeModelElement",
      "target":
"org.argouml.uml.diagram.use_case.ui.FigActor"
    },...
  ]
}
```

Validation

Feature: Use Case

```
//#if defined(USECASEDIAGRAM)
//@#$LPS-USECASEDIAGRAM:GranularityType:Package
public class FigActor extends FigNodeModelElement
```

Feature: Sequence

```
//#if defined(SEQUENCEDIAGRAM)
//@#$LPS-SEQUENCEDIAGRAM:GranularityType:Package
public class FigClassifierRole extends FigNodeModelElement
```
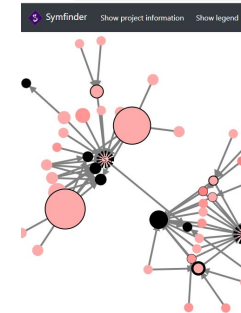

org.argouml.uml.diagram.
sequence.ui.
FigClassifierRole

org.argouml.uml.diagram.
deployment.ui.
FigClassifierRole

org.argouml.uml.diagram.
ui.FigNodeModelElement

org.argouml.uml.diagram.
use_case.ui.FigActor
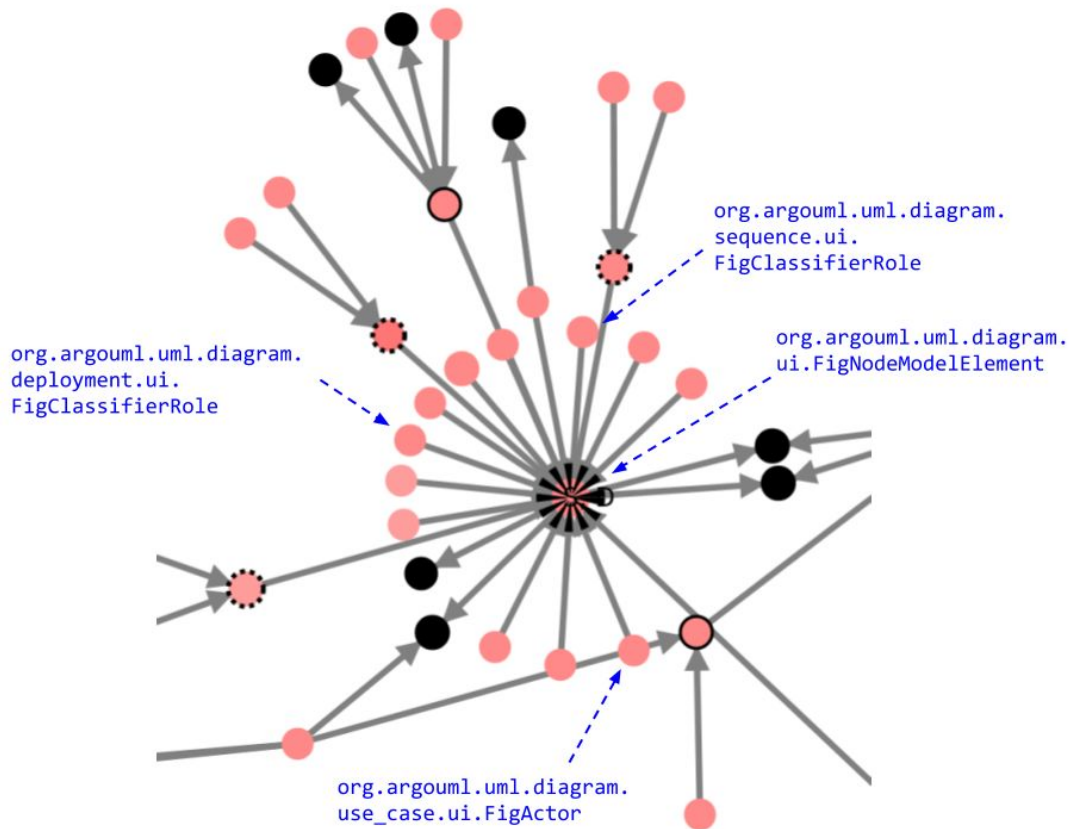
Relevance of the *vp-s*
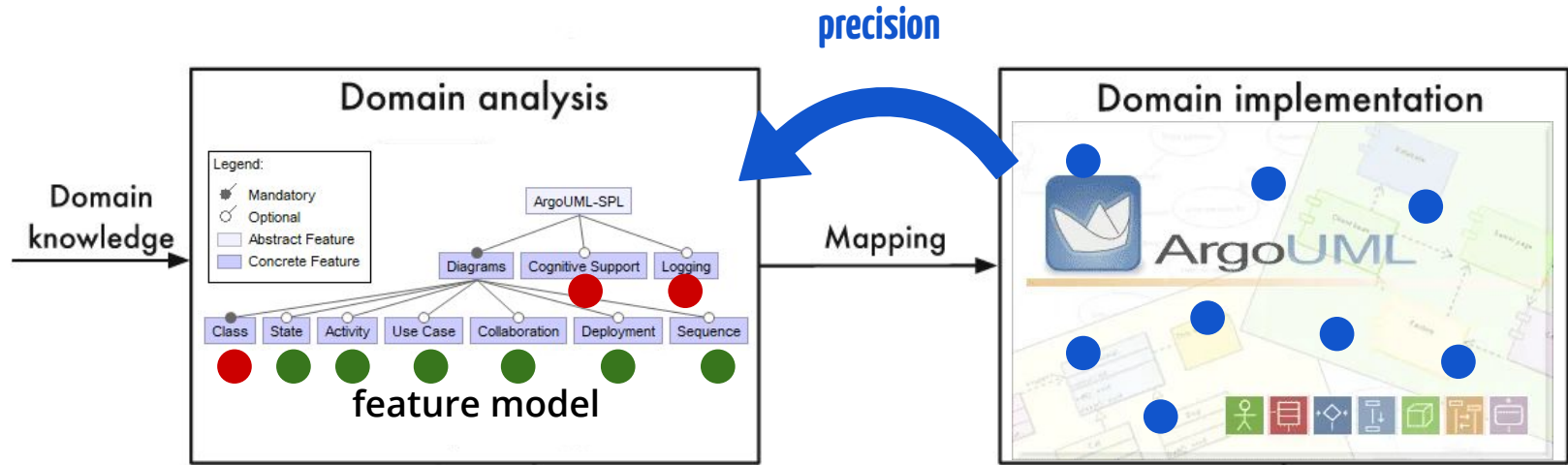
Precision:

Percentage of identified vp-s and variants that could be mapped to domain features

Relevance of the *vp-s*
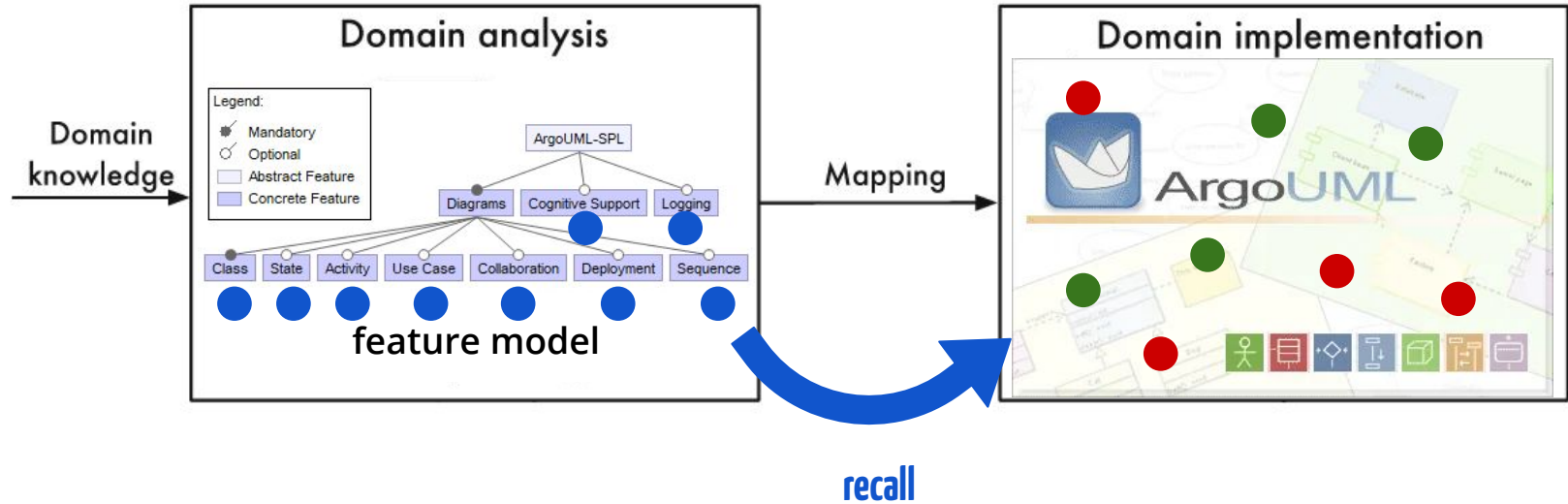
Recall:

Percentage of features' traces that could be mapped to identified vp-s and variants

Relevance of the *vp-s*

Calculating precision

$$precision = \frac{TP}{TP + FP} = \frac{|T_{gt} \cap I_{vp-v}|}{|I_{vp-v}|} = \frac{593}{1560} = 38\%$$

Low precision was **expected**:

- coarse grain features based on superficial domain knowledge

- not all identified places with a symmetry are related to variability

Relevance of the *vp-s*

Calculating recall

$$recall = \frac{TP}{TP + FN} = \frac{|T_{gt} \cap I_{vp-v}|}{|T_{gt}|} = \frac{593}{712} = 83\%$$

The missing 17% of traces are **not variability related**:

- initialization classes

- external libraries

Future work

Map the identified *vp-s* with variants to #ifdef directives

Take into account *vp-s* with variants at method level

Extend symfinder to be able to analyse projects in other languages

Mapping Features to Automatically Identified Object-Oriented Variability Implementations

The case of ArgoUML-SPL

Successful mapping to preexisting domain features

vp-s detection method is **little precise** but **highly robust** on ArgoUML-SPL

symfinder identifies *vp-s* **with variants relevant** for feature mapping

Availability:

- Public release: tag **vamos2020**
  https://github.com/DeathStar3/symfinder

- symfinder demonstration
  https://deathstar3.github.io/symfinder-demo/

Get the paper:

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