Dottorato in Scienze Computazionali e Informatiche, XXV Ciclo

UNSUPERVISED MACHINE LEARNING FOR SOFTWARE MAINTENANCE

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Dr. Anna Corazza

Ph.D. Candidate:

Valerio Maggio

June 5th, 2013

THESIS
G O A L

UNSUPERVISED MACHINE LEARNING FOR SOFTWARE MAINTENANCE

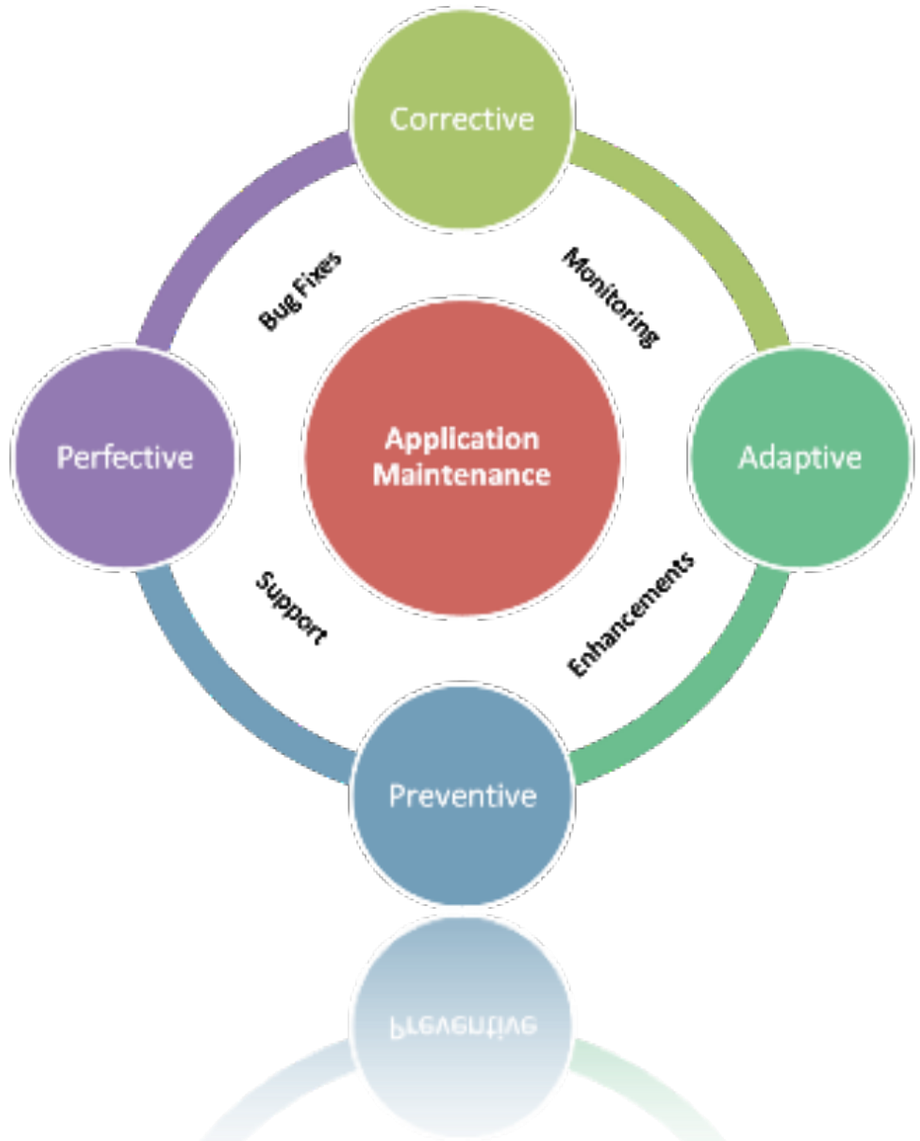
Define and experimentally evaluate solutions (techniques and prototype tools) for **automatic software analysis** to support software **maintenance** activities.

These solutions exploit (**un**supervised) **machine learning** techniques to mine information from the **source code**

SOFTWARE MAINTENANCE

"A software system must be continually adapted during its overall life cycle or it progressively becomes less satisfactory."
(cit. Lehman's First Law of Software Evolution)

There exist different **types** of Software Maintenance.



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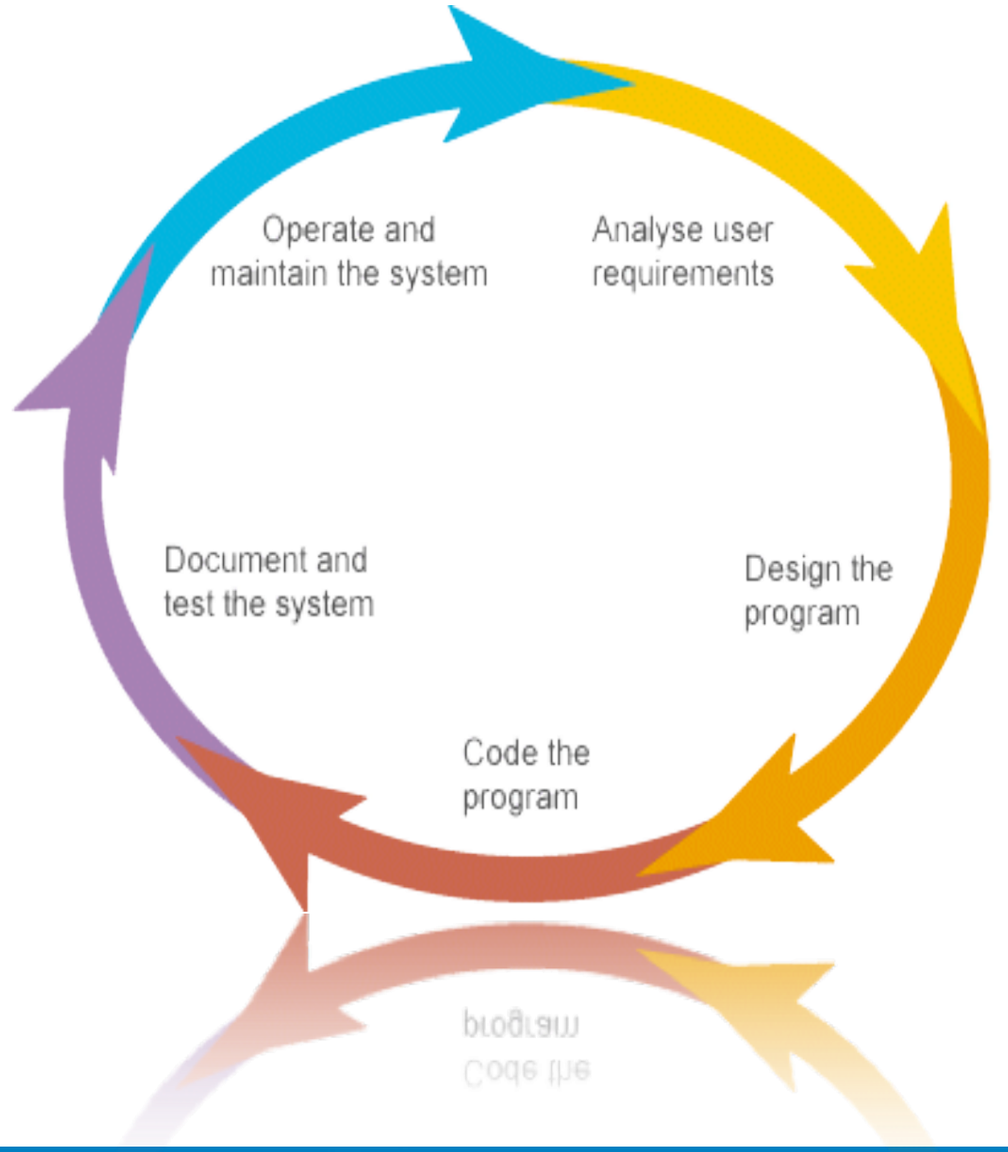
Software Maintenance represents the most **expensive**, **time consuming** and challenging phase of the whole development process.



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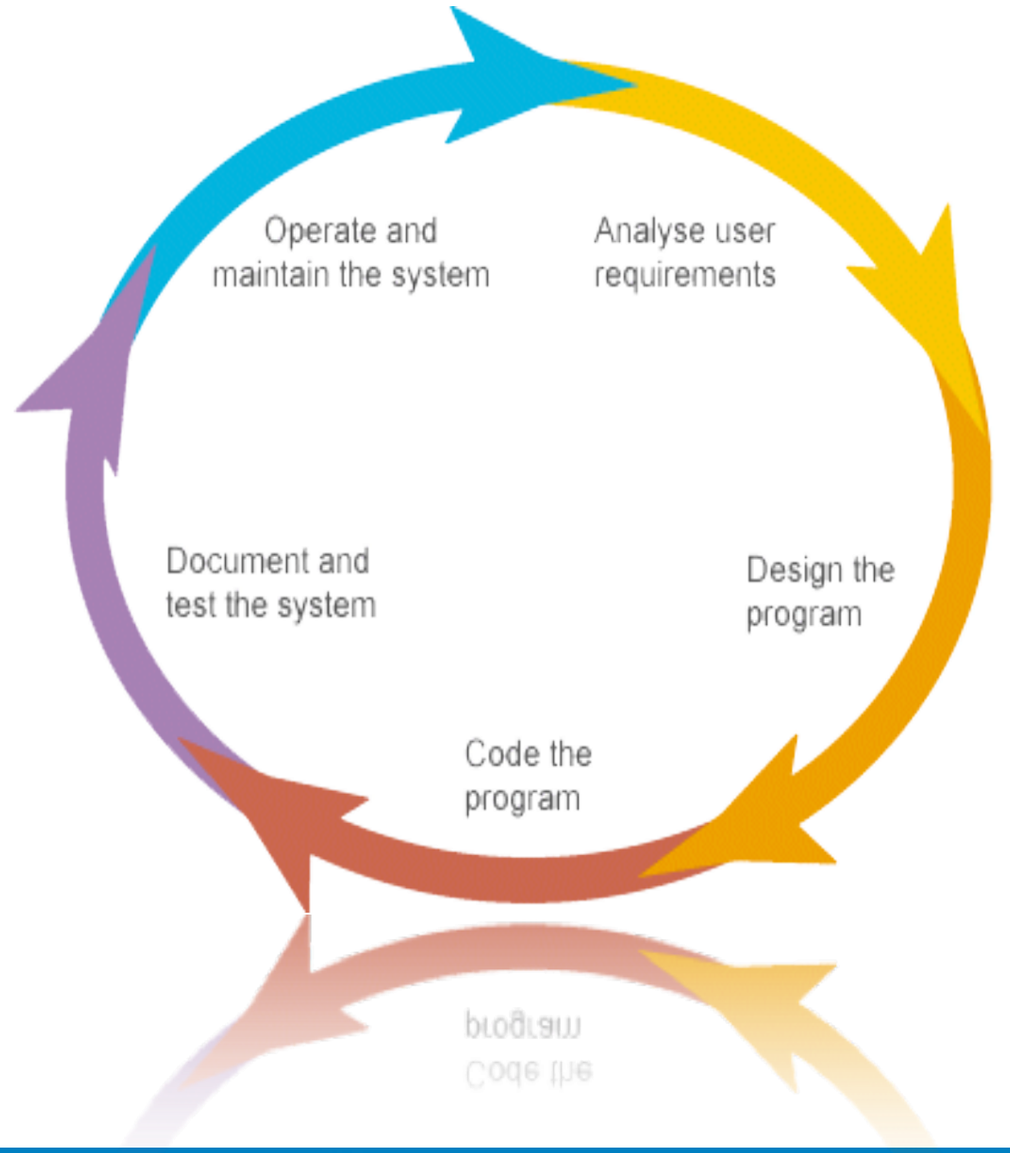
Software Maintenance could account up to the **85-90%** of the total software costs.



ISSUES

SOFTWARE MAINTENANCE

> *“Software Maintenance is about change!”*
> (cit. S. Jarzabek)

Change Analysis

ISSUES

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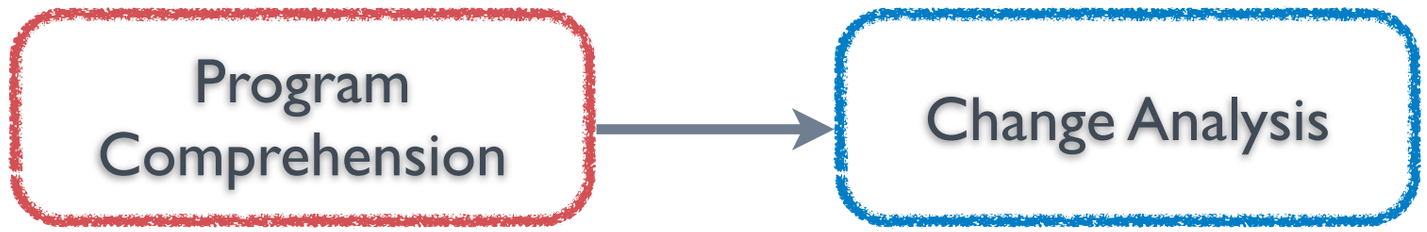

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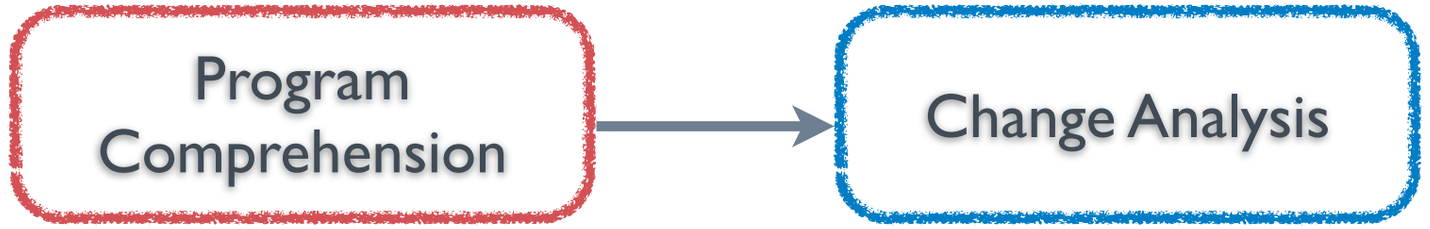

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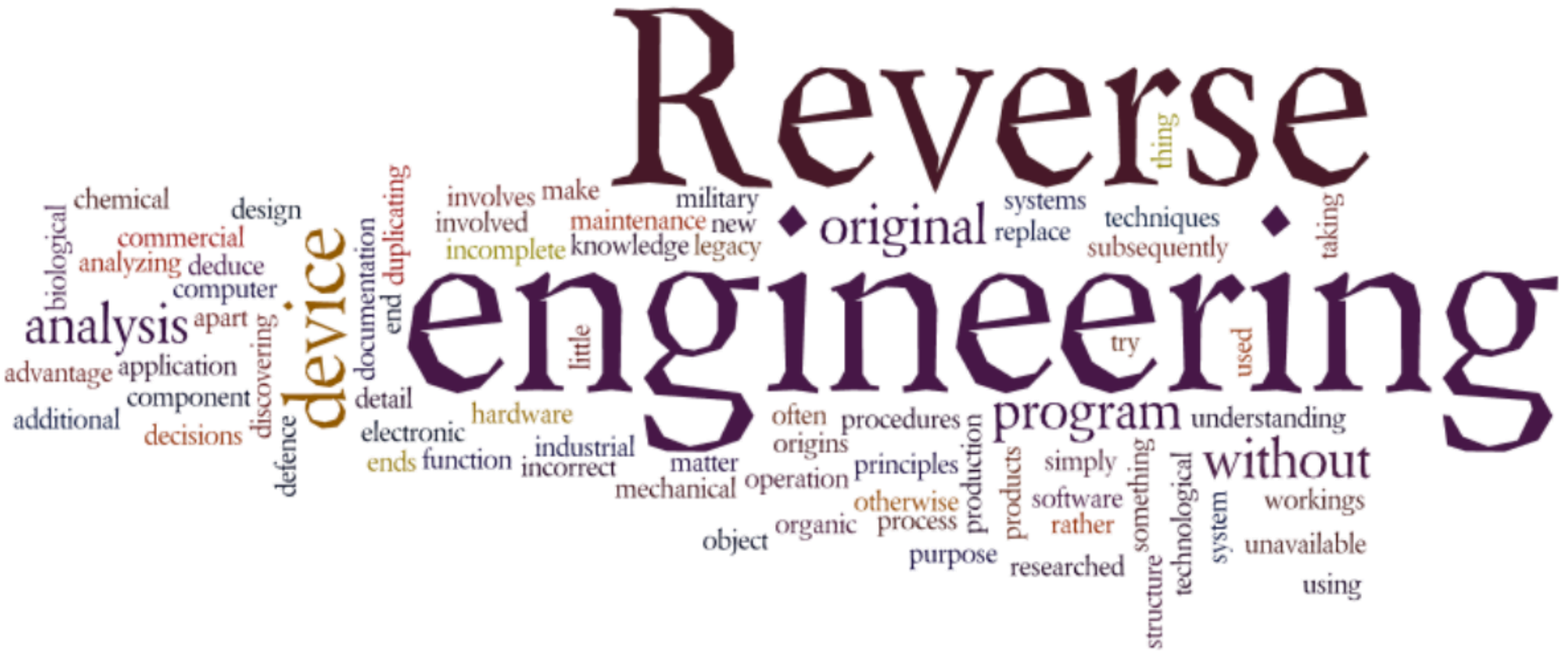
REVERSE ENGINEERING

- Definition of **tools** and **techniques** to support maintenance activities
  - **Goal**: Build higher-level *software models* in an **automatic fashion** gathering information from the **source code** or any other document
  - **Goal**: To aid the comprehension of the system



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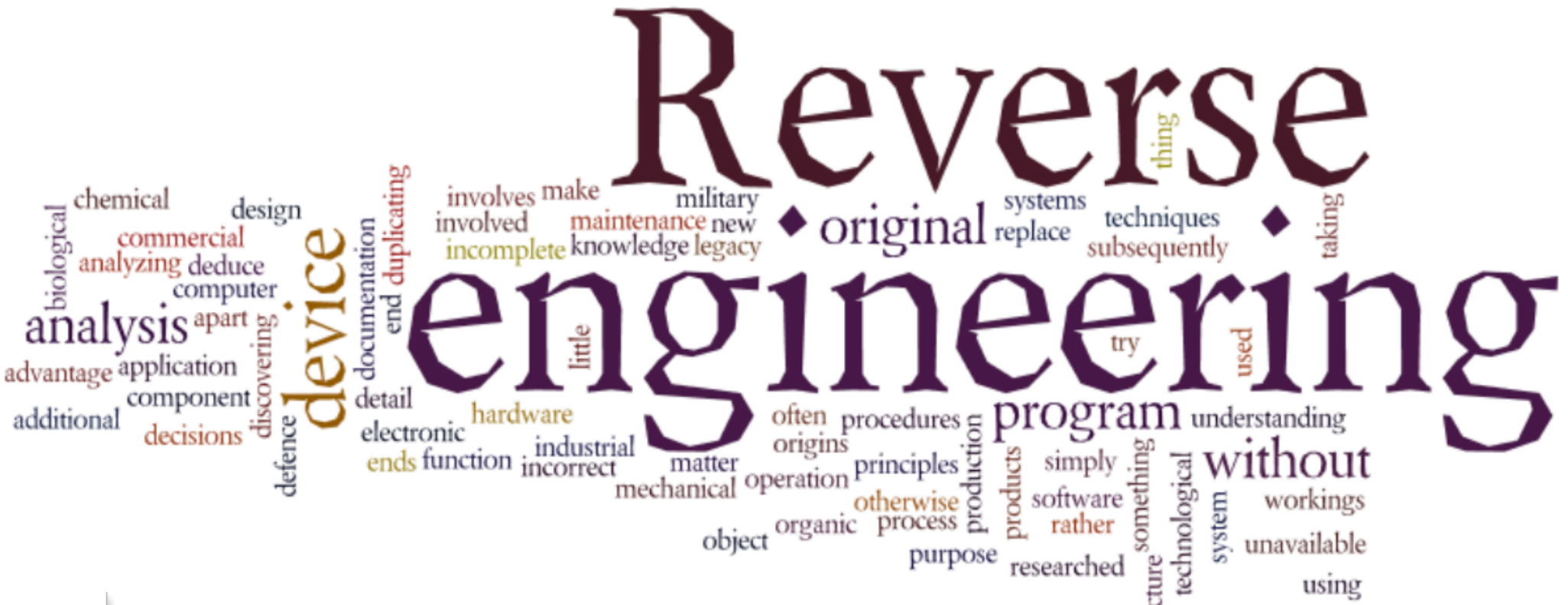

STATIC ANALYSIS

DYNAMIC ANALYSIS

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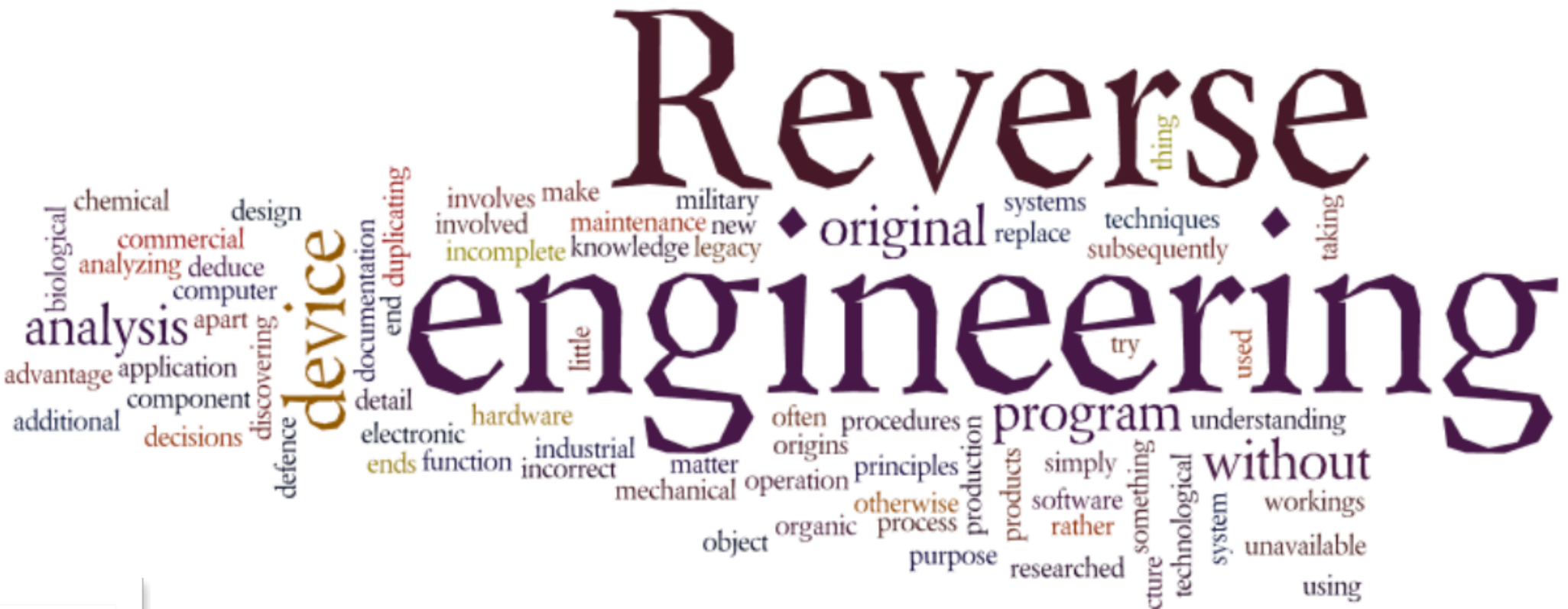

STATIC ANALYSIS

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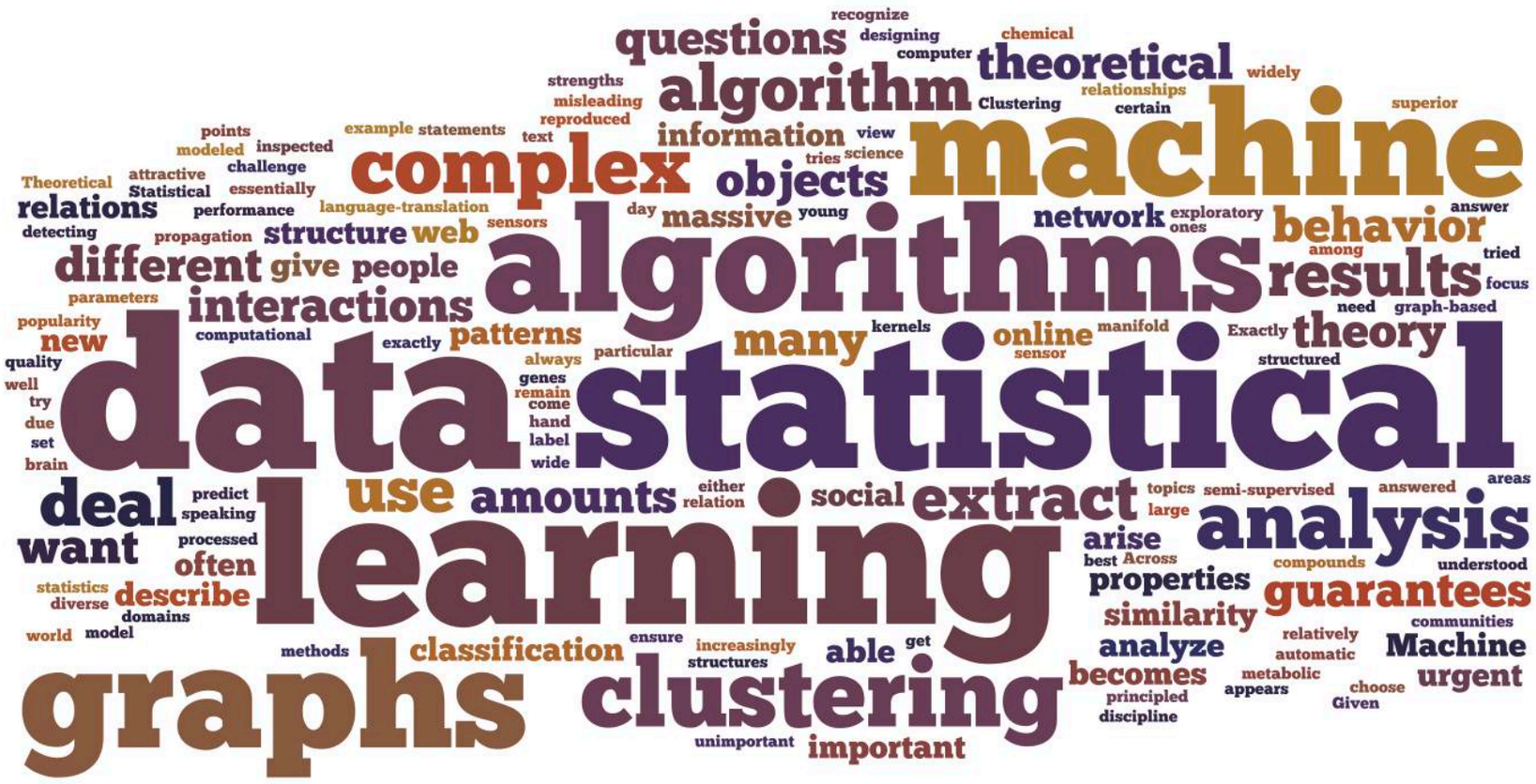

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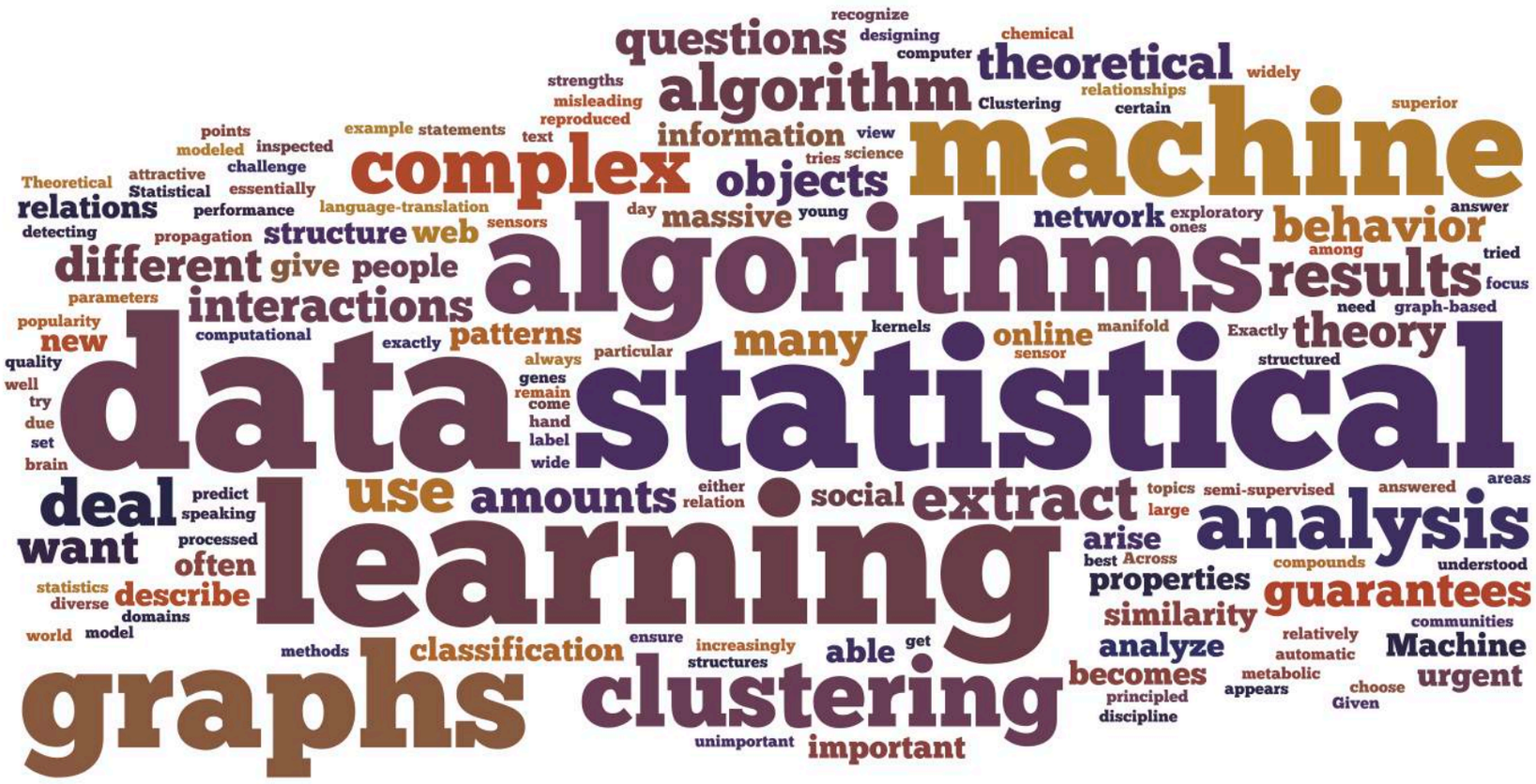
MACHINE LEARNING



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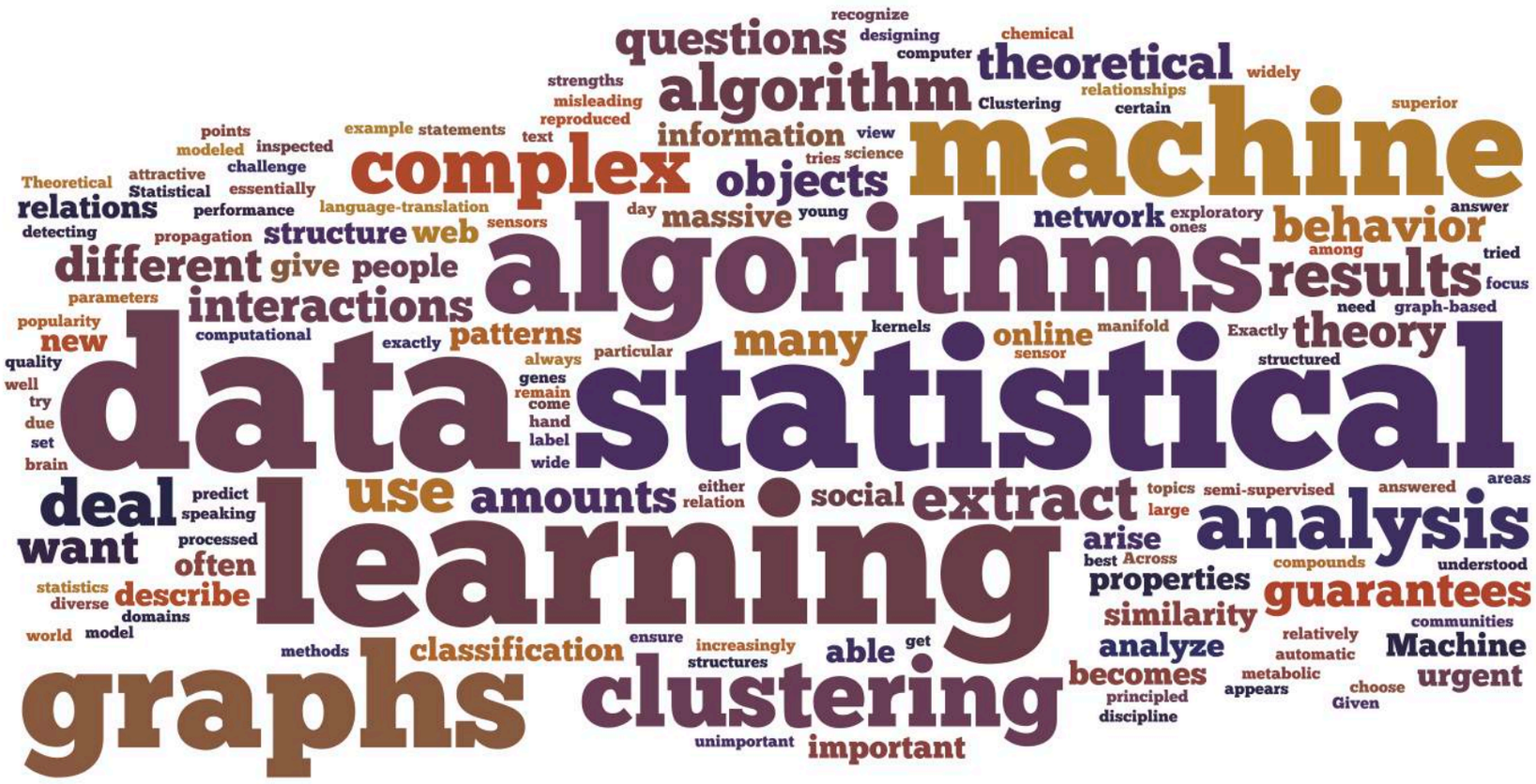

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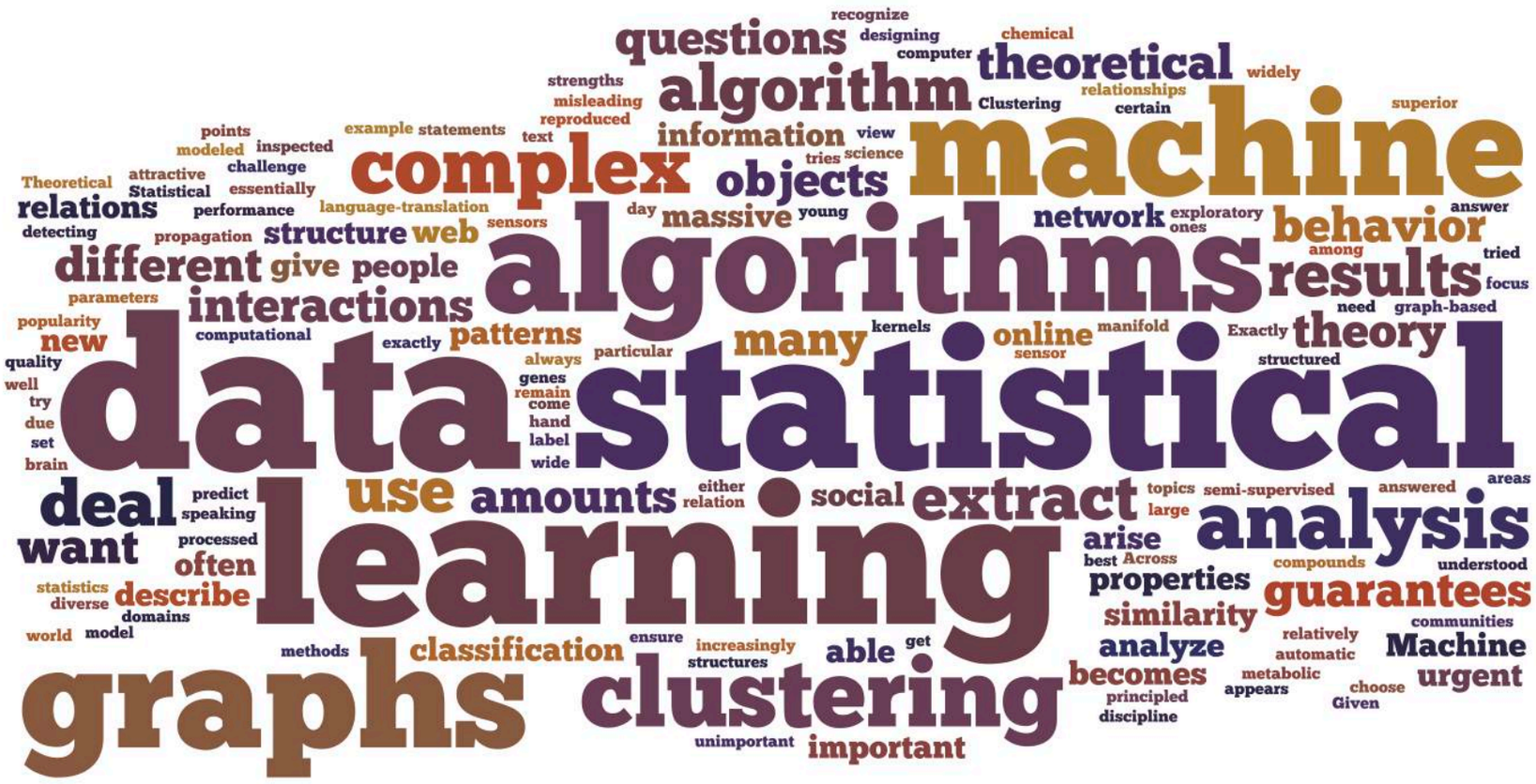

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  - the application of the **learning** algorithms to the considered data

UNSUPERVISED LEARNING

Learn by examples

- **Supervised Learning:**
  - Learn from **labelled** samples
- **Unsupervised Learning:**
  - Learn (directly) from the data

UNSUPERVISED LEARNING

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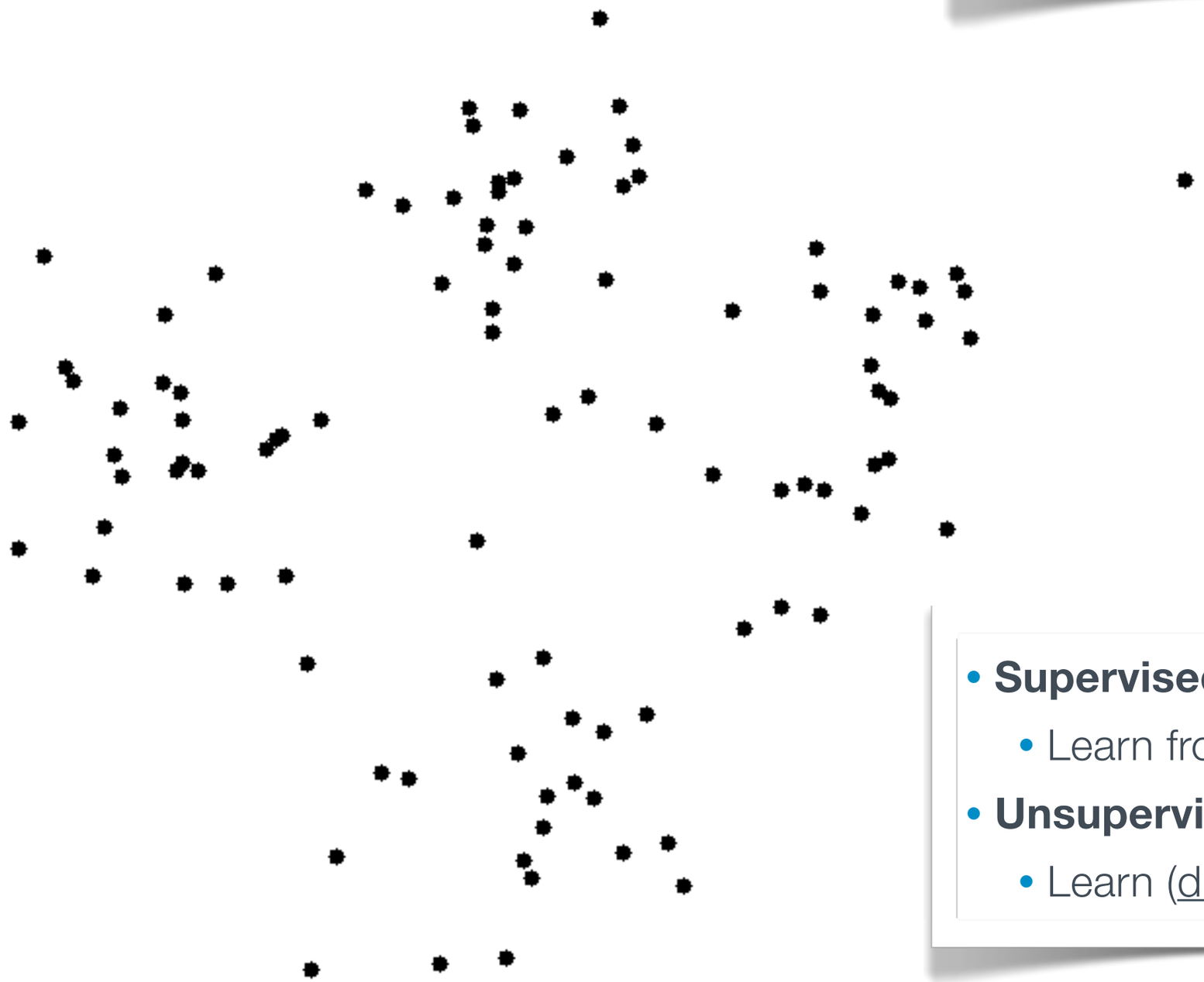

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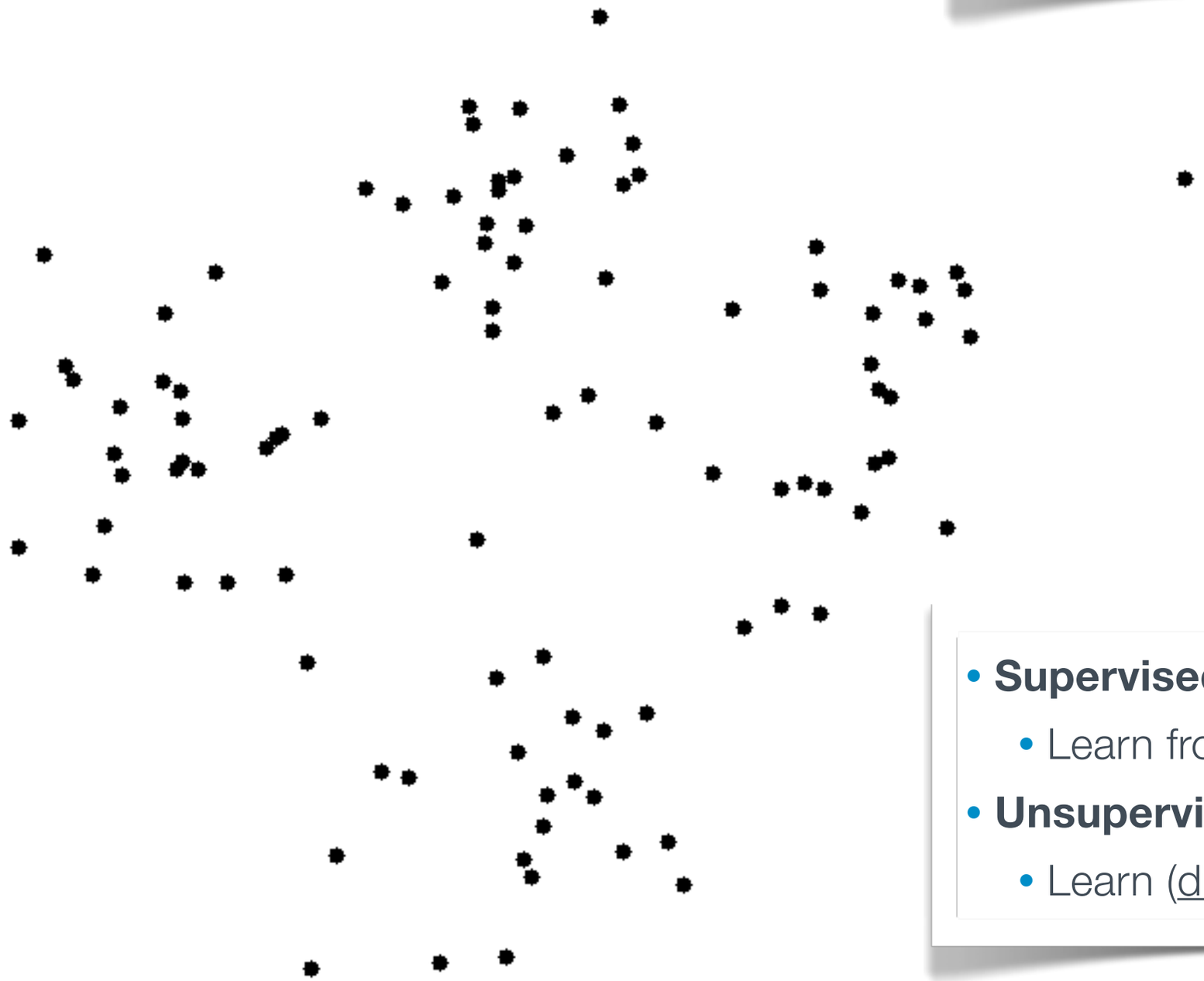

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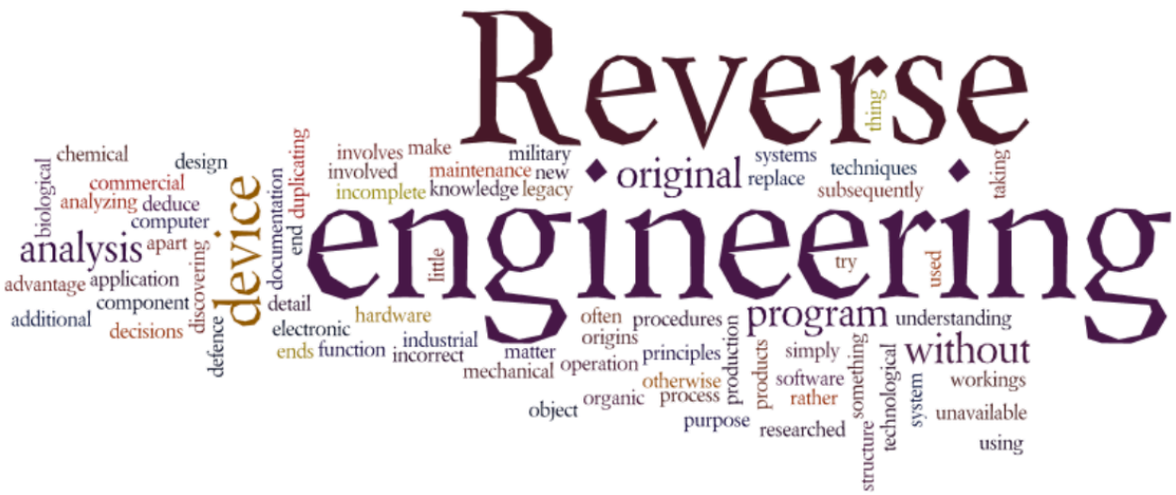
(+) No cost of labeling samples

(-) Trade-off imposed on the quality of the data

THESIS CONTRIBUTIONS



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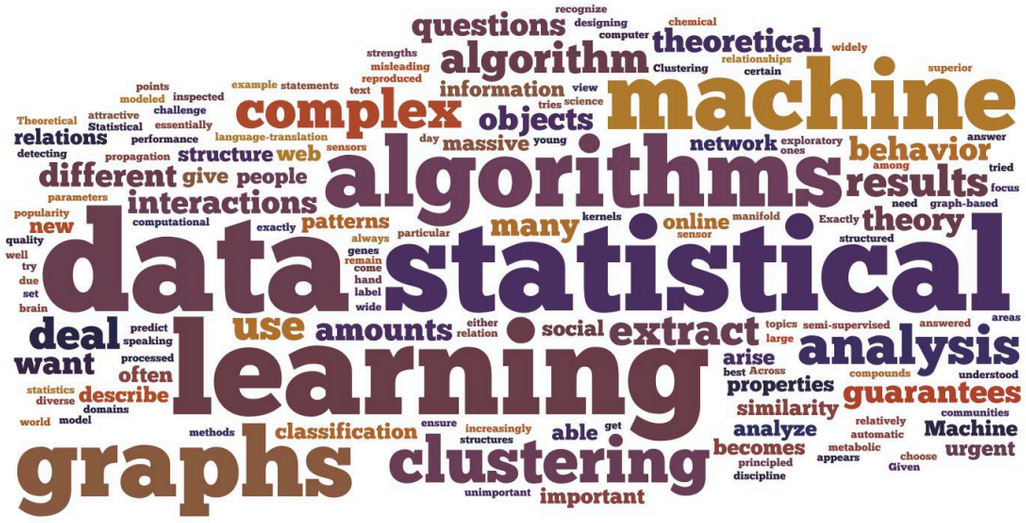
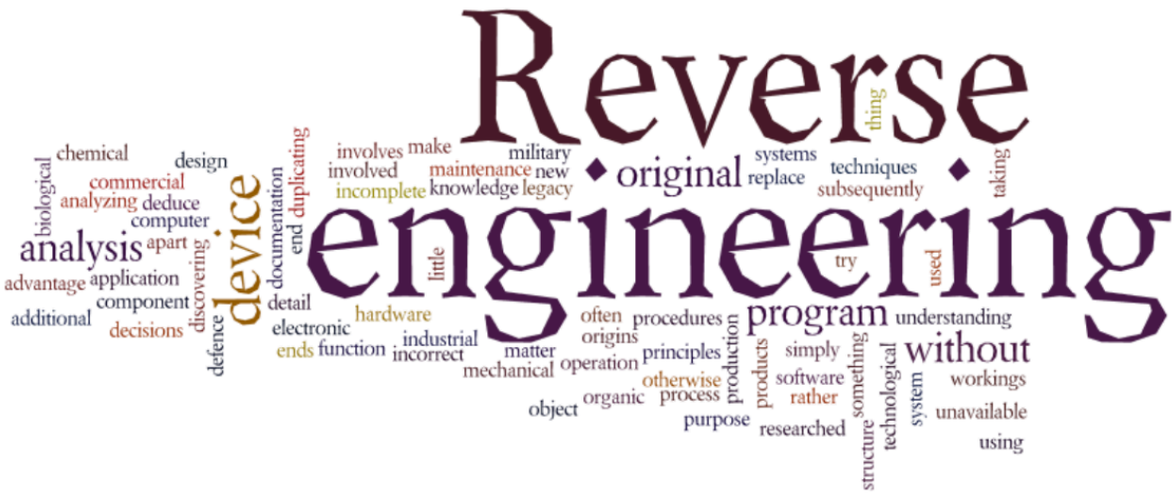


THESIS CONTRIBUTIONS

Contributions to three relevant and related **open issues** in Software Maintenance



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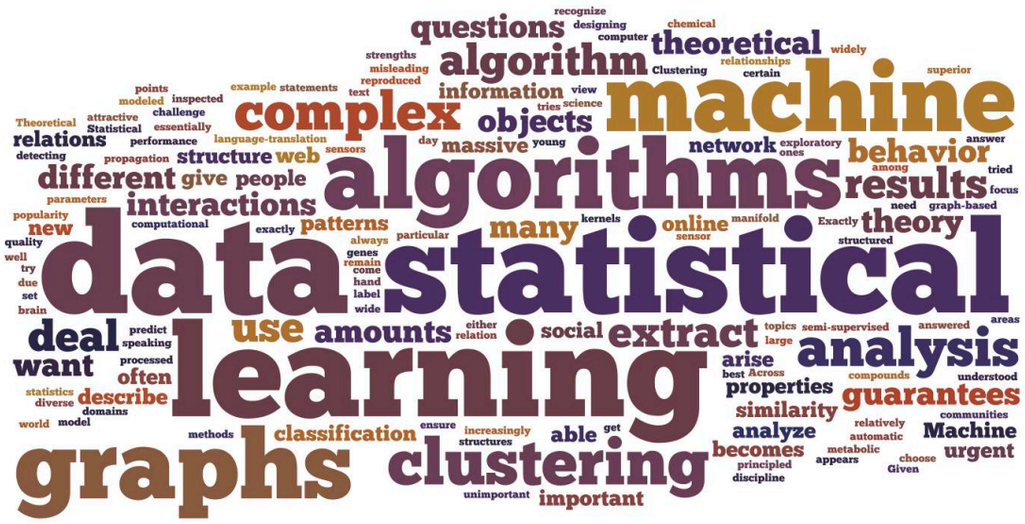

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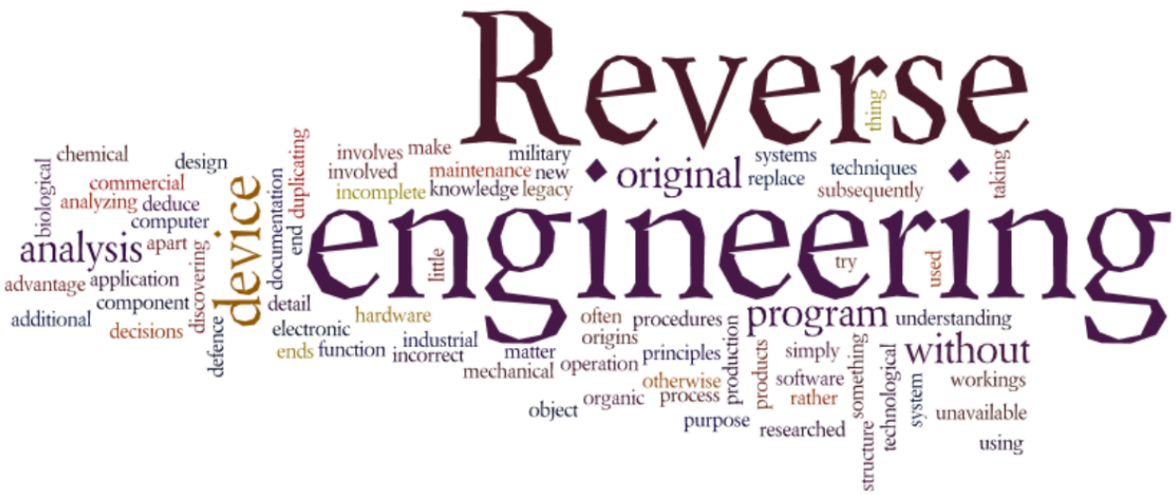

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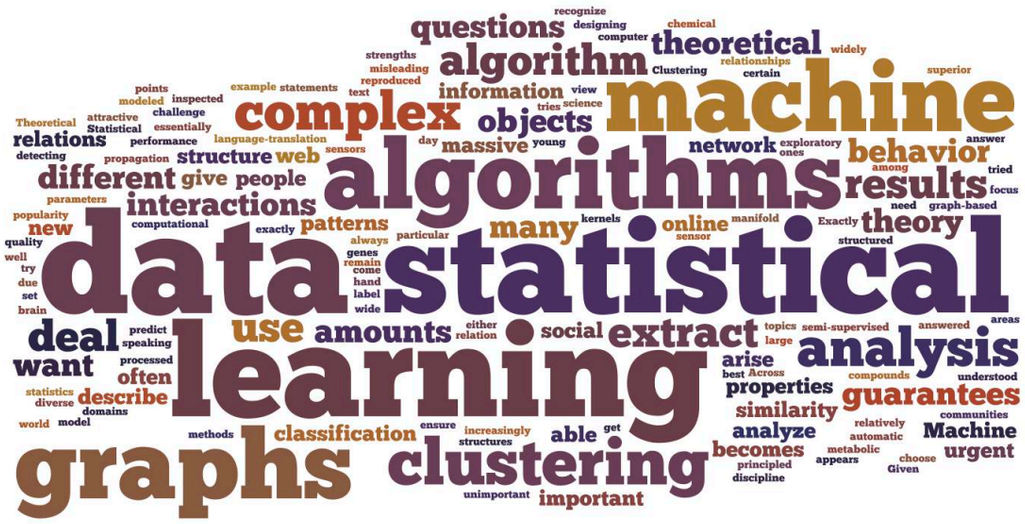


1. SOFTWARE RE-MODULARIZATION

2. SOURCE CODE NORMALIZATION

3. CLONE DETECTION

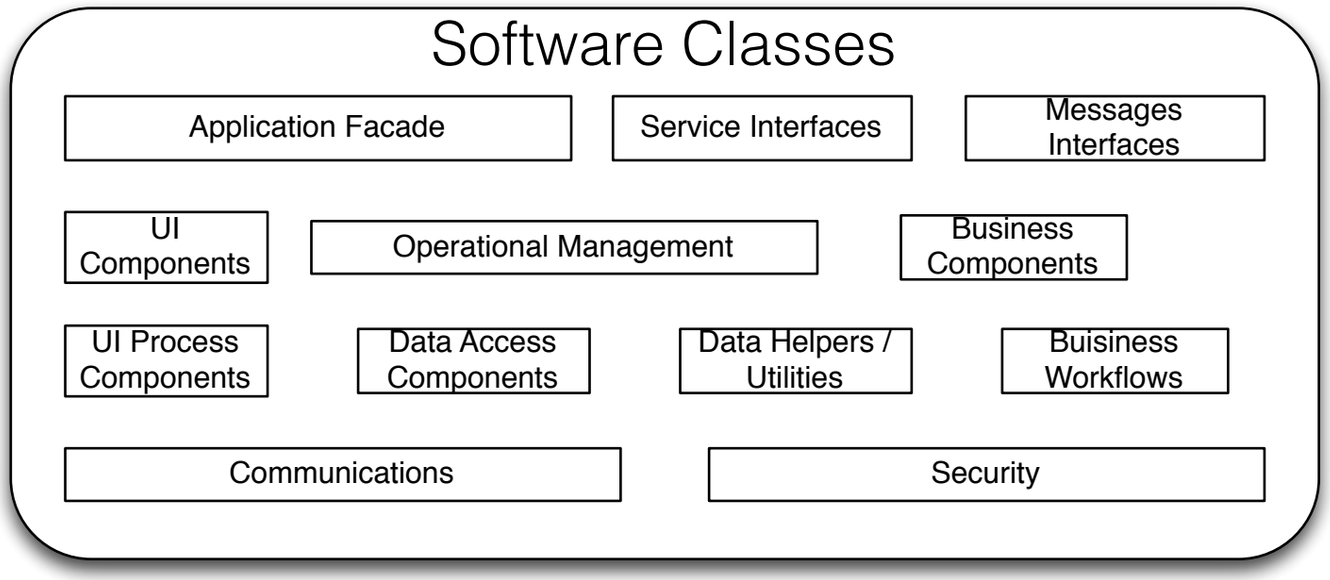
ISSUE
#1

SOFTWARE RE-MODULARIZATION

PROBLEM STATEMENT

SOFTWARE RE-MODULARIZATION

Re-modularization provides a way to support software maintainers by automatically grouping together (**clustering**) “related” software **classes**



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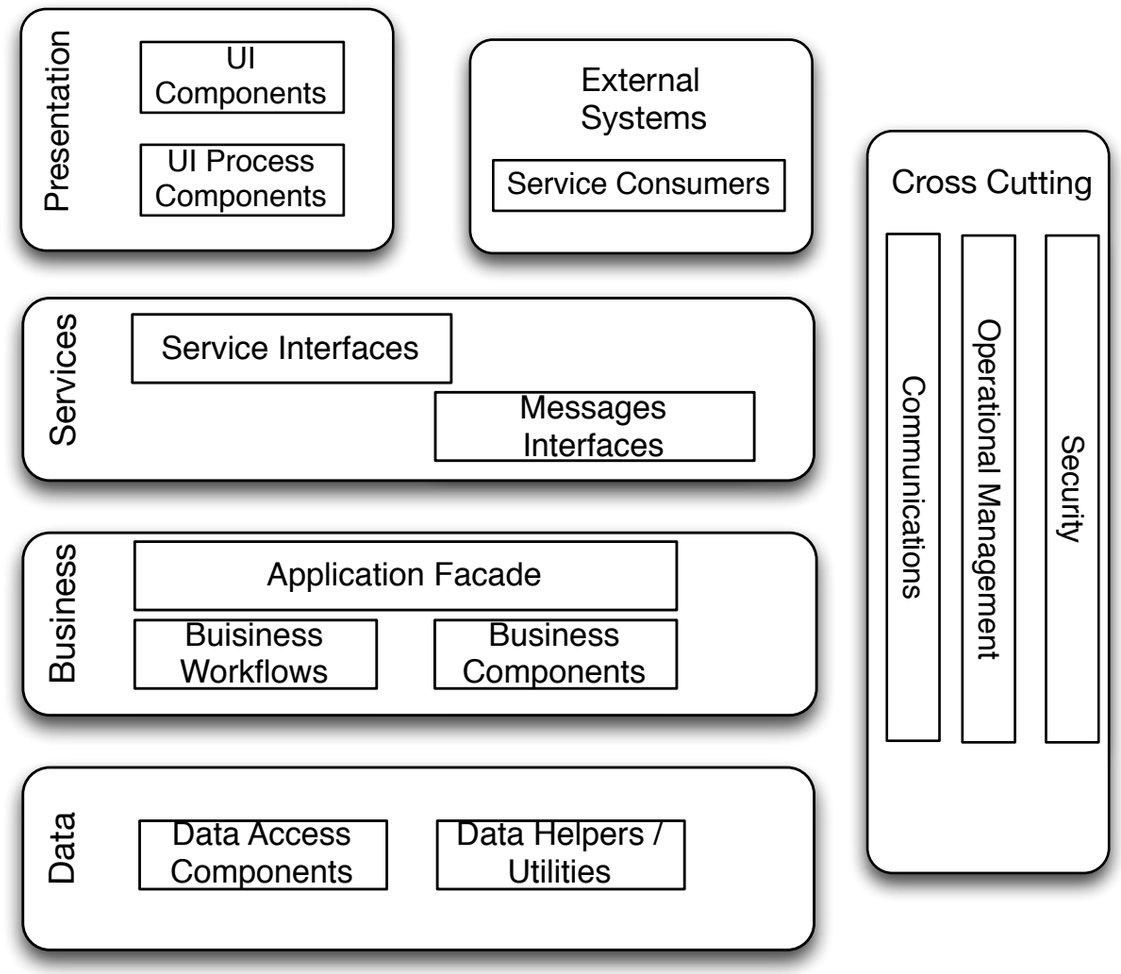

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 * <hr>
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 * <b>NullObject</b><br>
 * NullObject enables to treat handles that don't do
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 */
public class NullHandle extends LocatorHandle {

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     * The handle's locator.
     */
    protected Locator fLocator;

    public NullHandle(Figure owner, Locator locator) {
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    }

    /**
     * Draws the NullHandle. NullHandles are drawn as a
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     */
    public void draw(Graphics g) {
        Rectangle r = displayBox();

        g.setColor(Color.black);
        g.drawXORRect(r);
    }
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```

SOURCE CODE

LEXICAL INFORMATION

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SOURCE CODE **LEXICAL** INFORMATION

(IDEA): Exploit the **lexical information** gathered from the source code to produce **clusters** of classes that are lexically related.

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State of the Art: Information Retrieval (**IR**) based approaches.

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Implicit assumption: The “same” words are used whenever a particular concept occurs

IR INDEXING

1. Tokenization

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Draws, the, are,
NullHandle,
box, r,
Rectangle, g,
Graphics,
box,
displayBox,
...

2. Normalization

draw, **the**, **are**,
null, handl,
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ZONE | INDEXING

```
/**
 * Draws the NullHandle. NullHandles are drawn as a
 * red framed rectangle box.
 */
public void draw(Graphics g) {
    Rectangle r = displayBox();

    g.setColor(Color.black);
    g.drawXORRect(r);
}
```

RQ1: Do terms in different **Zones** provide different **contributions?**

ZONE INDEXING

1. Tokenization

```java
/**
 * Draws the NullHandle. NullHandles are drawn as a
 * red framed rectangle box.
 */
public void draw(Graphics g) {
    Rectangle r = displayBox();

    g.setColor(Color.black);
    g.drawXORRect(r);
}
```

Draws, the, are,
NullHandle,
box, r,
draw, g,
Graphics,
color,
displayBox,
...

2. Normalization

draw, ~~the~~, ~~are~~,
null, handl,
box, r,
draw, g,
graphic,
color,
display, box,
...

RQ1: Do terms in different **Zones** provide different **contributions?**

SOURCE CODE LEXICON

JFreeChart

```java
/**
 * Creates a vertical bar chart with default settings.
 * @param title The chart title.
 * @param categoryAxisLabel The label for the category axis.
 * @param valueAxisLabel The label for the value axis.
 * @param data The dataset for the chart.
 * @param legend A flag specifying whether or not a legend is required.
 */
public static JFreeChart createVerticalBarChart(String title, String categoryAxisLabel,
                                                 String valueAxisLabel, CategoryDataset data,
                                                 boolean legend) {

    JFreeChart chart = null;

    try {
        Axis categoryAxis = new HorizontalCategoryAxis(categoryAxisLabel);
        Axis valueAxis = new VerticalNumberAxis(valueAxisLabel);
        Plot plot = new VerticalBarPlot(categoryAxis, valueAxis);
        chart = new JFreeChart(data, plot, title, JFreeChart.DEFAULT_TITLE_FONT, legend);
    } catch (AxisNotCompatibleException e) {
        // this won't happen unless you mess with the axis constructors above
    System.err.println("ChartFactory.createVerticalBarChart(...) : axis not compatible.");
    } catch (PlotNotCompatibleException e) {
        // this won't happen unless you mess with the axis constructors above
    System.err.println("ChartFactory.createVerticalBarChart(...) : plot not compatible.");
    }
    return chart;
}
```

JEdit

```java
/**
 * Visits a local variable instruction. A local variable instruction is an
 * instruction that loads or stores the value of a local variable.
 *
 * @param opcode the opcode of the local variable instruction to be visited.
 *      This opcode is either ILOAD, LLOAD, FLOAD, DLOAD, ALOAD, ISTORE,
 *      LSTORE, FSTORE, DSTORE, ASTORE or RET.
 * @param var the operand of the instruction to be visited. This operand is
 *      the index of a local variable.
 */

void visitVarInsn (int opcode, int var);

/**
 * Visits a type instruction. A type instruction is an instruction that
 * takes a type descriptor as parameter.
 *
 * @param opcode the opcode of the type instruction to be visited. This opcode
 *      is either NEW, ANEWARRAY, CHECKCAST or INSTANCEOF.
 * @param desc the operand of the instruction to be visited. This operand is
 *      must be a fully qualified class name in internal form, or the type
 *      descriptor of an array type (see {@link Type Type}).
 */

void visitTypeInsn (int opcode, String desc);
```

JUnit

```java
public class TestListenerTest extends TestCase implements TestListener {
    private TestResult fResult;
    private int fStartCount;
    private int fEndCount;
    private int fFailureCount;
    private int fErrorCount;

    public void testFailure() {
        TestCase test= new TestCase("noop") {
            @Override
            public void runTest() {
                fail();
            }
        };
        test.run(fResult);
        assertEquals(1, fFailureCount);
        assertEquals(1, fEndCount);
    }
    public void testStartStop() {
        TestCase test= new TestCase("noop") {
            @Override
            public void runTest() {
            }
        };
        test.run(fResult);
        assertEquals(1, fStartCount);
        assertEquals(1, fEndCount);
    }
```

Xerces

```java
/Returns a string representation of the specified content spec
ublic static String toString(XMLContentSpec.Provider pr, StringPool strPool,
                             int contSpecInd) {

  // lookup content spec node
  XMLContentSpec contentSpec = new XMLContentSpec();

  if (pr.getContentSpec(contSpecInd, contentSpec)) {

      // build string
      StringBuffer stringBuffer = new StringBuffer();
      int    parentContentSpecType = contentSpec.type & 0x0f;
      int    nextContentSpec;
      switch (parentContentSpecType) {
          case XMLContentSpec.CONTENTSPECNODE_LEAF: {
              stringBuffer.append('(');
              if (contentSpec.value == -1 && contentSpec.otherValue == -1) {
                  stringBuffer.append("#PCDATA");
              }
              else {
                  stringBuffer.append(strPool.toString(contentSpec.value));
              }
              stringBuffer.append(')');
              break;
          } case XMLContentSpec.CONTENTSPECNODE_ZERO_OR_ONE: {
              pr.getContentSpec(contentSpec.value, contentSpec);
              nextContentSpec = contentSpec.type;
          }
```

SOURCE CODE LEXICON

JFreeChart

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 * Creates a vertical bar chart with default settings.
 * @param title The chart title.
 * @param categoryAxisLabel The label for the category axis.
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                                                 String valueAxisLabel, CategoryDataset data,
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    try {
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        Plot plot = new VerticalBarPlot(categoryAxis, valueAxis);
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        System.err.println("ChartFactory.createVerticalBarChart(...) : plot not compatible.");
    }
    return chart;
}
```

- Good lexicon in **every Zone**!

SOURCE CODE LEXICON

JEdit

```
/**
 * Visits a local variable instruction. A local variable instruction is an
 * instruction that loads or stores the value of a local variable.
 *
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 */

void visitTypeInsn (int opcode, String desc);
```

- Very good in **Comments**
- Very poor in **Method** and **Parameter** names

SOURCE CODE LEXICON

JUnit

```
public class TestListenerTest extends TestCase implements TestListener {
    private TestResult fResult;
    private int fStartCount;
    private int fEndCount;
    private int fFailureCount;
    private int fErrorCount;

    public void testFailure() {
        TestCase test= new TestCase("noop") {
            @Override
            public void runTest() {
                fail();
            }
        };
        test.run(fResult);
        assertEquals(1, fFailureCount);
        assertEquals(1, fEndCount);
    }
    public void testStartStop() {
        TestCase test= new TestCase("noop") {
            @Override
            public void runTest() {
            }
        };
        test.run(fResult);
        assertEquals(1, fStartCount);
        assertEquals(1, fEndCount);
    }
```

- Good in **Class** and **Attribute** names
- No **Comments** at all

SOURCE CODE LEXICON

Xerces

```
/**
 * Creates a vertical bar chart with default settings.
 * @param title The chart title.
 * @param categoryAxisLabel The label for the category axis.
 * @param valueAxisLabel The label for the value axis.
 * @param data The dataset for the chart.
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 */
public static JFreeChart

    JFreeChart chart = nu

    try {
        Axis categoryAxis
        Axis valueAxis =
        Plot plot = new V
        chart = new JFree
    } catch (AxisNotCompa
        // this won't hap
    System.err.println("C
    } catch (PlotNotCompa
        // this won't hap
    System.err.println("C
    }
    return chart;
}
```

```
ublic class Test
    private TestR
    private int f
    private int f
    private int f
    private int f

    public void t
        TestCase
            @Over
            publi
                f
            }
        };
        test.run(
        assertEqu
        assertEqu
    }
    public void t
        TestCase
            @Over...
            public void runTest() {
            }
```

```
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```

```
//Returns a string representation of the specified content spec
public static String toString(XMLContentSpec.Provider pr, StringPool strPool,
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    // lookup content spec node
    XMLContentSpec contentSpec = new XMLContentSpec();

    if (pr.getContentSpec(contSpecInd, contentSpec)) {

        // build string
        StringBuffer stringBuffer = new StringBuffer();
        int    parentContentSpecType = contentSpec.type & 0x0f;
        int    nextContentSpec;
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                break;
            } case XMLContentSpec.CONTENTSPECNODE_ZERO_OR_ONE: {
                pr.getContentSpec(contentSpec.value, contentSpec);
                nextContentSpec = contentSpec.type;
            }
```

- Poor in **Method, Parameter** names and **Comments**
- Good in Method **Code** and **Variable** names

SOURCE CODE LEXICON

JFreeChart

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JEdit

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 *      descriptor of an array type (see {@link Type Type}).
 */

void visitTypeInsn (int opcode, String desc);
```

RQ2: How to automatically **weight** the different contributions **?**

```
private TestResult fResult;
private int fStartCount;
private int fEndCount;
private int fFailureCount;
private int fErrorCount;

public void testFailure() {
    TestCase test= new TestCase("noop") {
        @Override
        public void runTest() {
            fail();
        }
    };
    test.run(fResult);
    assertEquals(1, fFailureCount);
    assertEquals(1, fEndCount);
}
public void testStartStop() {
    TestCase test= new TestCase("noop") {
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        }
    };
    test.run(fResult);
    assertEquals(1, fStartCount);
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              stringBuffer.append(')');
              break;
          } case XMLContentSpec.CONTENTSPECNODE_ZERO_OR_ONE: {
              pr.getContentSpec(contentSpec.value, contentSpec);
              nextContentSpec = contentSpec.type;
```

CONTRIBUTION

SOFTWARE RE-MODULARIZATION

- We propose a source code **Zone** Indexing

Corazza, A., Di Martino, S., Maggio, V., Scanniello, G.
Combining machine learning and information retrieval techniques for software clustering
(2012) Communications in Computer and Information Science, 255 CCIS, pp. 42-60. **ISSN:** 18650929 **ISBN:** 978-364228032-0

Corazza A., Di Martino, S., Maggio, V., Scanniello, G.
Investigating the use of lexical information for software system clustering
(2011) Proceedings of the European Conference on Software Maintenance and Reengineering, CSMR, art. no. 5741257, pp. 35-44.
ISSN: 15345351 **ISBN:** 978-076954343-7

CONTRIBUTION

SOFTWARE RE-MODULARIZATION

- We propose a source code **Zone** Indexing
- An approach to automatically **weight** the contribution of different **terms** in **Zones**
- *Maximum-Likelihood Estimation* (**MLE**) Approach

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CONTRI BUTION

SOFTWARE RE-MODULARIZATION

- We propose a source code **Zone** Indexing
- An approach to automatically **weight** the contribution of different **terms** in **Zones**
  - *Maximum-Likelihood Estimation* (**MLE**) Approach
- A *variant* of the **K-medoid** clustering algorithm
- Tailored to the **software clustering** task

Corazza, A., Di Martino, S., Maggio, V., Scanniello, G.
Combining machine learning and information retrieval techniques for software clustering
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K-MEDOID VARIANT

K-MEDOID VARIANT

ArrayHolder

GraphicsHolder

PropertyEditPanel

NumberAxisPropertyEditPanel

DateAxisPropertyEditPanel

ChartFrame

LineAndShapeRenderer

FigureLegend

LegendItem

HorizontalNumberAxis

StandardLegend

StackedVerticalBarRenderer

Non-extreme Distribution

property

VerticalNumberAxis

VerticalXYDataPlot

DataPlot

VerticalPlot

SampleXYDataset

SampleXYDatasetThread

LinearPlotFitAlgorithm

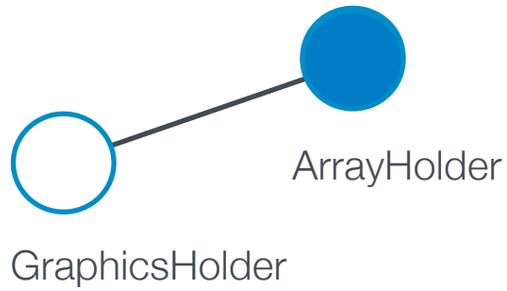
Plot

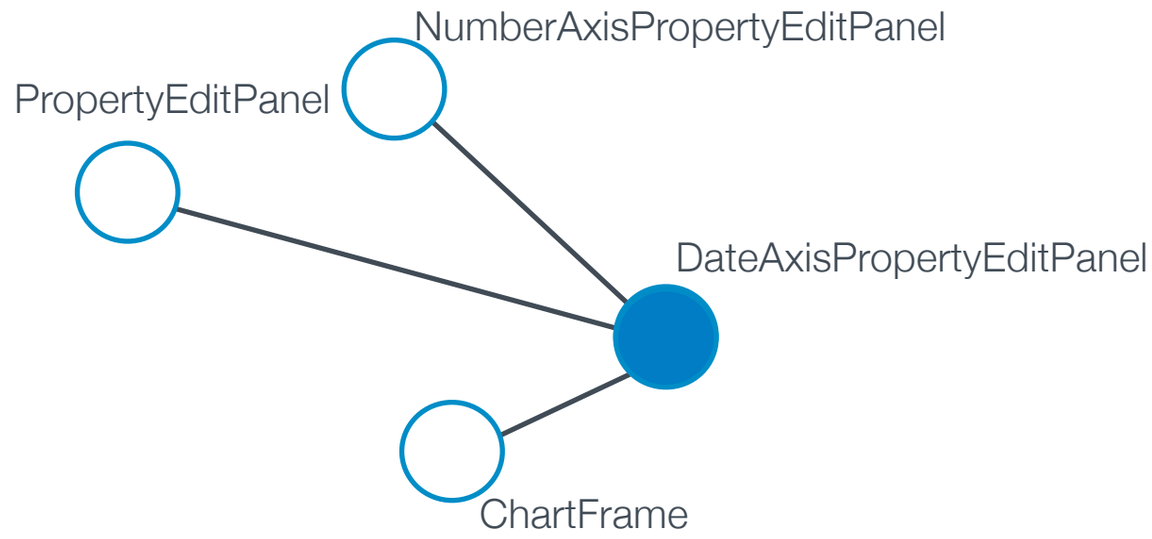
FitAlgorithm

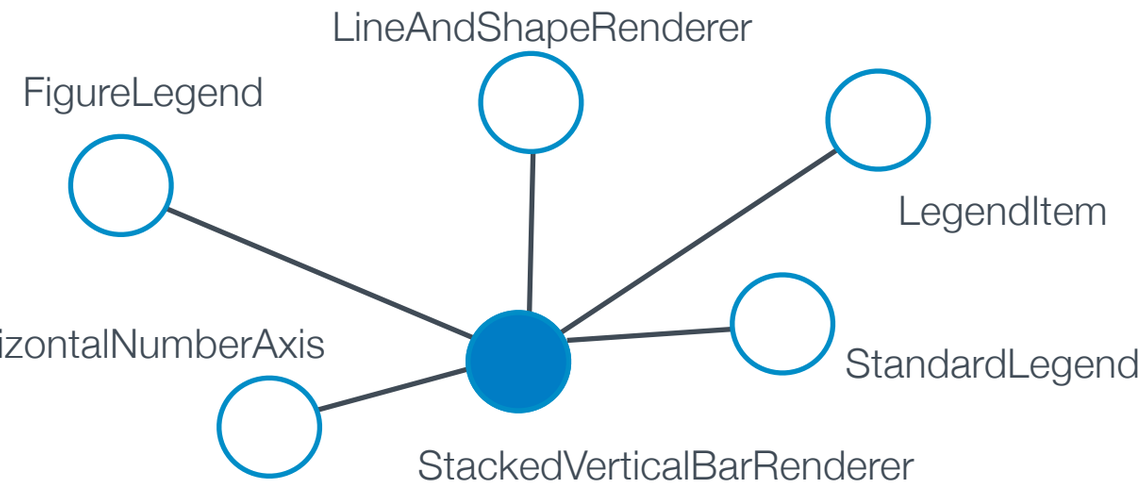
LinearPlotFit

PlotFitAlgorithm

K-MEDOID VARIANT

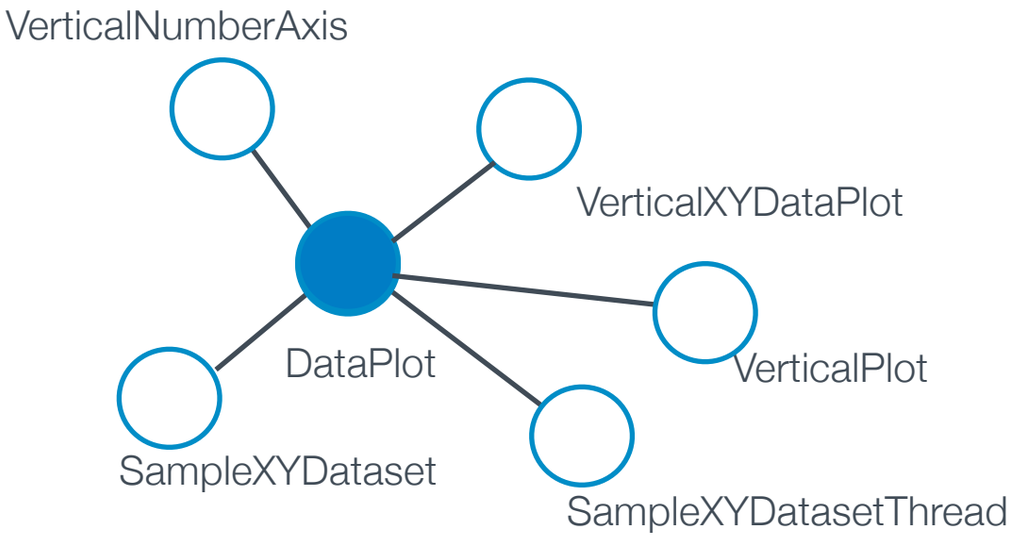


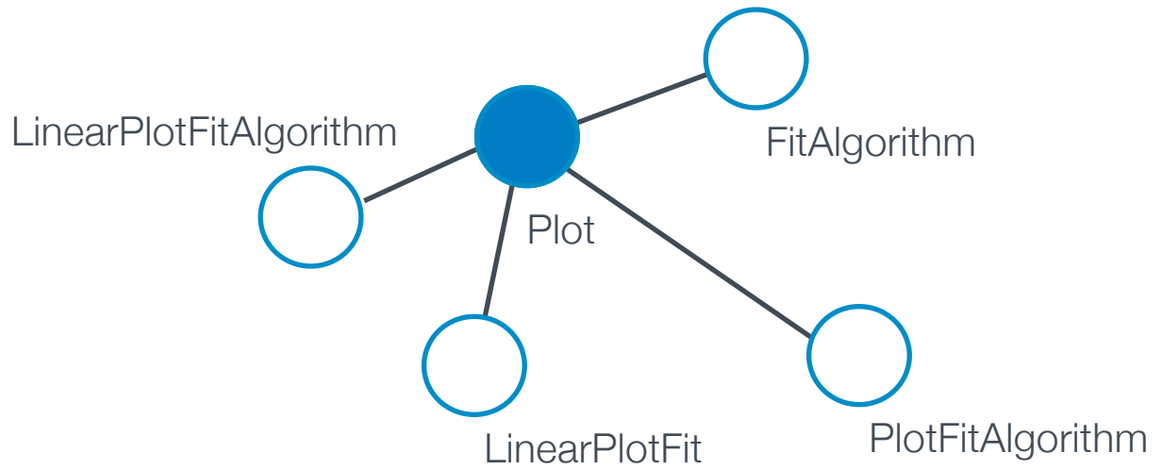




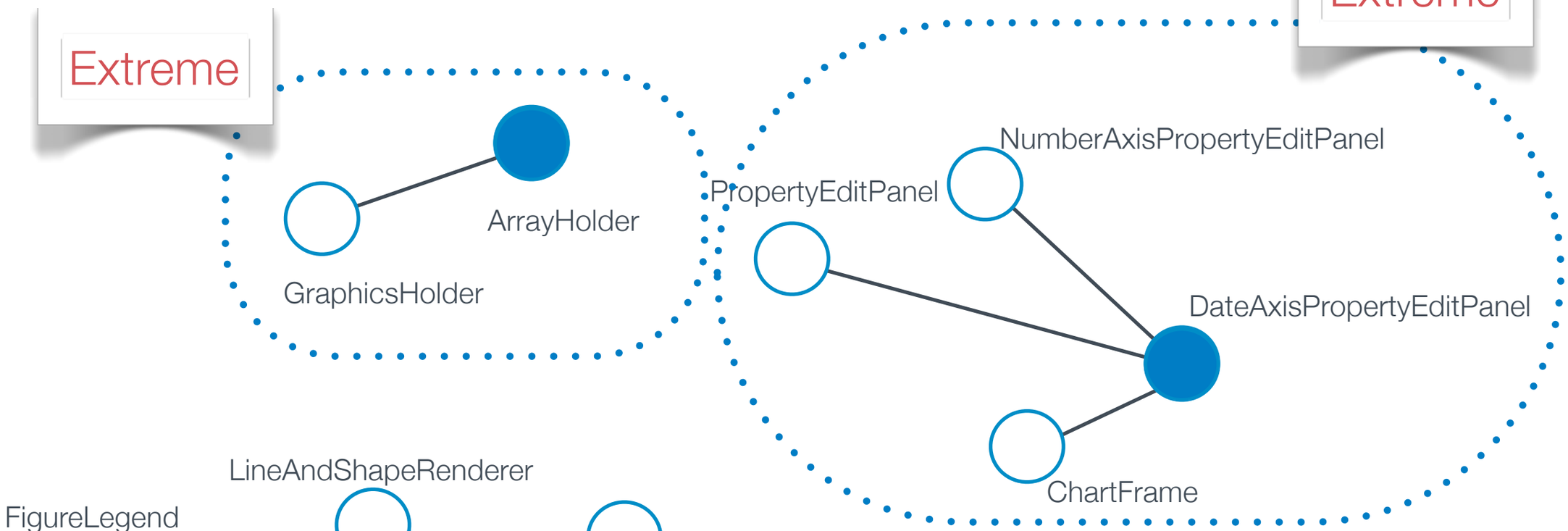
Non-extreme Distribution

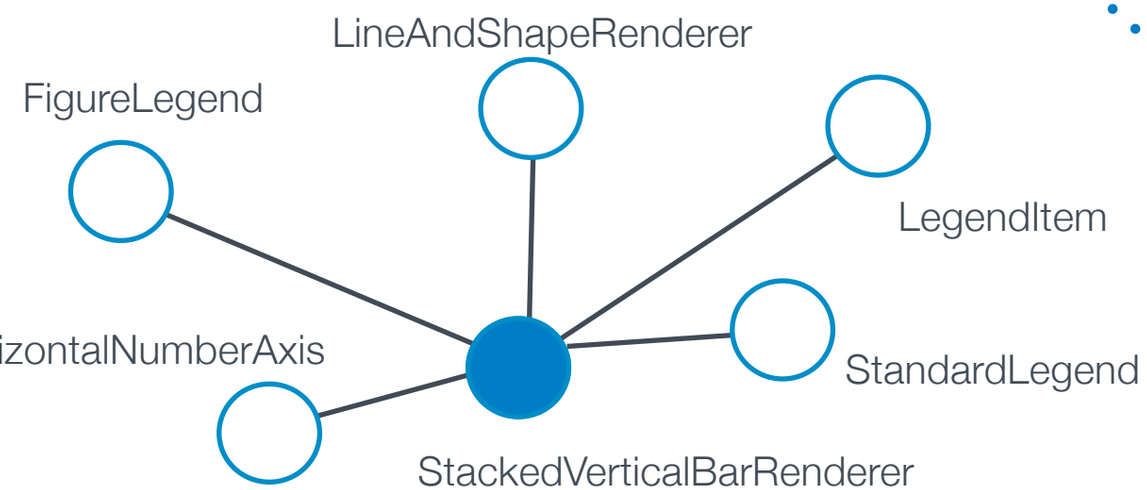
property





K-MEDOID VARIANT





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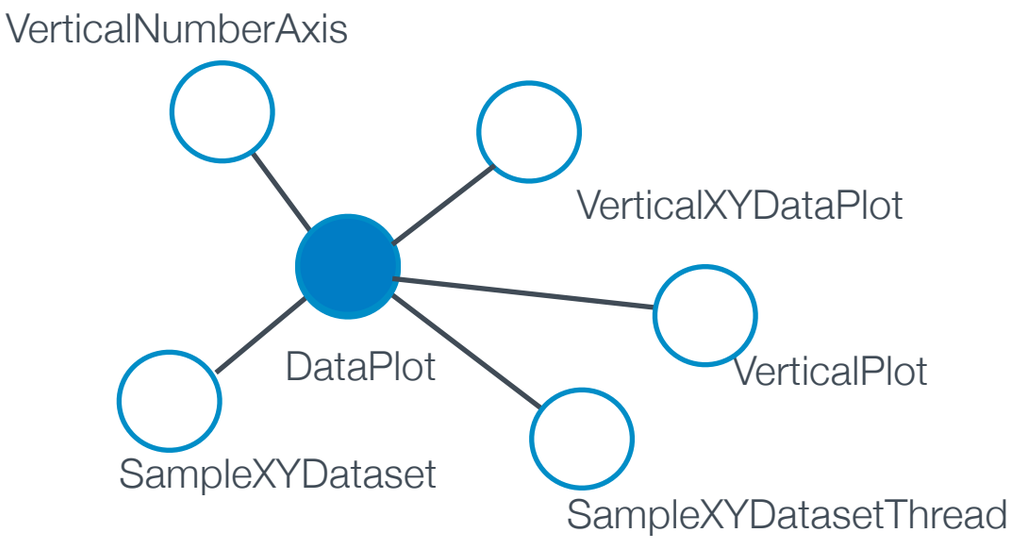

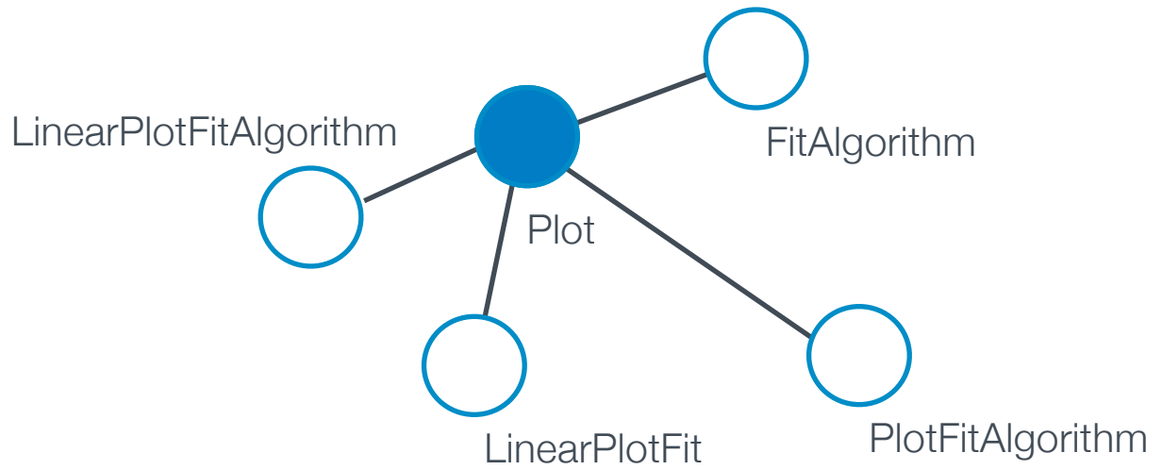

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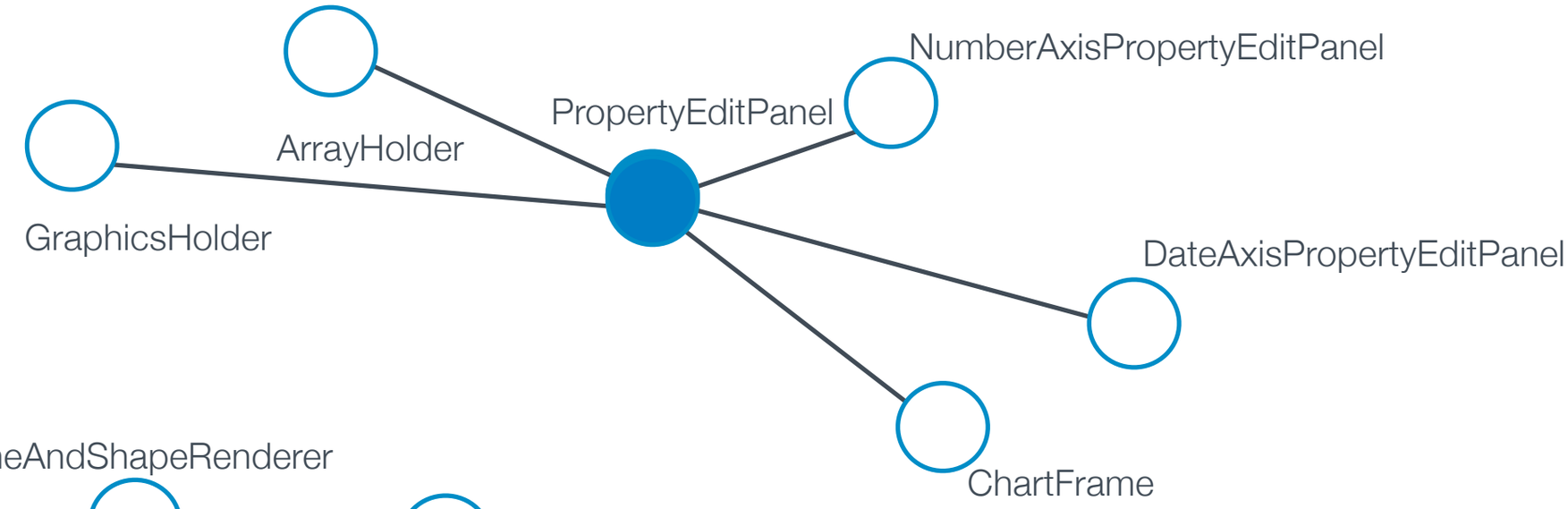

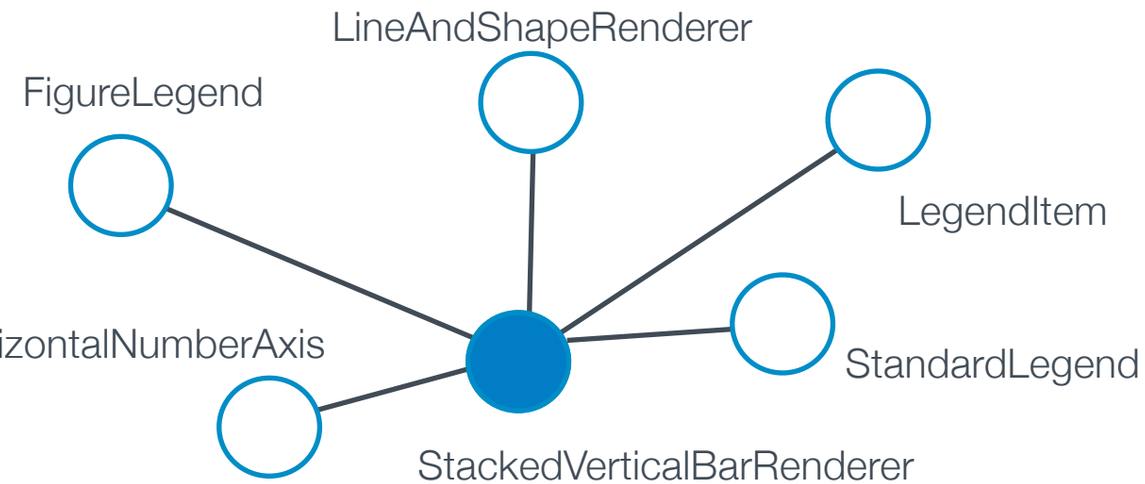

Non-extreme Distribution

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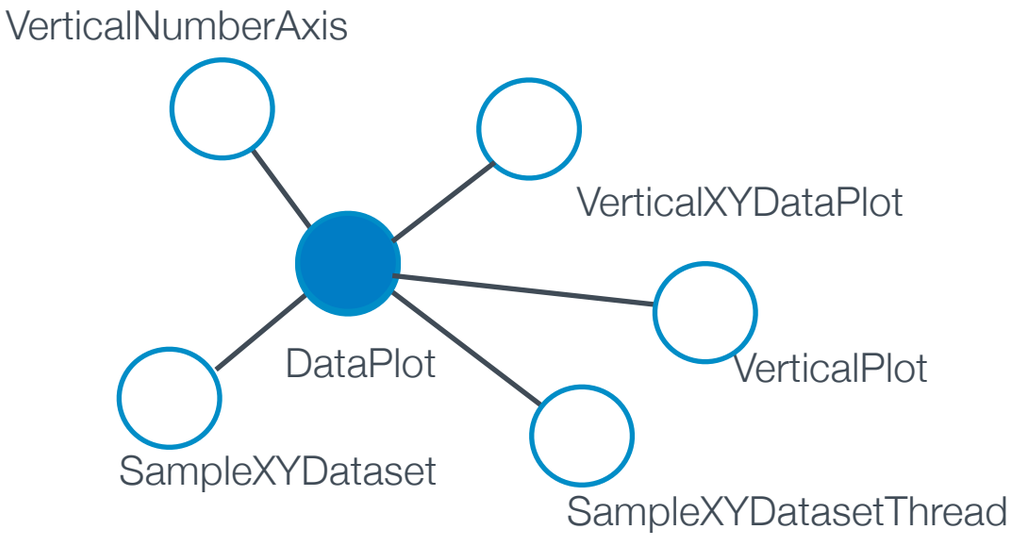
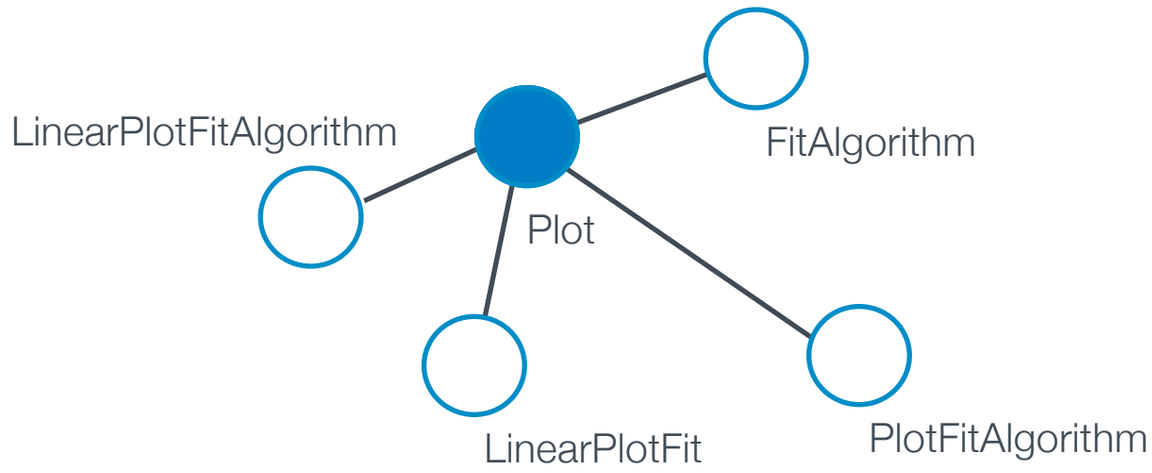




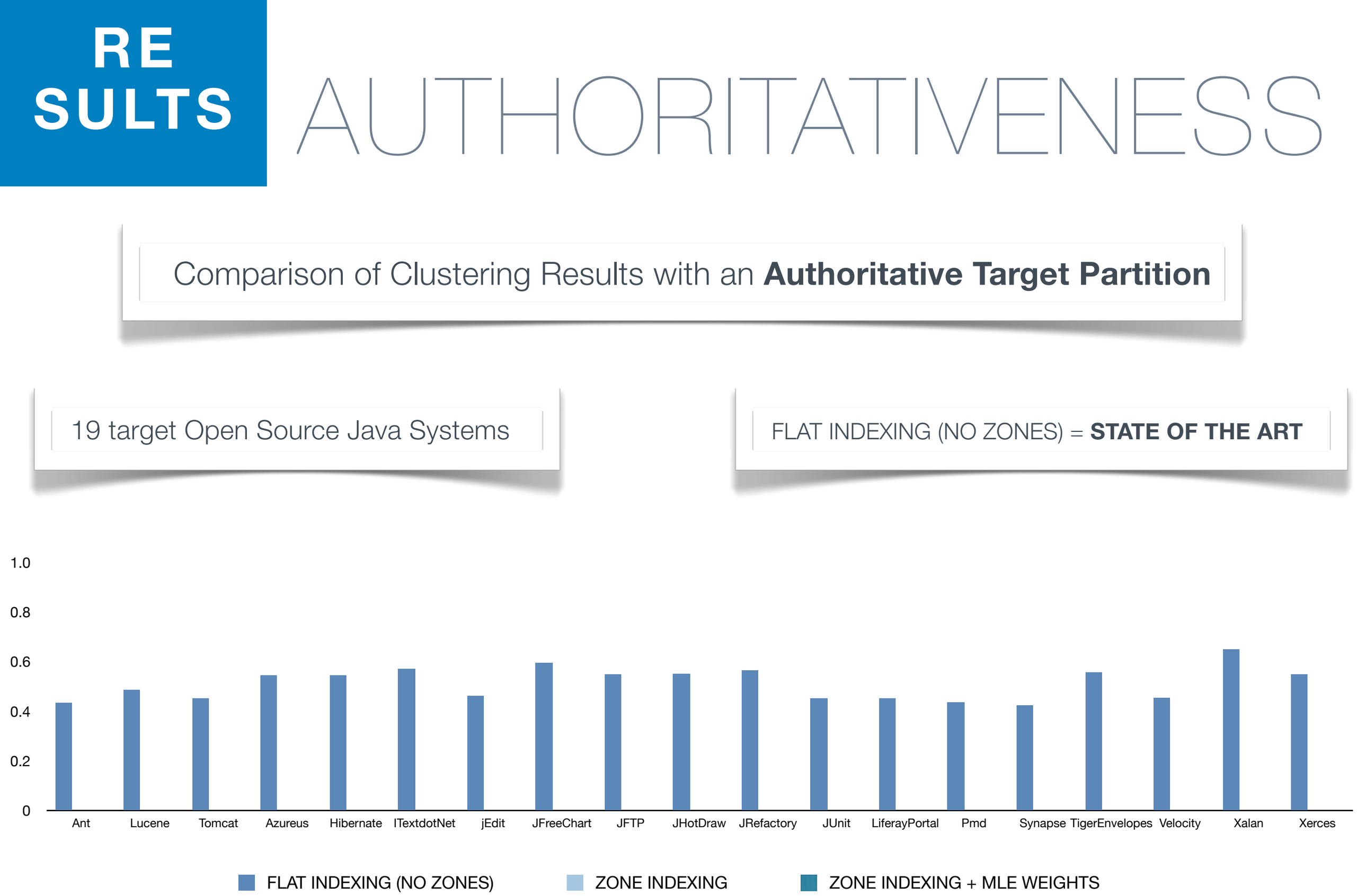
RESULTS

AUTHORITATIVENESS

Comparison of Clustering Results with an **Authoritative Target Partition**

19 target Open Source Java Systems

FLAT INDEXING (NO ZONES) = **STATE OF THE ART**



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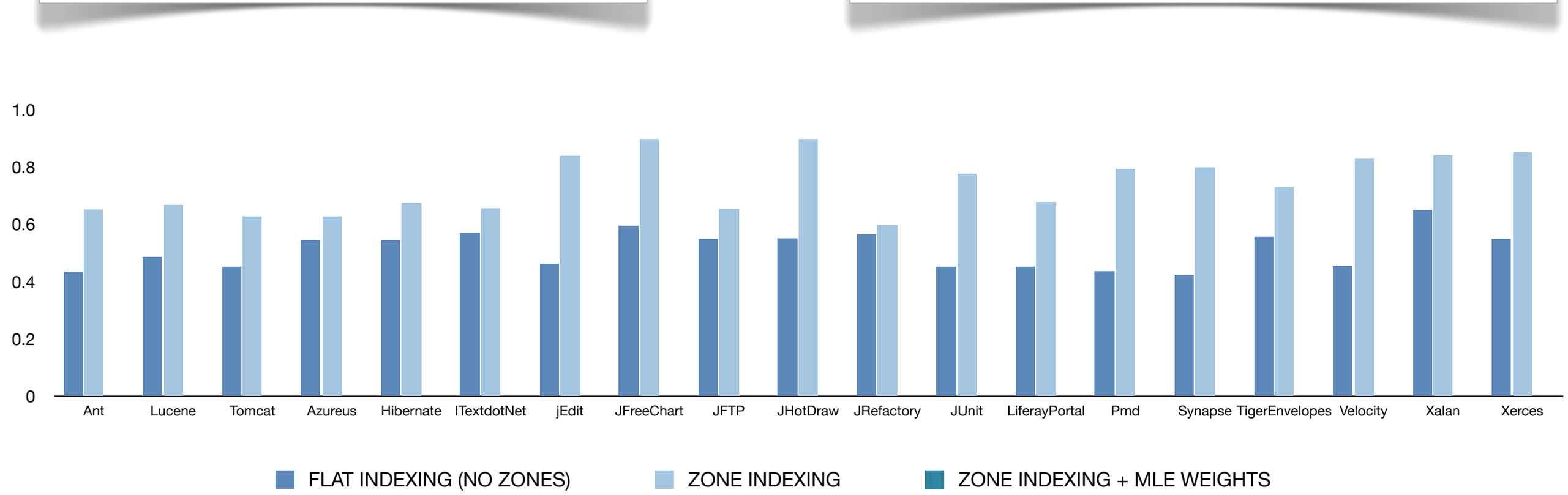

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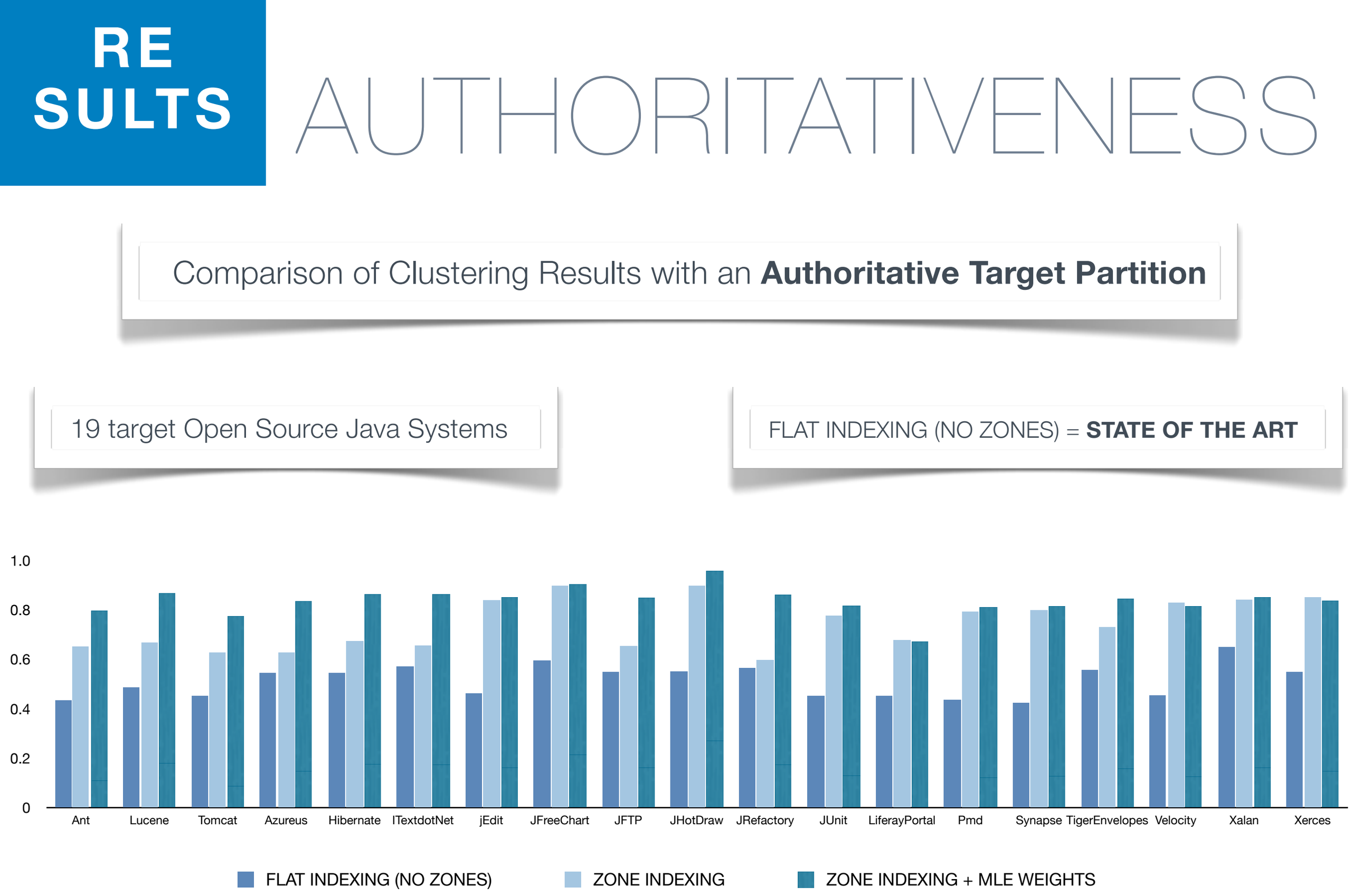

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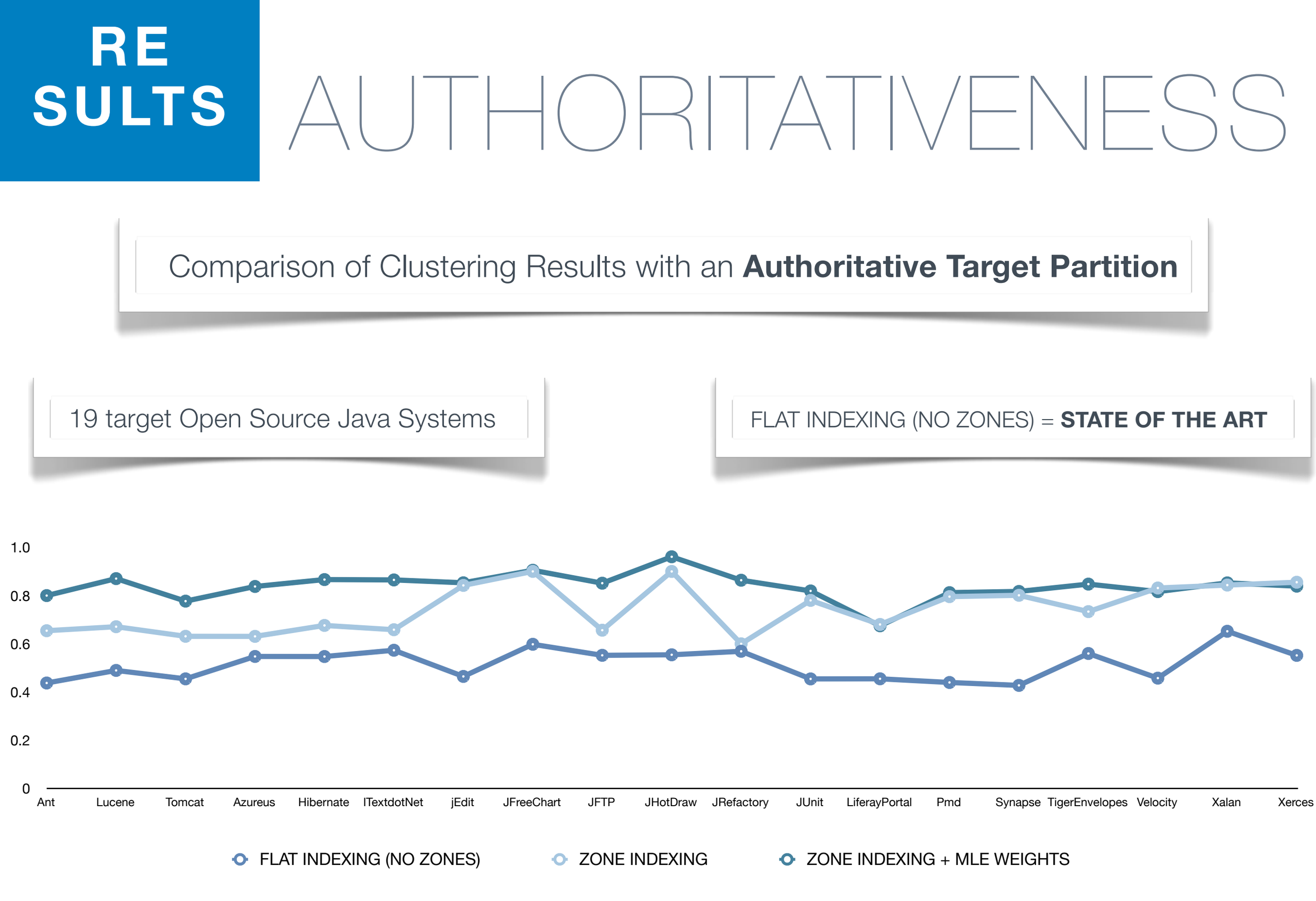
19 target Open Source Java Systems

FLAT INDEXING (NO ZONES) = **STATE OF THE ART**



ISSUE
#2

SOURCE CODE NORMALIZATION

SOURCE CODE

LEXICAL INFORMATION

```
/**
 * A handle that doesn't change the owned figure. Its only purpose is
 * to show feedback that a figure is selected.
 * <hr>
 */
public class NullHandle extends LocatorHandle {

    /**
     * The handle's locator.
     */
    protected Locator fLocator;

    public NullHandle(Figure owner, Locator locator) {
        super(owner, locator);
    }

    /**
     * Draws the NullHandle's framed rectangle.
     */
    public void draw(Graphics g) {
        Rectangle displayBox= displayBox();
        g.setColor(Color.black);
        g.drawDORRect(0);
    }
}
```

Implicit assumption: The “same” words are used whenever a particular concept occurs

SOURCE CODE

LEXICAL INFORMATION

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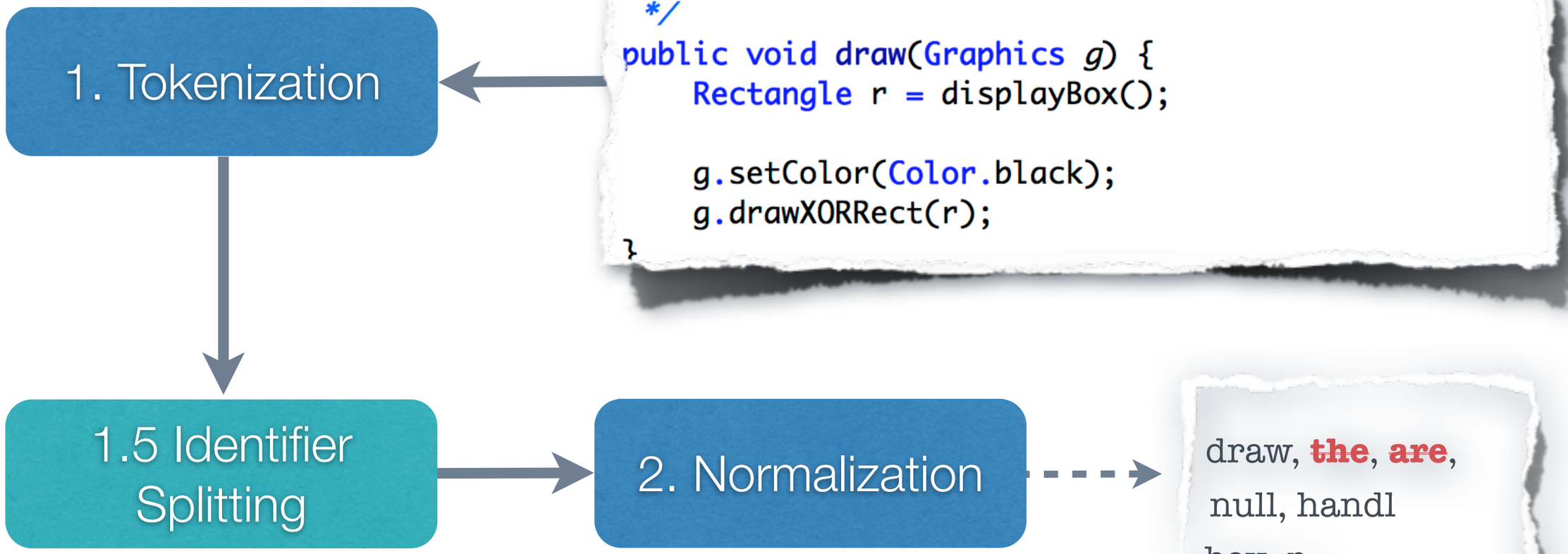
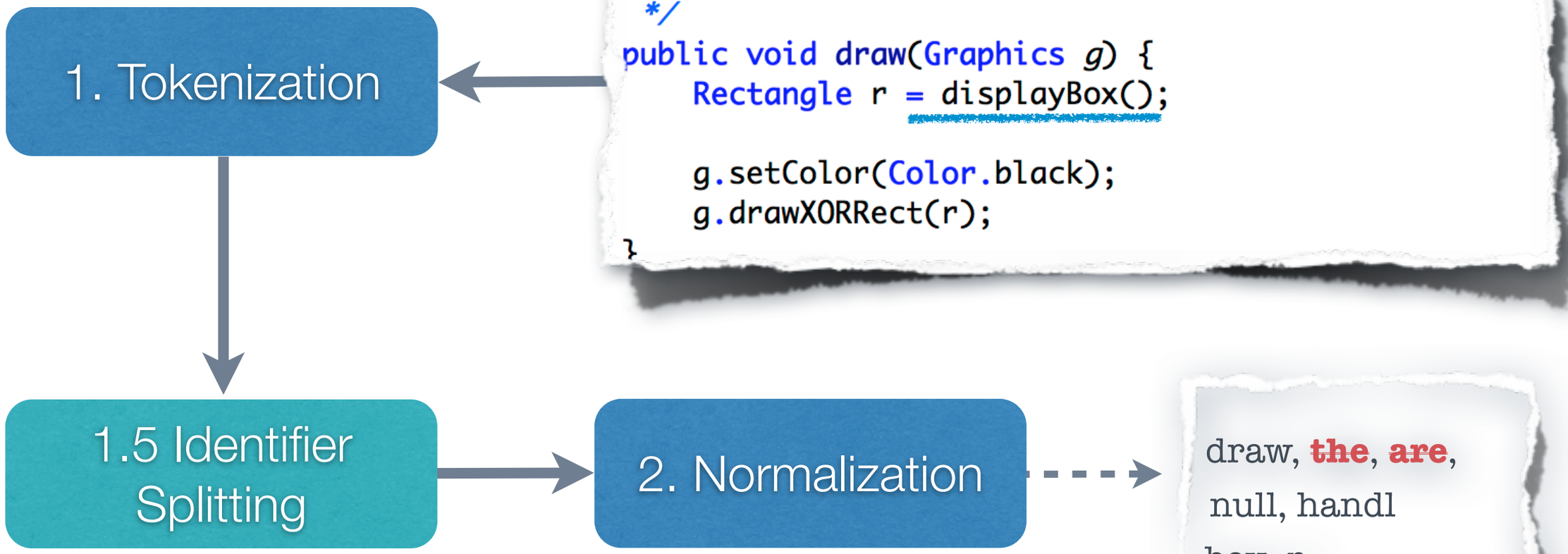
```

Implicit assumption: The “same” words are used whenever a particular concept occurs



- *Splitting algorithms* based on *naming conventions*
  - **camelCase** Splitter: `r'(?<=!^)([A-Z][a-z]+)'`
    - NullHandle ==> Null | Handle
    - displayBox ==> display | Box




```
/**
 * Draws the NullHandle. NullHandles are drawn as a
 * red framed rectangle box.
 */
public void draw(Graphics g) {
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- *Splitting algorithms* based on *naming conventions*
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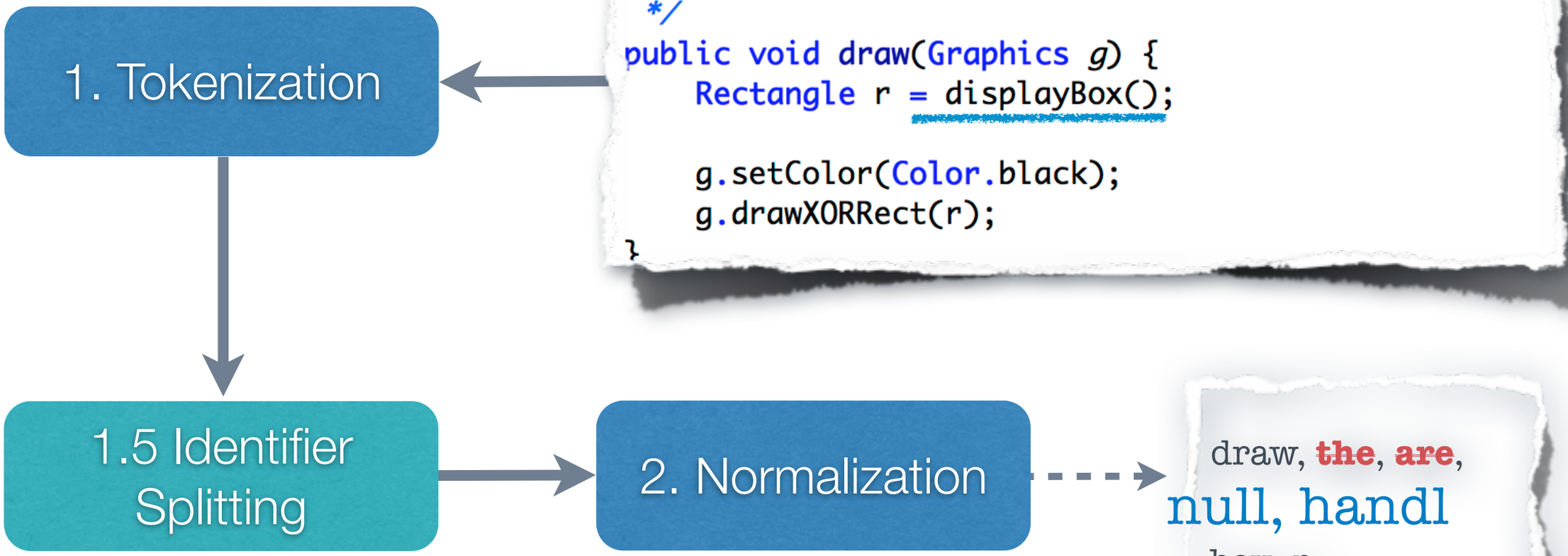
STATE OF THE ART TOOLS

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```

draw, ~~the~~, ~~are~~,
null, handl
box, r,
rectangl, g,
graphic,
color,
display, box
....

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IDENTIFIERS SPLITTING

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- **camelCase** Splitter: `r'(?<=!^)([A-Z][a-z]+)'`
  - `drawXORRect ==> drawXOR | Rect`

IDENTIFIERS SPLITTING

Splitting algorithms based on *naming conventions*

are not robust enough

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```

- **camelCase** Splitter: `r'(?<=!^)([A-Z][a-z]+)'`
  - `drawXORRect` ==> `drawXOR | Rect`
  - `drawxorrect` ==> NO SPLIT

ABBREVIATIONS EXPANSION

Splitting algorithms based on *naming conventions*

are not robust enough

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- Heavy use of **Abbreviations** in the source code
- `r` *as for* `Rectangle`
- `rect` *as for* `Rectangle`

Splitting algorithms based on *naming conventions*

are not ~~robust~~ enough

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CODE NORMALIZATION

1. Tokenization

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```

1.5 Code Normalization

2. Normalization

draw, ~~the~~, ~~are~~,
null, handl,
box, **rectangl**,
rectangl,
graphic,
color,
display, box,
draw, **xor**,
rectangl

- AMAP (Hill and Pollock, 2008)
- SAMURAI (Enslen, et.al , 2011)
- TIDIER (Guerrouj, et.al , 2011)
- GenTest+Normalize (Lawrie and Binkley, 2011)
- **LINSEN** (Corazza, Di Martino and Maggio, 2012)

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CONTRI BUTION

SOURCE CODE NORMALIZATION

- **LINSEN:** novel technique for code normalization
  - Able to **both** *Split Identifiers* and *Expand* possible occurring abbreviations

Corazza, A., Di Martino, S., Maggio, V.
LINSEN: An efficient approach to split identifiers and expand abbreviations
(2012) IEEE International Conference on Software Maintenance, ICSM, art. no. 6405277, pp. 233-242. **ISBN:** 978-146732312-3

CONTRI BUTION

SOURCE CODE NORMALIZATION

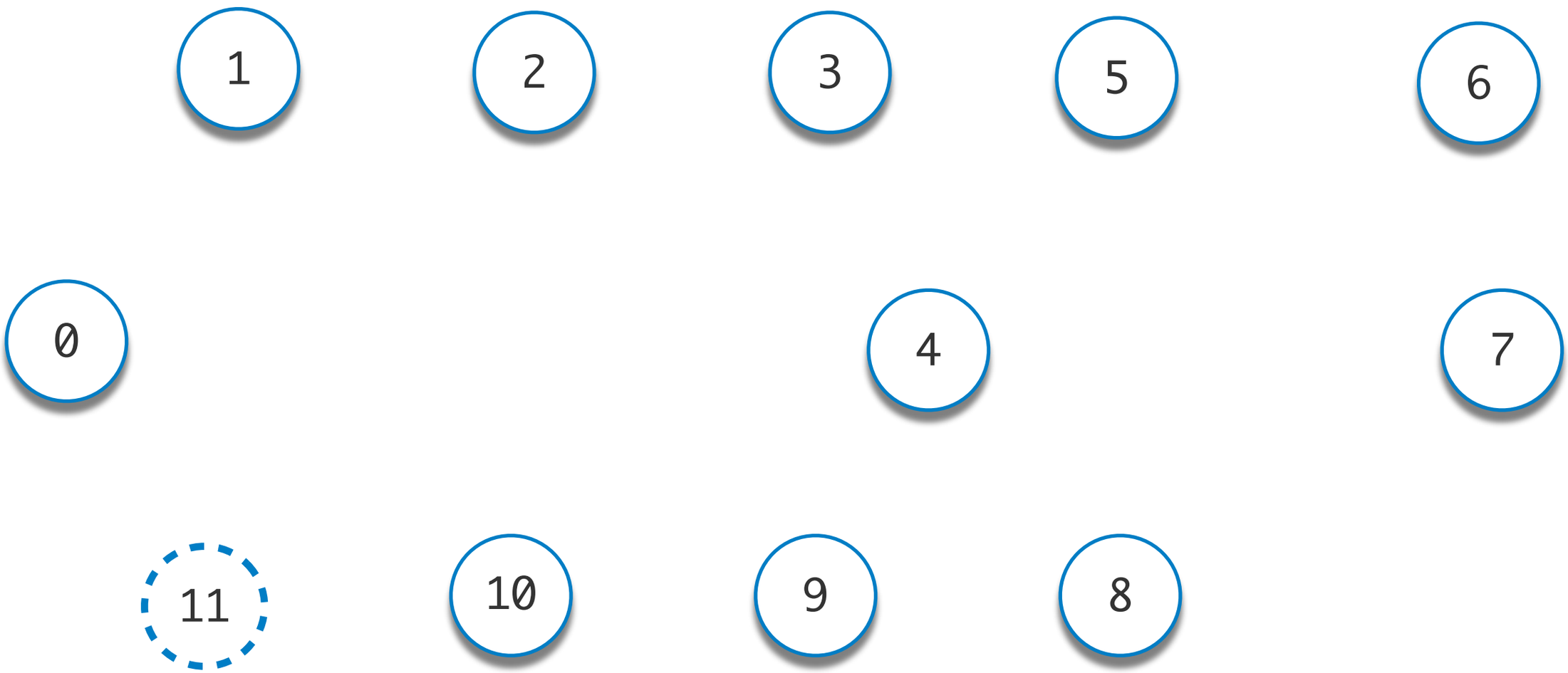
- **LINSEN:** novel technique for code normalization
  - Able to **both** *Split Identifiers* and *Expand* possible occurring abbreviations
- Based on an efficient String Matching technique: *Baeza-Yates&Perlberg Algorithm (BYP)*
  - Exploit different **Sources of Information** to find the matching words

Corazza, A., Di Martino, S., Maggio, V.
LINSEN: An efficient approach to split identifiers and expand abbreviations
(2012) IEEE International Conference on Software Maintenance, ICSM, art. no. 6405277, pp. 233-242. **ISBN:** 978-146732312-3

SKETCH OF THE ALGORITHM

Model: *Weighted* Directed Graph

Example: `drawXORRect` identifier



- **NODES** correspond to characters of the current identifier

SKETCH OF THE ALGORITHM

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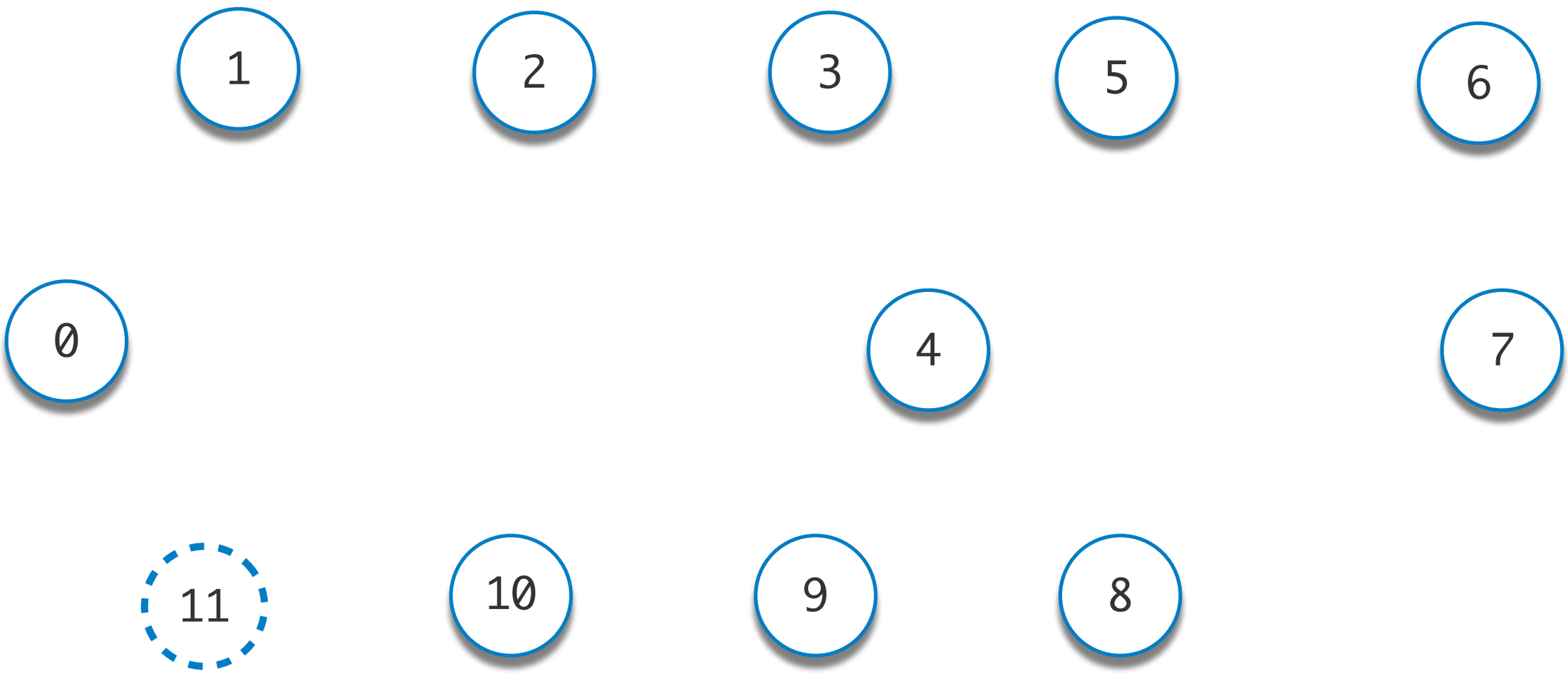

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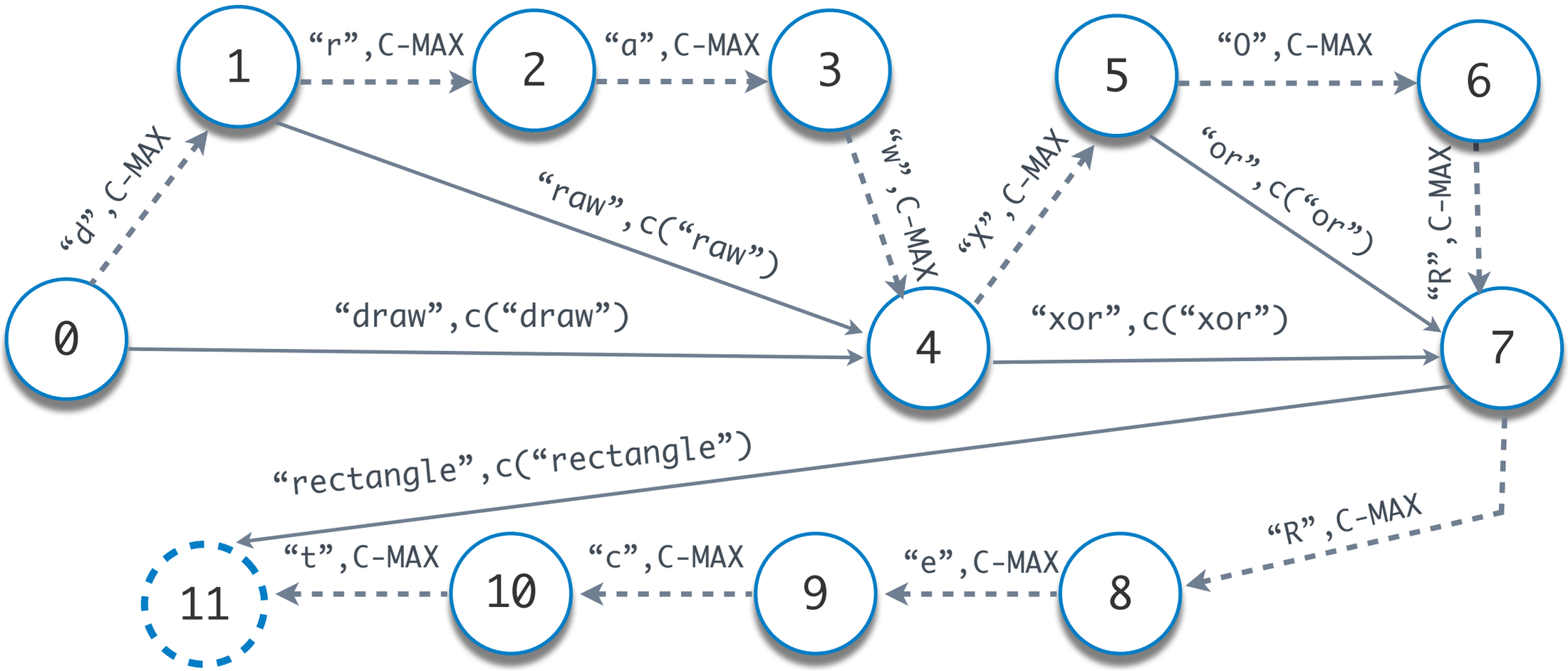
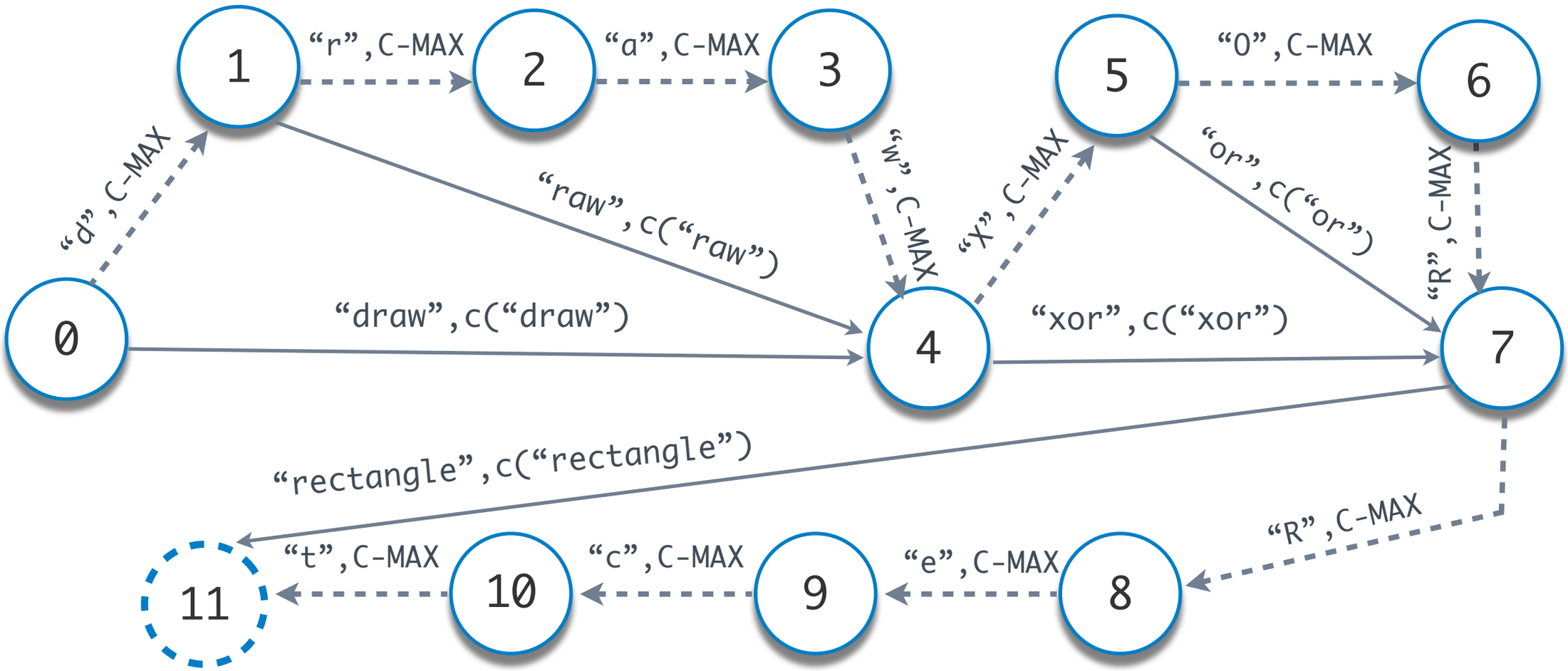


- **NODES** correspond to characters of the current identifier
- **ARCS** corresponds to matchings between *identifier substrings* and *dictionary words*
  - Padding Arcs to ensure the Graph always connected

SKETCH OF THE ALGORITHM

Model: *Weighted* Directed Graph

Example: `drawXORRect` identifier

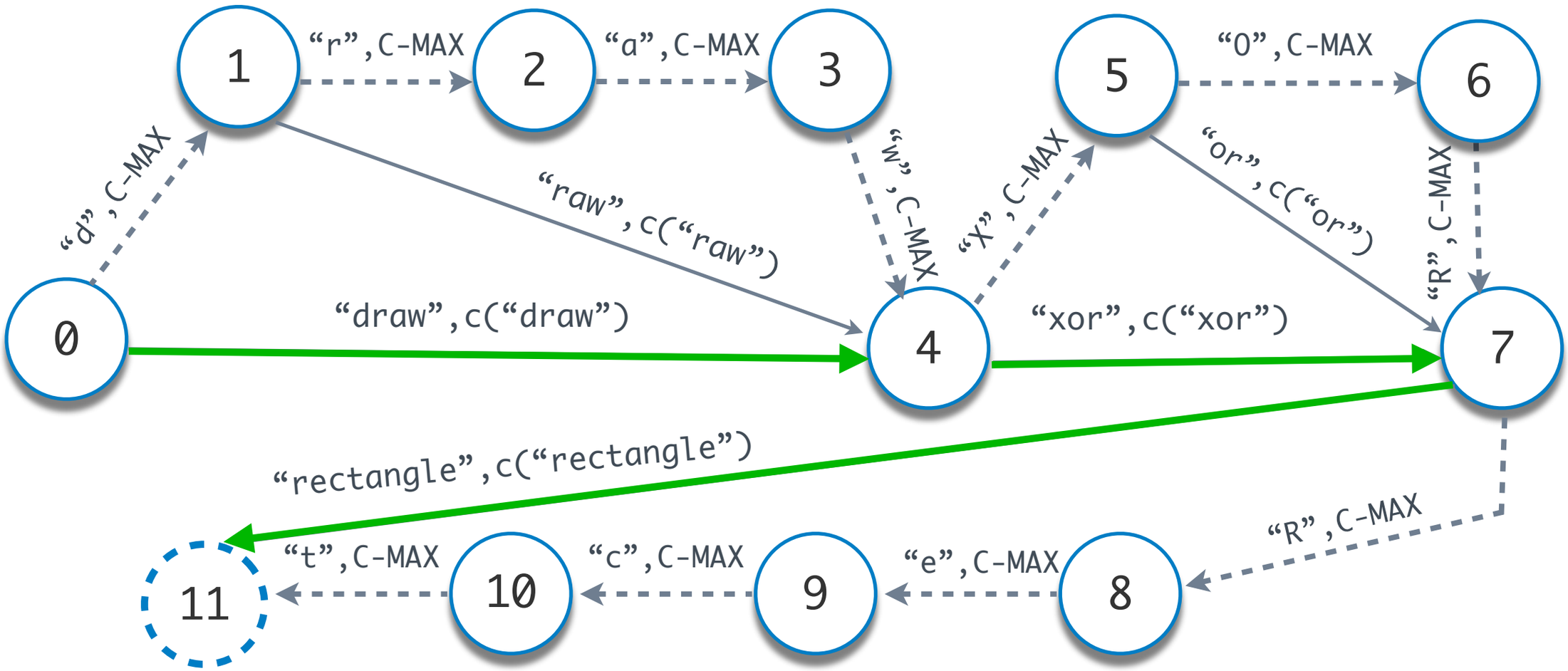


- Every Arc is **Labelled** with the corresponding dictionary word
- **Weights** represent the "cost" of each matching
- *Cost function* `[c("word")]` favors *longest words* and *domain-related* information

SKETCH OF THE ALGORITHM

Model: *Weighted* Directed Graph

Example: `drawXORRect` identifier



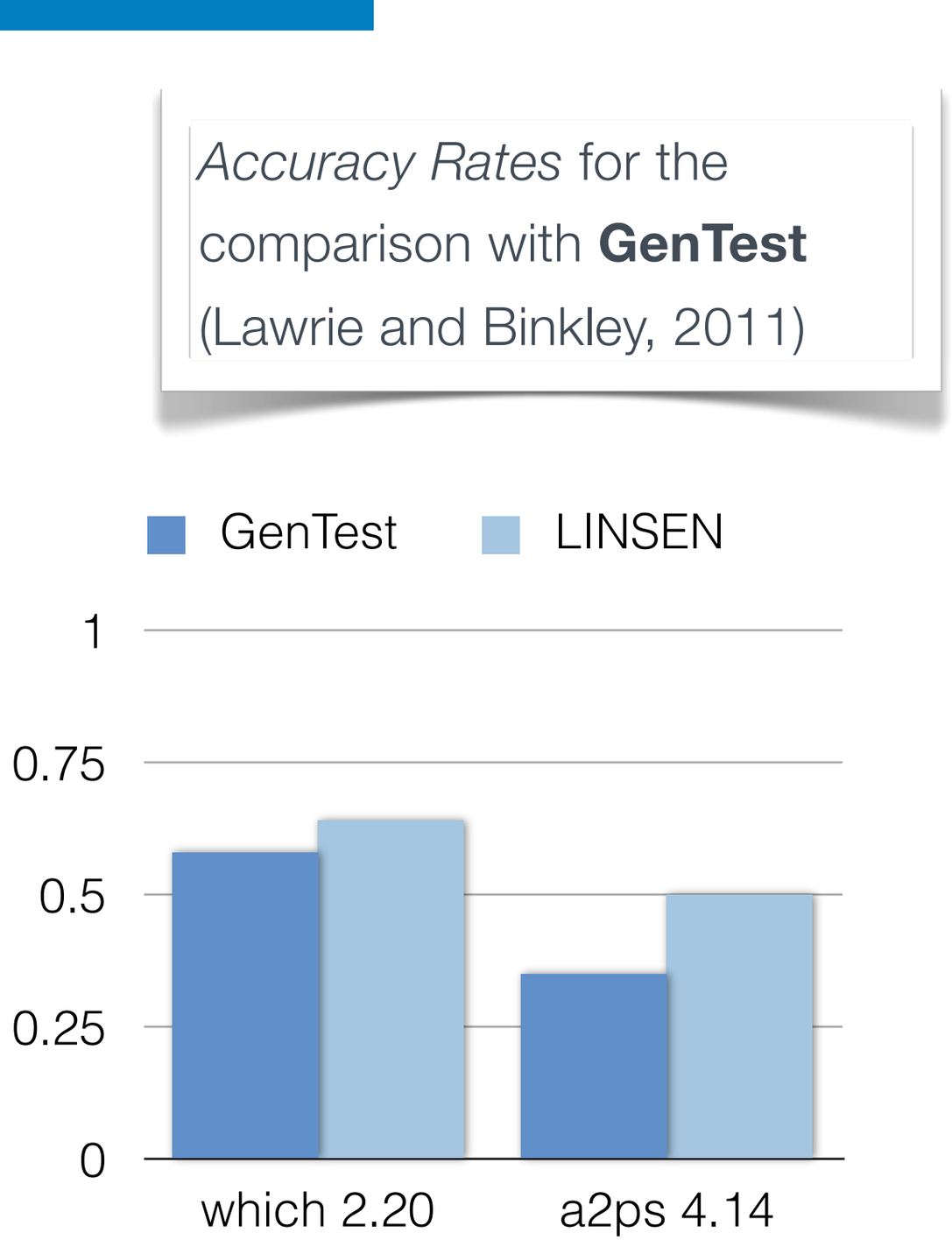
- The final **Mapping Solution** corresponds to the **sequence of labels** in the path with the **minimum cost** (*Djikstra Algorithm*)

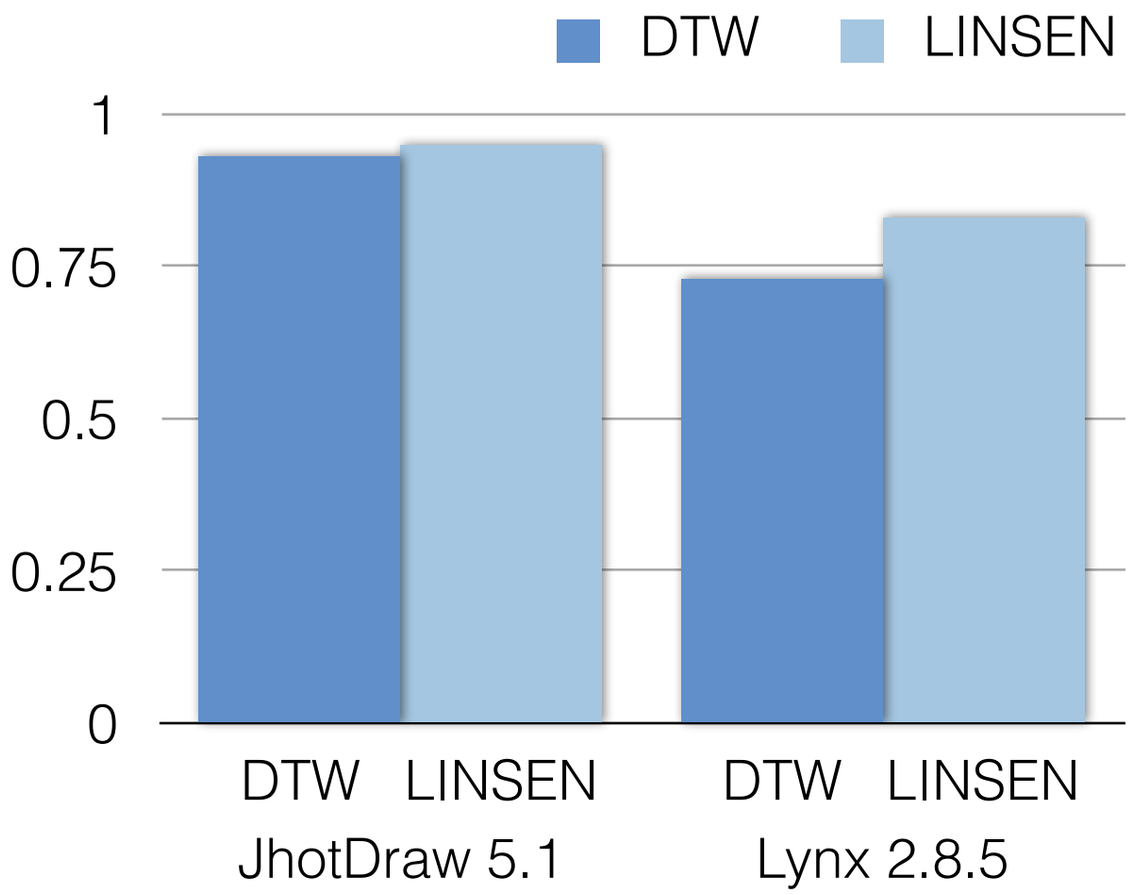
RESULTS # 1

SPLITTING

DTW $O(n^3)$

Accuracy Rates for the comparison with **GenTest** (Lawrie and Binkley, 2011)





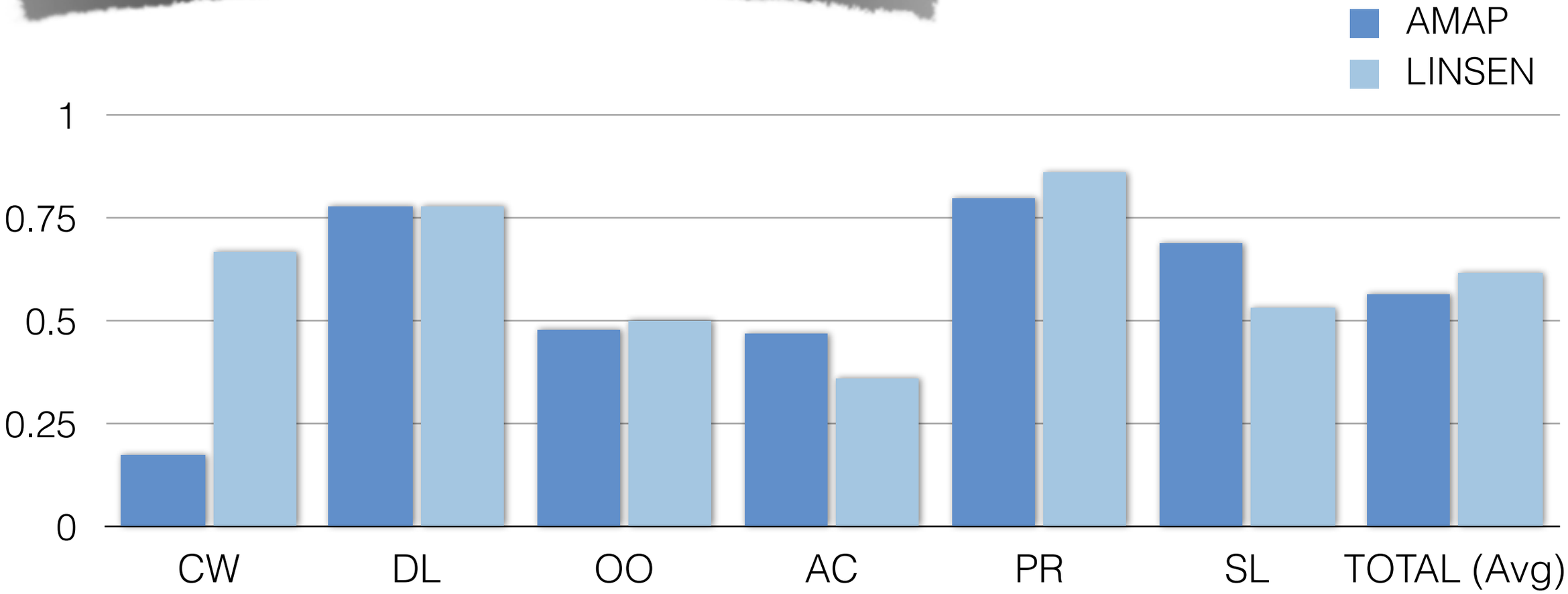
Accuracy Rates for the comparison with **DTW** (Madani et. al 2010)

RESULTS # 2

EXPANSION

CW: Combination Words
DL: Dropped Letters
OO: Others
AC: Acronyms
PR: Prefix
SL: Single Letters

Accuracy Rates for the comparison with **AMAP** (Hill and Pollock, 2008)

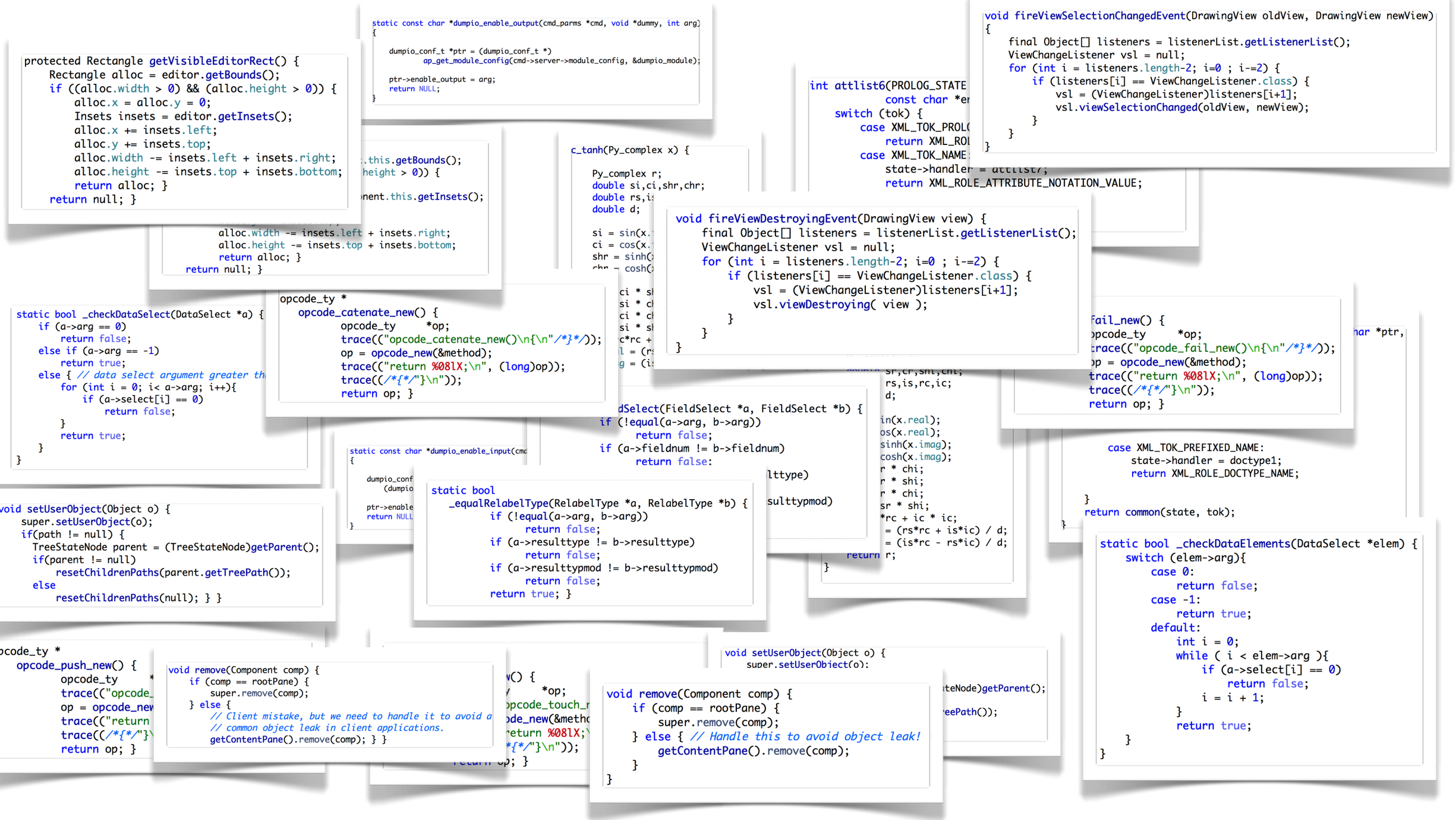


ISSUE
#3

CLONE DETECTION

PROBLEM STATEMENT

CLONE DETECTION



PROBLEM STATEMENT

CLONE DETECTION

```
opcode_ty *
   opcode_catenate_new() {
           opcode_ty      *op;
           trace(("opcode_catenate_new()\n{\n"/*}*/));
           op = opcode_new(&method);
           trace(("return %08lX;\n", (long)op));
           trace((/*{*/"}\n"));
           return op; }
```

```
opcode_ty *
    opcode_fail_new() {
           opcode_ty      *op;
           trace(("opcode_fail_new()\n{\n"/*}*/));
           op = opcode_new(&method);
           trace(("return %08lX;\n", (long)op));
           trace((/*{*/"}\n"));
           return op; }
```

Clones **Textual** Similarity

PROBLEM STATEMENT

CLONE DETECTION

```
static bool _checkDataSelect(DataSelect *a) {
    if (a->arg == 0)
        return false;
    else if (a->arg == -1)
        return true;
    else { // data select argument greater than zero
        for (int i = 0; i< a->arg; i++){
            if (a->select[i] == 0)
                return false;
        }
        return true;
    }
}
```

```
static bool _checkDataElements(DataSelect *elem) {
    switch (elem->arg){
        case 0:
            return false;
        case -1:
            return true;
        default:
            int i = 0;
            while ( i < elem->arg ){
                if (a->select[i] == 0)
                    return false;
                i = i + 1;
            }
            return true;
    }
}
```

Clones **Functional** Similarity

PROBLEM STATEMENT

CLONE DETECTION

```
void fireViewSelectionChangedEvent(DrawingView oldView, DrawingView newView)
{
    final Object[] listeners = listenerList.getListenerList();
    ViewChangeListener vsl = null;
    for (int i = listeners.length-2; i=0 ; i-=2) {
        if (listeners[i] == ViewChangeListener.class) {
            vsl = (ViewChangeListener)listeners[i+1];
            vsl.viewSelectionChanged(oldView, newView);
        }
    }
}
```

```
void fireViewDestroyingEvent(DrawingView view) {
    final Object[] listeners = listenerList.getListenerList();
    ViewChangeListener vsl = null;
    for (int i = listeners.length-2; i=0 ; i-=2) {
        if (listeners[i] == ViewChangeListener.class) {
            vsl = (ViewChangeListener)listeners[i+1];
            vsl.viewDestroying( view );
        }
    }
}
```

Sneaky **Bug!**

Clones affect the **reliability** of the system!

STATE OF THE ART TOOLS

Duploc

SDD

NiCAD

Dude

Simian

CLICS

Scorpio

Duplix

PMD

Dup

CPD

Duplix

Gemini

CCFinder

Shinobi

iClones

Clone Detective

Clone Digger

ConQAT

JCCD

Deckard

CloneDr

SimScan

KClone

STATE OF THE ART TOOLS

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Text Based Tools:

Text is compared line by line

iClones

Clone Detective

Clone Digger

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Token Based Tools:

Token sequences are compared to sequences

STATE OF THE ART TOOLS

Duploc

Dup

CPD

SDD

NiCAD

Dude

Simian

CLICS

iClones

Clone Detective

Syntax Based Tools:

Syntax subtrees are compared to each other

Clone Digger

ConQAT

JCCD

Deckard

CloneDr

SimScan

KClone

Scorpio

Duplix

PMD

STATE OF THE ART TOOLS

Duploc

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Shinobi

iClones

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Clone Digger

ConQAT

ICCD

KClone

Scorpio

Duplix

PMD

Graph Based Tools:

(sub) graphs are compared to each other

CONTRI BUTION

CLONE DETECTION

- Combining different sources of information to improve the effectiveness of the detection process

Corazza, A., Di Martino, S., Maggio, V., Scanniello, G.
A Tree Kernel based approach for clone detection
(2010) IEEE International Conference on Software Maintenance, ICSM, art. no. 5609715. **ISBN:** 978-142448629-8

Corazza, A., Di Martino, S., Maggio, V., Moschitti, A., Passerini, A., Scanniello, G., Silvestri F.
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- Application of **Kernel Methods** to Source Code **Structures**

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CONTRI BUTION

CLONE DETECTION

- Combining different sources of information to improve the effectiveness of the detection process
  - Structural and Lexical Information
- Application of **Kernel Methods** to Source Code **Structures**
- Typically applied in other field such as NLP or Bioinformatics

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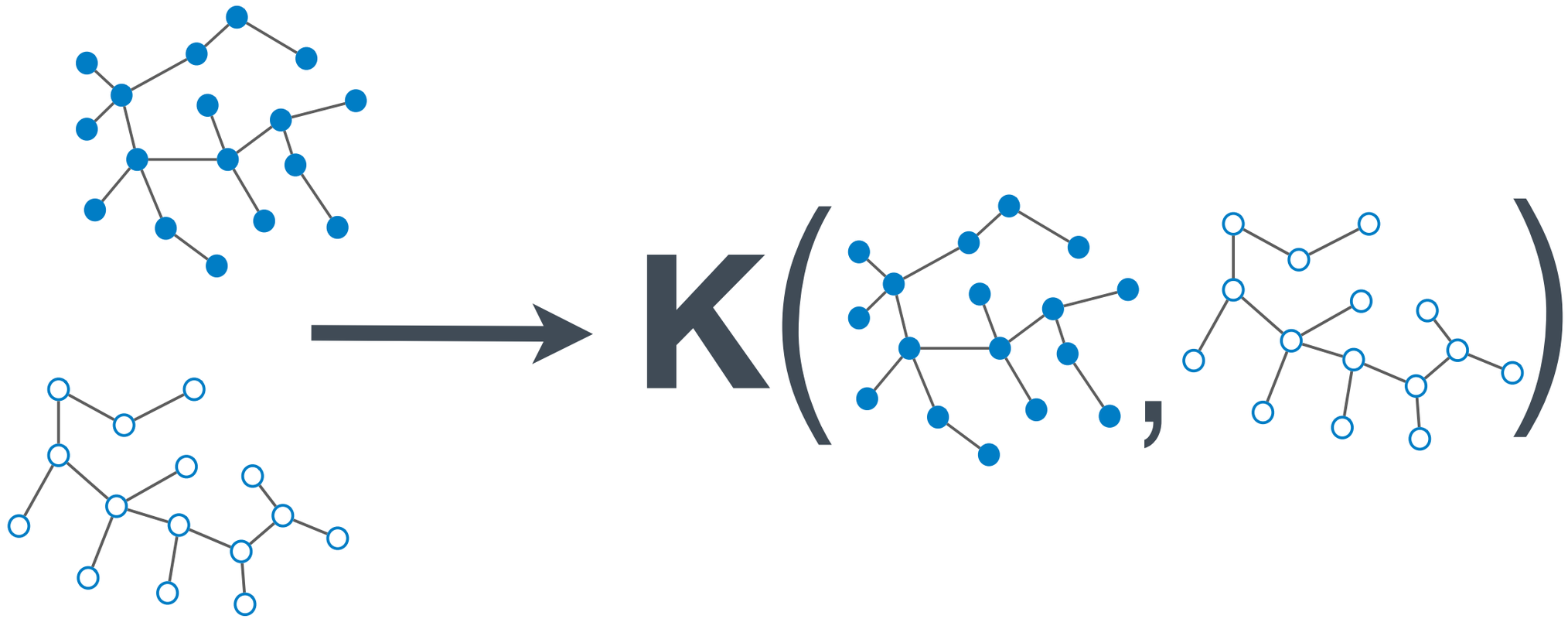
KERNELS FOR STRUCTURES

Computation of the **dot product** between (Graph) Structures



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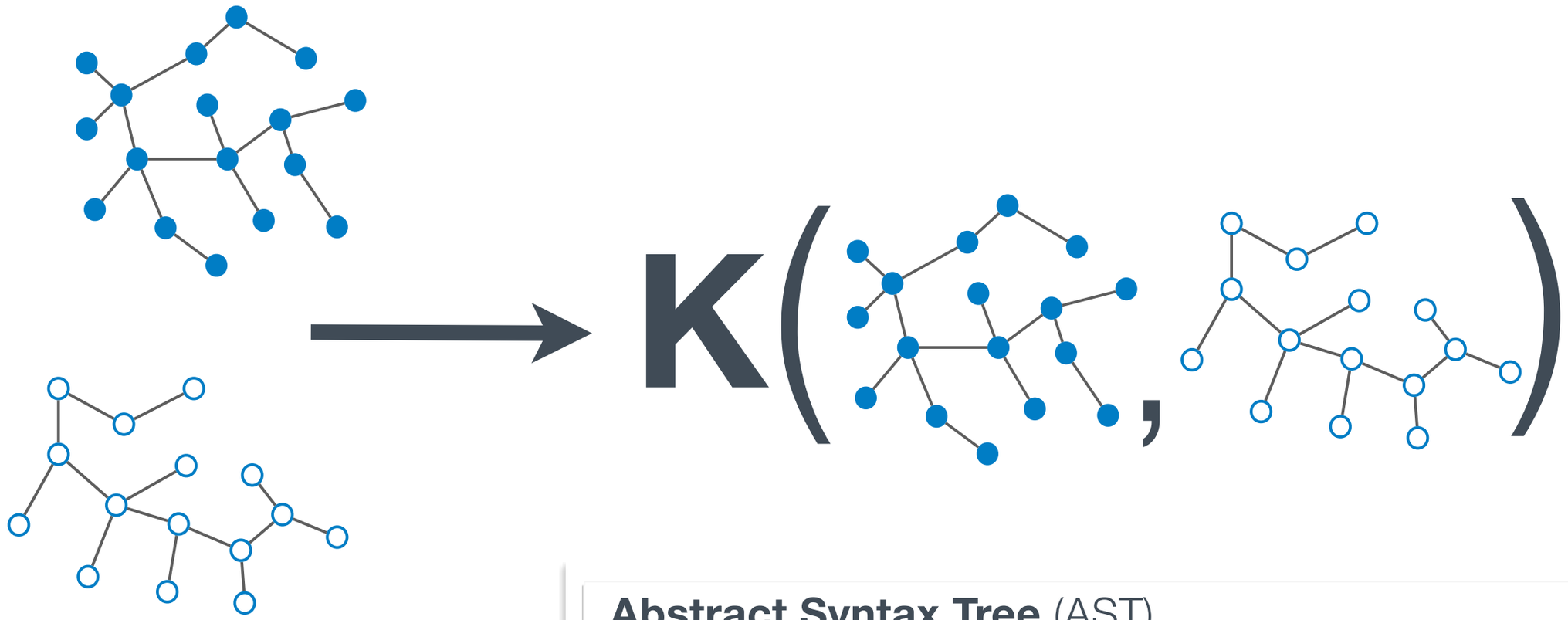

Abstract Syntax Tree (AST)

Tree structure representing the syntactic structure of the different instructions of a program (function)

Program Dependencies Graph (PDG)

(Directed) Graph structure representing the relationship among the different statement of a program

KERNELS FOR STRUCTURES

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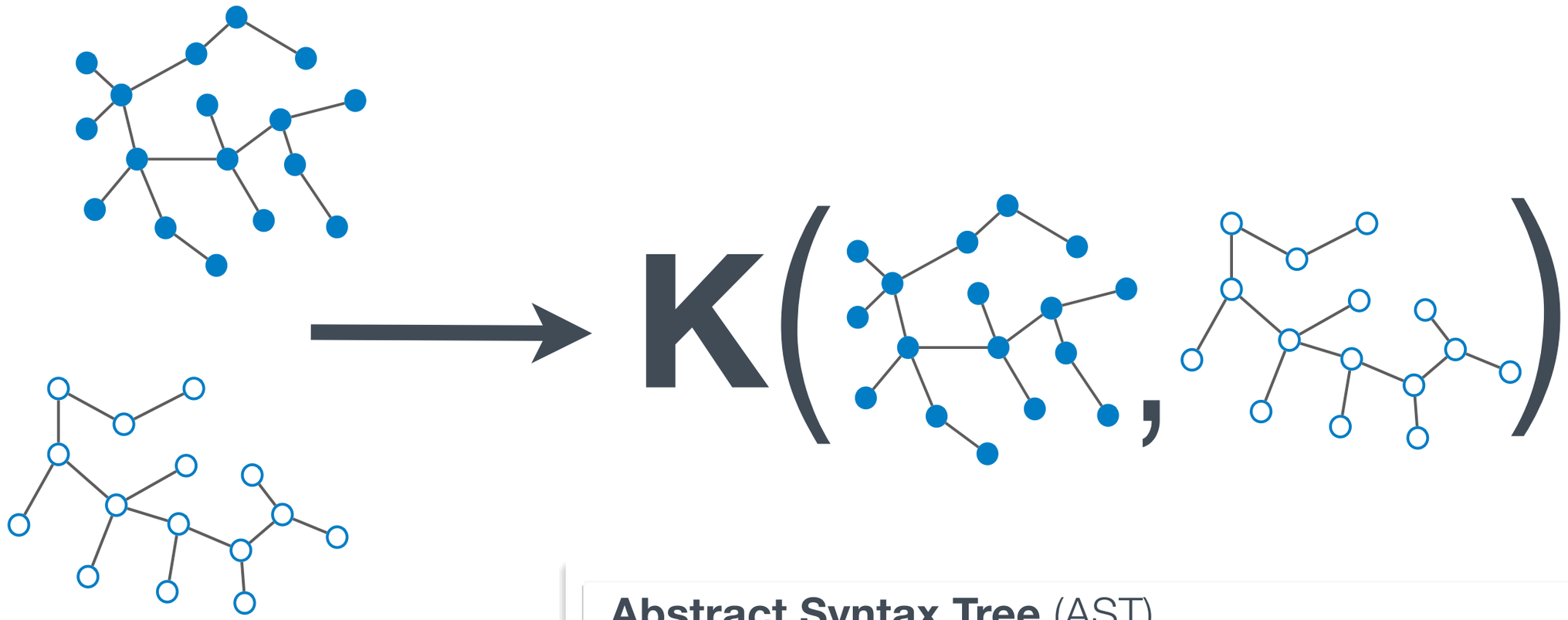


Abstract Syntax Tree (AST)

Tree structure representing the syntactic structure of the different instructions of a program (function)

Program Dependencies Graph (PDG)

(Directed) Graph structure representing the relationship among the different statement of a program

KERNEL FOR CLONES

CODE

```
while (x < y){
    x = x + 1;
    y = y - 1;
}
```

```
while (b > a){
    if (b > 0)
        c = 3;
    a = a + 1;
    b = b - 1;
}
```

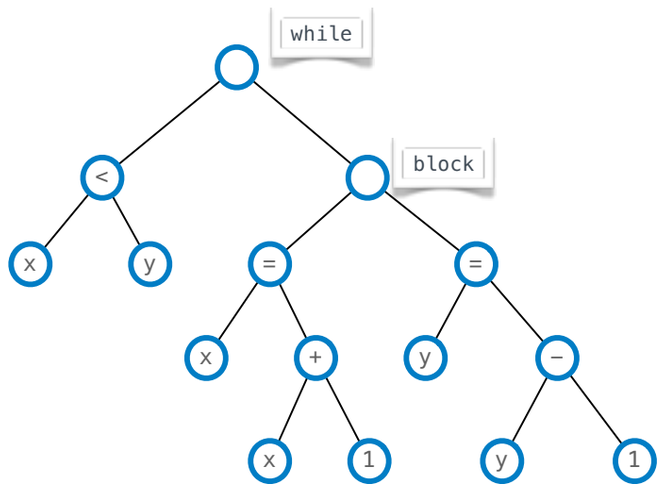
R CLONES

KERNEL FO

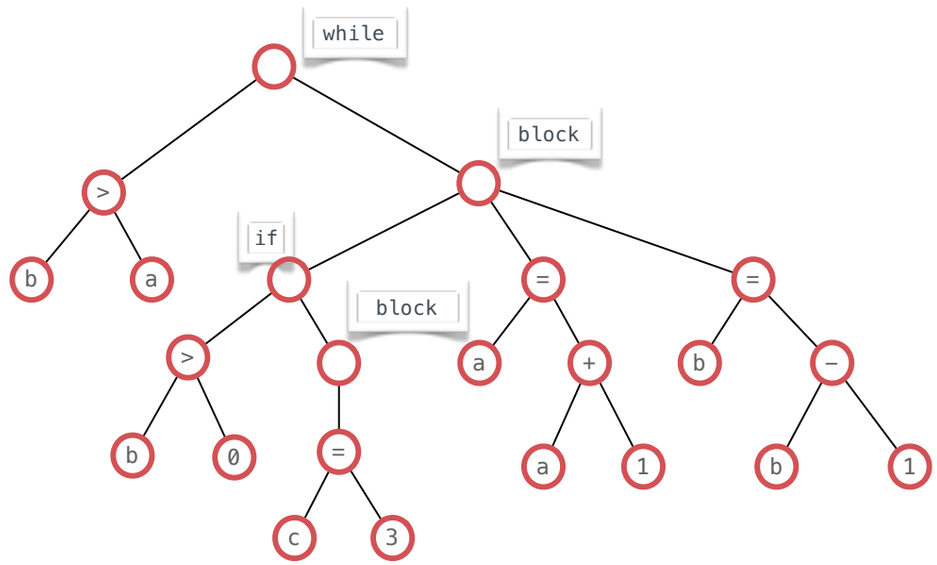
CODE

```
while (x < y){
    x = x + 1;
    y = y - 1;
}
```

AST




```
while (b > a){
    if (b > 0)
        c = 3;
    a = a + 1;
    b = b - 1;
}
```



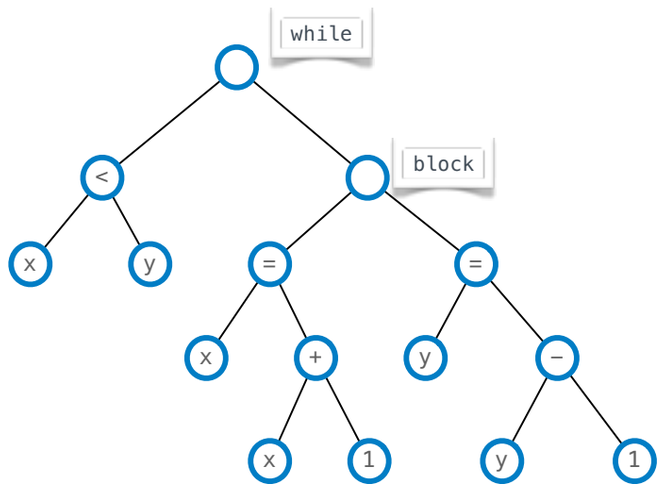
KERNEL FOR CLONES

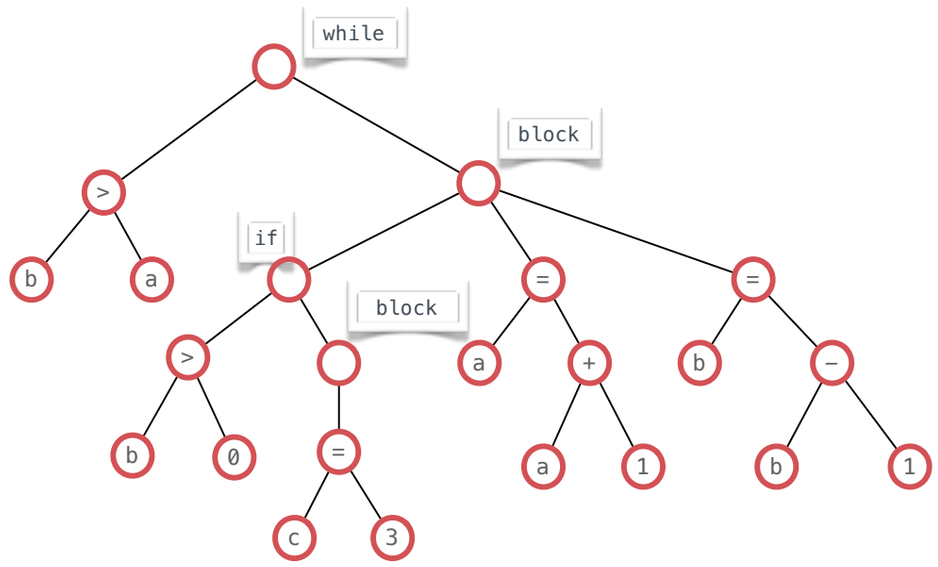
CODE

```
while (x < y){
    x = x + 1;
    y = y - 1;
}
```

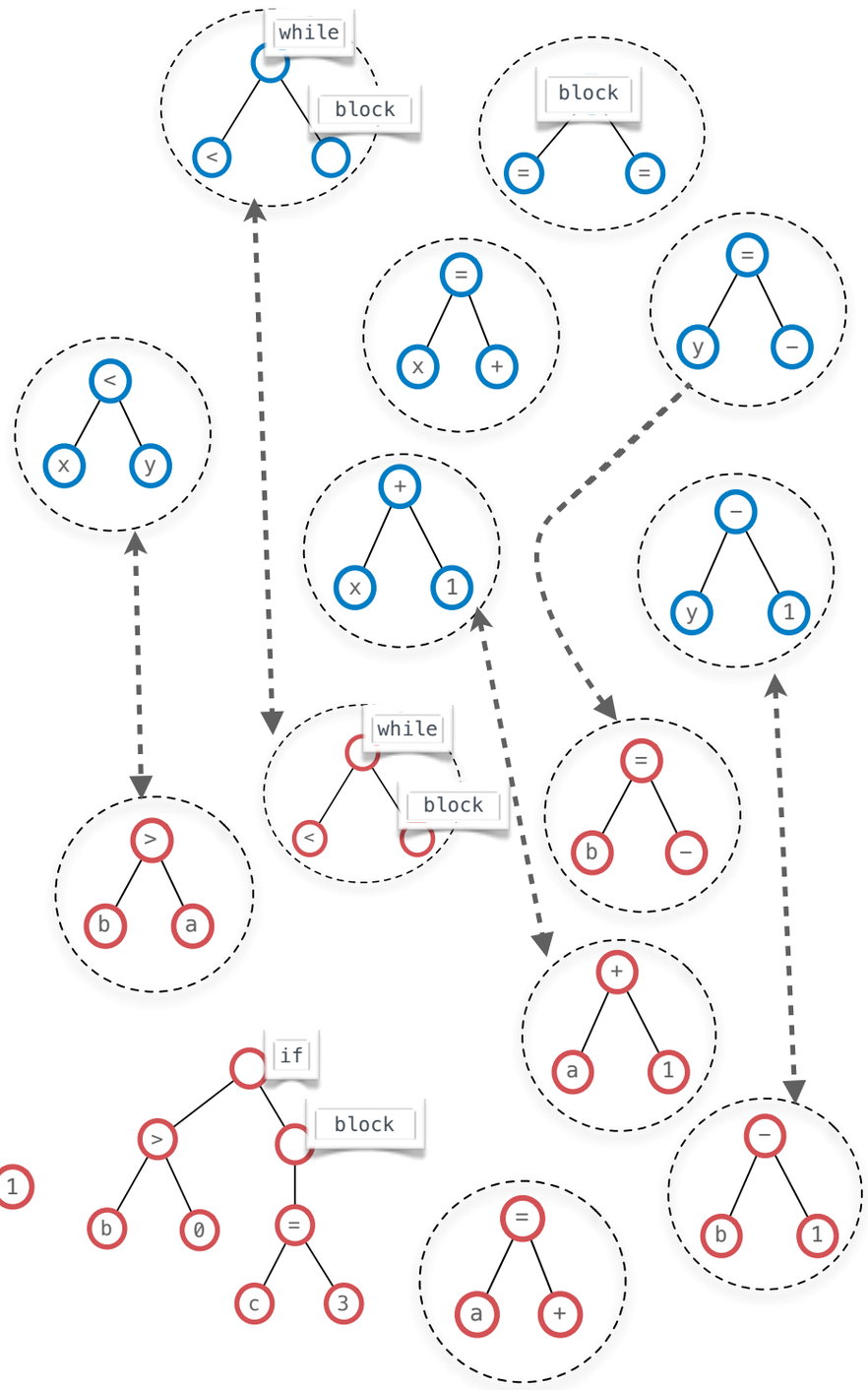
```
while (b > a){
    if (b > 0)
        c = 3;
    a = a + 1;
    b = b - 1;
}
```

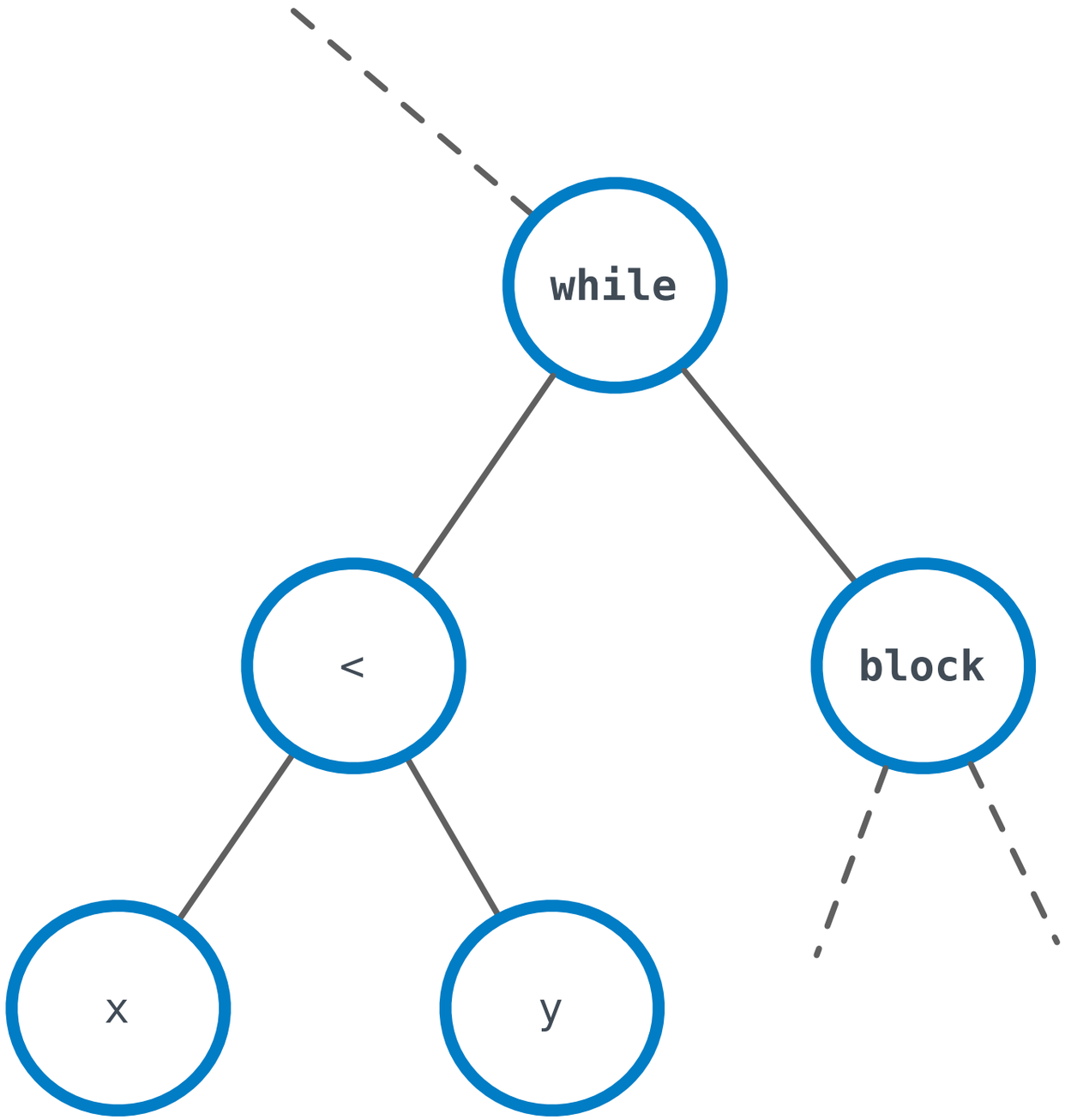
AST

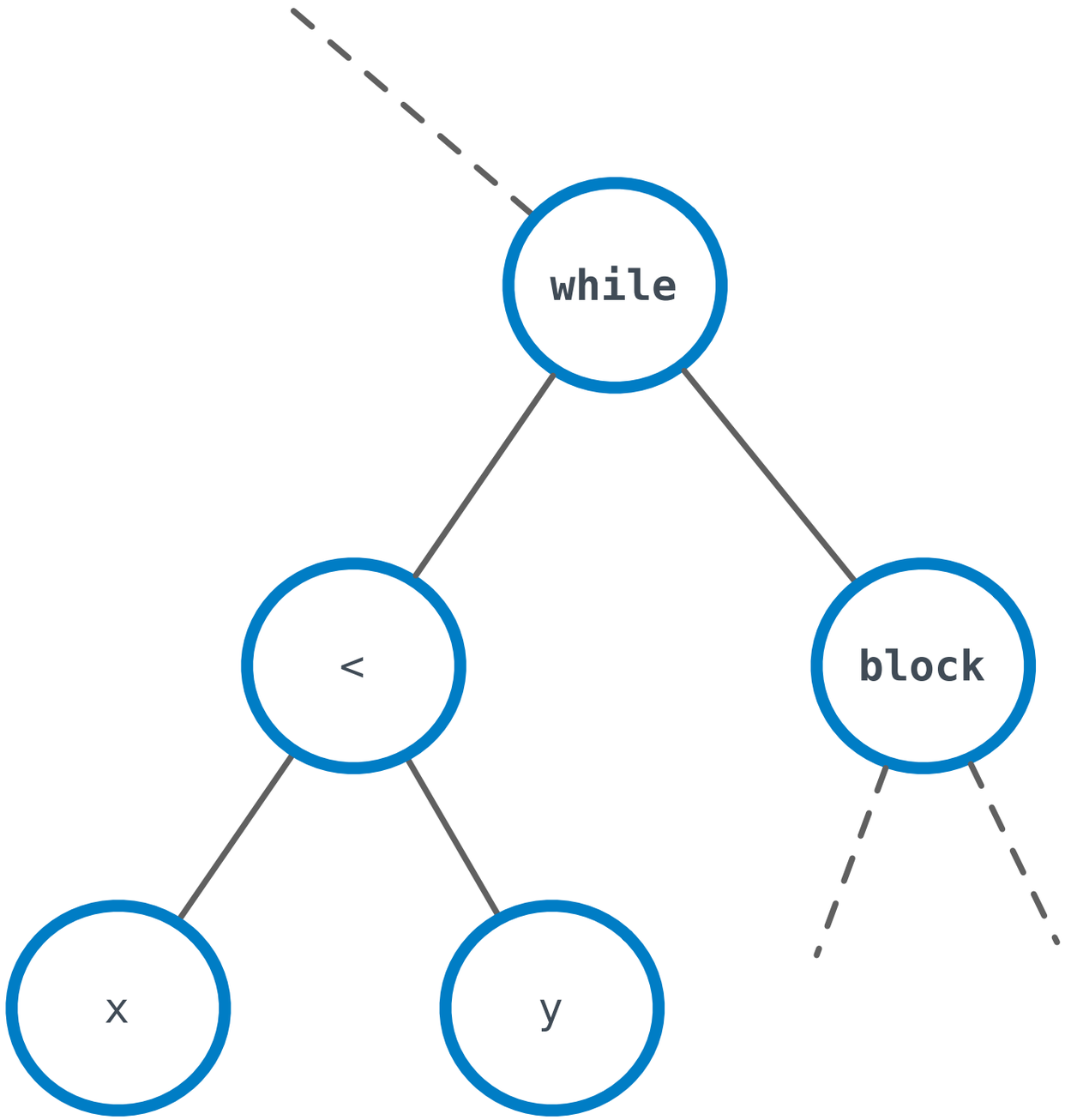




AST KERNEL



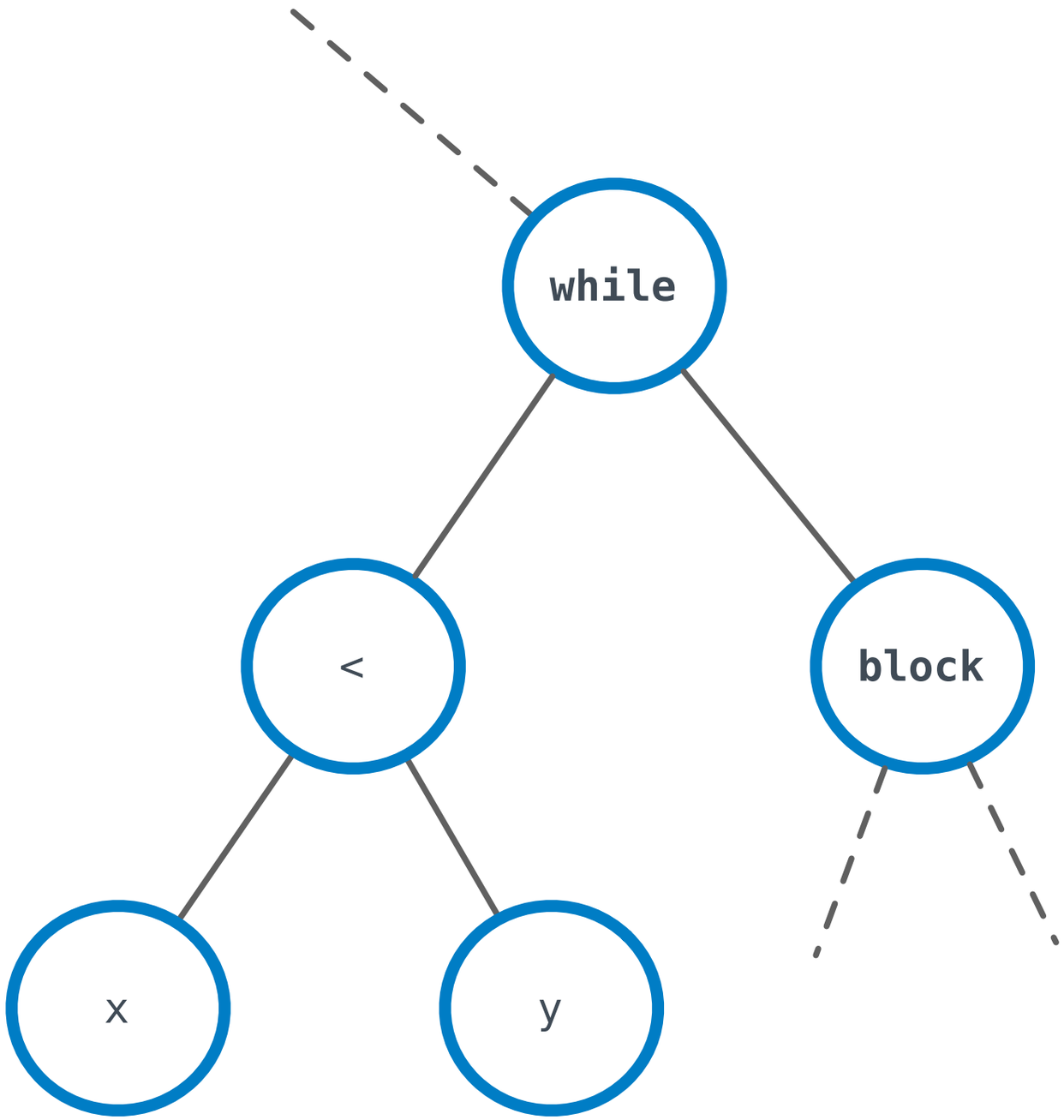

while
<
x
y
block



Instruction Class (IC)

i.e., `LOOP`, `CALL`, `CONDITIONAL_STATEMENT`

KERNEL FEATURES



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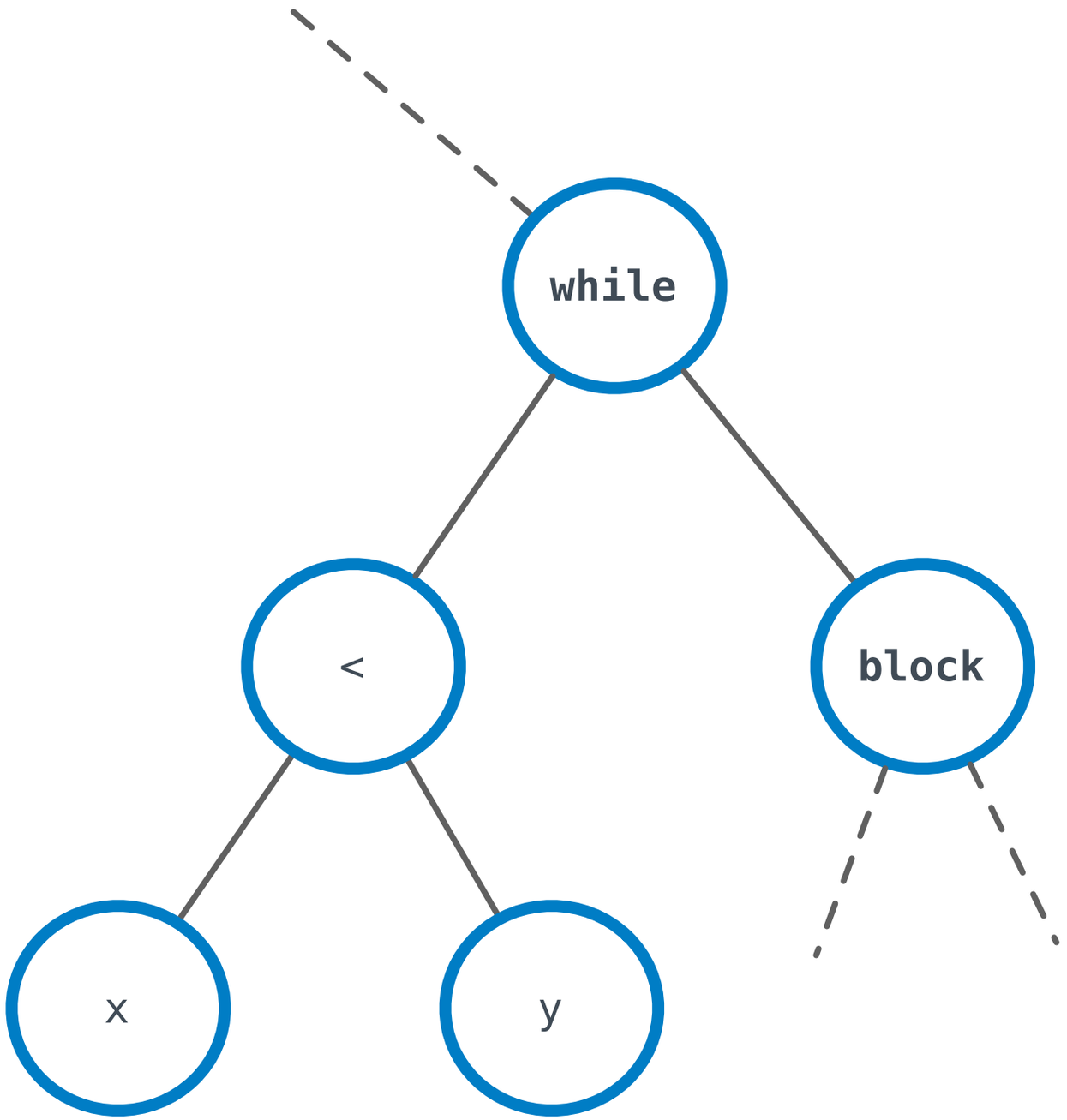

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i.e., Instruction Class of the closer statement node

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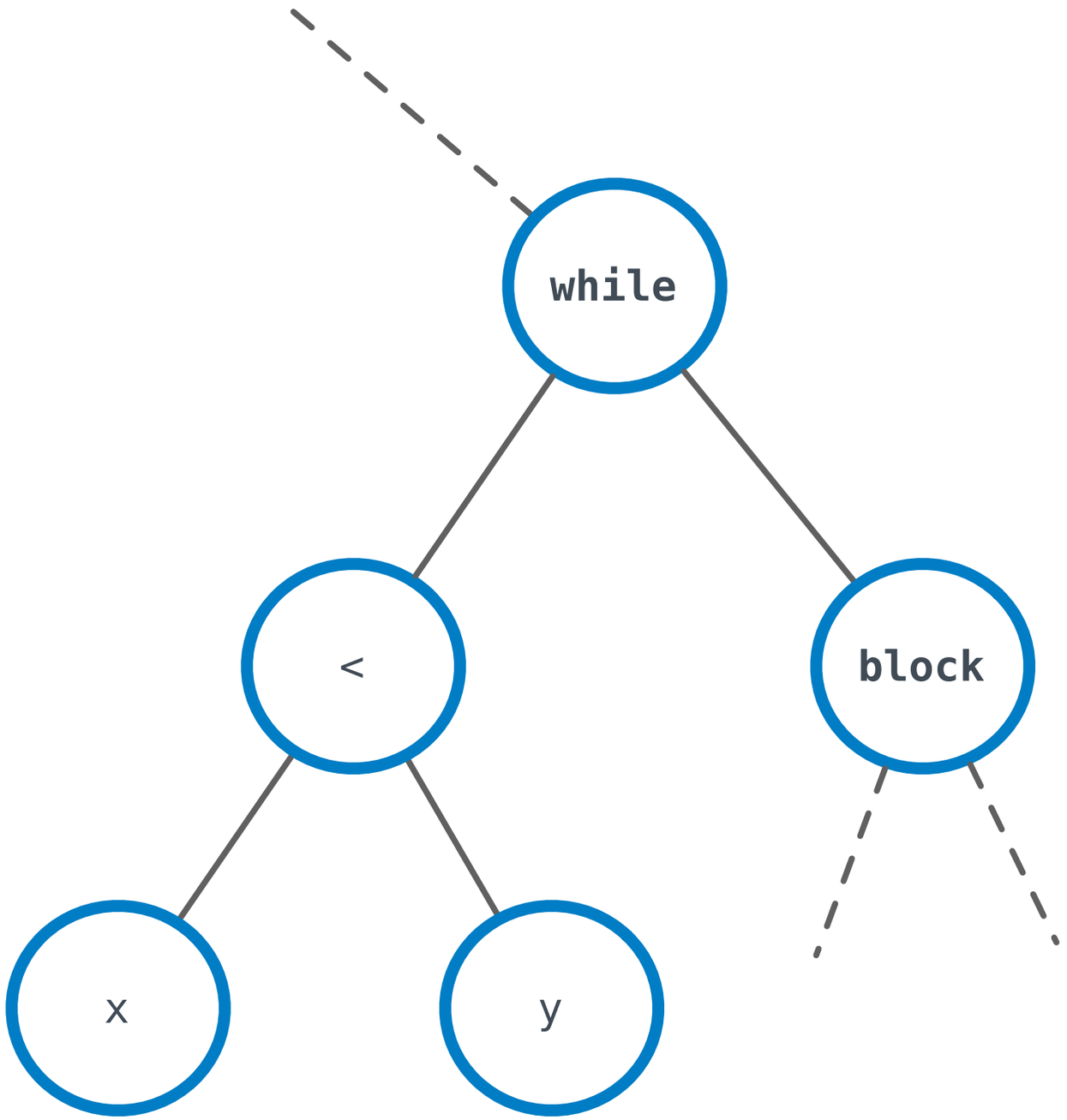

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Lexical information gathered (recursively) from leaves

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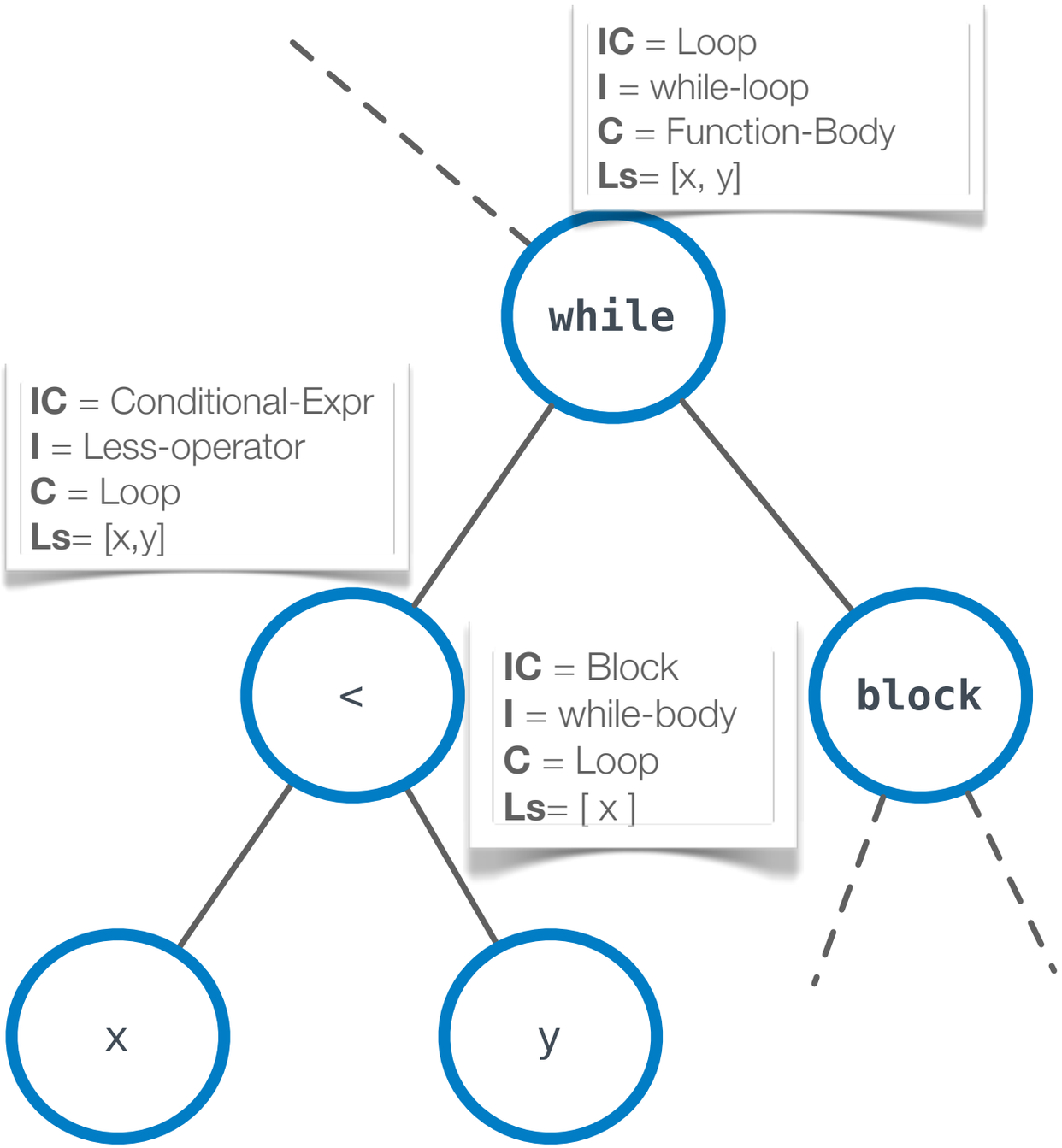

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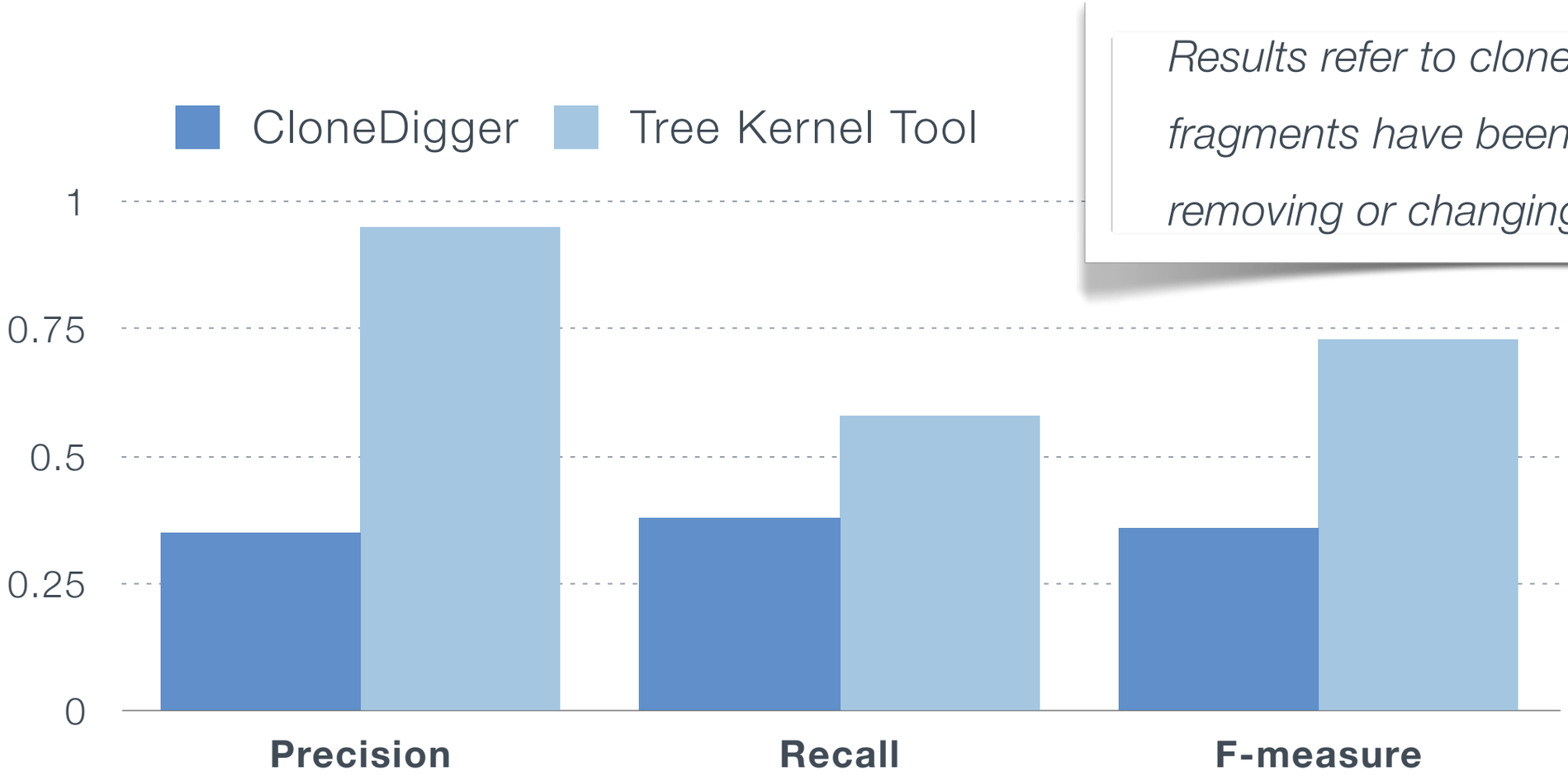
RESULTS CLONE DETECTION

- Comparison with another (pure) AST-based clone detector
- Comparison on a system with randomly seeded clones

Results refer to clones where code fragments have been modified by adding/ removing or changing code statements



CONCLUSIONS

SOFTWARE MAINTENANCE

"A software system must be continually adapted during its overall life cycle or it progressively becomes less satisfactory."
(cit. Lehman's First Law of Software Evolution)

Software Maintenance represents the most **expensive**, **time consuming** and challenging phase of the whole development process.

Software Maintenance could account up to the **85-90%** of the total software costs.

THESIS CONTRIBUTIONS

Contributions to three relevant and related **open issues** in Software Maintenance

1. **SOFTWARE RE-MODULARIZATION**
2. **SOURCE CODE NORMALIZATION**
3. **CLONE DETECTION**

SOURCE CODE **LEXICAL** INFORMATION

RESULTS # 2 EXPANSION

Accuracy Rates for the comparison with **AMAP** (Hill and Pollock, 2008)

CW: Combination Words
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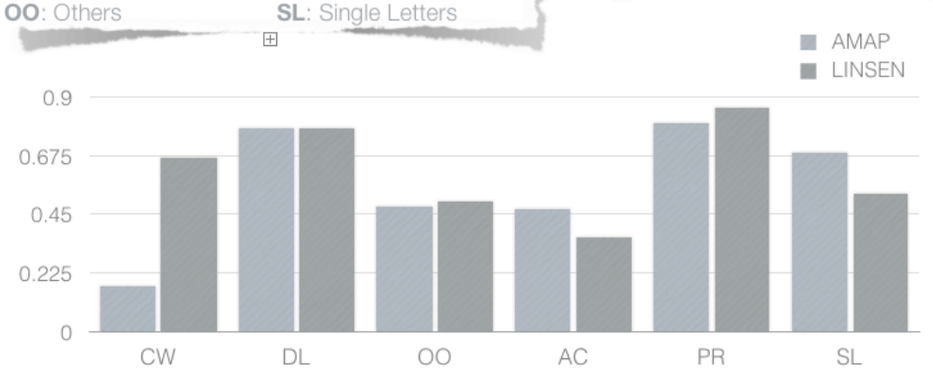

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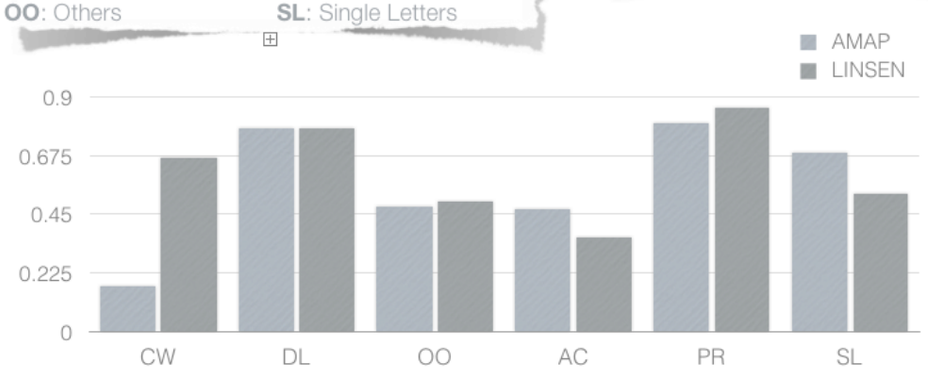

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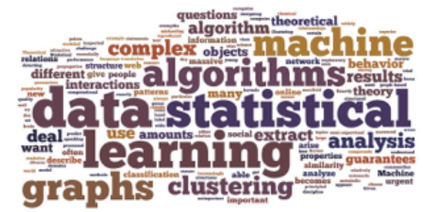

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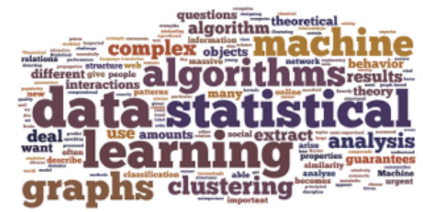

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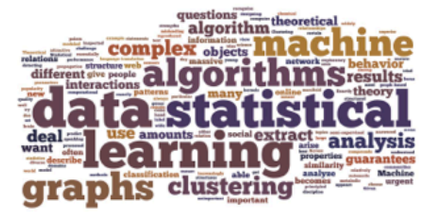

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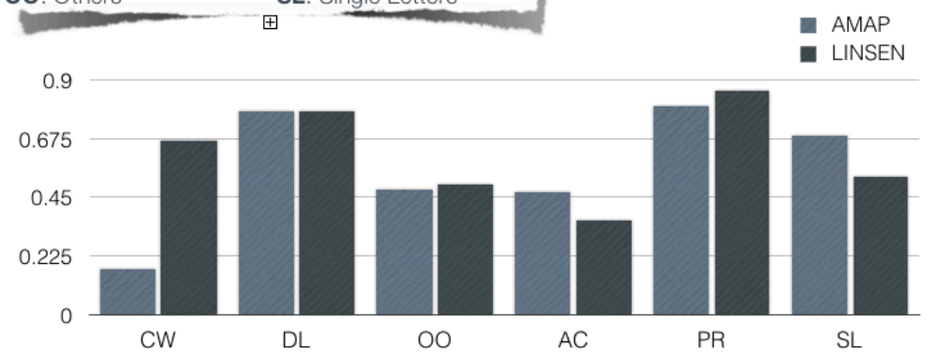

CONCLUSIONS

FUTURE RESEARCH DIRECTIONS

- **Re-modularization:**
  - Integrate code normalization algorithm (LINSEN) to lexical analysis
- **Code Normalization:**
  - Investigate the contributions of different **sources** of information used for disambiguations
- **Clone Detection:**
  - Combine Static (and Kernel methods) with Dynamic Analysis

THANK YOU

Valerio Maggio

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valerio.maggio@unina.it

June 5th, 2013 - *Ph.D. Defense*