E-SAN Thailand
Coding & AI Academy

โครงการวิจัยโมเดลระบบนิเวศการเรียนรู้ที่บูรณาการ CODING & AI สำหรับเยาวชน
Model of Learning Ecosystem Platform integrate with Coding & AI for Youth

โครงการย่อยที่ 6
การพัฒนาเยาวชนเพื่อเข้าสู่วิชาชีพขั้นสูงด้าน Coding & AI
ร่วมกับ Coding Entrepreneur & Partnership: Personal AI

ชื่อหัวข้อ Code Clone Detector - ระบบ AI สำหรับช่วยตรวจวัดความเหมือนของโค้ดและตรวจจับการคัดลอกโค้ด

ดร.ชัยยงค์ รักขิตเวชสกุล

E-SAN Thailand
Coding & AI Academy

โครงการวิจัยโมเดลระบบนิเวศการเรียนรู้ที่บูรณาการ CODING & AI สำหรับเยาวชน
Model of Learning Ecosystem Platform integrate with Coding & AI for Youth

Outline

การพัฒนาเยาวชนเพื่อเข้าสู่วิชาชีพชั้นสูงด้าน Coding & AI ร่วมกับ Coding Entrepreneur & Partnership: Personal AI

1. โค้ดที่เหมือนกันคืออะไร? (What are code clones?)
2. วิธีการสร้าง Machine Learning Model เพื่อตรวจจับโค้ดที่เหมือนกัน
3. วิธีการนำ Machine Learning Model ที่สร้างแล้ว มาตรวจจับโค้ดที่เหมือนกัน
4. การวัดประสิทธิภาพของ Machine Learning Model ที่สร้างขึ้น ในเชิงความแม่นยำ
5. การวัดประสิทธิภาพของ Machine Learning Model ที่สร้างขึ้น ในเชิงเครื่องมือ
6. บทสรุปและแนวทางการพัฒนาต่อในอนาคต

What are Code Clones ?

“ Two code fragments form a clone pair
if they are similar enough
according to a given definition of similarity. [1]”

ทำหน้าเหมือนกันไหม เขาต่างกันไหม

```java
public int sum(int a, int b){
    int sum;
    sum = a + b;
    return sum;
}
```

```java
public int sum(int num1, int num2){
    int result;
    result = num1 + num2;
    return result;
}
```

[1] Bellon et al., Comparison and Evaluation of Clone Detection Tools, IEEE TRANSACTIONS ON SOFTWARE ENGINEERING (2007)

Clone Types: Syntactic Based [2]

Type 1

```
public int sum(int a, int b){
    int sum;
    sum = a + b;
    return sum;
}
```

```
public int sum(int a, int b){
    int sum;
    sum = a + b;
    return sum;
}
```

Identical code fragments
except for layout, white space, and comments

Type 2

```
public int sum(int a, int b){
    int sum;
    sum = a + b;
    return sum;
}
```

```
public int sum(int num1, int num2){
    int result;
    result = num1 + num2;
    return result;
}
```

Identical code fragments
except for literals, identifiers, data types, layout, white space, and comments.

Type 3

```
public int sum(int a, int b){
    int sum;
    sum = a + b;
    return sum;
}
```

```
public int sum(int a, int b){
    return a + b;
}
```

Similar clone fragments
with added, changed, and removed some statements.

[2] Roy et al. Comparison and evaluation of code clone detection techniques and tools: A qualitative approach, Science of Computer Programming (2009)

Clone Types: Functionality Based [2]

TYPE 4

```
private static String getFormatByName(String name){
    if(name != null){
        final int j = name.lastIndexOf(".") + 1,
        k = name.lastIndexOf("/") + 1;
        if(j > k &&
        j < name.length()){
            return name.substring(j);
        }
    }
    return null
}
```

```
public static String getExtension(final String filename){
    if(filename == null ||
    filename.trim().length == 0 ||
    !filename.contain(".") ){
        return null;
    }
    int pos = filename.lastIndexOf(".");
    return filename.substring(pos+1);
}
```

Code fragments that have the same computation
but different in syntax or algorithm.

[2] Roy et al. Comparison and evaluation of code clone detection techniques and tools: A qualitative approach, Science of Computer Programming (2009)

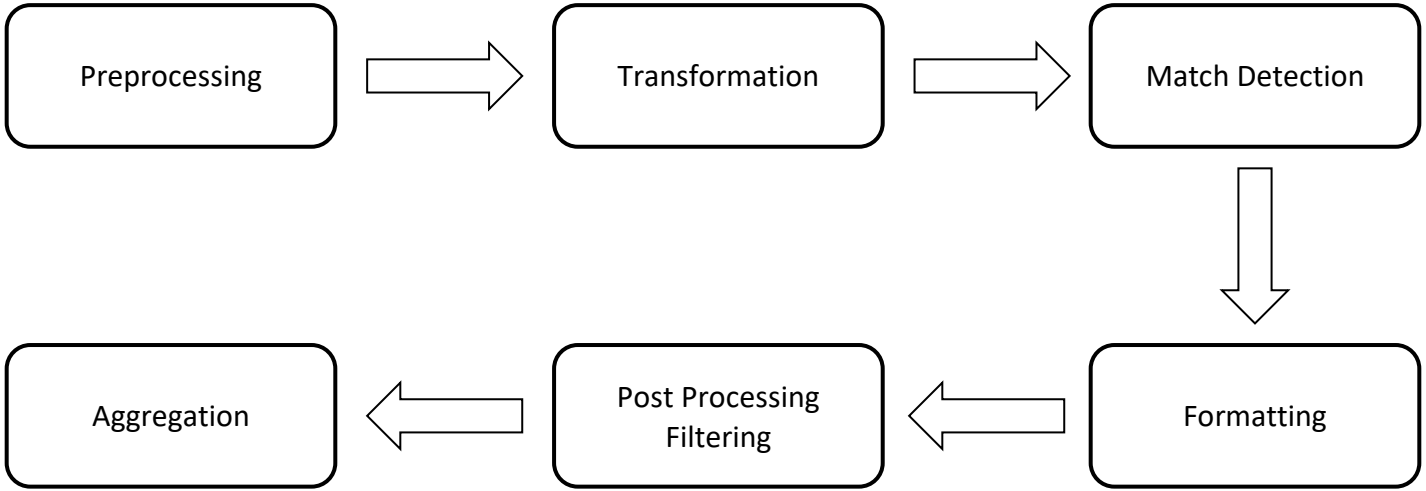
Why Code Clones need to be detect ?

5 ก้อปปี้

- Source code plagiarism detection [3]
- Code Clones can be harmful in software maintenance [1]
- To improve code quality by reducing code redundancy
  (usually occur 7-23% in software) [2]
- Some clones can be beneficial
  (e.g. software product line, well-written code) [4]
- **We need to detect clones so that we can manage them** [5]

[1] T. Kamiya, S. Kusumoto and K. Inoue, "CCFinder: a multilinguistic token-based code clone detection system for large scale source code," July 2002.
[2] Roy et al. Comparison and evaluation of code clone detection techniques and tools: A qualitative approach, Science of Computer Programming (2009)
[3] Prechelt, L., Malpohl, G., & Philippsen, M. (2002). Finding Plagiarisms among a Set of Programs with JPlag. *Journal Of Universal Computer Science*, *8*(11), 1016–1038.
[4] Kapser, C. J., & Godfrey, M. W. (2008). Cloning considered harmful considered harmful: patterns of cloning in software. *Empirical Software Engineering*, *13*(6), 645–692.
[5] D. Chatterji, J. C. Carver, and N. A. Kraft. Code clones and developer behavior: results of two surveys of the clone research community. *Empirical Software Engineering*, 21(4):1476–1508, Aug 2016.

Code Clone Detection Process



Problem Statements

- The existing techniques and tools are still facing challenges when detecting clones with several modifications (e.g., added/deleted/modified statements).
- Existing clone detection and plagiarism detection tools are difficult to use because it is command line based tool.

Objectives

1. To create a code clone detection tool using machine learning techniques and study its effectiveness.

2. To enhance the user experience of code clone detection tools

- providing code clone detection as a web application to users
- providing visualization of clone results

Merry: Web-Based Code Clone Detection System Using Machine Learning

Features

11 Syntactic Code Metrics
+
12 Semantic Code Metrics (code2vec)

Machine Learning

Decision tree, Random forest, SVM, SVM + SMO

BigCloneBench

Largest and Credible clone data

Web-based Tool with User Interface

GitHub Integration

Visualizations and reports

วิธีการสร้าง Machine Learning Model เพื่อตรวจจับโค้ดที่เหมือนกัน

Merry Engine Implementation

1. Building Merry Engine
2. Using Merry Engine for Clone Detection

1 Building Merry Engine

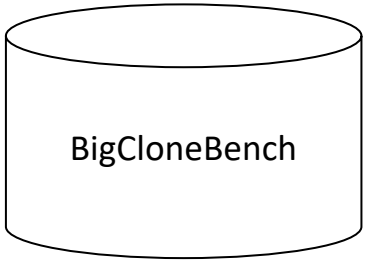
1.1 Data collection and preparation

เก็บข้อมูล และเตรียมข้อมูล

1.2 Code metrics extraction

1.3 Machine learning models

1.1 Data collection and preparation

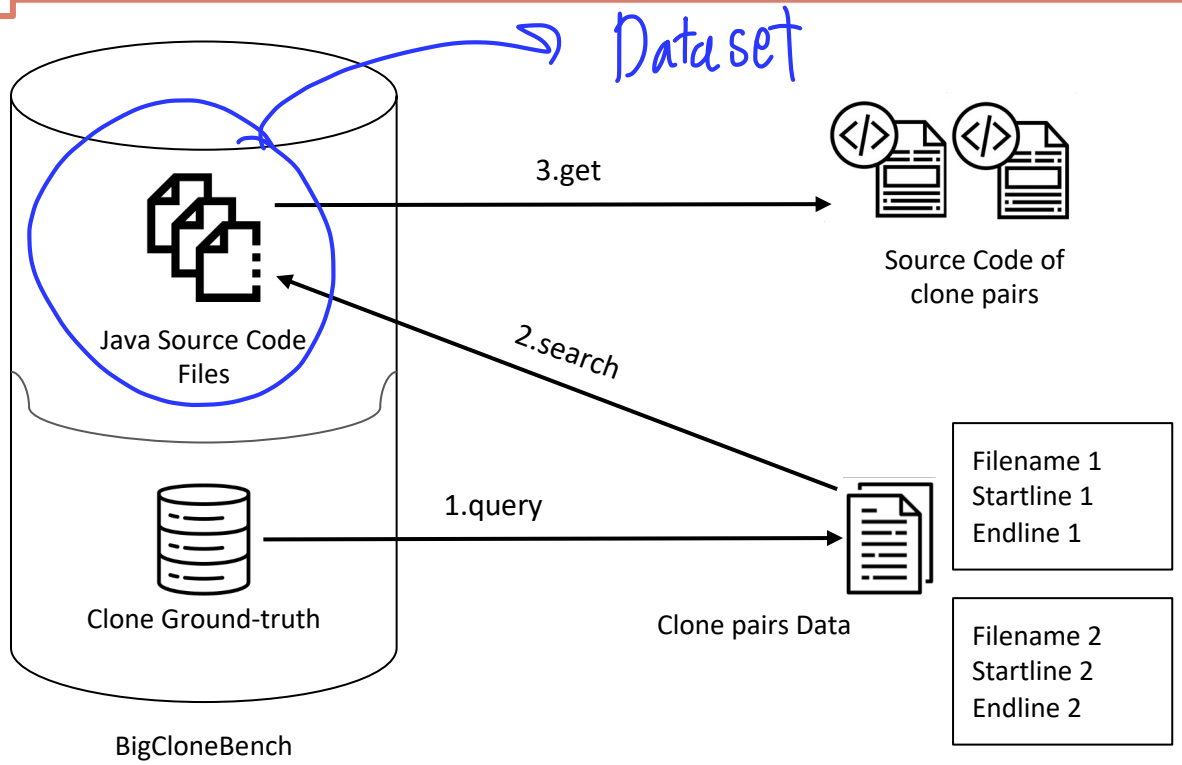


BigCloneBench [7]

- Largest and reliable clone data
- Well-known in code clone detection field
- Big data of inter-project repository IJaDataset 2.0
- Created from 25,000 Java projects
- Contains tagged true and false clone pairs

[7] Svajlenko J., Roy CK., “Evaluating clone detection tools with bigclonebench”, In: 2015 IEEE International Conference on Software Maintenance and Evolution (ICSME). IEEE; 2015. p. 131–140.

1.1 How do we get clone pairs from BCB?



1.1 Training Set and Testing Set Splitting

Training Data [8]

True Clone Pairs (22,663 pairs)				False Clone Pairs
Type 1	Type 2	Very Strong Type 3	Strongly Type 3	
13,750	3,104	1,207	4,602	22,663

Testing Data

True Clone Pairs (4,724 pairs - stratified sampling)				False Clone Pairs
Type 1	Type 2	Very Strong Type 3	Strongly Type 3	
2,383	557	307	1,477	18,893

[8] Li Z. et al., “CP-Miner: Finding copy-paste and related bugs in large-scale software code”, IEEE Transactions on software Engineering. 2006;32(3):176–192.

1.2 Code Metrics Extraction

Syntactic metrics

=

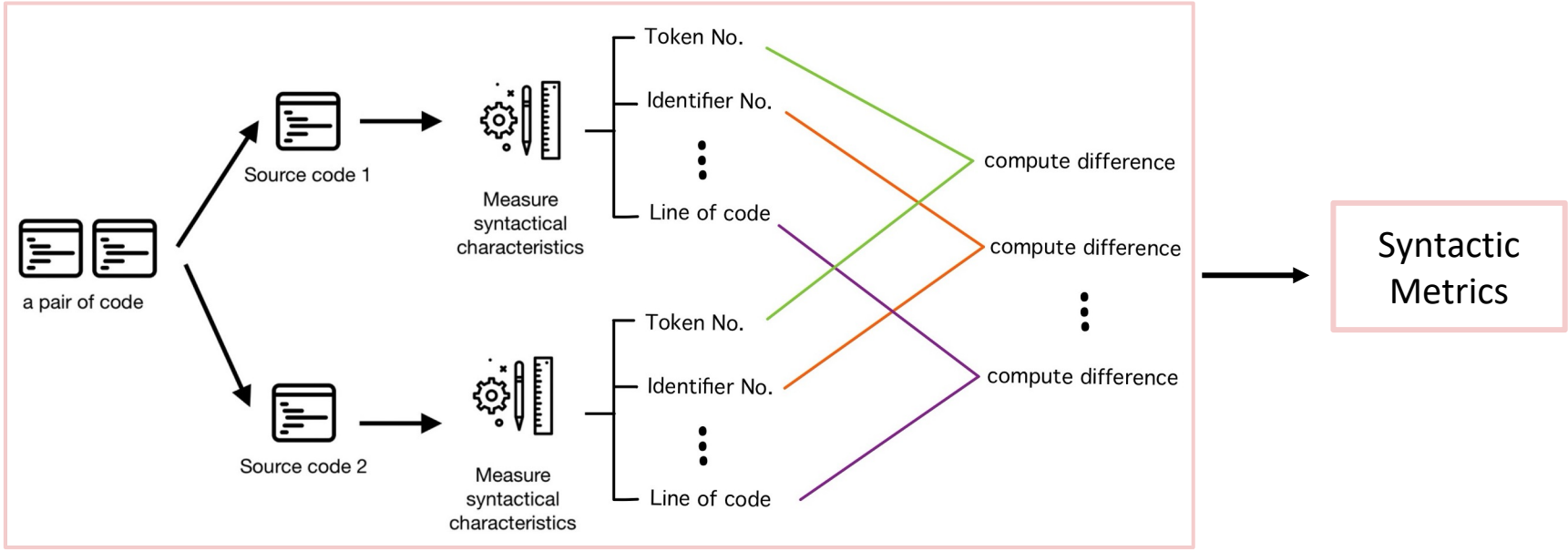
Metrics extracted from syntactic characteristics
of the source code fragments

Semantic metrics

=

Metrics that capture the behaviour of the source code fragments

1.2 Syntactic Code Metrics

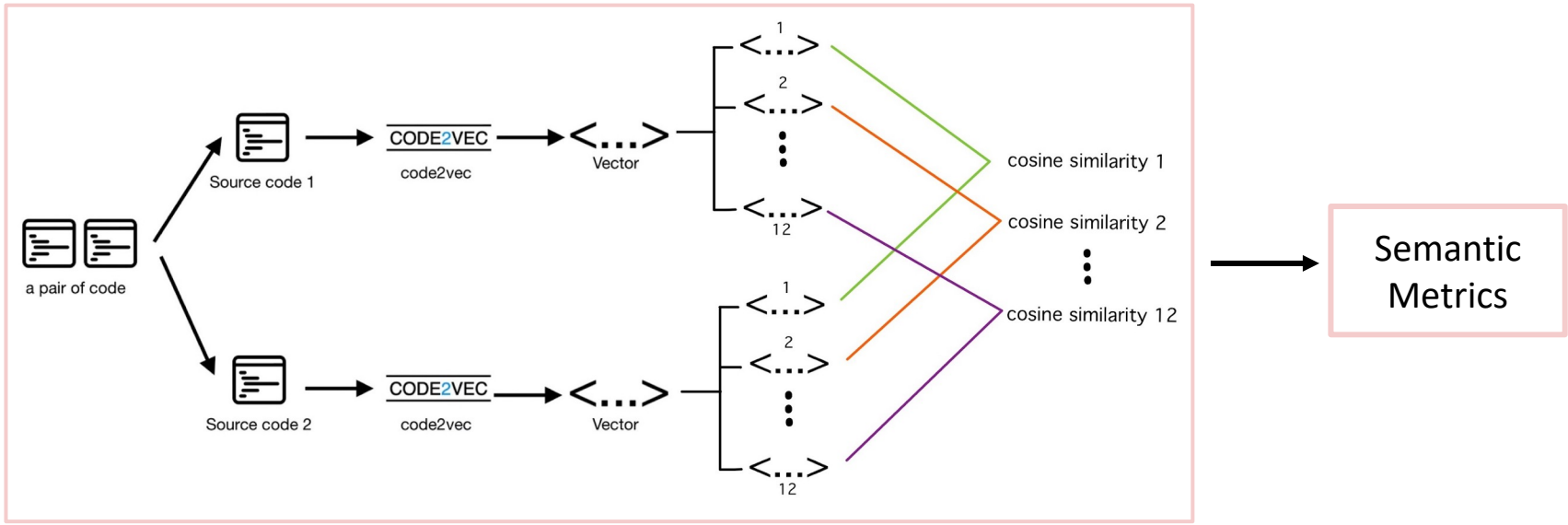


1.2 Syntactic Code Metrics

No.	Metric	Description
1	Token No [9]	Difference of number of tokens
2	Unique Token No [10]	Difference of number of unique tokens
3	Identifier No [10]	Difference of number of Identifiers
4	Unique Identifier No [10]	Difference of number of unique Identifiers
5	Operator No [10]	Difference of number of operators
6	Unique Operator No [10]	Difference of number of unique operators
7	Token Types Diversity [9]	Difference of number of unique token types
8	Diff File Name Score	File names difference score
9	Diff Method Name Score	Method names difference score
10	Similar Return Type	Same return type or not
11	DiffLOC	Difference of lines of code

[9] KoschkeR.,BazrafshanS., “Software-cloneratesinopen-sourceprogramswritten in C or C++”, In: 2016 IEEE 23rd International Conference on Software Analysis, Evolution, and Reengineering (SANER). vol. 3. IEEE; 2016. p. 1–7.
[10]Vara A., Rainer K., Chaiyong R., Morakot C., Thanwadee S., “Improving CloneDetection Precision using Machine Learning Techniques”, In: Proceedings of the201826thACMJointMeetingonEuropeanSoftwareEngineeringConferenceandSymposium on the Foundations of Software Engineering. IWESEP; 2019.

1.2 Semantic Code Metrics

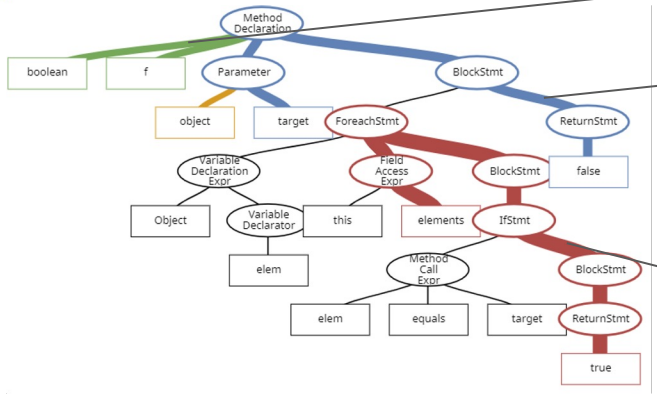


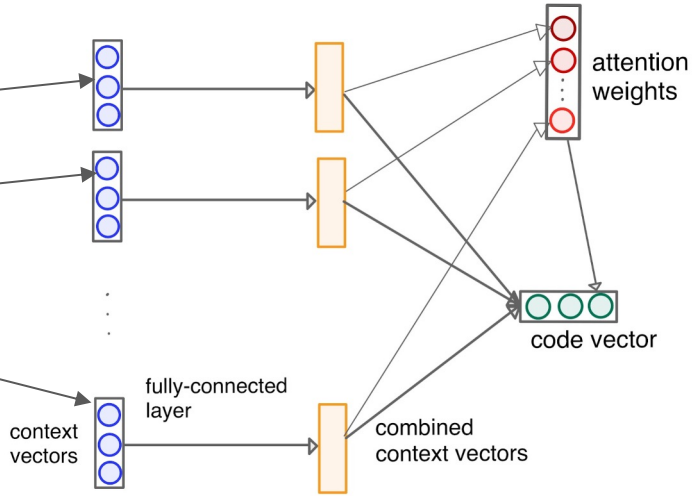
code2vec in Detail

code2vec is neural model that represent code snippet as fixed-length vectors (size = 384) that capture semantic of the source code [12].

```
boolean f(object target) {
    for(Object elem: this.elements) {
        if(elem.equals(target)) {
            return true;
        }
    }
    return false;
}
```

We use the pretrain model that trained from 12 M. of real software methods.





[12] Alon, U., Zilberstein, M., Levy, O., & Yahav, E. (2019). code2vec: learning distributed representations of code. POPL, 1–29.

1.2 Example of Code Metrics

source code 1

sum1.java

```
public int sum(int a, int b){
    int sum;
    sum = a + b;
    return sum;
}
```

source code 2

sum2.java

```
public int sum(int a, int b){
    return a + b;
}
```

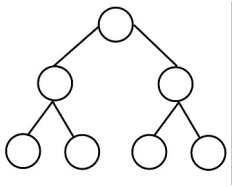
Syntactic metrics

Diff. No. Tokens	:	7
Diff. No. Unique Token	:	1
Diff. No. Identifier	:	3
Diff. No. Unique Identifier	:	0
Diff. No. Operator	:	1
Diff. No. Unique Operator No	:	1
Diff. Token Types Diversity	:	0
Diff. File Name Score	:	0.25
Diff. Method Name Score	:	0.0
Similar Return Type	:	TRUE
Diff. No. LOC	:	2

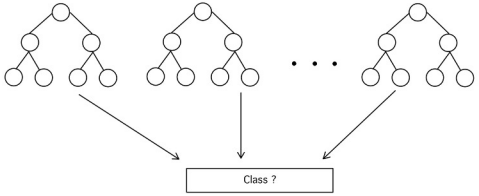
Semantic metrics

vector#1 similarity	:	0.5206784273085
vector#2 similarity	:	0.457455059252847
vector#3 similarity	:	0.588965399230431
vector#4 similarity	:	0.652574760995595
vector#5 similarity	:	0.529570896554088
vector#6 similarity	:	0.490625929242188
vector#7 similarity	:	0.792832125905209
vector#8 similarity	:	0.562600679903085
vector#9 similarity	:	0.799728586131479
vector#10 similarity	:	0.642114908324134
vector#11 similarity	:	0.540922173109001
vector#12 similarity	:	0.729365945085146

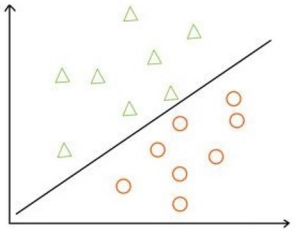
1.3 Machine Learning Models



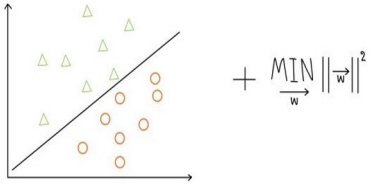
Decision Tree



Random Forest



Support Vector Machine

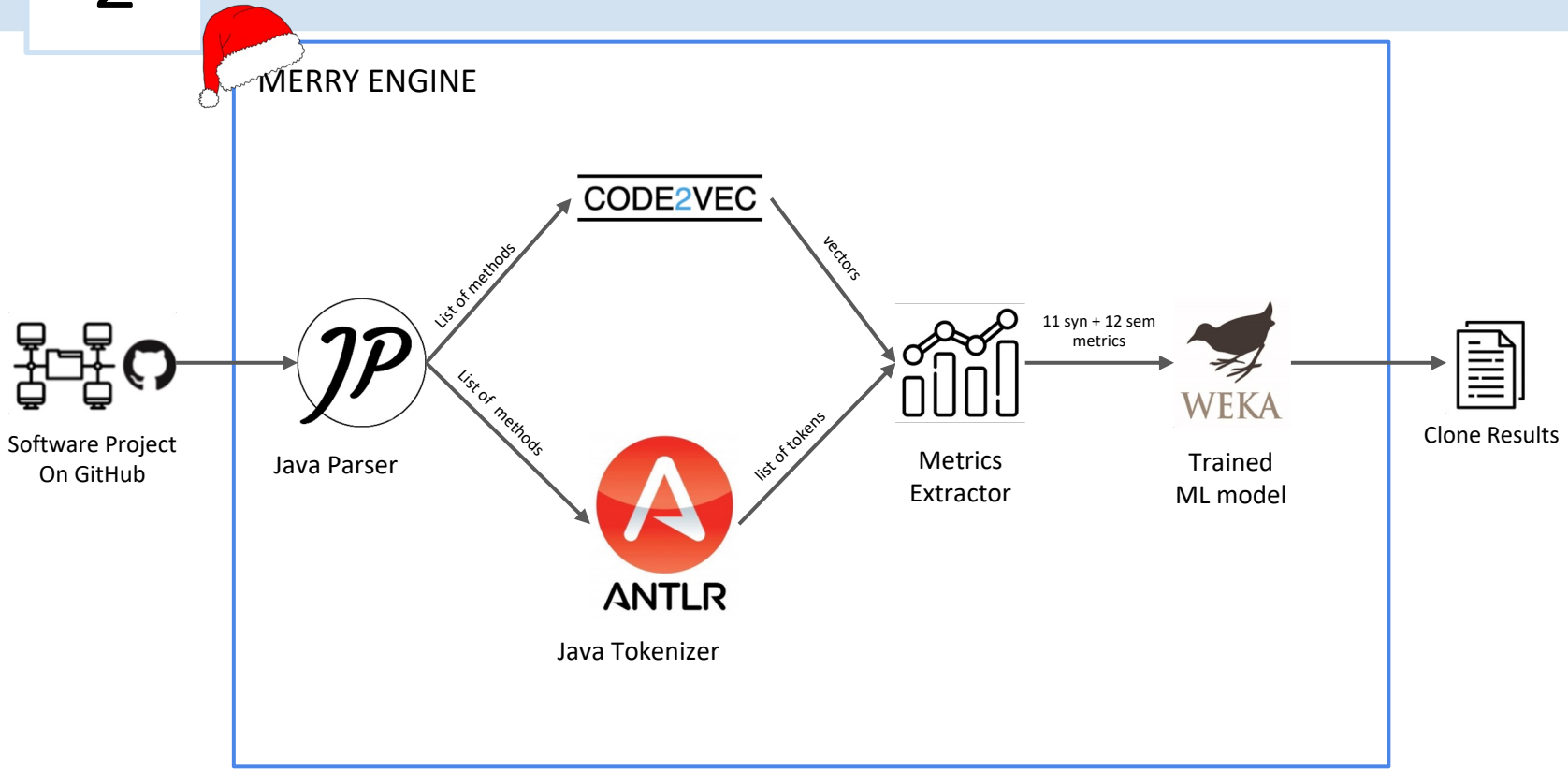


SVM using SMO

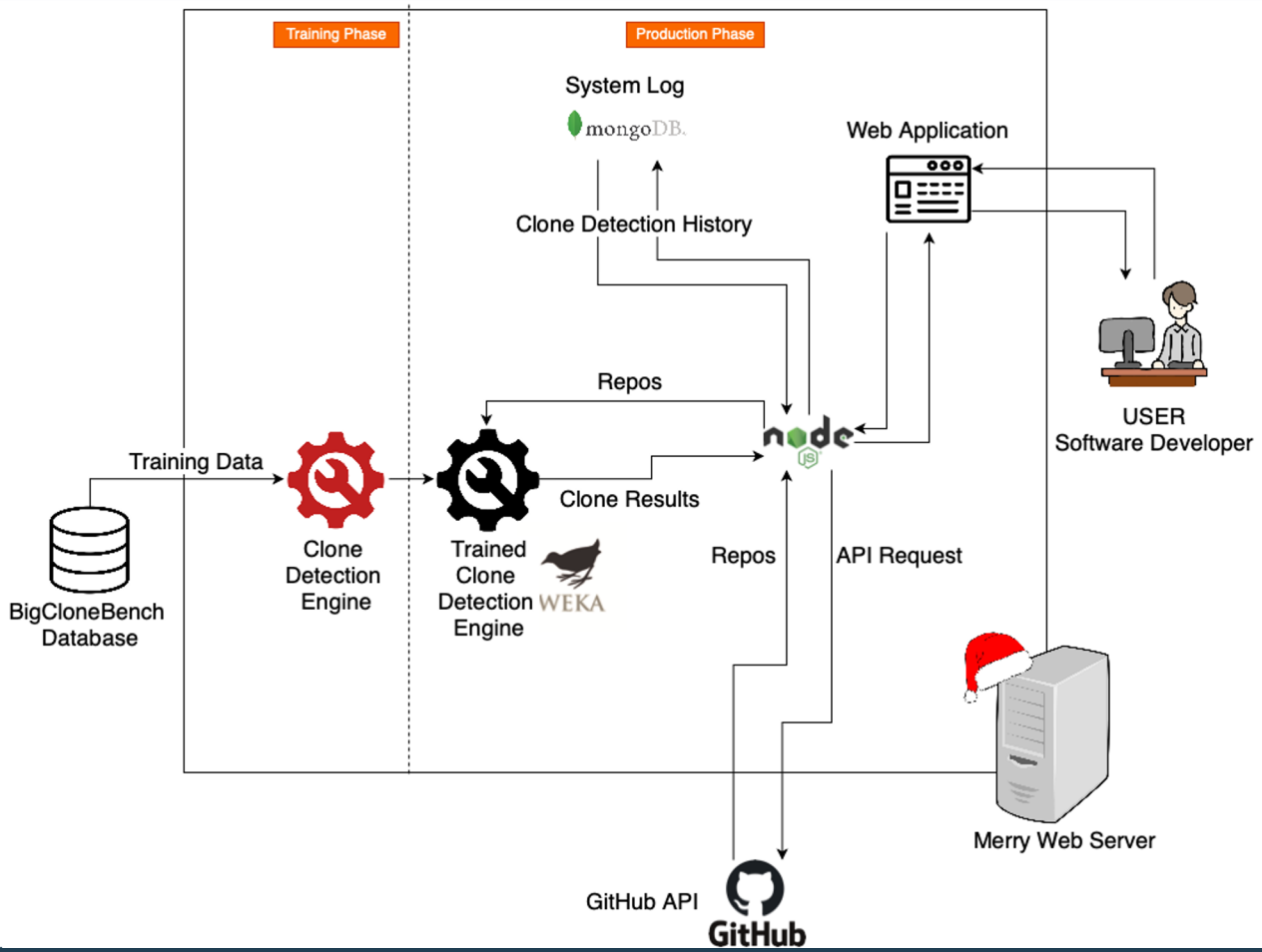
วิธีการนำ Machine Learning Model ที่สร้างแล้ว มาตรวจจับโค้ดที่เหมือนกัน

2

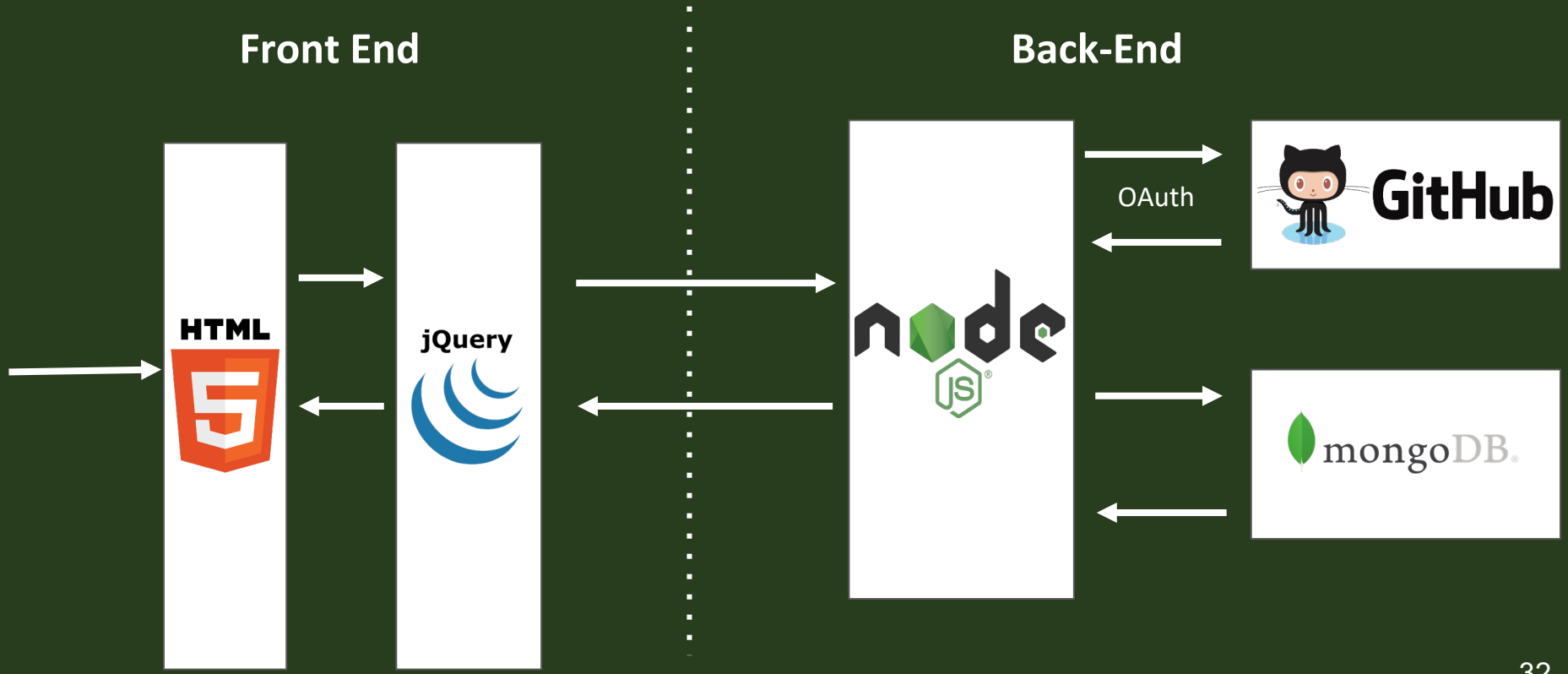
Using Merry Engine for Clone Detection



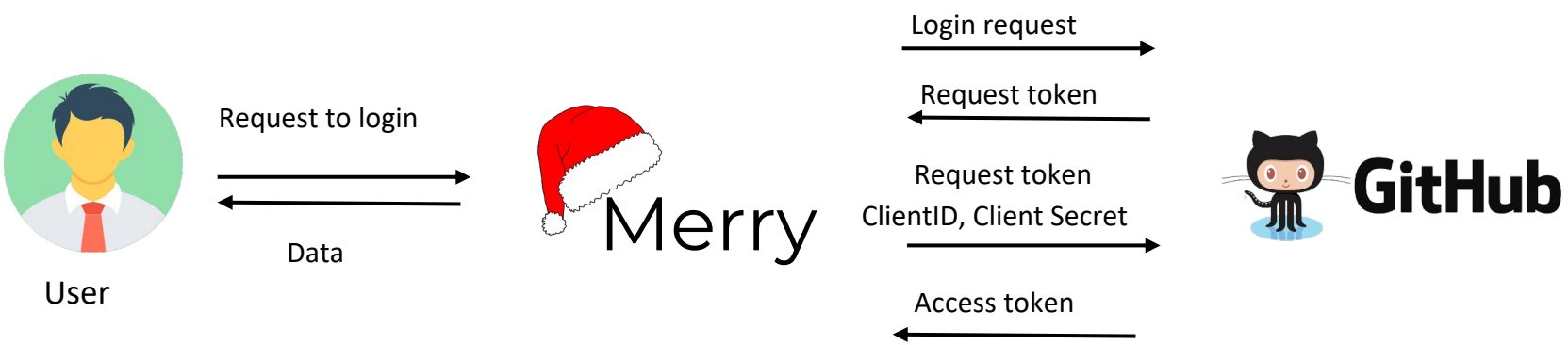
System Architecture



Frameworks and Tools



GitHub Integration



การวัดประสิทธิภาพของ Machine Learning Model ที่สร้างขึ้น ในเชิงความแม่นยำ

Evaluation

RQ1	How accurate is Merry code clone detection on BigCloneBench?
RQ2	How accurate is Merry code clone detection on real software projects?
RQ3	How likely are command line based tool and our Merry tool adopted by programmers?

Evaluation of Merry ML Clone Detection Engine using BCB

RQ1: How accurate is Merry code clone detection on BigCloneBench?

Evaluation of Merry ML Clone Detection Engine using BCB

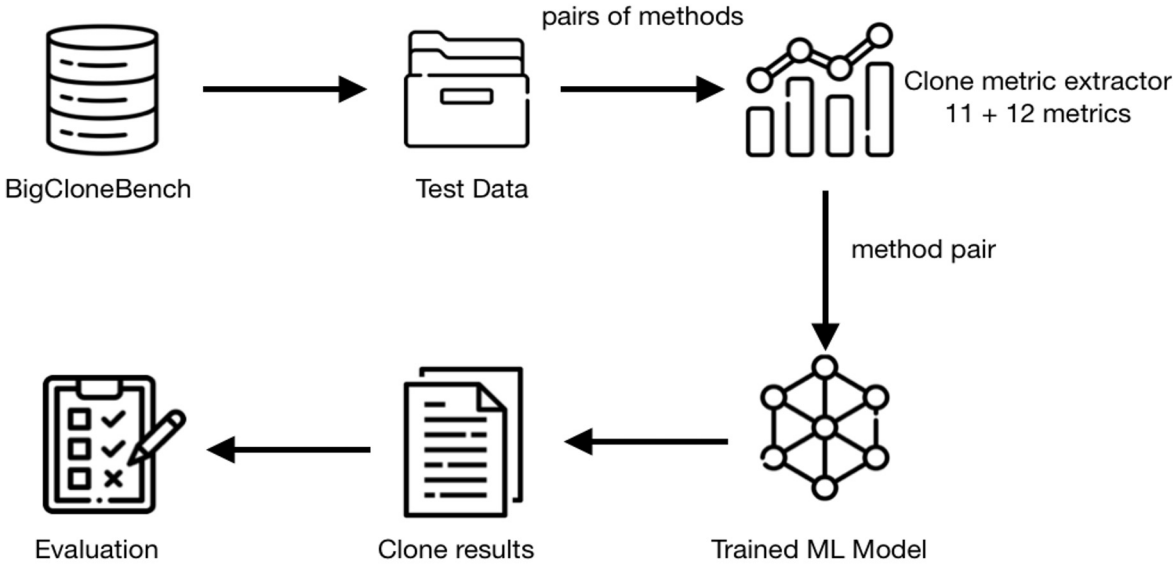
$$precision = \frac{True\ Positive}{True\ Positive + False\ Positive}$$

$$Recall = \frac{True\ Positive}{True\ Positive + False\ Negative}$$

$$F1 - score = 2 \cdot \frac{Precision - Recall}{Precision + Recall}$$

ยิ่งมากยิ่ง accurate

Evaluation of Merry ML Clone Detection Engine using BCB (cont.)

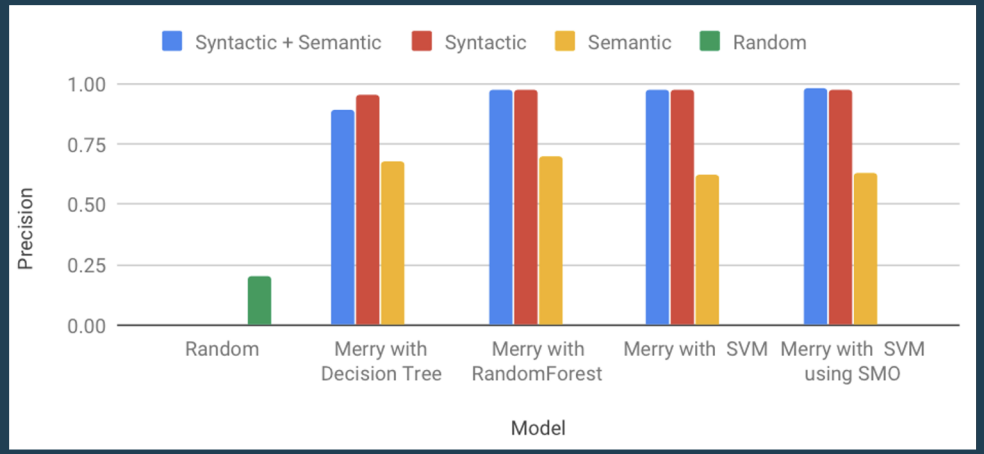


Evaluation of Merry ML Clone Detection Engine using BCB (cont.)

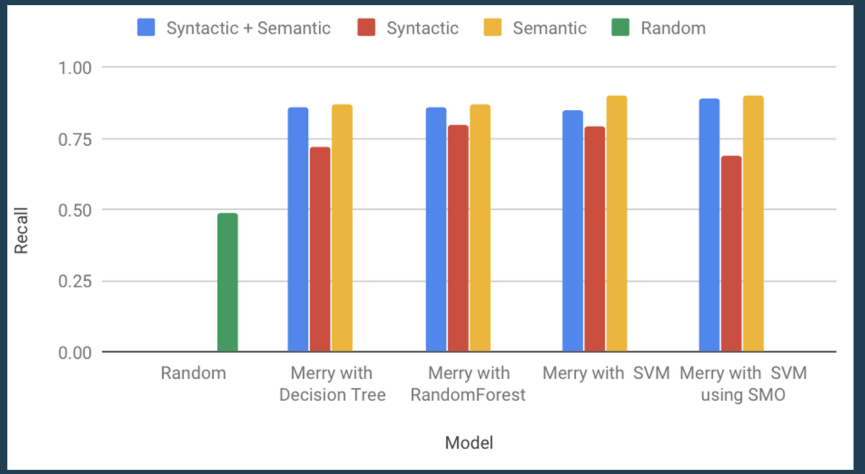
RQ1: How accurate is Merry code clone detection on BigCloneBench?

Model	Metrics	Precision	Recall	F1-Score
Randomization (baseline)		0.20	0.49	0.28
Decision Tree	Syntactic + Semantic	0.89	0.86	0.87
	Syntactic	0.95	0.72	0.86
	Semantic	0.68	0.87	0.76
Random Forest	Syntactic + Semantic	0.97	0.86	0.91
	Syntactic	0.97	0.80	0.87
	Semantic	0.70	0.87	0.78
SVM	Syntactic + Semantic	0.97	0.85	0.91
	Syntactic	0.97	0.79	0.87
	Semantic	0.62	0.90	0.73
SVM using SMO	Syntactic + Semantic	0.98	0.89	0.93
	Syntactic	0.97	0.69	0.81
	Semantic	0.63	0.90	0.74

Evaluation of Merry ML Clone Detection Engine using BCB (cont.)

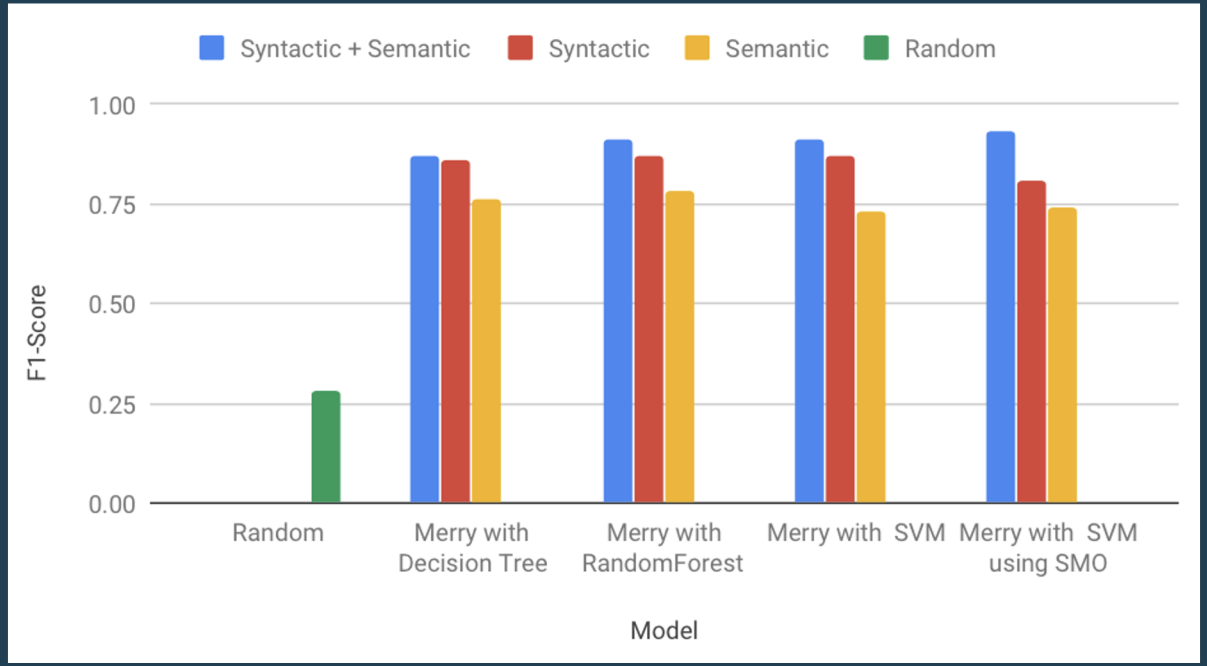


Precision



Recall

Evaluation of Merry ML Clone Detection Engine using BCB (cont.)

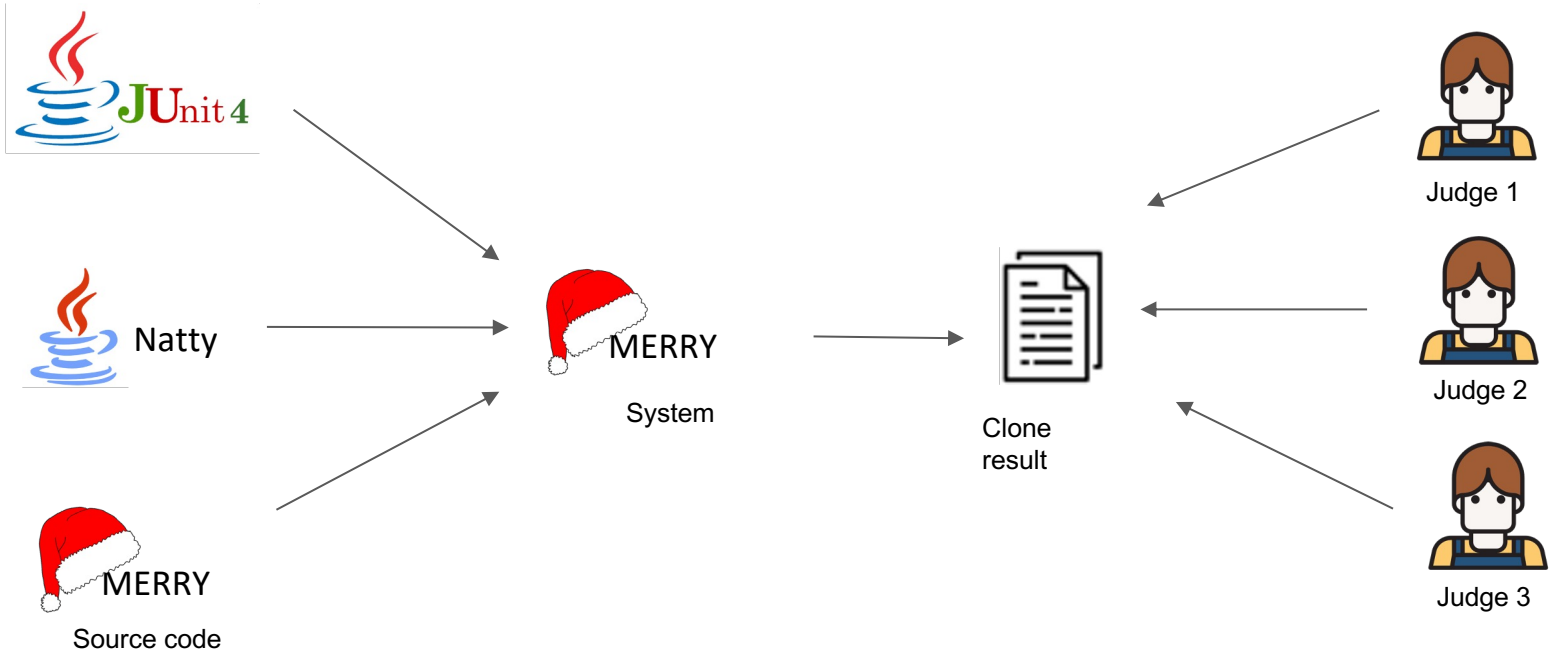


F1-score

Evaluation of Merry Clone Detection Engine on Real Software Projects

RQ2: How accurate is Merry code clone detection on real software projects?

Evaluation of Merry Clone Detection Engine on Real Software Projects



Percent of overall agreement = 69.34%

Fleiss' kappa = 0.39

Evaluation of Merry Clone Detection Engine on Real Software Projects

RQ2: How accurate is Merry code clone detection on real software projects?

Project	LOC	Methods	Clone pairs	TP	FP	Precision	Runtime (sec)
JUnit4	7550	1529	187	77	110	**0.41**	552
Natty	1761	146	9	7	2	**0.77**	99
Merry	931	102	8	6	2	**0.75**	115

The result of evaluation on real software project

Example of Detected Type-1 Clone Pair

Project : JUnit4

```
1.  private void runBefores() throws FailedBefore {
2.     try {
3.         try {
4.             List<Method> befores =
    testMethod.getBefores();
5.             for (Method before : befores) {
6.                 before.invoke(test);
7.             }
8.         } catch (InvocationTargetException e) {
9.             throw e.getTargetException();
10.        }
11.    } catch (AssumptionViolatedException e) {
12.        throw new FailedBefore();
13.    } catch (Throwable e) {
14.        addFailure(e);
15.        throw new FailedBefore();
16.    }
17. }
```

Filename: ClassRoadie.java
Startline: 51
Endline: 67

```
1.  private void runBefores() throws FailedBefore {
2.     try {
3.         try {
4.             List<Method> befores =
    testMethod.getBefores();
5.             for (Method before : befores) {
6.                 before.invoke(test);
7.             }
8.         } catch (InvocationTargetException e) {
9.             throw e.getTargetException();
10.        }
11.    } catch (AssumptionViolatedException e) {
12.        throw new FailedBefore();
13.    } catch (Throwable e) {
14.        addFailure(e);
15.        throw new FailedBefore();
16.    }
17. }
```

Filename: MethodRoadie.java
Startline: 128
Endline: 144

Example of Detected Type-2 Clone Pair

Project : JUnit4

```
1.  @Override
2.  protected Collection<FrameworkMethod>
    getSingleDataPointMethods(ParameterSignature sig) {
3.      Collection<FrameworkMethod> methods =
    super.getSingleDataPointMethods(sig);
4.      String requestedName =
    sig.getAnnotation(FromDataPoints.class).value();
5.      List<FrameworkMethod> methodsWithMatchingNames = new
    ArrayList<FrameworkMethod>();
6.      for (FrameworkMethod method : methods) {
7.          String[] methodNames =
    method.getAnnotation(DataPoint.class).value();
8.          if
    (Arrays.asList(methodNames).contains(requestedName)) {
9.              methodsWithMatchingNames.add(method);
10.         }
11.     }
12.     return methodsWithMatchingNames;
13. }
```

Filename: SpecificDataPointsSupplier.java
Startline: 56
Endline: 71

```
1.  @Override
2.  protected Collection<Field>
    getDataPointsFields(ParameterSignature sig) {
3.      Collection<Field> fields =
    super.getDataPointsFields(sig);
4.      String requestedName =
    sig.getAnnotation(FromDataPoints.class).value();
5.      List<Field> fieldsWithMatchingNames = new
    ArrayList<Field>();
6.      for (Field field : fields) {
7.          String[] fieldNames =
    field.getAnnotation(DataPoints.class).value();
8.          if
    (Arrays.asList(fieldNames).contains(requestedName)) {
9.              fieldsWithMatchingNames.add(field);
10.         }
11.     }
12.     return fieldsWithMatchingNames;
13. }
```

Filename: SpecificDataPointsSupplier.java
Startline: 39
Endline: 54

Example of True Type 3 Clone Pair

Project : JUnit4

```
1.  @Override
2.  public void evaluate() throws Throwable {
3.     before();
4.     List<Throwable> errors = new
    ArrayList<Throwable>();
5.     try {
6.         base.evaluate();
7.     } catch (Throwable t) {
8.         errors.add(t);
9.     } finally {
10.        try {
11.            after();
12.        } catch (Throwable t) {
13.            errors.add(t);
14.        }
15.    }
16.    MultipleFailureException.assertEmpty(errors);
17. }
```

Filename: ExternalResource.java
Startline: 48
Endline: 65

```
1.  @Override
2.  public void evaluate() throws Throwable {
3.     List<Throwable> errors = new
    ArrayList<Throwable>();
4.     try {
5.         next.evaluate();
6.     } catch (Throwable e) {
7.         errors.add(e);
8.     } finally {
9.         for (FrameworkMethod each : afters) {
10.            try {
11.                invokeMethod(each);
12.            } catch (Throwable e) {
13.                errors.add(e);
14.            }
15.        }
16.    }
17.    MultipleFailureException.assertEmpty(errors);
18. }
```

Filename: RunAfters.java
Startline: 23
Endline: 40

Example of False Clone Pair

Project : JUnit4

```
1.  protected void runChild(final FrameworkMethod
    method, RunNotifier notifier) {
2.     Description description =
    describeChild(method);
3.    if (isIgnored(method)) {
4.          notifier.fireTestIgnored(description);
5.     } else {
6.        Statement statement = new Statement() {
7.
8.             @Override
9.             public void evaluate() throws Throwable
    {
10.                methodBlock(method).evaluate();
11.            }
12.        };
13.        runLeaf(statement, description, notifier);
14.    }
15. }
```

Filename: BlockJUnit4ClassRunner.java
Startline: 91
Endline: 105

```
1.  public Result run(Runner runner) {
2.     Result result = new Result();
3.     RunListener listener = result.createListener();
4.     notifier.addFirstListener(listener);
5.     try {
6.
    notifier.fireTestRunStarted(runner.getDescription()
    );
7.         runner.run(notifier);
8.         notifier.fireTestRunFinished(result);
9.     } finally {
10.        removeListener(listener);
11.    }
12.    return result;
13. }
```

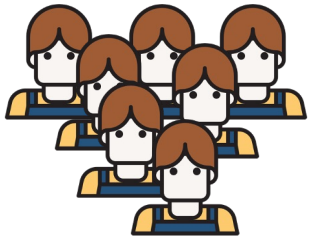
Filename: BlockJUnit4ClassRunner.java
Startline: 131
Endline: 143

การวัดประสิทธิภาพของ Machine Learning Model ที่สร้างขึ้น ในเชิงเครื่องมือ

Evaluation of Merry Web Application by Users

RQ3: How likely are command line based tool and our Merry tool adopted by programmers?

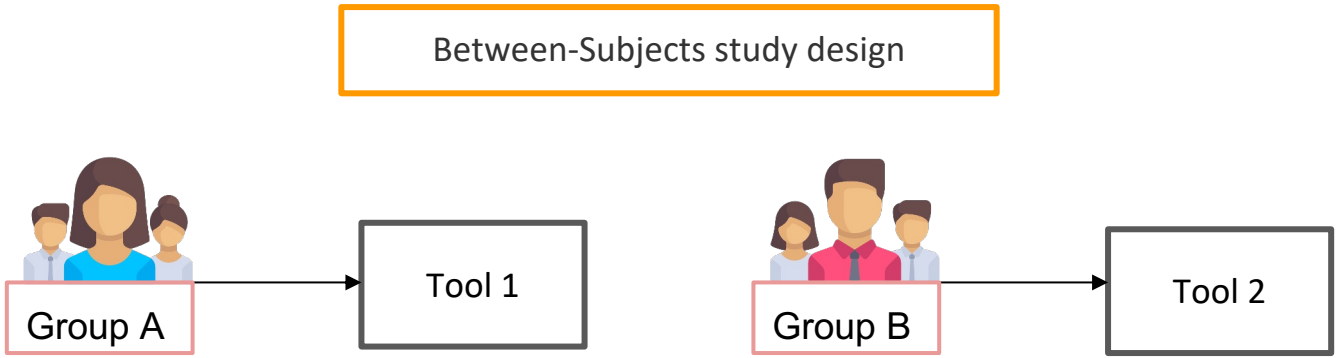
Target users



Computer Science students

Programers, Developers

User study methodology

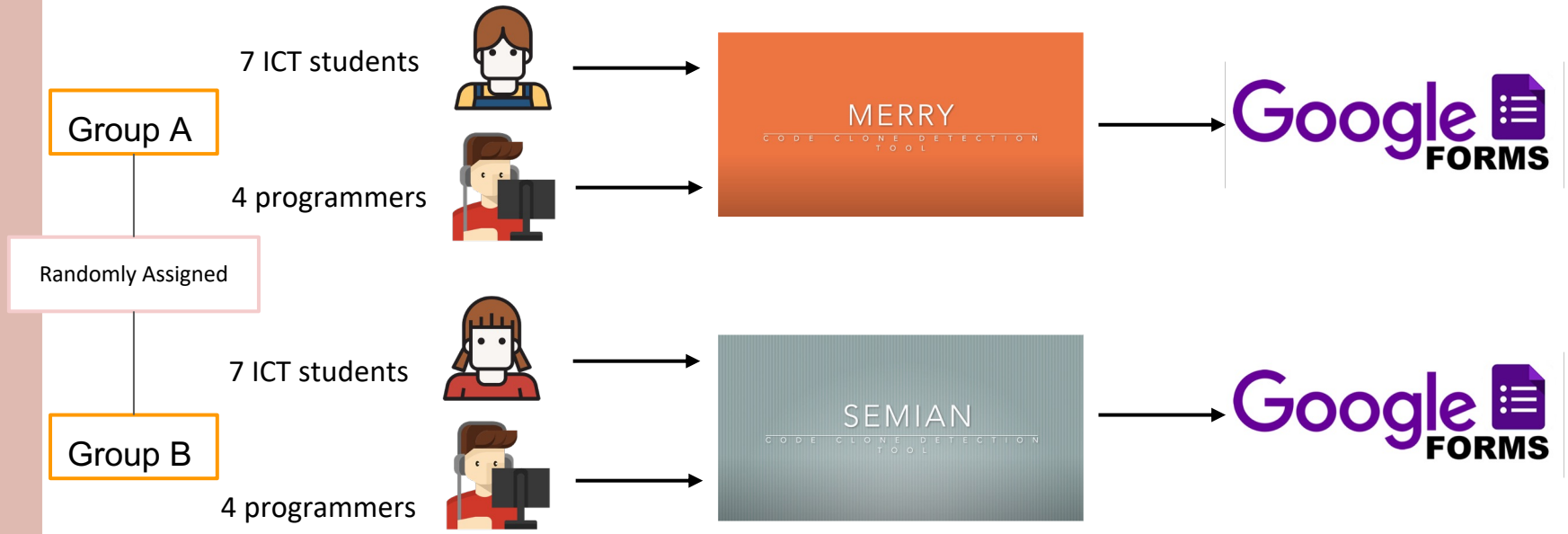


Reduce the impact of transfer across conditions

[13]Wettel, Richard, and Michele Lanza. “Software Systems as Cities: A Controlled Experiment.” *Wettel.github.io*, wettel.github.io/download/Wettel11a-icse.pdf.

Evaluation of Merry Web Application by Users

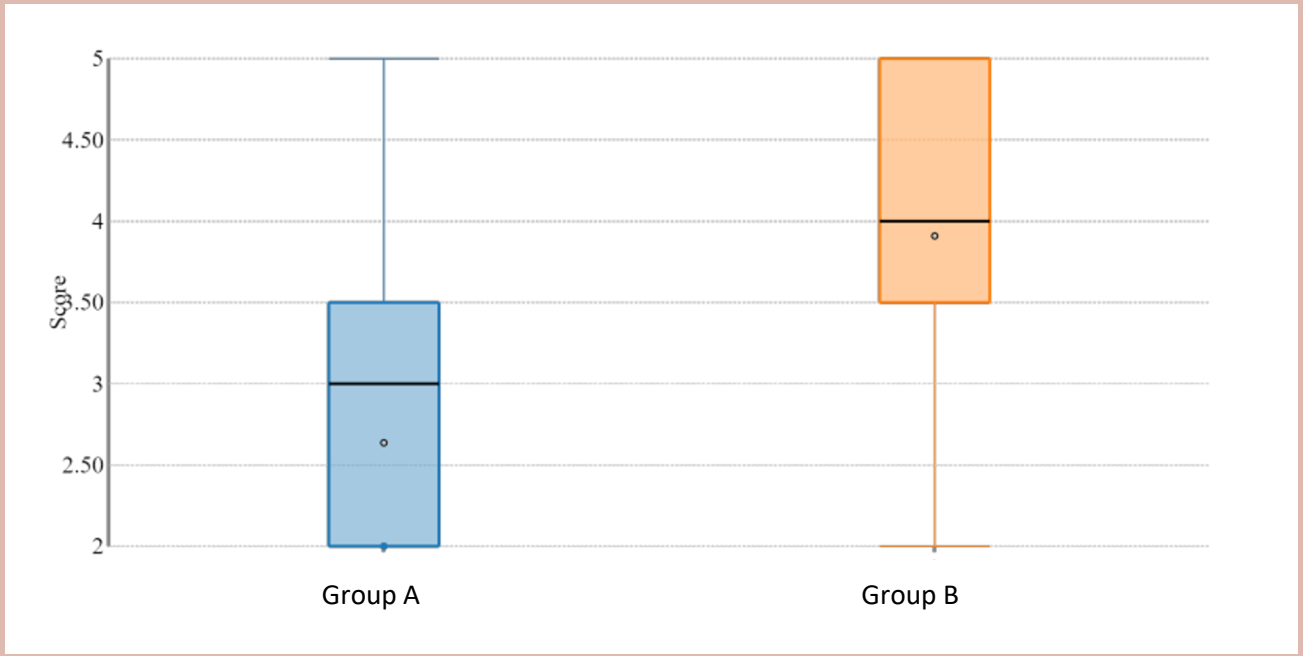
RQ3: How likely are command line based tool and our Merry tool adopted by programmers?



[13]Wettel, Richard, and Michele Lanza. “Software Systems as Cities: A Controlled Experiment.” *Wettel.github.io*, wettel.github.io/download/Wettel11a-icse.pdf.

Likeliness of using the tool

If this tool will be applied to one of your software project, how likely will you use it?

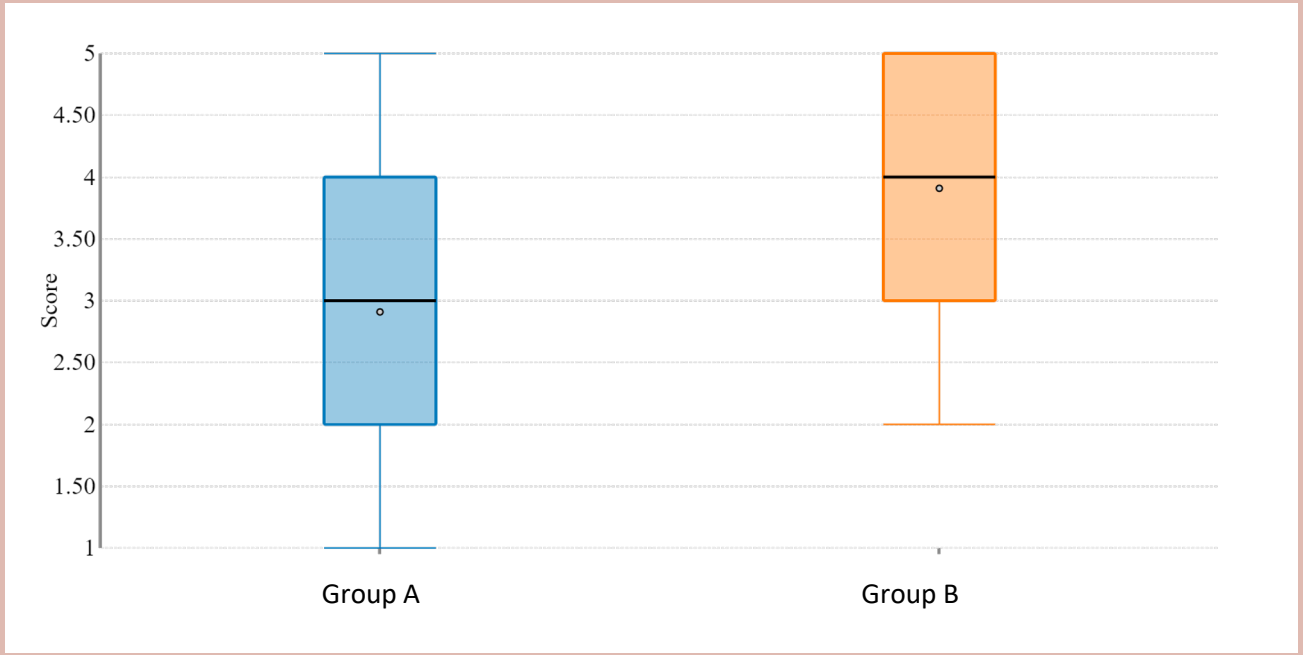


Group A = Simian command line based tool

Group B = Merry web based clone detection tool

Ease of Understanding

Did you find the tool easy to understand (how to run, how to interpret results)?

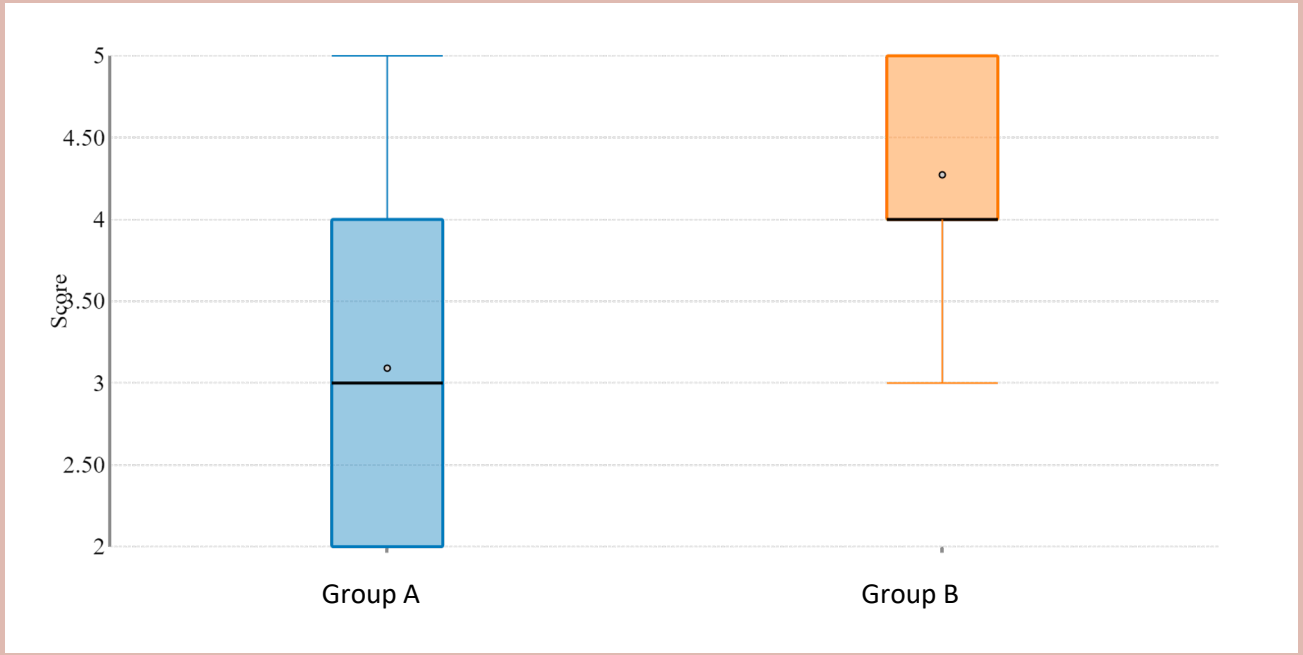


Group A = Simian command line based tool

Group B = Merry web based clone detection tool

Ease of Use

Did you find the tool easy to use
(environment needed to run to the tool and see the results)?



Group A = Simian command line based tool

Group B = Merry web based clone detection tool

บทสรุปและแนวทางการพัฒนาต่อในอนาคต

Conclusion

Conclusion

- We create a web-based code clone detection tool that use machine learning techniques, called Merry.
- The aim is to accurately detect clones and improve user experience.

Merry Engine

- The clone detection ML engine is based on 4 machine learning models.
- Evaluation of the performance of Merry by using BigCloneBench shows high precision and recall.
- Evaluation on the real software projects has varied performance.

Merry Web Application

- The web application is integrated with GitHub.
- It offers a user friendly and convenient code clone detection function.

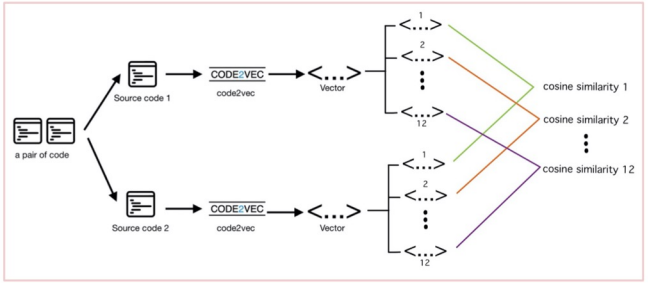
Problems and Limitations

- Supports only Java language
- code2vec poor run-time performance
- The evaluated precision and recall might not reflect on real software projects.
- Current MongoDB configuration has an issue where there is large amount.
- The user study results may be biased due to the sample size is small.

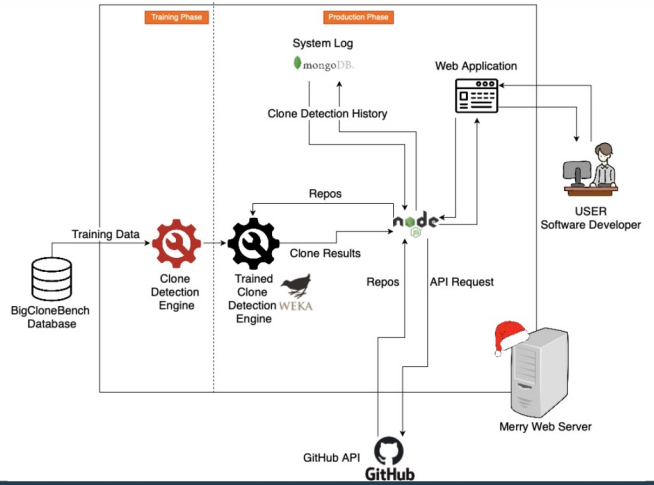
Future Work

- Expand the tool to detect clones in other languages
- Improve the code2vec run-time
- Create dedicated machine learning model per clone type
- Solve the MongoDB limitation by query a part of MongoDB document at a time
- Expand the number of participants in the user study.

1.2 Semantic Code Metrics

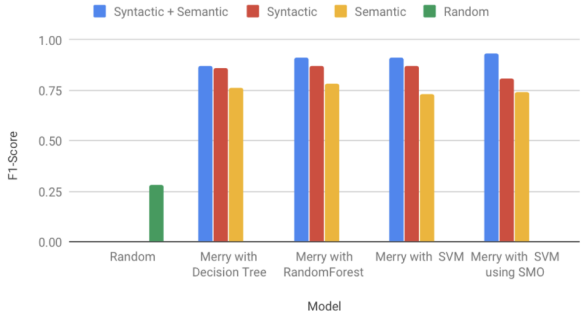


System Architecture



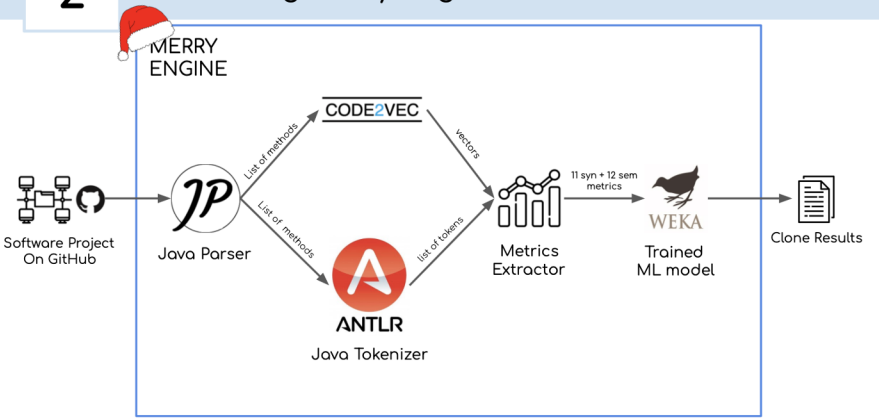
Evaluation of Merry ML Clone Detection Engine using BCB (cont.)

RQ1: How accurate is Merry code clone detection on BigCloneBench?



F1-Score

2 Using Merry Engine for Clone Detection



E-SAN Thailand
Coding & AI Academy

โครงการวิจัยโมเดลระบบนิเวศการเรียนรู้ที่บูรณาการ CODING & AI สำหรับเยาวชน
Model of Learning Ecosystem Platform integrate with Coding & AI for Youth

โครงการย่อยที่ 6
การพัฒนาเยาวชนเพื่อเข้าสู่วิชาชีพขั้นสูงด้าน Coding & AI
ร่วมกับ Coding Entrepreneur & Partnership: Personal AI

ชื่อหัวข้อ Code Clone Detector - ระบบ AI สำหรับช่วยตรวจวัดความเหมือนของโค้ดและตรวจจับการคัดลอกโค้ด

ดร.ชัยยงค์ รักขิตเวชสกุล








สร้างคน
ข้ามพรมแดน

Thailand Coding & AI Academy



สอวช

INET


THAI
PROGRAMMER

SST
SUN SMART TECH

The Asia Foundation

EVER

BOTNOI
GROUP

CODE COMBAT

ClusterKit

DOMECLOUD

Let's Code
Thailand

DMAP
DIGITAL MAKERS
ASIA PACIFIC


Google

FOCUS
ARENA

Coding Workshop

- ดูโค้ดแบบฝึกหัดได้ที่ https://colab.research.google.com/drive/1qZdJlYtSeLt3D2czSyFSch824-9AnJvu?usp=sharing
  หรือ Scan QR Code ด้านล่าง