Incremental clone detection for IDEs using dynamic suffix arrays

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Outline

Motivation

- Duplicated code is generally considered harmful to software quality
- Code clone detection, analysis and management is therefore important
- Incremental clone detection algorithms have not been thoroughly researched
- Incremental algorithms are useful in use-cases such as in IDEs

Our contribution

- CCDetect-LSP: An incremental clone detection tool for IDEs
- Uses a novel application of dynamic extended suffix arrays for clone detection
- Language- and IDE agnostic via Tree-sitter and LSP

Code clones

Definition (Code snippet)

A code snippet is a piece of contiguous source code in a larger software system.

Definition (Code clone)

A code clone is a code snippet which is equal or similar to another code snippet. The two code snippets are both code clones, and together they form a clone pair. Similarity is determined by some metric such as number of equal lines of code.

Clone types

- Code clones are classified into four types
  - Type-1: Syntactically identical
  - Type-2: Structurally identical
  - Type-3: Structurally similar
  - Type-4: Functionally similar (generally)

Clone type examples: type-1 and type-2

```
for (int i = 0; i < 10; i++) {
    print(i);
}
```

```
for (int i = 0; i < 10; i++) {
    // A comment

    print(i);
}
```

Figure: Type-1 clone pair

```
for (int i = 0; i < 10; i++) {
    print(i);
}
```

```
for (int j = 5; j < 20; j++) {
    print(j);
}
```

Figure: Type-2 clone pair

Clone type examples: type-3 and type-4

```
for (int i = 0; i < 10; i++) {
    print(i);
}
```

```
for (int i = 0; i < 10; i++) {
    print(i);
    print(i*2);
}
```

Figure: Type-3 clone pair

```
print((n*(n-1))/2)
```

```
int sum = 0;
for (int i = 0; i < n; i++) {
    for (int j = i+1; j < n; j++) {
        sum++;
    }
}
print(sum);
```

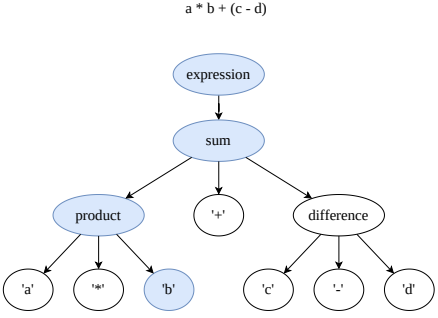
Figure: Type-4 clone pair

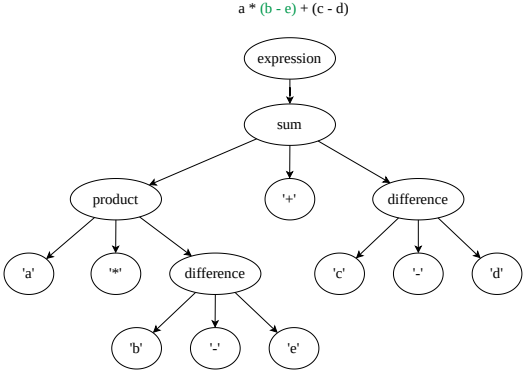
Clone detection

Clone matching techniques

- Text-based detection
  - Match based on raw source code
- Token-based detection
  - Match based on tokens
- Syntactic detection
  - Match based on AST
- Hybrid detection
  - Combine multiple approaches

Parsing and incremental parsing





Suffix tree

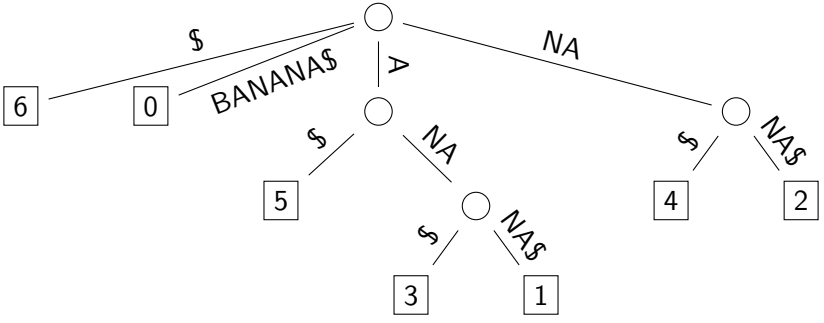


Figure: Suffix tree for $S = \text{BANANA\$}$

Suffix array

Index	Suffix
0	BANANA$
1	ANANA$
2	NANA$
3	ANA$
4	NA$
5	A$
6	$

(a) Suffixes

Index	Suffix
6	$
5	A$
3	ANA$
1	ANANA$
0	BANANA$
4	NA$
2	NANA$

(b) Sorted suffixes

Index	SA	ISA	LCP
0	6	4	0
1	5	3	0
2	3	6	1
3	1	2	3
4	0	5	0
5	4	1	0
6	2	0	2

(c) SA, ISA and LCP

Burrows-Wheeler transform

Index	CS
0	BANANA$
1	ANANA$B
2	NANA$BA
3	ANA$BAN
4	NA$BANA
5	A$BANAN
6	$BANANA

(d) Cyclic shifts

Index	CS
6	$BANAN**A**
5	A$BAN**AN**
3	ANA$B**AN**
1	ANANA$**B**
0	BANANA**$**
4	NA$BAN**A**
2	NANA$B**A**

(e) Sorted cyclic shifts and BWT

L	F
0	$Rank_A(0) + C[A] = 0 + 1 = 1$
1	$Rank_N(1) + C[N] = 0 + 5 = 5$
2	$Rank_N(2) + C[N] = 1 + 5 = 6$
3	$Rank_B(3) + C[B] = 0 + 4 = 4$
4	$Rank_\$(4) + C[\$] = 0 + 0 = 0$
5	$Rank_A(5) + C[A] = 1 + 1 = 2$
6	$Rank_A(6) + C[A] = 2 + 1 = 3$

(f) LF function

Table: S = BANANA$, BWT = ANNB$AA

CCDetect-LSP features

- CCDetect-LSP is implemented as an LSP server
  - List clones
  - Display clones inline with code
  - Jump between matching clones
  - Incremental updates on each edit

Implementation: Initial clone detection

- Algorithm which initially detects type-1 and optionally type-2 clones
- Pipeline of 5 phases, returns a list of clones
- Uses an extended suffix array for match detection
- Starting point: Assume documents are indexed

Detection algorithm overview

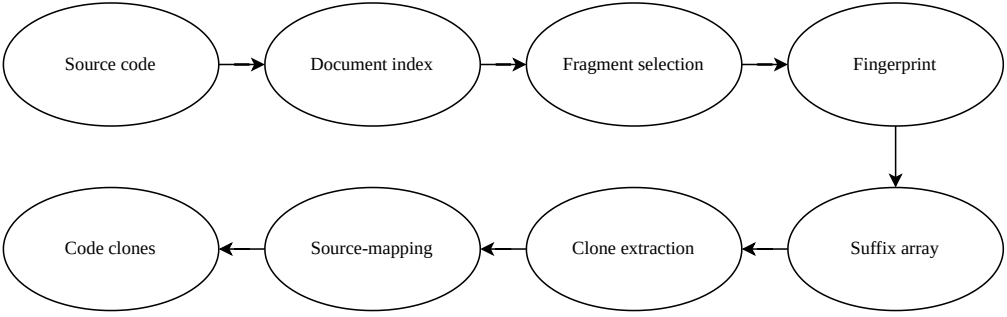


Figure: Overview of detection algorithm phases

Phase 1: Fragment selection

- Parse files using Tree-sitter
- Use a configurable Tree-sitter query to “capture” nodes
- Extract and store the tokens of captured nodes

Phase 2: Fingerprinting

- Consistently hash each token value with an increasing integer counter
- Store the fingerprint of each fragment in the document index
- For type-2 detection, hash the token type instead

Phase 2: Fingerprinting

- Example here

Phase 3: Suffix array construction

- Concatenate the fingerprints of each document in the index
- Construct SA, ISA and LCP array of the full fingerprint
- Uses “Induced sorting variable-length LMS-substrings” (SA-IS) algorithm

Phase 4: Clone extraction

Phase 5: Source-mapping

Implementation: Incremental clone detection

Results

Discussion

Conclusion

- Why do people use clone detection tools?

Demo

- Demo!

Implementation: LSP architecture and functionality

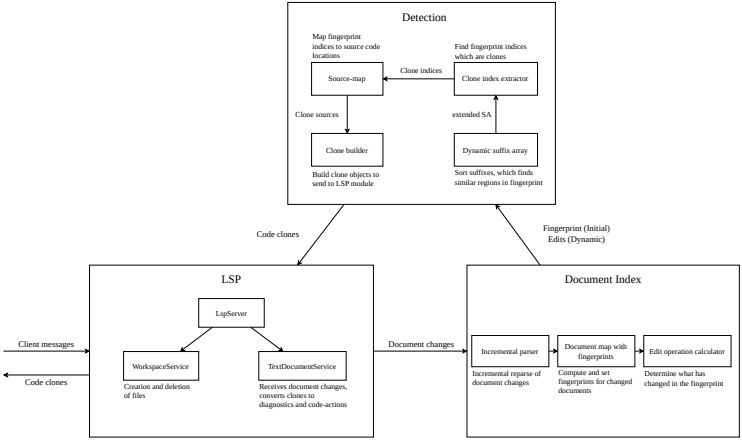


Figure: Architecture of CCDetect-LSP

LSP

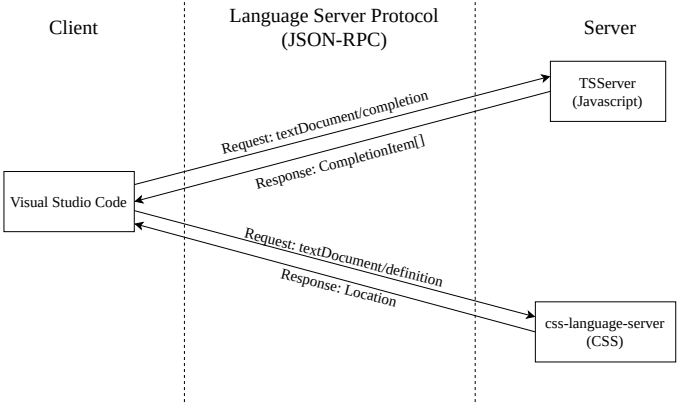


Figure: Example LSP server communication