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Outline

1. What is a code clone?
2. Discussions on the harmfulness of code clone
3. Importance of sharing industrial experiences with clone
4. Industrial application of clone analysis
   - Analysis tools
   - Result
5. Summary
What is a code clone?

- A code fragment that has identical or similar code fragments to it in source code.

- Introduced in source program by various reasons such as reusing code by `copy-and-paste'
Discussions on the harmfulness of code clone (Opponent)

There have been numerous discussions:

- **Cloning opponent:** “*clone should be avoided because it makes software maintenance difficult.*”
- Book on programming practice
- Research papers that is a little bit less than state-of-the-art

![Diagram](Image)

Bug is found

The other clones should be inspected.
Discussions on the harmfulness of code clone (Moderate & Proponent)

- **Moderate**: “Clone is unavoidable when a language lacks suitable modularization mechanism to eliminate it.”
  - e.g., it is difficult to merge code clones into a function in the case that the identifiers are unmatched.

- **Clone proponent**: “Clones do not often cause bugs, so leave it be.”
  - According to Rahman’s study [1] of OSS, there is no significant relationship among locations of bug and clones.

Importance of sharing experiences with cloning

- Which is truth of code clones?
  - There is no conclusion currently.
  - Probably it depends on the context of cloning [2].

- Sharing experience with cloning is a promising way for easy identification of harmful and harmless clones.

- Software engineering community has to report experience with clone detection and analysis.

Researches on cloning in industry

- Much research have been done on
  - Automatic clone detection
  - Analysis of code clones in OSS

- On the other hand, quantity of reports on cloning in industry has been lacking.
  - Ratio of clones to whole source code is higher in industry than in OSS
  - Rather than in OSS, clone causes a problem in industry.

It is needed to report an industrial experience with clone analysis.
Overview of industrial case study

1. Investigated an industrial software in terms of the following points by clone analysis technique.
   
   A. Is there significant difference in clones between the ends of the unit testing and the combined testing?
   
   B. Where clones are concentrated in the source code?
   
   C. What sort of characteristic clones are involved in the source code?

2. Interviewed developers for detected clones
Target software project

- Japanese governmental project
  - Software system for traffic infrastructure

- Source code
  - Approximately 100,000 LOC, and increased by 20 thousands after the unit test.
  - Main language is C/C++

- Organization
  - 5 vendors, each of which was assigned for a subsystem.
  - 1 project manager from a company different from the vendors
Tools for clone detection & analysis

- Clone detection tool: CCFinder [3]
  - Detection of lexically-similar code clones based on the identification of identical token sequences in source code

  - Scatter plot
  - Metrics for extracting clones

Token-based clone detection tool: 
CCFinder

Detection of identical token sequences
in source code

```java
1. static void foo() throws RESyntaxException {
2.     String a[] = new String [] { "123,400", "abc", "orange 100" };  
4.    int sum = 0;
5.    for (int i = 0; i < a.length; ++i)
6.        if (pat.match(a[i]))
7.            sum += Sample.parseInt(pat.getParen(0));
8.    System.out.println("sum = " + sum);
9. }

10. static void goo(String [] a) throws RESyntaxException {
11.    RE exp = new RE("[0-9,]+" unlawfully used in code.
12.    int sum = 0;
13.    for (int i = 0; i < a.length; ++i)
14.        if (exp.match(a[i]))
15.            sum += parseInt(exp.getParen(0));
16.    System.out.println("sum = " + sum);
17. }
```

Source files

Lexical analysis

Token sequence

Transformation

Transformed token sequence

Match detection

Clones on transformed sequence

Formatting

Clone pairs
Visually shows where code clones are

Both the vertical and horizontal axes represent the token sequence of source code

The original point is the upper left corner

● means that corresponding two tokens on the two axes are the same

F1, F2, F3, F4 : files
d1, d2 : directories
● : matched position detected as a practical code clone
● : matched position detected as a non-interesting code clone
Example of clone metrics

- **LEN(S):** the average length of code fragments (the number of tokens) in clone set $S$
  - clone set: a set of code fragments, in which any pair of the code fragments is a code clone
- **NIF(S):** the number of source files including any fragments of $S$

Example of file metrics

- **ROC(F):** the ratio of duplication of file $F$
  - if completely duplicated, the value is 1.0
  - if not duplicated at all, the value is 0.0
- **NOC(F):** the number of code fragments of any clone set in file $F$
# Amount of Code Clones in Subsystems

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<thead>
<tr>
<th>Company ID</th>
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<th>After combined testing</th>
</tr>
</thead>
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<td># clones</td>
<td>Duplicated ratio</td>
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Clones had increased during combined testing.
The parts D and E imply the creation of clones after the unit testing.

Interview

The developers insist that they added trusted library that has used in many products.
The part A treats geographical information of several types of vehicles. The code for the types are mostly cloned.

The part B involves statements for building SQL queries.

The part C involves initialization and finalization for a certain feature.
Example of detected clone
Clone metrics-based analysis

- **Longest clones**
  - A pair of 154 lines clones between the two files
  - Implications of copy-and-paste and forgetting modification

```cpp
/* ...XX..*/
void ...XX...()

/* ...XX..*/
void ...XX...()
```

AA**XX**BB.cpp

AA**YY**BB.cpp

Implication of forgetting modification to YY
Example of detected clones
File metrics-based analysis

- Source file containing the maximum number of clones
  
  ![Image]

  358 clones

- Most duplicated pair of source files
  
  ![Image]

  96% tokens are duplicated

Interview

Developers had expected this duplication since design phase.
Summary & Future work

- **Summary**
  - Discussed the importance of sharing industrial experiences with clone analysis
  - Presented industrial application of clone analysis
    - Many characteristic clones were extracted
    - According to interviews for some of the extracted clones, the developers expected the existence of clones.

- **Future work**
  - Conduct the further analysis for determining whether harmful clones or not