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   RESULTS & DISCUSSION

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A SYSTEMATIC APPROACH FOR DETECTION AND COST ESTIMATION OF CLONING IN VARIOUS PROGRAMMING LANGUAGES

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FARIDKOT

ABSTRACT

Real-world software systems contain substantial amounts of cloned code. While the negative impact of cloning on software maintenance has been shown in principle, we currently cannot quantify it in terms of increased maintenance costs. However, as long as its economic impact cannot be quantified, control of cloning is probable to be neglected in practice. This thesis presents an analytical cost model to estimate the maintenance effort increase caused by code cloning. The cost model can be used to assess the economic impact of cloning in a system and to evaluate investments in clone management tool support. To show its applicability, we report on a case study that instantiates the cost model for open source code for java programs. To fine out the cloning in the code. We identify the limitations of clone detection and control. Through a controlled experiment, we show that clone detection approaches are unsuited to detect behaviorally similar code that has been developed independently and is thus not the result of copy & paste. Finally, We implemented the clone cost model on some sample code to find out the cloning in similar code. And ConQat are useful tool to implement the clone cost model.

KEYWORDS

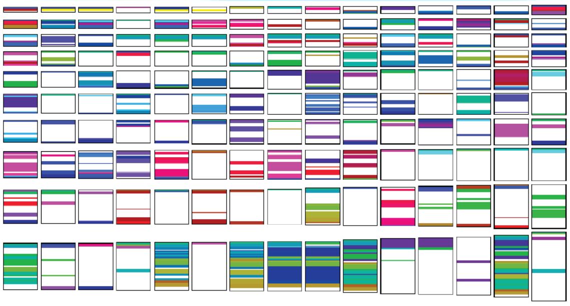
ConQat, Eclipse, clone, apache common collection.

INTRODUCTION

Software maintenance accounts for the majority of the total life cycle costs of successful software systems. Half of the maintenance effort is not spent on bug fixing or adaptations to changes of the technical environment, but on evolving and new functionality. Maintenance thus pre-serves and increases the value that software provides to its users. Reducing the number of changes that get performed during maintenance threatens to reduce this value. Instead, to lower the total life cycle costs of software systems, the individual changes need to be made simpler. An important goal of software engineering is thus to facilitate the construction of systems that are easy—and thus more economic—to maintain.

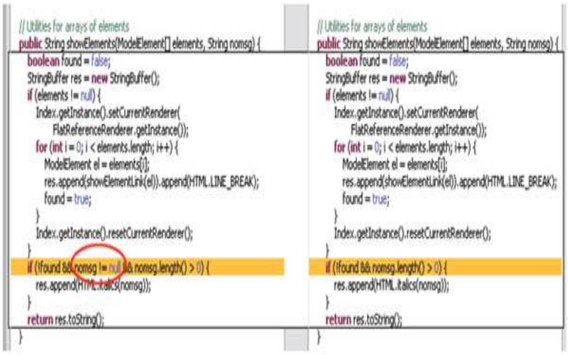
Software comprises a variety of artifacts, including requirements specifications, models and source code. During maintenance, all of them are affected by change. In practice, these artifacts often contain substantial amounts of duplicated content. Such duplication is referred to as cloning.

FIGURE 1.1: SHOWS THE CLONING IN USE CASE DOCUMENTS



Cloning hampers maintenance of software artifacts in several ways. First, it increases their size and thus effort for all size-related activities such as inspections—inspectors simply have to work through more content. Second, changes that are performed to an artifact often also need to be performed to its clones, causing effort for their location and consistent modification. If, e. g., different use case documents contain duplicated interaction steps for system login, they all have to be adapted if authentication is changed from password to keycard entry. Moreover, if not all clones of an artifact are modified consistently, inconsistencies can occur that can result in faults in deployed software. If, e. g., a developer fixes a fault in a piece of code but is unaware of its clones, the fault fails to be removed from the system. Each of these effects of cloning contributes to increased software lifecycle costs. Cloning is, hence, a quality defect.

FIGURE 1.2: CLONING THREATENS PROGRAM CORRECTNESS



```
// Utilities for arrays of elements
public String showElements(ModelElement[] elements, String nomsg) {
  boolean found = false;
  StringBuffer res = new StringBuffer();
  if (elements != null) {
    Index.getInstance().setCurrentRenderer(
        FlatReferenceRenderer.getInstance());
    for (int i = 0; i < elements.length; i++) {
      ModelElement el = elements[i];
      res.append(showElementLink(el)).append(HTML.LINE_BREAK);
      found = true;
    }
    Index.getInstance().resetCurrentRenderer();
  }
  if (!found && nomsg != null && nomsg.length() > 0) {
    res.append(HTML.italics(nomsg));
  }
  return res.toString();
}
```

```
// Utilities for arrays of elements
public String showElements(ModelElement[] elements, String nomsg) {
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  if (elements != null) {
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      res.append(showElementLink(el)).append(HTML.LINE_BREAK);
      found = true;
    }
    Index.getInstance().resetCurrentRenderer();
  }
  if (!found && nomsg.length() > 0) {
    res.append(HTML.italics(nomsg));
  }
  return res.toString();
}
```

The negative impact of cloning becomes tangible through examples from real-world software. We studied inspection effort increase due to cloning in 28 industrial requirements specifications. For the largest specification, the estimated inspection effort increase is 110 person hours, or almost 14 person days. For a second specification, it even doubles due to cloning1.

The effort increase due to the necessity to perform multiple modifications is illustrated in Figure 1.1, which depicts cloning in 150 use cases from an industrial business information system. Each black rectangle represents a use case, its height corresponding to the length of the use case in lines. Each colored stripe depicts a specification clone; stripes with the same color indicate clones with similar text. If a change is made to a colored region, it may need to be performed multiple times—increasing modification effort accordingly.

Finally, Figure 1.2 illustrates the consequences of inconsistent modifications to cloned code for program correctness2: a missing null check has only been fixed in one clone, the other still contains the defect and can crash the system at runtime.

2. LITERATURE SURVEY

Elmar Juergens proposed a **How Much is a Clone?** In this paper[1] Real-world software systems contain substantial amounts of cloned code. While the negative impact of cloning on software maintenance has been shown in principle, we currently cannot quantify it in terms of increased maintenance costs. However, as long as its economic impact cannot be quantified, control of cloning is probable to be neglected in practice. This paper presents an analytical cost model to estimate the maintenance effort increase caused by code cloning. The cost model can be used to assess the economic impact of cloning in a system and to evaluate investments in clone management tool -support. To show its applicability, we report on a case study that instantiates the cost model for 11 industrial software systems.

Lerina Aversano, Luigi Cerulo proposed a **How Clones are Maintained: An Empirical** Study in this paper the author suggest the clone maintenance, in this paper [2] Despite the conventional wisdom concerning the risksvrelated to the use of source code cloning as a software development strategy, several studies appeared in literature indicated that this is not true. In most cases clones are properly maintained and, when this does not happen, is because cloned code evolves independently.

Benjamin Hummel proposed [5] **"The Index-Based Code Clone Detection: Incremental, Distributed, Scalable"** in this Although numerous different clone detection approaches have been proposed to date, not a single one is both incremental and scalable to very large code bases. They thus cannot provide real-time cloning information for clone management of very large systems. We present a novel, index-based clone detection algorithm for type 1 and 2 clones that is both incremental and scalable. It enables a new generation of clone management tools that provide real-time cloning information for very large software. We report on several case studies that show both its suitability for real-time clone detection and its scalability: on 42 MLOC of Eclipse code, average time to retrieve all clones for a file was below 1 second; on 100 machines, detection of all clones in 73 MLOC was completed in 36 minutes.

3. OBJECTIVE OF THE WORK

1. The investigation of cloning has grown into an active area in the software engineering research community yielding, e. g., numerous detection approaches and a better understanding of the origin and evolution of cloning in source code.
2. The main objective of this work is to find out the cloning in various programming language source code.
3. Using ConQat tool, we can find out the cost of cloning and comparison of cost for different languages.

4. PROPOSED WORK: CLONE COST MODEL

A thorough understanding of the costs caused by cloning is a necessary foundation to evaluate alternative clone management strategies. Do expected maintenance cost reductions justify the effort required for clone removal? How large are the potential savings that clone management tools can provide? We need a clone cost model to answer these questions.

This chapter presents an analytical cost model that quantifies the impact of cloning in source code on maintenance efforts and field faults. Furthermore, it presents the results from a case study that instantiates the cost model for various programming languages and estimates maintenance effort increase and potential benefits achievable through clone management tool support.

DETAILED COST MODEL

This section introduces a detailed version of the clone cost model. Its first section introduces cost models for the individual process activities. The following sections employ them to construct models for maintenance effort and remaining fault count increase and the possible benefits of clone management tool support. We initially assume that no clone management tools are employed.

4.1 ACTIVITY COSTS

The activities Analysis, Design, and Other are not impacted by cloning. Their cloning induced effort overhead, ec, is thus zero. Their total efforts hence equal their inherent efforts.

Location effort depends on code size. Cloning increases code size. We assume that, on average, increase of the amount of code that needs to be inspected during location is proportional to the cloning induced size increase of the entire code base. Size increase is captured by overhead:

$$e_L^c = e_L^i \cdot overhead$$

Impact analysis effort depends on the number of change points that need to be determined. Cloning increases the number of change points. This increase is captured by overhead:

$$e_{IA}^c = e_{IA}^i \cdot overhead$$

Implementation effort comprises both addition and modification effort:

$$e_{Impl} = e_{Impl_{Mod}} + e_{Impl_{Add}}.$$

We assume that effort required for additions is unaffected by cloning in existing source code. We assume that the effort required for modification is proportional to the amount of code that gets modified, i. e., the number of source locations determined by impact analysis.

The modification ratio mod captures the modification-related part of the inherent implementation effort:

$$e_{Impl}^c = e_{Impl}^i \cdot mod \cdot overhead$$

Quality Assurance effort depends on the amount of code on which quality assurance gets performed. Both modifications and additions need to be quality assured. Since the measure overhead captures size increase of both additions and modifications, we do not need to differentiate between them, if we assume that cloning is, on average, similar in modified and added code. The increase in quality assurance effort is hence captured by the overhead measure:

$$e_{QA}^c = e_{QA}^i \cdot overhead$$

4.2 MAINTENANCE EFFORT INCREASE

Based on the models for the individual activities, we model cloning induced maintenance effort e^c for a single change request like this:

$$e^c = overhead \cdot (e_L^i + e_{IA}^i + e_{Impl}^i \cdot mod + e_{QA}^i)$$

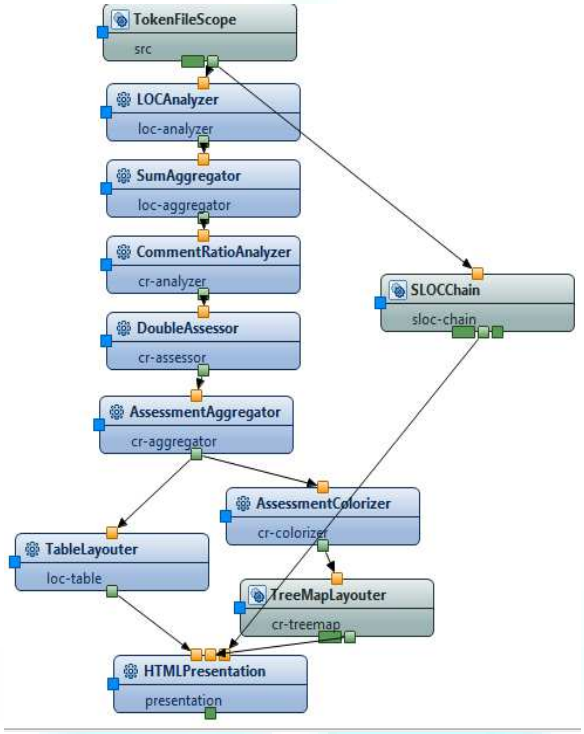
The relative cloning induced overhead is computed as follows:

$$\Delta e = \frac{overhead \cdot (e^i_L + e^i_{IA} + e^i_{Impl} \cdot mod + e^i_{QA})}{e^i_A + e^i_L + e^i_D + e^i_{IA} + e^i_{Impl} + e^i_{QA} + e^i_O}$$

This model computes the relative effort increase in maintenance costs caused by cloning. It does not take impact of cloning on program correctness into account.

5. IMPLEMENTATION OF CLONE COST MODEL

CASE STUDY 1: IMPLEMENTATION OF CLONE COST MODE IN JAVA LANGUAGE.



In new programming languages For Example Java, C#.

Requirement – To implement a clone cost model on some sample code and produce results that show how the model can prove effective in maintaining software systems that have substantial amount of cloned code.

Tools used – ConQAT with Eclipse Indigo IDE as editor

Samples of code used -

1. JabRef - an open source bibliography reference manager (Java)
2. Apache Common Collections – an extension of Java Reference library (Java)

Associated Terminology -

1. *Lines of code (LOC)* – denote the sum of the lines of code of all source files, including comments and blank lines.
2. *Source statements (SS)*- are the number of all source code statements, not taking commented or blank lines and code formatting into account.
3. *Redundancy free source statements (RFSS)*- are the number of source statements, if cloned source statements are only counted once. It thus estimates the size of a system from which all cloning is perfectly removed.

For example, if a file contains 100 statements (and no clones) in version 1, and 50 of them are duplicated in the file to create version 2. SS increases to 150, but RFSS remains at 100.

4. *Overhead* - denotes the ratio by which a system's size has increased due to cloning. It is computed as For the above example (in 3.), the resulting overhead is 0.5, denoting a cloning induced size increase by 50%
5. Δe – The difference in amount of effort required per change request in a software that has certain amount of cloned code and has no tool support.

It is calculated as:

$$\Delta e = \frac{overhead \cdot (e^i_L + e^i_{IA} + e^i_{Impl} \cdot mod - e^i_{QA})}{e^i_A + e^i_L + e^i_D + e^i_{IA} + e^i_{Impl} + e^i_{QA} + e^i_O}$$

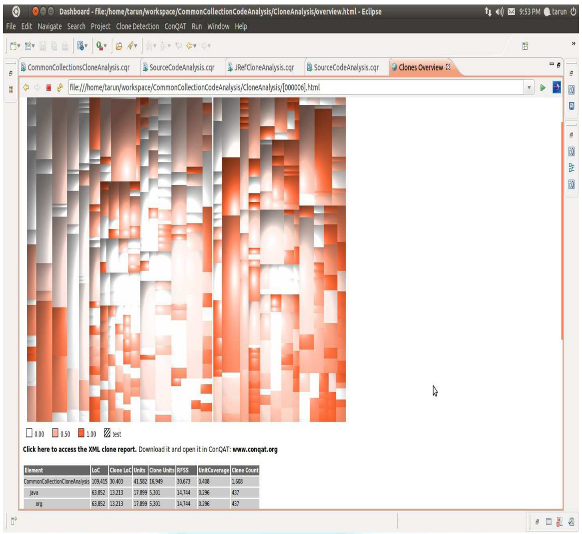
Procedure -

1. Prepared and configured the conQAT tool and downloaded the Java Source codes for the analysis.
2. Created new project for a particular code and configured the conQAT code blocks for the source code analysis and clone analysis.
3. Prepared the run configurations for the conQAT analysis.
4. Generated the reports by running conQAT processors.
5. Implemented the derived formulas of the cost model and compiled the results.

Results -

Screen shots of the conQAT reports:

CLONE ANALYSIS OF APACHE COMMON COLLECTIONS



Click here to access the XML clone report. Download it and open it in ConQAT: **www.conqat.org**

Element	LoC	Clone LoC	Units	Clone Units	RFSS	UnitCoverage	Clone Count
CommonCollectionCloneAnalysis	109,415	30,403	41,582	16,949	30,673	0.408	1,608
java	63,852	13,213	17,899	5,301	14,744	0.296	437
org	63,852	13,213	17,899	5,301	14,744	0.296	437

EFFORT DISTRIBUTION ASSUMED FOR THE CALCULATIONS

According to the thesis the average effort distribution has been calculated as:

Table 1. Effort distribution

Activity	[31]	[6]	[36]	Estimate
Analysis			26%	5%
Location		13%		8%
Design	30%	16%	19%	16%
Impact Analysis				5%
Implementation	22%	29%	26%	26%
Quality Assurance	22%	24%	17%	22%
Other	26%	18%	12%	18%

We assume that 50% (8% location, 5% impact analysis, (26% X 0.63) of implementation and 22% quality assurance; rounded from 51.38% to 50% since the available data does not contain the implied accuracy.) of the overall maintenance effort are affected by cloning. To estimate the impact of clone indication tool support, we assume that 10% of that effort are used for impact analysis (5% out of 50% in total). In case clone indication tools are employed, the impact of cloning on maintenance effort can thus be reduced by 10%.

FINAL RESULTS OF COST MODEL EXECUTION

Name of Library and Language	kLOC	kSS	kRFSS	Overhead	Δe	Δe_{tool}
JabRef(Java)	117	74	47	57%	28%	25%
Apache Common Collections (Java)	109	55	31	77%	39%	34%

CONCLUSION

In this paper, we have implemented the analytical cost model, this cost model is used to quantify the economic effect of cloning on maintenance efforts. It can be used as a basis to evaluate clone management alternatives.

Instead of computing absolute costs, the model computes maintenance effort increase relative to a system without cloning. Since in a relative cost model many factors that are independent of cloning remain constant, they do not need to be reflected in it. We implemented the cost model Using ConQat tool and find out the clone in the various open source in java language. Based on the results, some projects can achieve considerable savings by performing active clone management.

FUTURE WORK

There is a definitive need for future work in this area. The assumptions the cost model is based on need to be validated. The consequences of cloning on the number of field failures needs to be modeled quantitatively, instead of qualitatively as currently done in the model. We plan to perform sensitivity analysis to determine the relative importance of the individual parameters to guide instantiation in practice. Furthermore, we intend to instantiate the model using project specific effort parameters. Lastly but most importantly, we need to validate the correctness of the results, e. g., through comparing efforts on projects before and after clone consolidation with the predicted efforts.

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