Minning Software Repositories for Defect Categorization

Sakthi Kumaresh, and Ramachandran Baskaran

Abstract—Early detection of software defects is very important to decrease the software cost and subsequently increase the software quality. Success of software industries not only depends on gaining knowledge about software defects, but largely reflects in the manner in which information about defect is collected and used. In software industries, individuals at different levels from customers to engineers apply diverse mechanisms to detect the allocation of defects to a particular class. Categorizing bugs based on their characteristics helps the Software Development team take appropriate actions to reduce similar defects that might get reported in future releases. Classification, if performed manually, will consume more time and effort. Human resource having expert testing skills & domain knowledge will be required for labeling the data. Therefore, the need of automatic classification of software defect is high.

This work attempts to categorize defects by proposing an algorithm called Software Defect CLustering (SDCL). It aims at mining the existing online bug repositories like Eclipse, Bugzilla and JIRA for analyzing the defect description and its categorization. The proposed algorithm is designed by using text clustering and works with three major modules to find out the class to which the defect should be assigned. Software bug repositories hold software defect data with attributes like defect description, status, defect open and close date. Defect extraction module extracts the defect description from various bug repositories and converts it into unified format for further processing. Unnecessary and irrelevant texts are removed from defect data using data preprocessing module. Finally grouping of defect data into clusters of similar defect is done using clustering technique. The algorithm provides classification accuracy more than 80% in all of the three above mentioned repositories.

Index Terms—Software Defect, Defect Classification, Bug Repository, Clustering, Bug Categorization.

I. INTRODUCTION

Software defect can be defined as imperfections in software development process which disenables the software to fail to meet the desired expectations [14]. Software defects are inherent in the software process development, and it is also a significant factor contributing to software quality.

Developing defect free software product is impossible, but the organization can aim at minimizing defects by investing majority of the effort in detecting and preventing defects through effective defect management process. Software defect detection is done at various phases of software development through activities like Requirement’s Review, Code Inspection, walkthrough and testing. Detected defects are then stored in software repositories for further analysis.

Software bug repositories holds large amount of useful information about software defects [5]. It contains attributes of defects like defect id, description, status, open date, close date etc. Software description holds text data which tells us details about the defect. Bugs are reported to these repositories by non-technical people who cannot assign correct class to these bugs. Developers may be proficient in one particular domain, assigning a particular bug to relevant developer is important as it could save time and would help to maintain the interest level of developers. However, assigning the right bug to the right developer is quite difficult for tri-ager without knowing the actual class; the bug belongs to. [6]

Data mining techniques can be applied to handle large amount of data and text mining in particular to extract the knowledge from bug repositories. Categorizing defects into types and performing analysis may be beneficial to software organizations, but defects are not grouped into categories as it involves huge effort and time [10]. Thus there is a need for an automated approach that could help developers assign category labels to defects during defect analysis [10].

This work attempts to categorize bugs into classes by proposing an algorithm called SDCL. The algorithm proposed, works in three modules namely Defect extraction module, Data pre-processing and clustering module. Defect extraction module extracts the defect data from various software repositories like Bugzilla, JIRA and Eclipse and converts it into a unified format. Defect details collected from various bug repositories are then pre-processed for efficient defect categorization. Parsing the defect data, Stop word removal and Stemming is performed through data pre-processing module.

A. Defect Classification

Classification is one of the popular data mining techniques to categorize the defects into classes. Software bug classification is the process of classifying the software bugs into different categories. Classification of the software defect data is done in order to get deeper insight into defect details. Software defect classification is an essential part of improving software quality. Manual classification consumes lot of time and effort and people with domain knowledge and testing skills are required. Numerous techniques and algorithms are available.
B. Clustering Technique

A cluster is a collection of similar objects which shows some similar characteristics between them and shows some dissimilar characteristics between the objects in other clusters. There are number of clustering algorithms available and various techniques exist for measuring the distances for the clusters data points [7].

Clustering technique is very useful in the text domain, where the objects to be clustered can be of different type such as documents, paragraphs, sentences or terms. Clustering can be used for number of tasks like information retrieval, web analysis, marketing and medical diagnostic, corpus Summarization and Document Classification [12]. In this work, clustering is done using vector space model, in which the closeness between the defect data is identified using cosine similarity measure. The efficiency of our algorithm is tested on data collected from three software repositories Bugzilla, JIRA and Eclipse. The results show that our defect categorization algorithm could achieve an accuracy of more than 80%.

The rest of this paper is structured as follows. Section 2 gives details about bug repository. Section 3, reviews the related work on software defect classification using clustering technique. Section 4 details about the proposed Software Defect Clustering (SDCL) through three modules namely, Defect Extraction module, Data pre-processing and clustering module. Section 5 briefs about implementation details and section 6 presents the performance measure of the proposed algorithm. Finally section 7 concludes the paper with future research.

II. BUG REPOSITORY

Organizations aim to develop defect free software, but defects are inevitable during software development. So, all software projects need defect tracking system to track the defects related to software. Software bugs are managed using bug tracking tools like Bugzilla, JIRA etc. These are online repositories which contain useful information about software defect in HTML or XML format. Knowledge discovery from such software bug repositories is essential to know about the details of the defects. These repositories posses useful information about defects like defect summary, description, open date, closed date, severity, priority, user comments etc. Many of the defect related attributes like defect description are in textual form. To extract knowledge from bug repositories data mining techniques can be used. In this work, an attempt has been made to categorize the defect in different labels on the basis of defect description using clustering technique. In order to take corrective actions for the defects, the defects have to be assigned to the right person. This can be accomplished by categorizing the bugs into various categories.

III. LITERATURE SURVEY

Mining software repositories is essential as it contains information about defects. Software defect prediction, classification is done using software repositories. An approach to automatically identify the duplicate bug reports in the software bug repositories is proposed by Jalbert and Weimer [1]. Naresh kumar et al [5] presented a software bug classification algorithm, CLUBAS (Classification of Software Bugs Using Bug Attribute Similarity). CLUBAS is a hybrid algorithm, and is designed by using text clustering, frequent term calculations and taxonomic terms mapping techniques thereby categorizing bug data. Neelofar et al [6] realizes that assigning a particular bug to relevant developer could save time and would help to maintain the interest level of developers by assigning bugs according to their interest. However, assigning right bug to right developer is quite difficult for tri-ager without knowing the actual class, the bug belongs to. Hence in this paper, they have classified the bugs in different labels on the basis of summary of the bug. Lian Yu et al [9] discusses that it is hard to understand the crux of the problem and the debuggers must be well equipped with domain knowledge. In [7] Naresh Kumar Nagwani et al used Suffix Tree Clustering (STC) algorithm for software bug classification. STC can be applied to create the clusters of software bug record. Surendra Naidu [8] proposed the system for classifying various defects using decision tree based defect classification technique, which is used to group the defects after identification. P. V. Ingle et al [13] have presented different types of clustering methodology and categorize cluster as simple, medium and complex cluster. They does defect clustering using K means clustering algorithm. NLP based Information Retrieval system for mining defect data repository based on the quality of text description was proposed by Schugerl P et al [4]. Ferdian Thung [10] has worked on defect categorization technique by analyzing both texts from bug reports and code features from bug fixes. Analyzed data from three software system and classified them according to three categories of Orthogonal Defect Classification (ODC). The categories include control and data flow, structural and non-functional. Thung was able to achieve 77.8% accuracy by using SVM multi class classification algorithm.

An algorithm, Lingo is proposed by Osinski et al. [2] for clustering search results of text documents, Lingo uses algebraic transformations of the term-document matrix, and frequent phrase extraction using suffix arrays. Qinbao Song et al [3] have proposed a FAST algorithm for selecting the Feature subset for clustering and evaluated empirically. In this they have adopted the efficient Minimum-Spanning Tree (MST) method.

IV. SOFTWARE DEFECT CLUSTERING (SDCL) ALGORITHM

Software defect reports that are extracted from bug repositories contain lot of defect related attributes. Attributes like Defect description and summary are the important one in
the bug repository which holds text data. For Effective
categorization of the software defect, a text classification
scheme is required. This work, attempts to categorize software
defects by proposing an algorithm called Software Defect
CLustering (SDCL) algorithm. This algorithm contains three
modules to perform defect categorization using bug data from
software repositories. The various modules used in this
algorithm are Defect Extraction, pre-processing and clustering
which is depicted in fig 1. Defect Extraction module extracts
defect data from various bug repositories and stores in primary
database. Stemming the defect data and stop word removal is
done during pre-processing. Finally defect clusters are created
based on the cosine similarity measure.

There is no universal correct way to categorize bugs, it is
recommended to adapt some taxonomy to categorize bugs. By
categorizing bugs, we can pick bug category that has more
number of bugs, focus on it, and take preventive actions in
future projects in order to avoid such defects from recurring
[15]. While adopting taxonomy to categorize bugs, this work
attempts to use Logical and syntax defects in addition to
assignment and interface bug taxonomy given by Orthogonal
Defect Classification (ODC). The following algorithm
presents the various steps involved in SDCL.

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**Algorithm: SDCL (Software Defect Clustering)**

**Input:** Defect data from software Bug Repositories

**Output:** Software Defect Clusters

**START**

```
def Extract(bug_Db):
    # Convert defect reports from bug repositories to unified format
    # and store in database for further analysis.
    u_def_Rep = Get bug(db), Eclipse(db), JIRA(db) // Get the defect
    # reports from Bugzilla, Eclipse and JIRA.
    u_def_Rep = Conv_def_Rep(defect_report, Common format) // Convert
    # the data sources from various software repositories in unified
    # (Common) format and store it in database for further analysis.

def PreProcess(u_def_Rep):
    # Preprocess the defect description from various defect repositories
    # and handle stop words.
    # The unnecessary text may include text found between hyphens,
    # after bullets and between parentheses.
    pre_proc_Def = u_def_Rep // Preprocess defect description.
    # Stemming is applied to the defect description.
    pre_proc_Def = Stemming(pre_proc_Def) // Stemming algorithm
    # attempts to replace a word, to the “stem” or main root of the word.
    # This reduces the frequency of unique words. Commonly used

def Cluster(pre_proc_Def):
    # Find defect clusters and assign class labels.
```

**END**

---

**Fig. 1 Software Defect Clustering (SDCL)**

**A. Module 1: Defect Extraction**

Fig 2 shows the interface created for defect extraction. In this
module, the steps involved in extracting defect reports from
various sources are taken one by one. Initially bug reports
from various bug repositories are taken as input. Later these
reports are converted into unified format to enable them to
store in database for further analysis.

**Fig. 2 Defect Extractions**

Steps involved in defect extraction are shown below:

**Module 1: (Defect Extraction)**

```
def Extract(defect_data):
    # Get defect reports from Bugzilla, Eclipse and JIRA.
    # Convert defect reports to unified format.
    # Store in database for further analysis.
    defect_report = Get缺陷_report(Bugzilla, Eclipse, JIRA) // Get the defect
    # reports from Bugzilla, Eclipse and JIRA.
    defect_report = Convert_def_report(defect_report, Common format) // Convert
    # the data sources from various software repositories in unified
    # (Common) format and store it in database for further analysis.

def PreProcess(defect_report):
    # Preprocess the defect description from various defect repositories
    # and handle stop words.
    # The unnecessary text may include text found between hyphens,
    # after bullets and between parentheses.
    pre_proc_def = defect_report // Preprocess defect description.
    # Stemming is applied to the defect description.
    pre_proc_def = Stemming(pre_proc_def) // Stemming algorithm
    # attempts to replace a word, to the “stem” or main root of the word.
    # This reduces the frequency of unique words. Commonly used

def Cluster(pre_proc_def):
    # Find defect clusters and assign class labels.
```

**B. Module 2: Data Pre-processing**

Defect description is one of the important attribute of the
defect reports. It gives details about defect. As these data are
available in the form of text, we need to do some processing in
order to make it available for defect analysis. Here, every
defect description is treated as Bag-of-words. Data pre-
processing involves three steps namely parsing the data, stop
word removal and applying stemming to the text. Parser does
the process of removing unnecessary text from the defect
description. The unnecessary text may include text found
between hyphens, after bullets and between parentheses.[19]
DefParser function outputs each defect description as a set of
words by removing the unnecessary semicolons, colons,
exclamation marks etc. Interface created for doing the pre-
processing task is shown in figure 3.

**Fig. 3 Data Pre-processing**

Another pre-processing task involves the elimination of “stop”
words. Stop words are very common words like the articles
“the” and “a” that do not add to the information content of a
text string. These words are irrelevant to the defect analysis
and are therefore eliminated. A further task that is performed
in text mining is “stemming.” Stemming algorithm attempts to
replace a word, to the “stem” or main root of the word. It
reduces the frequency of unique words. Commonly used
algorithm for stemming is the “Porter’s Algorithm” [18]. Module 2 gives the steps involved in pre-processing.

Module 2 (Pre-processing)
pre-process( on_def_Reps)

START
Repeat the following until EOF
Treat every defect description in the bug database (Def
description[ ]) as a "bug description"
BagOfWords[ ] ← DefParser(Def descr[ ]) // DefParser function outputs the
each defect description as a set of words by removing unnecessary

| Semicolons, colon, exclamation marks etc.
stop.BagOfWords[ ] ← BagOfWords[ ] // Eliminate stop words from the
BagOfWords[ ]; Words that are not relevant to Software Defect
sim.BagOfWords[ ] ← str.BagOfWords[ ]; // Apply stemming over the
BagOfWords[ ]; Stemming words are reduced to their root.
pre_proc.Def[ ] ← sim.BagOfWords[ ]; // outputs pre-processed defects
term.Data[ ] ← tokens_tok.pre_proc.Def[ ]; // tokemizer divides the data
from the pre-processed defects into components and stores in term.Data[ ]

STOP

C. Clustering
Clustering is the process of grouping a set of data object into
classes of similar objects [11]. It is the most common form of
unsupervised learning, meaning, finding natural grouping of
instances given un-labeled data. Clustering help users
understand the natural grouping or structure in data set. The
quality of a clustering result depends on the similarity measure
used by the clustering method and its implementation [16].

As software defect description holds text data, Clustering of
defects based on the similarity of terms in defect description is
done in this study. For this purpose, distance based clustering
algorithm is used to find the similarity measure between the
defect description. One of the popular similarity function
called cosine similarity is employed to find the closeness
between two defect descriptions.

Cosine similarity comes under vector space model. The set of
defect description in a collection then is viewed as a set of
vectors in a vector space. Vectors deals only with numbers. In
this work, we are dealing with defect description which holds
text data. Hence TF and IDF are used to convert text into
numbers so that it can be represented by a vector. In reality
each defect description will be of different size. On a large
defect description, the frequency of the terms will be much
higher than the smaller ones. Hence normalization of text
based on its size is necessary. A simple way to achieve this is
to divide the term frequency by the total number of terms.
Using (1), we can find out the similarity between two defect
descriptions. Various steps involved in clustering are shown in
module 3.

Cosine Similarity (Ddx,Ddy) = Dot product(Ddx,Ddy) / || Ddx|| * || Ddy|| [17]

(1)

Dot product (Ddx,Ddy) = Ddx[0] * Ddy[0] + Ddx[1] * Ddy[1] * ... *
Ddx[n] * Ddy[n]

|| Ddx|| = square root(Ddx[0]^2 + Ddx[1]^2 + ... + Ddx[n]^2)

|| Ddy|| = square root(Ddy[0]^2 + Ddy[1]^2 + ... + Ddy[n]^2)

V. IMPLEMENTATION DETAILS
The entire algorithm is implemented in java eclipse
environment with a maximum of 2500 defect reports. Defect
reports with missing data are eliminated. Defect reports are
taken from three different repositories with 495, 1083, 2095

records for experimentation of the algorithm. Java supports
traversing into the xml using parsers. The bug reports that are
retrieved from bug repositories are in the xml format which
are later stored in primary database using java program. The
Document Object model and Simple Application for XML
(SAX) are the popular parsing tools in java. DOM is
comparatively slow and supports adding new elements to the
xml file. But here the requirement is to store the xml
content in a database. Using SAX the data from the xml file
are transferred to the local variables and then using JDBC, the
data are stored in the database.

2. PERFORMANCE MEASURE
Table 1 illustrates a confusion matrix to evaluate the
performance of classification problem. Accuracy and F-
measure are the two performance measure that is used in this
study.

<table>
<thead>
<tr>
<th>TABLE I. CONFUSION MATRIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>Same Cluster</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>Same Class</td>
</tr>
<tr>
<td>Different Classes</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Measure</th>
<th>Formula</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision</td>
<td>TP / (TP + FP)</td>
<td>Precision is the ratio of the number of correctly classified defects and the actual number of defects which was assigned to the type.</td>
</tr>
</tbody>
</table>
Recall is the ratio of the number of correctly classified software defects and the number of software defects which belongs to the type.

Accuracy is defined as the number of defects that are correctly classified to the total number of defects.

### TABLE III: RESULTS

<table>
<thead>
<tr>
<th>Data Sources</th>
<th>Instances</th>
<th>Precision</th>
<th>Recall</th>
<th>F-Measure</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>JIRA</td>
<td>495</td>
<td>0.279</td>
<td>0.354</td>
<td>0.312</td>
<td>84.84%</td>
</tr>
<tr>
<td>Eclipse</td>
<td>1083</td>
<td>0.419</td>
<td>0.372</td>
<td>0.394</td>
<td>89.38%</td>
</tr>
<tr>
<td>Bugzilla</td>
<td>2095</td>
<td>0.253</td>
<td>0.306</td>
<td>0.277</td>
<td>82.24%</td>
</tr>
</tbody>
</table>

**A. Accuracy and Rand index**

The Rand index measures the percentage of decisions that are correct. It is simply the measure of accuracy [20]. The accuracy measure for the JIRA, Eclipse and Bugzilla are shown in fig 4. It is observed from the experimental results that accuracy wise SDCL performs well and maintains more than 80% accuracy for different samples in all of the above mentioned repositories.

**B. Precision and Recall**

The following chart shows the performance of SDCL algorithm in terms of precision and Recall. It gives good precision for Eclipse data records than other two repositories.

**C. F-Measure**

F-Measure is a combined measure of Precision and Recall parameters. F-Measure is calculated using (2). Fig 5 shows the F-Measure for the three repositories taken for study. From the F-Measure view point, the values are consistent for JIRA and Eclipse, and it is slightly lesser for Bugzilla. The higher value of F-measure indicates higher quality of the classifiers. SDCL performed well for JIRA and Eclipse when compared to Bugzilla.

\[
F = \frac{2 \times \text{precision} \times \text{recall}}{\text{precision} + \text{recall}}
\]

**VII. CONCLUSION**

Defect classification is a difficult task to perform unless and otherwise the person involved in classifying defect has extensive knowledge about software testing. Moreover classifying defect involves lot of time, cost and effort. Therefore, this work attempts to do automatic defect classification through clustering techniques. The clustering technique helps the project managers to know the category of defect and helps them to assign right defect to the right personnel.

Realizing the need for automatic defect categorization, in this work, SDCL algorithm is proposed for categorization of software defects using clustering technique. Here, clustering is done based on vector space model using cosine similarity to judge the closeness between text data. Once the similar defects are grouped according to the above technique, from each clustered defect description, frequent terms are generated, and the term with highest frequency is assigned as a class label to the cluster. Defect clusters are created under the category, syntax and logical in addition to assignment and interface defect taxonomy given by ODC.

In order to improve the efficiency of the algorithm, the future scope of the work is related to extracting key phrases from the defect description and then applying clustering technique to group defect data into various categories. By doing so, the time involved in similarity calculation and the comparison of terms in the text can be reduced thereby reducing the response time of the automatic defect classification system.

**REFERENCES**


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