

SuiteRec: Automatic Test Suite Recommendation System Using Code Clone Detection Tool

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Abstract—This document is a model and instructions for L^AT_EX. This and the IEEEtran.cls file define the components of your paper [title, text, heads, etc.]. *CRITICAL: Do Not Use Symbols, Special Characters, Footnotes, or Math in Paper Title or Abstract.

Index Terms—component, formatting, style, styling, insert

I. INTRODUCTION

近年、ソフトウェアに求められる要件が高度化・多様化する一方、ユーザからはソフトウェアの品質確保やコスト削減に対する要求も増加している [1]. その中でも開発全体のコストに占める割合が大きく、品質確保の要ともいえるソフトウェアテストを支援する技術への関心が高まっている。しかし、現状では単体テスト作成作業の大部分が人手で行われており、多くのテストを作成しようとするのとそれに比例してコストも増加してしまう。このような背景から、ソフトウェアの品質を確保しつつコスト削減を達成するために、様々な自動化技術が提案されている。

既存研究で提案されている EvoSuite[2] は、単体テスト自動生成における最先端のツールである。EvoSuite は、対象コードを静的解析しプログラムを記号値で表現する。そして、対象コードの制御パスを通るような条件を集め、条件を満たす具体値を生成する。単体テストを自動生成することで、開発者は手作業での作成時間が自動生成によって節約することができ、またコードカバレッジを向上することができる。しかし、自動生成によって機械的に作成されるテストコードは対象のコードの作成経緯や意図に基づいて生成されていないので、可読性が低く開発者に信用されていないことや後の保守作業を困難にするといった課題がある [3]. このことは、自動生成ツールの実用的な利用の価値に疑問を提示させる。テストが失敗するたびに、開発者はテスト対象のプログラム内での不具合を原因を特定するま

たは、テスト自体を更新する必要があるかどうかを判断する必要がある。自動生成されたテストは、自動生成によって得られる時間の節約よりも読みづらく、保守作業に助けになるというよりかむしろ邪魔するという結果が報告されている。

本研究では、この課題を解決するために OSS に存在する既存の品質の高いテストコード推薦するツール SuiteRec を紹介します。SuiteRec は類似コード検出ツールを用いてクローンペア間でのテスト再利用を考えます。入力コードに対して類似コードを検出し、その類似コードに対応するテストスイートを開発者に推薦します。さらに、テストコードの良くない実装を表すメトリクスであるテストスメルを開発者に提示し、より品質の高いテストスイートを推薦できるように推薦順位がランキングされています。

提案ツールの評価では、被験者によって SuiteRec の使用した場合とそうでない場合でテストコードの作成してもらい、テスト作成をどの程度支援できるかを定量的および定性的に評価しました。その結果、提案ツールの利用は分岐が多く複雑なプログラムのテストスイートを作成する際に、コードカバレッジを向上させることができることや、ツールを使用して作成テストコードの品質が高いことが分かった。また、定性的な評価として実験後にアンケートを実施し、推薦ツールを使った場合多くの被験者は自分の作成したテストコードに自信が持てることが分かった。

II. BACKGROUND AND RELETED WORK

Unit testing. 単体テストの実行タスクでは、ソフトウェアを動作させ、それぞれのテストケースにおいてソフトウェアが期待通りの振る舞いをするかを確認する。テスト工程のコスト削減のため、テスト実行タスクにおいて、単体テストでは JUnit などのテスト自動実行ツールの利用が産業界で進んでいる。しかし、テスト設計タスクは未だ手動で行うことが多く、自動化技術の実用化および普及が期待さ

Identify applicable funding agency here. If none, delete this.

れている。単体テスト設計タスクで作成されるテストケースは、テスト手順、テスト入力値、テスト期待結果から構成される。テスト手順に従ってテスト対象のソフトウェアにテスト入力値を与え、その出力結果をテスト期待結果と比較する。これが一致していればテストは合格となり、一致しなければ不合格となる。単体テスト設計タスクにおいては、多くの場合同値分割法、境界地分析法などのテストケース作成技法を用いてテスト入力値を作成するが、ソフトウェアの要求通りに動作するかを確認するために多くのバリエーションのテスト入力値を作成する必要がある。

Test case generation. 既存の研究 [4] は、既存のテストケースを再利用、自動生成、または再適用できることによって、ソフトウェア開発のテスト工程における時間とコストを大幅に節約できることを示している。テスト生成技術は、主にランダムテスト (RT)、記号実行 (SE)、サーチベーステスト (SBST)、モデルベース (MBT)、組み合わせテストの 5 つに分類できる。SE はさらに静的記号実行 (SSE) と動的記号実行 (DSE) に分けられる。RT とは、ソフトウェアにランダムな入力を与えるテスト手法である。無造作・均一にテストを実行するランダムテストは自動化に適しているが、コードカバレッジ率向上、バグ検出の観点において、テストケース 1 件当たりの効率性は著しく悪い。SE は対象コードを静的解析してプログラムを記号値で表現し、コード上のそれぞれのパスに対応する条件を抽出し、パスごとにパスを通るような入力値を満たすべき条件を集める。そして、パスごとにその条件を SMT ソルバ [5] などの制約ソルバを用いて解き、得られた具体値をテスト入力値とする。SBST は、達成したい要件に対する達成度合いを定量的に評価できるように設計した評価関数に基づいて、ヒューリスティック探索アルゴリズムを用いて達成したい要件を満足するテストスイートを生成する技術の総称である。MBT はモデルに基づいてテストスイートを生成する技術の総称である。モデルは何らかの形でテスト対象を記述したものであり、要求分析や設計のためのモデルを活用することもあれば、テストのためにモデルを作成することもある。CT は、パラメータ間の相互作用に起因する不具合を効果的に発見するためにテストケースとしてパラメータに割り当てる値の組み合わせを生成する手法である。

Test reuse using clone pairs.

A. Maintaining the Integrity of the Specifications

The IEEEtran class file is used to format your paper and style the text. All margins, column widths, line spaces, and text fonts are prescribed; please do not alter them. You may note peculiarities. For example, the head margin measures proportionately more than is customary. This measurement and others are deliberate, using specifications that anticipate your paper as one part of the entire proceedings, and not as an independent document. Please do not revise any of the current designations.

III. PREPARE YOUR PAPER BEFORE STYLING

Before you begin to format your paper, first write and save the content as a separate text file. Complete all content and organizational editing before formatting. Please note sec-

tions III-A–III-E below for more information on proofreading, spelling and grammar.

Keep your text and graphic files separate until after the text has been formatted and styled. Do not number text heads— \LaTeX will do that for you.

A. Abbreviations and Acronyms

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, ac, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

B. Units

- Use either SI (MKS) or CGS as primary units. (SI units are encouraged.) English units may be used as secondary units (in parentheses). An exception would be the use of English units as identifiers in trade, such as “3.5-inch disk drive”.
- Avoid combining SI and CGS units, such as current in amperes and magnetic field in oersteds. This often leads to confusion because equations do not balance dimensionally. If you must use mixed units, clearly state the units for each quantity that you use in an equation.
- Do not mix complete spellings and abbreviations of units: “Wb/m²” or “webers per square meter”, not “webers/m²”. Spell out units when they appear in text: “. . . a few henries”, not “. . . a few H”.
- Use a zero before decimal points: “0.25”, not “.25”. Use “cm³”, not “cc”).

C. Equations

Number equations consecutively. To make your equations more compact, you may use the solidus (/), the exp function, or appropriate exponents. Italicize Roman symbols for quantities and variables, but not Greek symbols. Use a long dash rather than a hyphen for a minus sign. Punctuate equations with commas or periods when they are part of a sentence, as in:

$$a + b = \gamma \quad (1)$$

Be sure that the symbols in your equation have been defined before or immediately following the equation. Use “(1)”, not “Eq. (1)” or “equation (1)”, except at the beginning of a sentence: “Equation (1) is . . .”

D. \LaTeX -Specific Advice

Please use “soft” (e.g., `\eqref{Eq}`) cross references instead of “hard” references (e.g., (1)). That will make it possible to combine sections, add equations, or change the order of figures or citations without having to go through the file line by line.

Please don’t use the `{eqnarray}` equation environment. Use `{align}` or `{IEEEeqnarray}` instead. The `{eqnarray}` environment leaves unsightly spaces around relation symbols.

Please note that the `{subequations}` environment in \LaTeX will increment the main equation counter even when there are no equation numbers displayed. If you forget that, you might write an article in which the equation numbers skip from (17) to (20), causing the copy editors to wonder if you’ve discovered a new method of counting.

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\LaTeX can’t read your mind. If you assign the same label to a subsection and a table, you might find that Table I has been cross referenced as Table IV-B3.

\LaTeX does not have precognitive abilities. If you put a `\label` command before the command that updates the counter it’s supposed to be using, the label will pick up the last counter to be cross referenced instead. In particular, a `\label` command should not go before the caption of a figure or a table.

Do not use `\nonumber` inside the `{array}` environment. It will not stop equation numbers inside `{array}` (there won’t be any anyway) and it might stop a wanted equation number in the surrounding equation.

E. Some Common Mistakes

- The word “data” is plural, not singular.
- The subscript for the permeability of vacuum μ_0 , and other common scientific constants, is zero with subscript formatting, not a lowercase letter “o”.
- In American English, commas, semicolons, periods, question and exclamation marks are located within quotation marks only when a complete thought or name is cited, such as a title or full quotation. When quotation marks are used, instead of a bold or italic typeface, to highlight a word or phrase, punctuation should appear outside of the quotation marks. A parenthetical phrase or statement at the end of a sentence is punctuated outside of the closing parenthesis (like this). (A parenthetical sentence is punctuated within the parentheses.)
- A graph within a graph is an “inset”, not an “insert”. The word alternatively is preferred to the word “alternately” (unless you really mean something that alternates).
- Do not use the word “essentially” to mean “approximately” or “effectively”.
- In your paper title, if the words “that uses” can accurately replace the word “using”, capitalize the “u”; if not, keep using lower-cased.
- Be aware of the different meanings of the homophones “affect” and “effect”, “complement” and “compliment”, “discreet” and “discrete”, “principal” and “principle”.
- Do not confuse “imply” and “infer”.
- The prefix “non” is not a word; it should be joined to the word it modifies, usually without a hyphen.
- There is no period after the “et” in the Latin abbreviation “et al.”.
- The abbreviation “i.e.” means “that is”, and the abbreviation “e.g.” means “for example”.

An excellent style manual for science writers is [7].

F. Authors and Affiliations

The class file is designed for, but not limited to, six authors. A minimum of one author is required for all conference articles. Author names should be listed starting from left to right and then moving down to the next line. This is the author sequence that will be used in future citations and by indexing services. Names should not be listed in columns nor group by affiliation. Please keep your affiliations as succinct as possible (for example, do not differentiate among departments of the same organization).

G. Identify the Headings

Headings, or heads, are organizational devices that guide the reader through your paper. There are two types: component heads and text heads.

Component heads identify the different components of your paper and are not topically subordinate to each other. Examples include Acknowledgments and References and, for these, the correct style to use is “Heading 5”. Use “figure caption” for your Figure captions, and “table head” for your table title. Run-in heads, such as “Abstract”, will require you to apply a style (in this case, italic) in addition to the style provided by the drop down menu to differentiate the head from the text.

Text heads organize the topics on a relational, hierarchical basis. For example, the paper title is the primary text head because all subsequent material relates and elaborates on this one topic. If there are two or more sub-topics, the next level head (uppercase Roman numerals) should be used and, conversely, if there are not at least two sub-topics, then no subheads should be introduced.

H. Figures and Tables

a) *Positioning Figures and Tables:* Place figures and tables at the top and bottom of columns. Avoid placing them in the middle of columns. Large figures and tables may span across both columns. Figure captions should be below the figures; table heads should appear above the tables. Insert figures and tables after they are cited in the text. Use the abbreviation “Fig. 1”, even at the beginning of a sentence.

TABLE I
TABLE TYPE STYLES

Table Head	Table Column Head		
	Table column subhead	Subhead	Subhead
copy	More table copy ^a		

^aSample of a Table footnote.

Fig. 1. Example of a figure caption.

Figure Labels: Use 8 point Times New Roman for Figure labels. Use words rather than symbols or abbreviations when writing Figure axis labels to avoid confusing the reader. As an

example, write the quantity “Magnetization”, or “Magnetization, M”, not just “M”. If including units in the label, present them within parentheses. Do not label axes only with units. In the example, write “Magnetization (A/m)” or “Magnetization {A[m(1)]}”, not just “A/m”. Do not label axes with a ratio of quantities and units. For example, write “Temperature (K)”, not “Temperature/K”.

ACKNOWLEDGMENT

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

REFERENCES

Please number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first ...”

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the abstract or reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors’ names; do not use “et al.”. Papers that have not been published, even if they have been submitted for publication, should be cited as “unpublished” [4]. Papers that have been accepted for publication should be cited as “in press” [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

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