A Novel Technique for Generation and Optimization of Test Cases Using Use Case, Sequence, Activity Diagram and Genetic Algorithm

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Abstract: This paper presents a novel approach for generation of test cases from UML design diagrams. In this new generation scheme, we have considered use case diagram, activity diagram and sequence diagram. Our approach consists of converting the use case diagram into use case diagram graph (UDG), activity diagram into activity diagram graph (ADG) and sequence diagram into sequence diagram graph (SDG). After that three graphs UDG, ADG and SDG are integrated to form System Graph (SYTG). The System Graph is then traversed to generate test cases also optimized using Genetic Algorithm. The generated test cases are suitable to detect maximum number of faults like use case dependency, interaction, scenario, pre-post condition faults and error handling.

Key words: Activity diagram, genetic algorithm, online examination system, sequence diagram, system testing graph, use case diagram.

1. Introduction

Software Testing plays a very important part in life cycle of software development. It is a trade-off between budget, time and quality. With the increase in size and complexity of software products, time and effort required also increases. More than 50% of the software development cost is spent on Software testing.

Our approach for testing the object oriented system is generation of test cases from UML Models. Although it is a challenging task for analysis of UML (Unified Modeling Language) models [1] since the information is distributed across several model views yet they reduce the complexity of the problem with increase in size and complexity.

Use Case Diagrams [1] are basically for high level requirement analysis of a system. So during requirement phase of a system, functionalities are captured in use cases. Actors in the use case diagram are human users, some internal applications or may be some external applications. Fig. 1(a) shows the use case diagram for online examination system. On the other hand a sequence diagram explains how processes operate with one another and in which order. Fig. 2(a) shows the sequence diagram for Online Examination System. An Activity Diagram shows the operational work flow of any system. An activity ultimately results in some action which is shown in Fig. 3(a).

In this paper, we have proposed the test case generation from three types of UML diagrams as Use case diagram, Sequence diagram and Activity diagram. First of all use case diagram is converted in use case dia-
gram graph, sequence diagram is converted in sequence diagram graph and activity diagram is converted in activity diagram graph. Then two algorithms are proposed for system testing graph which is formed by integrating the three graphs. After that genetic algorithm is being applied to optimize the test cases generated from system testing graph. The resulting test suite aims to cover maximum number of faults by covering all the possibilities.

The paper is organized as follows. In Section 2, we discuss the existing work done on test case generation techniques using different UML diagrams. In Section 3, we discuss the use case diagram, sequence diagram and activity diagram for online examination system. Also, we have converted the diagrams into graphs and the three are integrated into the system testing Graph (SYTG) and finally the test cases are generated and being optimized using Genetic Algorithm. Section 4 contains the Case study for test case generated and optimized for On Line Examination System. Section 5 contains the Conclusion and Future work. Last Section 6 contains the used references.

2. Related Work

Test cases are generated using three different techniques illustrated in different works like specification based, code based and model based. In this section, we survey various research papers related to test case generation techniques using UML diagrams.

Abinash Tripathy and Anirban Mitra [3] presented an approach to generate test cases by using together UML Activity diagram and Sequence Diagram [3]. In this approach first the activity diagram is being converted into activity graph and the sequence diagram is being converted into sequence graph and then the two graphs are integrated to form system Graph. Then the System Graph is being traversed to form the test cases by using Depth First Search Method (DFS) on an example of ATM card validation.

M. Sharma, Rajiv mall [4] has proposed an algorithm, to generate test case from a combination of use case diagram and sequence diagram. First of all, they convert the use case diagram into use case graph and then sequence diagram into sequence graph. Integrating the two graphs a System Graph is being generated. How the two graphs are integrated is not clearly mentioned. Also the test cases generated are not optimized.

Namita Khurana and R.S.Chhillar presented an approach [5] to Generate and optimize the test cases generated by Sequence Diagram and State Chart Diagram. First of all Sequence Diagram is being converted into Sequence Graph and the State Chart Diagram is being converted into state chart graph and then the two are integrated to form the System Graph. Then Genetic Algorithm is being applied on the resulting System Graph to generate and optimize the test cases.

Ajay Kumar Jena, Santosh Kumar and Durga Prasad Mohapatra [6] presented an approach to generate test cases from Activity diagram. First of all an activity table is generated which is converted into Activity flow graph. After that Genetic Algorithm is applied to generate and optimize the test cases.

3. Proposed Approach

We present our work to generate optimized test cases from UML models. UML Model is standard by object management group. It is a modeling language in software engineering. It is being designed to specify, construct and document to software artifacts with support to special aspects of software such as dynamics and structural aspects [1].

3.1 Conversion of UCD to UCDG

Use case diagram also known as behavior diagrams used to describe a set of use cases (actions) that some system can perform in collaboration with one or more external users (actors).
Fig. 1 (a). Use case diagram for online examination system. Fig. 1 (b). UCDG for online examination system.

Fig. 2 (a). Sequence diagram for online examination system.
3.2 Conversion of SD to SDG

This section presents the conversion of Sequence Diagram into Sequence Diagram Graph.

Fig. 2. (b) SDG for online examination system.

3.3 Conversion of AD into ADG

This section describes the conversion of Activity Diagram into Activity Diagram Graph.

Fig. 3. (a) Activity diagram for online examination system.
3.4 Integration of ADG, SDG and UDG into SYTG

After conversion of diagrams into Graphs, our next step is to integrate the three graphs into a single graph which is called System Graph (SYTG).

**Definition of System Testing Graph (SYTG)**

The system testing Graph is defined as $SYTG=\{S, N, T, F\}$, where $S$ is initial node of the system graph. $N=\{\text{NUDG} \ U \ \text{NSG} \ U \ \text{NAG}\}$ is the set of all nodes of three graphs. $T=\{\text{TSG} \ U \ \text{TUDG} \ U \ \text{TAG}\}$ is set of transitions of the three graphs. $F$ is the final node of SYTG.

Next we present the algorithm to generate the system testing graph from UCDG, SDG, and ADG.

**Algorithm 1: ASDG (Activity-Sequence Diagram Graph)**
**Input:** Activity Diagram Graph (ADG) and Sequence Diagram Graph (SDG)

**Output:** Activity–Sequence Diagram Graph (ASDG)

1) \( P = \text{Identify all the paths of (ADG)}. \)
2) For each path \( p_i \in P \) do
3) \( A_j = A_i \) //Start with the \( A_i \) the starting node
4) For each activity \( A_j \) of path \( p_i \) do
5) If \( c_i \in A_j \) //current node has multiple conditions
   6) \( \beta = A_i - 1 \rightarrow SG \) //Edge from the previous node to the sequence Graph
   7) \( \gamma = SG \) (Last) \( \rightarrow A_i+1 \) //connect the last node of SG to the next node of AG. Edge from unsuccessful final node of SG to node \( A_i+1 \) where the value of \( V=0 \) else edge from successful final node of SG to node \( A_i+1 \) where the value of \( V=1 \)
8) End If
9) If \( c_i \notin A_i \)
10) \( \delta = A_i \rightarrow A_i+1 \) //connect the present node to the next node of the same Activity Graph.
11) End If
12) End For
13) End For
14) End

**Algorithm 2:** System Graph

**Input:** ASDG, UCDG

**Output:** System Graph (SYTG)

1) \( P = \text{Identify all the paths of (UCDG)} \)
2) For each path \( p_i \in P \) do
3) \( \alpha = u_i \rightarrow A_i \) (ASDG) //Connects the successful node of Use case diagram (UCDG) to \( A_i \) (ASDG)(Initial Node) otherwise the Unsuccessful final node of UCDG to unsuccessful node of the system Graph. Now start with \( u_i \) as the starting Node.
4) End For
5) End

### 3.5 Generation and Optimization of Test Cases

After creating SYTG Graph, our next step is to generate the test cases. After generating the test cases we need to optimize those test cases. For Optimization we need to apply an Evolutionary Algorithm, so we apply here Genetic Algorithm for Optimization of test cases.

**Algorithm 3:** Test Set Generation-Optimization

**Input:** - System Graph (SYTG)

**Output:** - Optimized test cases

1) Identify all the paths \( P = \{p_1, p_2, p_3, p_4, p_5, \ldots\} \) from start node to a final node in SYTG.
2) Assign weights to the individual nodes. The actual weight of the child node is weight of the parent node plus one. If a child has multiple parents then weight of that node is the sum of the weights of the parent's node. Also weight is allocated to paths from left to right.
3) Calculate the (x) cost of each path as the cost of that path is sum of the weights of that path.
4) Apply Genetic Algorithm to the graph (SYTG).
5) Calculate the fitness value
   For each path cost(x) has been calculated.
   Apply the fitness function as \( F(x) = x \times x \)
Now calculate the probability for individual as 
\[ P(i) = \frac{F(x)}{\sum F(x)} \]

6) Generate the random numbers to calculate the new population.

7) Apply Crossover operation on the pair of chromosomes. Mate first two individuals together by applying single point crossover from 3rd bit from right.

8) Apply Mutation function by mutating every fifth bit only in case when random number generated is less than 0.4.

9) Whole process is repeated till the fitness value minimizes or maximum number of generations is reached or all the paths have been covered.

10) Best test path is generated or we can say that the test cases are optimized.

11) End.

7. Case Study

This section shows the case study done on the example Online Examination System. The possible paths generated from the above graph in (Fig. 4) are:

<table>
<thead>
<tr>
<th>Path No.</th>
<th>Chromosome</th>
<th>(X)</th>
<th>(X \times Y)</th>
<th>Probability</th>
<th>Cumulative Probability</th>
<th>Associated bin</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>010110011</td>
<td>179</td>
<td>32041</td>
<td>0.115538</td>
<td>0.11553</td>
<td>0-0.2</td>
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<td>011100001</td>
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<td>50625</td>
<td>0.182550</td>
<td>0.29808</td>
<td>0.2-0.4</td>
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<td>101000101</td>
<td>325</td>
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<td>161</td>
<td>25921</td>
<td>0.093469</td>
<td>0.77243</td>
<td>0.7-0.8</td>
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<tr>
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<td>162</td>
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<td>0.9-1</td>
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Table 2. Selection of New Generation

<table>
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<tr>
<th>Random No.</th>
<th>Falls into bin</th>
<th>Selection</th>
<th>Crossover</th>
<th>Mutation</th>
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<td>0.73425</td>
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<td>0.75671</td>
<td>4</td>
<td>010100001</td>
<td>010100001</td>
<td>010100001</td>
</tr>
</tbody>
</table>

Table 3. Fitness of Next Population

<table>
<thead>
<tr>
<th>Path No.</th>
<th>Chromosome</th>
<th>(X)</th>
<th>(X \times Y)</th>
<th>Probability</th>
<th>Cumulative Probability</th>
<th>Associated bin</th>
</tr>
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<tbody>
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<td>105625</td>
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<td>010100001</td>
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<tr>
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<td>010100001</td>
<td>161</td>
<td>25921</td>
<td>0.082053</td>
<td>0.833840</td>
<td>0.8-0.9</td>
</tr>
<tr>
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<td>010100001</td>
<td>163</td>
<td>26569</td>
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<td>0.9-1</td>
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</tr>
</tbody>
</table>

Table 4. Selection of New Generation

<table>
<thead>
<tr>
<th>Random No.</th>
<th>Falls into bin</th>
<th>Selection</th>
<th>Crossover</th>
<th>Mutation</th>
</tr>
</thead>
<tbody>
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<td>01010001</td>
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<td>10100001</td>
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<td>0.61225</td>
<td>3</td>
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<td>01010001</td>
<td>010110001</td>
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</tbody>
</table>
Table 5. Fitness of Next Population

<table>
<thead>
<tr>
<th>Path No.</th>
<th>Chromosome</th>
<th>$X$</th>
<th>$X \times X$</th>
<th>Probability</th>
<th>Cumulative Probability</th>
<th>Associated bin</th>
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<td>010100001</td>
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<td>162</td>
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</table>

From these tables it may be observed that, the fitness value has been changed in two generations. The difference between the values of the chromosomes between two generations also started decreasing. We noticed that the new population again contains the test case 3. By further calculations; we observed that the test case 3 is the optimized test case.

8. Conclusion and Future Work

UML diagrams are converted into graphs and then are integrated to generate the test cases. Genetic algorithm is also applied to optimize the test cases. The proposed model covers maximum number of faults. So, time and cost for test case generation is also minimized. The approach is applied on Online Examination System. In our future aspects the proposed approach can be automated. Also the same approach can be applied on different UML models.

References


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