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Survey on Metamorphic Testing For Overcoming Oracle Problem in Software Testing

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***Abstract*— - Software Engineering is a branch of computer Science which is used for delivering an efficient and reliable product based on the customer's requirements. Software testing is one of the strategies for identifying the correctness of a program. The conflict arises when a bug is found even after completion of testing. This approach is known as Oracle Problem. A Metamorphic testing (MT) is one of the methods proposed by Chen in 1998 for making the Oracle problem less severe. This MT creates follow-up test cases and compares the output with the original output. If there is no error between the outputs then the test case is correct. If any fault exists between the outputs then a bug is identified and it shows that there is a fault in the given test case. This paper presents survey on metamorphic testing which is applied on various domains in computer science, related applications, and research challenges.**

***Keywords*— Software testing, Metamorphic Testing, Software Engineering, Oracle problem**

I. INTRODUCTION

Software Testing (ST) is the key factor for assuring the quality of the product. If the ST does not unveil the fault then the situation is referred as Oracle Problem. The oracle problem is one in which there is no specific existence of data for verifying the correctness of the output. The [2] oracle is often the human tester who checks the testing result manually, as manual prediction and verification of program output greatly decreases the efficiency and increases the cost of testing. One of the key challenges of ST is Oracle Problem. In order to overcome this problem a new approach Metamorphic Testing (MT) was proposed for making the problem less severe. In this paper we would like to focus on the survey, MRs and applications of MT.

A. Metamorphic Testing (MT)

MT has been developed to alleviate the oracle problem. MT employs some problem domain specific properties, namely Metamorphic Relations (MRs) for verifying the correctness of the output. MR is an expected relation among the inputs and outputs of multiple executions of objective program. MT generates Follow-up test cases based on MRs for the source input and compares the outputs of source and follow-up outputs. If the outputs are same then there is no error in the given test case, if any violation occurs it will result to failure of test case. A successful test case is one which produces correct output. If these multiple inputs and their outputs do not satisfy MRs [5] it implies an incorrect implementation. MT [9] has emerged as an effective and efficient approach to alleviating the oracle problem. MT [10] can provide a way to determine the correctness of testing outputs with MRs between a series of outputs that corresponds to a series of inputs.

Consider for instance, if the source input z produces output f(z), then using MT we create follow-up input as z' such that we can foretell f(z') based on f(z); if the outputs match as expected i.e., f(z) = f(z') then the test case is successful or else a failure is detected. In [1] a lot of research has been done on developing test case strategies, and also identified 10 MRs for generating metamorphic test cases for testing. In [2] order to achieve best results MT should be combined with other testing methods such as special-value testing.

For testing a range of bioinformatics programs [3] MT method was proposed, as MT verifies whether a pair of test outputs conform to a set of domain specific properties, called MRs, thus increases the number and variety of test cases that can be applied, and also applied MT to test two open-source bioinformatics programs, namely GNLab and SeqMap. In the absence of oracle [4] presented an approach called Automated Metamorphic System Testing which involves the automation of MT at system level by checking that the MRs of the entire application hold after its execution, another approach called Heuristic Metamorphic Testing which is used for reducing false positives and address some cases of non-determinism, and described the implementation framework called Amsterdam.

B. Metamorphic Relations (MRs)

One of the most challenging aspects in MT is finding out MRs. The effectiveness of MRs can play a crucial role in the testing process. One of the aspect [6] by providing a set of MRs between input Feature Models (FMs) and their set of products and a test data generator relying on them. Given an FM and its known set of products, a set of neighbour FMs together with their corresponding set of products are automatically generated and used for testing different analyses. The evaluation of this approach using mutation testing as well as real faults and tools reveals that most faults can be automatically detected within a few seconds.

Presented a case study [7] to analyse the relationship between the execution behaviour and the fault-detection effectiveness of MRs and shown that there is a certain degree of correlation between the code coverage achieved by a metamorphic relation and its fault-detection effectiveness.

Additive: ++/-- numerical values by constant
Multiplicative: Multiply numerical values by constant
Permutative: Permutate the order of elements in a set
Invertive: Take the inverse of each element in a set
Inclusive: Add a new element to a set
Exclusive: Remove an element from a set
Compositional: Create a set from some number of smaller sets

Classes of MRs

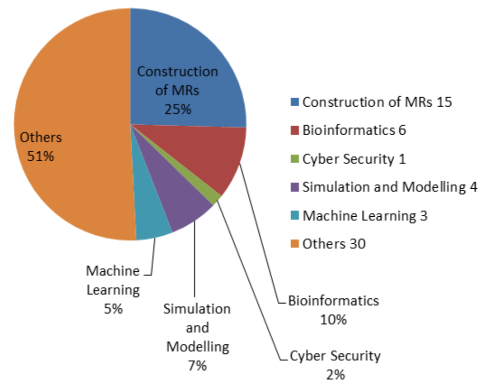
Suggested an simple method [8], namely the composition of MRs, for systematically constructing new MRs, and also observed that the new MRs are very likely to deliver a higher cost-effectiveness of MT than the original MRs.

II. RELATED WORK

This paper shows the survey on MT from various journal sites like IEEE, ResearchGate, ACM and Google Scholar. Results have shown that various concepts of MT which was applied in various fields of computer science.

A. Literature Survey

The keyword used for conducting survey on MT is ‘metamorphic testing’. The papers have been sorted out based on the highly focused application research areas.



Highly focused concepts on MT

B. Applications of MT

MT can be applied in different areas of computer science such as bioinformatics [3], Machine Learning [12], Simulation and Modelling [16, 17], Cybersecurity [18], and in other concepts. The main aim of MT is to generate best MRs for generating successful test cases. MT can be used in both Numerical and Non-Numerical applications.

Bioinformatics:

In bioinformatics MT can be applied where oracle cannot identify or verify the correctness of the problem. So MT is used in large data bases, phylogenetics and microarray analysis.

Machine Learning (ML):

ML plays a crucial role for predicting MRs [11, 12] in MT using graphing techniques so that, the time can be reduced for generating successful test cases.

Cybersecurity:

The [18] authors report how MT detected previously unknown bugs in real-world critical applications such as code obfuscators, giving evidence that software testing requires diverse perspectives to achieve greater cybersecurity.

C.Limitations of MT

Sometimes satisfaction of MR doesn’t guarantee the correctness of the output. It cannot prove the absence of faults.

III. CONCLUSION

This paper presents a survey and applications of MT which can be useful for getting effective output results. MT is based on generation of MRs which are helpful for generating successful test cases. MT is the best solution for Oracle Problem.

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