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A NOVEL TEST CASE PRIORITIZATION USING MENDEL OPERATOR BASED GENETIC ALGORITHM

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ABSTRACT

This paper aims at prioritization of test cases such that the testing effort reduces significantly while the code coverage remains almost the same. This is achieved by a novel Mendelian Operator based Genetic Algorithm by following two principles i.e. segregation and independent assortment of alleles. The doctrinal sense of simple GA is conceptually improved by inducing Mendel operator in the reproduction cycle. Besides the traditional genetic operators of selection, crossover and mutation, Mendel's principles are included, in the form of an operator in the genetic algorithm's evolution process. The proposed approach is different than the simple or conventional GA in terms of Mendel's dominance, recessiveness, genotype, phenotype and the Punnett square. The results obtained have comparable coverage's and are better than those of the conventional GA in terms of size of test suit. In this paper, a telemedicine project is taken for experimentation, developed for remote doctor allocation for facilitating the on line assistance to the patients.
Keywords: *Mendelian Operator; Genetic Algorithm; Regression Testing; Test case Prioritization.*

1. INTRODUCTION

Regression testing is a type of functional testing that is a part of black box testing technique. It consists of rerunning those tests that are wedged by code change. It is utilized to confirm improved software and check faults which are established into formerly tested code. When any major change has occurred in the system, then it focuses on finding defects and also uncovers new bugs including old bugs as well that have come back. In regression testing if bugs are found earlier, then debugging will also start and bugs may be fixed easily and rapidly. It verifies the correctness of the software previously developed and tested after performing any changes. It assures that the software is backward compatible i.e. there is consistency in the newer version of software with the older version and changes are intentional. It plays important role in overall test effort on each application release. The efficiency of testing decreases the risk of bugs in each release according to business needs which require faster regression testing with frequent releases under financial constraints. It includes rerunning the software and executing all the test cases whenever it was changed or linked with some other software. It doesn't seem practical to run all the time consuming test case again and again, specially, in shortage of resources during regression testing. Thus test case prioritization techniques are adopted for cost-effectiveness of regression testing.

Prioritization of test cases is used to arrange and perform the tests orderly to save time as well as cost. TCP for early fault detection minimizes testing costs, increases reliability and leads to identification of high risk defects earlier. Many researchers have introduced many methods for TCP (Test Case Prioritization) in regression testing. There are three techniques for test case prioritization in the literature (). In the first technique, test cases are dependent on the total coverage of the code. In second technique, test cases are dependent on their reporting of code elements which are not enclosed before, and in the last one, test cases depends on their expected capability to expose errors. This paper works with respect to code-coverage-based techniques used in testing.

TCP being the optimization problem having large search space of exponential size can be better solved using genetic algorithm. Typical genetic algorithm depends on the theory of Darwin that signifies the reproductive success and disparity survival. GAs are heavily accompanied with randomization and probabilities. Moreover, they fall in the local minima while dealing with large search spaces. Mendelian inheritance theory has been adapted here by making certain changes on the base theory. Mendel operator works on the dense form gene i.e. allele. Thus, the probability of evolving out new individuals has been increased. The dominant, hybrid, recessive and phenotype

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characteristics are applied to the chromosomes and Mendelian operator is simulated on test case prioritization. Mendelian Operator improves the performance of the Genetic algorithm during solution generation and reproduction. The developed technique is applied on a simulated telemedicine project developed for remote doctor allocation.

Rest of the paper has been organized as follows: Section II reviews the existing research work on TCP. Section III lays down the background details of Mendelian genetics. In Section IV Problem has been formulated. Section V explains the proposed work. Experimental Analysis has been done in section VI. Finally Section VII concludes the whole research work.

2. LITERATURE SURVEY

Rothermel et al. [1] has presented new techniques for test Case Prioritization. This paper deals with the effectiveness of these techniques for increasing detection of fault - measuring how rapidly errors are detecting during testing process. In this paper, authors provide professional persons with functional, cost-efficient approach for developing regression testing method through TCP.

Rothermel et al. [2] has discussed numerous approaches to prioritize test cases for regression testing using test execution information. This paper based upon three techniques, in the first techniques, test cases are depending on the total coverage of code. In second technique, test cases depending on their reporting of code elements which are not enclosed before, and in last one, test cases depending on their expected capability to expose errors. This paper shows the results with respect to code-coverage-based techniques, if code coverage techniques are used in testing. The efficiency of regression testing is required to minimize the risk of bugs in each release.

S. Elbaum et al. [3] has explained several questions raised by previous work to develop the rate of fault detection. The main purpose of this testing is to finding side effects in new version of code. Based upon several new controlled experiments and case studies fine-granularity techniques typically outperformed compare to other methods.

Carlson et al. [4] has presented a new test case prioritization technique to improve rate of fault detection using clustering approach. Even when testing activities are shortened, the number of faults also reduced that gaffed through testing process. In this paper, initially clustering approach is used to examine the associations in huge data in software repositories that will make simpler test case prioritization method by separating test cases into groups which have alike properties. To develop fault detection rate, data on real approaches are used. As a result of this paper, TCP method may increase the fault detection rate using clustering approach.

Arafeen et al. [5] has explained the clustering technique which includes the code analysis which may develop the efficiency of test case prioritization approach. In this paper, empirical study has been performed by utilizing java program with many versions and requisite documents. The software which is independently developed and its operation will provide better testing and improved security.

Kayes et al. [6] has proposed algorithm for prioritize test cases. In this paper, analysis of prioritize and non prioritize test cases has been done by utilizing the presented metric. In the presented metrics, the time for execution is uniform. Moreover, this work executed a novel regression test prioritization algorithm which gives priority to the test cases. It can be observed from the results that the prioritized test cases are very efficient in finding the dependency between the faults.

Thangavel Prem Jacob et al. [7] have explained a new approach which is clustering based TCP to reduce the testing effort. This proposed approach helps to improve the software quality. In this paper, prioritizing the test case has increased the effectiveness of the test case using novel approach of clustering.

Daniel Di Nardo et al. [8] in this paper, prioritization approach has been presented which is depending on the finer grained coverage criteria. This criterion is very efficient and better as compared to all other approaches. TCP is used to arrange and perform test cases orderly to save cost and time and is more efficient and widely used by the testers. The major purpose of the paper is to estimate and contrast the prioritization methods.

Hettiarachchi Charitha et al. [9] have presented a novel test case prioritization approach which is

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useful in the defect types to recognize dangerous necessities. In this work, prioritizes test cases is depending on the association among test cases and these necessities.

Kaur Arvinder et al. [11] have presented a new genetic algorithm to prioritize the test cases on the basis of code coverage information. To develop fault detection rate, data on real approaches are used. As a result of this paper, TCP method may increase the fault detection rate using clustering approach.

Muthusamy Thillaikarasi et al. [12] have presented a novel technique for prioritization of test cases in the regression testing process. The implementation of presented technique has been done on a banking application project. APFD metric is used to calculate the effectiveness. The proposed algorithm is a lot better in earlier fault detection than random techniques and also improve fault detection rate in testing stage.

An extensive survey of the literature suggests that there has been a growing interest towards Test Case Optimisation using Meta-heuristic approach. TCP is used to arrange and perform test cases orderly to save cost and time and is more efficient and widely used by the testers. However, there are a number of algorithms available which can consume a lot of time and effort and needs to be optimized.

3. MENDELIAN PRINCIPLE

Mendel's standards have constantly connected to the hereditarily repeating animal in a common habitat. Mendel's work is known to a great extent through his Experiments in Plant Hybridization distributed in 1865. It provided details regarding eight years of experimentation with the garden pea. Mendel settled on a few ponder decisions on inheritance which were critical to deduce the laws of legacy. Mendelian inheritance theory describes the rules by which the genes are inherited by the offspring. New offspring always carries the properties of both of its parents but only one parent's properties are dominant. But it doesn't mean that the other parent's properties are suppressed, they are just hidden. After inter-off springs' mating one of the new offspring may have the properties of second parent as well. By experimenting with pea plant breeding, Mendel developed following three laws of inheritance that described the transmission of genetic traits:
(1) Law of Dominance
(2) The segregation of alleles;
(3) The independent assortment of alleles.

The major differences between Mendel's and conventional approach lies in dominance, recessiveness, genotype, phenotype and the Punnett square [14] shown in Table 3. Results of the crossover for an individual who have *n*-gene pairs provide 4*n* possibilities. Here, *n* defines the number of gene pairs. Each offspring defined in this Punnett square such as RRyy, RrYy is its genotype. However, every offspring has a phenotype (visual) that is reciprocal to its genotype (genetic form). To clarify, suppose that in the offspring with RrYy genotype; R defines the roundness gene, r the wrinkled gene, Y the green color gene, and y the yellow color gene. For this genotype, the phenotype is green and rounded. The reason for this is the green color gene is dominant to the yellow color gene while the roundness gene is dominant to the wrinkled gene.

		P	
		B	**b**
M	**B**	BB	Bb
	b	Bb	bb

where **M** = Maternal **P** = Paternal

4. PROBLEM FORMULATION

Test case prioritization using Mendel genetics has been applied on a simulated telemedicine project developed for remote doctor allocation. **Telemedicine software** is the platform used by providers to connect with patients, and share video and images. It is convenient, accessible for patients with least cost, accessible to consultants from specialists with increased patient engagement and better patient care. It is integrated with a provider's electronic health record and scheduling systems. It has a complex integrated service used in hospitals, homes, private physician offices, and other healthcare facilities. Originally, health

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professionals developed this technology to reach remote patients living in the rural areas. But with time, medical staff and the U.S. government transformed it to reach urban populations with healthcare shortages, and to respond to medical emergencies by sharing medical consults and patient health records without delay. Some most popular telemedicine solutions specialties are *Teleradiology*, Telepsychiatry *Teledermatology Teleopthamology* etc. The information needed for disease diagnosis includes identifying information, source of the history, chief complaint, history of present illness, associated signs & symptoms, past medical history, family history, personal and social history, medication review, allergies, detailed review of symptoms, provider-directed patient self-examination (including mobile medical devices if needed). Fig.1 Represents a simulation of the telemedicine software.

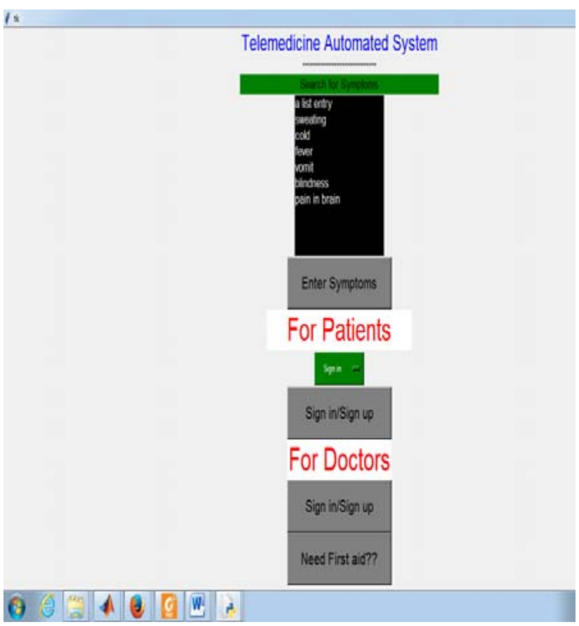

Figure 1. Simulation Of The Telemedicine Software

Through this software we help the patient in disease diagnosis and reducing the consultation time by providing the appointment with the specialist. The procedural steps for appointment module of the multi-agent system for diagnosis are as follows:-

1. The patient using the patient agent files the request for appointment, which invokes the Appointment agent.
2. The appointment agent interface with the patient agent and main agent, with its main function being to give confirmed appointment information to the appointment requesters.
3. The main agent interface with appointment agent and doctor agent. The purpose of core in main agent is to cross examine the request of appointment against doctor schedule to provide accessible appointment slots.
5. The purpose of core in the doctor agent is to obtain doctor‘s schedule distantly and interface with the doctor‘s appointment database and the schedule agent.
6. The schedule agent interfaces with the main agent and gives proof of doctor‘s schedule and confirmed appointments.

The following database tables have been used in the proposed scheme.

1. Doctors Data
2. Patient’s data
3. Doctor-Expertise
4. Disease-Expertise
5. Disease-Test
6. Disease-Symptoms
7. Doctor-Authentication
8. Doctor-Patient
9. Patient-Test
10. Doctor Schedule
11. Patient Prescription

There are a number of test cases available which can consume a lot of time and effort. A selective number of test cases needs to be selected which would be otherwise used for the same purpose. The priorities of the test cases need to be decided on the basis of several parameters. The parameters for the test case prioritization need to be chosen and a model needs to be developed which would set priority among the test cases. First of all a data set needs to be generated which would be utilized for our proposed algorithm testing. The main reason of regression testing is to find side effects in new version of code or to establish whether modify in single element of the software involve another element of the software. In this paper, the aim is to decrease this cost by prioritizing test cases.

5. PROPOSED METHODOLOGY

The paper proposes a novel Mendelian operator based GA for test case prioritization. The proposed work is based on Mendel’s principle based on pea experiments which may be summarized in ideology as: (1) Law of Dominance; (2) The

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segregation of alleles; and (3) The independent assortment of alleles.

The principle of Mendel is simpler to coordinate with the Genetic Algorithm. The main steps of the proposed algorithm are shown in Fig 2 and summarized below:

1. determine the objective function (Statement Coverage for test case prioritization)
2. generate an initial population (inipop) (binary),
3. calculate fitness,
4. roulette wheel selection of gametes along with elitism,
5. evaluate local dominance or recessiveness of attributes
6. determine the resulted genotypes,
7. segregation of the alleles,
8. make the Punnett square according to Mendel's Principle
9. crossover and mutation
10. discover the new genotypes and phenotypes,
11. repeat the steps 3 to 10 until the terminating condition

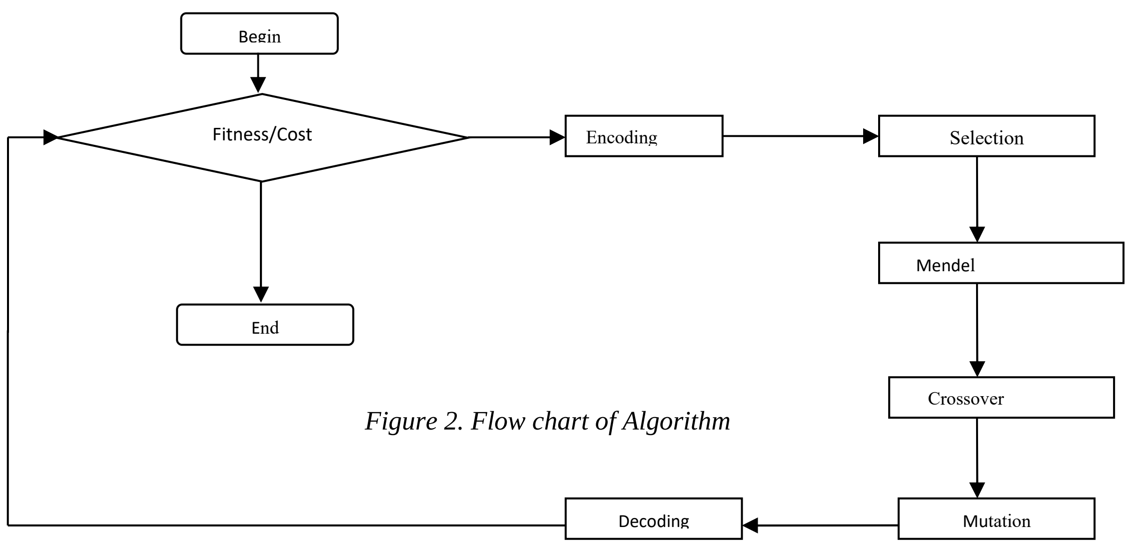


Figure 2. Flow chart of Algorithm

Implementation Details:

Chromosome Representation:

This work utilizes the binary encoding approach for representing the test cases. The length of chromosome is determined by the total number of test cases. Generally, all genes may be encoded by utilizing the 'zero' and 'one'. The 'one' signifies that the test case is selected and zero signifies that it should be dropped.

Fitness Computation:

Since it is very rare for a tester to know the location of all faults in *P* prior to testing, the prioritization technique must estimate how likely a test is to find defects, which factors into the function St. Fitness of chromosome is computed based on the code coverage of test suit. Code coverage for each test case is calculated as the number of statements covered by the particular test case. Mathematically, it is calculated as the follow:

$$StatementCoverage(\%) = \frac{No.of\ statements\ covered}{Total\ no.of\ statements} \times 100$$

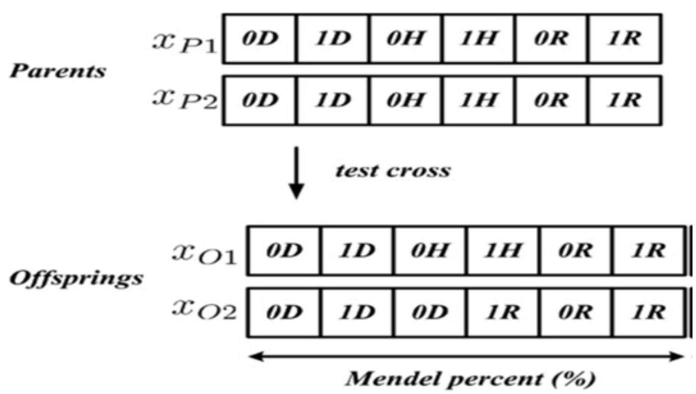
Operators Used:

Roulette Wheel Selection is done along with elitism. If new population has been produced by crossover and mutation, then there will be chances to lose the best chromosomes. Elitism is the general method that copies the best chromosome of each iteration to the new population. This elitism process may enhance the performance of genetic algorithm by preserving the better fit individual.

The operator of Mendel generates progeny chromosomes from the host chromosomes by the laws given by Mendel. Two parental chromosomes x_{P1} and x_{P2} can generate one child chromosome x_{O1} as stated in Table 1. $attr_{P1}$ and $attr_{P2}$ are the attributes of genes of the parental chromosomes x_{P1} and x_{P2} ; $attr_{O}$ is the attribute of genes of children chromosome x_{O1} or x_{O2}. To acquire the next child chromosome x_{0i} , the productive method requires to be repeated.

.

attrO		*attrP₁* D	*attrP₁* H	*attrP₁* R
	D	100%*D*	50% D 50% H	100%*H*
attrP₂	*H*	50% D 50% H	25% D 50% H 25% R	50% R 50% H
	R	100%*H*	50% R 50% H	100%*R*



There are three category of attributes of a gene which has been considered here. They are as follows:

- D (Dominant, the pure and dominant gene)
- R (Recessive, the pure and recessive gene), and
- H (Hybrid, the hybrid gene).

Mendel operator is introduced following the selection operator, which can thus take advantage of the Mendel operator's local search ability [Exchange rates determination based on genetic algorithms using Mendel's principles: Investigation and...]. The reason for this is that if we insert Mendel operator in the genetic algorithm after the mutation operator then depending on probability of transmutation, it may produce an unstable population that will misguide the output for entire method biologically and mathematically. The basic method of mutation is able to generate new recombination of improved solutions at a given rate,

but the possibility of damage to the dominated population, loss of good solutions and convergence trend also occurs. The Mendel operator will amplify such an unstable population with its local search ability from a micro evolutionary point of view. The common process of transformation is capable to produce the enhanced results at a given cost. Single point

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crossover and bit flip mutation are applied along with Mendel operator to enhance the diversity in the population. Additionally, the presented encoding method is not general for various issues and so often improvement should be made after crossover and mutation

4. EXPERIMENTS AND RESULTS

We have performed experimentation in MATLAB framework. Empirical results are obtained using a specially devised simulation toolkit of Mendel-GA for MATLAB, known henceforth here as SGALAB. A simulated telemedicine software project has been developed for generating the test cases and its detailed description is given in section III. The original version of the program contains statements and test cases. The test cases and the coverage of the statements by the test cases are represented as a binary matrix given in Table 3.

Table 3. Binary Matrix

	C 1	C 2	C 3	C 4	**C 5**	C 6	C 7	C 8	C 9	C 10	C 11	C 12	C 13	C 14	C 15	C 16	C 17	C 18	C 19	C 20	C 21
T 1	1	1	0	0	**1**	0	1	0	0	1	0	1	0	0	1	0	1	0	1	0	0
T 2	0	0	0	1	**0**	1	0	1	0	1	0	1	1	1	0	1	0	1	0	1	0
T 3	1	0	1	0	**1**	0	0	1	0	0	0	0	0	0	0	0	1	0	0	1	0
T 4	1	1	0	1	**0**	1	0	0	1	0	1	0	1	0	0	1	0	1	0	0	1
T 5	1	0	0	0	**1**	0	1	0	1	0	0	1	0	0	1	0	1	0	1	0	1
T 6	0	1	1	0	**1**	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	1
T 7	1	0	0	1	**0**	1	0	0	1	1	0	1	1	0	0	1	0	1	0	0	1
T 8	1	1	0	1	**0**	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0
T 9	0	1	0	1	**0**	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	1
T 10	1	1	1	0	**1**	1	0	0	1	0	1	0	1	0	0	0	1	1	0	0	1
T 11	1	0	0	0	**0**	1	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0
T 12	0	0	0	0	**0**	1	1	1	0	0	0	0	1	0	1	0	0	1	1	1	0
T 13	0	1	1	1	**0**	0	0	0	1	1	1	0	1	0	0	1	0	0	0	0	1
T 14	0	0	0	1	**1**	0	1	0	0	1	0	0	1	0	0	1	1	0	1	0	0
T 15	0	0	0	0	**1**	0	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0

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T 16	1	1	0	1	**0**	1	0	0	1	0	1	0	1	0	0	1	0	1	0	0	1
T 17	1	0	0	0	**1**	0	1	0	1	0	0	1	0	0	1	0	1	0	1	0	1
T 18	0	1	1	0	**1**	0	0	1	1	0	0	0	1	0	0	0	1	0	0	1	1
T 19	1	0	0	1	**0**	1	0	0	1	1	0	1	1	0	0	1	0	1	0	0	1
T 20	1	1	0	1	**0**	0	0	0	0	1	1	0	1	0	0	1	0	0	0	0	0
T 21	0	1	0	1	**0**	1	1	1	1	1	0	0	0	0	1	1	0	1	1	1	1
T 22	1	1	1	0	**1**	1	0	0	1	0	1	0	1	0	0	0	1	1	0	0	1
T 23	1	0	0	0	**0**	1	0	1	0	0	0	0	0	0	1	0	0	1	0	1	0
T 24	0	0	0	0	**0**	1	1	1	0	0	0	0	1	0	1	0	0	1	1	1	0
T 25	0	1	1	1	**0**	0	0	0	1	1	1	0	1	0	0	1	0	0	0	0	1
T 26	0	0	0	1	**1**	0	1	0	0	1	0	0	1	0	0	1	1	0	1	0	0
T 27	1	0	1	0	**1**	0	0	1	0	1	0	1	0	1	0	0	1	0	0	0	0

All the results are generated using the following parameters of the genetic algorithms as listed in Table 4. Parameters have been tuned after some experimentation.

Table 4. Empirical Parameters for Mendel GA	
Max generations	100
Crossover probability	0.9
Mutation probability	0.001
Population	50
Selection operator	Roulette Wheel
Crossover operator	Single point
Mutation operator	Bit Flip
Encoding method	Binary
Mendel percentage	1 (full chromosome length)

Evaluation metrics

In order to evaluate the effectiveness of the given test case, prior knowledge of the statement coverage under test is assumed. A regression test suite prioritization can be empirically evaluated based on the weighted average of the percentage of statement coverage over the life of the test suite and size of the test suit. The impact of test suite minimization was measured by calculating the reduction in fault detection effectiveness as follows:

$$1-\frac{\text{number of faults detected by the reduced test suite}}{\text{number of faults detected by the original test suite}}\times 100$$

Comparison & Results

The comparative results between proposed technique and simple GA using different criteria are shown below based on the attributes of comparison i.e. Size & Coverage. The Proposed Technique optimizes test cases based on coverage and thereby, reducing the time required in testing which is quite large in simple GA. The Fig. 7 a shows the comparison between proposed technique and conventional GA technique based on size of representative set generated. The comparison of proposed Mendel GA based technique and simple GA is shown in figure 2. Fig 6.describes the fitness evaluation process of Mendel GA and Simple GA respectively. Over the full evolution time the fitness values of Mendel GA grow up quickly to a steady status while GA performs gradually. Also Simple GA pre converges to local optimum whereas Mendel GA reaches the near optimal solution.

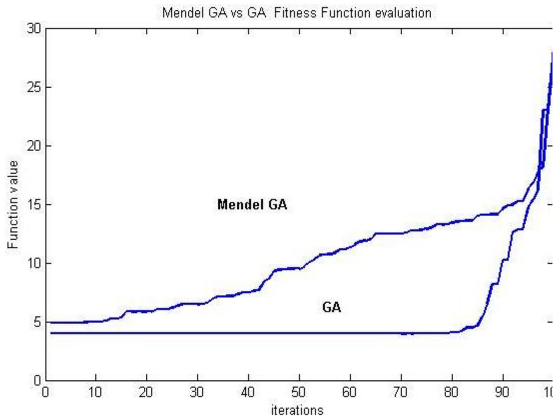

Fig3: Fitness evaluation during the evolutionary cycle

	Coverage	No of Test Case
Original Test Suit	100	27
Mendel GA	98.3	11
SGA	91.1	15

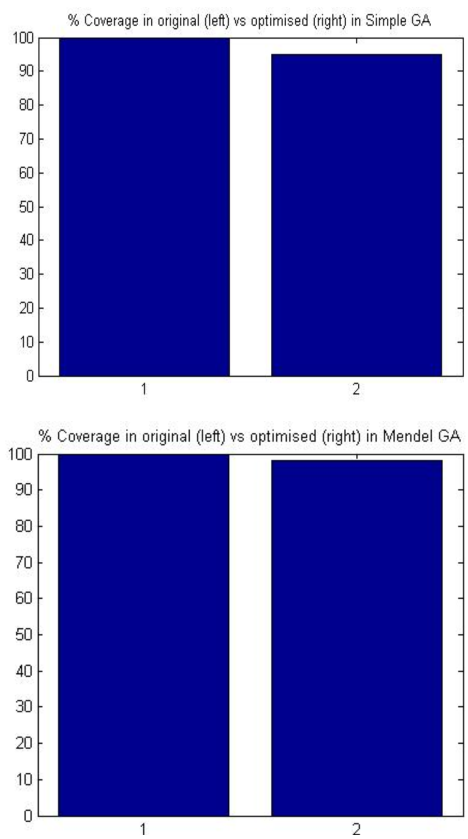

Fig. 4: Coverage of original and optimized test

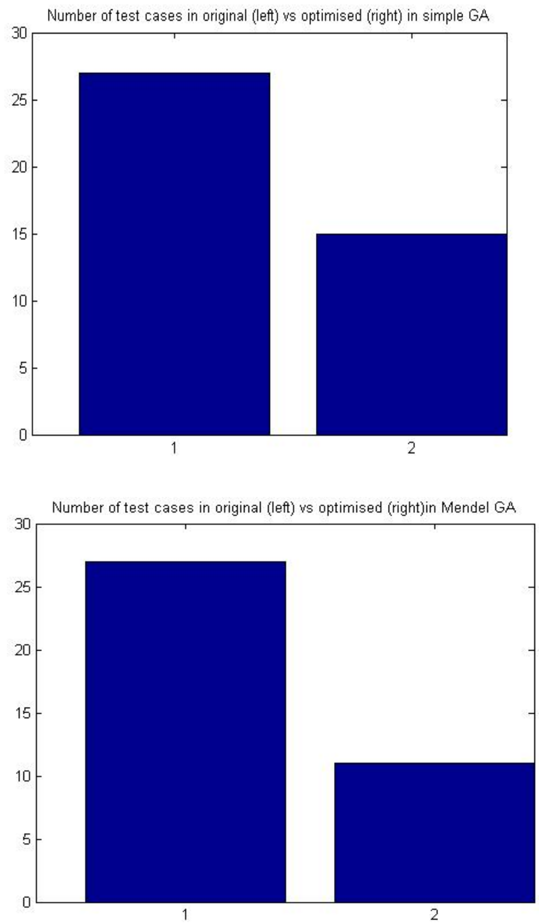

Fig. 5: Number of reduced test cases.

Table 5 and 6 summarize the results of the proposed approach and simple genetic algorithm. As observed from the figure in simple GA the number of test cases is reduced from 27 to 15 with significant loss in the coverage. But the reduction in number of test cases in Mendel GA (from 27 to 11) is noteworthy with only a slight loss in the coverage. This establishes the efficacy of our algorithm which performs well in order to improve the optimization of test cases. The convergence of our proposed algorithm is shown in figure 4. It shows that the Mendel GA shows the better results initially than simple GA. Mendel GA shows better convergence than simple GA.

6. CONCLUSION

Regression testing is an expensive, but imperative part of the software development process. It verifies the correctness of the software previously

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developed and tested after performing any changes. Test case prioritization techniques are adopted for cost-effectiveness of regression testing. They order test cases in such a way that those cases that are expected to outperform others in detecting software faults are run earlier in the testing phase. In this paper, Mendel GA is applied for test case prioritization. The new approach shows the better results in terms of coverage and size of test suit. This is desired as the entire test suit raises the testing effort. The testing effort is reduced with minimum effect on performance using Mendelian genetics for test case prioritization. Compared with the results of standard GA, Mendel-GA outperforms. There are numerous applications of the test case prioritization in software industry. A hybrid of various other TCP techniques can be designed and tested for efficacy. Other clustering algorithms can be applied and tested for efficacy. Test case parameters can be further optimized for evaluation of results.

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