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Application of Genetic Algorithm and Particle Swarm Optimization in Software Testing

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Abstract: *This paper will describe a method for optimizing software testing by finding the most error prone paths in the program. This can be achieved by a meta-heuristic technique, that is by using genetic algorithm and particle swarm optimization. As exhaustive software testing is not possible where software is tested with all the possible inputs , those parts of software are also tested which are not error prone..Goal is to generate test cases using both the algorithms and then comparative study is done between Particle swarm optimization and genetic algorithm.*

Keywords: *Software Testing, Meta-heuristics , Genetic Algorithms, Particle Swarm Optimization, Software test cases.*

I. Introduction

Testing is the one of the crucial phase that is performed during software development. It is a primary technique which is used to gain consumer confidence in the software. It is conducted by executing the program developed with test inputs and comparing the observed output with the expected one .[1]Software testing is done to identify any errors or missing requirements in contrary to the actual requirements. It is done to validate the quality of the software testing using minimal cost and efforts and to generate high quality test cases. It uncovers the error in the software, including errors in requirement analysis, design document, coding, system resources and system environments, hardware problems and their interfaces to the software .[2] It is very time consuming and laborious activity. It is costly and consumes about 50% of the cost of the software development.[3]. Main goal of testing to find as many faults as possible in a software. As mentioned earlier it a time consuming activity ,as it is impossible to test the software unit with all the combinations of inputs so there is a need to design minimum no. of test cases that will discover as many faults as possible . However, software testing automation is not a straight forward process. For years a lot of research have been done in this area to generate test cases ,researchers developed methods like random test case generator, symbolic test data generators and dynamic test data generators**.** This paper applied the EST (Evolutionary software testing) techniquie.EST is the automatic software test case generation technique which in turn will reduce the cost of development of software. EST interprets the task of test case generation as an optimization problem and tries to solve it using a search technique .EST uses an meta-heuristic search technique that is genetic algorithm to convert the task of test case generation into an optimal problem. Evolutionary Testing search for optimal test parameter combinations that satisfy a test criterion. Test criterion is represented fitness function that measures how well optimization parameters that are automatically generated are satisfying the given test criterion .There are variety of techniques for test case generation but in this paper we will focus on genetic algorithm and particle swarm optimization technique.

This paper will present the result of our research in into the application of GA and PSO search approach, to find optimal solution in the software construct.

II. Genetic Algorithm

Genetic Algorithm (GA) are heuristic search algorithm.[4]They are based on the evolutionary idea of natural selection and genetics. Genetic algorithm is inspired by the Dalton's theory about evolution that is survival of the fittest. Genetic algorithm is a part of evolutionary computing which is a growing field of Artificial Intelligence. GA exploits the historical information to direct the search in region of better performance with in the search space. [5] In this way competition among individuals for better resources results in fittest individual dominating over the weaker ones. Genetic Algorithms are more robust hence they are better than conventional AI(Artificial Intelligence). GA does not break easily even if there is a slightly change in the input and it also does not get affected by noise. GA offer benefit over typical search of optimization problem in searching large state space, multimodal search space and n dimensional surface.

Distinct element in GA is individual and population. Individual represents single solution while population represents set of Solutions which is currently involved in this search process. Each individual is represented as chromosome. That is an Initial pool of chromosomes. Population size can be few dozens to thousands. To do optimization fitness function is required to select the best solution from the population and

discard those not so good solutions. GA consists of following operators that is Selection Operator chromosomes are selected for cross-over based on the value of the fitness function Cross- Over Operator combine two chromosomes to produce new chromosomes. Mutation Operator in this value is randomly changed to create new genes in the individual.

Pseudo code of GA

```
Initialize (population)
Evaluate Fitness  of the population
While (termination condition is met) do
{
Selection(Population)
Cross-over(Population)
Mutation(population)
Evaluate (Population)
 }
```

GA [6] starts with randomly generated population of individuals or chromosomes .Fitness of individual is calculated based on some fitness function. After the fitness is calculated selection of individuals is done based on the Roulette –Wheel Selection method i.e an individual having higher fitness value has the more chance of getting selected .Then Cross over operator is applied to produce new offspring in the population that may have better characteristics than their parents. Mutation is done to introduce new individual in the population .its is done by flipping the bit of the chromosomes.

III. Particle Swarm Optimization

Particle Swarm Optimization (PSO) [7] is a relatively recent heuristic search method. It is similar to GA in the sense that both are evolutionary algorithms .It is one of the meta-heuristics approach that optimizes a problem and try to improve candidate solution iteratively. PSO is generally used to solve those problems whose solution can be represented as a point in an n-dimensional space. In PSO potential solution is called particle. A number of particles are randomly set into motion through this space. Each particle posses its current position, current velocity ,and its pbest position .Pbest is the personal best position explored so far. It also incorporates Gbest that global best position achieved by all its individuals. It is a simple approach and it is effective across a variety of problem domains.

Pseudo code for PSO

The PSO algorithm consists of just few steps, which are repeated until some stopping condition is met. The steps are as follow:

- Initialize the population of individuals with current position and, velocity.
- Evaluate the fitness of the individual particle (Pbest).
- Keep track of the individual highest fitness (Gbest).
- Modify velocity based on Pbest and Gbest location.
- Update the particle position.

PSO starts with initialization of particle velocity and current position. Here particle is in 2-D space . Fitness value of the particle is calculated according to function. If the fitness of the particle is better than its previous value update particle x and y position that is its personal best position. Also if the value is better than gbest position update global best position of the particle. Apply equations to update the x and y velocity vector of the particles. Process repeats until termination criteria is met or the optimal solution is found.

IV. Implementation

Genetic Algorithm is implemented in c language. result is as follows. GA approach to problem to maximize the function (1) $F(x)=x^3-x^2$. X represent 5 digit unsigned binary integer .i.e x can take value [0,31]. Four randomly generated solution to problem are 14,18,24,30. Fitness of the individual is calculated by the function F(x).String no. 4 has the maximum value having more chances of getting selected. here N is 4 . One point Crossover is performed in a couple. New offspring is generated. Mutation is performed. We get new generation Again the process is repeated till the maximum possible value of the solution is obtained .Luckily in this case in the second iteration we will get desired value. Whereas In most of the cases GA traps in local optima. But here We have got the global optimum solution.

Table 1

String N o.	Initial Population	Value of x	$F(x)=X^3-x^2$	pi	Expected Count(N*pi)
1	01111	15	3150	0.072	0.289
2	10010	18	5508	0.126	0.505
3	10101	21	8820	0.202	0.809
4	11110	30	26100	0.598	2.395
Sum			43578	1	4
Average			10894	0.25	1
Max			26100	0.598	2.395

Table 2

Before Crossover	After Crossover	Mutation Of element 3 at position 2	New Generation is as follows (Value of x)
01111	01110	01110	14
10010	10011	10011	19
10101	10100	10110	22
11110	11111	11111	31

Particle Swarm Optimization

For Mathematical function (2) $val=(x-15)^4-(y-20)^2+9$

Particle is initialized with current position and velocity. Program will search for optimal solution through the movement of particle. Program will keep track of personal best and global best position of the particle and update its position and velocity .Optimal solution here is to minimize the mathematical function .PSO is implemented in C language. How the particle moves in the search space to find global best solution is shown in the Fig 1 & Fig 2. Finally the optimum solution is found when x=15 and y=20.For more complex problems where it is not possible to easily solve the problem mathematically ,these algorithms can be used.

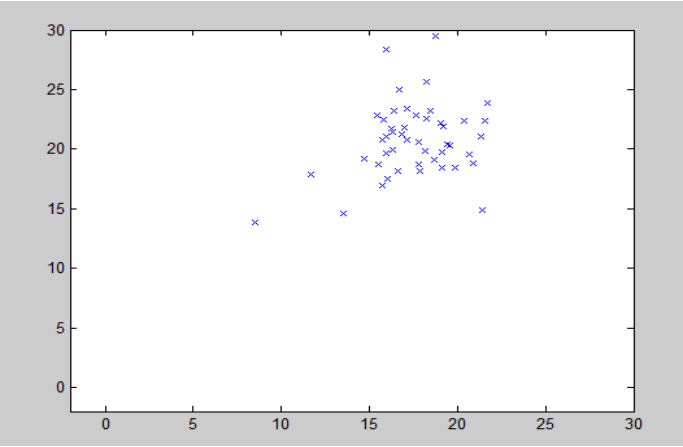

Figure 1 Movement of particles to find optimum solution

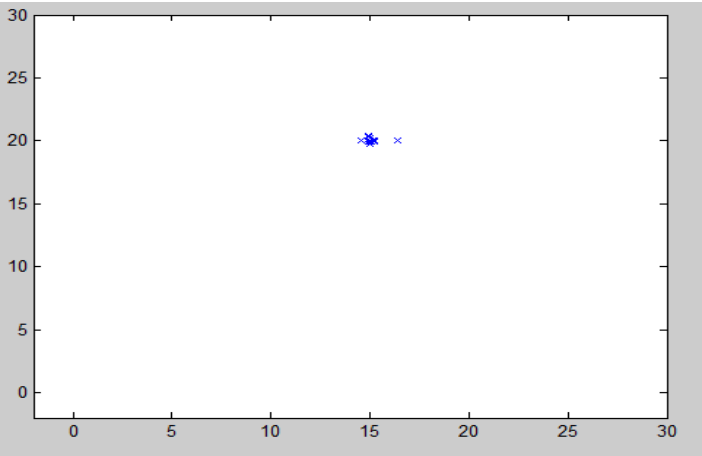

Figure 2 Global best solution

V. Comparison Of GA And PSO

Genetic Algorithm and Particle Swarm Optimization technique are both evolutionary search algorithm and have been applied in variety of problem domains.[8 &9] GA can be applied to number of problems like N-queens problem, Travel salesman problem to find optimal solution. GA suffers from the drawback that it traps in local optima, that is it does not know how to sacrifice short term fitness for long term fitness. It does not keep in account the global best position of the individual. This drawback is overcome by Particle Swarm optimization technique which tracks the particle personal best position as well as global best position ,hence it moves toward global optima without getting trapped in local optima. GA has been popular because of its parallel nature of search ,and essentially because it can solve non linear ,multi model problems. It can handle both Continuous and discrete variables where as PSO can easily handle Continuous variables. In comparison to GA ,PSO has few parameters and it is easy to implement .Calculation of PSO Algorithm is very simple though it is difficult to implement with problem of non coordinate system .It is problem dependent, Problem having continuous variables PSO is superior to GA .Many researchers have compared both the technologies .PSO outperforms GA, and is more effective in general however superiority of PSO is problem dependent.

VI. Conclusion

PSO is relatively recent heuristic approach, It is similar to Genetic algorithm in a way that they both are population based evolutionary algorithms. Paper is reported on the application of Genetic Algorithm and Particle Swarm Optimization. Paper described the basic concepts of GA and PSO ,how the test cases are generated using genetic algorithm and how they are useful in finding the optimal solution to the problem. Comparative study is done between both the algorithm where GA can be useful and how PSO overcome the drawback of GA. We also intend to extend the approach described here so that it is useful to solve many problems like knapsack problem.

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