

# **PROGRAM STRUCTURES AND ALGORITHM**

## **INFO 6205**

### **KNAPSACK PROBLEM USING GENETIC ALGORITHM**



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## **PROBLEM STATEMENT:**

The knapsack problem or rucksack problem is a problem in combinatorial optimization: Given a set of items, each with a weight and a value, determine the number of each item to include in a collection so that the total weight is less than or equal to a given limit and the total value is as large as possible. It derives its name from the problem faced by someone who is constrained by a fixed-size knapsack and must fill it with the most valuable items.[1]

We have optimized Knapsack Problem using Genetic Algorithm.

## **APPROACH:**

A genetic algorithm (GA) uses natural selection process that is similar to biological evolution to optimize constrained and unconstrained problems. Population of each solution is modified and children for the next generation by their parents. Optimal solution achieved over successive generations.

### **Initial Setup:**

- The number of items is set to 10. The value of weight and volume are assigned to each item.
- The capacity of the sack is set to 50 and volume is set to 2500.
- The crossover probability and mutation probability is set to 0.5 and 0.03 respectively.
- The following steps are repeated for 100 generation until the stopping criteria is met.

### ***Step 1: Generating the population***

The chromosomes are generated based on the based on the population size. Each bit in the chromosome is assigned 0 or 1 until the population length is reached. Here we have chosen population size as 10.

### ***Step 2: Breeding***

Two chromosomes are randomly chosen and according to the probability crossover and mutation functions are performed.

**The population breeding is done *parallelly* using Java 8 Parallel Stream.**

### ***Step 3: Crossover***

If the probability is less than 0.5 then crossover functionality is performed according to the crossover point.

Example:

Chromosome 1: 01 | 10 | 01 | 10 | 0 | 1  
                  ↓       ↓       ↓  
Crossover:     01 | 10 | 01 | 10 | 0 | 0  
                  ↑       ↑       ↑  
Chromosome 2: 10 | 10 | 10 | 10 | 1 | 0

#### **Step 4: Mutation**

If the probability is less than 0.03 then the mutation functionality is performed according to the mutation point. If there are two consecutive 1 bits then 0 bit is added in between them or If there are two consecutive 0 bits then 1 bit is added in between them

Example: if mutation point = 3, Based on the chromosome values the one of the following mutation occurs.

Case 1: Chromosome: 01 | 00 | 01 01 01  
                          ↓  
Mutation:     01 | 0 1 0 | 01 01 01

Case 2: Chromosome: 01 | 00 | 01 01 01  
                          ↓  
Mutation:     01 | 1 0 0 | 01 01 01

Case 3: Chromosome: 01 | 11 | 01 01 01  
                          ↓  
Mutation:     01 | 1 0 1 | 01 01 01

Case 4: Chromosome: 01 | 11 | 01 01 01  
                          ↓  
Mutation:     01 | 0 1 1 | 01 01 01

#### **Step 4: Checking Fitness**

Fitness is checked for each new population. For Fitness we are taking two traits, volume and weight. If the bit in the chromosome is 1 then the weight and volume of the item in that particular index is added to the total capacity and total volume respectively. If the total capacity and volume is less than or equal to the sack capacity and sack volume then that fitness value is returned. The population with the highest fitness rate is selected as the best in that generation.

*The fitness value of population is stored in a Map and sorted by the fitness value.*

### ***Step 5: Stopping criteria***

If the mean fitness value of 4 consecutive generations is the same then the algorithm is stopped. If generations 11, 12, and 13 have the same average fitness value 25.6, the algorithm will stop.

### **OUTPUT:**

The number of items: 10  
the weight of item 1: 13  
the volume of item 1: 767.7449040428301  
the weight of item 2: 9  
the volume of item 2: 353.2233699130104  
the weight of item 3: 9  
the volume of item 3: 521.8429977167773  
the weight of item 4: 1  
the volume of item 4: 3.6332248513128773  
the weight of item 5: 22  
the volume of item 5: 443.0928335217951  
the weight of item 6: 24  
the volume of item 6: 1160.0583941921864  
the weight of item 7: 6  
the volume of item 7: 159.16023819837162  
the weight of item 8: 14  
the volume of item 8: 1370.263553052531  
the weight of item 9: 12  
the volume of item 9: 747.8418654759108  
the weight of item 10: 16  
the volume of item 10: 1409.9138059170418  
The knapsack capacity: 50  
The knapsack volume: 3000.0  
The population size: 10  
The maximum number of generations: 100  
The crossover probability: 0.5  
The mutation probability: 0.03

Generation 1:

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Population:

0 -- 0101000111  
1 -- 1011101110  
2 -- 1100111111  
3 -- 1010000110

4 -- 0100001110  
5 -- 1110001100  
6 -- 1111111000  
7 -- 1000100001  
8 -- 1000010000  
9 -- 1011111000

Fitness Score:

-----

0 - 0.0  
1 - 0.0  
2 - 0.0  
3 - 0.0  
5 - 0.0  
6 - 0.0  
7 - 0.0  
9 - 0.0  
8 - 7.0  
4 - 26.0

Best solution:0100001110

Average fitness: 3.3

Best Fitness Score: 26.0

Generation 2:

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Population:

0 - 0100001110  
1 - 0100001110  
2 - 0100001110  
3 - 0100001110  
4 - 0100001110  
5 - 0100001110  
6 - 0100001110  
7 - 0100001110  
8 - 0100001110  
9 - 0100001110

Fitness Score:

-----

0 - 26.0  
1 - 26.0  
2 - 26.0  
3 - 26.0  
4 - 26.0  
5 - 26.0  
6 - 26.0  
7 - 26.0  
8 - 26.0  
9 - 26.0

Best solution 2: 0100001110

Average fitness: 26.0

Best Fitness: 2: 26.0

Number of times Crossover Occured: 1

Number of times Cloning Occured: 4

Mutation did not occur

Generation 3:

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Population:

0 - 0100001110  
1 - 0100001110  
2 - 0100001110  
3 - 0100001110  
4 - 0100001110  
5 - 0100001110  
6 - 0100001110  
7 - 0100001110  
8 - 0100001110  
9 - 0100001110

Fitness Score:

-----

0 - 26.0  
1 - 26.0  
2 - 26.0

3 - 26.0  
4 - 26.0  
5 - 26.0  
6 - 26.0  
7 - 26.0  
8 - 26.0  
9 - 26.0

Best solution 3: 0100001110

Average fitness: 26.0

Best Fitness: 3: 26.0

Number of times Crossover Occured: 2

Number of times Cloning Occured: 3

Mutation did not occur

Generation 4:

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Population:

0 - 0100001110  
1 - 0100001110  
2 - 0100001110  
3 - 0100001110  
4 - 0100001110  
5 - 0100001110  
6 - 0100001110  
7 - 0100001110  
8 - 0100001110  
9 - 0100001110

Fitness Score:

-----

0 - 26.0  
1 - 26.0  
2 - 26.0  
3 - 26.0  
4 - 26.0  
5 - 26.0  
6 - 26.0  
7 - 26.0

8 - 26.0

9 - 26.0

Best solution 4: 0100001110

Average fitness: 26.0

Best Fitness: 4: 26.0

Number of times Crossover Occured: 3

Number of times Cloning Occured: 2

Mutation did not occur

Generation 5:

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Population:

0 - 0100001110

1 - 0100001110

2 - 0100001110

3 - 0100001110

4 - 0100001110

5 - 0100001110

6 - 0100001110

7 - 0100001110

8 - 0100001110

9 - 0100001110

Fitness Score:

-----

0 - 26.0

1 - 26.0

2 - 26.0

3 - 26.0

4 - 26.0

5 - 26.0

6 - 26.0

7 - 26.0

8 - 26.0

9 - 26.0

Best solution 5: 0100001110

Average fitness: 26.0



Best Fitness: 5: 26.0

Number of times Crossover Occured: 3

Number of times Cloning Occured: 2

Mutation did not occur

Generation 6:

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Population:

0 - 0100001110

1 - 0100001110

2 - 0100001110

3 - 0100001110

4 - 0100001110

5 - 0100001110

6 - 0100001110

7 - 0100001110

8 - 0100001110

9 - 0100001110

Fitness Score:

-----

0 - 26.0

1 - 26.0

2 - 26.0

3 - 26.0

4 - 26.0

5 - 26.0

6 - 26.0

7 - 26.0

8 - 26.0

9 - 26.0

Best solution 6: 0100001110

Average fitness: 26.0

Best Fitness: 6: 26.0

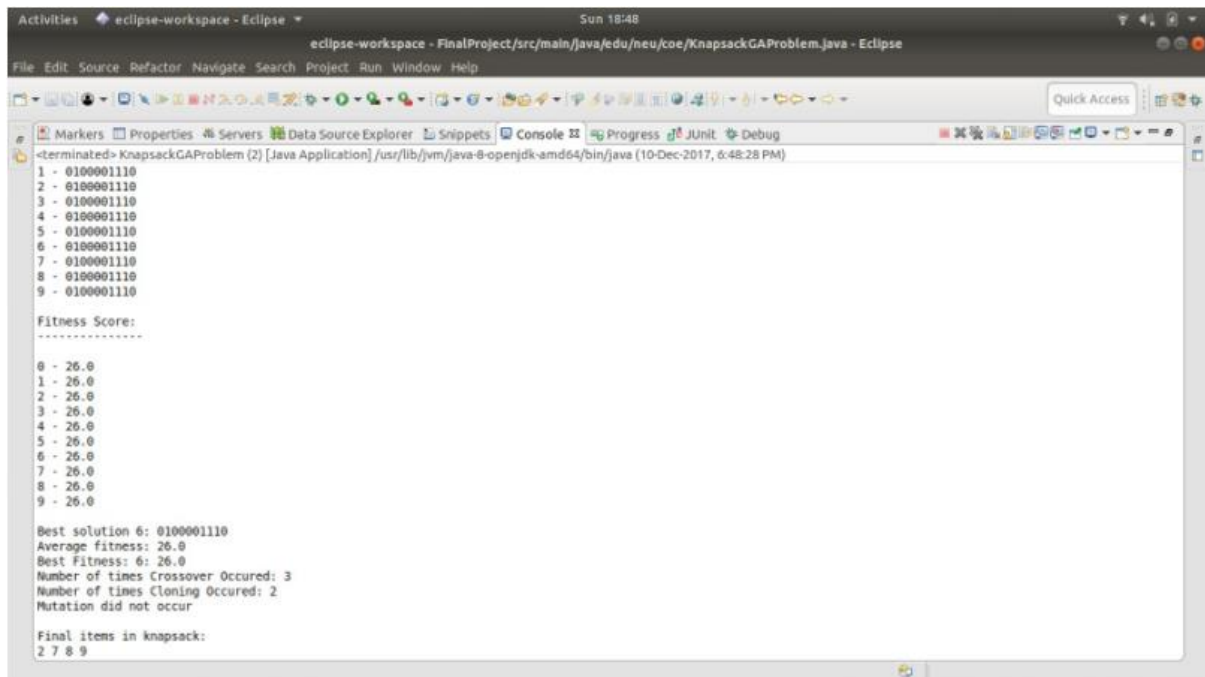
Number of times Crossover Occured: 3

Number of times Cloning Occured: 2

Mutation did not occur

Final items in knapsack:

2 7 8 9



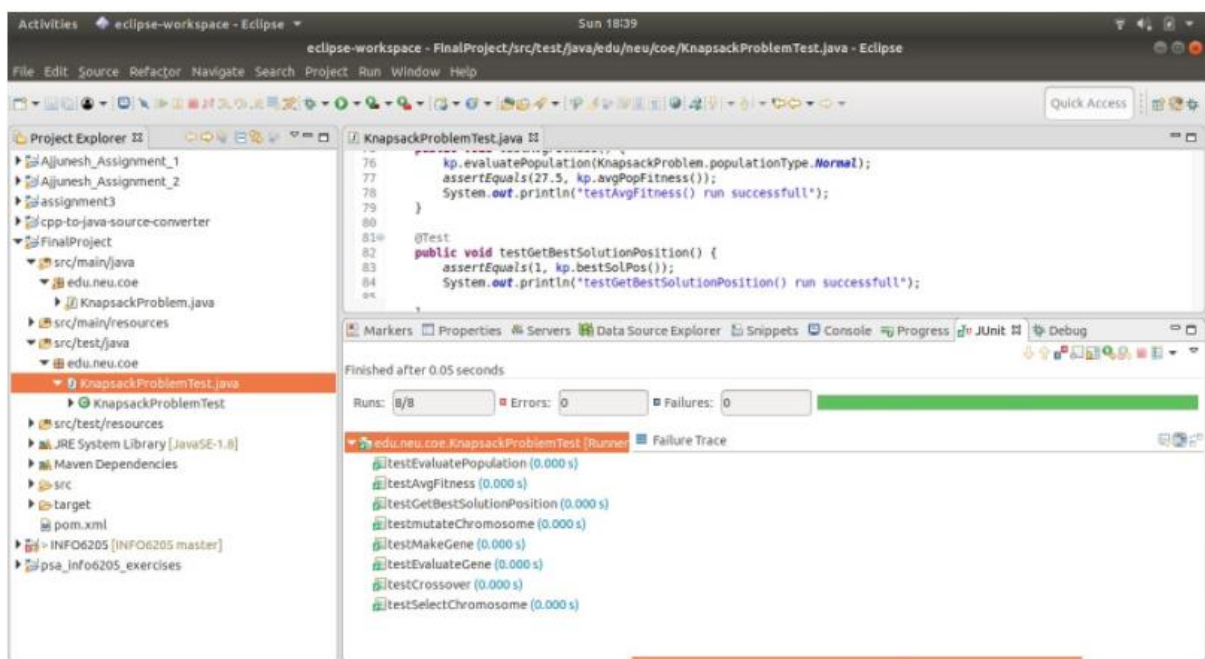
```
1 - 0100001110
2 - 0100001110
3 - 0100001110
4 - 0100001110
5 - 0100001110
6 - 0100001110
7 - 0100001110
8 - 0100001110
9 - 0100001110

Fitness Score:
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0 - 26.0
1 - 26.0
2 - 26.0
3 - 26.0
4 - 26.0
5 - 26.0
6 - 26.0
7 - 26.0
8 - 26.0
9 - 26.0

Best solution 6: 0100001110
Average fitness: 26.0
Best Fitness: 6: 26.0
Number of times Crossover Occured: 3
Number of times Cloning Occured: 2
Mutation did not occur

Final items in knapsack:
2 7 8 9
```

Test case:



```
76 kp.evaluatePopulation(KnapsackProblem.populationType.Normal);
77 assertEquals(27.5, kp.avgPopFitness());
78 System.out.println("testAvgFitness() run successful");
79 }
80
81 @Test
82 public void testGetBestSolutionPosition() {
83     assertEquals(1, kp.bestSolPos());
84     System.out.println("testGetBestSolutionPosition() run successful");
85 }
86
```

Finished after 0.05 seconds

Runs: 8/8 Errors: 0 Failures: 0

edu.neu.coe.KnapsackProblemTest [Runner] Failure Trace

- testEvaluatePopulation (0.000 s)
- testAvgFitness (0.000 s)
- testGetBestSolutionPosition (0.000 s)
- testMutateChromosome (0.000 s)
- testMakeGene (0.000 s)
- testEvaluateGene (0.000 s)
- testCrossover (0.000 s)
- testSelectChromosome (0.000 s)

**REFERENCE:**

[1]. [https://en.wikipedia.org/wiki/Knapsack\\_problem](https://en.wikipedia.org/wiki/Knapsack_problem)