FS2017

Multi-Objective Evolutionary Algorithm

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COMP SCI 5401 FS2017 | ASSIGNMENT 1D

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Overview of Algorithm

This report is analyzing the results of a multi-objective evolutionary algorithm for the offline 2D Bin Packing problem. This algorithm is trying to optimize the horizontal distance the shapes occupy on the sheet. The primary purpose for this is to minimize the amount of stock needed to cut each given shape. The other objective the algorithm is trying to optimize is the vertical distance. This is primarily to avoid having to use the entire vertical spread of the stock so as to eliminate the need to cut shapes from the imperfect edges of the sheet. These optimizations evolve by making Pareto improvements to the population. When the algorithm is completed, it returns the best Pareto optimal front found to the user to decide which solution is truly most fit.

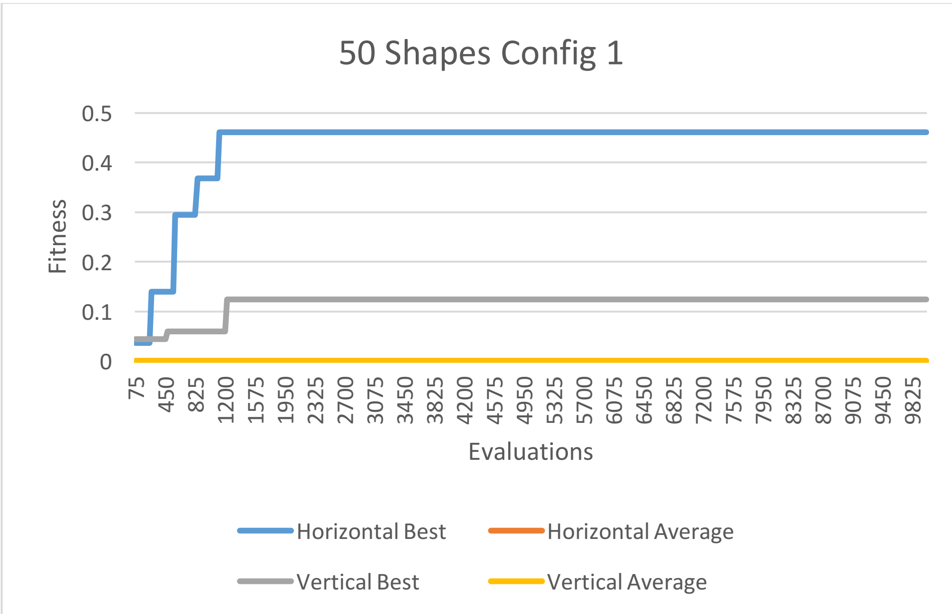
Overview of Experiment

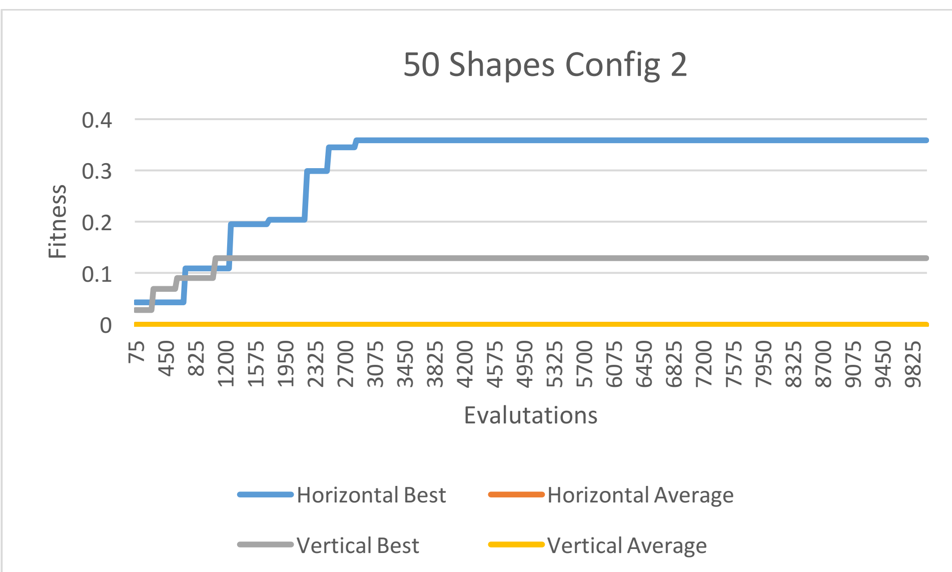
This experiment runs the algorithm using three different configurations on three different problem sets. These results are then analyzed to compare diversity as well as best achieved value for each of the objectives. The configuration differences are as follows:

- Configuration 1
    - Standard starting point to compare other two configurations to
- Configuration 2
    - Significant increase in population size and number of children spawned in each generation (4x)
- Configuration 3
    - Significant increase in mutation rate (3x)

The exact configuration files can be found in the “configuration files” portion of this report. Each of these configurations were run for each problem set, and then the results of each problem instance where then analyzed against each other to see if these changes made a statistical difference and if so which configuration yielded better results. The results of this experiment follow.

Configuration 1 vs 2





Horizontal Fitness Analysis

F-Test Two-Sample for Variances

	Config 1	*Config 2*
Mean	0.22666196	0.301798158
Variance	0.011089908	0.02604629
Observations	30	30
df	29	29
F	0.425776856	
P(F<=f) one-tail	0.01234153	
F Critical one-tail	0.537399965	

Above is the result of a two sample F test to determine if the variances are equal or not. Because the mean for the second variable is larger than the mean for the first variable and, we must assume unequal variances.

t-Test: Two-Sample Assuming Unequal Variances

	Config 1	*Config 2*
Mean	0.22666196	0.301798158
Variance	0.011089908	0.02604629
Observations	30	30
Hypothesized Mean Difference	0	
df	50	
t Stat	- 2.135556799	
P(T<=t) one-tail	0.018818569	
t Critical one-tail	1.675905025	
P(T<=t) two-tail	0.037637138	
t Critical two-tail	2.008559112	

Above is a t test for unequal variances. Because the t-stat is greater than the t-critical two tail value, we are led to reject the null hypothesis and conclude that configuration two is a better configuration for horizontal fitness.

Vertical Fitness Analysis

F-Test Two-Sample for Variances

	Config 1	*Config 2*
Mean	0.138746155	0.047607205
Variance	0.003878322	0.001119317
Observations	30	30
df	29	29
F	3.464900994	
P(F<=f) one-tail	0.000641341	
F Critical one-tail	1.860811435	

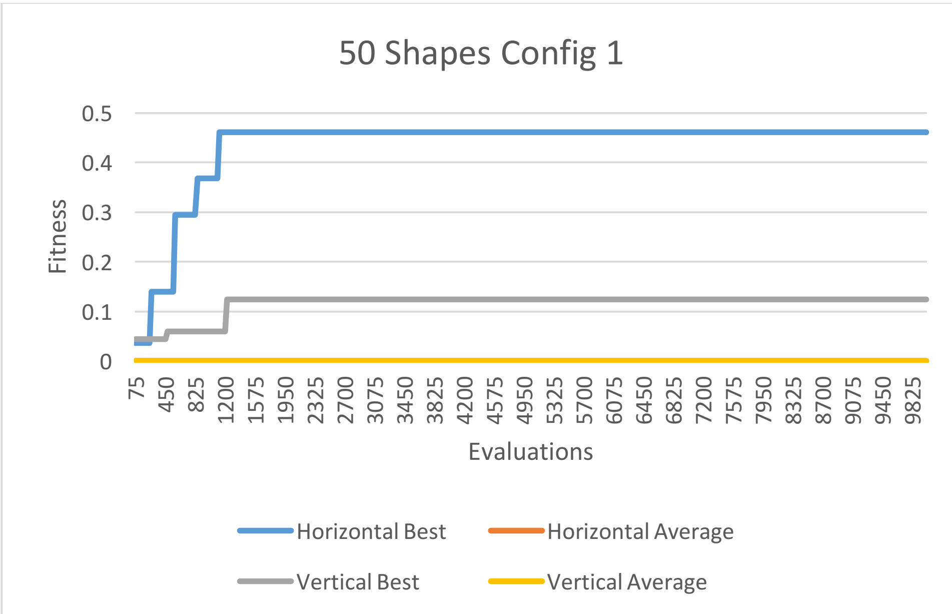
Above is the result of a two sample F test to determine if the variances are equal or not. Because the first variable has a better mean than the second variable, and f is greater than the f-critical value, we should assume unequal variances.

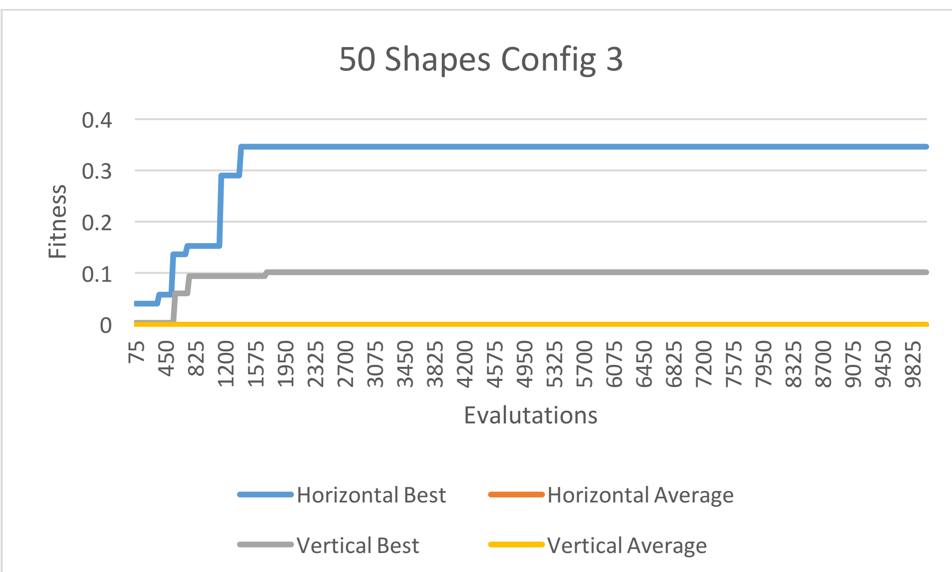
t-Test: Two-Sample Assuming Unequal Variances

	Config 1	*Config 3*
Mean	0.138746155	0.047607205
Variance	0.003878322	0.001119317
Observations	30	30
Hypothesized Mean Difference	0	
df	44	
t Stat	7.061259995	
P(T<=t) one-tail	4.64881E-09	
t Critical one-tail	1.680229977	
P(T<=t) two-tail	9.29762E-09	
t Critical two-tail	2.015367574	

Above is a t test for unequal variances. Because the t-stat is greater than the t-critical two tail value, we are led to reject the null hypothesis and conclude that configuration one is a better configuration for vertical fitness

Configuration 3





Horizontal Fitness Analysis

F-Test Two-Sample for Variances

	Config 1	*Config 3*
Mean	0.22666196	0.256655101
Variance	0.011089908	0.008037912
Observations	30	30
df	29	29
F	1.379699987	
P(F<=f) one-tail	0.195615844	
F Critical one-tail	1.860811435	

Above is an f test to determine if variances differ. Because variable two has a greater mean than variable 1 and the f critical value is greater than the f value, we must conclude variances are unequal.

t-Test: Two-Sample Assuming Unequal Variances

	Config 1	*Config 3*
Mean	0.22666196	0.256655101
Variance	0.011089908	0.008037912
Observations	30	30
Hypothesized Mean Difference	0	
df	57	
	-	
t Stat	1.187817837	
P(T<=t) one-tail	0.119915642	
t Critical one-tail	1.672028888	
P(T<=t) two-tail	0.239831285	
t Critical two-tail	2.002465459	

Above is the result of a t test for unequal variance variables. Because the t critical stat is greater than the t stat, we cannot reject the null hypothesis and cannot conclude that configuration 3 is a better configuration.

Vertical Fitness Analysis

F-Test Two-Sample for Variances

	Config 1	*Config 3*
Mean	0.138746155	0.11783583
Variance	0.003878322	0.005162272
Observations	30	30
df	29	29
F	0.75128203	
P(F<=f) one-tail	0.222994958	
F Critical one-tail	0.537399965	

Above is the result of an f test. Because variable 1 has a greater mean than variable 2 and the f value is greater than the f critical value, we must conclude there are unequal variances.

t-Test: Two-Sample Assuming Unequal Variances

	Config 1	*Config 3*
Mean	0.138746155	0.11783583
Variance	0.003878322	0.005162272
Observations	30	30
Hypothesized Mean Difference	0	
df	57	
t Stat	1.204544703	
P(T<=t) one-tail	0.116678444	
t Critical one-tail	1.672028888	
P(T<=t) two-tail	0.233356888	
t Critical two-tail	2.002465459	

Above is the result of a t test. Because the t critical value is greater than the t value, we cannot reject the null hypothesis and we cannot state conclusively that config 1 is better than config 3.

Configuration Files

50 Shapes

Configuration 1

```xml
<?xml version="1.0"?>
<config>
  <searchType dataType="String" >EvolutionarySearch</searchType>
  <seedSpecified dataType="Boolean" >false</seedSpecified>
  <fitnessEvals dataType="Integer" >10000</fitnessEvals>
  <runs dataType="Integer" >30</runs>
  <logFilePath dataType="String" >./log/1d/50Shapes/config1.txt</logFilePath>
  <solFilePath dataType="String" >./sol/1d/50Shapes/config1.txt</solFilePath>

  <showShapes dataType="Boolean">true</showShapes>
  <showConfig dataType="Boolean">true</showConfig>

  <!-- Evolutionary Parameters-->
  <populationSize dataType="Integer">75</populationSize>
  <numChildren dataType="Integer">25</numChildren>
  <mutationRate dataType="Double">0.25</mutationRate>
  <convergenceCriterion dataType="Integer">15</convergenceCriterion>

  <parentSelectionMethod dataType="String">kTournament</parentSelectionMethod>
  <parentSelectionTournamentSize dataType="Integer">4</parentSelectionTournamentSize>
  <parentsPerChild dataType="Integer">5</parentsPerChild>

  <survivorSelectionMethod dataType="String">kTournament</survivorSelectionMethod>
  <survivorSelectionTournamentSize
dataType="Integer">4</survivorSelectionTournamentSize>
  <multiaryOperator dataType="String">nPointCrossover</multiaryOperator>
  <numCrossoverPoints dataType="Integer">1</numCrossoverPoints>

  <!-- Assignment 1C Configurations -->
  <constraintSatisfaction dataType="String">repair</constraintSatisfaction>
  <penaltyCoefficient dataType="Double">0.33</penaltyCoefficient>

  <survivalStrategy dataType="String">Plus</survivalStrategy>

  <selfAdaptiveMutationRate dataType="Boolean">false</selfAdaptiveMutationRate>

</config>
```

Configuration 2

```xml
<?xml version="1.0"?>
<config>
  <searchType dataType="String" >EvolutionarySearch</searchType>
  <seedSpecified dataType="Boolean" >false</seedSpecified>
  <fitnessEvals dataType="Integer" >10000</fitnessEvals>
  <runs dataType="Integer" >30</runs>
```

```xml
  <logFilePath dataType="String" >./log/1d/50Shapes/config2.txt</logFilePath>
  <solFilePath dataType="String" >./sol/1d/50Shapes/config2.txt</solFilePath>

  <showShapes dataType="Boolean">true</showShapes>
  <showConfig dataType="Boolean">true</showConfig>

  <!-- Evolutionary Parameters-->
  <populationSize dataType="Integer">200</populationSize>
  <numChildren dataType="Integer">100</numChildren>
  <mutationRate dataType="Double">0.25</mutationRate>
  <convergenceCriterion dataType="Integer">15</convergenceCriterion>

  <parentSelectionMethod dataType="String">kTournament</parentSelectionMethod>
  <parentSelectionTournamentSize dataType="Integer">4</parentSelectionTournamentSize>
  <parentsPerChild dataType="Integer">5</parentsPerChild>

  <survivorSelectionMethod dataType="String">kTournament</survivorSelectionMethod>
  <survivorSelectionTournamentSize
dataType="Integer">4</survivorSelectionTournamentSize>
  <multiaryOperator dataType="String">nPointCrossover</multiaryOperator>
  <numCrossoverPoints dataType="Integer">1</numCrossoverPoints>

  <!-- Assignment 1C Configurations -->
  <constraintSatisfaction dataType="String">repair</constraintSatisfaction>
  <penaltyCoefficient dataType="Double">0.33</penaltyCoefficient>

  <survivalStrategy dataType="String">Plus</survivalStrategy>

  <selfAdaptiveMutationRate dataType="Boolean">false</selfAdaptiveMutationRate>
</config>
```


Configuration 3


```xml
<?xml version="1.0"?>
<config>
  <searchType dataType="String" >EvolutionarySearch</searchType>
  <seedSpecified dataType="Boolean" >false</seedSpecified>
  <fitnessEvals dataType="Integer" >10000</fitnessEvals>
  <runs dataType="Integer" >30</runs>
  <logFilePath dataType="String" >./log/1d/50Shapes/config3.txt</logFilePath>
  <solFilePath dataType="String" >./sol/1d/50Shapes/config3.txt</solFilePath>

  <showShapes dataType="Boolean">true</showShapes>
  <showConfig dataType="Boolean">true</showConfig>

  <!-- Evolutionary Parameters-->
  <populationSize dataType="Integer">75</populationSize>
  <numChildren dataType="Integer">25</numChildren>
  <mutationRate dataType="Double">0.75</mutationRate>
  <convergenceCriterion dataType="Integer">15</convergenceCriterion>

  <parentSelectionMethod dataType="String">kTournament</parentSelectionMethod>
  <parentSelectionTournamentSize dataType="Integer">4</parentSelectionTournamentSize>
  <parentsPerChild dataType="Integer">5</parentsPerChild>

  <survivorSelectionMethod dataType="String">kTournament</survivorSelectionMethod>
  <survivorSelectionTournamentSize
dataType="Integer">4</survivorSelectionTournamentSize>
  <multiaryOperator dataType="String">nPointCrossover</multiaryOperator>
```

```xml
  <numCrossoverPoints dataType="Integer">1</numCrossoverPoints>

  <!-- Assignment 1C Configurations -->
  <constraintSatisfaction dataType="String">repair</constraintSatisfaction>
  <penaltyCoefficient dataType="Double">0.33</penaltyCoefficient>

  <survivalStrategy dataType="String">Plus</survivalStrategy>

  <selfAdaptiveMutationRate dataType="Boolean">false</selfAdaptiveMutationRate>


</config>
```

100 Shapes

Configuration 1

```xml
<?xml version="1.0"?>
<config>
  <searchType dataType="String" >EvolutionarySearch</searchType>
  <seedSpecified dataType="Boolean" >false</seedSpecified>
  <fitnessEvals dataType="Integer" >10000</fitnessEvals>
  <runs dataType="Integer" >30</runs>
  <logFilePath dataType="String" >./log/1d/100Shapes/config1.txt</logFilePath>
  <solFilePath dataType="String" >./sol/1d/100Shapes/config1.txt</solFilePath>

  <showShapes dataType="Boolean">true</showShapes>
  <showConfig dataType="Boolean">true</showConfig>

  <!-- Evolutionary Parameters-->
  <populationSize dataType="Integer">75</populationSize>
  <numChildren dataType="Integer">25</numChildren>
  <mutationRate dataType="Double">0.25</mutationRate>
  <convergenceCriterion dataType="Integer">15</convergenceCriterion>

  <parentSelectionMethod dataType="String">kTournament</parentSelectionMethod>
  <parentSelectionTournamentSize dataType="Integer">4</parentSelectionTournamentSize>
  <parentsPerChild dataType="Integer">5</parentsPerChild>

  <survivorSelectionMethod dataType="String">kTournament</survivorSelectionMethod>
  <survivorSelectionTournamentSize
dataType="Integer">4</survivorSelectionTournamentSize>
  <multiaryOperator dataType="String">nPointCrossover</multiaryOperator>
  <numCrossoverPoints dataType="Integer">1</numCrossoverPoints>

  <!-- Assignment 1C Configurations -->
  <constraintSatisfaction dataType="String">repair</constraintSatisfaction>
  <penaltyCoefficient dataType="Double">0.33</penaltyCoefficient>

  <survivalStrategy dataType="String">Plus</survivalStrategy>

  <selfAdaptiveMutationRate dataType="Boolean">false</selfAdaptiveMutationRate>
```

```
</config>
```

Configuration 2

```xml
<?xml version="1.0"?>
<config>
  <searchType dataType="String" >EvolutionarySearch</searchType>
  <seedSpecified dataType="Boolean" >false</seedSpecified>
  <fitnessEvals dataType="Integer" >10000</fitnessEvals>
  <runs dataType="Integer" >30</runs>
  <logFilePath dataType="String" >./log/1d/100Shapes/config2.txt</logFilePath>
  <solFilePath dataType="String" >./sol/1d/100Shapes/config2.txt</solFilePath>

  <showShapes dataType="Boolean">true</showShapes>
  <showConfig dataType="Boolean">true</showConfig>

  <!-- Evolutionary Parameters-->
  <populationSize dataType="Integer">200</populationSize>
  <numChildren dataType="Integer">100</numChildren>
  <mutationRate dataType="Double">0.25</mutationRate>
  <convergenceCriterion dataType="Integer">15</convergenceCriterion>

  <parentSelectionMethod dataType="String">kTournament</parentSelectionMethod>
  <parentSelectionTournamentSize dataType="Integer">4</parentSelectionTournamentSize>
  <parentsPerChild dataType="Integer">5</parentsPerChild>

  <survivorSelectionMethod dataType="String">kTournament</survivorSelectionMethod>
  <survivorSelectionTournamentSize
dataType="Integer">4</survivorSelectionTournamentSize>
  <multiaryOperator dataType="String">nPointCrossover</multiaryOperator>
  <numCrossoverPoints dataType="Integer">1</numCrossoverPoints>

  <!-- Assignment 1C Configurations -->
  <constraintSatisfaction dataType="String">repair</constraintSatisfaction>
  <penaltyCoefficient dataType="Double">0.33</penaltyCoefficient>

  <survivalStrategy dataType="String">Plus</survivalStrategy>

  <selfAdaptiveMutationRate dataType="Boolean">false</selfAdaptiveMutationRate>



</config>
```

Configuration 3

```xml
<?xml version="1.0"?>
<config>
  <searchType dataType="String" >EvolutionarySearch</searchType>
  <seedSpecified dataType="Boolean" >false</seedSpecified>
  <fitnessEvals dataType="Integer" >10000</fitnessEvals>
  <runs dataType="Integer" >30</runs>
```

```
  <logFilePath dataType="String" >./log/1d/100Shapes/config3.txt</logFilePath>
  <solFilePath dataType="String" >./sol/1d/100Shapes/config3.txt</solFilePath>

  <showShapes dataType="Boolean">true</showShapes>
  <showConfig dataType="Boolean">true</showConfig>

  <!-- Evolutionary Parameters-->
  <populationSize dataType="Integer">75</populationSize>
  <numChildren dataType="Integer">25</numChildren>
  <mutationRate dataType="Double">0.75</mutationRate>
  <convergenceCriterion dataType="Integer">15</convergenceCriterion>

  <parentSelectionMethod dataType="String">kTournament</parentSelectionMethod>
  <parentSelectionTournamentSize dataType="Integer">4</parentSelectionTournamentSize>
  <parentsPerChild dataType="Integer">5</parentsPerChild>

  <survivorSelectionMethod dataType="String">kTournament</survivorSelectionMethod>
  <survivorSelectionTournamentSize
dataType="Integer">4</survivorSelectionTournamentSize>
  <multiaryOperator dataType="String">nPointCrossover</multiaryOperator>
  <numCrossoverPoints dataType="Integer">1</numCrossoverPoints>

  <!-- Assignment 1C Configurations -->
  <constraintSatisfaction dataType="String">repair</constraintSatisfaction>
  <penaltyCoefficient dataType="Double">0.33</penaltyCoefficient>

  <survivalStrategy dataType="String">Plus</survivalStrategy>

  <selfAdaptiveMutationRate dataType="Boolean">false</selfAdaptiveMutationRate>



</config>
```

100 Complex Shapes

Configuration 1

```
<?xml version="1.0"?>
<config>
  <searchType dataType="String" >EvolutionarySearch</searchType>
  <seedSpecified dataType="Boolean" >false</seedSpecified>
  <fitnessEvals dataType="Integer" >10000</fitnessEvals>
  <runs dataType="Integer" >30</runs>
  <logFilePath dataType="String" >./log/1d/100ComplexShapes/config1.txt</logFilePath>
  <solFilePath dataType="String" >./sol/1d/100ComplexShapes/config1.txt</solFilePath>

  <showShapes dataType="Boolean">true</showShapes>
  <showConfig dataType="Boolean">true</showConfig>

  <!-- Evolutionary Parameters-->
  <populationSize dataType="Integer">75</populationSize>
  <numChildren dataType="Integer">25</numChildren>
  <mutationRate dataType="Double">0.25</mutationRate>
  <convergenceCriterion dataType="Integer">15</convergenceCriterion>
```

```
  <parentSelectionMethod dataType="String">kTournament</parentSelectionMethod>
  <parentSelectionTournamentSize dataType="Integer">4</parentSelectionTournamentSize>
  <parentsPerChild dataType="Integer">5</parentsPerChild>

  <survivorSelectionMethod dataType="String">kTournament</survivorSelectionMethod>
  <survivorSelectionTournamentSize
dataType="Integer">4</survivorSelectionTournamentSize>
  <multiaryOperator dataType="String">nPointCrossover</multiaryOperator>
  <numCrossoverPoints dataType="Integer">1</numCrossoverPoints>

  <!-- Assignment 1C Configurations -->
  <constraintSatisfaction dataType="String">repair</constraintSatisfaction>
  <penaltyCoefficient dataType="Double">0.33</penaltyCoefficient>

  <survivalStrategy dataType="String">Plus</survivalStrategy>

  <selfAdaptiveMutationRate dataType="Boolean">false</selfAdaptiveMutationRate>


</config>
```

Configuration 2

```
<?xml version="1.0"?>
<config>
  <searchType dataType="String" >EvolutionarySearch</searchType>
  <seedSpecified dataType="Boolean" >false</seedSpecified>
  <fitnessEvals dataType="Integer" >10000</fitnessEvals>
  <runs dataType="Integer" >30</runs>
  <logFilePath dataType="String" >./log/1d/100ComplexShapes/config2.txt</logFilePath>
  <solFilePath dataType="String" >./sol/1d/100ComplexShapes/config2.txt</solFilePath>

  <showShapes dataType="Boolean">true</showShapes>
  <showConfig dataType="Boolean">true</showConfig>

  <!-- Evolutionary Parameters-->
  <populationSize dataType="Integer">75</populationSize>
  <numChildren dataType="Integer">25</numChildren>
  <mutationRate dataType="Double">0.25</mutationRate>
  <convergenceCriterion dataType="Integer">15</convergenceCriterion>

  <parentSelectionMethod dataType="String">kTournament</parentSelectionMethod>
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  <survivorSelectionMethod dataType="String">kTournament</survivorSelectionMethod>
  <survivorSelectionTournamentSize
dataType="Integer">8</survivorSelectionTournamentSize>
  <multiaryOperator dataType="String">nPointCrossover</multiaryOperator>
  <numCrossoverPoints dataType="Integer">1</numCrossoverPoints>

  <!-- Assignment 1C Configurations -->
  <constraintSatisfaction dataType="String">repair</constraintSatisfaction>
  <penaltyCoefficient dataType="Double">0.33</penaltyCoefficient>

  <survivalStrategy dataType="String">Plus</survivalStrategy>

  <selfAdaptiveMutationRate dataType="Boolean">false</selfAdaptiveMutationRate>
```

```
</config>
```

Configuration 3

```xml
<?xml version="1.0"?>
<config>
  <searchType dataType="String" >EvolutionarySearch</searchType>
  <seedSpecified dataType="Boolean" >false</seedSpecified>
  <fitnessEvals dataType="Integer" >10000</fitnessEvals>
  <runs dataType="Integer" >30</runs>
  <logFilePath dataType="String" >./log/1d/100ComplexShapes/config3.txt</logFilePath>
  <solFilePath dataType="String" >./sol/1d/100ComplexShapes/config3.txt</solFilePath>

  <showShapes dataType="Boolean">true</showShapes>
  <showConfig dataType="Boolean">true</showConfig>

  <!-- Evolutionary Parameters-->
  <populationSize dataType="Integer">75</populationSize>
  <numChildren dataType="Integer">25</numChildren>
  <mutationRate dataType="Double">0.75</mutationRate>
  <convergenceCriterion dataType="Integer">15</convergenceCriterion>

  <parentSelectionMethod dataType="String">kTournament</parentSelectionMethod>
  <parentSelectionTournamentSize dataType="Integer">4</parentSelectionTournamentSize>
  <parentsPerChild dataType="Integer">5</parentsPerChild>

  <survivorSelectionMethod dataType="String">kTournament</survivorSelectionMethod>
  <survivorSelectionTournamentSize
dataType="Integer">4</survivorSelectionTournamentSize>
  <multiaryOperator dataType="String">nPointCrossover</multiaryOperator>
  <numCrossoverPoints dataType="Integer">1</numCrossoverPoints>

  <!-- Assignment 1C Configurations -->
  <constraintSatisfaction dataType="String">repair</constraintSatisfaction>
  <penaltyCoefficient dataType="Double">0.33</penaltyCoefficient>

  <survivalStrategy dataType="String">Plus</survivalStrategy>

  <selfAdaptiveMutationRate dataType="Boolean">false</selfAdaptiveMutationRate>



</config>
```