“Genetic algorithms are preferred over other traditional search techniques such as Hill Climbing due to the reason that in hill climbing the problem of local optimum occurs a number of times. In case of GA the searching starts from multiple points instead of single point and hence chances of sticking to local maxima are very less. But this does not guarantee that GA will not stick to a local maximum. Therefore some measures needs to be taken for getting out of the local maximum. The problem of sticking to local maxima is termed as pre-mature convergence in GA. For preventing this problem some measures are proposed in literature. One of them is the use of SDT. The SDT are the social disaster techniques for getting out from a plateau. So far SDT has been successfully used in TSP, but there are no evidences from the literature that these can be used in other fields or not. In this chapter, these techniques are implemented on YM. Another technique in GA is elitism that has been implemented on YM in an attempt to improve the convergence. Although elitism is not a technique to prevent pre-mature convergence, yet this can also help in improving the convergence.”
7.1 Introduction

Since its origin GA has been improving day by day. The concept of elitism has been one of those techniques that help GA to improve the convergence towards solution generation by generation. Use of elitism at least guarantees that the performance of GA will not dip i.e. the best solution found in any generation will survive. Elitism is basically a replacement policy, which is also sometimes known as replace worst policy, which indicates that the worst fit chromosome(s) is/are replaced by the best chromosome(s).

Another concept that has come into force is that of Social Disaster Techniques (SDT). These techniques are designed to avoid premature convergence by introducing diversity in the population. The SDT comprises of two techniques named as Judgement Day and Packing. The purpose of both remains same i.e. avoiding premature convergence.

In the present chapter, it is intended to add elitism and SDT in GA to see their impact on convergence, if any. In the chapter 5, it was observed that in case roulette-wheel and tournament selection mechanism along with 1-point crossover using multiple time-slices, the optimum solution was never achieved during last time-slice. Hence it is worth checking that the impact of elitism and SDT in these cases.

7.2 Background

In the literature elitism has been used in a number of applications and it has been observed that elitism prove to be very good replacement strategy for the purpose of improved convergence. Some of the applications where elitism has been used successfully are described briefly:

Leung and Liang (2003) introduced a new technique called “adaptive elitist population search method”, which allowed extension of unimodal function optimization methods to locate all optima of multimodal problems in an efficient manner. Lozano et al. (2008) has proposed a replacement strategy for steady-state genetic algorithms considering two features of the candidate chromosome to be included into the population: a measure of the contribution of diversity to the population and the fitness function. In [Kim J.L. (2010)], the relationship between the elitist genetic algorithm performance and algorithm termination criteria was examined. A genetic algorithm with elitism has been proposed by Chakraborty and Chaudhary (2003). It has been established in that article that convergence has been achieved in a number of numerical examples by using elitism. In a paper by Yang (2007), an elitism-based immigrant scheme for genetic algorithms has been proposed. The immigrants have been found to be more adapting using elitism. Another proposal in the same paper has also been provided which is hybrid immigrants scheme using elitism based method and traditional
random approaches. Results in both the cases have been found to be better than traditional approaches. The paper by Grosan et al. studied the influence of elitism in Evolutionary Multiobjective Optimization. The paper presented some algorithms which use elitism and some algorithms which not use elitism and realizes a comparison of some algorithms for each category.

The SDT has been mostly used in TSP so far. In other cases SDT has not been much tried. Therefore, this attempt to implement SDT on Yield Management is more or less first of its kind. Some of the literature related to SDT is given below:

In a paper by Kureichick et al. (1996), some new features in genetic solution of the TSP have been suggested. One of those features is applying SDT very effectively. They proved that with the help of SDT TSP can be solved in more effective manner. SDT also have been successfully used in TSP by Choubey (2012) using DARO.

In another paper for preventing premature convergence to local maxima in GA via random offspring [Miguel Rocha and Jose Neves], some of the basic techniques were compared with an innovative one, the Random offspring Generation, was evaluated in its merits. Again TSP was taken as a problem.

7.3 Elitism and SDT

Elitism: In elitism, complete population of genome is replaced except for the best member of each generation which is carried over to next generation without modification [Winkler et al. (2009)]. When creating a new population by crossover and mutation, there are chances that the best chromosome is lost. Elitism is the name of the method that first copies the best chromosome (or few best chromosomes) to the new population [De Jong (1975)]. The rest of the population is constructed according to GA. Elitism can rapidly increase the performance of GA, because it prevents a loss of the best found solution.

SDT: The Social Disasters Technique (SDT) was introduced by Kureichick and colleagues (1996) in order to avoid the premature convergence to local optima, when the GA is applied to the TSP. The general idea is to diagnose the situations of loss of genetic diversity of the population, and in such a case to apply a catastrophic operator to it. These operators were defined with the purpose to return the population to an acceptable degree of genetic diversity, by replacing a number of selected individuals, by others, generated at random. Two different operators were considered.

Packing: Of all the individuals having the same fitness value, only one remains unchanged; all the others are fully randomized.
Judgment Day: Only the individual with the best fitness value remains unchanged; all the others are fully randomized.

7.4 Implementation using Genetic Algorithm

For solving the problem formulated in chapter 5, first a modified genetic algorithm with elitism has been proposed which is implemented using MATLAB and is stated below:

**ALGORITHM 7.1: GA_ELIT_YM (Genetic Algorithm with Elitism for Yield Management)**

Step 1: Init_pop = Randomly Generated population.
Step 2: curr_pop = Init_pop.
Step 3: While (!termination_criterion)
Step 4: Evaluate Fitness of curr_pop using fitness function.
Step 5: Select mating pool according to Roulette-wheel Selection.
Step 6: Apply One-point Crossover on mating pool with probability 0.80.
Step 7: Apply Mutation on mating pool with probability 0.03.
Step 8: Replace the worst chromosome (individual) in the population with the best one and add to curr_pop. // Elitism
Step 9: Replace remaining generation with (λ + μ)-update and add to curr_pop.
Step 10: End While
Step 11: End

In this algorithm the elitism has been applied in 8th step which is replacing the worst fit individual with the best fit individual. The other parameters of the GA remain same as in algorithm 5.1.

Now another variation of GA with Judgement Day will be proposed and is shown below:

**ALGORITHM 7.2: GA_JUDGE_YM (Genetic Algorithm with Judgement Day as SDT)**

Step 1: Init_pop = Randomly Generated population of size N.
Step 2: curr_pop = Init_pop.
Step 3: While (!termination_criterion)
Step 4: Evaluate Fitness of curr_pop using fitness function.
Step 5: Select mating pool according to Roulette-wheel Selection.
Step 6: Apply One-point Crossover on mating pool with probability 0.80.
Step 7: Apply Mutation on mating pool with probability 0.03.
Step 8: If standard_Deviation of fitness == 0    // Plateau
Step 9: $F_B =$ Best Fit Individual \hspace{1cm} // For Judgement Day SDT
Step 10: Temp_pop = Randomly generated population of size N-1.
Step 11: New_pop = Temp_pop + $F_B$
Step 12: Curr_pop = New_pop
Step 13: Else
Step 14: Replace remaining generation with $(\lambda + \mu)$-update and add to curr_pop.
Step 15: End if
Step 16: End While
Step 17: End

In this algorithm Judgement Day technique has been applied to avoid premature convergence. As shown in step 8, the standard deviation for the last 20 iteration is calculated (not shown in algorithm) and if it is found to be zero meant that a plateau has reached. Therefore Judgement Day technique is applied i.e. the best fit individual is sustained while the other individuals are randomly created in next iteration. The Judgement Day is applied three times as and when plateau has reached. In other iterations normal GA (algorithm 5.1) is implemented with standard method. The standard deviation is calculated using the following formula.

$$S = \frac{1}{N-1} \sum_{i=1}^{N} (x_i - \bar{x})^2$$

where $N$ is the number of elements in the sample and

$$\bar{x} = \frac{1}{N} \sum_{i=1}^{N} x_i$$

In the end, third variation of GA with packing SDT will be presented:

**ALGORITHM 7.3: GA_PACK_YM (Genetic Algorithm with Packing as SDT)**

Step 1: Init_pop = Randomly Generated population.
Step 2: curr_pop = Init_pop.
Step 3: While ( !termination_criterion)
Step 4: Evaluate Fitness of curr_pop using fitness function.
Step 5: Select mating pool according to Roulette-wheel Selection.
Step 6: Apply One-point Crossover on mating pool with probability 0.80.
Step 7: Apply Mutation on mating pool with probability 0.03.
Step 8: If standard_Deviation of fitness == 0    // Plateau
Step 9: $F_p =$ Select one individual (chromosome) each from the groups having same fitness values. \hspace{1cm} // For Packing in SDT
In the above algorithm, Packing technique has been applied with the same purpose of avoiding premature convergence. As shown again in step 8, the standard deviation for the last 20 iteration is calculated (not shown in algorithm) and if it is found to be zero meant that a plateau has reached. When a Plateau has reached, the Packing is applied i.e. one individual is selected from each group having same fitness is selected while the other individuals in each group are randomly created in next iteration. The Packing is also applied three times as and when plateau has reached, otherwise normal GA is applied in all other iterations.

All the three algorithms were implemented using MATLAB and the results are shown and explained through graphs and tables in the next section.

**7.5 Results and Observations**

In this case, a single flight is considered to operate between given origin and destination. The capacity of the flight is assumed to be 100. The following GA parameters are taken into considerations:

- Population size = 75
- Maximum number of iterations = 200
- Cross-over probability = 0.80
- Mutation probability = 0.03
- Number of simulations = 100

Using the above parameters and various combinations one can get graphs as shown in fig. 7.1- fig. 7.12. Also a table i.e. table 7.2 is drawn in the end which shows the comparison of maximum yield obtained in each case.

Results obtained for each combination of operators are shown below:

- Using combination of Roulette Wheel selection, Roulette Wheel selection with Elitism, and one-point crossover in both cases, the following results were obtained during first time period in a Multi Time-Period Environment:
By looking at the above two figures, it is evident that the performance of GA with and without elitism is same i.e. there is no impact of elitism during first time-period. This is due to the fact that the optimum convergence is reached as early as in 2\textsuperscript{nd} iteration.

- Using combination of Roulette Wheel selection, Roulette Wheel selection with Elitism, and one-point crossover in both cases, the following results were obtained during second time period in a Multi Time-Period Environment:
It can be observed by looking at figure 7.4 that results obtained in case of elitism are much better than the combination used without elitism. However the average population is behaving in more or less same manner.

- Using combination of Roulette Wheel selection, Roulette Wheel selection with Judgement Day Technique, and one-point crossover in both cases, the following results were obtained during first time period in a Multi Time-Period Environment:

By looking at the above two figures, it is again evident that the performance of GA with and without judgement day technique is same i.e. there is no impact of judgement day technique during first time-period. This is due to the fact that the optimum convergence is reached as early as in 2\textsuperscript{nd} iteration.
Using combination of Roulette Wheel selection, Roulette Wheel selection with Judgement Day Technique, and one-point crossover in both cases, the following results were obtained during second time period in a Multi Time-Period Environment:

![Fig.7.7: Lower Bound, Upper Bound, and Estimated Fitness](image)

![Fig. 7.8: Maximum and Average Fitness](image)

It can be observed from figure 7.8 that the results obtained in case of judgement day technique are better as compared to the situation when the judgement day technique is not applied. Another important observation is that the situation of plateau has changed in case of judgement day significantly as compared to no judgement day.

Using combination of Roulette Wheel selection, Roulette Wheel selection with Packing Technique, and one-point crossover in both cases, the following results were obtained during first time period in a Multi Time-Period Environment:
As in the previous two cases the convergence is reached very early, hence there is no impact of packing technique.

- Using combination of Roulette Wheel selection, Roulette Wheel selection with Packing Technique, and one-point crossover in both cases, the following results were obtained during first time period in a Multi Time-Period Environment:
Again it is evident from figure 7.12 that the results obtained by using packing are much better as compared to results without packing.

The table 7.1 shows the best estimated number of seats allocated for each time-period as obtained from chapter 5.

**Table 7.1: Lower, Upper and Best estimated demands in each assumed fare class in multiple time-slices**

<table>
<thead>
<tr>
<th>Fare Class</th>
<th>Time-Slice I</th>
<th>Time-Slice II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Demand</td>
<td>Demand</td>
</tr>
<tr>
<td></td>
<td>Lower Limit</td>
<td>Upper Limit</td>
</tr>
<tr>
<td>1</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>250</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>500</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>800</td>
<td>0</td>
</tr>
</tbody>
</table>

Finally table 7.2 shows the comparison of total of maximum yield obtained during all the time-periods in each case i.e. Roulette Wheel selection, Roulette Wheel selection with Packing Technique, Roulette Wheel selection with Judgement Day Technique and Roulette Wheel selection with Elitism along with one-point crossover. The comparison is also shown graphically through fig.7.13.

**Table 7.2: Comparison of Maximum Yield obtained during each case. The Average and Minimum within Maximum yield obtained is also considered**

<table>
<thead>
<tr>
<th></th>
<th>Roulette Wheel</th>
<th>Elitism</th>
<th>Judgement Day</th>
<th>Packing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Yield</td>
<td>27100</td>
<td>27600</td>
<td>27600</td>
<td>27600</td>
</tr>
<tr>
<td>Avg.(Max.) Yield</td>
<td>26270</td>
<td>26500</td>
<td>26800</td>
<td>26900</td>
</tr>
<tr>
<td>Min.(Max.) Yield</td>
<td>24650</td>
<td>25900</td>
<td>26150</td>
<td>26200</td>
</tr>
</tbody>
</table>
Fig. 7.13: Comparison of Maximum Yield during each case

By looking at table 7.2 and figure 7.13, it is evident that all the three techniques i.e. Elitism, Judgement day and Packing are producing better results as compared to simple GA. It can also be observed that the results of SDT are better as compared to Elitism. Within SDT, the result of Packing is found to better than Judgement day.

7.6 Interpretation

Upon comparing the results of various techniques implemented in this chapter, it has been observed that the results obtained by all the methods are same as shown in table 7.1 during time-period 1. But the results found in time-period 2 varies from the best estimated. In case of roulette wheel the optimum solution is never obtained in the specified 200 iterations. While in other cases, it is visible that in some cases optimum results are obtained. The findings of the chapter can be summarized as follows:

- By looking at fig. 7.1, fig.7.5 and fig.7.9, it is clear that global optimum is achieved in each case, which means if the global optimum is already obtained then the elitism, and SDT does not change it.
- Looking upon fig.7.2, fig.7.6 and fig.7.10, it can be observed that the average fitness of all types of populations is also very good during first time-period. Although it can also be observed that in fig.7.6 and fig.7.10, there are slight dips in the average population which are due to SDT.
- Looking at fig. 7.4, fig. 7.8 and fig. 7.12, it is clearly visible that elitism, and both the SDT performs better than roulette wheel technique and the pre-mature convergence is avoided in all the cases.
• Observing table 7.2 and graph 7.13, it is found that elitism and the SDT outperform the simple roulette wheel selection mechanism in most of the cases. However, it is visible that SDT provides better results than elitism. In can also be concluded that premature convergence can be prevented by using SDT and elitism.

7.7 Summary

In this chapter, the problem of premature convergence in yield management with the help of elitism and SDT in GA has been considered. The elitism and SDT are applied in case of multiple time-slices arrivals in YM. The techniques are applied in each time-slice and their impact on the convergence has been observed. It has been observed that convergence has been improved with the help of elitism and SDT in almost all the cases. The premature convergence problem can be avoided up to some extent through elitism and SDT. Till date SDT has only been applied to TSP. With the help of the work presented in this chapter, it has been observed that it can also be useful in Yield Management.