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Global Optimal Analysis of Variant Genetic Operations in Solar Tracking

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Abstract: Genetic Algorithms (GAs), Evolution Strategies (ES), Evolutionary Programming (EP) and Genetic Programming (GP) are some of the best known types of Evolutionary Algorithm (EA)where it is a class of global search algorithms inspired by natural evolution. Lots of research has been carried out in solar tracking system using different types of Evolutionary Algorithm. In this research, genetic algorithm is explored to maximize the performance of solar tracking system. This work evaluates the best combination of GA parameters by always fine-tuning the position of solar tracking prototype to receive maximum solar radiation. Both software and hardware have been developed to simulate related genetic algorithm results using a combination of variant genetic operators. Under conventional genetic algorithm operation, it is concluded that genetic algorithm with selective clonal mutation is able to produce the best fitness value at 0.98027 with both axles X and Y with inclination of +2 degree to the sun position.

Key words: Genetic Algorithm, Solar tracking, Selective Clonal Mutation (SCM)

INTRODUCTION

A solar tracker is a device onto which solar panels are fitted which tracks the motion of the sun across the sky ensuring that the maximum amount of sunlight strikes the panels throughout the day.(D.F.Fam, 2012) When it is compared to the price of the PV solar panels, the cost of a solar tracker is relatively low. Most photovoltaic (PV) solar panels are fitted in a fixed location platform, for example it is fitted on the sloping roof of a house or on framework fixed to the ground. Since the sun moves across the sky though the day, this is far from an ideal solution.

Solar panels are usually set up to be in full direct sunshine at the middle of the day facing South in the Northern Hemisphere or North in the Southern Hemisphere. Therefore morning and evening sunlight hits the panels at an acute angle reducing the total amount of electricity which can be generated each day. During the day the sun appears to move across the sky from left to right and up and down above the horizon from sunrise to noon to sunset. Figure 1 shows the schematic above of the Sun's apparent motion as seen from the Northern Hemisphere.(M.F.Khan and R.L.Ali, 2005)

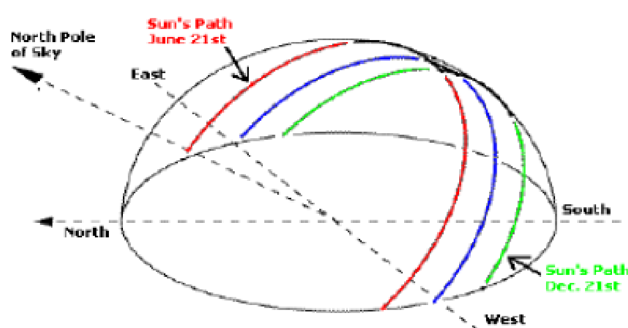

Fig. 1: Sun's apparent motion

Solar tracking can be implemented by using one-axis and for higher accuracy, two-axis sun-tracking systems. For a two-axis sun-tracking system, two types are known as: polar (equatorial) tracking and azimuth/elevation (altitude–azimuth) tracking. (Pitak Khlaichom, 2007) High-concentration solar requires the sun to be tracked with great accuracy for maximum output voltage.

Abdallah et al. designed and constructed a two-axes, open loop PLC controlled sun-tracking system. Their working principle is based on mathematical definition of surface position that is defined by two angles: the slope of the surface and azimuth angle. The slope is considered to be equal as zenith angle of the sun. Two tracking motors, one for the joint rotating about the horizontal N–S axis and the other for the joint rotating about the

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vertical axis is used. The daylight is divided into four intervals and the solar and motors speed are defined and programmed into PLC. They predicted that the power consumption to drive motors and control systems hardly exceeds 3% of power saved by the tracking system. They concluded that the use of two-axes tracking surfaces resulted in an increase in total daily collection of about 41.34% as compared to that of a fixed one (Abdallah S and Nijmeh S, 2004).

Figure 2 shows energy comparison between the tracker and the fixed surface inclined at 32°

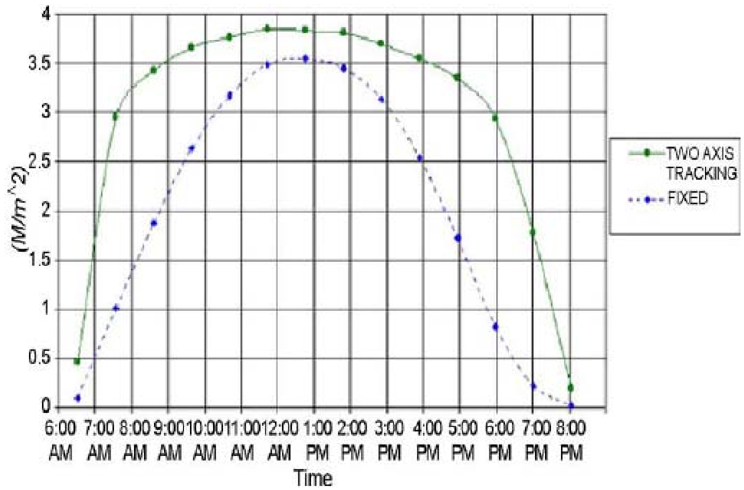


Fig. 2: Energy comparison between tracking and fixed solar system((Abdallah S and Nijmeh S, 2004)

Syamsiah Mashohor et al. evaluated the best combination of GA parameters to optimize a solar tracking system for PV panels in terms of azimuth angle and tilt angle. Simulation results demonstrated the ability of the proposed GA system to search for optimal panel positions in term of consistency and convergence properties. It has proved the ability of the GA-Solar to adapt to different environmental conditions and successfully tracked sun positions in finding the maximum power by precisely orienting the PV panels.(Syamsiah Mashohor, 2008)

In this research, A new operator namely GA selective clonal mutation (SCM) for better genetic solutions has been successfully designed and developed. Selective cloning has been done according to the best fitness value after the completion of each generation where best chromosome has been cloned more while worst chromosome cloned less. Selective mutation has been exercised for the best chosen chromosome so that it converges to the best desired solution faster. This operator has produced the best fitness function as compared to the conventional genetic algorithm operation and conventional genetic algorithm with crossover operation.

In the following section, methodology will be discussed followed by results of the simulation and detailed discussion. Finally, conclusion is presented to summary the finding of these three genetic operations.

MATERIALS AND METHODS

Below shows the block diagram of proposed genetic algorithm used in this solar tracking project:

GA creates an initial population (a collection of chromosomes) based on the turning angles, evaluates this population and evolves the population through multiple generations in the search for a good solution to the problem as illustrated in Figure 3. In GA process, the initial chromosomes are evaluated and selected for crossover operation. Throughout the evolution, there is a possibility of invalid genes produced in the initial offspring and this issue may confuse the GAs searching for best solution. Therefore, it is necessary having checking operator to clean and replace all the invalid genes during mutation process. Finally, the overall best chromosome would be kept for the next generation. This process will continue until the termination criteria are met or the best chromosome is produced.

Problem Formulation:

The problem formulation is given to optimize the tracking angle based on the highest intensity location. End users could define X-Y tuning parameters, X-Y coefficients, generation number, mutation rate and crossover rate using the developed visual basic interface as shown in figure 4 before running genetic algorithm program and result will be shown in figure 5. The solar tracker XY axles will always move in random angles from minimum zero degree to maximum forty five degree in each positive or negative direction. In the real life practice, genetic algorithm will be designed and search for the highest intensity location and hence XY tracker will be pointed to that particular designated angle determined by the best fitness value as shown below:

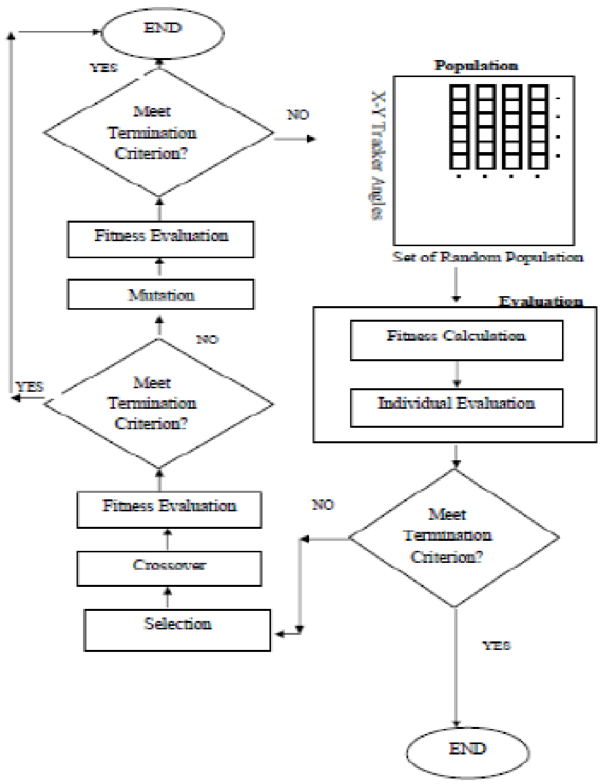


Fig. 3: Block Diagram of the Proposed Path Optimization (D.F.Fam, 2012)

$K(x_i) = (1/(\exp(A*(x_i)\alpha\hat{})))$, i = 0, 1 , 2 … i +1… n
$F(y_i) = (1/(\exp(C*(y_i)\beta\hat{})))$, i = 0, 1 , 2 … i +1… n (1)

Where,
xi = X tracker rotation degree (°)
yi = Y tracker rotation degree (°)
A = Controlling Parameter for X tracker
_ = Tuning Parameter for X tracker
C= Controlling Parameter for Y tracker
_ = Tuning Parameter for Y tracker
n = Number of generation

The fitness value obtained for each generation by X and Y axles are based on the fitness equation K(xi) and F(yi) as shown in the equation (1). The total fitness function G(zi) is expressed in Equation 2.

$G(z_i) = [K(x_i) * F(y_i)]$, i = 0, 1 , 2 … i +1… n (2)

Where, K(xi)= Fitness function for Tracker X
F(yi)= Fitness function for Tracker Y
G(zi)= Total fitness function for X-Y
n = Number of generation

Graphical User Interface:

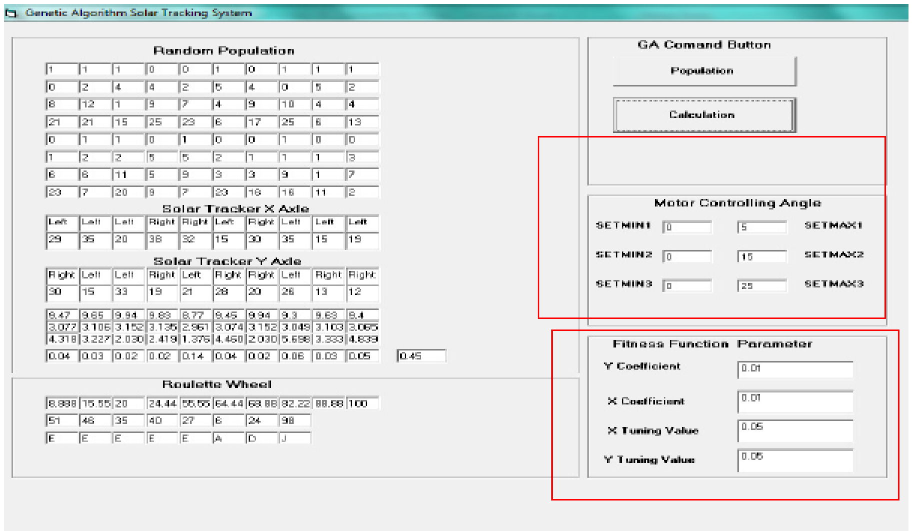


Fig. 4: GUI for Genetic Algorithm Processing

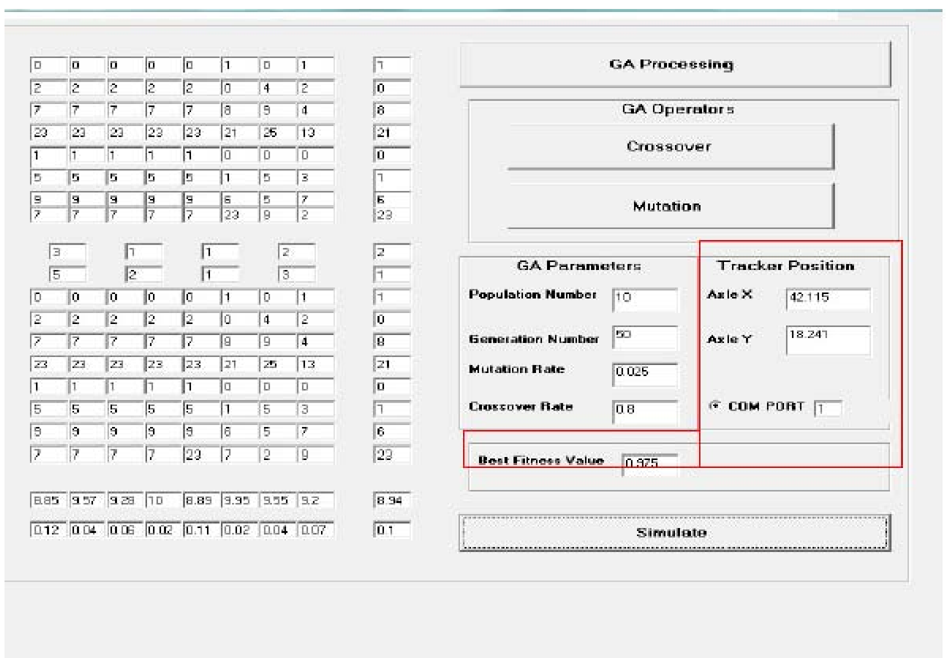


Fig. 5: Tracker XY Position and Best Fitness Value

The graphical user interface (GUI) shown in Figure 4 and Figure 5 are developed. The GUI consists of a Motor Controlling Angle Panel and Fitness Function Parameter Panel for users to insert the initial XY angles following the SetMin1, SetMin2 and SetMin3 column where the angle could be varied between zeros to forty five degree. Maximum forty five degree shows the maximum angle that X-Y axles could turn in each positive or negative direction. The Fitness Function Parameter Panel is used to set the XY coefficients and tuning values which are used to fine tune the fitness function in order to avoid premature convergence. Figure 4 shows the design of GA Parameter Panel used to define the population number, generation number, mutation rate and crossover rate. The length of the chromosomes is eight where the top four genes determine X angles whereas the bottom four genes determine Y angles. The first and fifth gene will determine the direction of XY where it could be positive or negative. All the generated angles are randomized according to the Setmin and Setmax angles where the maximum angle will be forty five degree. Once simulation button is clicked, the best fitness will be calculated and best angles for XY will be displayed according to the user defined GA parameters. This XY angles will be translated into motion controller movement to control the prototype which is used to locate the highest intensity location.

RESULTS AND DISCUSSION

In this section, there are comparison between different genetic operation which includes conventional genetic algorithm, genetic algorithm with crossover only and genetic algorithm with selective clonal mutation (SCM) operations.

The main objective of this comparison is to investigate which genetic operation produces best fitness value with the right XY axle's angles which indirectly proves the theoretical result.

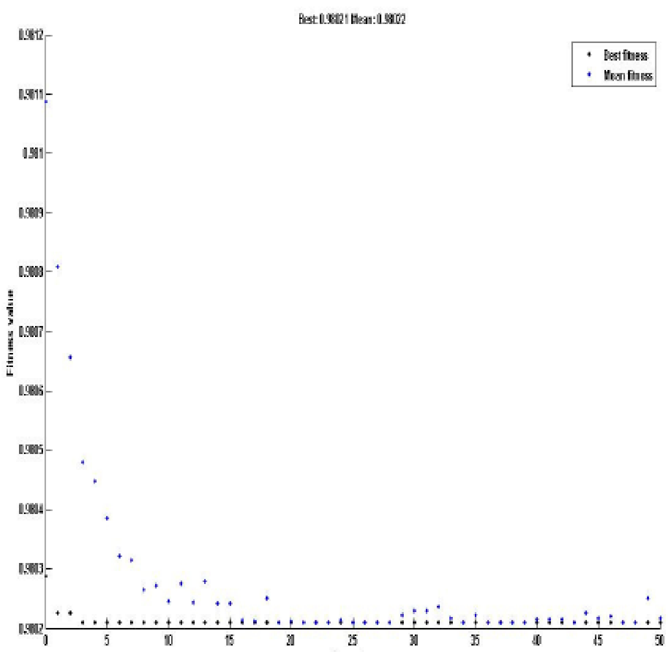
Conventional Genetic Algorithm:

Conventional Genetic Algorithm operation is the normal process of reaching global optimum via the determined population rate, number of generation, crossover rate and mutation rate.In this case, the GA parameter setting for this conventional genetic algorithm experiment is shown in table below The simulation has been carried out using the GA parameters as given in table 1 as below:

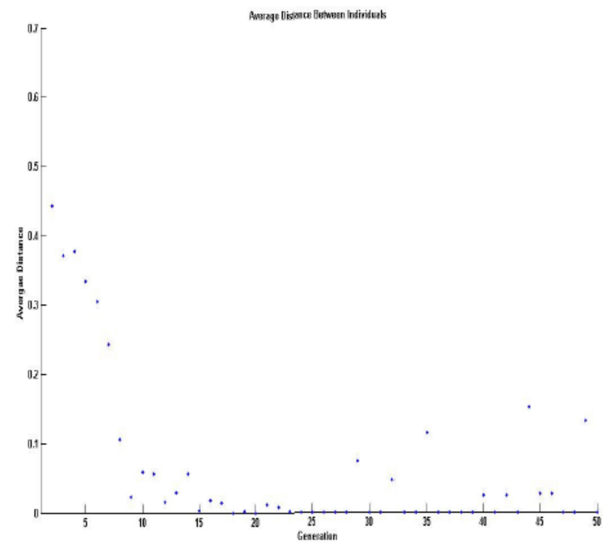
Table 1: GA Parameter Setting for Conventional GA

Simulation Parameter	Value
Maximum Generation	50
Population, *po*	50
Chromosome length	8
Selection Method	Roulette Wheel
Crossover Rate, *pc*	80%
Mutation Rate, *pm*	0.025
Mutation Point, *mp*	2
No. of Best Chromosomes Kept, *kb*	1
Crossover Type	Dynamic

Simulation below shows the result comparing these three different genetic operations:



Graph. 1: Fitness Value versus 50 generation



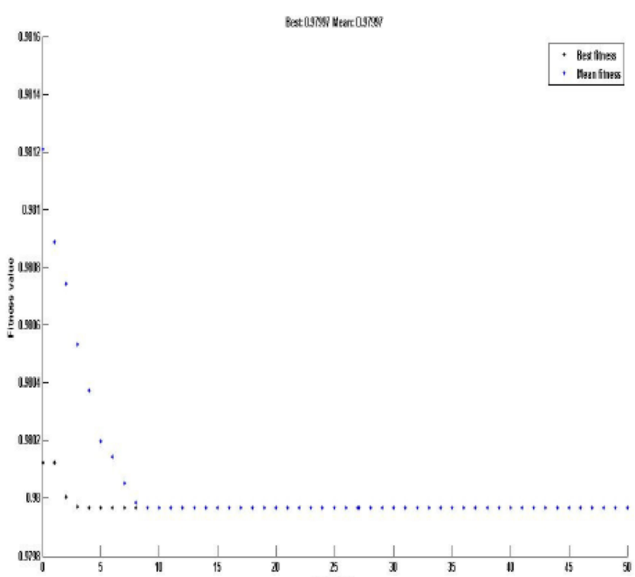
Graph. 2: Average distance between individuals versus 50 generation

Conventional Genetic Algorithm with Crossover:

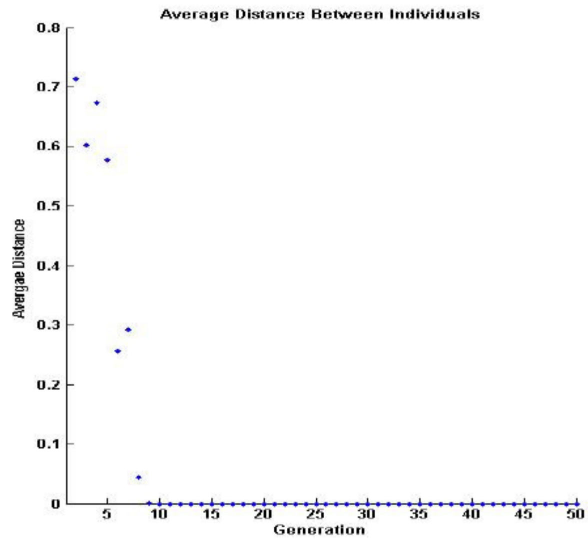
In this experiment, conventional genetic algorithm with crossover only is the operation where there is no mutation involved in the process. Theoretically, Mutation is an important operator to prevent the population from stagnating to any local optima. In other words, it is used to excite the convergence speed and avoid any trapping of local optima in the search space. The simulation has been carried out using the GA parameters as given in table 2:

Table 2: GA Parameter Setting for Conventional GA with Crossover only

Simulation Parameter	Value
Maximum Generation	50
Population, *po*	50
Chromosome length	8
Selection Method	Roulette Wheel
Crossover Rate, *pc*	80%
No. of Best Chromosomes Kept, *kb*	1
Crossover Type	Dynamic



Graph. 3: Fitness Value versus 50 generation



Graph. 4: Average distance between individuals versus 50 generation

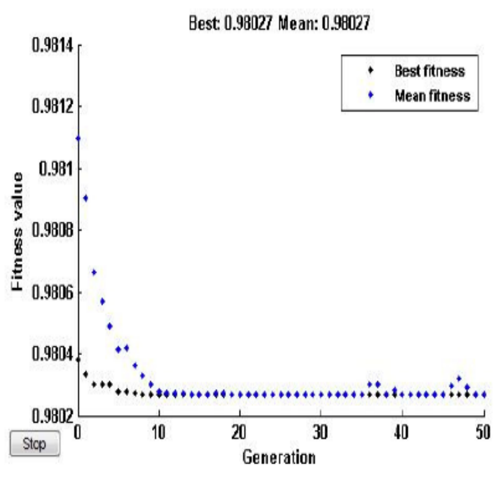
Conventional Genetic Algorithm with Selective Clonal Mutation:

GA with Selective Clonal Mutation (SCM) is a developed genetic operation where mutation will occur at the most significant part of chromosome in order to change the relevant bit and indirectly improves fitness value for the whole individual. This selective mutation is executed after cloning of the best chromosome has been completed for each generation. The best chromosome will be cloned with the same characteristic and brought forward to the next generation and restart the population process with another array of six randomly built chromosomes.

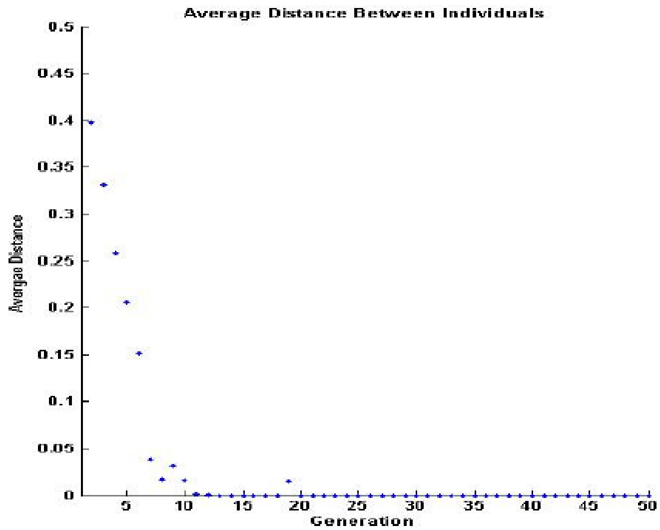
The simulation has been carried out using the GA parameters as given in table 3:

Table 3: GA Parameter Setting for Conventional GA with Selective Clonal Mutation(SCM)

Simulation Parameter	Value
Maximum Generation	50
Population, *po*	50
Chromosome length	8
Selection Method	Roulette Wheel
Crossover Rate, *pc*	80%
Mutation Rate, *pm*	0.025
Mutation Point, *mp*	2
Elitism Rate, *pe*	20%
Crossover Type	Dynamic



Graph. 5: Fitness Value versus 50 generation



Graph. 6: Average distance between individuals versus 50 generation

Table 4: Comparison of Fitness Value among GA Methods

GA Methods	Fitness Value	Axle X Angle (°)	Axle Y Angle (°)
Conventional Genetic Algorithm	0.98021	+3	+2
Conventional Genetic Algorithm with Crossover Only	0.97997	+6	+14
Conventional Genetic Algorithm with Selective Clonal Mutation (SCM)	0.98027	+2	+2

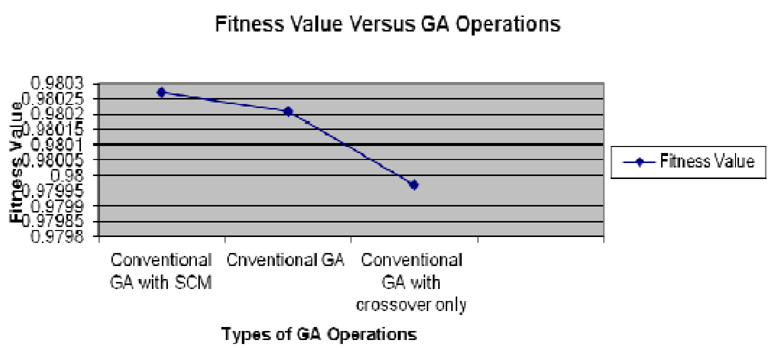


Fig. 6: Fitness Value Versus Variant Genetic Operations

Graph 5 indicates that convergence starts at 12th generation onwards where the best fitness value recorded is 0.98027. From graph 6, it could be concluded that distance between individual is minimal and starts converging from 12th generation onwards. Also, this developed selective clonal mutation will expedite the convergence process with the highest fitness value as compared to the other two GA methods which are conventional genetic algorithm and conventional genetic algorithm with crossover only operation . For GA with crossover, graph 4 indicates that convergence starts at 9th generation onwards where the best fitness value recorded is 0.97997. Graph 5 showed that trapping of local optima happens where earlier convergence occurs at 9th generation onwards. This is in compliance with the theoretical importance of mutation in an operation where premature convergence has happened in this experiment with an earlier convergence.However, conventional genetic algorithm simulates the result as appeared in graph 1 and 2 showed that Conventional GA approaches global optimum with higher fitness value as compared to GA with crossover operation. The comparison of these three methods with the Axles XY turning angles could be summarized in table 4 for better understanding and appreciation.Figure 6 shows the comparison of fitness values among these three variant genetic operations where it is observed that GA with SCM records the highest fitness value.

In theory, the best optimum fitness value corresponds to axles XY angles at 0 degree respectively.

Conclusion:

In this research, a simulator package has been developed and comparison between few other genetic operations has been carried out and best fitness value show that Genetic Algorithm with SCM performs better than Conventional GA and GA with Crossover operations. The proposed method improves search speed, good accuracy and approximate solution in the outdoor environment testing.

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Abbreviation:

GA, Genetic Algorithm; PV, Photovoltaic; GUI, Graphical User Interface; SCM, Selective Clonal Mutation

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