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Optimization of Light Switching Pattern on Large Scale using Genetic Algorithm

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***Abstract*—**Genetic Algorithm (GA) is an optimization technique that is based on the principle of natural evolution. It performs efficient search in global spaces to get an optimal solution. Optimization is carried out through natural exchange of genetic material between parents.GA has been widely used to solve various optimization problems. This paper analyses optimization of light patterns using genetic algorithm. Various parameters that affect optimization of light patterns have been designed. Depending upon the parameters an objective function is formulated that helps in the evaluation of optimal solution. The overall objective of the paper is to find out the optimal light pattern that meets the given constraints. An analysis of the effect of number of generations on the objective function is also performed. The algorithm satisfactorily results in optimization of light pattern in successive iterations.

Keywords — Constraints; Genetic algorithm; Light switching pattern; Objective function.

I. Introduction

Genetic Algorithm is an optimization technique that imitates the process of natural evolution. It is based on the Darwin theory of natural evolution "The survival of the fittest" [1], [2]. It is a powerful technique for inspecting a large solution space. The term Genetic algorithm was first coined by John Holland in 1960's [3]. The natural exchange of genetic material between parents results in optimization. Parents generates new off springs. The fitness of each individual is evaluated and the fittest individuals are allowed to survive. In computer world, strings of bits represent genetic material and procedure of natural selection is replaced by fitness function. Fitness function is used to determine the fitness of each individual solution [4].

Genetic algorithm is a heuristic search optimization technique that results in the optimization of the problem. Optimization is the process of finding the solution with best performance under the given constraints by maximizing the desired factors and minimizing the undesired ones. Optimization problems are the set of problems that provides the best results either by maximizing the profit or minimizing the effort. There are various optimization techniques such as Hill climbing which is based on local search. In Hill climbing technique a starting point is selected and successively the next closer points are selected and finally a goal point is achieved. Another optimization technique is Ant colony which imitates the behavior of ants. Initially, all ants search for food in arbitrary direction and once path is found than all ants move on that path. Simulated annealing is another optimization technique that yields the optimized results. Genetic algorithm is also an optimization technique that yields best optimized results.GA firstly selects the individual to produce next generation and then manipulates the selected individual to produce next generation [5]. Fitness of every possible solution is calculated. Genetic Algorithm differs from other optimization techniques in many ways such as GA searches parallely for solution which prevents it to stay in local solution, GA uses encoded chromosome rather than parameters itself and GA supports multi objectivity [6].

Genetic algorithm is widely used because it yields accurate results and has fast processing times in many applications such as in image processing [2], optimization of lightning design [7], home automation [8], electronic circuit designing, wireless sensors, training artificial neural networks, automated designs of room, multicriteria optimization problems [9], automation of street lights, traffic control systems and pedestrian crossing [10], security systems, clustering, computer automated designs, filtering and signal processing, power electronic designs [11], optimization of electrical distribution network [12] ,scheduling applications [13] and many more.

In recent years, it had been seen that lightning systems takes considerable amount of the global electricity consumption and also the total cost involved is very high. The total electricity consumption can be reduced by using different light patterns at different times. Light switching patterns are basically the different patterns of light that can be generated for different events. Mostly the light systems are fully operated at night time. But during night time there can be certain events depending upon which light is required. For example in a university during late night there is less requirement of light than at that time a different pattern of light can be adopted that may results in reduction of energy consumption. Optimization of light switching patterns not only reduces total energy consumption but also results in costs savings. Optimization of lightning systems can be achieved on large scale by developing switching patterns other than static light pattern developed by electrical wiring.

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In this paper, Genetic Algorithm has been applied to optimize light switching pattern. Various parameters are considered for this optimization problem including area of illumination of a pole, wattage of pole, priority of a pole and distribution of poles. The overall objective is to optimize all these parameters to generate a light pattern. Further, the formulation of cost function is done which is based on these parameters. The efficiency of genetic algorithm is greatly affected by objective function [14]. So, objective function is formulated very carefully. The effect of number of generations on objective function is also investigated.

The outline of the paper is as follows: Section II gives overview of genetic algorithm. Section III gives analysis of proposed methodology and highlights the technique in form of flowchart. Experimental results and performance evaluation are covered in Section IV. Conclusion of the paper is given in Section V.

II. Genetic Algorithm

Genetic algorithm is used to solve various optimization problems where solution space is very large. Any simple genetic algorithm iterates through five basic steps for finding an optimal solution [15]. The basic steps of genetic algorithm are shown in Fig. 1.

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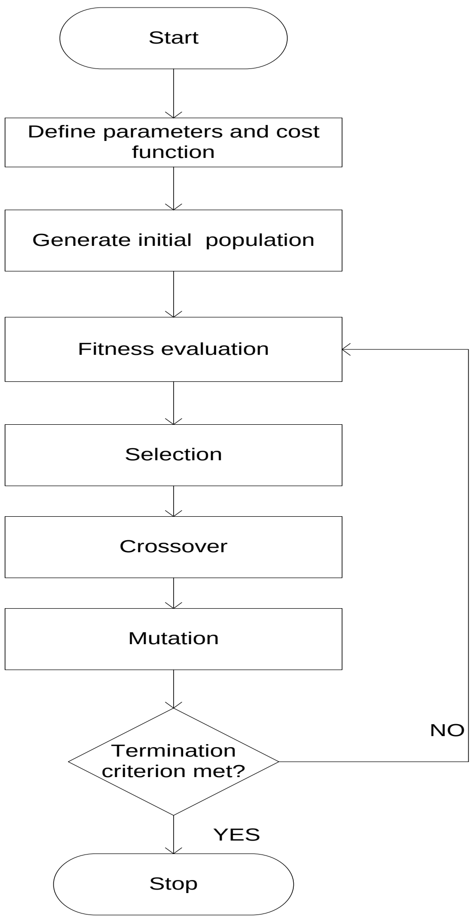

Fig. 1. GA Flowchart.

1. Initialization: To start with genetic algorithm an initial population of DNA must be generated. Each DNA represents solution to problem.
2. Evaluation: In this step each individual solution is evaluated. The evaluation is carried out using objective function. Objective function evaluates the fitness of each individual and determines the fittest individual.
3. Selection: This procedure includes selection of best individuals for crossover. The fitness value of all individuals is considered and the best individuals are selected as parents.
4. Crossover: After selection process, the selected parents are allowed to perform crossover to generate new individuals. The crossover is performed by selecting crossover point. The two parent chromosomes are crossed at crossover point.
5. Mutation: In order to prevent solutions to get trapped in local optima, mutation is performed. Mutation allows the solution to explore new solution space areas. Mutation allows the process to change some bits in the solution.

III. Proposed Methodology

In this paper, an attempt has been made to find the optimized light pattern using genetic algorithm. The proposed methodology is shown in the form of flow chart in Fig. 2. Following steps have been performed to achieve this objective.

A. *Parameter Initialization*

The objective function is governed by five parameters. These parameters are designed to be used in objective function for calculating the fitness of each solution. The five parameters are:

A_i: Area illuminated by i^{th} pole
TA: Total area illuminated by all poles
D_j: Sum of the difference between poles in j^{th} DNA
PR_i: Priority given to i^{th} pole
S_i: Status of i^{th} pole(1 for ON and 0 for OFF)
E_i: Energy consumed by i^{th} pole

B. *Population Initialization*

An initial population of random DNA's is generated. These DNA's are encoded in binary representation. Each DNA consists of genes g_1, g_2, g_3, g_4……..g_n. The value of a gene can be either 0 or 1 which represents the status of a pole. 0 represents the pole is in OFF state and 1 represent the pole is in ON state.

C. *Calculate Fitness function*

The fitness of each DNA is calculated using the fitness function F_j which is defined as:

$$F_j = \frac{\left(\sum_{i=1}^{n} A_i \div TA\right) * D_j * \sum_{i=1}^{n} PR_i}{\sum_{i=1}^{n} S_i * \sum_{i=1}^{n} E_i}$$

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Where: Fj is the fitness value of j^{th} DNA, Ai is the area illuminated by i^{th} pole, TA is the total area illuminated by all poles, D_j is the difference between consecutive poles in j^{th} DNA, PR_i priority given to i^{th} pole, S_i is the status of i^{th} pole and E_i is the energy consumed by i^{th} pole.

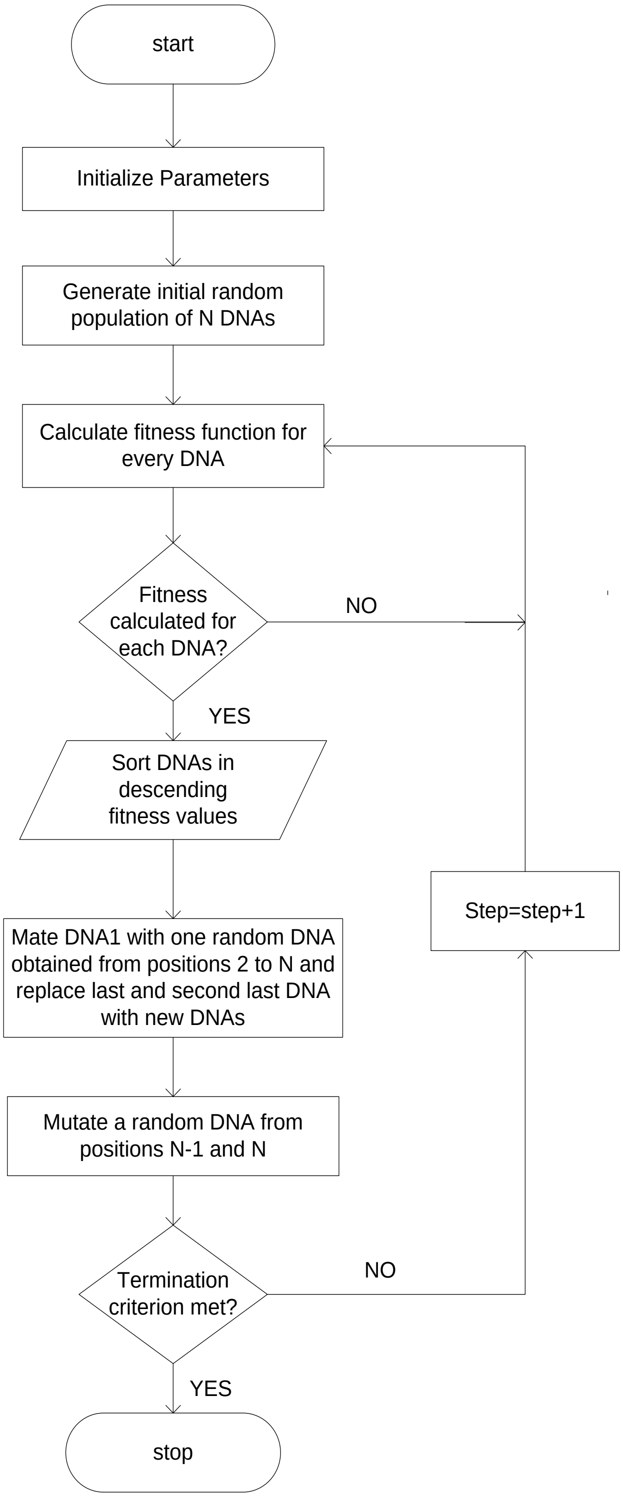

Fig. 2. Flow chart of proposed methodology.

D. Sort the fitness function F_j in descending order

The obtained value of fitness function for different DNA's is sorted in descending order.

E. Arrange the DNA's according to the sorted fitness function

The DNAs are then arranged according to their fitness values so that the first DNA represents the fittest DNA. This DNA population will now be used in further steps.

F. Mating

Mating is carried out between two DNAs. For mating two parent DNAs are required. The first DNA in the DNA population represents first parent $Parent_1$ and the second parent i.e. $Parent_2$ will be selected randomly from positions 2 to N. $Parent_1$ and $Parent_2$ are represented as:

$$Parent_1 = g_1, g_2, g_3 \ldots\ldots g_n$$

$$Parent_2 = g_1, g_2, g_3 \ldots\ldots g_n$$

A random position *i* for crossover is generated. This random position is also called crossover point. The DNAs are spliced and the new off springs generated are represented as:

$$O_1 = [Parent_1(1:i), Parent_2(i+1:n)]$$

$$O_2 = [Parent_2(1:i), Parent_1(i+1:n)]$$

O_1 represents first offspring and O_2 represent second off spring. Now, place the new off springs in place of DNA_{N-1} and DNA_N. The new DNA population consists of previous genes from DNA_1 to DNA_{N-3} and the last two DNAs are replaced by new off springs.

G. Mutation

Mutate a random DNA through position N-1 and N that represents new off springs. Any random position in selected DNA is generated and the bit position is mutated.

H. Go to step 2 and repeat

The algorithm is repeated to a number of generations that are predefined. When the stopping criterion is reached the algorithm terminates and the output obtained will be the final output.

In order to test and analyse the algorithm we have surveyed an actual location and data related to poles such as area of illumination of poles, wattage of poles and physical distribution of poles have been collected. Each pole is assigned a priority depending upon various factors like security, physical distribution etc. The value of the priority ranges from 10 to 1 i.e. from highest priority to lowest priority. The data is collected for 25 poles. For simplicity three types of poles are considered P1, P2 and P3 with area of illumination as10m, 20m and 30m respectively and wattage as 50W, 70W and 100W respectively. Genetic Algorithm is applied on the collected data to produce optimized pattern. Analysis of different parameters is done for different iterations. Thus, based on the data collected an optimal pattern had been generated using genetic algorithm.

IV. RESULTS AND DISCUSSION

An initial population of 10 DNA's is generated for setting up genetic algorithm. Each DNA consists of 25 genes that represent the number of poles. The investigations are carried for different iterations 1, 5, 10, 50, 100, 250, 500 and 1000.

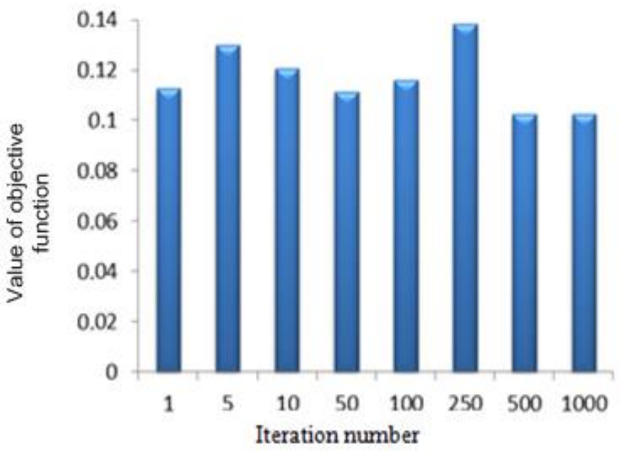

Fig. 3. Effect of successive iterations on objective function.

The value of the objective function at different iterations is shown in Fig. 3. The value of objective function becomes stable after 1000 generations. So, 1000 generations is considered as the stopping criterion.

TABLE I. Effect of successive iterations on objective function.

Iteration number	Value of objective function
1	0.1130
5	0.1301
10	0.1205
50	0.1116
100	0.1160
250	0.1386
500	0.1026
1000	0.1026

Table I shows the variation of objective function at different iterations. The value of objective function is evaluated from different parameters i.e. area covered, number of ON poles, total energy consumed and the sum of priorities of poles in pattern. As the initialization is random therefore, the generated output may vary. The objective function depends upon various factors. Some factors are maximizing the cost function such as percentage of area illuminated, sum of priorities in a pattern and the physical distribution of poles in a pattern and some are minimizing the cost function namely number of poles illuminated in a pattern and energy consumed by a pattern.

TABLE II. Effect of number of iterations on Parameters.

Iteration no.	Area (%)	No. of ON poles	Energy Efficiency (%)	Sum of priorities
1	50	9	54	60
5	56	9	50	63
10	60	10	46	66
50	66	11	40	70
100	63	11	42	71
250	63	10	44	74
500	73	14	30	83
1000	73	14	30	83

Table II represents value of different parameters at iterations 1, 5, 10, 50, 100, 250, 500 and 1000. For iteration 1 the percentage of area illuminated is 50 per cent which is quite low. The value of sum of priorities is 60 which indicate that the 9 bulbs that are illuminated are of low priority. Though, energy efficiency is 54 per cent but the pattern obtained contains poles with low priorities. For iteration number 5 the percentage of area illuminated increases to 56 per cent and the value of sum of priorities is 63 which is better than previous value. Thus, moving from iteration 5 to iteration 1000 the value of area and sum of priorities is increasing. For 1000 iteration number the area illuminated is 73 per cent and sum of priorities is 83. The values obtained indicate that 73 per cent of the area is illuminated with 14 poles and the energy efficiency is 30 per cent. The final pattern obtained consist most of the poles with high priority. So, the light pattern obtained illuminates all the poles with high priorities resulting in the optimization of poles required to illuminate the area and the energy efficiency. Fig. 4 shows the graphical representation of the value of parameters at different iterations.

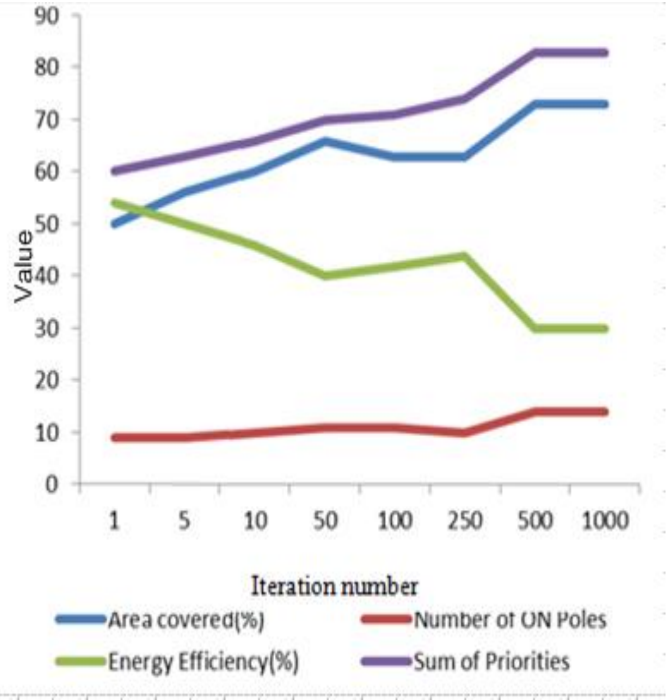

Fig. 4. Effect of successive iterations on Parameters.

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V. CONCLUSION

Genetic algorithm is a powerful optimization technique that generates best optimal solutions for various problems. In this paper a light pattern optimization problem is considered and investigations are carried out to generate the optimal light pattern. Designing of various parameters that affect the optimization of light pattern is performed. Five parameters are considered for optimization of light pattern namely area illuminated by pattern, number of ON poles in pattern, energy consumed by pattern, distribution of poles in a pattern and the priority given to a pole. To optimize these parameters an objective function is formulated. To cover all the aspects of the problem, objective function is carefully formulated. Experimentation is performed on an area with three different types of poles. Different types of poles have different wattage and tendency to illuminate the area. The algorithm is then implemented and the results are analysed for different number of generations. The results obtained are significant. The final pattern obtained results in illumination of area with less number of poles.

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