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Effect of Multiple Light Sources on the Alignment of Solar Panels using Genetic Algorithm

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Abstract- Solar energy may be considered as the ethical renewable energy source in our environment because it does not introduce any pollution. Solar panels are used for converting the solar energy into electrical energy. The most important factor for receiving maximum solar energy is the tracking system used for aligning the solar panel in the direction of the sun. Several techniques have been used in the literature for tracking the sun. Use of genetic algorithm has shown several advantages for different applications. The objective of this paper is to investigate the effect of multiple local maxima of light intensity on the estimation of global maxima using genetic algorithm for the alignment of solar panel. The distribution of light intensity was simulated using multiple Gaussians having different mean values and standard deviation. The analysis of the result showed that the proposed system is able to detect global maxims efficiently and therefore the system can be used for enhancing the tracking capabilities of the solar panels for automatic alignment.

***Keywords*—** Solar panel alignment, Genetic Algorithm, Solar tracking.

I. Introduction

Solar energy is one of the most commonly used energy, that attracts the people to itself due to its several advantages. The need of solar energy is rapidly increasing day by day but its efficiency is not to the mark. More advanced improved instruments and hardware parts are needed to achieve high efficiency for solar panels. The efficiency of solar panels is directly or indirectly dependent upon solar tracking techniques up to an extent. In this paper we are proposing a genetic solar tracking technique [1].

The emphasis to renewable energy was given in the start of 20th century due to the diminishing and limited resources of non-renewable energy sources. [2]. Solar energy may be considered as the most environment friendly source of energy as it does not create any disturbance or pollution in the nature. Solar energy generates the electric power without harassing the environment and it is free of cost on the earth. It has low running or working cost. The production of energy is without any moving part, hence, no friction losses. Installation is fast, long life, economical, clean, interruption less, and more reliable. On the negative side, its installation cost is high and efficiency is low [3].

A photovoltaic cell is the basic requirement for conversion of solar energy into electrical [1].Crystalline silicon is used for the construction of solar cells, the photon generated by the sun strikes it and move the valence band electrons to conduction band, leading to voltage generation across the cell electrodes [5]. Different techniques have been proposed by the researchers worldwide for alignment of solar panels to collect data from the sun and the same is set in six different solar panels arranged in six different directions with an angle of 45°. The position of the sun during the day time decides orientation of photovoltaic system and it is determined by azimuth and elevation angle. Elevation angle is the angle between direction of sunshine and the horizon [7]. Solar cells operates satisfactorily whenever the angle between the solar panels to the sun is less than 5°, otherwise PTZ are energized to update the panel orientation [4]. Maximum power point tracking controller captures maximum power from the photovoltaic module [1]. The output of the solar panels depends on the intensity of sun rays and angle of incidence. The angle can be changed after three month to improve output. Solar tracking plays an important role in solar energy generation.

Solar tracking decreases the angle of incidence, maximizing the output power. Either single or the dual axis tracking is used for improving the efficiency. Single axis tracks in one direction and the duel axis tracks in two directions by using single and two motors respectively. Single axis is economical but dual axis tracking is preferred over single axis as it depicts the change in path of sun efficiently [8].

Some researchers have proposed RST controller based optimal algorithm controlling the rotation of photovoltaic panel to follow the sun movement for maximum power point tracking [3]. Photoelectric detection GPS module, voltage current detection module single chip microcomputer communication module, clock circuit, Drive module also work for solar power tracking. Photovoltaic detection module, GPS module, voltage current detection module are connected with single chip microcomputer and output communication module contains clock circuit and drive module. GPS module provides the system latitude and longitude information [5]. There are two types of solar trackers. Passive solar tracker contains low boiling liquid. Sun vaporized the liquid attaining a new equilibrium by shifting the mass. Gravity is responsible to move the track and follow the sun. Active solar trackers are further classified into triangular, single axis, double axis tracking cells. A triangular solar cell consists of two solar cells kept in a triangular position w.r.t each other. The angle of incidence at rest is same for both the cases but as the sun

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changes its position, the angle of incidence makes more light to concentrate on one cell as compared to the other causing a voltage difference. Efficiency of triangular solar cell is more than fixed solar cell [6]. Genetic algorithm can be used to make the solar panels track the sun.

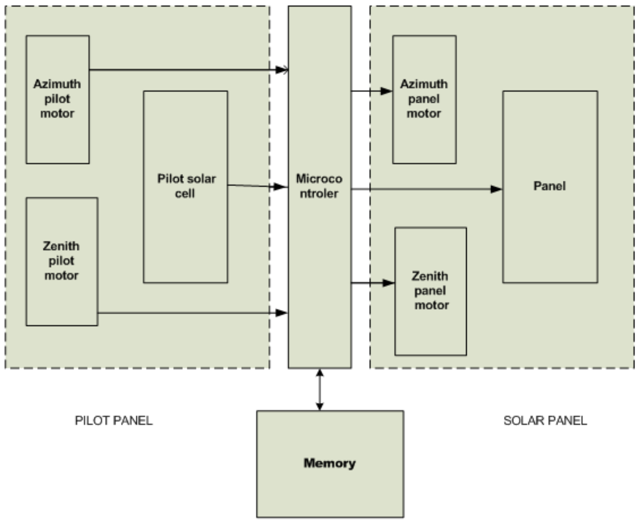

Fig. 1. Block diagram solar system

In the above Figure 1 there are two panel's pilot panel and solar panel. Each panel has three sub blocks pilot panel contain azimuth pilot motor, zenith pilot motor and pilot solar cell. Whereas solar panels contain azimuth panel motor, zenith panel motor and panel. There are two more blocks of microcontroller and memory. The change in solar position is reflected by the azimuth panel motor and zenith panel motor, azimuth panel motor is a motor which depicts the change in azimuth angle and zenith panel motor depicts change in zenith angle. Pilot solar cell reflects the change in solar energy. Microcontroller controls the whole panel working besides solar tracking. The track record of maxima is stored in memory, so as to use it next stage. The solar panel changes its position w.r.t the sun as per the azimuth and zenith angle.

Genetic Algorithm is based on the theory of natural selection process given by Charles Darwin. Optimization is the first step in the process of genetic algorithm and is executed through the exchange of genetic material. Out of a pack of ten DNAs, one best is chosen and is mated with the random DNA. In the algorithm, mate the DNAs by taking one best and one random DNA out of ten for the best result. The mated DNA is compared with the previous pair and the mutations are carried forward to achieve better results. The genetic algorithm is better as an error in the algorithm disturbs only a part or component of the algorithm or system and rest of the system stays perfect without being disturbed. It finds its application in optimizing the problem, signal processing robotic vision system, medical imaging object localization, stock market and variety of other field. The scope of the paper is limited to the case, where two intensity maxima are present with Gaussian distribution for simulating the intensity pattern Gaussian mixtures model (GMM) is used

II. METHODOLOGY

A Gaussian mixtures mode is a parametric probability density function represented as a weight sum of Gaussian component densities GMM are commonly used as a parametric model of the probability distribution of continues measurement.

A Gaussian mixture model is a weighted sum of 2 component Gaussian densities given by the equation.

$$p\left(\mathbf{x}\middle|\lambda\right)=\sum_{i=1}^{M}\omega_i g\left(\mathbf{x}\middle|\mu_i,\sum{}_i\right)$$

where $\mathbf{x}$ is a two dimensional continuous valued data vector, $i=1,\cdots,M$, ω_i the mixture weights, and $g\left(\mathbf{x}\middle|\mu_i,\Sigma_i\right)$ the component densities. Each component density is a *D*-variate Gaussian function of the form,

$$g\left(\mathbf{x}/\mu_i,\Sigma_i\right)=\frac{1}{(2\Pi)^{\frac{D}{2}}\left|\Sigma_i\right|^{\frac{1}{2}}}\exp\left\{-\frac{1}{2}(\mathbf{x}-\mu_i)^T\Sigma_i^{-1}(\mathbf{x}-\mu_i)\right\}$$

where $\mathbf{x}$ is a *D*-dimensional valued data vector with mean vector μ_i, and covariance matrix Σ_i. The mixture weight satisfy the constrain.

The complete Gaussian mixture model is parameterized by the mean vector, covariance matrix and weight from all component densities. These parameters are collectively represented by the matrix. $\sum_{i=1}^{M}\omega_i=1$

$$\lambda=\left\{\omega_i,\mu_i,\Sigma_i\right\}\ i=1,\cdots,M$$

In this paper, $\mathbf{x}$ is a two dimensional continuous valued data representing the solar intensities at different azimuth and zenith angles recorded using a pilot solar cell. Hence, Σ_i simply represents standard deviation. Proposed methodology is shown in Fig 2 in the form of a flow chart. The algorithm is explained as follows.

1. Capture intensity map of the sun

Capture the intensity map of the sun by using pilot solar cell at different azimuth and zenith angles. In the proposed system, two small dc motors are used for capturing the intensity at predefined angles. The captured data is stored in the microcontroller for further processing. The repetition cycle of the pilot system is kept around 1 s. The resolution of the angles is fixed at $5°$. In the present investigations, the intensity

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map is simulated using GMM as described above with two Gaussians.

2. Initialize population

An initial population of 10 DNAs with random parameters is generated. Continuous genetic algorithm is used for estimating the global maxima in the intensity map. Each random DNA has two genes representing azimuth and zenith angles of the global maxima.

3. Global maxima estimation

The global maxima are assumed to be obtained when the improvement in the cost function or fitness function ceases to change.

4. Calculate fitness function

The intensity map is assumed as the fitness function. For different values of the azimuth and zenith, the corresponding intensity is fetched from the output of the pilot cell stored in the microcontroller memory.

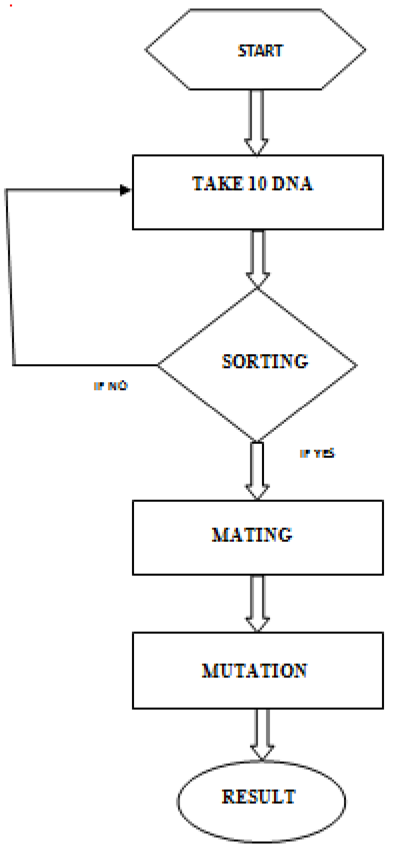

Fig. 2. Flow chart of genetic algorithm

5. Sort the fitness in descending order

The fitness function obtained for the population of DNAs is sorted in descending order.

6. Obtain DNAs corresponding to sorted fitness function

Sorted DNAs according to the fitness functions are obtained. The first DNA represents the best DNA.

7. Estimation of the sun position as zenith and azimuth

The position of the sun can be found by using azimuth and zenith for obtaining the best result, otherwise repeat the algorithm steps.

8. Mating

Best DNA is taken from the sorted list and allowed to mate with another DNA selected randomly from the remaining 9 DNAs.

9. Mutation

Mutation is a process in which the next generation population of chromosomes differs from the initial generation. Most probably the average fitness improves by this procedure and the best organism from the first generation are selected for breeding along with a small proportion of less fit function [9]. Here, a random change of azimuth or zenith angle by 1° is incorporated in the mutation.

III. RESULT AND DISCUSSIONS

The accuracy of the estimation of global maxima position from the given intensity map was investigated using genetic algorithm as described in the previous section. The intensity map shape depends upon the shape of the two Gaussians used in the formulation of resultant mixture densities. The two Gaussians are described by the mean positions, standard deviations, and weights. The effect of standard deviation of Gaussian II on the estimation of global maxima is shown in Fig 3. The standard deviation of first Gaussian is fixed at 20 and the standard deviation of second Gaussian is varied from 10 to 60. The weight of the first Gaussian is fixed at 10 and that of second Gaussian as 12. The mean position of the first Gaussian is fixed at [80, 40] and that of second Gaussian is [140, 240]. This information may be represented as

$$\lambda = \{10,[80,40],20;12,[140,240],10:60\}$$

The results of this investigation are listed in Table I and plotted in Fig. 3.

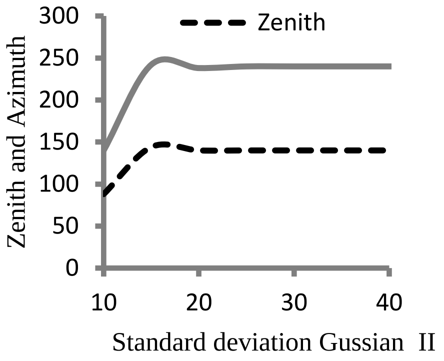

Fig.3. Effect of standard deviation of Gaussian I on the estimation of azimuth and zenith.

It is clear from Fig. 3 that for standard deviation of Gaussian II less than 20, the estimated azimuth and zenith angles are not correct. The accuracy stabilizes when the standard deviation goes above 20. The estimated angles coincide with the global maxima as indicated by Gaussian II having the mixture weight as 12 that is more than the mixture weight of Gaussian I that is 10.

TABEL I. Effect of standard deviation on the estimation of global maxima.

SD	Zenith	Azimuth
10	80	140
15	144	242
20	140	238
25	140	240
30	140	240
35	140	240
40	140	240
45	140	240
50	140	240
55	140	240
60	140	240

The effect of standard deviation of Gaussian I on the estimation of global maxima is shown in Fig 4. The standard deviation of second Gaussian is fixed at 30 and the standard deviation of second Gaussian is varied from 10 to 50. The weight of the first Gaussian is fixed at 10 and that of second Gaussian as 12. The mean position of the first Gaussian is fixed at [80, 40] and that of second Gaussian is [140, 240]. This information may be represented as

$$\lambda = \{10,[80,40],10:50;12,[140,240],30\}$$

The results are listed in Table II and plotted in Fig. 4.

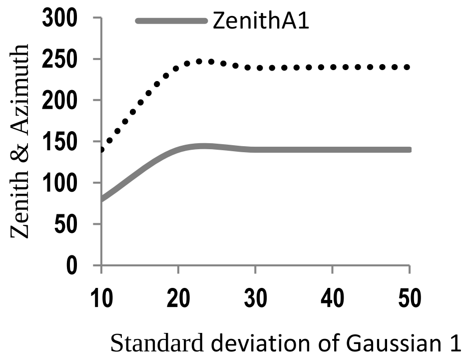

Fig.4. Graph Effect of standard deviation of Gaussian II on the estimation of azimuth and zenith.

For standard deviation of Gaussian I less than 20, the estimated azimuth and zenith angles are not correct. The accuracy stabilized when the standard deviation goes above 20. The estimated angles coincide with the global maxima as indicted by Gaussian I having the mixture weight as 12 that is more than the mixture weight of Gaussian I that is 10.

TABEL II. Effect of standard deviation on the estimation of global maxima.

SD	Zenith	Azimuth
10	80	140
20	140	240
30	140	239
40	140	240
50	140	240

IV. CONCLUSION

In the proposed technique, the multiple intensity maxima were simulated using Gaussian mixture model and the global maxima was estimated using genetic algorithm. The effect of standard deviations of the constituent Gaussians on accuracy of the estimation of the maxima was investigated by varying the standard deviation and keeping the other parameters constant. The investigation of the results showed that it is possible to find out the position of the global maxima provided the standard deviation of two Gaussians is maintained more than 30 and 40. The concept can be applied for the automatic alignment of the solar panels for maximum efficiency.

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