Identifying solar suitability of a region using Fuzzy logic

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Abstract-Identification of solar potential of a region is important so as to reduce the return period of investment and to identify untapped regions like Himalayas, Tibet, Southern Andes etc. which were not considered to be good enough to tap the energy economically. This paper encompasses the use of fuzzy with weighted functions in identifying the same. The proposed method used various environmental constraints like solar irradiance, solar hour, latitude etc. for identifying the potential. For the sake of simplicity we have used only three of the above mentioned parameters but these parameters can be scaled up to any level, as desired by the experts, and also weights assigned to every parameter can be varied as per requirements and application area.

Keywords- solar, potential, classification, fuzzy, weights, estimation, solar hour, latitude, irradiance

I. Introduction

Today, solar energy provides only a tiny bit of the electricity we use due to different technological and economic constraints. In the future, it could be a major source of energy. Scientists are looking for new ways to capture and use solar energy. This could be aided by a proper solar potential estimation technique which can beforehand determine the possible benefits of establishing a unit to harvest it. We used fuzzy logic for estimation of the same. We classified a region as a potential good, average or poor candidate for harvesting solar energy on the basis of three characteristics. In this paper estimation of potential is quite generic and not application specific. For particular applications we can consider the relevant parameters and assign them suitable weights accordingly.

II. Fuzzy Building Blocks

Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. The idea of fuzzy logic was first advanced by Dr. Lotfi Zadeh of the University of California at Berkeley in the 1960s. Dr. Zadeh was working on the problem of computer understanding of natural language. Natural language (like most other activities in life and indeed the universe) is not easily translated into the absolute terms of 0 and 1. (Whether everything is ultimately describable in binary terms is a philosophical question worth pursuing, but in practice much data we might want to feed a computer is in some state in between and so, frequently, are the results of computing.)

Fuzzy logic includes 0 and 1 as extreme cases of truth (or "the state of matters" or "fact") but also includes the various states of truth in between so that, for example, the result of a comparison between two things could be not "tall" or "short" but ".38 of tallness."

Fuzzy logic seems closer to the way our brains work. We aggregate data and form a number of partial truths which we aggregate further into higher truths which in turn, when certain thresholds are exceeded, cause certain further results such as motor reaction. A similar kind of process is used in artificial computer neural network and expert systems. It may help to see fuzzy logic as the way reasoning really works and binary or Boolean logic is simply a special case of it.

The essential characteristics of fuzzy logic as founded by Zadeh Lotfi are as follows.

- In fuzzy logic, exact reasoning is viewed as a limiting case of approximate reasoning.
- In fuzzy logic everything is a matter of degree.
- Any logical system can be fuzzified
- In fuzzy logic, knowledge is interpreted as a collection of elastic or, equivalently , fuzzy constraint on a collection of variables
- Inference is viewed as a process of propagation of elastic constraints.[4]

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III. Fuzzy in Identifying Solar Potential

We have used fuzzy logic in identifying solar potential of a region because fuzzy proved to be a good concept in providing the uncertainties which are present while we identify the solar potential of an area using the classical methods.

For identifying the solar potential we studied various factors affecting it like amount of solar radiation falling on a region per year,average sun hours for a region, latitude of the area, connectivity to road, slope of the terrain, population of the area, hydro graphic features, easy access to road and power grid, environmental constraints, land use etc.[5].For the sake of simplicity we focused on three of these parameters namely latitude, solar irradiance an area receive in a year and the average number of solar hours. For every constraint we made a fuzzy graph as depicted below:

A. Amount of Solar Irradiance an Area Receive:

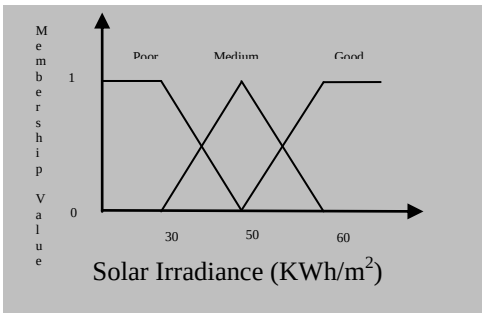


Fig1. Solar Irradiance

B. Duration of sunlight:

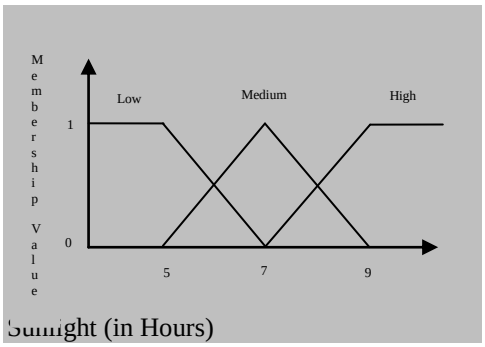


Fig 2: Sunlight

C. Latitude of area:

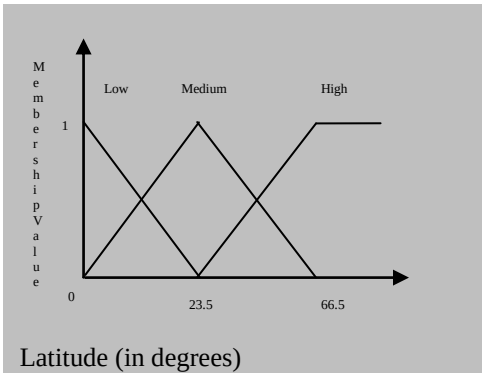


Fig 3. Latitude

Fig.1, 2, 3 define various categories for every graph as how the various input values can be classified. The membership functions were determined based on the graph for every possible category.

Weights were used to show the significance of each property. Weighting function assigns weight to participating constraints according to their importance in identifying solar potential in a particular region.

Suitability of a region was further divided into three categories namely good, average and poor based on following characteristics of each of them:Good potential: low latitude, high solar irradiation, high solar hours, etc.Average potential: medium latitude, medium solar irradiance, medium solar hours, etc.Poor potential: high latitude, poor solar irradiance, low solar hours, etc.

The membership value was determined for every category using:

$$\mu(x(p)) = \sum \lambda_i \, \mu_{Ai}(x_i(p)) \qquad (1)$$

Where $\sum \lambda_i = 1 \; \forall \; \lambda_i \geq 0$.[3]

Here we have assigned related weights (λ_i): 0.4 to Amount of solar irradiance, 0.4 to Duration of sunlight and 0.2 to Latitude.$\sum\lambda_i$=1 the sum of three is 1.

Final membership value (μ) is calculated by:

$$\mu = \max(\mu_{good}, \; \mu_{avg}, \; \mu_{poor}) \qquad (2)$$

IV. Advantages

A. Readily available data:

The data needed is freely available on internet and other records maintained by government hence there is no need to first do some special survey in gathering that data.

B. Fast to implement:

As the approach is quite simple it is also fast to implement it, hence no need to wait for long time for the results.

C. Computationally inexpensive:

Simplicity has also made it computationally inexpensive. You can estimate it with simple paper and pen provided you have the various input parameters required by the approach.

D. Scalable:

The approach used has an added advantage of being very much scalable. We can simply add various parameters with suitable weights as per the need of experts.

V. Example

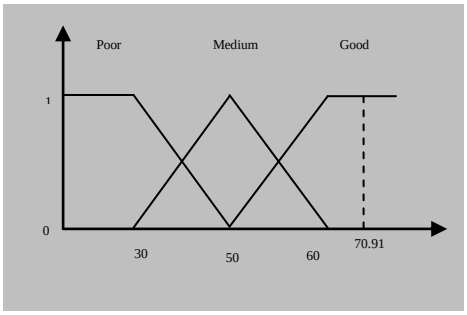
We are calculating the suitability for two cities i.e. Jaisalmer and London.
The data required is mentioned as below[1][2]:

Table 1. Relevent Data of Various Locations

City	Solar irradiation (kW h /m^2)	Sun light received (in hours)	Latitude (in degree)
Bogota, Colombia	57.03	4.16	57.03
Lhasa, Tibet	66.34	7.92	29.5
Montana, USA	40.38	7.25	47.5
Jaisalmer, India	70.91	9.33	26.92
London, UK	32.49	4.16	51.51
Antarctica	26.81	8.58	77.85
Gangtok, India	46.69	6.41	27.33
Anchorage, Alaska	32.02	5.66	61.19
Ulaanbaatar, Mongolia	48.87	7.75	47.93

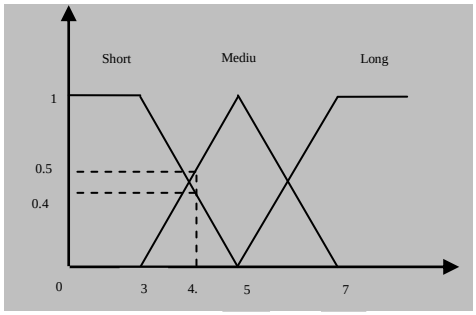
Membership graph for amount of solar irradiation:

A. Jaisalmer:



The value 70.91 belongs to only one category i.e. High and corresponding to it its membership grade is 1.

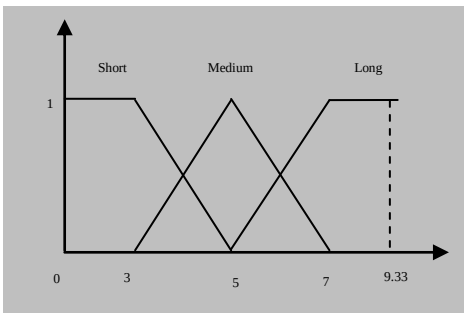
B. London:



The value 32.49 belongs to two categories i.e. low and medium, and corresponding to them their membership grades are 0.8755 and 0.1245 respectively.

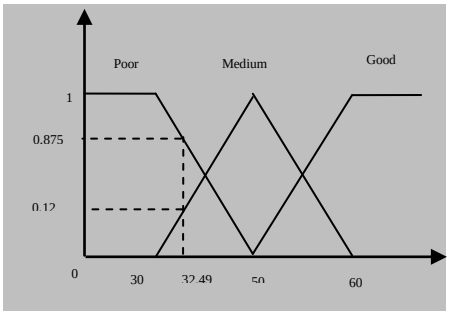
Membership graph for duration of sunlight received on average per day:

A. Jaisalmer:



The value 9.33 belongs to only one category i.e. High and corresponding to it its membership value is 1.

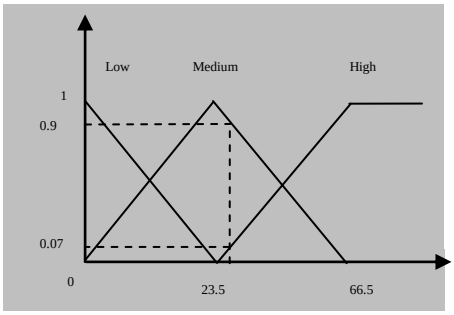
B. London:



The value 4.16 belongs to two categories i.e. short and medium, corresponding to them their membership grades are 0.42 and 0.58 respectively. Their equivalent membership value can be written as min(0.42,0.58)= 0.42

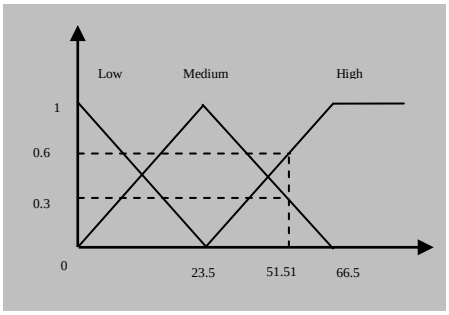
Membership graph for latitude of location is:

A. Jaisalmer:



The value 26.92 belongs to two categories i.e. medium and high, and corresponding to them their membership grades are 0.93 and 0.07 respectively.

B. London:



The value 51.51 belongs to two categories i.e. medium and high, and corresponding to them their membership grades are 0.348 and 0.65 respectively.

For a region membership values for the three classes can be shown as:

City	M.V(Good)	M.V(average)	M.V(poor)
Jaisalmer	0.80	0.18	0.014
London	0.00	0.34	0.66

Now the overall suitability of the area can be concluded as:

2. Jaisalmer: Good
3. London: Poor

VI. Conclusion:

Our approach could successfully identify the solar potential sources which were untapped till late like Bogota and Tibet.

City	M.V(Good)	M.V(average)	M.V(poor)
Bogota	0.40	0.156	0.4
Lhasa	0.58	0.368	0.052

Thus we can see membership value of both the cities is more in the class of"good" hence both are good candidates of harvesting solar energy.

By using fuzzy logic without rule base we have improved the scalability of our system in a way that more parameters can be subsequently added so as to better the chances of correctly classifying the region under observation. The approach of using weighted functions has also provided the flexibility of assigning varying degree of importance to the parameters.

Acknowledgment

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