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New Technique for Global Solar Radiation Prediction using Imperialist Competitive Algorithm

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ABSTRACT

In this paper, imperialist competitive algorithm as a computational method is implemented in MATLAB software to estimate monthly average daily global solar radiation on horizontal surface for some different climate cities of Iran. The experimental coefficients for Angstrom model have been calculated using imperialist competitive algorithm for all different climate cities and output data compared with the coefficients obtained by statistical regression techniques Results indicated that imperialist competitive algorithm is a suitable method to find the best experimental coefficients based on Angstrom model and its predicted coefficients have more accuracy than coefficients estimated by statistical regression techniques.

KEYWORDS: Imperialist competitive algorithm, Global solar radiation, Experimental coefficients, Statistical regression techniques.

INTRODUCTION

Global Solar Radiation (GSR) is the most important parameter for design and development of various solar energy systems [35]. Solar radiation data provide information on how much of the sun's energy strikes a surface at a region on earth, during a particular time period [3]. In developing countries, GSR measurements are usually made a few sites, because there are not many solar observation stations, as well as expensive equipments are required to achieve solar radiation quantity.

Many studies have been done by researchers to predict solar radiation using available geographic and meteorological parameters such as minimum and maximum temperature, solar radiation hours, relative moisture, elevation, rainfall, wind speed and etc [13, 17, 33]. These studies led to different models for solar radiation assessment. Angstrom (1924) proposed first empirical relation for GSR estimation based on applying sunshine hours for a long time [4]. Prescott (1940) modified Angstrom model and is known as Angstrom-Prescott model [23]. Page (1961) gave the coefficients of the Angstrom-Prescott model, which is believed to be applicable anyplace in the world [22]. Bahel and his colleagues (1987) developed a worldwide correlation based on radiation data and sunshine hours for 48 stations around the world, with different meteorological and geographical conditions [5]. A new time-dependent model was proposed in 1990[31]. Ninomiya (1994) considered the effect of rainy days [20]. Burari and his colleagues (2001) developed a model for estimation of global solar radiation in Bauchi with special regression coefficients [7]. Chandel and his colleagues (2005) proposed a model based on temperature [9]. Other multi parameter models were presented by Trabea and colleagues [29], Ojosu and Komolafe [21] and Garg and Garg [12].

Due to complex nature of proposed models, robust solution techniques are required to solve the problem. These techniques can be divided in two general groups: Statistical Regression Techniques (SRTs) and intelligent methods. In the statistical regression literatures group, Zabara [32], Samuel [25], Newland [19], Yazdanpanah [30], Sivamadhavi and Samuel [26] tried to estimate GSR by regression techniques based on mentioned above or new proposed models for different places in the world. In the intelligent literatures category, Mellit and his colleagues (2005) offered an artificial neural network model for prediction solar radiation data with application for sizing stand-alone photovoltaic power system [2]. Other studies of this category includes: a fuzzy model for the prediction of solar radiation [24], genetic algorithm optimization of wavelet neural network for daily solar radiation prediction [14], and a new model for predicting GSR using Particle Swarm Optimization [17].

This study proposes a new technique based on Imperialist competitive algorithm to predict the monthly average daily global solar radiation on horizontal surface by estimation the experimental coefficients of Angstrom model. The proposed method is evaluated by testing it on four different climate cities of Iran and its performance to determine the experimental coefficients has been investigated using the introduced statistical indicator, absolute fraction of variance.

The remainder of this paper is organized in the following manner: In section 2, concept of imperialist competitive algorithm and overall its progress is reviewed. In Section 3, Angstrom model and process to find the

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best experimental coefficients is investigated based on imperialist competitive algorithm implemented in MATLAB software, comparisons between ICA and SRT results, as well as ICA and real measured data are presented in section 4. Finally, section 5 contains a summary of the results and conclusions.

IMPERIALIST COMPETITIVE ALGORITHM

Imperialist Competitive Algorithm (ICA) is a computational method that is used to solve the different types of optimization problems [1, 34]. This algorithm is based on assimilation and competition policies. Imperialist countries are trying to attract other colonies to increase power of their governments and eventually dominate on the whole world (at this time the issue has been solved).

ICA overall progress

This algorithm begins with a random initial population which they are called countries. Some of the best elements of the population are selected as imperialists and other are considered as colony countries. Imperialists depending on power which varies inversely with the cost function will attract the colonies by a particular process [1].

Figure 1 shows the movement of colonies toward the imperialist. The imperialist countries attract the colonies according to language and culture parameters. In this figure, the distance between the colony and the imperialist is shown by d. x and θ are random numbers with uniform distributions which are defined by equation 1.

$$x \approx U(0, \beta \times d), \theta \approx U(-\gamma, \gamma) \qquad (1)$$

$\beta > 1$, makes different directions to the imperialist. In equation 1, γ is a optional parameter that by increasing it, the search space around the imperialists will be larger and its reduction lead to colonies move nearby the interface vector between the colony and imperialist. In most implementations, $\pi/4$ and 2 values are suitable choices for γ and β parameters respectively [11].

Imperialist competitive algorithm progress is described as following steps:

a. Define an objective function.
b. Generation some random solutions in the search space and create initial empires.
c. Assimilation: colonies move towards imperialists from different directions.
d. Revolution: Random changes occur in the characteristics of some countries.
e. Exchange position between a colony and Imperialist. A colony with a better position than an imperialist has the chance to take the control of empire by replacing the existing imperialist.
f. Imperialistic competition: All imperialists compete to take possession of colonies from each other.
g. Eliminate the powerless empires. Weak empires lose their power gradually and finally, they will be eliminated.
h. Check the stopping criteria: if the stop condition is satisfied, then stop, else go to step *c*.

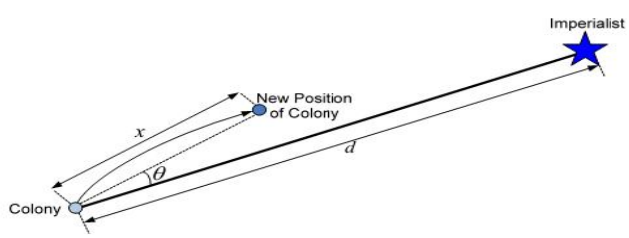

Fig1. Colony movement towards imperialist

PROPOSED METHODOLOGY

In this paper, Imperialist competitive algorithm is applied to estimate monthly average daily GSR on horizontal surface for 4 different climate cities of Iran. All required data such as minimum and maximum temperature, solar radiation hours, relative moisture, elevation and etc, have been provided by Iran Meteorological Office. Table 1 presents information of cities considered in this study. In this table, information of longitude, latitude, altitude and all data collected ranges have been given for all 4 cities.

TABLE 1
INFORMATION OF CONSIDERED CITIES

City	Longitude° E	Latitude ° N	Altitude(m)	Data type 1 ranges	Data type 2 ranges
Bojnoord	57.2	37.47	1112.0	1984-2001	2002-2005
Hamadan	48.53	34.87	1741.5	1985-2001	2002-2005
Mashhad	59.63	36.27	999.2	1980-2000	2001-2003
Tbriz	46.28	38.08	1361.0	1987-2001	2002-2005

Collected data contains installation and validation parts, that they are called data type 1 and date type 2 respectively. Imperialist competitive algorithm based on Angstrom sunshine model is implemented in (MATLAB 20011a) software for all four cities to find the experimental coefficients according to the real data. Figure 2 shows the process which is required to determine experimental coefficients of Angstrom model using ICA. Angstrom sunshine model is presented by equation 2[4, 23].

$$\frac{H}{H_O} = A + B(\frac{S}{S_O}) \qquad (2)$$

Where H is the monthly average radiation on surface, H_O is the monthly average radiation in absence of atmosphere, S is the monthly average Sunshine hours, S_O is the monthly average of daytime at a special location , *a* and *b* are the regression coefficients (To study about how to calculate H_O and S_O , refer to[27]).

RESULTS AND DISCUSSION

For verification purposes, two set of data is utilized from Iran Meteorological Office. Table 1 indicates the details of both data collection ranges. As can be seen in table 1, the data collected ranges included in this study are great enough to achieve meaningful results. $\frac{H}{H_O}$ and $\frac{S}{S_O}$ parameters have been measured separately for both data types. $\frac{H}{H_O}$ and $\frac{S}{S_O}$ measured values are shown in figure 3 for all considered cities. Data type1 is applied to imperialist competitive algorithm implemented in MATLAB software to explore the experimental coefficients based on method which is described as a flowchart in figure 2. As can be seen in Figure 2, the data type 1 of each city will be applied separately to the algorithm. The data are divided in two types of colonial and imperialist countries and followed competitive algorithm process as described in Part II. After setting the exit condition of algorithm, the obtained results are compared with the data type 2 for each city to ensure the sufficient accuracy of the answers. If the answers are not close to the real values, this process is repeated until a proper convergence will be obtained between proposed algorithm results and data type 2.

Optimal coefficients are calculated based on minimization a cost function that is defined as equation 3.

$$C = \sum_{i=1}^{n}[(S_i - R_i)^2] \qquad (3),$$

Where, $S_i = (\frac{H}{H_O})real_i$ and $R_i = (\frac{H}{H_O})suggested_i$ are the real and forecasted monthly average daily GSR falling on a horizontal surface respectively, and n is the total observations.

After each program running, coefficients obtained by ICA, will be compared with the data type 2 as long as a sufficient agreement can be observed between obtained coefficients and data type2 values. The performance of ICA is satisfactory using the parameter values have been shown in table 2, for all cities.

TABLE 2
ICA RESULTANT PARAMETERS

Number of population	200
Number of imperialists	20
Number of colonies	180
Revolution rate	0.3
Iterations	220

The accuracy of ICA suggested coefficients is investigated by using introduced statistical indicator, absolute fraction of variance (R^2). R^2 is described by the following equation:

$$R^2 = 1 - \frac{\sum_{i=1}^{n}(X_i - R_i)^2}{\sum_{i=1}^{n}(R_i)^2} \qquad (4)$$

(R_i, S_i and n have been defined in equation 3).

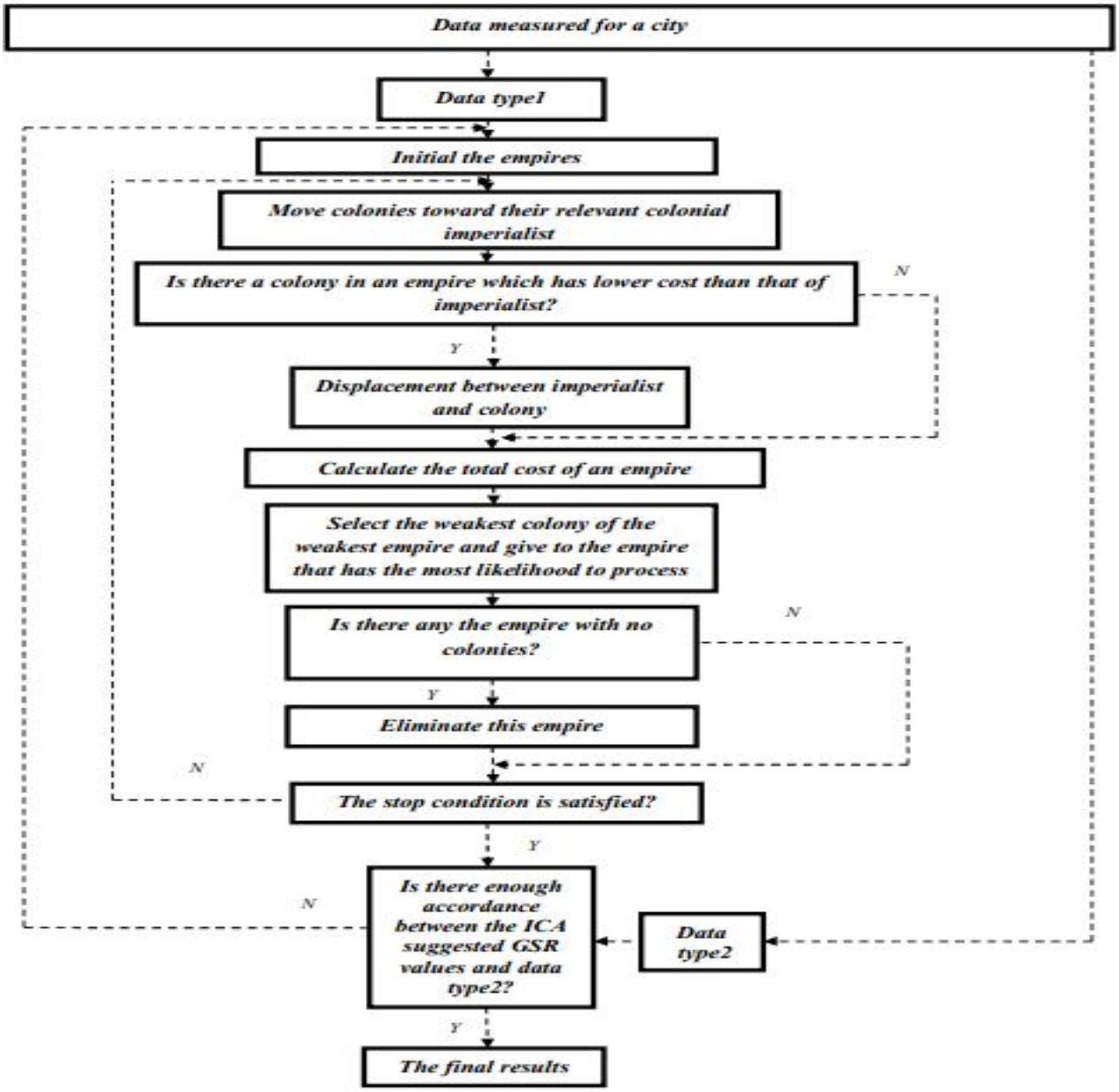

Fig2. Process of determining experimental coefficients using ICA

Table 3 includes A and B suggested experimental coefficients based on Angstrom model using imperialist competitive algorithm, as well as accuracy evaluation of ICA proposed coefficients through R^2 indicator for all four cities separately. As can be seen from table 3, Hamadan and Mashhad cities by R^2 =0.991 and 0.972 have forecasted coefficients with maximum and minimum accuracy between all cities, respectively.

Since all suggested experimental coefficients for all cities of table 3 have R^2 values more than o.97, so ICA results are in good agreement with the real measured data.

The experimental coefficients obtained by ICA, SRT and their R^2 values have been compared for all locations, and related results are presented in table 4. As can be seen from table 4, The ICA suggested experimental coefficients have more accuracy compared with SRT results.

TABLE 3
ICA SUGGESTED EXPERIMENTAL COEFFICIENTS RELATED ABSOLUTE FRACTION OF VARIANCES

City	A	B	R^2
Bojnnoord	0.354	0.358	0.988
Hamadan	0.379	0.243	0.991
Mashhad	0.346	0.298	0.972
Tabriz	0.341	0.417	0.980

TABLE 4
COMPARISONS BETWEEN ICA AND SRT RESULTS

City name	Technique	A	B	R^2
Bojnoord	ICA	0.354	0.358	0.988
	SRT	0.343	0.368	0.986
Hamadan	ICA	0.379	0.243	0.991
	SRT	0.382	0.245	0.966
Mashhad	ICA	0.346	0.298	0.972
	SRT	0.322	0.311	0.914
Tabriz	ICA	0.341	0.417	0.980
	SRT	0.338	0.421	0.971

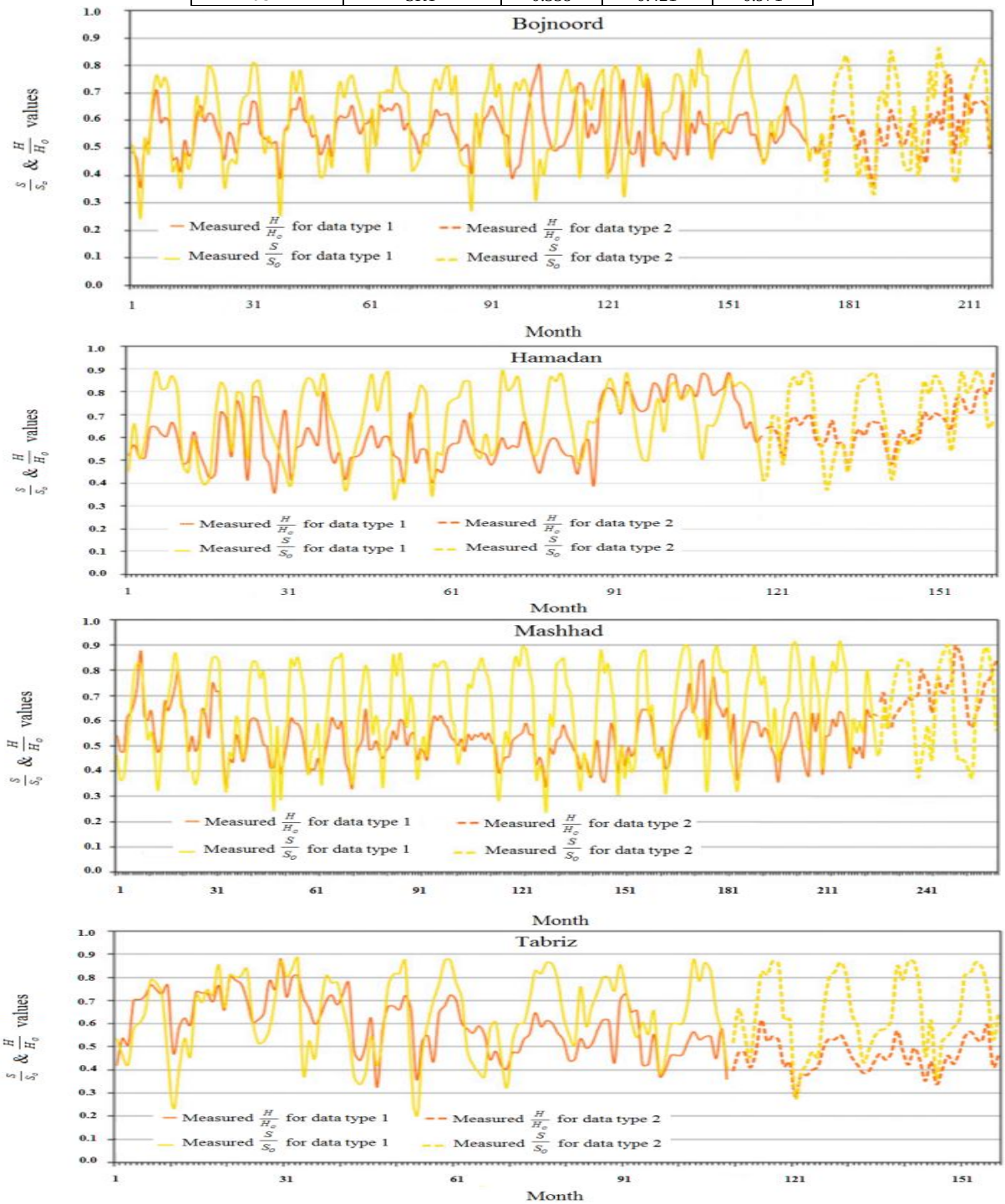

Fig3. The measured H/H_0 and S/S_0 values for both data types in Bojnoord, Hamadan, Mashhad and Tabriz cities

CONCLUSION

This study proposed a new technique based on Imperialist competitive algorithm implemented in MATLAB software to predict the monthly average daily global solar radiation on horizontal surface for 4 different climate cities in Iran. The performance of imperialist competitive algorithm to determine the experimental coefficients of Angstrom model has been investigated using introduced statistical indicator, absolute fraction of variance. Since all obtained coefficients by imperialist competitive algorithm have absolute fraction of variance values more than 0.97, so this algorithm performance is confirmed to estimate global solar radiation on horizontal surface for all four cities. Also a comparison is accomplished between imperialist competitive algorithm proposed results and experimental coefficients obtained by statistical regression techniques for all locations. The comparison results showed that proposed experimental coefficients by the new method have more accuracy compared with the statistical regression techniques results.

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