Potential of adaptive neuro-fuzzy system for prediction of daily global solar radiation by day of the year

Kasra Mohammadi\textsuperscript{a,}, Shahaboddin Shamshirband\textsuperscript{b,*}, Chong Wen Tong\textsuperscript{c}, Khubaib Amjad Alam\textsuperscript{d}, Dalibor Petkovič\textsuperscript{e}

\textsuperscript{a}Faculty of Mechanical Engineering, University of Kashan, Kashan, Iran
\textsuperscript{b}Department of Computer System and Technology, Faculty of Computer Science and Information Technology, University of Malaya, 50603 Kuala Lumpur, Malaysia
\textsuperscript{c}Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
\textsuperscript{d}Department of Software Engineering, Faculty of Computer Science and Information Technology, University of Malaya, 50603 Kuala Lumpur, Malaysia
\textsuperscript{e}University of Niš, Faculty of Mechanical Engineering, Department for Mechatronics and Control, Aleksandra Medvedeva 14, 18000 Niš, Serbia

\textbf{ARTICLE INFO}

Article history:
Received 8 October 2014
Accepted 10 January 2015

\textbf{Keywords:}
Global solar radiation estimation
ANFIS technique
Day of year
Empirical models

\textbf{ABSTRACT}

Estimating the horizontal global solar radiation by day of the year ($R_{\text{day}}$) is particularly appealing since there is no need to any specific meteorological input data or even pre-calculation analysis. In this study, an intelligent optimization scheme based upon the adaptive neuro-fuzzy inference system (ANFIS) was applied to develop a model for estimation of daily horizontal global solar radiation using $R_{\text{day}}$ as the only input. The chief goal was identifying the suitability of ANFIS technique for this aim. Long-term measured data for Iranian city of Tabass was used to train and test the ANFIS model. The statistical results verified that the ANFIS model provides accurate and reliable predictions. Making comparisons with the predictions of six day of the year-based empirical models revealed the superiority of ANFIS model. For the ANFIS model, the mean absolute percentage error, mean absolute bias error, root mean square error and correlation coefficient were 3.9569%, 0.6911 MJ/m\textsuperscript{2}, 0.8917 MJ/m\textsuperscript{2} and 0.9908, respectively. Also, the daily bias errors between the ANFIS predictions and measured data fell in the favorable range of −3 to 3 MJ/m\textsuperscript{2}. In a nutshell, the survey results highly encouraged the application of ANFIS to estimate daily horizontal global solar radiation using only $R_{\text{day}}$.

\copyright 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Solar energy has been recognized in recent years as a proper alternative energy source owing to its unique characteristics which is free, environmentally friendly and broadly accessible in most locations across the globe [1,2]. In this regard, countries are performing tremendous efforts to assign a high priority to solar energy harnessing. Nevertheless, prior to devoting any attempt for each project, accessibility to reliable and accurate solar radiation information is highly essential for experts to install and design solar energy technologies effectively [3–6]. In fact, lack of precise information on solar radiation has been a fundamental limitation in development of solar energy applications. Therefore, over the previous decades, developing suitable models and techniques to estimate the horizontal global solar radiation has been the primary objective of many researches. For this aim, a considerable number of meteorological and geographical parameters have been utilized as input elements to estimate the horizontal global solar radiation via proposed models [7–19]. Basically, despite the great history of above-mentioned empirical models as well as their relatively accurate global solar radiation estimates for many locations, the major deficiency of such models is their dependency to one or more certain meteorological or geographical input parameters.

In addition to the above-mentioned models, developing and establishing some simple models to estimate daily horizontal global solar radiation based upon day of the year as the sole input element have been the focus of some investigations in recent years [20–26]. These day of the year-based (DVB) models enjoy two significant advantages. The first merit of them is that they can be conveniently applied as there is no need to use any specific input element. Furthermore, unlike the other empirical models, applying the DVB models does not require any pre-calculation analysis such as calculating some parameters including the maximum possible sunshine duration or extraterrestrial solar radiation.

In the realm of DVB models, a sine wave model was proposed by Bulut and Büyükalaca [20] to estimate the global solar radiation on
Adaptive neuro-fuzzy inferences system (ANFIS) is a type of soft computing methodologies employed by some researchers to estimate daily global solar radiation. It is a hybrid intelligent system that merges technique of the learning power of the ANNs with the knowledge representation of fuzzy logic. The main advantages of the ANFIS model are computationally efficiency and adaptability. The ANFIS model can be embedded as a module for estimating solar radiation data.

Mellit et al. [37] used ANFIS techniques to model the global solar radiation based upon sunshine duration and air temperature in Algeria. Moghaddamnia et al. [38] provided a comparison between different nonlinear models such as ANFIS to estimate the daily global solar radiation using extraterrestrial radiation, precipitation, air temperature and wind speed in Brue catchment, UK. Mohanty [39] presented an ANFIS-based model to predict monthly mean global solar radiation in Bhubaneswar, India. The ANFIS predictions were compared with Angström-Prescott model and some other intelligent approaches. Mohanty et al. [40] carried out a comparative study between three soft computing methodologies including ANFIS, Multi layer Perceptron (MLP) and Radial Basis Function (RBF) for prediction of monthly mean global solar radiation in three locations of India. Güçlü et al. [41] performed an investigation to apply ANFIS model, Angström-Prescott model and some proposed models named dependency models for estimating the global solar radiation in Turkey using sunshine duration as input. Piri and Kisi [42] employed ANFIS technique and some more techniques to predict global solar radiation in two Iranian cities based on sunshine hour, air temperature and relative humidity as input parameters.

Inspection of published articles in the realm of solar radiation prediction reveals that no study has been devoted to estimate global solar radiation by day of the year via any artificial and computational intelligence techniques such as ANFIS. Consequently, in this study, an application of adaptive neuro-fuzzy inferences system (ANFIS) is proposed to develop a soft computing-based model for estimation of daily horizontal global solar radiation by day of the year as a single input. The prime aim is evaluating the sufficiency of ANFIS scheme to provide a convenient way for accurately predicting the daily global solar radiation using only one simple input. For this purpose, long-term measured daily horizontal global solar radiation for city of Tabass situated in a sunny region of Iran has been used. The potential of developed ANFIS model is further appraised and verified by providing statistical comparisons between its predictions with those of six DYB models established in a previous study.

2. Study area and data set

In this study, the long-term measured daily global solar radiation on a horizontal surface (H) for city of Tabass was utilized. Tabass is located in South-Khorasan province with geographical location of 33°36’N and 56°55’E and elevation of 711 m above the sea level. Tabass climate is characterized with hot summers and rare snowfall in the winters [43]. Also, based upon the Köppen climate classification, Tabass is classified as hot desert climate.
classification its climate is categorized as BWh, which relates to arid desert hot [44]. For Tabass, the monthly average temperature varies between 7.7 °C and 34.8 °C, also the yearly average is 21.7 °C. The monthly average relative humidity varies from 20% to 57% with annual average of 33%. According to the long-term averaged data, the daily horizontal global solar radiation varies in the range of 9.71–29.85 MJ/m² throughout the year with the yearly average of 20.14 MJ/m². These values show that Tabass enjoys remarkable solar energy potentials which can be harnessed efficiently via various technologies. Thus, accurate prediction of global solar radiation for this region would be highly essential and demanding for solar engineers and experts. The daily global solar radiation data set provided by Iranian Meteorological Organization (IMO) for Tabass contain 132 months measured data from January 1988 to December 1998. The precision of the developed models to estimate the solar radiation is chiefly influenced by the quality of raw data utilized. The data cleaning procedure generally aims at enhancing the data quality by checking and filtering them from any uncertainty or erroneous. In horizontal global solar radiation data used in this study, there were some missing and also unreliable values possibly due to instruments’ malfunction. To overcome this issue and enhance the quality of raw data, the following procedure was applied in present study:

1. To identify the incorrect global solar radiation values, the daily clearness index \(k_d\) was computed and the values which were out of range of 0.015 < \(k_d\) < 1 were eliminated [45].

2. If in a month there were a few missing or unreliable global solar radiation values they were substituted by proper values obtained using interpolation [45].

The available data for this study are divided into two parts of training and testing data sets. Data set for the period of 1988–1994 is utilized for training phase. While the data sets for the period of 1995–1998 is used for testing phase. To achieve further consistency in the provided data sets and more accuracy in the predictions of the ANFIS model, each data set was averaged over the whole related years. In fact, the system is trained using one year averaged daily data set obtained from the period of 1988–1994. Also, it is tested based upon one year averaged daily data set achieved from the period of 1995–1998.

Fig. 1 illustrates the daily averaged measured global solar radiation on a horizontal surface for Tabass used for training and testing phases. It is evident that global solar radiation values of training and testing phases are consistent with each other such that there are minor differences between the values of each data set for most days of the year. This proves that despite the intermediate and unpredicted natures of global solar radiation in each specific day within various years, the solar radiation values for city Tabass are not associated with high fluctuation from training to testing data set.

3. Adaptive neuro-fuzzy application

3.1. Neuro-fuzzy computing

Soft computing is an innovative approach in the construction of systems that are computationally intelligent which possess humanlike expertise within a specific domain. These systems are supposed to adapt in changing environments, learn to do better and explain their decision making process. It is usually more beneficial to employ several computing methods in a synergistic way rather than building a system based exclusively on one technique only. This is useful in confronting real-world computing problems. The result of such synergistic use of computing techniques is the construction of complementary hybrid intelligent systems. The epitome of designing and constructing intelligent systems of this kind is neuro-fuzzy computing: firstly, neural networks recognizing patterns and adapting to cope with evolving environments; and secondly, fuzzy inference systems which include human knowledge and implement decision making and differentiation. The combination and integration of these two complementary methodologies produces a novel discipline called neuro-fuzzy computing.

3.2. Adaptive neuro-fuzzy inference system

The ANFIS (adaptive neuro-fuzzy inference system) is a class of adaptive networks functionally equivalent to the fuzzy inference systems. In this study, the fuzzy inference system used has one input and one output. In this study, the first-order Sugeno fuzzy model [46–48], with two fuzzy if-then rules was used as following:

\[
\text{Rule 1 : if } x \text{ is } A \text{ then } f_1 = p_1x + r_1 \\
\text{Rule 2 : if } x \text{ is } B \text{ then } f_2 = p_2x + r_2
\]

Fig. 2 shows the corresponding equivalent ANFIS architecture. Nodes of the same layer have similar functions. The output of the \(i\)th node in layer \(l\) is denoted as \(O_{il}\).

Layer 1: Each node \(i\) in this first layer is an adaptive node with a node function [49]

\[
O_{ij} = \mu_A(x), \text{ for } i = 1, 2
\]

where \(x\) is the input to node \(i\) (here input \(x\) represent \(n_{day}\)) and \(A_i\) or \(B_{i-2}\) is an associated linguistic label (such as ‘small’ or ‘large’). In other words, \(O_{ij}\) is the membership grade of a fuzzy set \(A\) and \(B\). It stipulates the extent to which the specified input \(x\) satisfies the quantifier \(A\). In this instance, the membership function for can be any suitable parameterized membership function. The generalized

![Fig. 1. Long-term averaged measured daily global solar radiation used for training and testing phases.](image)

![Fig. 2. ANFIS architecture with the sole input parameter of \(x = n_{day}\).](image)
bell function is used here as it has the best abilities for the generalization of nonlinear parameters [50]:

$$\mu_A(x) = \frac{1}{1 + \left(\frac{x-a}{b}\right)^2}$$  \quad (4)

where \(\{a, b, c\}\) is the variable set. The bell-shaped function varies accordingly as the values of the variables change, therefore manifesting different types of membership functions for fuzzy set A. Variables in the first layer are called premise variables. The bell-shaped function depends on three parameters \(a, b\) and \(c\). The parameter \(b\) is usually positive. The parameter \(c\) is located in the center of the curve as shown in Fig. 3.

Layer 2: Each node in the 2nd layer is a fixed node and its output is the consequent of all signals which are incoming [51]:

$$O_{2i} = w_i = \mu_A(x), \quad i = 1, 2$$  \quad (5)

Every node output represents the firing strength of a rule.

Layer 3: Each node in the 3rd layer is a fixed node. The \(i\)th node calculates the proportion of the firing strength of the \(i\)th rule to the sum of the firing strength of all rules' [52]:

$$O_{3i} = \bar{w}_i = \frac{w_i}{w_1 + w_2}, \quad i = 1, 2.$$  \quad (6)

For the sake of convenience, outputs of this layer are called normalized firing strengths.

Layer 4: Each node \(i\) in this 4th layer is an adaptive node with a node function [46–48]:

$$O_{4i} = \bar{w}_i f_i = \bar{w}_i(p_i x + r_i)$$  \quad (7)

where \(w_i\) is a normalized firing strength from the 3rd layer and \(\{p_i, q_i, r_i\}\) is the node’s variable set. In this layer, the variables are referred to consequent parameters.

Layer 5: In the 5th layer, the single node is a fixed node. The fixed node calculates the total output as the summation of all signals which are incoming [49–52]:

$$O_{5i} = \sum_i w_i f_i = \frac{\sum_i w_i f_i}{\sum_i w_i}$$  \quad (8)

The parameters in the ANFIS architectures were identified by applying the hybrid learning algorithms. In the forward pass of this algorithm, functional signals go forward until Layer 4. Consequent parameters are identified by the least squares estimate. In the backward pass, the error rates propagate backwards. Premise parameters are updated by the gradient descent.

4. Performance assessment criteria

The robustness of proposed ANFIS model is evaluated via different statistical indicators including the bias error (BE), mean absolute percentage error (MAPE), mean absolute bias error (MABE), root mean square error (RMSE) and correlation coefficient (\(R\)). The nominated statistical indicators are reviewed briefly in the following.

The bias error (BE) shows the deviation of estimated values from measured ones. BE is used to express the closeness and agreement between the measured and the calculated values and is expressed by:

$$BE = (H_{ce} - H_{cm})$$  \quad (9)

where \(H_{ce}\) is the \(i\)th calculated solar radiation value and \(H_{cm}\) is the \(i\)th measured global solar radiation value.

The MAPE, another accuracy level estimator of models, shows the mean absolute percentage difference between the estimated and real data. Also, the MABE represents the average quantity of total absolute bias errors between the estimated and measured values. The MAPE and MABE are calculated by the following equations:
are the averaged calculated values by ANFIS and

\[ R = \frac{1}{n} \sum_{i=1}^{n} (H_{i,c} - H_{i,m}) \]

where \( n \) is the total number of observations.

The RMSE determines the precision of the model by comparing the deviation between the estimated and real data. The RMSE has always a positive value and is calculated by:

\[ \text{RMSE} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (H_{i,c} - H_{i,m})^2} \]

The \( R \) provides a measure of level of the linear relationship between the estimated and the measured values. The \( R \) is obtained by:

\[ R = \frac{\sum_{i=1}^{n} (H_{i,c} - \bar{H}_{c}) (H_{i,m} - \bar{H}_{m})}{\sqrt{\sum_{i=1}^{n} (H_{i,c} - \bar{H}_{c})^2 \sum_{i=1}^{n} (H_{i,m} - \bar{H}_{m})^2}} \]

where \( H_{c,avg} \) and \( H_{m,avg} \) are the averaged calculated values by ANFIS model and the measured values, respectively.

It is worth mentioning that the smaller values of BE, MAPE, MABE and RMSE represent further precision of the estimated global solar radiation and in an ideal case they are zero. The \( R \) ranges between -1 and +1. The \( R \) values around -1 or +1 indicate that there is a perfect linear relationship between the estimated values and measured ones whereas \( R \) around zero shows that there is no linear relationship.

### 5. Results and discussion

In this study, the potential of ANFIS technique to estimate the daily horizontal global solar radiation using day of the year as a single input was appraised. To achieve further reliability in the evaluations, the developed ANFIS model was tested by a data set that was not used during the training process. The suitability of the proposed ANFIS system was assessed statistically using different well-known indicators. Then to ensure the accuracy level of the ANFIS model, its performance was compared against six DYB empirical models. Following offers the most significant results attained in this research work.

#### 5.1. Assessing the capability of developed ANFIS model

At the beginning, the ANFIS networks were trained with the long-term averaged measured data. Three bell-shaped membership functions were used to fuzzify the ANFIS input. Various types of membership function and also number of membership function were tested to recognize the most favorable type and number of membership functions. After training process the ANFIS networks were tested to calculate the daily horizontal global solar radiation (\( H \)) based on days of the year (\( n_{\text{day}} \)). Long-term measured daily global solar radiation (\( H \)) as the output parameter and the number of days (\( n_{\text{day}} \)) as the input parameter were collected and defined for the learning techniques. For this aim, one year averaged global radiation data achieved from the period of 7 years from January 1998 to December 1994 was used to train the samples and the one year averaged daily data set obtained from the remaining period of January 1995 to December 1998 was served to test the samples.

Fig. 4(a) and (b) show the scatter plots between the measured and computed global solar radiation values via the developed ANFIS model, respectively for training and testing phases. It is clear that there are favorable agreements between the ANFIS predictions and the measured ones as the amount of deviations of data points from the perfect 1:1 line are truly limited. This proves the high rate of correlation between the measured and the estimated values.

#### Table 1

Performance of the proposed ANFIS model based upon different statistical indicators.

<table>
<thead>
<tr>
<th>Model no.</th>
<th>MAPE (%)</th>
<th>MABE (MJ/m²)</th>
<th>RMSE (MJ/m²)</th>
<th>( R )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training</td>
<td>4.6402</td>
<td>0.8267</td>
<td>1.0482</td>
<td>0.9869</td>
</tr>
<tr>
<td>Testing</td>
<td>3.9569</td>
<td>0.6911</td>
<td>0.8917</td>
<td>0.9908</td>
</tr>
</tbody>
</table>

#### Table 2

The established DYB empirical models for city of Tabass [25].

<table>
<thead>
<tr>
<th>Model no.</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>( H = 20.1645 - 8.7616 \cos \left( \frac{2\pi}{365} n_{\text{day}} + 6.3046 \right) ) (14)</td>
</tr>
<tr>
<td>(2)</td>
<td>( H = 9.9665 + 18.2827 \left</td>
</tr>
<tr>
<td>(3)</td>
<td>( H = 19.5882 + 9.0923 \sin \left( \frac{\pi}{180} n_{\text{day}} + 11.2088 \right) ) (16)</td>
</tr>
<tr>
<td>(4)</td>
<td>( H = 20.4643 + 0.9238 \sin \left( \frac{\pi}{180} n_{\text{day}} - 6.6075 \right) - 8.9104 \cos \left( \frac{\pi}{180} n_{\text{day}} + 6.1639 \right) ) (17)</td>
</tr>
<tr>
<td>(5)</td>
<td>( H = 28.1651 \exp \left[ -0.5 \left( \frac{\left( n_{\text{day}} - 190.3837 \right)}{365} \right)^2 \right] ) (18)</td>
</tr>
<tr>
<td>(6)</td>
<td>( H = 11.7585 + 0.0314 n_{\text{day}} + 0.0024 n_{\text{day}}^2 - 1.31 \times 10^{-5} n_{\text{day}} + 1.78 \times 10^{-9} n_{\text{day}}^2 ) (19)</td>
</tr>
</tbody>
</table>
Making a comparison between Fig. 4 (a) and (b) reveals that, as expected, the predicted values during the testing phase are relatively less scattered compared to the training phase.

Fig. 5 illustrates the day by day comparison between the measured and estimated global solar radiation on a horizontal surface via the ANFIS model for the testing phase. Obviously, the achieved agreements between the measured data and ANFIS predictions are excellent in most days throughout the year. This achievement would be particularly attractive and worthwhile since the developed model is not dependent upon to any meteorological or geographical elements for predicting the global solar radiation.

To assess the potential of the proposed ANFIS model on a more definite and tangible basis, the reliable statistical parameters of MAPE, MABE, RMSE and $R$ were computed and the achieved results.
are offered in Table 1 for both training and testing phases. The presented values in Table 1 indicate that small differences exist between the estimated global solar radiation values and the measured ones. In fact, the low values of MAPE, MABE, and RMSE along with the high value of $R$ demonstrate the high capability of the developed ANFIS model to estimate the daily horizontal global solar radiation based upon the day of the year.

5.2. Comparison with the day of the year-based empirical models

The superiority of the developed ANFIS model can be justified by providing some comparisons with DYG empirical models. To achieve this, the performance of the ANFIS-based model is verified against the six DYG empirical models previously established by Khorasanizadeh and Mohammadi [25] for city of Tabass. Table 2 shows these six DYG models established based upon the long-term measured daily data set for Tabass. Since exactly the same database was utilized in the previous study, the comparison may completely be reliable and noteworthy. It is worth mentioning that in the empirical models presented in Table 2, $H$ is the daily global solar radiation on a horizontal surface and $n_{day}$ is the number of the day, counted from the first of January. For the 1st of January $n_{day}$ is 1 and for 31st of December is 365.

The values of MAPE, MABE, and $R$ obtained by the study of Khorasanizadeh and Mohammadi [25] to evaluate the performance of six established DYG models for Tabass are listed in Table 3. Clearly, the model (4) with hybrid sine and cosine functional form shows higher accuracy compared to the other models. Nevertheless, by making a comparison between the statistical results listed in Table 3 with those of Table 1 it is apparently found that the ANFIS model enjoys greater performance compared to all calibrated DYG empirical models. Thus, the developed ANFIS model can be introduced as the superior model to estimate the daily horizontal global solar radiation by the day of the year.

To provide further comparison between the predictions of ANFIS model with those of six DYG models, the values of daily bias error (BE) were computed. Fig. 6 illustrates the histogram plots of daily BE for the developed ANFIS model in both training and testing phases as well as the six DYG empirical models. Histogram is an useful diagram to represent the probability occurrence of a given variable in any specific interval. In fact, Fig. 6 shows the histogram of the number of days throughout the year falling in different intervals of BE. The positive ranges of BE indicate the overestimation and the negative ranges represent underestimation. It is worthwhile to mention that the model with lower range of BE provides further accuracy. In addition, provided that a higher number of days fall in the lower ranges of BE, the model will be further precise. Consequently, the superior performance is achieved for the ANFIS model in the testing phase. As a comparison, for the developed ANFIS model the calculated values of BE range from -3 MJ/m$^2$ to +3 MJ/m$^2$. Whereas for the model (4), as the best empirical model, the BE falls between -3 MJ/m$^2$ and +4 MJ/m$^2$. Furthermore, for different intervals of BE, a higher number of days fall into lower range of BE for the ANFIS model compared to the model (4). These comparisons may be performed between the ANFIS model and the other DYG models to identify the superiority of ANFIS technique. The BE analysis conducted may be regarded as a further verification of the previous statistical analysis to introduce the ANFIS as the best model.

6. Conclusions

In this research work, the adaptive neuro-fuzzy inference system (ANFIS) was applied to estimate the daily horizontal global solar radiation by day of the year as the only input. Basically, the prediction of global solar radiation based upon day of the year offers two advantages. First, there is no dependency to any specific input element such as meteorological data. Furthermore, there is no need to any pre-calculation analysis. As a matter of fact, this study aimed at identifying the potential of ANFIS technique to predict the global solar radiation by day of the year. For this aim, long-term measured horizontal global solar radiation data for city of Tabass, as a case study, was utilized. The predictions accuracy of the developed ANFIS model was appraised using different statistical indicators such as BE, MAPE, MABE, and $R$. Afterwards to validate the adequacy of the developed ANFIS model its performance was compared against the six DYG empirical models previously established by Khorasanizadeh and Mohammadi [25] for city Tabass. As a more statistical analysis, the BE was served to assess the models’ performance in different days. The survey results vividly demonstrated that ANFIS would be an efficient technique to provide the highly accurate predictions of daily horizontal global solar radiation using day of the year as the sole input. In fact, the results specified that application of ANFIS technique eventuates in attaining the highest precision so that the developed ANFIS model outperformed all the six DYG empirical models.

To conclude, the proposed ANFIS model can be utilized to estimate the horizontal global solar radiation with favorable level of reliability and precision. Generally, the developed ANFIS model in this study enjoys a series of merits including the simplicity, easy usage as well as high accuracy. As a result, the suggested ANFIS model would play a notable role in various applications such as designing, simulating and monitoring the solar energy technologies, particularly in isolated areas with no access to specific meteorological elements.

Acknowledgments

The authors would like to thank the University of Malaya for the research grants allocated for the financial support (RP015C-13AET) and High Impact Research Grant (HIR-D000015-16001). Special appreciation is also credited to the Malaysian Ministry of Education (MOE) for the Fundamental Research Grant Scheme (FP053-2013B). Also, this work was supported by University of Malaya under the Bright Sparks program (BSP 1632-13).

References


