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A new approach for forecasting OPEC petroleum consumption based on neural network train by using flower pollination algorithm

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ABSTRACT

Petroleum is the live wire of modern technology and its operations, with economic development being positively linked to petroleum consumption. Many meta-heuristic algorithms have been proposed in literature for the optimization of Neural Network (NN) to build a forecasting model. In this paper, as an alternative to previous methods, we propose a new flower pollination algorithm with remarkable balance between consistency and exploration for NN training to build a model for the forecasting of petroleum consumption by the Organization of the Petroleum Exporting Countries (OPEC). The proposed approach is compared with established meta-heuristic algorithms. The results show that the new proposed method outperforms existing algorithms by advancing OPEC petroleum consumption forecast accuracy and convergence speed. Our proposed method has the potential to be used as an important tool in forecasting OPEC petroleum consumption to be used by OPEC authorities and other global oil-related organizations. This will facilitate proper monitoring and control of OPEC petroleum consumption.

1. Introduction

Recently, a new meta-heuristic algorithm called the Flower Pollination Optimization Algorithm (FP) with remarkable balance between consistency and exploration was proposed by [47]. The switch probability or proximity probability is used to switch between common global pollination to intensive local pollination. The effectiveness and robustness of the PFA can be attributed to the following two reasons: (1) Insect pollinators can travel in long distances which enable the flower pollination (FP) to avoid local landscape to search in a very large space. (2) The FP ensures that similar species of the flowers are consistently chosen which guarantee fast convergence to the optimal solution. The FP is found to perform better than the genetic algorithm (GA), particle swarm optimization (PSO) [47], and artificial bee colony (ABC) [42] in solving optimization problems.

Artificial Neural Network (NN)is referenced as one of the most powerful techniques ever established [27] and is heavily applied in soft computing because of its effectiveness and robustness. The NN tolerates missing and erroneous values and any association can be modeled with arbitrary accuracy. In NN, new cases can automatically be accommodated by updating the learning of the NN. The NN is considered as one of the most reliable and promising computational intelligence techniques [31]. The FP can be applied to train NN to create a model for the forecasting of Organization of the Petroleum Exporting Countries (OPEC) petroleum consumption.

Human activities in today's modern world would not be possible without energy. Energy is the live wire of modern technology and its operations, with economic development being positively linked to energy. As such, a lack of energy can make human life very difficult or even impossible [40]. About 2/3 of the world's energy needs are supplied by petroleum and gas [6]. The consumption of petroleum is positively related to economic growth [17], meaning that the more developed an economy is, the more the petroleum

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consumption will increase. Conversely, if economic activities do not improve, the consumption of petroleum will reduce accordingly. The world's petroleum consumption growth is estimated at 1.3 million bbl/d forthe year 2013, with an average of 90.5 million bbl/d used in the same year. On the other hand, in 2014 and 2015 the consumption growth was estimated at 1.0 million bbl/d and 0.9 million bbl/d, respectively [15].

About 1/3 of the global petroleum supply is provided by 6 countries from the Organization of the OPEC, including Saudi Arabia, Iran, Iraq, Kuwait, United Arab Emirates, and Qatar [14]. Five of these OPEC countries are among the world's top 5 countries with the highest proven reserves of petroleum. The combined petroleum reserves for these six OPEC countries comprise over 60% of the global proven petroleum reserves [7]. The OPEC produces as well as exports petroleum to other parts of the world, which shows that OPEC has played a significant role in fueling the world's economic activities in previous decades [28].

The OPEC petroleum consumption has increased 7 times within 40 years, to 8.5 million bbl/d. Petroleum consumed by OPEC is nearly as much as that consumed by the People's Republic of China. This represents1/5 of the OPEC petroleum production. The rapid consumption of petroleum by OPEC could possibly pose a challenge to OPEC's capability to increase the export of petroleum to other countries that rely on OPEC to supply petroleum. The growth of petroleum consumption by OPEC is estimated at 5.1% annually, which is growing faster than OPEC's income growth of 3.3% [19].

It was found that predicting petroleum (energy) is required for the proper management of supply, demand, production, investment analysis, analysis of revenue generation, and management of research related to energy. A better tomorrow depends on the accuracy of today's decisions [16]. The petroleum consumption, production, prices, demand, etc. are characterized by their high uncertainty level. The uncertain nature of energy makes conventional methods unfit for forecasting it [22,8]. However, meta-heuristic algorithms have extensively been mentioned in literature for solving complex problems. Meta-heuristic algorithms are more powerful than conventional mathematical programming [37], because the diversification feature of meta-heuristic algorithms ensures that the search space is thoroughly searched while the intensification guarantees that the best among current solutions is selected. Meta-heuristic algorithms are capable of solving large problems more robustly and faster [41].

A number of meta-heuristic algorithms have been mentioned in literature, such as GA, ABC, PSO, firefly, etc. [18]. Some meta-heuristic algorithms have been used for solving optimization problems [13], such as training NN to build a model for oil consumption prediction. The ability of meta-heuristic algorithms to improve convergence speed and accuracy, and prevent BPNNs from being trapped in local minima has motivated researchers to apply such algorithms to build a model for oil consumption prediction. For example, Chiroma et al. [9] proposed a model for energy consumption in Greece based on the co-active neuro fuzzy inference system and Azadeh et al. [4] trained an NN based on GA searches to build a model to forecast electrical energy consumption in Turkey. Padmakumari et al. [32] applied fuzzy NNs (FNN) because the FNN combines the power of NNs and fuzzy logic to create a robust synergistic model for the forecasting of long-term energy consumption. The NN parameters were optimized through ABC to forecast oil consumption in 4 different countries in the Middle East [10]. The oil demand in Iran was estimated using GA and PSO [2]. An excellent review of the applications of meta-heuristic algorithms in oil consumption modeling is in Ref. [40]. However, the FP has demonstrated improved performance over established meta-heuriatic algorithms [11].

Previous literature mainly rely on GA, ABC and PSO to create a model for the forecasting of oil consumption. The PSO has the possibility of being trapped in a premature convergence in view of the fact that the PSO optimization evolve mostly by evaluation of self-position with neighboring positions and global positions for all the particles as a single pattern. The diversification of result in GA by crossover and mutation typically led to large number of unnecessary iterations which hider efficiency in problem solving [49]. The performance of GA typically decreases because of the GA insufficient balance between exploration and exploitation. The GA has strong exploitation and weak exploration [25]. The PSO also lacks sufficient balance between exploitation and exploration [35]. The ABC lacks balancing between exploration and exploitation because its solution search shows that the ABC exploration is good while exploitation is poor [23].

However, a newly proposed FP outperform the performance of the GA, ABC and PSO in terms of accuracy and convergence speed because of its remarkable balance between consistency and exploration.

To advance forecasting accuracy and convergence speed, deviate from local minima and optimized the NN weights and biases, we proposed to train the NN by using FP for the forecasting of OPEC petroleum consumption.

The remaining sections of the paper are organized as follows. Section 2 presents the proposed methodology, comprising a description of FP, NN and the hybrid of FP and NN. Section 3 describes OPEC petroleum consumption data. Section 4 provides experiments set up and Section 5 presents results and discussion followed by the concluding remarks and future research in Section 6.

2. The proposed method

This section discusses the basic theoretical background of the FP and NN required to understand our proposed method of forecasting OPEC oil consumption. The section contains two major subsections: the basic FP operation, and how it functions to achieve the desired goal. A brief description of the NN model and reference for further details on the description of NN is given, since it is extensively discussed in the literature. The theoretical background of the FP and NN hybridization is described in detail.

2.1. Flower pollination algorithm

Yang [47] emulated the characteristics of biological flower pollination in flowering plants to develop the flower pollination algorithm based on the following rules:

1. The global pollination processes are biotic and there is cross pollination, in which pollen transporting pollinators perform the Levy flight.
2. Local pollination is viewed as ambitious self-pollination.
3. Reproduction probability is considered flower constancy, which is proportional to the resemblance between two flowers concerned.
4. The switching probability controls both the local and global pollination $p \in [0,1]$. Local pollination can have a fraction p that is significant in the entire pollination process due to physical proximity and wind.

The plant can possess multiple flowers and every flower patch typically emits millions or even billions of pollen gametes in real-life pollination. To simplify the proposed algorithm development, it is assumed that each plant has a single flower and each flower emits only a single pollen gamete. This results in the elimination of the need to differentiate a pollen gamete, plant or solution to a problem. Basically, a solution x_i to a problem are equivalent to a flower