Overview of Computational Intelligence Application on Prediction of Global Solar Radiation

Stephen Gbenga Fashoto
Department of Computer Science
University of Swaziland, Kwaluseni, Swaziland
gbengafash@yahoo.com, sgfashoto@iniswa.sz

***Abstract* - Computational Intelligence is not just about robots. It is also about understanding the nature of intelligent thought and action using computers as experimental devices. New applications using computational intelligence are still being developed, although computational intelligence is an established field. The essence of this keynote address is to give a general picture of the research directions which may give an insight into the future of this research area. Meanwhile, an attempt to comprehensively address how computational intelligence may enhance the progress of global solar radiation can be addressed in near future.**

Keywords: Computational Intelligence, Methodologies of Computational Intelligence, Global Solar Radiation

I. INTRODUCTION

As its history proves, computational intelligence is not just about robots. It is also about understanding the nature of intelligent thought and action using computers as experimental devices. The notion of Computational Intelligence was first used by the IEEE Neural Networks Council in 1990. This Council was originally founded in the 1980s by a group of researchers interested in the development of biological and artificial neural networks. On November 21, 2001, the IEEE Neural Networks Council became the IEEE Neural Networks Society, to become the IEEE Computational Intelligence Society two years later by including new areas of interest such as fuzzy systems and evolutionary computation, which they related to Computational Intelligence in 2011(Rao & Sarma, 2016).

The first clear definition of Computational Intelligence was introduced by Bezdek in 1994: a system is called computationally intelligent if it deals with low-level data such as numerical data, has a pattern-recognition component and does not use knowledge in the Artificial Intelligence (AI) sense, and additionally when it begins to exhibit computational adaptive, fault tolerance, speed approaching human-like turnaround and error rates that approximate human performance.

According to Bezdek (1994), Computational Intelligence is a subset of Artificial Intelligence. The artificial one is based on hard computing techniques and the computational one is based on soft computing methods, which enable adaptation to many situations.

It has been the endeavour of scientists and technologists to investigate and design systems which perform like human beings. Even though, there is still no commonly accepted definition of computational intelligence.

Computational intelligence (CI) is a set of nature-inspired computational methodologies and approaches to address complex real-world problems to which mathematical or traditional modeling can be useless for a few reasons: the processes might be too complex for mathematical reasoning, it might contain some uncertainties during the process, or the process might simply be stochastic in nature (*Nazmul & Hojjat ,2013)*. Computational intelligence techniques and their applications are fast-growing with attention and tremendous effort by researchers over the years (Rao & Sarma,2016).

Indeed, many real-life problems cannot be translated into binary language for computers to process, such as prediction of global solar radiation. Solar energy is one of the alternative energy sources for the future. A number of sub-Saharan African countries are blessed with a good quantum of solar radiation, which could jumpstart their clean energy needs of the 21st century and beyond. Empirical models are mostly linear, and are unable to effectively deal with empirical irregularities, resulting from the dynamism of the measurement process that is riddled with noise. Computational Intelligence therefore provides solutions for such problems.

II. METHODOLOGIES/PRINCIPLES OF COMPUTATIONAL INTELLIGENCE

Computational Intelligence is an evolving collection of methodologies, which aims to exploit tolerance for imprecision, uncertainty, and partial truth to achieve robustness, tractability, and low cost (Dote and Ovaska, 2001). Computational Intelligence provides an attractive opportunity to represent the ambiguity in human thinking with real life uncertainty. Fuzzy logic (FL), neural networks (NN), Learning theory, Probabilistic methods and evolutionary computation (EC) are the core methodologies of Computational Intelligence. However, FL, NN, learning theory, probabilistic methods and EC should not be viewed as competing with each other, but synergistic and complementary instead.

The five methodologies of Computational Intelligence are discussed below:

a. Fuzzy Logic

Fuzzy Logic is one of the core methodologies of CI; it consists of measurements and process modelling made for real life's complex processes. It can face incompleteness, and most importantly ignorance of data in a process model, contrarily to Artificial Intelligence, which requires exact knowledge. Fuzzy logic is mainly useful for approximate reasoning, and doesn't have learning abilities, a much needed qualification that human beings have (Nazmul & Hojjat ,2013).

b. Neural Network

Neural Networks (ANN) is composed of simple elements operating in parallel. These elements are inspired by biological nervous systems. As in nature, the connections between elements largely determine the network function. A neural network is trained to perform a particular function by adjusting the values of the connections (weights) between elements. Typically, neural networks are adjusted, or trained, so that a particular input leads to a specific target output (Howard et al., 2008). Neural networks can be classified into five groups: data analysis and classification, associative memory, clustering, generation of patterns and control. Generally, this method aims to analyze and classify medical data, proceed to fraud and face detection, and most importantly deal with nonlinearities of a system in order to control it.

c. Evolutionary Computation

Based on the process of natural selection firstly introduced by Charles Robert Darwin, the evolutionary computation consists in capitalizing on the strength of natural evolution to bring up new artificial evolutionary methodologies. It also includes other areas such as evolution strategy, and evolutionary algorithms which are seen as problem solvers *(De Jong, 2006).* This principle's main applications cover areas such as optimization and multi-objective optimization, to which traditional mathematical techniques aren't enough anymore to apply to a wide range of problems such as DNA Analysis and scheduling problems.

d. Learning Theory

Still looking for a way of "reasoning" close to the level of humans', learning theory is one of the main approaches of Computational Intelligence. In psychology, learning is the process of bringing together cognitive, emotional and environmental effects and experiences to acquire, enhance or change knowledge, skills, values and world views (Ormrod, 1995; Illeris, 2004). Learning theories then helps understand how these effects and experiences are processed, and also helps in making predictions based on previous experience (Worrell, 2015).

e. Probabilistic methods

Being one of the main elements of fuzzy logic, probabilistic methods first introduced by Paul Erdos and Joel Spencer (1974), aim to evaluate the outcomes of a Computation Intelligent system, mostly defined by randomness. Therefore, probabilistic methods bring out the possible solutions to a reasoning problem, based on prior knowledge *(Ajoy & Dobrivoje, 2006).*

III. APPLICATIONS OF COMPUTATIONAL INTELLIGENCE IN THE PREDICTION OF GLOBAL SOLAR RADIATION USING NEURAL NETWORK METHODOLOGIES

As an example of the way CI methodologies are been applied, we here consider the use of Neural Networks in the prediction of Global Solar Radiation.

Solar energy is one of the most important and efficient alternative sources of energy in the entire world, especially in tropical regions (e.g. Nigeria) with vast amounts of daily solar radiation (Nwokoye, 2006). Nigeria receives an annual average daily solar radiation of about 5250 $Whm^{-2}day^{-1}$ at the coastal areas, and 7000 $Whm^{-2}day^{-1}$ at the northern boundary. The average sunshine hours all over the country is about 6.5 h (Chineke and Igwiro 2008; Yakubu and Medugu, 2012). Thus, Nigeria has enormous solar energy potential which is essential for so many applications in the country. According to Scheer and Kelley (2002), a number of developing (and tropical) countries have expanded interest in the exploration of solar energy sources for the provision of electricity and water supply in rural and semi-urban areas (like Zaria in Nigeria). Solar radiation is used directly to produce

electricity using photovoltaic (PV) systems and solar thermal systems (Safari and Gasore, 2009).
A number of scientists and engineers rely on radiation information in order to design effective and efficient solar energy systems, crop growth models, and other agricultural systems (Ulgen and Hepbasli, 2004). The interest in solar energy-powered systems has increased in many parts of the world (including Nigeria), because of the need for more environmentally friendly power generation to secure both the future power demand and the survival of the planet (Ehnberg and Bollen, 2005).

Global solar radiation (GSR) data in Zaria, Kaduna state, Nigeria is currently provided through actual measurements by pyranometers. There is no doubt that measured data are the best source of information on solar radiation; however, the measurement of solar parameters is made only in meteorological stations (Saffaripour and Mehrabian, 2009). In scenarios of absence of actual measured data due to instrument failure or lost data records, the alternative source of data is usually prediction models based on readily available weather data at the site. Okole and Emano (2002) developed empirical models, based on weather data for the Zaria site. However, the accuracy of the models is low because they were based on the principle of linearity; the empirical regularities in a dynamic process are not necessarily linear and are not always evident because they are masked by noise.

A. Case Study Design

The global solar radiation and climatological data was obtained from the Nigerian Meteorological Agency (NIMET), Zaria, Nigeria for the period of forty-two (42) months (January, 2012 to June, 2015).Various climatic parameters namely; minimum and maximum temperature, relative humidity, sunshine hours, and GSR were used in developing the empirical correlation and Neural Network (NN) model for predicting the monthly average global solar radiation (Massaquoi, 1988).
The forty two months data (January 2012 to June 2015) from NIMET- Zaria Station (Kaduna State) was split into two. Thirty six months' (January 2012 to December 2014) dataset comprising of temperature difference, sunshine hours and GSR were used for training the neural network and six months' data (January to June 2015) comprising of temperature difference, sunshine hours and GSR were used for testing the NN model.

The Neural Network model was developed using WEKA version 3.6.10 data analysis software. The multilayer perceptron (MLP) under classified tab was selected for the WEKA application using two input parameters (S_0 and ΔT).

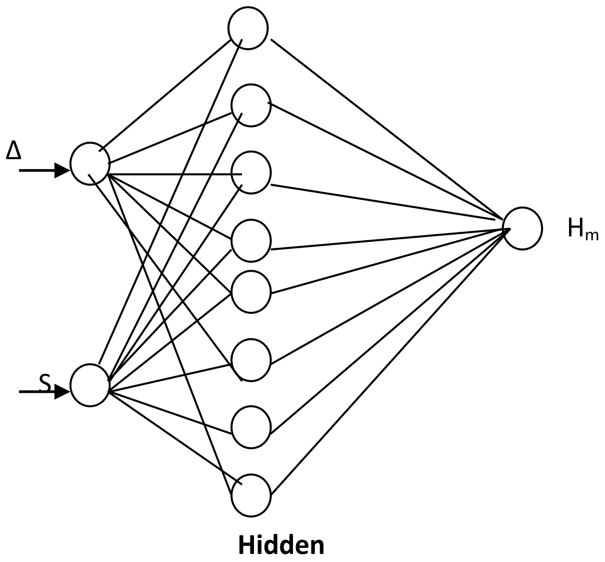

Figure 1 NN structure for the prediction of global solar radiation

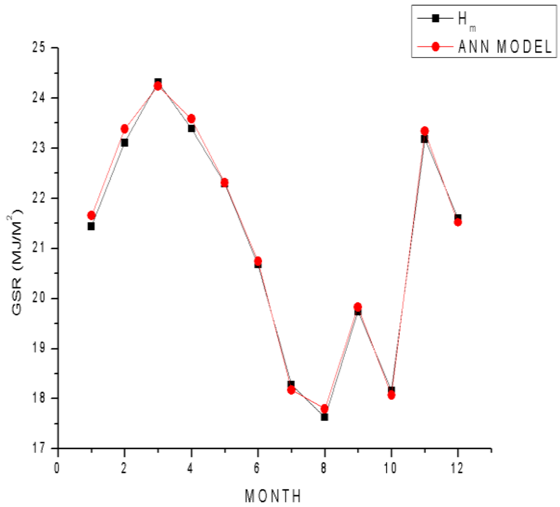

Figure: 2 shows a graphical comparison between the performance of NN and measured GSR.

From Figure 2 above, it is very evident that the NN model (r=0.9984) performed better than the empirical model(r= 0.807) as compared with measured GSR values across the months.

Table 1: Comparison of NN model performance with empirical model

MODEL	Correlation coefficient r	RMSE
Empirical Model	0.807	0.234
NN model	0.9984	0.146

The NN model with two input parameters, gives a lower RMSE 0.146 and correlation coefficient of 0.9984, while the empirical model gives RMSE of 0.234 and correlation coefficieint of 0.807 as shown in Table 1.

IV. PROSPECTS OF COMPUTATIONAL INTELLIGENCE

CI is providing solutions for decision making in several branches of science, engineering, business and management.

Although these methodologies/principles are becoming increasingly common and powerful tools for designing intelligent system for global solar radiation, there are a number of important practical considerations to bear in mind:

(1) The ultimate aim is to solve practical problems in the prediction of global solar radiation, so the techniques considered need to be simple, robust and reliable.

(2) Different types of computational intelligence methodologies/principles will generally be required for different global solar radiation problems, depending on their different practical requirements.

(3) The application of a single computational intelligence technique will often be insufficient on its own to provide solutions to all the practical issues.

(4) Traditional global solar radiation approaches should not be abandoned – they should be considered alongside the computational intelligence methodologies/principles.

(5) Hybrid systems involving combinations of neural computation, fuzzy logic, and evolutionary algorithms, as well as traditional techniques, are a more promising approach for improving the performance of global solar radiation.

(6) A key idea behind computational intelligence is *automated optimization*, and this can be applied to both the structure and parameters of global solar radiation systems. Neural network style learning is good for tuning parameters. Evolutionary approaches can be applied to optimize virtually all aspects of these systems.

V. CONCLUSION

Computational Intelligence is gaining more popularity in respect of integrating capability over multiple disciplines and the capability of incorporating imprecision and uncertainty. New applications using computational intelligence are still being developed, although computational intelligence is an established field. The essence of this keynote address is to give a general picture of the research directions which may give an insight into the future of this research area. Meanwhile, an attempt to comprehensively address how computational intelligence may enhance the progress of global solar radiation can be addressed in near future.

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