

Killer whale-backpropagation (KW-BP) algorithm for accuracy improvement of neural network forecasting models on energy-efficient data

Saadi Bin Ahmad Kamaruddin¹, Nor Azura Md Ghani², Hazrita Ab Rahim³, Ismail Musirin⁴

^{1,3}Department of Business Studies, Faculty of Business, Economics and Accounting, HELP University, Subang 2 Campus, Persiaran Cakerawala, Subang Bestari, Seksyen U4, 40150 Shah Alam, Selangor, Malaysia

²Center for Statistical Studies and Decision Sciences, Faculty of Computer and Mathematical Sciences, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

⁴Electrical Engineering Department, Faculty of Electrical Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia

Article Info

Article history:

Received Jun 19, 2019

Revised Aug 10, 2019

Accepted Aug 26, 2019

Keywords:

Backpropagation algorithm

Energy-efficient

Forecasting

Green technology campus

Killer whale

ABSTRACT

Green technology building is not newly introduced to the world nor Malaysia, but it is rarely practiced globally and now it has promoted noteworthy due to destructions caused by human hands towards the nature. Now people started to realize that the world is polluted by many hazardous substances. Therefore, Help University came up with the effort of preserving the nature through a new Green Technology campus, which has been fully operated since year 2017. In this research, neural network forecasting models on energy-efficient data of Help University, Subang 2 green technology campus at Subang Bistari, Selangor has been done with respect to value-for-money (VFM) attribute. Previously there were no similar research done on energy-efficient data of Help University, Subang 2 campus. The significant factors with respect to energy or electricity saved (MW/hr) in the year 2017 variable were studied as recorded by Building Automation and Control System (BAS) of Help University Subang 2 campus. Using multiple linear regression (stepwise method), the significant predictor towards energy saved (MW/hr) was Building Energy Index (BEI) (kWh/m²/year) based p-value < $\alpha=0.05$. A mathematical model was developed. Moreover, the proposed neural network forecasting model using Killer Whale-Backpropagation Algorithm (KWBP) were found to better than existing conventional techniques to forecast BEI data. This research is expected to specifically assist maintenance department of Help University, Subang 2 campus towards load forecasting for power saving planning in years to come.

Copyright © 2019 Institute of Advanced Engineering and Science.
All rights reserved.

Corresponding Author:

Saadi bin Ahmad Kamaruddin,

Department of Business Studies,

Faculty of Business, Economics and Accounting,

HELP University, Subang 2 Campus, Persiaran Cakerawala, Subang Bestari,

Seksyen U4, 40150 Shah Alam, Selangor, Malaysia.

Email: saadi.ak@help.edu.my

1. INTRODUCTION

Fossil or even electricity is one of the main contributors towards global climate changes as the excessive use and consumption of fossil energy will wind up in releasing a huge amount of greenhouse gasses into the atmosphere [1]. Hence, few methods such as improvement of energy efficiency, frequent use of renewable-energy, preservation of a healthy indoor environment, having green plant in the building compound area, increase use of sustainability of natural resources are few of the has caught the

world's attention [2]. Green building, or known as energy-efficient building is a construction of building that fulfils the needs stated above and capable of reducing greenhouse effect by reducing the dependency of fossil or electricity use [3]. To support the concept of energy efficiency and the use of sustainable energy in buildings, the government of Malaysia has also lunched a few projects as an act of demonstration, educational and enhance public awareness programs [4]. Green technology office building is one of the showcase projects that have high performance in energy efficiency [5]. Malaysia Energy Centre (PTM) that is now currently known as Technology Corporation officer building is the proof of that this concept "green technology" is commercially viable for modern buildings in Malaysia and in the region [6]. The building is actually based on Automated Energy Saving (AES) concept. The aim of this project is to apply modern forecasting algorithm on energy-efficient data of HELP Subang 2 green technology campus, which were captured by Building Automation and Control System (BAS) as shown in Figure 1.



(a)



(b)

Figure 1. (a) HELP Subang 2 green technology campus, and (b) Building Automation and Control System (BAS)

Electricity is one of earth-shaking resources in this century. It is the major source of power for most of the country's economic activities [7]. Moving towards energy sustainability will require modifications not only in the way energy is supplied, but also in the way it is used as well, called energy planning [8]. Green building refers to both assembly and the implementation of processes that are environmentally responsible and resource-efficient throughout the building's life cycle from the planning, construction, operation, maintenance, renovation, and demolition phase [9]. In order to achieve such achievement, the contractor, architects, engineers, and the client at all stages have to work closely together [10].

A Green building is a concept that complements the classical building design with concerns of economy, durability, comfort and also utility [11]. World Green Building Council currently is conducting a research on the benefits that green building can contribute towards the health and productivity of the people using it and is also working with the World Bank to promote Green Buildings in Emerging Markets [12]. There are also other measurement tools such as Green Building Index (GBI) predominantly used in Malaysia [13].

HELP University is one of the first higher education institutions that implements green building concept to its campuses. Hence, there is none if not a few research conducted on HELP University Subang 2 campus. With such limited time and no prior research conducted in this university, this research may be able to assist HELP university in terms of energy efficiency practices to its full potential. Other than that, there was also no prior model of value-for-money (VFM) implemented on HELP university's energy-efficiency time series data. HELP University has already shown its support by constructing its new campus to be more energy efficient and more nature friendly which is situated in Subang Bestari near Subang Airport. The campus is equipped with Automated Infrared Sensor ceiling light which automatically turns on when sensor picks up and motion; this helps the building to conserve more energy especially during holidays and also during the night when nobody is in the building. The green campus is largely decorated with green plants and also trees to enhance student awareness towards green environment. The building was completed in 2016; however, the building is yet to reach an optimum level of energy efficiency even having approximately 2 years in operation. The Building Energy Index (BEI) of the building is yet to achieve an optimum level. And this research paper will try it best to implement technology which can contribute in achieving the ideal Building Energy Index (BEI).

The research objectives related to the research questions are as follows:

- To determine the significant factors respecting to energy or electricity saved (MW/hr) recorded by Building Automation and Control System (BAS) of Help University Subang 2 campus.
- To develop mathematical model of energy efficient data which satisfies value-for-money (VFM) attribute of Help University Subang 2 campus.
- To propose a robust neural network model for load forecasting at HELP University Subang 2 campus based on output in (a) which satisfies the VFM attribute.

At the end of this research, forecasters or engineers of HELP University's maintenance department to improve their load forecasting activities, and achieve a satisfactory level of green technology building's GBI. By helping HELP University to reach its full potential in energy efficiency, it can contribute economically to RMK11 as an annual electricity generation of electricity cost around RM15.1 billion [15]. The research outline of this paper starts research motivation, followed by research limitation, problem statement, research questions, research objectives, and research significance. Moreover, the next sections are the related literatures, followed by the methodology, the results and discussions, as well as the conclusions.

2. RELATED LITERATURES

Neural Network is needed for filtration and classification of the many factors that can be provided by a cause and then to predict the effects of it and either to improve or to minimise damages through certain patterns or characteristics [15]. Machine learning will be a very crucial part for the neural network where it is used to learn from the existing data that has been collected or so, in a form of computerized algorithm [16]. Apparently that the more data that it uses and the more relative numbers it uses for its learning purposes the more accurate it becomes [17]. Machine learning algorithms are widely and commonly used in current society to improve not only in prediction but also to impose on building for better energy consumptions and energy efficiency, for example cooling the campus with collected rain water cooling system is a very good example [18], which is currently practiced by HELP university. Energy efficiency is being promoted to influence other universities and encouraging them to do the same not just because of the normal factors, but also the factors of the stakeholder, government, managers, and even faculty perceptions [19].

3. METHODOLOGY

In this research, the HELP Subang 2 load forecasting data is obtained from the maintenance department, Help University Subang 2 campus for the year 2017 recorded in monthly basis. For confirmation, one may contact the general line +603-27162000. Data collected include electricity usage measured in kilowatt hour (kWh), carbon emissions, energy saved measured in megawatt hour (MWh) and money saved throughout daily data starting from 06:45:00 pm on 8th May 2017 to 12:00:00 pm on 31st December 2017 (every 15 minutes) with the university operating at regular capacity. The limitation of this research is terms of availability data, since this campus is new. The scope of this research will analyse the

HELP University electricity usage, money saved, Building Energy Index (BEI) (kWh/m²/year) and Carbon Dioxide (Co₂) Emission dated for the year 2017 were recorded Building Automation and Control System (BAS) of Help University Subang 2 campus.

The flowchart of this research shown in Figure 2. Once the data assembled as shown in Figure 3, determination of neural network time series models were made [20-21]. The critical part of this research was the implementation of proposed killer whale algorithm on iterated least median squares algorithm to replace the ordinary backpropagation algorithm which was based on mean squared error [22].

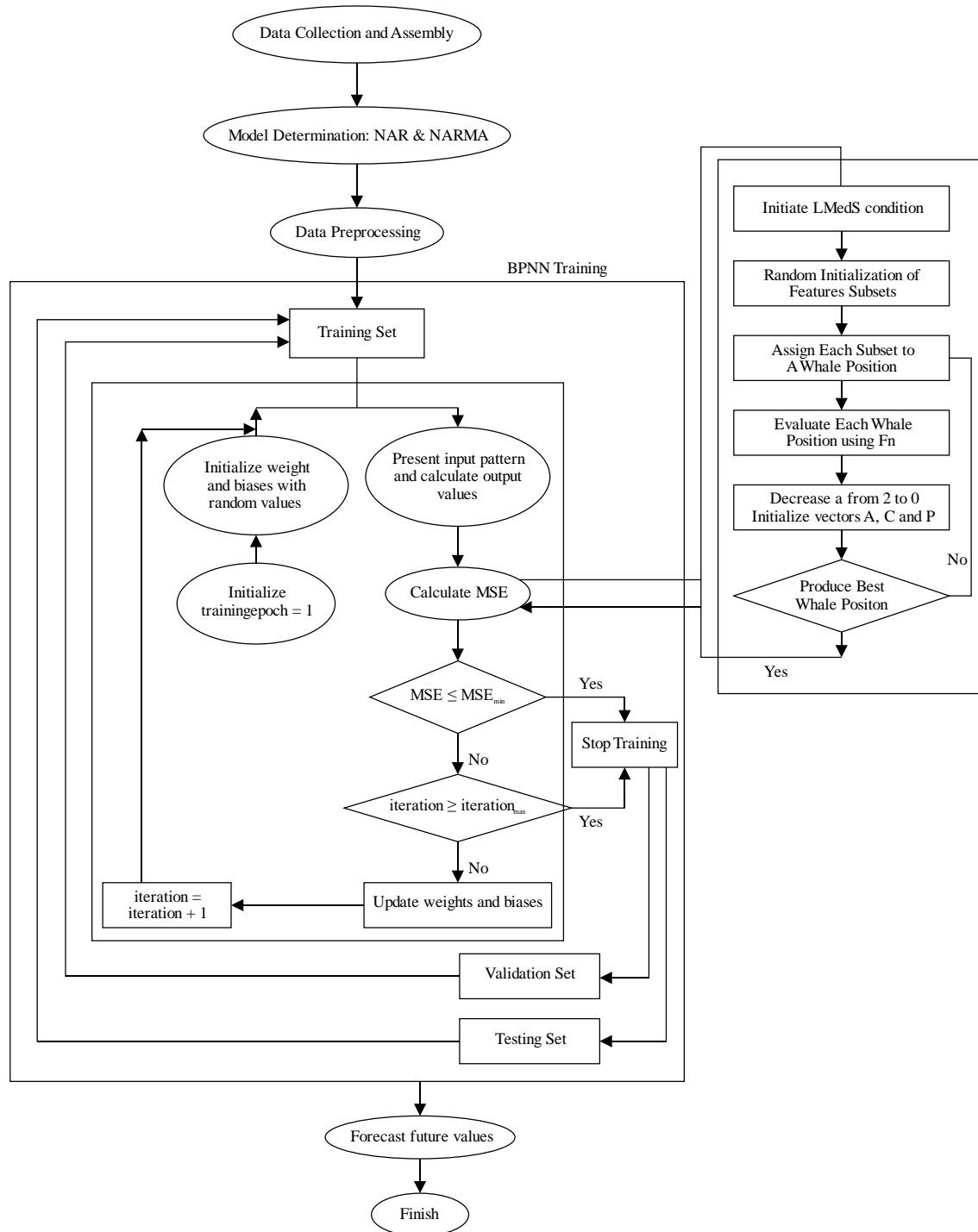


Figure 2. Flow of Killer Whale Backpropagation Neural Network (KW-BPNN) Algorithm

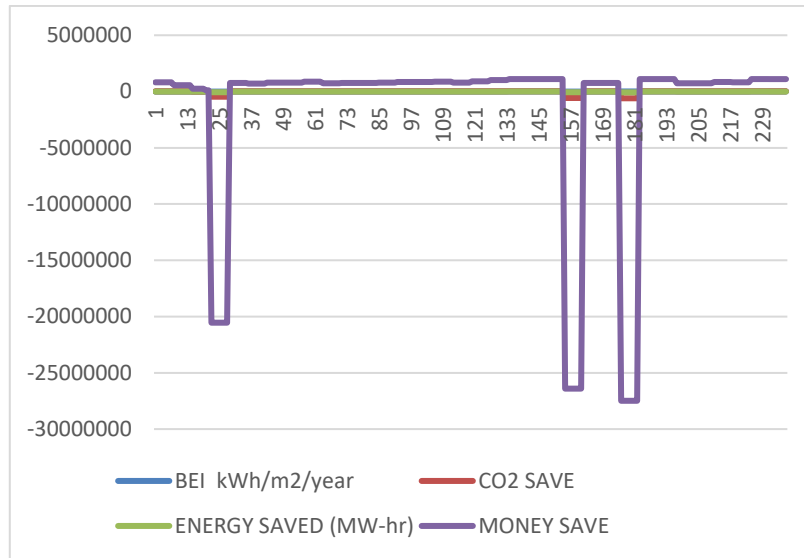


Figure 3. Time Series Dataset in This Research

4. RESULTS AND DISCUSSIONS

Using statistical analysis, Building Energy Index (BEI) (kWh/m²/year) and Carbon Dioxide (Co₂) Emission were the significant predictors towards energy saved (MW/hr) based p-value < α = 0.05. Table 1 shows the RMSEs of BPNN-NAR and BPNN-NARMA by different algorithms on Building Energy Index (BEI) data. Based on ordinary backpropagation algorithm, the best configuration was 15-15-15. Table 2 shows the descriptive statistics of the variables involved in this research. Table 3 shows the coefficients table from multiple liner regression (stepwise) technique. From Table 4, the best configuration for killer whale backpropagation algorithm was 30-30-30. Firefly algorithm on backpropagation and particle swarm optimization on backpropagation performed equally good where the best configurations for both algorithms were 20-20-20. Comparing the performance for all algorithm, it can be concluded that the proposed killer whale backpropagation (KWBP) neural network was found to better than existing conventional techniques, where the RMSE for BPNN-NAR was 0.00078 and BPNN-NARMA was 0.00085 as shown in Figure 4. This means that the best model for building Energy Index (BEI) data is BPNN-NAR with KW-BPNN optimization with configuration sigmoid-linear 30-30-30 for input lags, error lags and hidden nodes respectively. This research is expected to specifically assist electrician in Help University towards load forecasting for power system planning and operation in years to come. All the objectives of this research have been successfully achieved. The final numerical model to determine energy saved was

Table 1. Variables Involved in This Research

Variables	Description
BEI kWh/m ² /year*	building energy index kWh/m ² /year
CO ₂ SAVE	emissions of CO ₂ per kWh of energy produced
ENERGY SAVED (MW-hr)	electricity saved Megawatt hours (MWh)/Hours (h)
MONEY SAVE	money saved in ringgit malaysia (RM)

$$ENERGYSAVE D = 3030.785 - 15.154 * BEIkWhm + 8.535E - 8 * MONEYSAVE.$$

This research is expected to give a significant contribution and demonstration in the effort of countering the current global warming issue parallel to 11th Malaysia Plan-RMK11 objectivity. RMK11 or also known as 11th Malaysian Plan is the final five years plan in excursion towards achieving Vision 2050. In the near future, this research can be further improved by adapting the techniques [27-30], and the sample size should be increased. The related previous works can be referred in [31-35].

Table 2. Descriptive Statistics

	Mean	Std. Deviation	N
ENERGYSAVED2017MWhr	-3855.9677	20146.86217	238
BEIkWhm2year	454.4559	1329.47074	238
CO2SAVE	-30847.7464	161174.89991	238
MONEYSAVE	-1415794.8587	7351296.63381	238

Table 3. Coefficients (Stepwise Method)

Model	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta			
(Constant)	3030.785	.294			10314.555	.000
1 BEIkWhm2year	-15.154	.001	-1.000		-10269.725	.000
MONEYSAVE	8.535E-8	.000	.000		.320	.749

Table 4. RMSEs of BPNN-NAR and BPNN-NARMA by different algorithms on Building Energy Index (BEI) data

Input Lags	Error Lags	Hidden Nodes	BPNN		KW-BPNN		FFA-BPNN		PSO-BPNN	
			BPNN-NAR	BPNN-NARMA	BPNN-NAR	BPNN-NARMA	BPNN-NAR	BPNN-NARMA	BPNN-NAR	BPNN-NARMA
References			[23]	[24]	[24]	[25]	[25]	[26]	[26]	
5	5	5	0.000975	0.00104	0.00104	0.00145	0.00112	0.00154	0.00112	0.00154
10	10	10	0.000877	0.00108	0.00105	0.00146	0.00102	0.00133	0.00102	0.00133
15	15	15	0.000857	0.00104	0.00105	0.00147	0.00096	0.0012	0.00096	0.0012
20	20	20	0.001008	0.00138	0.0011	0.00154	0.00081	0.00089	0.00081	0.00089
25	25	25	0.001011	0.00138	0.00106	0.00145	0.00098	0.00124	0.00098	0.00124
30	30	30	0.001014	0.00139	0.00078	0.00085	0.0011	0.00152	0.0011	0.00152
35	35	35	0.001017	0.0014	0.00098	0.00127	0.00113	0.00159	0.00113	0.00159
40	40	40	0.00102	0.00141	0.00106	0.00146	0.00113	0.00159	0.00113	0.00159

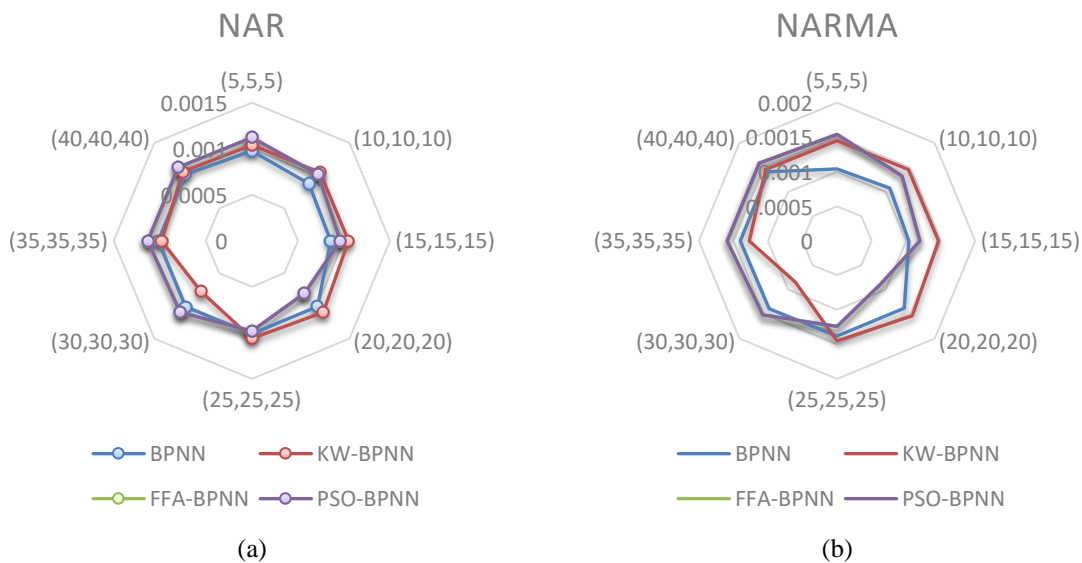


Figure 4. (a) Performance Comparisons of NAR Model in This Research, and (b) Performance Comparisons of NARMA Model in This Research

5. CONCLUSIONS

This paper has presented the performances of multiple evolutionary programming techniques on energy-efficient data of Help University, Subang 2 campus. Through the implementation on the BEI dataset; it can be highlighted that the proposed KW-BPNN is a flexible and robust algorithm to solve the optimal power scheduling process in the attempt to control the loss in power system. With only minor modification in the BP algorithm, better results have been achieved which in turn can be translated into value-for-money attributes. The developed optimized NAR and NARMA models should be tested on simulation datasets in

order to observe their diversified capabilities. It is a good note to mention that the developed optimization algorithm is efficient on neural network time series models. On top of that, application of the proposed robustified algorithm on big datasets should be next endeavours.

ACKNOWLEDGMENT

We would like to dedicate our gratefulness to Help University for supporting this research under IRGS Stater Grant No. 19-04-005. Not to be forgotten endless gratitude to the Maintenance Department of Help University, Subang 2 campus for the data sharing.

REFERENCES

- [1] W. W. Kellogg, *Climate change and society: consequences of increasing atmospheric carbon dioxide*, Routledge, 2019.
- [2] P. Breeze, *Power generation technologies*, Newnes, 2019.
- [3] G. Trencher & J. Van der Heijden, "Instrument interactions and relationships in policy mixes: Achieving complementarity in building energy efficiency policies in New York, Sydney and Tokyo," *Energy Research & Social Science*, 54, 2019, pp. 34-45.
- [4] U. H. Obaidallah, M. Danaee, M. A. A. Mamun, M. Hasanuzzaman & N. A. Rahim, "An application of TPB constructs on energy-saving behavioural intention among university office building occupants: a pilot study in Malaysian tropical climate," *Journal of Housing and the Built Environment*, 34(2), 2019, pp. 533-569.
- [5] T. Susca, "Green roofs to reduce building energy use? A review on key structural factors of green roofs and their effects on urban climate," *Building and Environment*, 106273, 2019.
- [6] Saravanan (Ed.), "Malaysia-PTM ZEO Building," *Roof and Façade Asia*, 5, 46, 2008.
- [7] T. K. Rudel, *Shocks, States, and Sustainability: The Origins of Radical Environmental Reforms*. Oxford University Press, 2019.
- [8] Á. Halldórsson, C. Sundgren & J. Wehner, *25 Sustainable supply chains and energy: where 'planet' meets 'profit'*, Handbook on the Sustainable Supply Chain, 444, 2019.
- [9] V. Y. Tam & K. N. Le, *Sustainable Construction Technologies: Life-cycle Assessment*, Butterworth-Heinemann 2019.
- [10] P. Jiang, Analysis of national and local energy-efficiency design standards in the public building sector in China," *Energy for Sustainable Development*, 15(4), 2011, pp. 443-450.
- [11] C. J. Kibert, *Sustainable construction: green building design and delivery*, John Wiley & Sons, 2016.
- [12] J. S. Khan, R. Zakaria, S. M. Shamsudin, N. I. A. Abidin, S. R. Sahamir, D. N. Abbas & E. Aminudin, "Evolution to Emergence of Green Buildings: A Review," *Administrative Sciences*, 9(1), 6, 2019.
- [13] S. C. Chua & T. H. Oh, "Green progress and prospect in Malaysia," *Renewable and Sustainable Energy Reviews*, 15(6), 2011, pp. 2850-2861.
- [14] H. Leong, "Rising cost of electricity generation-Business News | The Star Online," retrieved from <https://www.thestar.com.my/business/business-news/2017/04/01/rising-cost-of-electricity-generation/>, 2019.
- [15] I. W. Woods, K. H. Roberts & R. K. Racine, "Neural Neural Network," Major Qualifying Projects, 2019.
- [16] R. Miiikkulainen, J. Liang, E. Meyerson, A. Rawal, D. Fink, O. Francon,... & B. Hodjat, "Evolving deep neural networks," *Artificial Intelligence in the Age of Neural Networks and Brain Computing*, 2019, pp. 293-312.
- [17] D. Spiegelhalter. *The Art of Statistics: Learning from Data*, Penguin UK, 2019.
- [18] T. Luna, J. Ribau, D. Figueiredo & R. Alves, "Improving energy efficiency in water supply systems with pump scheduling optimization," *Journal of cleaner production*, 213, 2019, pp. 342-356.
- [19] Y. Li, N. Zhu & B. Qin, "What Affects the Progress and Transformation of New Residential Building Energy Efficiency Promotion in China: Stakeholders' Perceptions." *Energies*, 12(6), 2019, pp. 1027.
- [20] S. N. Kadir, N. M. Tahir, I. M. Yassin & A. Zabidi, "Malaysian tourism interest forecasting using nonlinear autoregressive moving average (NARMA) model," *2014 IEEE Symposium on Wireless Technology and Applications (ISWTA)*, 2014, pp. 193-198.
- [21] I. M. Yassin, A. Zabidi, M. K. M. Salleh & N. A. Khalid, "Malaysian tourism interest forecasting using Nonlinear Auto-Regressive (NAR) model," *2013 IEEE 3rd International Conference on System Engineering and Technology*, 2013, pp. 32-36.
- [22] A. Rusiecki, "Robust learning algorithm based on iterative least median of squares," *Neural processing letters*, 36(2), 2012, pp. 145-160.
- [23] N. A. M. Ghani, S. B. A. Kamaruddin, N. M. Ramli & A. Selamat, "Authenticating ANN-NAR and ANN-NARMA models utilizing bootstrap techniques," *Asian Conference on Intelligent Information and Database Systems*, 2017, pp. 761-771.
- [24] T. R. Biyanto, S. Irawan, H. Y. Febrianto, N. Afdanny, A. H. Rahman, K. S. Gunawan,... & T. N. Bethiana, "Killer whale algorithm: an algorithm inspired by the life of killer whale," *Procedia computer science*, 124, 2017, pp. 151-157.
- [25] N. A. M. Ghani, S. B. A. Kamaruddin, N. M. Ramli, I. Musirin & H. Hashim, "Modified BPNN via Iterated Least Median Squares, Particle Swarm Optimization and Firefly Algorithm," *Indonesian Journal of Electrical Engineering and Computer Science*, 8(3), 2017, pp. 779-786.

- [26] S. B. A. Kamaruddin, S. M. Tolos, P. C. Hee, N. A. M. Ghani, N. M. Ramli, N. B. M. Nasir,... & M. S. Huq, "The quadriceps muscle of knee joint modelling Using Hybrid Particle Swarm Optimization-Neural Network (PSO-NN)," *Journal of Physics: Conference Series*, Vol. 819, No. 1, 2017, p. 012029.
- [27] E. A. Lim et al., "An Improved Radial Basis Function Networks Based on Quantum Evolutionary Algorithm for Training Nonlinear Datasets", *IAES International Journal of Artificial Intelligence (IJ-AI)*, Vol 8, No 2, 2019.
- [28] S. K. Das et al., "Development of Path Planning Algorithm of Centipede Inspired Wheeled Robot in Presence of Static and Moving Obstacles Using Modified Critical-Snake Bug Algorithm", *IAES International Journal of Artificial Intelligence (IJ-AI)*, Vol 8, No 2, 2019.
- [29] X. Huang, X. Zeng, R. Han and X. Wang, "An enhanced hybridized artificial bee colony algorithm for optimization problems," *IAES International Journal of Artificial Intelligence (IJ-AI)*, Vol. 8, No. 1, 2019, pp.87-94.
- [30] K. Lenin, "Shrinkage of real power loss by enriched brain storm optimization algorithm", *IAES International Journal of Artificial Intelligence (IJ-AI)*, Vol. 8, No. 1, 2019, pp. 1-6.
- [31] S. B. A. Kamaruddin, N. A. M. Ghani & N. M. Ramli, "The Improved BPNN-NAR and BPNN-NARMA Models on Malaysian Aggregate Cost Indices with Outlying Data," *Jurnal Teknologi*, 78, 2016, pp. 12-3.
- [32] S. B. A. Kamaruddin, N. A. M. Ghani & N. M. Ramli, "The enhanced BPNN-NAR and BPNN-NARMA models for Malaysian aggregate cost indices with outlying data," *2015 IEEE Conference on e-Learning, e-Management and e-Services (IC3e)*, 2015, pp. 43-48.
- [33] S. B. A. Kamaruddin, N. A. M. Ghani & N. M. Ramli, "Consolidated Backpropagation Neural Network for Malaysian Construction Costs Indices Data with Outliers Problem," *Pertanika Journal of Science & Technology*, 26(1), 2018.
- [34] N. A. M. Ghani, S. B. A. Kamaruddin, N. M. Ramli, N. B. M. Nasir, B. S. B. K. Kader & M. S. Huq, "The quadriceps muscle of knee joint modelling using neural network approach: Part 1," *2016 IEEE Conference on e-Learning, e-Management and e-Services (IC3e)*, 2016, pp. 52-57.
- [35] N. A. M. Ghani, S. B. A. Kamaruddin, N. M. Ramli, N. B. M. Nasir, B. S. B. K. Kader & M. S. Huq, "The quadriceps muscle of knee joint modelling using neural network approach: Part 2," *2016 IEEE Conference on Open Systems (ICOS)*, 2016, pp. 53-58.