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A Novel Ensemble Deep Learning Model for Building Energy Consumption Forecast

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ABSTRACT

The issue of energy limitation has gained attention as a crisis faced by societies. Buildings play a major role, in energy consumption making it crucial to accurately predict their energy usage. This prediction problem has led researchers to explore machine learning techniques in the field of energy efficiency. In this study we investigated the performance of used machine learning methods like Random Forest (RF) Multi Layer Perceptron (MLP) Linear Regression (LR) and deep learning methods for predicting building energy consumption. The findings revealed that deep learning outperformed methods in solving this problem. To address this we proposed a voting based solution that combines three CNN models with structures and a Deep Neural Network (DNN) method. We applied our proposed method to the WiDS Datathon dataset and achieved promising results. Each of the deep learning methods used in the proposed method provide suitable results and finally, the voting them is done by the averaging. Due to the fact that the proposed method obtains the final result from voting regression models with high accuracy, it is considered a robust model that will be able to provide a suitable prediction against new data.

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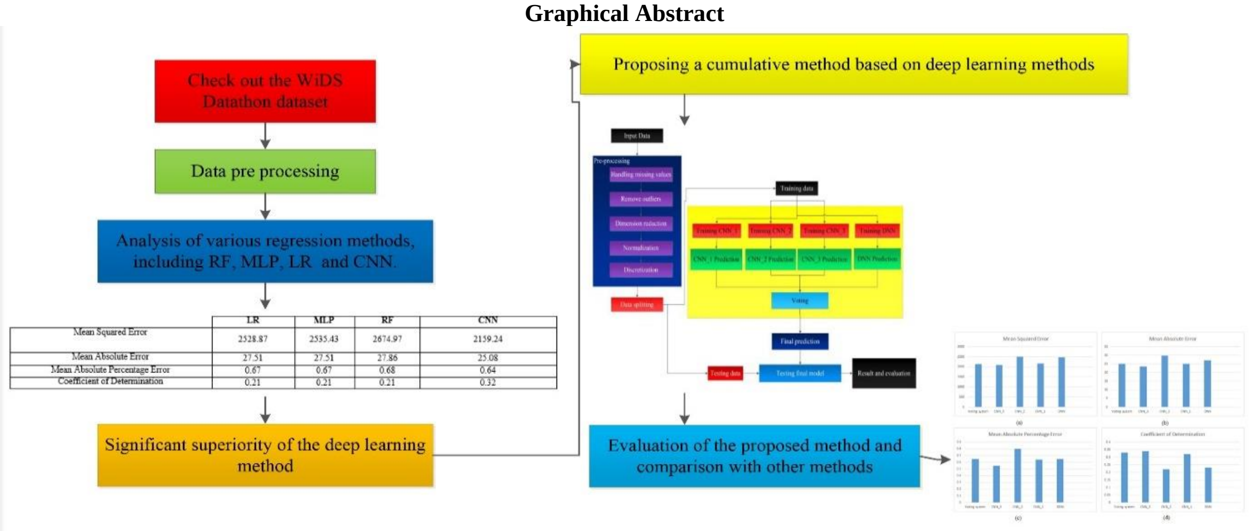
Graphical Abstract



1. INTRODUCTION

The increasing energy consumption at the global level has led to many environmental problems, such as air pollution, global warming, and climate change. Therefore, the management of human activities is necessary to preserve life on earth [1]. In addition, the limitation of energy reserves is a problem that has caused

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many concerns in many countries. Conventional energy sources are not sustainable and obtaining and using fresh reserves is becoming more challenging day by day [2].

These problems have drawn the attention of researchers to the prediction of energy consumption in different fields [3]. Since the contribution of buildings in energy consumption is significant (36 % of the total global energy), predicting building energy consumption and optimizing energy consumption has become a fundamental issue [4].

The building sector is a major energy consumer, accounting for a significant percentage of global energy consumption of CO_2 emissions, and over time its annual growth rate increases. The increase in building energy consumption has been due to population growth and increased demand for building comfortable environments. This increased use of energy consumption in the building sector raises concerns about supply issues and global environmental impacts. Therefore, energy efficiency in this sector is needed to reduce carbon emissions and reduce supply problems, and it serves as the basis for many advanced building energy management techniques, such as safety monitoring, demand response and optimization control.

Hence, a precise method for predicting building energy consumption for energy management systems is important and challenging. However, building energy consumption data often shows nonlinear and non-stationary patterns that make forecasting more difficult.

With the increasing demand for energy consumption, the necessity of activity in this field is still ongoing, as well as up-to-date articles in this field are presented in prestigious journals. In order to address the mentioned problems, in this research, a new approach to predicting energy consumption using artificial intelligence techniques has been presented in order to increase accuracy. In this research, the combination of deep learning and artificial intelligence techniques will be used to develop a solution to the problem that offers both good accuracy and efficiency.

The innovations of this research can be expressed as follows:

• Integrated use of deep learning methods in predicting energy consumption in the building field which includes various networks such as torsion, recursive network, etc. Was.

- Optimize the parameters of several deep learning methods simultaneously in order to achieve higher accuracy. This optimization is applied with the help of a successive halving method.

• Feature selection with the help of recursive feature removal to achieve higher performance.

• Apply the voting process between the results of applying different deep models based on the weights assigned to each model.

In addition, increasing urbanization and the development of cities is one of the issues that aggravates this concern in many countries [5]. One of the available solutions to control this problem is to predict the energy consumption of the building before designing and building the structure. This prediction can lead to the optimal construction of buildings and energy saving. Building energy prediction is related to several factors such as the behavioral characteristics of the building occupants, physical characteristics of the structure, environmental conditions and weather. These cases have complicated the accurate prediction of this issue. Various tools have been provided to simulate building energy consumption and their performance depends on many input parameters. In fact, for the correct use of this tool, accurate and extensive information must be available. In practice, this issue itself has become a new challenge and the unavailability of this information leads to the poor performance of these tools [6]. One of the available solutions to solve this problem is the use of machine learning techniques that are used in various fields [7]. These methods do not require a lot of information and can provide a suitable forecast using the historical data of each region.

Machine learning algorithms and models use patterns and inference to learn, rather than using clear instructions. In this way, they easily identify trends and patterns without the need for human intervention. The widespread use of machine learning methods in various fields to manage multidimensional and complex data in a short time and using limited resources is significant. In addition, researchers' attention to this field has led to the continuous improvement of its techniques.

In this way, it is possible to predict the building's energy needs in any area by using the available data and using the machine learning technique, and avoid possible future problems. The proper performance of machine learning methods largely depends on the models used for learning and the available data. In this research, an approach based on deep learning techniques is used, which processes data in a way inspired by the human brain and recognizes complex patterns. In addition, this research will use a standard data set that has been collected and used by several research teams in recent years, and will keep the possibility of comparing the results for future research.

In the continuation of this research, in section 2, the recent work done in the field of using machine learning and deep learning techniques in the problem of predicting building energy consumption are presented. In section 3, the proposed voting-based system is discussed and its details wiare explained. In section 4, explanations about the data set used are provided. The results of the implementation of the proposed method and its components are presented in section 5, and finally, conclusion is stated in section 6.

2. RELATED WORK

Currently machine learning and deep learning algorithms have proven their ability to manage sequential data and are used to solve many data- driven problems [8, 9]. In Yazdan et al. [10] used RNN to predict energy consumption. The results of this research showed that the proper efficiency of this method is obtained by increasing the number of courses and setting the parameters properly. Olu-Ajayi and Alaka [11] introduced machine learning techniques including artificial neural network, support vector machine and decision tree; they have applied on a dataset of multiple buildings and were able to predict the average amount of energy consumption in buildings.. The results obtained from this research showed that the artificial neural network showed the best performance among the evaluated methods and achieved values of 2.80 and 7.85 in RMSE and MSE criteria, respectively.

A building energy consumption prediction model called SSA-CNNBiGRU was proposed by Wei and Bai [12] which combines SSA, CNN and BiGRU methods. Actual data is used from a number of office buildings in the UK. The obtained results and comparison with other machine learning techniques showed the appropriate accuracy of the proposed method of this research. So that in the MAE criterion, the values of 76.85 and 77.70 were obtained for the prediction of electricity consumption and gas consumption, respectively. A new architecture based on hybrid deep learning was proposed by Jogunola et al. [13] using two layers of CNN and BLSTM and LSTM. This method was used to predict energy consumption in commercial and residential buildings in areas such as Canada and the United Kingdom, and satisfactory results were obtained.

An electric load forecasting model was proposed by Alsharekh et al. [14] in which the input data which includes spatial and temporal features is pre-processed. After that, a method based on R-CNN and MLLSTM is used to learn patterns in two steps. The results of implementing the proposed method on the IHEPC and PJM datasets showed a relative reduction in the error rate.

Khan et al. [15] investigated several deep learning methods and finally a CNN-based model was proposed to extract new features from the analyzed data to predict the energy required in residential and commercial buildings. The features extracted in the previous step are used by the LSTM encoder and decoder to generate prediction sequences. Khan et al. [16] presented a framework for predicting short-term electric energy consumption; which first deals with data preprocessing and cleaning. In the continuation of this research, CNN is used to extract the pattern. The output obtained from this section is sent to a stacked LSTM. Evaluation of this system on the IHEPC and PJM datasets provided good results.

Amalou et al. [17] investigated a number of deep learning methods, such as RNN, LSTM and GRU to solve the problem of energy consumption management and prediction. The results of this research on the SGSC data set showed that among the mentioned methods, GRU provides the best performance., LSTM, GRU and combined LSTM-GRU learning methods were used by Çetiner [18] to predict energy consumption. The proposed method of this research was applied to the dataset published by ENTSO-E (European Distribution Authority). The results of the research showed that the combined LSTM-GRU method has relatively higher training time, however, it has achieved appropriate accuracy.

Wang et al. [19], a multi-scale recurrent neural network (MCRNN) was proposed that uses multi-scale convolution units to gather information about temperature, air pressure, light data. Bi-RNN is used to obtain the dependence between the expressed factors. In the proposed method of this research, a recurrent convolutional connection is used to filter useful multi-scale and long-term information. Lei et al. [20] first used the rough sets theory to reduce the effective factors. In the following, the extracted features were used as the input of a deep neural network to predict the energy consumption of the building in the short and medium term. The results of the proposed method with other methods proved the appropriate accuracy of this method.

El Alaoui et al. [21] focused on predicting the energy consumption of an administrative building through the utilization of machine learning and statistical techniques. The study aims to develop accurate and efficient models for forecasting energy usage, which can contribute to energy management and conservation efforts. They collect and analyze historical energy consumption data from an administrative building, along with relevant external variables like weather conditions and occupancy patterns. This data is then utilized to develop predictive models using machine learning algorithms, such as artificial neural networks and support vector regression. Additionally, statistical methods, including autoregressive integrated moving average models, were employed for benchmarking purposes and model comparison. The models' performances were compared based on three statistical indicators: normalized root mean square error (nRMSE), mean average error (MAE), and correlation coefficient (R). The results show that all studied models have good accuracy, with a correlation coefficient of $0.90 < R < 0.97$. The artificial neural network outperforms all other models (R=0.97, nRMSE=12.60%, MAE= 0.19 kWh).

3. PROPOSED METHOD

In this study, several machine learning regression

TABLE 1. Comparison of previous works

Evaluation	Data collection	Method	Reference
RMSE / 0.084	OPSD, Germany	RNN	(10)
RMSE / 2.80	MHCLG + Meteostat	ANN	(11)
MAE/ 76.85 MAE/ 77.70	Real office buildings in the UK	SSA-CNNBiGRU	(12)
MSE / 0.09	commercial and domestic building in Canada and UK	CBLSTM-AE	(13)
MSE / 0.002 MSE / 0.0005	IHEPC and PJM datasets	R-CNN + ML-LSTM	(14)
MSE / 0.19 RMSE / 0.47	UCI residential building dataset	CNN + LSTM-AE b	(15)
RMSE / 14.85 RMSE / 3.4	IHEPC and PJM datasets	CNN + stacked LSTM	(16)
RMSE / 0.034	SGSC	GRU	(17)
MSE / 0.0013	Germany energy consumption data set	LSTM-GRU	(18)
RMSE / 38.3016	Residential building in Belgium	MCRNN	(19)
Relative error/ 7%	Civil public and laboratory building	RS-DBN	(20)

methods, including Random Forest (RF), Multi-Layer Perceptron (MLP), Linear Reggression (LR), and Convolutional Neural Networks (CNN) were used to analyze the investigated data set. The results showed that the CNN method has a significant superiority over the other investigated techniques. Since deep learning methods can detect complex patterns in data with appropriate accuracy, in this research, deep learning methods were further investigated. Different structures of CNN and Deep Neural Network (DNN) were investigated and finally a method based on voting was proposed to predict building energy consumption. The proposed method of this research is shown in Figure 1. Since deep learning methods work well on data and perform well, it is difficult to choose the best method among them. To get better results in the proposed method of this research, voting technique has been used. The proposed voting regression-based method is a meta-estimator that averages the predictions of individual models and provides a final prediction. In this method, instead of providing a strong model, a combination of several models is used. In the proposed method, each model examines aspects of the data structure and the result of the final model will be more robust. In methods with appropriate robustness, one can be sure that the performance of the model does not change and does not deviate significantly when using new data compared to the training data. As can be seen in the figure, in the proposed research system, three different versions of CNN and a DNN models are applied to the training data after the pre-processing of the obtained data. The specifications of the CNNs used in the proposed method are given in Table 2. The results obtained from voting methods will be presented as the final prediction.

We examined different methods of deep learning approaches with different parameters; finally, the architecture proposed in this article has provided the best results.

4. DATA SET

In this research, the WiDS Datathon dataset is used to check the energy consumption prediction model. WiDS Datathon has been created in collaboration with various institutions and universities such as Stanford University, Harvard University and the WiDS Datathon Committee. This continuously developing dataset is collected by research teams and university researchers around the world for climate change mitigation and energy efficiency. The WiDS Datathon 2022 used in this research contains approximately 100k observations of building energy consumption records, and each record represents the energy consumption information of a building over the course of one year. This information was collected over 7 years from several different states of the United States. In each record, information related to 31 features is recorded, which includes building characteristics, climate characteristics of the region (the region where the building is located), geographical characteristics of the region, the year in which the information was checked, and the amount of energy consumption. Among the things that are checked for building specifications are things like the type of

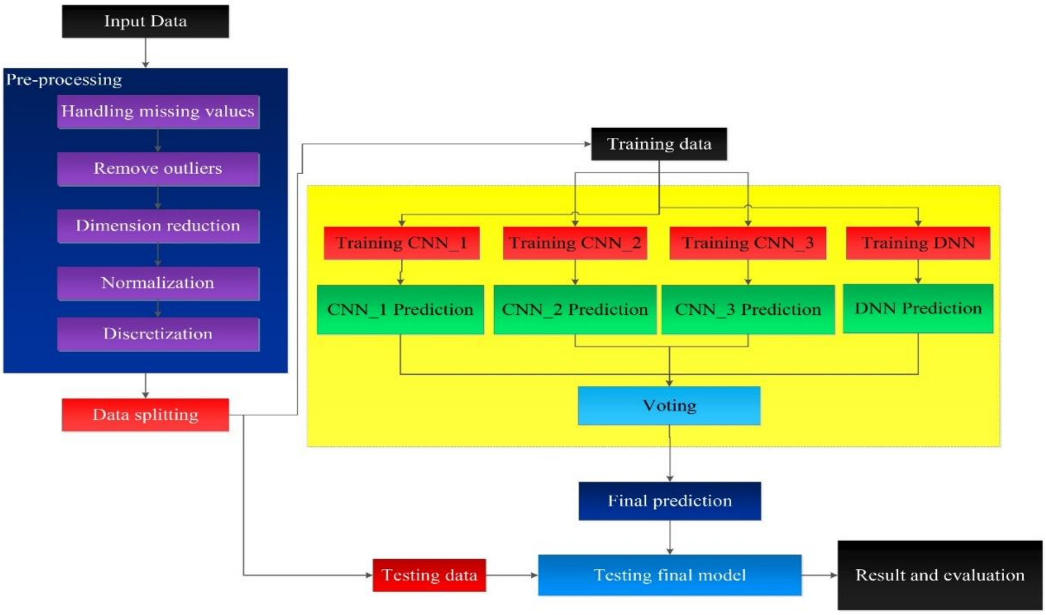

Figure 1. Flowchart of the proposed method

TABLE 2: The specifications of the CNNs used in the proposed method

	Layer (type)	Output Shape	Param #
CNN_1	Conv1D_1 (Conv1D)	(None, 54, 64)	640
	dropout_2 (Dropout)	(None, 54, 64)	0
	Conv1D_2 (Conv1D)	(None, 52, 32)	6176
	Conv1D_3 (Conv1D)	(None, 51, 16)	1040
	MaxPooling1D(MaxPooling1D)	(None, 25, 16)	0
	flatten_2 (Flatten)	(None, 400)	0
	Dense_1 (Dense)	(None, 64)	25664
	Dense_2 (Dense)	(None, 1)	65
CNN_2	Conv1D_1 (Conv1D)	(None, 58, 32)	192
	dropout_1 (Dropout)	(None, 58, 32)	0
	Conv1D_2 (Conv1D)	(None, 56, 32)	3104
	MaxPooling1D (MaxPooling1D)	(None, 28, 32)	0
	flatten_1 (Flatten)	(None, 896)	0
	Dense_1 (Dense)	(None, 32)	28704
	Dense_2 (Dense)	(None, 1)	33
CNN_3	Conv1D_1 (Conv1D)	(None, 56, 64)	512
	dropout (Dropout)	(None, 56, 64)	0
	Conv1D_2 (Conv1D)	(None, 54, 32)	6176
	Conv1D_3 (Conv1D)	(None, 53, 16)	1040
	MaxPooling1D (MaxPooling1D)	(None, 26, 16)	0
	flatten (Flatten)	(None, 416)	0
	Dense_1 (Dense)	(None, 32)	13344
	Dense_2 (Dense)	(None, 1)	33

building, the floor area of the building and the year of its construction. Among the climatic and geographical data recorded in this dataset, we can mention things like minimum, average and maximum temperature, annual rainfall in the building site, maximum wind speed and its direction. More information about this dataset is available on the Kaggle site.

In order to use the WiDS Datathon data set in this research, pre-processing operations were first applied to the data. Management of missing values, removal of outliers, dimensionality reduction, normalization and discretization are among the things that have been done in the pre-processing of the data set investigated in this research.

5. RESULTS AND DISCUSSION

In order to better compare the performance of the proposed method in this research, the performance of the basic regression methods that are used in many researches are first examined. In the first experiment, RF, MLP, LR, and CNN methods were applied separately on the training data set, and the results obtained from their application on the test data set are given in Table 3. As can be seen from the results of this table, the results obtained from the CNN method are significantly superior to other methods. Among RF, MLP and LR regression methods, LR regression method has the best performance. However, the CNN method has performed better than it in terms of MSE, MAE, MAPE and Coefficient of Determination by 369.63, 2.43, 0.03 and 0.11, respectively. The comparison of the methods in different criteria in Figure 2 clearly shows the superiority of the CNN.

In the continuation of this section, the performance results of the proposed method of this research and the deep learning methods used in it were compared. As stated in the previous section, three regression models based on CNN that have different structures and one regression model based on DNN have been used in the proposed method. The results recorded by each of them are given in Table 4. Figure 3 shows the comparison of the efficiency of deep learning methods and the implemented basic methods (LR, MLP and RF). Comparison of the graphs obtained from this figure show that deep learning methods are superior in various criteria.

TABLE 3. Comparison of the results obtained from LR, MLP, RF, and CNN

	LR	MLP	RF	CNN
Mean Squared Error	2528.87	2535.43	2674.97	2159.24
Mean Absolute Error	27.51	27.51	27.86	25.08
Mean Absolute Percentage Error	0.67	0.67	0.68	0.64
Coefficient of Determination	0.21	0.21	0.21	0.32

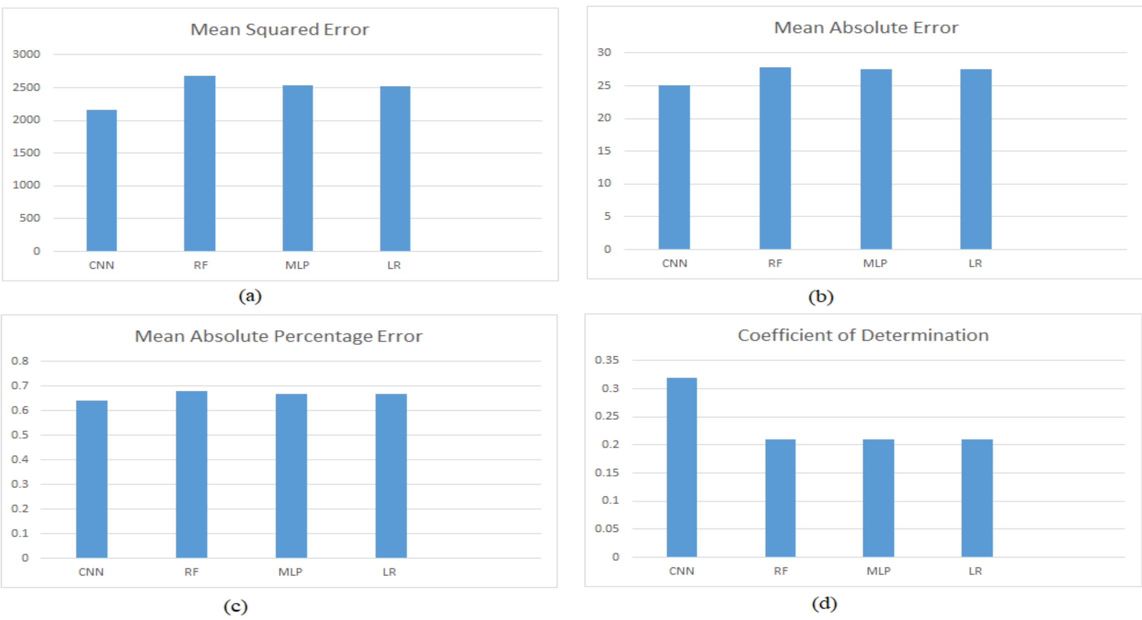

Figure 2. Performance comparison of LR, MLP, RF, and CNN in (a): Mean Squared Error (b): Mean Absolute Error (c): Mean Absolute Percentage Error and (d): Coefficient of Determination

TABLE 4. Comparison of the results obtained from DNN, CNN_1, CNN_2, CNN_3 and Voting system

	DNN	CNN_1	CNN_2	CNN_3	Voting system
Mean Squared Error	2457.63	2159.24	2495.87	2092.89	2126.62
Mean Absolute Error	27.02	25.08	29.72	23.45	25.00
Mean Absolute Percentage Error	0.65	0.64	0.80	0.55	0.65
Coefficient of Determination	0.23	0.32	0.22	0.34	0.33

Figure 3. Performance comparison of LR, MLP, RF, CNN_1, CNN_2, CNN_3 and DNN in (a): Mean Squared Error (b): Mean Absolute Error (c): Mean Absolute Percentage Error and (d): Coefficient of Determination

Figure 4 shows the comparison of deep learning methods and the proposed voting-based method. The results of this study show that the CNN_3 method is the best available method and the proposed method of this research is the second best method in the results with a small difference. The proposed method consists of voting regression models and the average of the methods used in it is used to obtain the final result. In this way, the final result obtained is directly related to the results of the basic methods used, and the final result will be less than the best available method among the basic methods. This small difference in the accuracy of the system can be ignored compared to the more robustness of the proposed method.

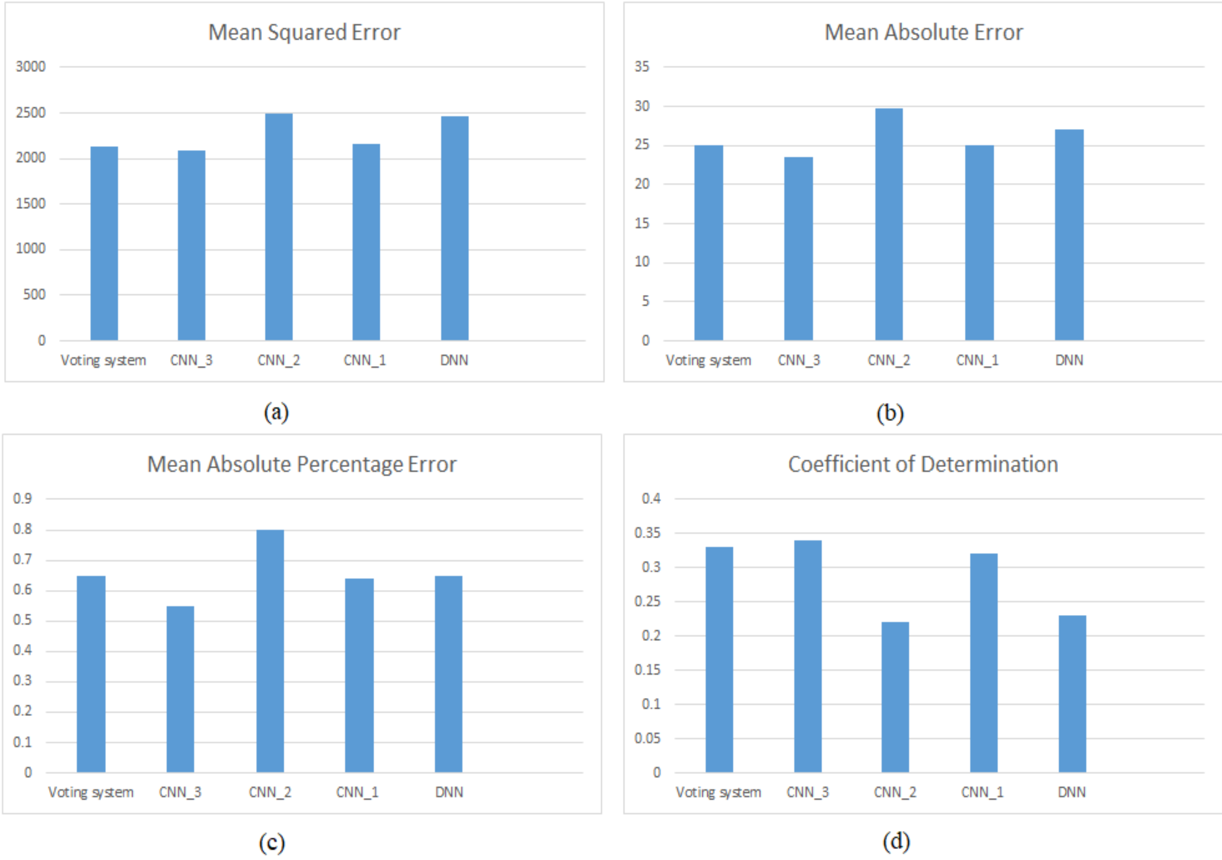

Figure 4. Performance comparison of DNN, CNN_1, CNN_2, CNN_3 and Voting system in (a): Mean Squared Error (b): Mean Absolute Error (c): Mean Absolute Percentage Error and (d): Coefficient of Determination

6. CONCLUSION

In this research, first, a number of machine learning regression models were used to predict building energy consumption. For appropriate review of the methods, the WiDS Datathon data set was used, which is available to all researchers and makes it possible to compare the results for future research. The results of the investigations showed that the compared deep learning method recorded relatively more appropriate results in all the investigated criteria, including MAE, MSE, MAPE and R2. In this way, in the continuation of this research, a method based on voting of deep learning methods was proposed. Each of the deep learning methods used in the proposed method provide suitable results and finally, the voting between these regression methods is done by the averaging. Due to the fact that the proposed method obtains the final result from voting regression models with high accuracy, it is considered a robust model that will be able to provide a suitable prediction against new data.

7. REFERENCES

1. Zabihian F, Fung A. Fuel and GHG emission reduction potentials by fuel switching and technology improvement in the Iranian electricity generation sector. International Journal of Engineering (IJE). 2009;3(2):159.
2. Al-johani H, Saleh Z, Almalki A, Almalki A, AbdelMeguid H. Advancements in Green Hydrogen Production using Seawater Electrolysis in Tabuk, Saudi Arabia. International Journal of Engineering (IJE). 2023;15(3):42.
3. Olu-Ajayi R, Alaka H, Owolabi H, Akanbi L, Ganiyu S. Data-Driven Tools for Building Energy Consumption Prediction: A Review. Energies. 2023;16(6):2574. https://doi.org/10.3390/en16062574
4. Khalil M, McGough AS, Pourmirza Z, Pazhoohesh M, Walker S. Machine Learning, Deep Learning and Statistical Analysis for forecasting building energy consumption—A systematic review. Engineering Applications of Artificial Intelligence. 2022;115:105287. https://doi.org/10.1016/j.engappai.2022.105287
5. Yu J, Chang W-S, Dong Y. Building energy prediction models and related uncertainties: A review. Buildings. 2022;12(8):1284. https://doi.org/10.3390/buildings12081284
6. Runge J, Zmeureanu R. Forecasting energy use in buildings using artificial neural networks: A review. Energies. 2019;12(17):3254. https://doi.org/10.3390/en12173254

7. Sheikhi S, Kheirabadi MT, Bazzazi A. An effective model for SMS spam detection using content-based features and averaged neural network. International Journal of Engineering. 2020;33(2):221-8. https://doi.org/10.5829/ije.2020.33.02b.06
8. Amasyali K, El-Gohary NM. A review of data-driven building energy consumption prediction studies. Renewable and Sustainable Energy Reviews. 2018;81:1192-205. https://doi.org/10.1016/j.rser.2017.04.095
9. Ardabili S, Abdolalizadeh L, Mako C, Torok B, Mosavi A. Systematic review of deep learning and machine learning for building energy. Frontiers in Energy Research. 2022;10:786027. https://doi.org/10.3389/fenrg.2022.786027
10. Yazdan MMS, Khosravia M, Saki S, Al Mehedi MA. Forecasting Energy Consumption Time Series Using Recurrent Neural Network in Tensorflow. 2022. https://doi.org/10.20944/preprints202209.0404.v1
11. Olu-Ajayi R, Alaka H, editors. Building energy consumption prediction using deep learning. EDMIC 2021 CONFERENCE PROCEEDINGS ENVIRONMENTAL DESIGN & MANAGEMENT INTERNATIONAL CONFERENCE: Confluence of Theory and Practice in the Built Environment: Beyond Theory into Practice; 2021: Obafemi Awolowo University, Ile-Ife. Retrieved from https://oauife.edu.ng/
12. Wei S, Bai X. Multi-Step Short-Term Building Energy Consumption Forecasting Based on Singular Spectrum Analysis and Hybrid Neural Network. Energies. 2022;15(5):1743. https://doi.org/10.3390/en15051743
13. Jogunola O, Adebisi B, Hoang KV, Tsado Y, Popoola SI, Hammoudeh M, Nawaz R. CBLSTM-AE: a hybrid deep learning framework for predicting energy consumption. Energies. 2022;15(3):810. https://doi.org/10.3390/en15030810
14. Alsharekh MF, Habib S, Dewi DA, Albattah W, Islam M, Albahli S. Improving the Efficiency of Multistep Short-Term Electricity Load Forecasting via R-CNN with ML-LSTM. Sensors. 2022;22(18):6913. https://doi.org/10.3390/s22186913
15. Khan ZA, Hussain T, Ullah A, Rho S, Lee M, Baik SW. Towards efficient electricity forecasting in residential and commercial buildings: A novel hybrid CNN with a LSTM-AE based framework. Sensors. 2020;20(5):1399. https://doi.org/10.3390/s20051399
16. Khan ZA, Ullah A, Haq IU, Hamdy M, Mauro GM, Muhammad K, et al. Efficient short-term electricity load forecasting for effective energy management. Sustainable Energy Technologies and Assessments. 2022;53:102337. https://doi.org/10.1016/j.seta.2022.102337
17. Amalou I, Mouhni N, Abdali A. Multivariate time series prediction by RNN architectures for energy consumption forecasting. Energy Reports. 2022;8:1084-91. https://doi.org/10.1016/j.egyr.2022.07.139
18. ÇETİNER H. Recurrent Neural Network Based Model Development for Energy Consumption Forecasting. Bitlis Eren Üniversitesi Fen Bilimleri Dergisi. 2022;11(3):759-69. https://doi.org/10.17798/bitlisfen.1077393
19. Wang H, Ma W, Wang Z, Lu C. Multiscale convolutional recurrent neural network for residential building electricity consumption prediction. Journal of Intelligent & Fuzzy Systems. 2022;43(3):3479-91. https://doi.org/10.3233/jifs-213176
20. Lei L, Chen W, Wu B, Chen C, Liu W. A building energy consumption prediction model based on rough set theory and deep learning algorithms. Energy and Buildings. 2021;240:110886. https://doi.org/10.1016/j.enbuild.2021.110886
21. El Alaoui M, Chahidi LO, Rougui M, Lamrani A, Mechaqrane A. Prediction of Energy Consumption of an Administrative Building using Machine Learning and Statistical Methods. Civil Engineering Journal. 2023 May 1;9(5):1007-22. http://dx.doi.org/10.28991/CEJ-2023-09-05-01

Persian Abstract

چکیده

مسئله محدودیت انرژی به عنوان بحرانی که جوامع با آن روبرو هستند مورد توجه قرار گرفته است. ساختمان ها نقش مهمی در مصرف انرژی دارند و پیش بینی دقیق مصرف انرژی انها بسیار مهم است. این مشکل پیش بینی باعث شده است که محققان تکنیک های یادگیری ماشین را در زمینه بهره وری انرژی کشف کنند. در این مطالعه عملکرد روش های یادگیری ماشینی مورد استفاده مانند جنگل تصادفی (RF) شبکه عصبی چند لایه کاملا متصل (MLP) رگرسیون خطی (LR) و یادگیری عمیق برای پیش بینی مصرف انرژی ساختمان مورد بررسی قرار گرفت. یافته ها نشان داد که یادگیری عمیق در حل این مشکل از روشهای دیگر بهتر عمل می کند. برای رسیدگی به این موضوع، ما یک راه حل مبتنی بر رای گیری را پیشنهاد کردیم که سه مدل شبکه‌های عصبی پیچشی CNN را با ساختارها و روش شبکه عصبی عمیق DNN ترکیب می کند. ما روش پیشنهادی خود را به مجموعه داده های WiDS Datathon اعمال کردیم و به نتایج امیدوار کننده ای دست یافتیم. هر یک از روش های یادگیری عمیق مورد استفاده در روش پیشنهادی نتایج مناسبی را ارائه می دهند و در نهایت رای‌گیری آنها با میانگین انجام می شود. با توجه به اینکه روش پیشنهادی نتیجه نهایی را از مدل های رگرسیون رای گیری با دقت بالا به دست می آورد، یک مدل قوی محسوب می شود که قادر به ارائه پیش بینی مناسب در برابر داده های جدید خواهد بود.