Application of Neural Networks to improve Energy Efficiency for household appliances

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***Abstract*—This paper presents a method for predicting an appliance's power consumption based on data collected by basic sensors. The collected data includes temperature, humidity, and current draw of the appliance over a specific period. A neural network is trained using this data to make power consumption predictions, which can be used to suggest the optimal appliance settings based on external factors observed during usage time. The proposed method can optimize energy consumption and reduce costs by providing personalized appliance settings based on real-time external conditions.**

***Index Terms*—Current draw, external variables, home appliance, artificial neural network.**

I. Introduction

Neural networks have been increasingly used in recent years to determine appliance efficiency in order to reduce power consumption without affecting the quality of life. The application of neural networks in this field allows for the development of efficient and accurate models that can be used to identify patterns and trends in energy consumption, and make predictions about future energy usage. These models can then be used to optimize appliance usage and reduce energy waste, resulting in significant cost savings and a reduction in overall power consumption. Additionally, the use of neural networks in this context can also help to improve the overall performance and functionality of appliances, ensuring that they meet consumer needs while still being energy efficient.

A. Air Conditioners

An air conditioner is a device that is designed to cool, dehumidify, and filter the air in a room or building. It operates by removing heat from the air inside and transferring it outside, thus reducing the temperature and creating a more comfortable living or working environment. Modern air conditioners come in a variety of sizes and types, including window units, portable units, and central air systems, to suit the specific needs of different spaces and buildings. They also feature advanced technologies, such as energy-saving modes, programmable thermostats, and air filtration systems, that enhance their performance and improve indoor air quality. Whether you are looking to cool a single room or a large building, an air conditioner provides a reliable and efficient solution for maintaining a comfortable environment.

B. Artificial Neural Networks

Artificial Neural Networks (ANNs) are mathematical models inspired by the structure and function of the human brain. They are used for tasks such as image recognition, natural language processing, and decision-making. ANNs consist of interconnected nodes, or "neurons," that process and transmit information through weighted connections. The output of each neuron is determined by a mathematical activation function that summarizes the input from other neurons. ANNs can be trained using large amounts of data to adjust the weights of their connections, enabling them to make predictions or decisions with increasing accuracy.

This paper details the implementation of an artificial neural network (ANN) for predicting the current draw of an air conditioner based on external humidity and temperature as well as the parameters set on the air conditioner. The ANN is trained using data to make predictions about the current draw, which can be used to determine the efficiency of the air conditioner. By obtaining the temperature and humidity data from a public weather source and using an efficiency curve created from the data, the paper suggests different parameters that can be set on the air conditioner to increase its efficiency.

C. BEE Efficiency Ratings

The Bureau of Energy Efficiency (BEE) has introduced a star rating system, Indian Seasonal Energy Efficiency Ratio (ISEER), to rate air conditioners in India. ISEER takes into account the varying temperatures in different regions of India and provides a more accurate measure of air conditioner efficiency, leading to lower electricity bills for consumers. ISEER measures energy efficiency based on performance at outside temperatures between 24-43°C and replaces the previous standard, IS 1391, which tested air conditioners at a fixed outside temperature of 35°C. ISEER ratings have been introduced on a voluntary basis for variable speed air conditioners since June 2015 and will become mandatory for all air conditioners starting in January 2018. The new ratings are expected to result in higher energy efficiency and reduced energy consumption. [4]

D. Drawbacks in existing standards of efficiency

There are limitations of the current ISEER (Indian Seasonal Energy Efficiency Ratio) method for measuring the efficiency of air conditioners in India. The weighted average approach used in ISEER can overgeneralize Indian weather conditions, resulting in inaccuracies in determining the efficiency of air conditioners in specific regions. This can cause inefficiencies, even with the correctional parameters used by the Bureau of Energy Efficiency (BEE). [3]

While the five-star rating system indicates the highest efficiency as per Indian standards, it fails to provide sufficient information to the layman on how to use the air conditioner in the most efficient manner. The lack of information on the optimal parameters to set the air conditioner at, can lead to a discrepancy between the energy rating and the actual energy consumption of the air conditioner in a given weather condition in a specific region.

II. METHODOLOGY

A. Neural Network implementation

In this study, we implemented a machine learning workflow using TensorFlow to build and train a neural network model for predicting current based on temperature and humidity data. The workflow consisted of several steps, including loading data from a CSV file using pandas, separating input and output features, defining a neural network model using the Sequential class from Keras, compiling the model using the mean squared error loss function and the Adam optimizer, and training the model using the fit() function. The model was trained for 100 epochs with a batch size of 32, and the trained model was saved to disk for future use.

The input and output data were preprocessed by converting them to NumPy arrays. The neural network model was defined with three dense layers with different numbers of neurons

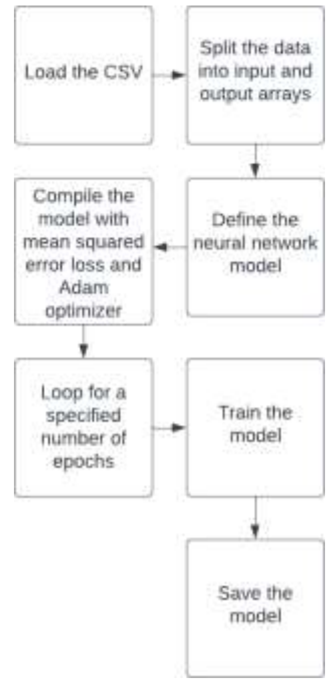

Fig. 1. Neural Network Training Flowchart

and activation functions. The first two layers used the ReLU activation function, while the final layer did not have any activation function. The model was compiled with the mean squared error loss function and the Adam optimizer with a learning rate of 0.001. The model was trained using the fit() function, which optimized the model parameters to minimize the loss function.

The model's performance was evaluated by calculating the mean squared error (MSE) and the mean absolute error (MAE) on the test data. The model's ability to predict current based on temperature and humidity was assessed using visualizations and statistical metrics.

The trained model was saved to disk using the save() function for future use. Overall, the implementation of the machine learning workflow using TensorFlow provided a reliable and efficient way to build and train a neural network model for predicting current based on temperature and humidity data.

B. Data collection implementation

The NodeMCU is a powerful microcontroller board that can be programmed with the Arduino IDE and connected to various sensors and data sources. In this project, we use a NodeMCU board to create a plug and play system that measures external temperature and humidity using a TH11 sensor, measures the current an air conditioner is drawing using an ACS712 30A sensor, and sends the data to Google Sheets for storage and analysis.

To get started, we need to wire up the sensors to the NodeMCU board, as described in the previous summary. Once

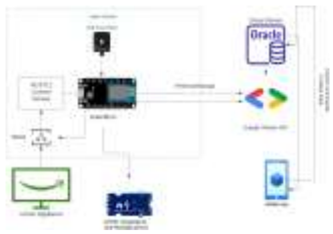

Fig. 2. Block Diagram of Data Collection setup

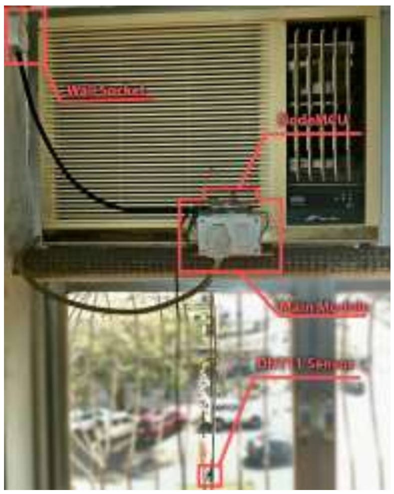

Fig. 3. Physical Data Collection Setup

the sensors are connected, we can program the NodeMCU board to read the sensor values and send them to Google Sheets.

To send the data to Google Sheets, we use Google Apps Script, which is a scripting language based on JavaScript that can be used to automate Google Suite applications. We create a Google Sheet with the necessary columns for the sensor data, and then create a web app using Google Apps Script that accepts HTTP POST requests and adds the data to the Google Sheet.

In the NodeMCU program, we use the ESP8266 HTTP-Client library to send HTTP POST requests to the webhook URL provided by the Google Apps Script web app. We format the sensor data as a JSON object and include it in the body of the HTTP POST request.

The Google Sheet is picked up by the VPS at Oracle Cloud Infrastructure at an interval period of thirty minutes, and stored locally as a .csv file. After every subsequent download, a backup of the previous .csv file is stored in a separate folder.

The python based Neural Network script mentioned in the previous sub-section then executes, training itself to predict the missing variable (Power in Amps), and considers the addition of the new data.

III. Results

A. Result Data

The data obtained from the NodeMCU apparatus can provide valuable insights into the external temperature and humidity, as well as the energy consumption of air conditioners. The TH11 sensor is capable of measuring the external temperature and humidity with high accuracy, providing real-time data on the environmental conditions that air conditioners are operating in. The ACS712 30A sensor, on the other hand, is capable of measuring the current drawn by air conditioners, which can be used to calculate the energy consumption of the air conditioner. By collecting and analyzing this data, policy-makers and energy experts can gain a better understanding of the energy consumption patterns of air conditioners, as well as the impact of external conditions on their performance. This can help in developing more effective energy efficiency policies and programs that can reduce energy consumption and greenhouse gas emissions, while also promoting the use of more energy-efficient air conditioners.

TABLE I

Table Head	**Training Data**		
	Power Draw	***Humidity***	***Temperature***
1	2030W	0	43°C
2	1755W	0	42°C
3	1718W	0	41°C
4	1748W	0	40°C
5	1683W	0	39°C
6	1770W	0	38°C
7	1655W	4	37°C
8	1746W	4	36°C
9	1731W	7	35°C
10	1798W	8	34°C
11	1801W	17	33°C
12	1824W	17	32°C
13	1831W	21	31°C
14	1824W	25	30°C
15	1805W	21	29°C
16	1782W	34	28°C
17	1737W	33	27°C
18	1717W	49	26°C
11	1706W	56	25°C
11	1692W	59	24°C
11	1797W	43	23°C

Power(A) averaged for each °C change

B. Results for the implemented Neural Network

The developed neural network can help make suggestions on the expected current that an air conditioner draws by taking into account the external humidity and temperature. By training the neural network on a large dataset of external conditions and the corresponding current draw of air conditioners, it can learn to identify patterns and correlations between these variables. Once the neural network is trained, it can be used to predict the expected current draw of an air conditioner based on the external humidity and temperature inputs. This can help in developing more accurate energy efficiency ratings for air conditioners, which can help consumers make more informed purchasing decisions. The accuracy of the neural

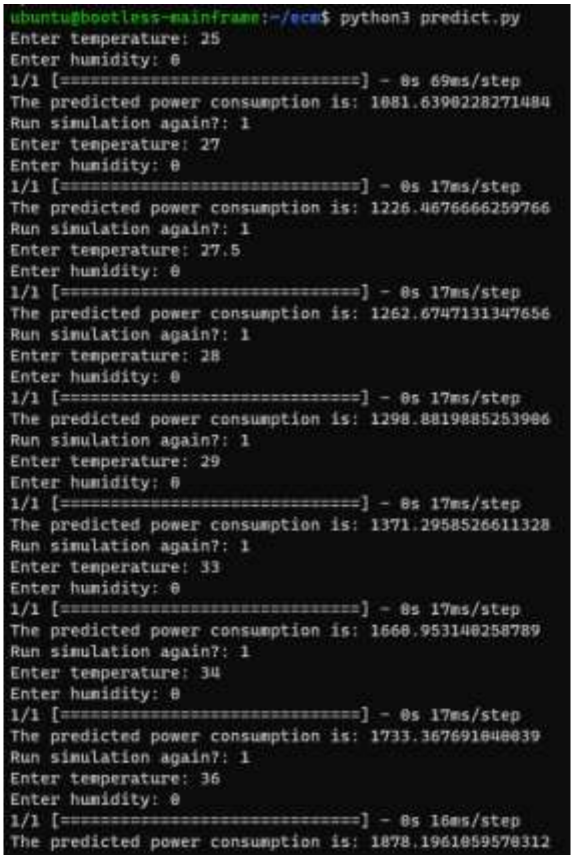

Fig. 4. Terminal Output for Neural Network

network predictions is depicted in Figure 6. A reference graph, as shown in Figure 5 and obtained from a separate source than the training data, has been provided to facilitate comparison of the neural network's power draw predictions with the actual data collected from real-life scenarios. Additionally,

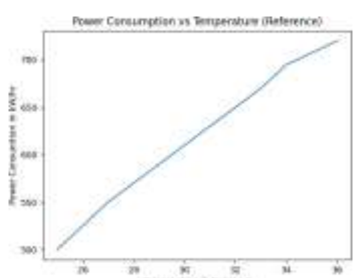

Fig. 5. Plotted Power Consumption vs Temperature graph from reference

the neural network can be used by policymakers and energy experts to identify regions where air conditioners are operating inefficiently, and to develop targeted interventions to improve their energy efficiency. Overall, the use of the developed neural network can help in promoting the use of more energy-efficient air conditioners, while also reducing energy consumption and greenhouse gas emissions.

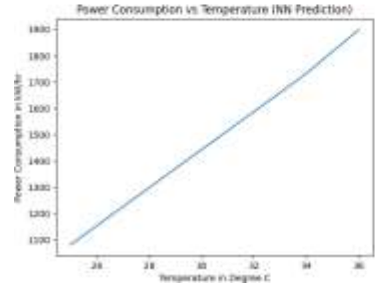

Fig. 6. Plotted Power Consumption vs Temperature graph from Neural Network

C. Limitations

One of the limitations of data collection for the neural network in the real world is that it is difficult to isolate and control all variables that may impact the performance of air conditioners. For instance, factors such as building design, insulation, and occupancy patterns can all impact the energy consumption of air conditioners, and it is difficult to control these factors in the real world. Additionally, the performance of air conditioners can vary depending on their age, maintenance, and other factors, which can also be difficult to control.

The widely known external conditions like temperature and humidity have a directly proportional relationship with the power draw of an air conditioner. The relation of temperature-humidity of the region the data was collected in however, is inversely proportional, meaning, peak highest temperatures caused in the daytime are accompanied by the lowest humidity percentage records, and vice versa for night time. These effects all-in-all, tend to cancel out lot of good data that could be gained by controlling these factors well, as this temperature-humidity relation isn't consistent for the entire nation, and especially not for the world as a whole.

To address these limitations, more competent agencies responsible for the public efficiency rating system can implement this approach with all controls in place. For instance, they can develop standardized testing protocols that take into account the impact of external conditions on the performance of air conditioners, and they can conduct these tests in controlled environments to isolate and control all relevant variables. Additionally, they can develop more rigorous standards for air conditioner maintenance and performance, and they can implement monitoring programs to ensure that air conditioners continue to perform efficiently over time. By implementing these controls, more competent agencies can ensure that the data collected for the neural network is more reliable and accurate, which can help in developing more effective energy efficiency policies and programs.

D. Future Scope

1) Addition of equipment to automatically determine appliance type, model, manufacturer, etc.: The recognition that a majority of household appliances operate on a distinct frequency derived from the power supply and the ability to detect and utilize these frequencies to distinguish between devices without the requirement of any user input has come to fruition [2]. The integration of sensors for this purpose would significantly reduce the burden on the user.

2) Integration with energy management systems: The data collected by the NodeMCU apparatus can be integrated with energy management systems to provide energy experts and policymakers with insights into regional variations in energy consumption, as well as the impact of external conditions on energy consumption. This can help in developing more effective energy efficiency policies and programs that are tailored to the specific needs of different regions.

3) Expansion to other appliances: The approach used in this project can be expanded to other appliances, such as refrigerators, washing machines, and dishwashers, to develop more accurate energy efficiency ratings and to promote the use of more energy-efficient appliances.

4) Integration with renewable energy systems: The data collected by the NodeMCU apparatus can be integrated with renewable energy systems, such as solar panels and wind turbines, to optimize the use of renewable energy sources based on the environmental conditions and energy consumption patterns of appliances.

IV. Conclusion

In conclusion, the development of a neural network using external temperature and humidity data to predict the current draw of an air conditioner is a promising approach to improving energy efficiency ratings. By taking into account regional variations in environmental conditions, this approach can provide more accurate and reliable energy efficiency ratings, which can help consumers make more informed decisions about which appliances to purchase and how to use them more efficiently. The NodeMCU apparatus developed in this project provides a practical example of how this approach can be implemented in the real world, and the integration with Google Sheets using Google Appscript and a webhook URL can enable real-time monitoring of the energy consumption of air conditioners. While there are limitations to the data collection process in the real world, more competent agencies responsible for the public efficiency rating system can implement this approach with all controls in place to ensure more accurate and reliable data collection. The future scopes of this project are also promising, including integration with smart home systems, energy management systems, and renewable energy systems. Overall, this project demonstrates the potential for using artificial neural networks to improve energy efficiency and reduce greenhouse gas emissions, while also providing valuable insights into regional variations in energy consumption.

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