AN INTELLIGENT SYSTEM TO AUTOMATE HUMIDITY MONITORING AND HUMIDIFIER CONTROL USING INTERNET-OF-THINGS (IOT) AND ARTIFICIAL INTELLIGENCE

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ABSTRACT

Air conditioners are widely used in family homes all over the world. However, the side effects of using air conditioners and dehumidification can cause health problems if people remain in low-humidity environments. This paper traces the development of a software application and system to create an intelligent humidifier that automatically turns on or off for convenience or for those who cannot engage manual control. We applied our application to a humidifier for several days and conducted a qualitative evaluation of the approach. Results affirmed the usability and capacity of our automatic control system.

KEYWORDS

IoT, Machine Learning, Deep Learning, Artificial Intelligence.

1. INTRODUCTION

Since the first modern air conditioner was invented in 1902 by Willis Haviland Carrier, air conditioning has grown to become an indispensable part of people's lives. [1] It adjusts the room temperature, especially during scorching summers. However, problems can come with prolonged use of air conditioning, and a drop in indoor humidity levels is one of them. Although the air conditioner is not a dehumidifier, dehumidification is part of the cooling process since moisture is drawn out of the room together with heat. [2] This moisture collects on the evaporator coil, and is drained out of the home via the condensate pan and drain line. Heating a room during the winter has a similar effect since as the room is heated, the relative humidity drops.

People don't usually feel comfortable in dry air. Low humidity in a room can even cause health problems, such as frequent sore throats, chapped lips, and bloody noses. This is because as moisture evaporates, we lose a vital layer of protection that is effective at filtering bacteria. Also, when our noses and lips are split and irritated, the capillaries are more exposed, making it easier for microbes to pass directly into our bloodstream. In addition, some studies suggest that viruses such as influenza thrive in environments with low humidity. [3] Besides health problems, low humidity can also cause issues like splitting wooden floorboards or furniture.

To keep room humidity at comfortable levels, a humidifier can help. However, it is impossible to keep our attention on the internal environment all the time to decide whether to turn a humidifier

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on or off, especially during work or sleep. Our appliance will solve this problem by evaluating the indoor environment and automatically turning the humidifier on or off.

In this paper, we trace the current humidifier market to find the best way to maintain the optimal humidity that can decrease when the AC system is cooling or heating a room. Our goal is to create a product that automatically monitors the indoor environment and works to maintain optimal humidity levels. Our method is inspired by Google Nest, which maintains a user's desired temperature by controlling the AC system using machine learning. There are some advantages of our product over a humidifier with machine learning. First, our system can predict the indoor environment, including humidity, by monitoring existing weather data and learning users' preferences. Second, it can automatically turn the humidifier on or off to maintain a certain humidity level, allowing users to remain comfortable while focusing on their work or sleeping. Third, our device can easily be applied to an existing humidifier in a user's home. There is also a mobile app to help users control our device. Therefore, our system has some advantages over the existing products.

We used support vector learning (SVM) and regression models to build the basic program needed for our device. [4] Through adjusting the regression model, polynomial features, and input data sets, we tested the accuracy of various machine learning models via the mean square error method to determine the most appropriate model to use.

The rest of this paper is organized as follows: Section 2 introduces the details of the challenges we encountered during the design and development of the sample; Section 3 focuses on our solutions in response to the challenges mentioned in Section 2; Section 4 presents relevant details on how we conducted the experiment, followed by related works in Section5. Finally, Section 6 provides concluding remarks, as well as the possible future applications of our device.

2. CHALLENGES

In order to develop a software application and system to create an intelligent humidifier that automatically turns on or off for convenience or for those who cannot engage manual control, a few challenges were identified as follows.

2.1. Challenge 1: AC systems reduce humidity when both heating and cooling

Air conditioners are widely used in people's homes as a necessary piece of equipment to help regulate the indoor environment. However, the only element most AC systems control is the temperature. Actually, other aspects such as the humidity should be considered to modify the indoor environment to meet optimal comfort levels. AC also plays the role of a dehumidifier since it removes water vapor in the air. [5] When air hits the cold evaporator coil inside the air handler, the AC makes the humidity condense on the oil and drain into the pipe that then exits outdoors. This also applies to the AC's heating system as well. Heating dries the air, causing the relative humidity to drop. For example, in the northern areas of China, people usually feel dry and uncomfortable when they get up in the morning during winter because the heat must stay on at night. They cannot turn it off because the heating pipes were buried underground by the government during urban planning. In short, existing devices that help modify indoor environments can have drawbacks, and are often unable to increase the humidity in the room.

2.2. Challenge 2: Health concerns of using humidifiers

Obviously, we can use humidifiers to increase humidity levels indoors. However, this is not a perfect solution. Popular portable humidifiers have drawbacks. First, people have to monitor them manually depending on their humidity preferences. While focusing on work or sleeping, they cannot always do this consistently, which means they may to keep the humidifier on or off and suffer an uncomfortable environment. The second disadvantage is that using a humidifier all the time wastes water and electric power. What is worse, overuse of humidifiers can also lead to health problems. If left on all the time, high humidity and misty conditions can have a negative effect on the lungs. [6] Also, humidifiers have the potential to release minerals and microorganisms into the air. These microorganisms might not be directly harmful, but can greatly affect people with asthma. Unclean humidifiers facilitate the growth of certain bacteria, which is associated with coughing and the common cold. Therefore, humidifiers require regular cleaning to reduce bacterial growth.

3. SOLUTION

To resolve the problem of having to turn a humidifier on or off or overuse it, some may choose to buy advanced humidifiers with automatic control systems. [7] While these options work, they can be expensive. For example, digital smart mist sensor humidifiers sell for up to $100 in the online store of Target™ (see Figure 1). These models usually only sense humidity and cannot adjust other indoor elements such as temperature or allergy management.

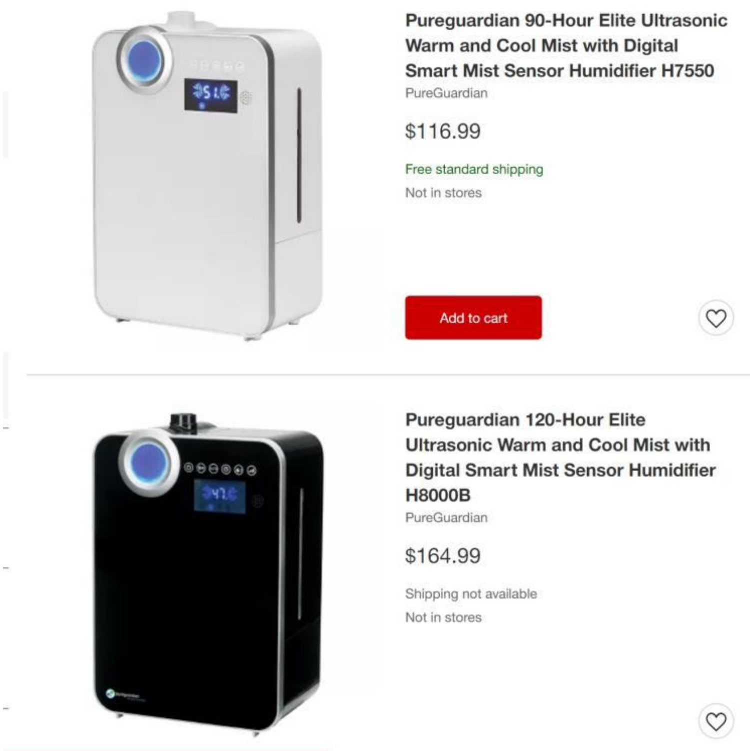

Figure 1. Examples of advanced humidifiers with automatic control systems

The name of our application is HC, which stands for Humidity Conditioner. The application was implemented using Thunkable. We used machine learning to make regular humidifiers into smart devices that serve as real-time humidity monitoring systems to offer automatic and remote humidity control. The application has two main pages: the login page and a page that features a humidity indicator, real-time humidity and temperature data, and a dynamic background that provides the weather and time (see Figure 3).

The HC application has a login page that allows users to sign in using multiple devices to control the humidifier. The home page displays real-time data in its and allows users to see the current humidity levels in percentages to manage their humidifier using an indicator/slider as a controller. There is also a button that allows users to choose from three modes: on/off/auto. On or off modes allow users to control the humidifier manually, while the auto mode uses machine learning to regulate the humidity according to users' specifications and preferences.

We used the raspberry pi 3 as the processor for our device. [9] The raspberry pi was selected over a microprocessor single-board microcontroller, such as an Arduino uno, for its Wi-Fi connectivity and storage capabilities to store data from the temperature-humidity sensor. [8]

The sensor used in our device is a DHT22 digital temperature-humidity sensor. [10] The DHT22 was chosen for several reasons including its compatibility with the raspberry pi, ease of use, low cost, and range and accuracy of readings. It can read humidity ranges from 0 to 100% with 2-5% accuracy and temperature ranges from -40 to 80°C with ±0.5°C accuracy with a sampling rate of 0.5 Hz.

The final component of our device is a power strip with a built-in power relay that provides power to both the raspberry pi and any humidifier. [15] The built-in power relay allows the raspberry pi to turn the outlet the humidifier is connected to on or off. The power strip has three outlet modes: always on, usually off, and usually on. The "off" is usually off by default unless a current is sent to the power relay. Similarly, the "usually on" mode is on by default unless a current is sent to the power relay.

The device requires that the raspberry pi be plugged into the power strip in the always on outlet and the humidifier in the usually off outlet, then a two-wire, signal and ground wire from the raspberry pi's gpio pins is connected to the power relay. Once powered, the raspberry pi reads the humidity levels from the DHT22 sensor. When the humidity level falls below the target threshold, the raspberry pi sends a signal to the power relay, turning on the humidifier plugged into the "usually off" outlet. Also, when the humidity level goes over the threshold, the raspberry pi stops the signal, turning off the humidifier.

In the HC application, we used machine learning for prediction and classification. [11] We used prediction at the bottom half of the home page where the predicted humidity levels are displayed (see Figure 2). Machine learning allows the system to predict patterns of humidity by studying existing data as well as users' manual control history. When users turn the humidifier on or off, the system uses these preferences to optimize its predictions.

In addition, the auto mode takes advantage of machine learning classification. The algorithm divides current and predicted humidity data to two categories, then decides whether to turn the humidifier on or off.

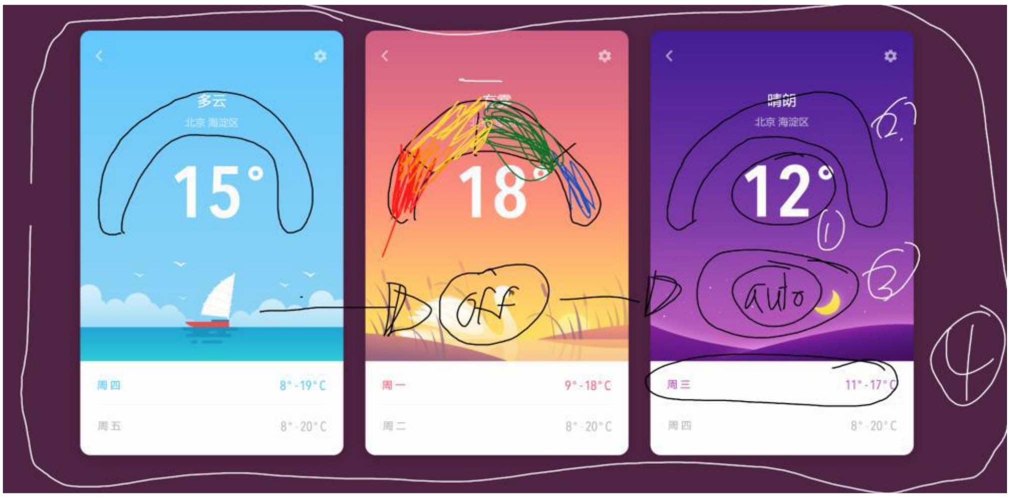

Figure 2. Humidity Conditioner UX

Figure 3. Display data including weather and time

For the design of the home page, we broke the page down into four rows (see Figure 4). In the first row, we added a "Humidity" title. In the second, real-time humidity levels are displayed. For the third row, we added a button that allows users to choose from three modes—on/off/auto. The fourth row displays other indoor-environment data, including the current temperature, weather, and predicted humidity levels. There is also a time-input that displays the present time at the top of the homepage.

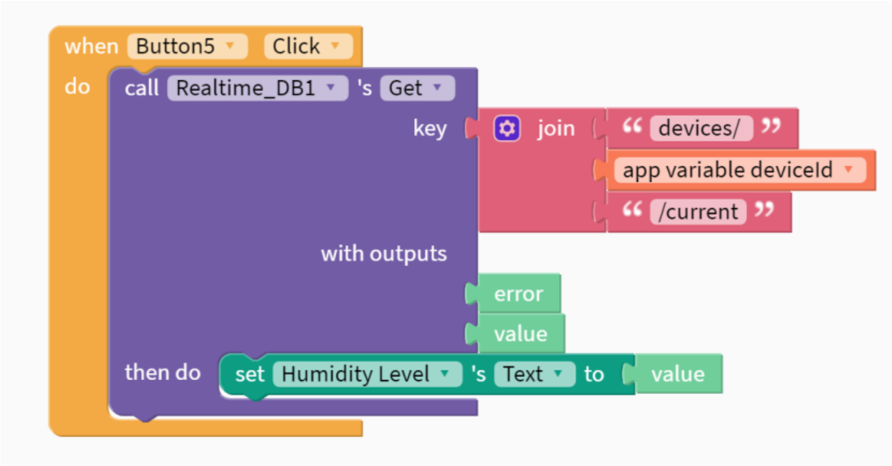

Figure 4. Humidity Conditioner's homepage display rows

The block code of our home page operates as follows: users click on the button and the system retrieves their account and calls on the real-time database (firebase) for an output of either a percentage humidity level in or an error. The system then translates the real-time humidity to text and displays it in the second row of the homepage.

4. EXPERIMENT

We performed experiments to verify that our predictive models worked, and to ensure that we were selecting the optimal model, data, and parameters to produce the most accurate and satisfactory experience for users.

We conducted two experiments to evaluate the accuracy of two machine learning models—prediction and classification—by changing polynomial degrees and data set features. [12] The first experiment aimed to find a machine learning model that predicts indoor humidity based on other environmental elements such as temperature and wind speed. This experiment compared and evaluated the accuracy of three models created with sixteen data sets using polynomial degrees of 1, 2, and 3, respectively, to determine which was the most optimal one. The second experiment was conducted with the intake of sixteen datasets using different set features to find the best-fit machine learning model to determine whether or not to turn the humidifier on or off depending on environmental elements such as temperature and wind speed. We performed these experiments not only to verify that our predictive models work, but also to ensure that we were selecting the optimal model, data, and parameters to produce the most accurate and satisfactory experience for users.

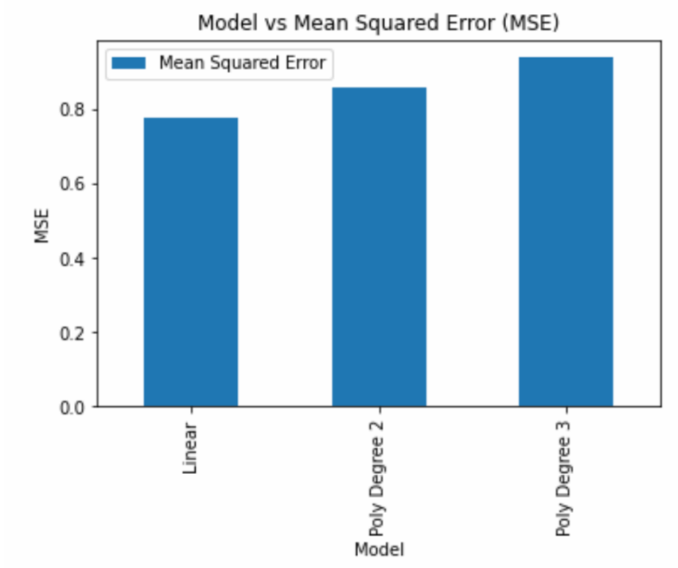

Figure 5. Experiment 1 data showing the best fit prediction model (polynomial degree of 3)

In experiment 1, we applied different polynomial parameters to the same data set to find out which model would produce the most accurate algorithm. The result of experiment 1 shows that, along with polynomial degrees of 1, 2, and 3, the accuracy of each is 0.787, 0.869, and 0.942 respectively. It revealed that the best fit prediction model is the one with a polynomial degree of 3 (see Figure 5).

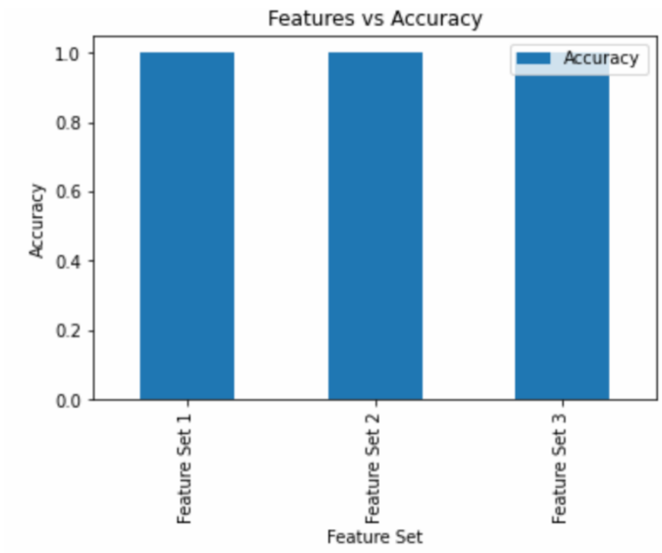

Figure 6. Experiment 2 data showing the accuracy of the three models were the same (1.0)

For experiment 2, we compared the SVM machine learning models that differ by their data sets to determine the best one for classification. We tried the three features of humidity, temperature, and air quality in varied combinations: the first was temperature and wind speed, the second was humidity and wind speed, and the third was temperature, humidity and wind speed. It turned out that the accuracy of these three models were all the same, which was 1.0 (see Figure 6).

5. RELATED WORK

Biqing, Li, et al. created an intelligent air humidifier. [13] Their design adopts STC89C52RC SCM control and connects via the auxiliary circuit to achieve automatic testing and sound-light alarm and to turn on the humidifier. They first set a desired level of humidity, D_0, then test the current indoor humidity. If the current value does not meet the required one, the humidifier turns on automatically. Our product is different in that we use machine learning, which allows us to predict the indoor environment based on temperature and humidity data instead of having to test the indoor environment.

Baughman, A., et al. studied the health risks brought on by high humidity. [6] They found that "[t]he primary influences of humidity on health are through biological pollutants." Most health issues are caused by pollutants such as fungi as well as viruses such as Streptococcus, Legionella, and the common cold and flu. In Section 2: Challenges, we review some of the negative effects of high humidity and misty conditions that can be brought about by keeping humidifiers on for too long. The releasing of minerals and microorganisms by humidifiers can also affect people with asthma. Therefore, machine learning is helpful in controlling humidifiers to reduce these associated health issues.

Ku, K. L., et al. addresses the creation of an automatic control system for thermal comfort within an entire building. [14] Their model utilizes "an adaptive neuro fuzzy inference system and a particle swarm algorithm" to create a nonlinear multivariable inverse PMV model so as to determine thermal comfort temperatures. Similarly, our design also makes use of machine learning. However, two main points make our design different from Ku's. The first is that our design aims to control the indoor humidity at optimal levels based on existing data including temperature. The second is that our model is made for one-room environments instead of entire buildings. Our product is therefore best for maintaining the moisture requirements of a single room.

6. CONCLUSION AND FUTURE WORK

Our application, HC, applies machine learning to help automatically control a humidifier to maintain optimal levels of indoor humidity. Two experiments were conducted to ensure the accuracy of two machine learning models—prediction and classification. In the first experiment, we determined the best prediction model by importing existing weather data and testing with different polynomial degrees. Our conclusion was that degree 3 is the best fit for the model. The second experiment was conducted with the intake of datasets with different set features to find the best model to classify whether to turn the humidifier on or off. The three SVM machine learning models performed at the same high accuracy level. As a result, our intelligent humidifier control application allows users to focus on their work without the necessity of manually maintaining or monitoring humidity levels.

Our application still has limitations, however. It currently does not learn preferences to improve its prediction and classification over time. In the future, we can optimize our application further by importing code that allows it to study users' preferences as they manually control the humidifier over time. Also, our design can only be applied to an existing humidifier, which may be inconvenient for some who don't already have one. To remedy this in future, we may design a more integrative model that includes both a basic humidifier and intelligent control system.

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