Using Deep Learning Approaches to Predict Indoor Thermal and Outdoor Rainfall Probability by Embedded Weather Box

Kuei-Chung Chang, Shing-Yu Yeh, Chin-Sheng Yu and Hung-Yu Chen
Dept. of Information Engineering and Computer Science, Feng Chia University, Taiwan, R.O.C.

Abstract**-- The body of elderly is not only low resistance but also poor temperature regulation and sensitivity. Slight weather changes may cause colds, fever and other diseases. Therefore, how to use a simple application to give people a thermal comfortable living space will be an important issue. Raining can not only affect thermal comfort but also cause inconvenience to people, e.g., shopping or hanging the clothes. This paper aims to use the Arduino weather box to collect the weather data from the living space, and then these data can be analyzed via Support Vector Machine (SVM) and Neural Network (NN) to predict thermal comfort and probability of rainfall. Experimental results show that the accuracy of prediction for temperature using BPN can approximate to 77%, and the accuracy of prediction for rainfall using SVM can approximate to 76%.**

I. INTRODUCTION

In recent years, Taiwan is facing a surge in the population aging. For the elderly, the weather changes will affect their physical discomfort. Because of the lack of resistance, slight temperature changes are likely to cause colds, fever and other diseases. So we need to provide them the temperature changes and notify them whether they need to wear clothes to avoid the cold. If we can provide the current temperature and the temperature changes in the future, the possibility of sick can be prevented. Raining can not only affect the temperature changes but also limit activities that people can choose. Raining will make the surrounding air becomes moist and uncomfortable. If we can provide rainfall prediction system, people can be easy to plan their home living.

The authors used air temperature, mean radiant temperature, relative humidity, air velocity for influencing factors, and using clothing and activity level for personal parameter to predict thermal comfort [1]. The authors used personal measurements from the Microsoft Band to predict the thermal comfort [2]. The author experimented with a variety of different methods, and use RMSE to compare the pros and cons. They claimed SVM's result is up to 3 times better than Fanger's result. In [3], authors used indoor environmental influence factors and user's biological information and clothing to predict the thermal comfort. The author experimented with a variety of different methods, and use accuracy to compare the pros and cons. They find SVM's result is up to 2 times better than Fanger's result. The authors used outdoor environmental influence factors, wind speed, solar radiation, outdoor temperature, respectively [4]. The authors experimented with SVM and BPN, and use MSE to compare the pros and cons. They find SVM's result is up to 2 times better than BPN's result. The authors used air temperature, mean radiant temperature, air velocity, globe temperature, relative humidity, metabolic rate and clothing insulation level to predict the thermal comfort [5].

In this paper, we use an Arduino board to build an indoor weather box to collect seven types of sensing data including temperature, humidity, air pressure, visible light, infrared, ultraviolet, and rainfall. We use the Support Vector Machine (SVM) and Neural Network (NN) to analyze the data for prediction, and some methods were proposed to increase the prediction accuracy.

II. PROPOSED APPROACH

A. Design of Weather Prediction System

The weather prediction system architecture is shown in Fig. 1. We used Arduino to design a weather prediction box to collect weather data. Five sensors are used to build the weather prediction box including DHT11, raindrop sensor, ESP8266, BMP180, Grove sunshine sensor. The indoor real-time temperature, indoor average temperature, indoor humidity, air pressure, visible light, and infrared and ultraviolet light are used to predict the indoor temperature and rainfall probability of next hour.

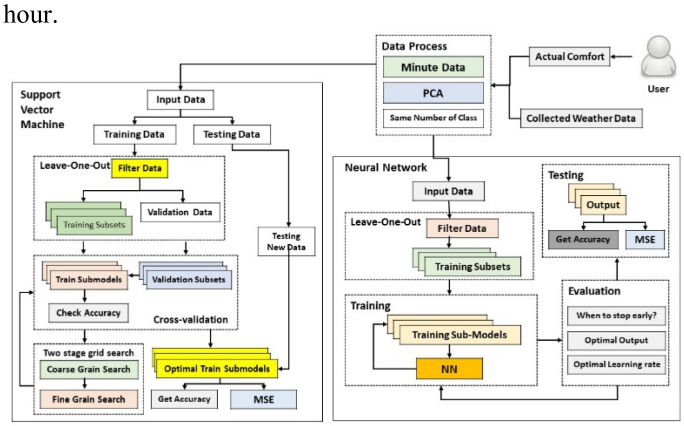

Fig. 1. Architecture of weather prediction system

For understand the reliability of the data collected, we used three different correlation coefficients, including Pearson, Spearman, and Kendall, to find out the properties used and the prediction relevance. Then we use principal component analysis to reduce the dimensionality of the dataset and retain the factors that make the most impact.

We use support vector machines to predict the next hour's temperature and probability of rainfall. First, we remove some outliers through Leave-One-Out, and then use the Two-stage grid search to find the appropriate cost and Gamma parameters to avoid under fitting or over-fitting problems. Finally, cross-validation is used to find the most accurate model.

In addition to support vector machine, we also try to use neural networks to predict the temperature and rainfall probabilities for the next hour. During the training phase, we trained the dataset using a Recurrent Neural Network (RNN). It causes the next output value to be related to the last output value. There are many different RNN architectures, and we chose Backpropagation Network (BPN) to train the data before exporting to get better results. It calculates the gradient of the loss function of all the weights in the network, and the gradient will feedback to the optimization method to update the weights to minimize the loss function. So, we combine RNN and BPN to train data. Finally, cross-validate with early stopping is used to avoid over-fitting problems.

III. Experimental Results

We deployed the Arduino weather box near the window and collect the data every 10 seconds show as Fig. 2. We collect data for six months to train and test the model.

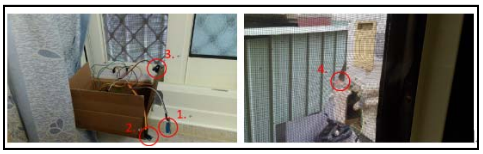

Fig. 2. Arduino weather box

For Support Vector Machine (SVM), we train a new model every hour. The training data is determined according to the actual situation of the average temperature. For example, if the average temperature is 21 ℃ , we will take dataset of temperature interval between 19℃ and 23℃ to train the new model. We use data within 72 hours before training to train a new model for rainfall probability prediction.

For Neural Network (NN), we record the possible temperature values of the training data. The possible temperature values represent all possible predicted temperature values in the training data, and we will use average temperature to limit the number of possible temperature values below 5 (avg-2, avg-1, avg, avg+1, avg+2).

We try to predict the temperature of next hour; Fig. 3 shows the prediction results using BPN. We analyzed how the temperature changes (1: rises; 0: constant; -1: drop) in next hour to measure the accuracy. Also, Spearman correlation coefficient is used to determine whether the result is changing with the actual trend. Finally, we determine the accuracy according to whether it is changing with actual trends and has the correct changes. For these experiments, we compared SVM, BPN, and RNN_BP, and the result of BPN is more predictable of the trend of temperature changes. The overall prediction results of BPN (77%) is better than that of SVM (69%) and RNN_BP (45%). The approach in [4] represented that SVM is more suitable for predicting temperature value. From our experimental results, BPN is more suitable for predicting the trend of temperature changes.

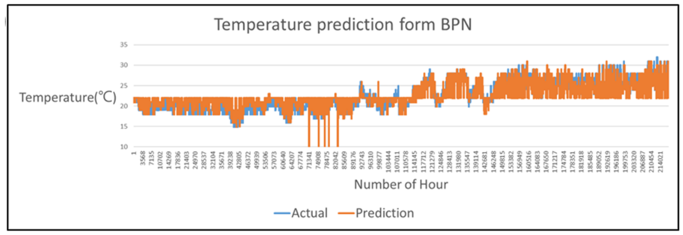

Fig. 3. Temperature prediction results of BPN (Acc.:90%, Spearman:85%)

We used raining data for training set to predict the probability of rainfall. Fig. 4 shows prediction results using SVM. We can find that the SVM can distinguish between raining and not raining, and the accuracy is 76%. We can find that the number of occurrences of raining is nine, and the proposed SVM can successfully forecast rainfall nine times.

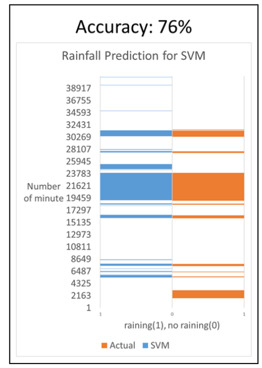

Fig. 4. Prediction results of rainfall using SVM

IV. Conclusion

In this fast-paced society, people demand a comfortable life. The weather will change over time; if we can build a prediction model to forecast temperature variations and probability of rainfall, we can establish a comfortable and convenient living space. The experiments show that using backpropagation network can get best results in prediction of temperature, and using support vector machine can get best results in rainfall probability.

References

[1] Lai Jiang, "A personal thermal sensation model based on occupants' feedback", The 7th International Conference of SuDBE2015, Reading, UK, July 2015

[2] Emil Laftchiev, Daniel Nikovski, "An IoT System to Estimate Personal Thermal Comfort", 2016 IEEE 3rd World Forum on Internet of Things (WF-IoT), Dec. 2016.

[3] Asma Ahmad Farhan, Krishna Pattipati, Bing Wang, "Predicting Individual Thermal Comfort using Machine Learning Algorithms", 2015 IEEE International Conference on Automation Science and Engineering (CASE), October 2015.

[4] Cai Qi, Wang Wenbiao, Wang Siyuan, "Application of Indoor Temperature Prediction Based on SVM and BPNN", 2015 27th Chinese Control and Decision Conference (CCDC), May 2015.

[5] Lai Jiang, Runming Yao, "Modelling personal thermal sensations using C-Support Vector Classification (C-SVC) algorithm", Building and Environment, pp.98-106, Jan. 2016.