Human Behavior Recognition in a Smart Home by Artificial Neural Networks

Narut Butploy* , Pakin Maneechot, Nivadee Klungsida

Faculty of Industrial Technology KampangPhet Rajabhat University, KampangPhet 62000, Thailand
***Corresponding author's email:** narut@kpru.ac.th
Received: 07/05/2020, Accepted: 30/12/2020

Abstract

This research aimed to find a model for predicting human behaviours using electronic monitoring system. The experiment study used WEKA, a well-established data mining model applied to real-world problem solving. The study focused on the network configuration of ANN. The results showed that a 2-layered neural network gives the best learning outcomes. However, the learning outcome was not good enough, but study still showed that neural network techniques can be used to help recognize and predict behaviours, and can be used to predict information from other intelligent systems, such as smart home systems.

Keywords:

Recognition, Intelligent Home Systems, Artificial Neural Networks, Smart Home

1. Introduction

Several studies to model human behavior have been conducted in the past. Aitor and Obaidat studied behavior models to detect the risks related to the frailty and MCI of young adults [1]. Phan et al. did a deep learning approach for human behavior prediction with explanations based on health and social networks [2]. Yan and Au made a correlation analysis between students' online learning behavior features and their course grades to attempt to build prediction models that are effective even if these were based on limited data [3]. The programmed observation of explicit "Activities of Daily Living" (ADLs), collected from studies in gerontology, for an appraisal of the freedom level of an individual, is among the most challenging research fields of Ambient Intelligence [4].

The smart home is the application and use of the conveniences of modern home life using advanced digital technologies such as home fiber-optic cables [5] and wireless sensors. These allow the exchange of resources, information and communication among such homes and within the homes using external detection systems that provide the residents both convenience and security. These are done through modern service and management systems [6]. Belghith and Obaidat developed an optimization system for the routing applications to find the best routes that save energy, increase the life of sensors and safety protocols using WSN, a wireless sensor system to create a smart home system prototype, which can meet the lifestyle needs in a smart city [7]. One of the interesting things about smart home system development is the study of the behaviors of the residents such as their electricity usage.

The neural network system is one of the data mining techniques that recognize behavior data and classify the research data using the neural network system to accurately predict the rate of indoor electricity usage [8, 9]. It uses data from two sensors to determine whether the door is open or close to detect activity and uses a neural network (ANN) to detect entry and exit activity from a room in a home or office space, and use the information collected from the applications of the control of the ventilation and air conditioning systems [10]. As mentioned above, this aims to develop a smart home system to recognize the behavior of the subjects in a smart home, using a wireless sensor system with sensors installed in different areas. This can be used to help create a model for the recognition and prediction of the living behavior of smart home inhabitants. These behaviors should be used to help improve the installation of home facilities and develop further the design and construction of smart home systems in the future.

2. Methods

2.1. Data

This experiment uses data sets from the UCI machine learning repository website, which is opened for data mining and automation. Wireless sensors at various points in the house, such as showers, washbasins, gas stoves, front doors, refrigerators, closets, closets, toilets, seats, beds, microwaves, and toasters were installed to collect the data needed in this study. There were two sets of daily record activities done, one for 14 days and another one for 21 days.

Table 1 Details of the data.

Number of Field	Activity of User 1	Activity of User 2	Class Detail
4 (Day_Start,Time_Start, Day_End,Time_EndActivity)	248 (rows)	493 (rows)	Leaving, Toileting, Showering, Sleeping, Breakfast, Lunch, Dinner, Snack, Spare_Time/TV, Grooming

Table 2 Example of user activity.

Day_Start	Time_Start	Day_End	Time_End	Activity
2012-2-11	8.17	2012-2-11	8.28	Toileting
2012-2-11	8.35	2012-2-11	9.10	Breakfast
…	…		…	….
…	…		…	…
2012-2-12	01.09	2012-2-12	07.40	Sleeping

Table 1 shows the numbers of behaviour of users A & B. The meaning of the behaviour is the activity that the user performs under sensor detection. There is a total of 10 behaviours (10 class). The WEKA program software has 3 groups of data mining algorithms: classification, clustering, and association. From the learning inputs, a model can be developed for testing the data. Table 2 shows a sample of user data comprising four fields, time, date, class fields, including behaviour for classified information.

2.2 Data classification using Artificial Neural Networks

In this study, we use the Artificial Neural Network (ANN) data classification technique, in which the artificial neural network is used as a mathematical model for data classification. This is done by calculating the connections between neural networks. The basic idea of this technique comes from the study of the bioenergy network in the brain, which consists of neurons. Each of these neurons has its activation sequence that results to the continuous connection of the neurons [8]. Some neurons may affect actions that cause a learning environment or weight that allow the network to show a desired behavior that may require a long-term calculation process. The neural network consists of a data import layer, hidden layer, and result layer. Sometimes the network may not have a hidden layer, called layer1, in the network. However, if the network has a hidden layer, the number of the hidden layers maybe 1 or more:

$$y_j^1 = f(\sum_{i=1}^{m}(w_{j,i} * p_i) + b_i) \quad (1)$$

$$y_j^2 = f(\sum_{i=1}^{m}(w_{k,j} * y_j^1) + b_k) \tag{2}$$

Where *w* is the weight of input data, and b is the bias function, and the stimulation can be explained as follows.

$$f(x) = x \tag{3}$$

$$f(x) = \frac{1}{1+e^{-n}} \tag{4}$$

$$f(x) = \left(\frac{2}{1+e^{-2n}}\right) - 1 \tag{5}$$

When Eq. (3) is the original linear function, the result is like a linear Eq. (4). The sigmoid function is a non-linear function, with values between 0 and 1, and Eq. (5) that, the tanh function looks remarkably similar to a sigmoid and is not linear. The results are in the range -1 to 1. Once the equation is calculated, the equation and the function of the excitation function can be created as the network model as in Figure 1.

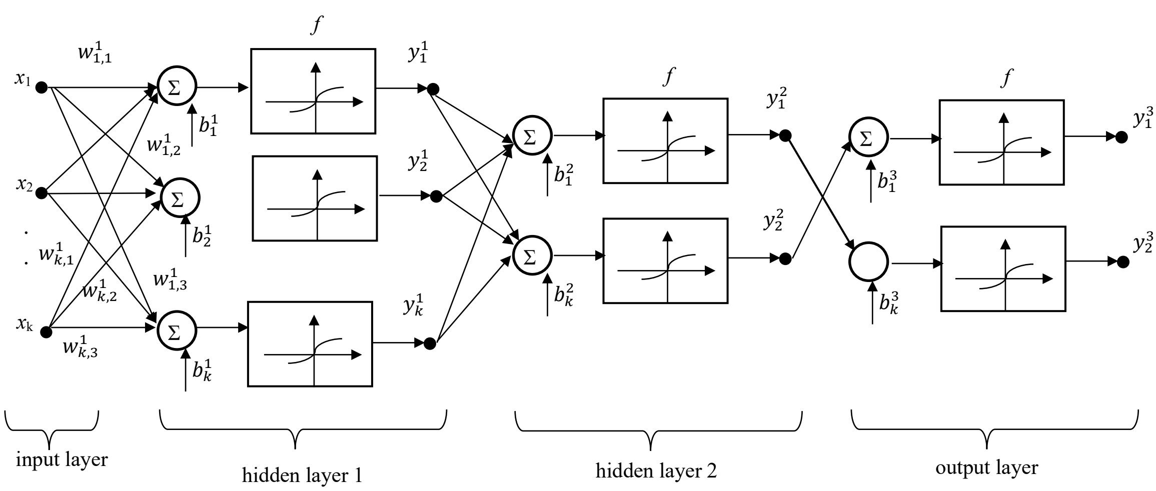

Fig. 1 The artificial neural network.

Figure 1 shows an example of the neural network function when calculating the results from the Eq. (1). The *y* value obtained in the hidden layer 1 is calculated from the input data combined with the weight value. The values are then adjusted with the trigger function. When *y* values are obtained from this layer, the results are sent to the nodes in the next layer which becomes the input of the hidden layer 2, which is then calculated using the Eq. (2). The process is the same till the last layer.

2.3 Experimental Setup

This work is divided into 2 sets, namely the learning data set for teaching the system to do the artificial neural network and the testing data as in the Figure 2.

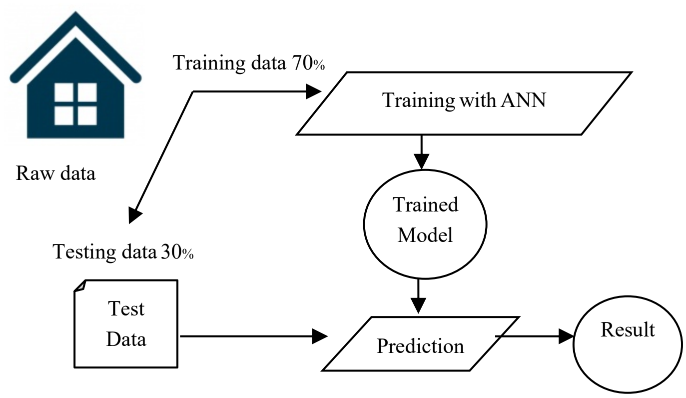

Fig. 2 An overview of the experiment.

After importing 70% of the data into the artificial neural network system, the results will be put into the Trained Model and 30% of the data are then use for testing and experimentation. How accurate this model can be used to classify information on performance measurement, is based on the correctness (correct classification of instances) and the tolerances between the results from the model and the actual results (RMSE).

2.4 Example of ANN

Figure 1 shows how artificial neural network works as calculated according to Eq. (1). For example, the user activity from table 2 were performed by *date start, time start, date end, and time end.* In this structure, the input layer is given by x_1 = date_start, x_2= time_start, x_3= date_end and x_4= date end, and the WEKA software randomized the weight and bias. The first hidden layer is given by y_1^1= $f((x_1 * w_1) + (x_2 * w_2) + (x_3 * w_3) + (x_4 * w_4) + b_1^1)$. The second hidden layer is given by y_1^2= $f(y_1^1 + y_2^1 + \cdots + y_k^1 + b_1^2)$. After the calculations are completed the results are compared with the actual data (y_1^3 or y_2^3). If the results are not close to the actual data, the artificial neural network work l returns to adjust the weight and learns again.

3. Results and Discussion

In this study, we present the overall efficiency of a recognition and classification model. The recognition model consists of the creation, time, accuracy and the error values of the model as shown in Figure 2. This model will be used to predict the behavior of the subject in the house and what he will do, by calculating the root mean square error values. This is a good decision criterion when the sample size is small, and the error is also small, [11] which can be calculated as follows:

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(\hat{y}_i - y_i)^2}{n}} \tag{6}$$

Where $\hat{y}_i$ is equal to the predicted value in position *i* and y_i is the true value in position *i,* Eq. (6), and the results are shown in Figure 2. We will use the results of the data classification model to find the error for each row, if the error approaches zero. This implies good results for the classification, which is also an indication that the recognition model is very reliable.

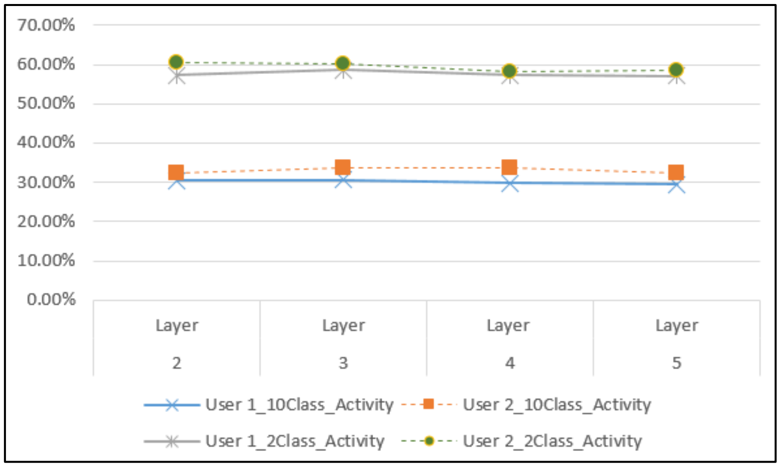

Fig. 3 Find the optimal amount of hidden layer.

Figure 3 shows comparisons of learning accuracy by increasing the hidden layer of the artificial neural network. The results show that increasing the number of the hidden layer does not result in greater values. Hence, it is stopped at 5 hidden layers and chose 2 hidden layers for this experiment.

Table 3 The efficiency of ANN 2-layers model.

	Evaluation Criteria (Training Data: 70%)						**Prediction (Test Data: 30%)**	
	10 class			2 class			10 class	2 class
	Time to Build a Model	Correctly classification	Incorrectly classification	Time to Build a Model	Correctly classification	Incorrectly classification	RMSE	RMSE
User A	0.38	30.482%	69.518%	0.35 Sec	57.241%	42.759%	1.449	1.394
User B	0.72	32.429%	67.571%	0.69 Sec	60.390%	39.610%	1.35	1.178

Table 3 shows the results from the building and prediction model for the 2-layers neural network, but with many behaviors (classes): Leaving, Toileting, Showering, Sleeping, Breakfast, Lunch, Dinner, Snack, Spare Time/TV, and Grooming. The amount of information is low, because, there is a variety of identities in the information. The learning accuracy from Table 3 shows that when it is 10 classes, the accuracy for Users A & B respectively, is 30.482% and 32.429%. The authors classified the behaviors into 2 groups: Health (Leaving, Toileting, Showering, Grooming, Sleeping) and Emotion (Breakfast, Lunch, Dinner, Snack, Spare Time/TV) and found out that the cognitive behavior of the neural network has improved. The behavior patterns can be predicted more accurately at 57.241% and 60.390%. When predicting the behavior that would occur relative to the actual behavior, the error was 1.394% and 1.178%. In order to ensure that the accuracy of the built network was optimal, the researcher also experimented with creating 3 additional hidden layers as shown in Table 4.

Table 4 Experiment with adding hidden layer.

	Correctly classification 10 class			Correctly classification 2 class		
	3 Layer	4 Layer	5 Layer	3 Layer	4 Layer	5 Layer
User 1	30.578%	29.862%	29.486%	58.565%	57.216%	57.114%
User 2	33.786%	33.532%	32.411%	60.112%	58.126%	58.631%

Table 4 presents the learning accuracy values by adding a hidden layer each to 3, 4 and 5. The results showed that the accuracy did not improved if the number-layers are more than 2. Thus, in this experiment, we stopped at layer 5- and selected a 2-layers neural network for learning.

4. Conclusion

This is a research on classification of human behavior in a smart home environment using wireless sensors. This study focused on creating a suitable data classification model with ANN. The study found out that there is a problem because the number of features are not sufficient for studying the model. However, the authors adjusted the classification of the behaviors into 2 groups and found out that there is an improvement in the cognitive behavior of the neural network. The data is called the Activities of Daily Living (ADLs), which are recognized using binary sensors data set from the UCI website. The recognition results to the correct classification of users A and B, at instances of 30.482% and 32.429%, respectively. In the case of 10 classes, the correct classification instances are at 57.241% and 60.390%, respectively. The misclassification causes the number of fields under study to become too small. There are only days, times, and uncertain behaviors for each user activity such as user A eating time at 30 minutes, while user B spends only 10 minutes, performs other activities and thus have more activities. However, due to the uncertain behavior of both users, the daily activities have also changed a lot. Although only 2 classes are included, the time of each activity is unstable, and this has greatly affected the study of the neural network. Therefore, the authors think that further research is needed to increase the learning fields, namely location, temperature, and humidity that will affect behavior, and the neural networks will learn better as will they have now more factors and information to study. This research study demonstrated the use of a suitable neural network model, which can obtain the behavior of e a user inside an experimental home using behavior sensors. This study will be useful in the development of smart home designs.

References

[1] Almeida, A. & Azkune, G. (2018). Predicting human behaviour with recurrent neural networks. *Applied Sciences, 8,* 1-13.

[2] Phan, N., Dou, D., Piniewski, B., & Kil, D. (2016). A deep learning approach for human behavior prediction with explanations in health social networks: social restricted Boltzmann machine (SRBM+). *Social Network Analysis and Mining*, *6*, 1-14.

[3] Yan, N., & Au, O. T. S. (2019). Online learning behavior analysis based on machine learning. *Asian Association of Open Universities Journal, 14*(2), 97-106.

[4] Bruno, B., Mastrogiovanni, F., Sgorbissa, A., Vernazza, A., & Zaccaria, R. (2013, May 6-10). *Analysis of human behavior recognition algorithms based on acceleration data*. 2013 IEEE International Conference on Robotics and Automation, Karlsruhe.

[5] Mayer, A., & Biscaglia, S. (1989, October 15-18). *Modelling and analysis of lead acid battery operation*. Eleventh International Telecommunications Energy Conference, Florence.

[6] Razzak, M. I., Naz, S., & Zaib, A. (2017). Deep learning for medical image processing: Overview, challenges and future. In Dey, N., Ashour, A., & Borra, S. (eds), *Classification in BioApps: Lecture Notes in Computational Vision and Biomechanics*. Cham, Springer.

[7] Belghith, A. & Obaidat, M. S. (2016). Wireless sensor networks applications to smart homes and cities. In Obaidat, M. S., & Nicopolitidis, P. (eds), *Smart Cities and Homes*. Massachusetts, Morgan Kaufmann.

[8] Li, M., Gu, W., Chen, W., He, Y., Wu, Y., & Zhang, Y. (2018). Smart home: Architecture, technologies and systems. *Procedia Computer Science, 131*, 393-400.

[9] Skocir, P., Krivic, P., Tomeljak, M., Kusek, M., & Jezic, G. (2016). Activity detection in smart home environment. *Procedia Computer Science*, *96*, 672-681.

[10] Jomprapan, R. (2012). *Missing imputation in multiple linear regression analysis* (master's thesis). Bangkok, National Institute of Development Administration.