Intelligent over the environment using neural network

Kuo-An Hwang
Professor, Department of Computer Science and Information Engineering, and Department of Information and Communication Engineering, Chaoyang University of Technology
kahwang@cyut.edu.tw

Liang-Fu Chen
Department of Information and Communication Engineering, Chaoyang University of Technology
s9730605@cyut.edu.tw

摘要

本研究利用類神經網路學習使用者行為，針對個人行為特徵(個人習慣)做出判斷，利用其特性模仿行為，且預先判斷使用者下一步動作，對空間中的電器進行預先控制。

在多人的辦公環境下，由於資料挖掘時需架設感應器，其架設範圍大、數量多，且感測器本身無法辨別使用者，我們將感應器分成個人與共用兩類，透過前後資料比對等方法，判斷並追蹤使用者進而分類，利用兩端點資料整理後，可把多人資料畫分為個人資料，記錄其行為反應並學習後，透過個使用者擁有的特徵值，可分辨個使用者行為，達到多人智能控制的目的。

關鍵詞：類神經網路、智能環境、智慧控制。

Abstract

This study used artificial neutral network to learn users' behaviors, make judgments according to the individuals' behavior characteristics, predict the individuals' next actions based on their characteristics of imitative behavior, in order to pre-control the electric appliances in the environment.

In a multi-user office environment, it is necessary to install sensors for data mining. Due to the large scope and quantity of sensors required, and the sensors cannot identify the users, this study divided the sensors into two types, namely private and global. By comparing the data, this study judged and tracked the users, and sorted data of multiple persons into individual data, and then recorded their behaviors and reactions for learning. Through the feature values of users, their user behaviors could be distinguished in order to achieve multi-user intelligent control.

Keywords: artificial neutral network, intelligence environment, intelligent control

1. INTRODUCTION

Intelligence environment is an information technology to make life more convenient and automatic. It has become one of the popular topics now. As people spend most their time at "home", as well as "workplace", intelligence environment is often applied in residences and offices.

Since human behaviors have a certain level of periodicity [1], especially in the work environment, when developing an intelligence environment, most of the automation design follows the routine activities of users. Some studies [1]~[2] have attempted to develop intelligent environments for homes or office environments of single user.

Image recognition can be applied to identify users for studying the periodicity of user activities [3]~[9]. But as users have stronger sense of privacy, the image recognition method is often rejected. Sensor-learning method is more appreciated to be applied for an individual environment. Therefore, this study also adopted the method of sensor- defined tracking.

BP artificial neutral algorithm [10] has been widely applied to classify the data of activities of sensors. It has good classification effect. By defining the input and output ends, the data that seem disordered and unable to converge could be converged to the expected value through calculation in the implicit layer. The result is a vector matrix, and the matrixes can respectively represent different activities. The vector matrix can be used to understand the classification method between sensor and behavior and its characteristics, in order to achieve imitation and prediction.

However, as future happenings cannot be predicted precisely, some activities must be controlled and adjusted manually in an intelligence environment [1]~[9]. But to require users to have routine activities counters to the original intention of intelligence environment. Nevertheless, multi-user environment is a realistic environment in life. But multi-user environment have more variations and difficulty in determining the users. Different users may trigger the sensors repeatedly, thus making the classification of behaviors difficult. As it covers a larger space, there are more complications in identifying users, as compared to single-user environment.

In this study, we installed sensors in a multi-user office environment. The environment was divided into private space of a user and the global space. We aimed at reducing user operating environment behavior and reduce energy consumption. We will learn and imitate complex human behavior in the environment.

2. Related Works

2.1 Artificial neutral network

According to [1], users' behaviors have a certain level of regularity, but are easily changed by the environment. Sensors can only collect a large amount of data, but cannot identify the users' behaviors. The BP artificial neutral network is one of the common methods for human behavior identification. It converges the diffused values into the expected output result as Formula 1.

$$\left\{\begin{matrix} (S_{11}, & S_{12} & ,\dots, & S_{1,n-1}, & S_{1n}) \\ (S_{21}, & S_{22} & ,\dots, & S_{2,n-1}, & S_{2n}) \\ & & \vdots & & \\ (S_{k1}, & S_{k2} & ,\dots, & S_{k,n-1}, & S_{kn}) \\ & & \vdots & & \\ (S_{m1}, & S_{m2} & ,\dots, & S_{m,n-1}, & S_{mn}) \end{matrix}\right\} \Rightarrow \left\{\begin{matrix} O_1 \\ O_2 \\ \vdots \\ O_j \\ \vdots \\ O_p \end{matrix}\right\}$$

Where O_i denotes the ith activity.

p is the number of the activities. It can be considered as a set of daily behaviors.

S_j denotes the jth sensor. n is the number of sensors. S_{kj} is the state of S_j at time k, its value is either 0 or 1.

$(S_{k1}, S_{k2}, \dots, S_{kn})$ is the state vector of an activity.

m is the number of state vectors.

There are multiple activities in the daily routine, and the activity may be repeated, thus, by reorder and divide the input state matrix into $[S_1, S_2, \dots S_j, \dots, S_p]$

$$\hat{S}_j \Rightarrow \begin{bmatrix} S_{11} & S_{12} & \dots & S_{1i} & \dots & S_{1,n-1} & S_{1n} \\ S_{21} & S_{22} & \dots & S_{2i} & \dots & S_{1,n-1} & S_{2n} \\ & \vdots & & & & & \\ S_{k_j1} & S_{k_j2} & \dots & S_{k_ji} & \dots & S_{k_j,n-1} & S_{k_jn} \end{bmatrix} \Rightarrow O_j$$

$j=1,\dots,p$, $i=1,\dots,n$, k_j is the number of state vectors of activity O_j, and

$\Sigma_{kj} = m$

3. Method and Process

In the system, a sensor sends a packet to the network at the time when it detects an activity occurs. A packet is with four fields, RC, ID, Time, State, separated by commas:

RC is the region code, used to identify the place, where the sensor situates. RC = 1 for a private space, and 0 for global space. Each sensor has its own ID. Sensors can be divided into three types according to environment and types, namely position sensor, entrance sensor and power sensor. The Time and State record the time and state of the sensor at the activity occurs. The state may be 0/1 for the OFF/ON of the sensor.

3.1 Event classification stage

dentifying users in a multi-user environment is a difficult task. As input and output values are required in the learning algorithm, classifying and extracting the users under a single time series is also difficult. By data comparison, this study classified the time series of different users, as shown in Figure 1.

The continuous events from individual sensor to entrance sensor are defined as a continuous behavior. These two types of sensors can be considered as one endpoint sensor. Thus, when the individual sensor or entrance sensor is considered as the initial point, the other is the end point. The behavior contained in these two types of sensors is considered as continuous action. The user can be defined through the individual sensor.

When the event occurs, as shown in Figure 1, the endpoint sensor is identified first to determine whether the event is from individual sensor. If yes, subsequent reaction is tracked to find the ending point; if not, the data are compared to find the origination point of the event to track the subsequent event. Finally, when the two events occur, the data can be extracted and stored in user data, so that the user could be defined, and single time series for the user could be saved.

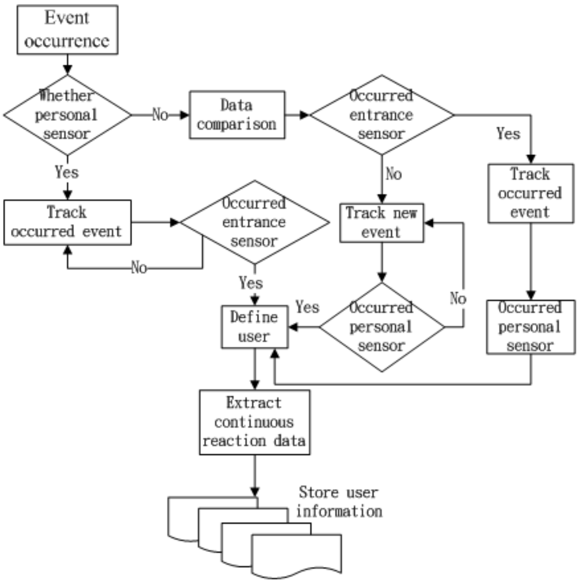

Figure 1 Information classification flow chart

3.2 Characteristic learning stages

Users have certain characteristics, which are also known as habits. Thus, [] suggested that users' behaviors have periodicity. Artificial neutral network is an individualized algorithm, and BP algorithm has been proven to have good classification results in behavioral analysis. BP artificial neutral network can be divided into input layer, hidden layer and output layer. Single user's behavior can be learnt by sensor and status change [7]. Under a multi-user environment, this study used event classification process to divide multi-user environmental data into individual environment data.

Input $S = (S_1, S_2, \ldots S_n)$ into the sensor, "S" denotes the state vector of the sensor, "S_n" is the status change of a sensor; $S_n = \begin{cases} -1, \text{Off} \\ 1, \text{On} \end{cases}$, reaction time "$T_n$" and "$S_n$" are used as input value; "$_n$" denotes the code name of sensor; output $O=(O_1, O_2, \ldots, O_n)$, " On" denotes an activity of the user, "m" denotes different amounts of activity produced, "$f1$" denotes the result of hidden layer, and it is calculated as output layer and input values, to obtain the result of "$f2$".

It is assumed that the user's activity is known from the status collected by sensors. The activities are converged and defined within six types of behaviors. The six behaviors, namely at work, off work, lunch break, temporary leave (0-10 min), leave 1 (10-60 min) and leave 2 (60-120 min) according to the time of entrance and leave.

Each user has one's own behavior matrix, which includes the above six behaviors. In the prediction stage, the matrix is used for comparison.

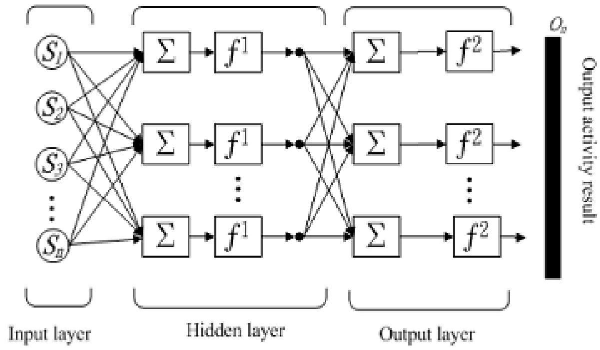

Figure 2 Artificial neutral network

3.3 Predictive control stage

Based on the classification results gained from the learning stage, users' behaviors could be classified. As complex factors may be involved in a multi-user environment when the event occurs, data should be processed first to classify and compare the data for the behaviors included in the two end points. The common behaviors occurred in a multi-user environment is event overlap, repeated triggering, and event interruption. According to the process shown in Figure 3, two endpoint events should be identified first, then whether it is the single event should be confirmed; if not, the situation of event overlap and continuous trigger may occur in time series. As the same time series may involve multiple users and events, time series should be divided according to the number of users, and repeated events should be deleted. After retaining overlapped events, the user of the time series could be defined, and behaviors can be classified through data and behavior matrix.

Time series is a type of single-direction series. Figure 4 shows the reaction result of all sensors, the recorded time. During the course of reaction, users and sensors cannot be identified. For the data recordings of the sensors during the reaction, the user cannot be known, thus, the judgment process is carried to identify the user in the events and reaction. The data are classified based on the users, and the reaction ID, time and state are recorded.

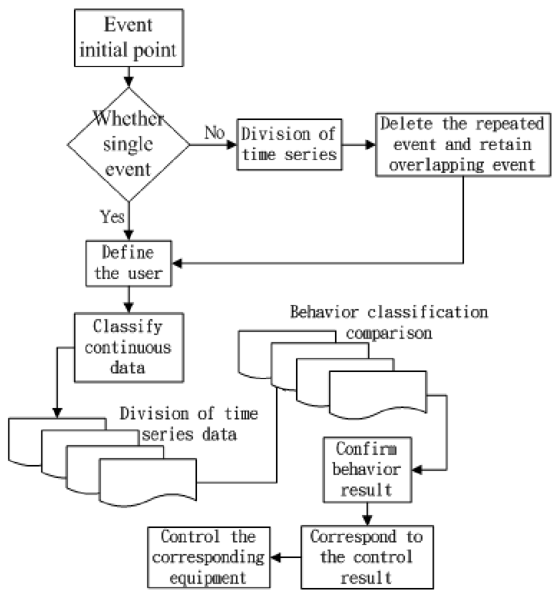

Figure 3 Time series division and control

Based on data classification, users' behavior characteristics can be known, and behavior judgment is carried out according to the characteristics to determine the behavioral types. When the user leaves temporarily the office, he/she needs to turn off some of the electric appliances; when the user leaves the office after work, all electric appliances should be turned off; when the user is at the office, the order of the electric appliances that require waiting time when turning, such as computer, air conditioner, copying machine, etc., to be turned on is based on the user's behavioral characteristics. These appliances should be turned off automatically when the user leaves for energy saving.

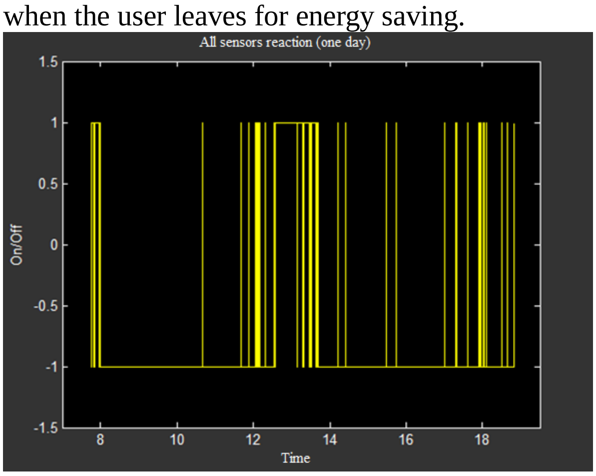

Figure 4 Reaction of all sensors

4. Results of User Behaviors

4.1 Simulation environment

This study simulated a multi-user environment to solve the complex situation in such environment with dozens or even hundreds of users.

This study simulated an office environment with eight users (Figure 5), where the sensors include user sensors, moving sensor and power sensor, and the sensors of the person space include table lamp, computer, socket and user sensor. Power sensor is for both personal and sharing space.

An event is divided into three stages, which are data classification, learning and predication. As each user has one's own periodicity, only the data of the multi-environment is classified and recorded. The user's characteristics can be learnt through the stored data, and the user's own vector matrix can be used to determine and predict the user's behavior.

Table 1 Individual user's daily behavior process

User	User1	User2	…
Daily behavior	At work	Off work	…
	Leave 2	Temporary leave	…
	Leave 1	Temporary leave	…
	Temporary leave	Lunch break	…
	Lunch break	Leave 1	…
	leave	Temporary leave	…
	Temporary leave	Temporary leave	…
	Leave 1	Off work	…
	Leave 1		…
	Off work		…

4.2 Simulation data

Overlapped event, repeated event, event interruption are common in simulation data. They are made to be more complicated for simulation, such as (1) different users and different events take place at the same time; (2) different behaviors take place at the same time, but on different dates, in order to reflect the complexity of a multi-user environment. Table 3 shows each user's behavior in one day. The time of occurrences on different dates are added to the variables in order to reflect the uncertainty and variation of users' behaviors.

Table 2 Sensor reaction of user behavior

User	User1			User2			..
Behavior	At work	Leave 1	...	At work	Leave 1	...	..
Sensor process	M0	U1	...	M0	U1	...	..
	M1	M1	...	M1	M2	...	..
	U1	M0	...	M2	M1	...	..
				U1	M0	...	..
						⋮	⋮

There are five shared sensors, eight private sensors and one entrance sensor in the environment, which are used to simulate the moving sensors triggered when users enter and leave the environment. Table 1 (daily activities) and Table 2 (sensor contents) are used to generate Table 3. There will be differences between the occurrence time of behaviors on different dates. Table 3 shows the data for 30 days, including behavior, time, ID and state.

Table 3 User's activity

User(1)	At work	07:52:11
	Leave 1	09:54:33~ 10:47:21
	Temporary leave	11:31:02~ 11:38:41
	Lunch break	12:07:49
	⋮	⋮
User(2)	At work	07:58:59
	Temporary leave	08:43:02~ 08:51:41
	Leave 2	08:54:33~ 10: :47:37
⋮	⋮	⋮
User(8)	At work	07:58:51
	Temporary leave	08:51:36~ 08:54:29
	⋮	⋮

4.3 Behavior classification

The division of user data and tracking in the behavior sequence under a continuous period of time is the main topic of this study. As the events are in time sequence, based on the previous data, the event owner could be identified. As shown in Figure 5, the entrance sensor (M0) is the first triggered event, and the event sequence is entrance sensorM0->moving sensorM1->personal space sensor U1. Since M0 is the shared sensor, it cannot classify the event when the trigger occurs, thus, when M0 occurs, the user cannot be known. As the event occurs from M0->M1->U1, the owner of continuous trigger events can be tracked and fixed; in this case, it is User1.

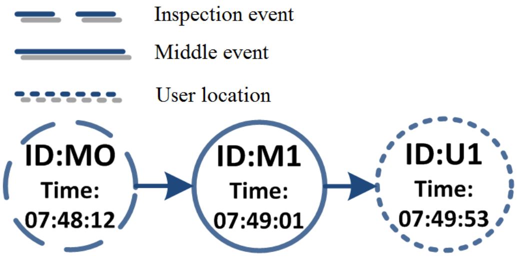

Figure 5 Tracking the user when entering the space

Figure 6 shows that the user leaves personal space and triggers the sensing element M0. By comparing with the previous in a given range of time, the user can be identified. For U1->M1->M1->M0, the occurrence place of event is M0, thus, by reversing the sequence, U1←M1←M1←M0, the event owner can be known.

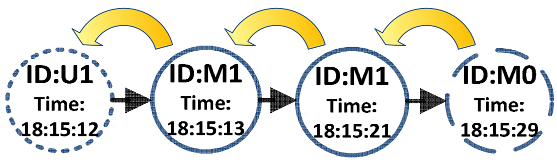

Figure 6 Reverse search of the user

Although data comparison could be used to identify the event owner, the method is only applicable to single-user environment, instead of multi-user environment, as shown in Figure 4.

Figure 7 shows that User 3's event occurs first, and User 1 enters in the middle, U3->M2->U1->M1->M1->M0, of which, the M1, that occurs twice, are triggered by User 5 and User 1, respectively. M0 sensor is triggered only once because User 5 and User 1 triggered M0 at the same time. This is an example of the repeated event, overlapping event and user interruption that occur frequently in a multi-user environment.

Figure 6 shows the division method when two users are involved at the same time. The events of User 1 are divided (Figure 6), and User 5 triggers U3->M2->U1 first, thus, U1 divide into two records for User 3 and User 1.

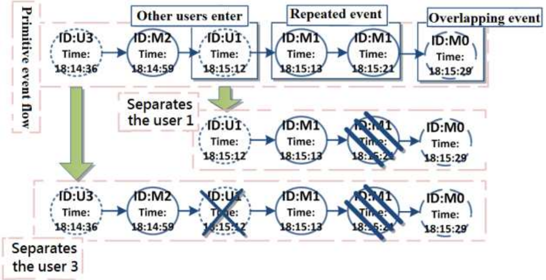

Figure 7 Dividing the users

With two user records, the repeated event is deleted by choosing the sensors which have the two closest time records. The modification is as follows:

User3 = U3->M2->M1->M1->M0

User3 = U3->M2->M1->M1->M0

User3 = U3->M2->M1->M0

After division (Figure 8), the stored data could be used for learning of division. The record is saved after user identification. This method could reduce the difficulty in learning under a multi-user environment.

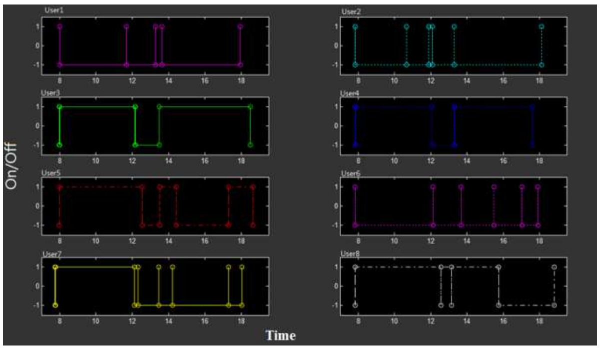

Figure 8 Division of users

4.4 Behavior judgment

User behavior identification is based on statistics and learning algorithm []. This study applied BP artificial neutral network algorithm. Although it has been prove to have good classification result, it could only be applied to a single-user environment. Thus, this study used behavior and user division for a multi-user environment.

This study applied 10-day data for training, and 20-day data for testing. Although it was not discussed in previous study [], this method could make accurate predication in a single-user multi-behavior environment, with a recognition rate of 97% (Table 4).

Table 4 Different environment recognition and predictive rate

	Prediction	Recognition
	The original classification method	
Single-user environment	83%	97%
	Marker classification method	
Single-user environment	85%	93%
Multi-user environment	78%	86%

Using the marker classification and recognition method, this study classified the users, and conducted training according to each user's behaviors. The results showed that 93% recognition rate and 78% prediction rate were achieved, which are higher than the previous result. However, when the method was applied to a single-user environment, the recognition rate was lower than the previous rate. It is because the training and recognition in this study are mainly for predicting user behavior, instead recognition. However, the rate is still as high as 93%. In both single-user and multi-user environment, the proposed method has good prediction result.

5. Conclusions and Future Study

This study proposed a novel method to identify user behavior in a multi-user environment. In order to solve the problem of multi-user detection and tracking, we classify the multi-user data under the condition of continuous time into multiple single environment data. BP artificial neutral network was applied to learn the users' behaviors. Users' behavior characteristics were derived with sample sensor state data. And then they were used to identify users' behaviors. The proposed method could effectively identify users in a multi-user environment and record their behaviors. It could be applied in office environment, as well as in home environment.

This study only applied the proposed method in simulation and testing. In the future, the sensors could be installed in real environment to realize the control system through actual data.

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