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Smart Home Design Based on the Behavior Pattern of Empty-Nest Elderly

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Abstract: Aiming at the social status quo of serious population aging in China, and the social elderly care problems caused by the increasing number of empty-nest elderly, this paper proposes to study the home behavior model based on empty-nest elderly and construct a smart home appliance system. The behavior prediction algorithm is used to predict the next behavior of the empty-nest elderly, the LSTM neural network is used to conduct behavior training, and then a test environment is built to apply the behavior prediction algorithm to the smart home appliance system. The test results show that the use of behavior prediction algorithms can improve the intelligence of the smart home system, which greatly increases the convenience of the empty-nest elderly's daily life.

1. Introduction

With the rapid development of the Internet of Things and artificial intelligence technologies, behavior prediction and recognition have gradually received widespread attention. Research has found that high-tech information technology and AI technology have laid a solid foundation for intelligent systems in society and have also provided new ideas for the "elder care career" of the empty-nest elderly, and have become a powerful means to solve the problem of social elderly care. Formerly, a scholar Dong Mingtao proposed the research of smart home power system based on deep learning, using deep learning algorithms to realize the construction of smart home power system [1], Wang Jun proposed the design and implementation of the IoT smart home monitoring and control system based on user behavior analysis [2]. Although the above research discusses and analyzes the home smart system, it does not meet the smart home needs of the empty-nest elderly in a real sense. The too-smart home system does more harm than good to the elderly. Therefore, how to grasp the "smart scale" of home furnishings and use intelligent technology to design a set of smart home products that are more suitable for the empty-nest elderly has become an inevitable trend in the current aging society. Combined with the empirical research of many scholars, the three classic behavior patterns of the empty-nest elderly living alone in daily life, behavior deviation, loneliness and depression, and loss and dependence are deeply studied. By constructing a smart home appliance system and using behavior prediction algorithms to predict the next behavior of the empty-nest elderly, using LSTM neural network for behavior training, using behavior prediction algorithms to improve the intelligence of the smart home system, and helping the empty-nest elderly realize autonomous homes Pension.

2. The overall structure of the smart home system

Starting from the home appliance system in the smart home, it aims to build an intelligent home appliance system suitable for the empty-nest elderly. The system needs to meet the needs of local data storage, data processing feedback, network connection and security. According to the above four-point demand analysis, a smart home appliance control system based on LSTM is established. As shown in Figure 1, the overall structure mainly includes four levels, namely the acquisition layer, the transmission layer, the data layer and the service layer [3]. The content of each job is different, and the division of labor is clear.

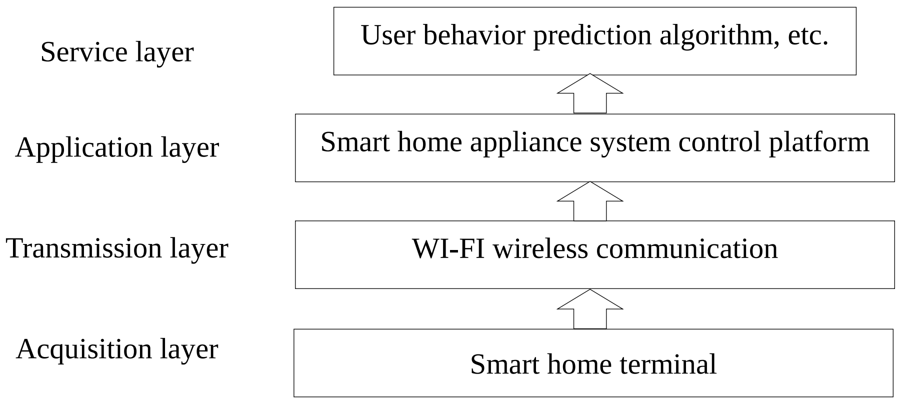

Figure 1: Smart home appliance control system based on LSTM

2.1 Acquisition layer

The acquisition layer belongs to the terminal of the smart home system, and its main function is to use artificial intelligence technology to collect data information in the home environment of the empty-nest elderly, including indoor parameters such as temperature, humidity, light, and formaldehyde [4]. After the sensor collects the indoor parameters, it will be sent to the Arduino microcontroller together, and then after the Arduino microcontroller is connected to the host computer control platform, data communication can be carried out.

2.2 Transmission layer

The transmission layer mainly uses WiFi wireless communication network for data transmission. The indoor parameters collected by sensors are mainly transmitted to the control platform using WiFi network, and the subsequent data is stored and analyzed. Due to the simple networking of WiFi wireless communication network technology, the network covers a wide area. The wall barrier has little effect on the signal strength and is suitable for daily home environment [5].

2.3 Application layer

The application layer is a smart home appliance system control platform built with java EE technology. This platform provides an entrance for system users to access the system, and at the same time connects to the traditional free cross-platform database system MySQL.

2.4 Service layer

The main function of the service layer is to process and analyze massive amounts of data in a timely manner through user behavior prediction algorithms, dig out useful information from these data and build a knowledge base, at the same time, it is connected to the traditional free cross-platform database system MySQL.

3. The next step behavior prediction design ideas of behavior embedding

In general, the traditional smart home will have a variety of different sensors and devices to perceive people's behavior, so the behavioral activities must be mapped to the vector space before the behavioral perception [6]. To distinguish the intentions and behaviors of different behaviors, it is necessary to group the same intentions and the same participants in the same vector space.

In the same group of behaviors, a vector represents a single behavior. Because the vectors are randomly generated, when the behaviors represented by some vectors are related, there is still no relationship between them. Therefore, the one-hot vector can be transformed into an n-dimensional vector, and its associated behavior will be transformed into an associated vector accordingly. Among them, the one-hot vector is represented as a vector with only one value of dimension 1, and other values of 0. The transition of position behavior at time tc is determined by the behavior that occurs between tc-n and tc+n. As shown in the behavior embedding in Figure 2, the behavior activity at time tc is used as the input vector, and the surrounding behavior activities are trained as the output vector [7]. The n-dimensional vector of the behavior activity on tc is constructed by the weights of the neural network prediction layer (n represents the dimension of the prediction layer). It can be seen that all algebraic operations can be applied in the vector space to realize the intelligence of the smart home appliance control system.

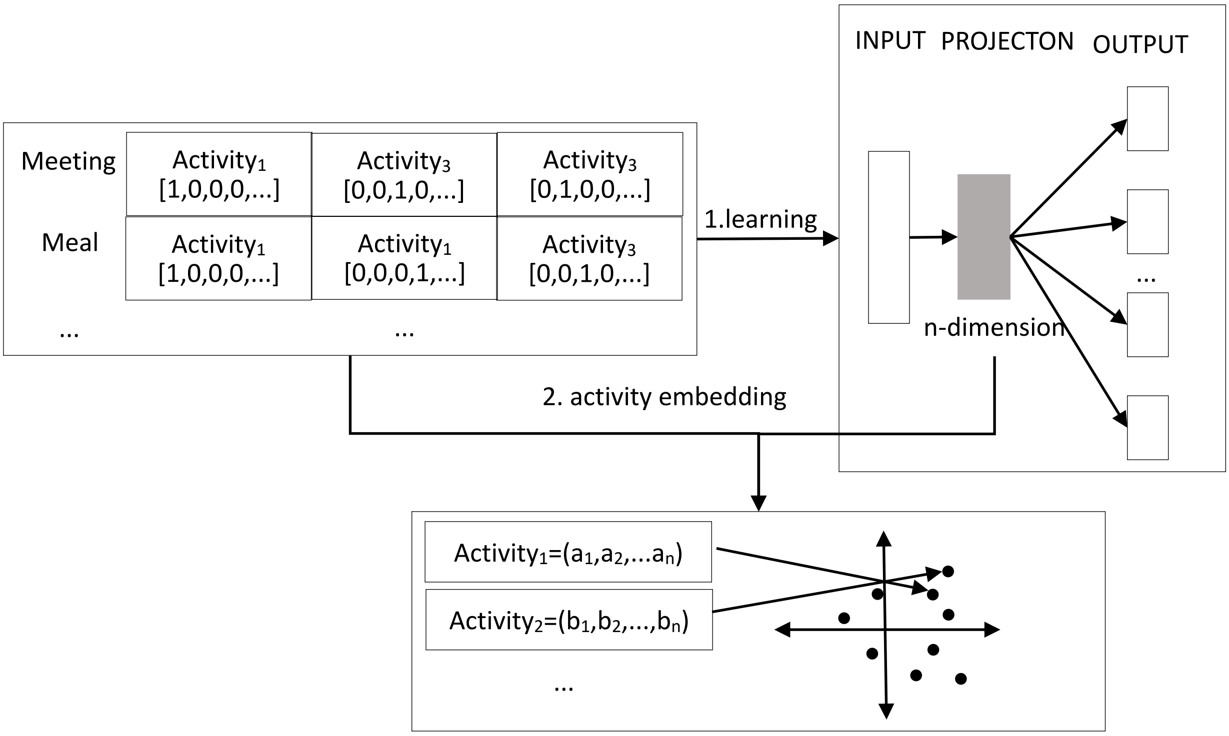

Figure 2: Behavior embedding process

In order to determine the number of the most valuable candidates, the k-means clustering algorithm is used to divide the n-dimensional vectors corresponding to all behaviors into k different clusters. The number of clusters k is determined by the Elbow Method. The main idea of the elbow method is to increase the number of k to see the percentage of variance and select the value of k on the "elbow" when the variance begins to flatten out [8]. Then set the number of candidates for the next behavior to the maximum value of the behavior in the cluster. The output of the LSTM network generally selects some vectors that are closest to the output vector as the final candidates.

LSTM can also be called long and short-term memory cyclic neural network. It has a very accurate and detailed data information transmission mechanism, which can effectively solve the long-term dependence of the system [9]. LSTM is the basic unit in the overall framework of Encoder-Decoder, so it can complete the data encoding and decoding arranged in time sequence. LSTM can also learn long-term dependencies and has a memory function for historical data with long time intervals.

LSTM includes three kinds of "gates", namely forget gate, input gate and output gate. The main function is to protect and control the cells in the neural network. The gates in LSTM are combined to form the hidden layer in the model, which is called block [10]. Among them, the main function of the input gate is to control the intensity of the new input data; the main function of the forget gate is to maintain the intensity of the value at the previous moment; the main function of the output gate is to control the intensity of the output data.

$$i_t = \sigma\left(\sum W_{xi} x_t + \sum W_{hi} x_{t-1} + \sum W_{ci} x_{t-1} + b_i\right) \quad (1)$$

$$f_I = \sigma\left(\sum W_{xf} x_t + \sum W_{hf} x_{t-1} + \sum W_{co} x_{t-1} + b_0\right) \quad (2)$$

$$o_t = \sigma\left(\sum W_{xo} x_t + \sum W_{ho} x_{t-1} + \sum W_{co} x_{t-1} + b_0\right) \quad (3)$$

$$c_t = f_t c_{t-1} + i_t \tanh\left(\sum W_{xc} x_t + \sum W_{hc} x_{t-1} + b_c\right) \quad (4)$$

$$h_t = o_t \tanh\left(c_t\right) \quad (5)$$

In formulas (1), (2), (3), (4), (5), i1 represents the input gate; f1 represents the forget gate; o1 represents the output gate; c1 represents the vector value of the memory unit; w is expressed as the repeated weights of the input in each type; b represents the bias term; σ represents the S-curved sigmoid function, its main function is to control the weight and intensity of the unit passing through, and control its size between 0 and 1; t is the activation vector between cells. Tanh is expressed as a hyperbolic tangent function, and ⊙ is expressed as a multiplication operation element by element.

Compared with the traditional network, the LSTM neural network has stronger and more stable performance. It can use the transmission gate to update and delete various input and output information. With the characteristics of long-term memory, this unique feature is conducive to tracking information over a long period of time. It can be seen that the input gate, forget gate, and output gate can realize the LSTM (Long Short-Term Memory) model for memory.

4. Application of behavior prediction algorithm

4.1 Setting up the test environment

In order to apply the behavior prediction algorithm to the smart home system of the empty-nest elderly, the first step is to build a platform for testing to simulate the real living environment of the empty-nest elderly in their daily lives. The test requires two lamps to simulate the master bedroom lamp and the bedside lamp; an electronic sensor is placed at the entrance of the room, and a motion sensor is placed on the bed in the room; and a light sensor is also installed on the ceiling. Each group of sensors and lights will be connected to the Arduino microcontroller to ensure that it is connected to the WiFi wireless communication network environment to communicate and interact with the control platform.

4.2 Application of behavior test algorithm

Assume that the empty-nest elderly has five behaviors, namely rest, reading, hanging out, absent and others. As shown in Table 1, the table clearly shows the ambient lighting conditions under different behaviors. In addition, the characteristics of the date, hour, location, and behavior of various behaviors need to be marked as 4 variables, including DT, HT, LT, and AT. Use 0 and 1 to represent the current action and the expected action. For example, DT0 and DT1 represent the current date and the expected date, respectively. In the HT variable, the daytime is divided into 8 time periods, so HT can be valued in 1-8. The variable LT is represented by 4 values, such as idle, doorway, headboard and both. In addtion, both means that the two motion sensors are both active. The variable DT can be either "working day" or "weekend".

Table 1: Ambient lighting conditions of empty-nest elderly in different behaviors

Behavior	Illumination Transmitter	Lying Lamp	Bedside Lamp
Rest	Off	Off	Off
Hangout	Ignore	Off	On
Read	On	Ignore	On
Other	Bright	On	Ignore
Absent	Ignore	Off	Off

In order to make the test result more realistic, the predictive function will not be enabled until the setting variables AT0, DT0, HT0 and LT0 are changed. The main purpose is to allow the empty-nest elderly to actively issue instructions when they want to actively issue instructions. In addition, when the behavior, location, or time of the empty-nest elderly change (such as entering a new time interval or a new day), the system must respond again.

5. Test results and analysis

In order to verify that the behavior prediction algorithm can automatically predict the next lighting control behavior based on the behavior sequence made by the empty-nest elderly, a 4-day test is set, including weekdays and weekends. During the test, two tests were conducted, namely, disabling and enabling behavior prediction. The system counts the number of times that the empty-nest elderly actually presses the button to turn on or turn off the lights as an index to measure the accuracy of the prediction. When the predictive algorithm is stopped, the empty-nest elderly needs to issue 65 instructions in the home environment of the test. The summary results of each time interval are shown in Figure 3. Time intervals 1-8 are 0-3 hours, 3-6 hours...21-24 hours, respectively.

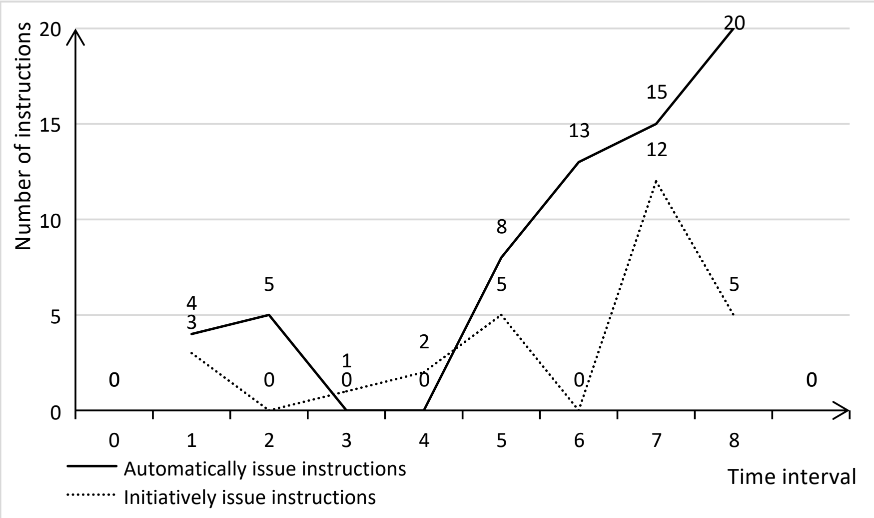

Figure 3: The command record issued by the empty nester in the experiment

It can be seen from Figure 3 that after enabling the behavior prediction function, the empty-nest elderly only pressed the switch 28 times, which is a 56.9% reduction in the number of instructions compared to the previous setting standard. The three stages of 3-6 hours, 15-18 hours and 21-24 hours are in good condition. Among them, the performance of the smart home system with behavior prediction function turned on for 6-9 hours and 9-12 hours is lower than that of the unopened smart home system.

A questionnaire survey was conducted on 120 empty-nest elderly people. The content of the survey was their satisfaction with the use of the smart home system. The survey criteria are agree, general, and disagree. As shown in table 2:

Table 2: Feedback from the survey of empty-nest elderly people using smart home systems

Problem	Agree/100%	General/100%	Disagree/100%
The system is easy to understand and operate	91.37	8.63	0.00
Can meet the needs of daily life	82.58	7.20	0.22
Can reduce loneliness	87.20	10.35	2.45
Can improve the level of intelligence in life	94.92	5.08	0.00

It can be seen from Table 2 that 91.37% of the empty-nest elderly think that the system is easy to understand and easy to operate, 8.63% of the elderly think it is general; 82.58% of the empty-nest elderly think that this system meets the needs of daily life; 87.58% of the empty-nest elderly believed that using a smart home system can reduce loneliness; 94.92% of empty-nest elderly people feel that this system can make their lives more intelligent.

6. Conclusion

To sum up, the smart home appliance system is built based on the empty-nest elderly's home behavior patterns, using behavior prediction algorithms to predict the next behavior of the empty-nest elderly, and apply behavior prediction algorithms to the smart home appliance system after behavior training through the LSTM neural network. The test results show that the use of behavior prediction algorithms can improve the intelligence of the smart home system, reduce the loneliness of the empty-nest elderly through the smart home system, and meet the daily needs of the empty-nest elderly.

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