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A fuzzy clustering model of information appliance

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Abstract

The purpose of this study is to propose a fuzzy clustering model of information appliances (IA). There are two sub-models, saying information appliance cluster engine (IACE) and user interactive model (UIM), in this model. The function of IACE is to process the users' recognitions of IA devices. The UIM is the interface of IACE with the IA intelligent agents (IAIA). Via the proposed model, the IAIA can be more humanistic, and convenient for user. Also, via the implementation of this model, we can have the analysis of the optimal effectiveness.

1. Introduction

Along with the prosperity of internet, information appliance (IA), plays an important role for the future. The IA devices can be expanded to related information products. A satisfactory IA control mechanism can promote the integrity IA facilities, also, it enable the home network system more comfortable and convenience.

Lee and Huang [1] proposed an IA controlling model (IACM), which can control IA devices through home management broker. Chang [4] proposed the controlling mechanism of UPnP network under client-server architecture. Lee and Chen [2] presented IA intelligent agents (IAIA) to ensure the security and convenience of home environment. Wu and Jan [3] proposed home network management system integrating WAP and SMS by mobile communication devices. The home network has been expanded from local control to remote control, and from physical control to wireless control.

In this study, we propose a fuzzy clustering model of IA (FCIA). Via the proposed model, the IAIA can be more humanistic, and convenient for user. Also, via the implementation of this model, we can have the analysis of the optimal effectiveness.

2. FCIA

We proposed the fuzzy cluster model of information appliance (FCIA) is in information appliance control model (IACM) as shown in Figure 1. FCIA can promote the group capability of IA intelligent agent for managing IA devices to receive the user's requirements for clustering of IA devices and response clustering results.

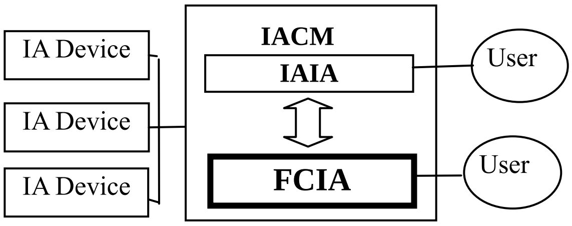

Figure 1 IA controlling model

There are two sub-modules, saying IA clustering engine (IACE) and user interaction model (UIM) in FCIA, as showing Figure 2. Also, there is an IA device database (IADD). The functions of these components are as the followings:

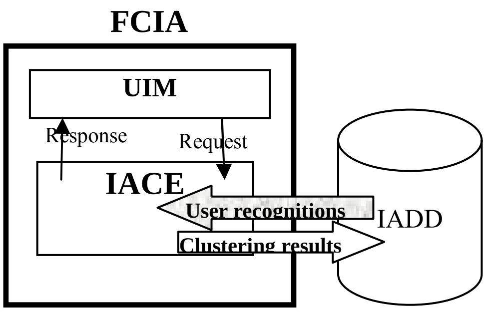

Figure 2 Fuzzy clustering model of IA

- IACE: IACE is the core of this model. The users' recognitions of IA device are clustered through fuzzy cluster.
- UIM: UIM plays the interface among users, IAIA, and IACE. The various operating parameters of IACE can be defined via UIM.
- IADD: IADD stores the individual user's recognitions of IA devices and the clustering results of IACE.

According to user's submission, UIM will request the clustering demands to IACE, then, IACE will response clustering results to UIM.

2.1 IACE

The IACE is responsible for clustering works of IAs. It processes user's recognitions of IA to cluster IA devices, and it facilitates the management of remote control. The Figure 3 illustrates the operation flow of IACE:

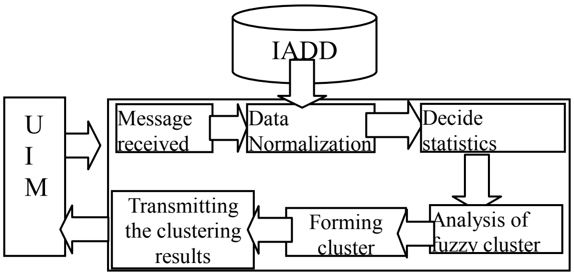

Figure 3 The operation flow of IACE

When the recognition of user are put into the IACE, the input and output will be transmitted to user through UIM. The format of data input, which is accepted by IACE, is shown in figure 4:

User_Name	Group_Number	λ-Valuee	Mode

Figure 4 The Format of Data Input for IACE

User_Name represents the user who enters the engine. Group_Number is the cluster quantity of definition result. λ-Value is used for analysis of fuzzy cluster and the size of λ-Value will decide the number of cluster's category. The value of λ is between 0 and 1, larger the λ, less general the category, and smaller the λ, more refined the category. The Mode is responsible for distinguishing the mode of IACE used the current time, for example, 0 means proceeding clustering for all factors, 1 means proceeding clustering only for user's recognition with devices, 2 means proceeding clustering for data of hardware equipments.

As the user's recognition data are put into the IACE, the input and output will be transmitted to user through UIM.

After IACE receiving data, the step of entering IACE is – message received. The data received in the message format will be analyzed on this step, and then the command will be transmitted to the data normalization. The data will be acquired from IADD according to the command received. After acquiring the user's data from IADD, the procedure will enter into the step of data normalization, the data acquired from IADD will be normalized. The data format of IADD is shown in figure 5, X_i (i|i>0) represents the category of IAs, and Y_j (j|j>0) represents the conditions of measure. For the data normalization, we employ the formula (1) [7] to proceed normalization:

$$X_{ij} = \frac{X_{ij} - \{X_{ij}\}_{Min}}{\{X_{ij}\}_{Max} - \{X_{ij}\}_{Min}} \quad (1)$$

{Xij} Min represents the minimum of actual measurement value in row j
{Xij} Max represents the maximum of actual measurement value in row j

After normalization, the data will be transmitted to the step of deciding statistics. The normalized data will be used to calculate the similarity of respective measurement attribute among IAs, consequently the fuzzy similar matrix is generated. For the IACE's deciding statistics, we apply the max-min method [7] as shown in (2):

$$r_{ij} = \frac{\sum_{k=1}^{n} Min(X_{ik}, X_{jk})}{\sum_{k=1}^{m} Max(X_{ik}, S_{jk})} \quad (2)$$

The fuzzy similar matrix is transmitted to the step of analysis of fuzzy clustering. The fuzzy similar matrix is clustered via the fuzzy clustering. We apply the netting method [7] and the maximum number method [7] for fuzzy clustering.

Finally, the clustering results are transmitted to UIM via transmitting procedure. IACE will generate the cluster of IAs.

	Y_1	Y_2	…	Y_n
X_1	R_{11}	R_{12}	…	R_{1m}
X_2	R_{21}	R_{22}	…	R_{2m}
…	…	…	…	…
Xn	R_{n1}	R_{n2}	…	R_{nm}

Figure 5. The storing method of IADD

2.2 The Weighing Factors of FCIA

This research incorporates the recognition conditions of security, entertainment, information acquiring, necessity for life, communication, comfort and convenience of devices and the recognitions of individual user of IA devices, as shown in Figure 6. The clustering information is acquired through IACE. Due to the different recognitions of individual user, the clustering results are different.

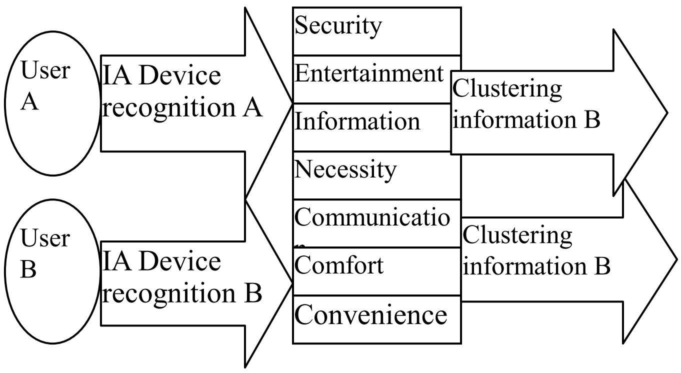

Figure 6 User's recognition

We ranged the user's recognitions of IA into seven grades, as shown in Table1. In many cases, we cannot express uncertainty problems simple by using the concept of probability. With the availability of concept of fuzzy set theory, we can solve the problem under fuzzy circumstances. Moreover, fuzziness can be quantified by using the properties of fuzzy numbers. We made the linguistic values 1, 2, … , 7 into corresponding reasonable fuzzy numbers with triangular membership functions.

Table 1 The Table of comparisons for semantic and fuzzy number

	Fuzzy Number	Grade of relavance
7	$N_7=\left(\frac{5}{6},\frac{6}{6},\frac{6}{6}\right)$	Definitely high
6	$N_6=\left(\frac{4}{6},\frac{5}{6},\frac{6}{6}\right)$	High
5	$N_5=\left(\frac{3}{6},\frac{4}{6},\frac{5}{6}\right)$	Slightly high
4	$N_4=\left(\frac{2}{6},\frac{3}{6},\frac{4}{6}\right)$	Middle
3	$N_3=\left(\frac{1}{6},\frac{2}{6},\frac{3}{6}\right)$	Slightly low
2	$N_2=\left(0,\frac{1}{6},\frac{2}{6}\right)$	Low
1	$N_1=\left(0,0,\frac{1}{6}\right)$	Definitely low

3. Implementation of IACE

In this section, we detail the practical environment for the model, and calculate the acquired data that describe AI's fuzzy clustering model by steps illustrated in Figure 6. Two clustering models are analyzed by maximum trees and netting mode, by substituting different λ interceptive value, different clustering models and the corresponding λ interceptive value can be obtained to represent the relationship between the clustering results. UIM's Web interactive Main interface will be presented at the end of this section.

3.1 Practical Environment

For the purpose of ease manipulation, cross-platform, and remote-control capability, we have applied Java Server Page (JSP) and Java Servlet written Web Server structure, and Java 2 Platform Standard Edition v 1.4.2 API Specification is utilized for constructing FCIA's model. This model is constructed upon Tomcat server software that employs browsers as its interface; above-mentioned are done with a Pentium III 700GHz Notebook that is powered by OS Windows Professional and Microsoft Access 2002 database.

3.2 Calculating Procedure of Empirical Data

IACE's fuzzy calculation is illustrated in this part as shown in Table 2. The diversity recognitions based on users' recognition on IA machine that may give a relevant level for machine and assessment factors.

Table 2 IA device of user's recognition

	Device Name	Security	Entertainment	Information receive	daily necessities	communication	comfortable	convenience
(X1)	washing machine	1	1	1	5	1	2	7
(X2)	air conditioning	1	1	1	4	1	7	1
(X3)	refrigerator	1	1	1	7	1	6	4
(X4)	microwave oven	1	1	1	6	1	1	7
(X5)	lighting	5	5	1	6	1	3	5
(X6)	decoration lighting	1	6	1	5	1	5	4
(X7)	TV	2	7	7	4	3	2	2
(X8)	server	5	1	4	1	4	1	3
(X9)	PDA	2	2	5	2	3	1	4
(X10)	game box	1	7	3	1	1	1	1
(X11)	Set-Top Box	1	6	6	1	4	1	3
(X12)	DVD	1	7	3	2	1	1	1
(X13)	notebook	1	2	7	3	5	1	2
(X14)	Mobile phone	1	3	5	5	7	1	4
(X15)	Infrared ray sensor	7	1	1	7	1	1	5
(X16)	Temperature sensor	7	1	2	7	1	1	2
(X17)	Smoke sensor	7	1	1	6	1	1	1
	Maximum	7	7	7	7	7	7	7
	Minmum	1	1	1	1	1	1	1

The data will be stored in IADD. After normalizing user's recognition with IA devices, the data is presented in Table 3.

Table 3 Normalization of user's recognition with IA devices

	Security	Entertainment	Information receivability	daily necessities	communication	comfortable	convenience
(X1)	0.00	0.00	0.00	0.67	0.00	0.17	1.00
(X2)	0.00	0.00	0.00	0.50	0.00	1.00	0.00
(X3)	0.00	0.00	0.00	1.00	0.00	0.83	0.50
(X4)	0.00	0.00	0.00	0.83	0.00	0.00	1.00
(X5)	0.67	0.67	0.00	0.83	0.00	0.33	0.67
(X6)	0.00	0.83	0.00	0.67	0.00	0.67	0.50
(X7)	0.17	1.00	1.00	0.50	0.33	0.17	0.17
(X8)	0.67	0.00	0.50	0.00	0.50	0.00	0.33
(X9)	0.14	0.14	0.57	0.14	0.29	0.00	0.43
(X10)	0.00	1.00	0.33	0.00	0.00	0.00	0.00
(X11)	0.00	0.83	0.83	0.00	0.50	0.00	0.33
(X12)	0.00	1.00	0.33	0.17	0.00	0.00	0.00
(X13)	0.00	0.17	1.00	0.33	0.67	0.00	0.17
(X14)	0.00	0.33	0.67	0.67	1.00	0.00	0.50
(X15)	1.00	0.00	0.00	1.00	0.00	0.00	0.67
(X16)	1.00	0.00	0.17	1.00	0.00	0.00	0.17
(X17)	1.00	0.00	0.00	0.83	0.00	0.00	0.00

Table 4 Matrix of IA device's fuzzy relation

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}	X_{16}	X_{17}
X_1	1.00	0.18	0.63	1.00	0.56	0.50	0.15	0.10	0.19	0.00	0.08	0.05	0.14	0.31	0.50	0.26	0.26
X_2	0.18	1.00	0.41	0.18	0.30	0.39	0.16	0.00	0.05	0.00	0.00	0.06	0.10	0.10	0.14	0.16	0.18
X_3	0.63	0.41	1.00	0.63	0.68	0.72	0.17	0.08	0.16	0.00	0.07	0.04	0.12	0.31	0.48	0.27	0.24
X_4	1.00	0.18	0.63	1.00	0.56	0.50	0.15	0.10	0.19	0.00	0.08	0.05	0.14	0.31	0.50	0.26	0.29
X_5	0.56	0.30	0.68	0.56	1.00	0.74	0.28	0.16	0.23	0.09	0.14	0.13	0.15	0.33	0.50	0.30	0.33
X_6	0.50	0.39	0.72	0.50	0.74	1.00	0.50	0.08	0.19	0.14	0.19	0.19	0.15	0.34	0.33	0.16	0.17
X_7	0.15	0.16	0.17	0.15	0.28	0.50	1.00	0.10	0.40	0.40	0.59	0.45	0.55	0.48	0.16	0.18	0.15
X_8	0.10	0.00	0.08	0.10	0.16	0.08	0.10	1.00	0.51	0.11	0.42	0.11	0.37	0.30	0.27	0.25	0.21
X_9	0.19	0.05	0.16	0.19	0.23	0.19	0.40	0.51	1.00	0.19	0.46	0.24	0.48	0.40	0.19	0.13	0.09
X_{10}	0.00	0.00	0.00	0.00	0.09	0.14	0.40	0.11	0.19	1.00	0.44	0.89	0.16	0.19	0.00	0.05	0.00
X_{11}	0.08	0.00	0.07	0.08	0.14	0.19	0.59	0.42	0.46	0.44	1.00	0.41	0.53	0.52	0.07	0.04	0.00
X_{12}	0.05	0.06	0.04	0.05	0.13	0.19	0.45	0.11	0.24	0.89	0.41	1.00	0.21	0.23	0.04	0.10	0.05
X_{13}	0.14	0.10	0.12	0.14	0.15	0.15	0.55	0.37	0.48	0.16	0.53	0.21	1.00	0.54	0.11	0.13	0.09
X_{14}	0.31	0.10	0.31	0.31	0.33	0.34	0.48	0.30	0.40	0.19	0.52	0.23	0.54	1.00	0.30	0.24	0.17
X_{15}	0.50	0.14	0.48	0.50	0.50	0.33	0.16	0.27	0.19	0.00	0.07	0.04	0.11	0.30	1.00	0.71	0.69
X_{16}	0.26	0.16	0.27	0.26	0.30	0.16	0.18	0.25	0.13	0.05	0.04	0.10	0.13	0.24	0.71	1.00	0.85
X_{17}	0.26	0.18	0.24	0.29	0.33	0.17	0.15	0.21	0.09	0.00	0.00	0.05	0.09	0.17	0.69	0.85	1.00

After data normalized, the similarity between each data would be calculated. This study would employ max-min method for showing the distance between each data, as in Table 4.

In addition, we show two fuzzy clustering methods as netting mode and maximum trees by fuzzy relation matrix $\underset{\sim}{R}$, and substituting different λ interceptive value, the compared and contrast diagram is shown in Figure 7.

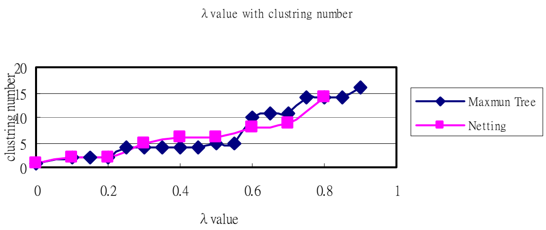

Figure 7 Diagram of with different λ interceptive value

With maximum numbers method and λ=0.5, then we obtained cluster result as in Table 6.

Table 5 maximum trees and λ =0.5 interceptive value

Cluster 1	Digital Washing Machine, Digital Microwave, Digital Fridge, Digital Deco Lamps, Digital Light,
Cluster 2	Home Server, PDA
Cluster 3	Digital TV, Notebook, Set-top Box, mobile phones.
Cluster 4	DVD Player, Game station
Cluster 5	Digital Air Condition
Cluster 6	IR Sensor, Temperature Sensor, Smoke Detector

3.3 System Prototype

This study designs the Fuzzy Clustering Models, as an UIM screenshot in Figure 8, which facilitate user's ease interactivity with IACE. Since it is web base, it is even more user-friendly.

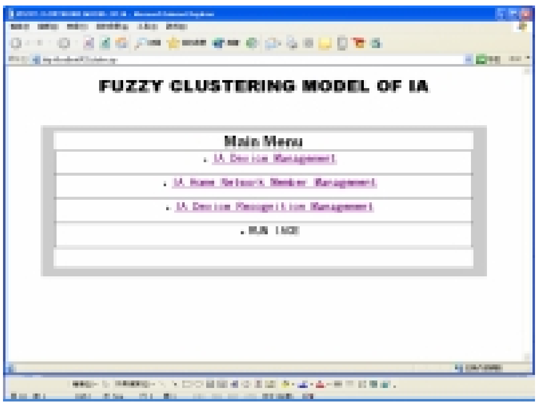

Figure 8 Prototype of FCIA System

4. Conclusion

This study presents a prototype for FCIA model, and shows its feasibility empirically with the result analytically assessed. We made some comments about this model.

(1) It would be more convenient to provide quantities of clustering instead of applying λ interceptive value.

(2) As Figure 7, the suitable clustering results for two methods are between λ=0.4 and 0.6. In this range, maximum number method of clustering is more stable than netting clustering method. Besides, maximum trees method is more economical in terms of calculating system data. Therefore, maximum trees method is preferable in this model.

(3) As in Figure 6, the model presented in this study can cluster AI devices according to user's recognition. Clustering results may be assigned for different types of users.

As above mention, the FCIA makes IAIA be more humanistic, and convenient for user.

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