Mem. Fac. Eng., Osaka City Univ., Vol. 49, pp. 75–82 (2008)

Development of Preference Learning System for Assistance of Individual Transportation Mode Choice

Yuki IWAI* and Takashi UCHIDA**

(Received September 30, 2008)

Synopsis

In order to achieve a policy goal of promoting public transport use by providing information, a convenient system which shows information concerning public transport is highly demanded. We conceive an assistance system which recommends transportation mode and/or route based on preferences of a user. The study, as a preliminary stage, aims to develop a learning sub-system, which is based on neural network (NN), in this system. Firstly we made the framework of the NN and conducted questionnaire surveys for calibration. Then the study applied the NN to transportation mode and route choice. As a result, the NN developed achieved agreement level of about 70%. The resulted NN is also analyzed from the viewpoint of causal-relationship between individual attributes and preference elements, which composes the NN. The analysis shows higher benefit when the system is used by new comers than by old inhabitants.

KEYWORDS: Transportation mode choice, Route choice, Neural Network, ITS, Assistance system

1. Introduction

Recently, the conversion from the private car use to the public transport use is requested to solve traffic congestion, environment problems originated from car traffic, etc. As one of the promising solutions, providing information concerning public transport to people who often use private cars is expected to enhance the using of public transport.

Today, transportation mode and route offering systems, *e.g.* NAVI TIME[2)], are widely spread. These systems have reduced human's work load for some extent. However, the number of traffic route composed of many transportation modes and routes types in urban area often become very huge. In addition, personal preference regarding transport mode/route choice varies among people. Therefore, existing systems are to be improved for daily use by individuals.

It is thought that one solution to this problem is to recommend some concrete traffic modes and routes based on individual preferences. So we conceived an assistance system which automatically learns individual user's preferences of transportation choice through daily use of the system. As the first step to achieve the entire system, the study aim to develop the learning sub-sysem, which is based on neural network (NN).

* Student, Department of Civil Engineering

** Associate Professor, Department of Civil Engineering

2. Outline of the assistance system

Fig.1 shows the schematic outline of the assistance system. Table 1 describes the process shown in Fig.1. Tables 2 – 4 shows examples of main variables in the process. Note that in Table 2 the more a weight of a preference item approaches to 1, the more it is important.

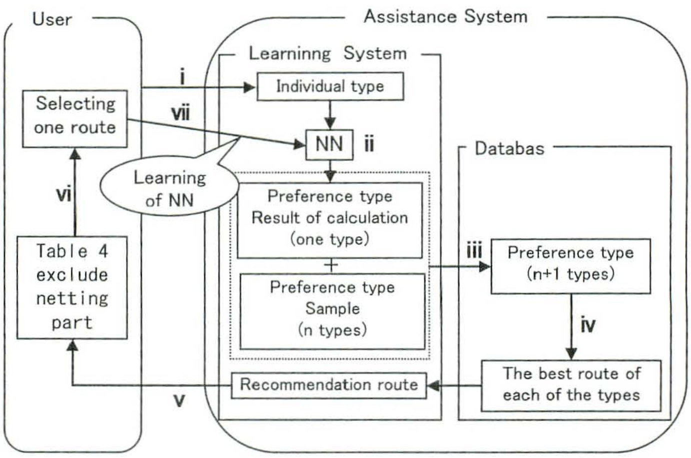

Fig.1 Outline of assistance system

Table 1 Processes in Fig.1

i	A user input an individual type(Age, Time, etc.) into the system.
ii	The system calculates a preference type of the user based on the individual type.
iii	Preference type, result of calculation and sample, shown in Table 2, are sent from the system to a database.
iv	The best route agreeable to each of the preference types, shown in netting part of Table 4, is selected from route candidates, shown in
v	As recommendation routes, the best routes including concrete values,shown in Table 4 exclude netting part, are offered to the user.
vi	The user selects the most favorite one from offered routes.
vii	The system transforms the selected route into teacher signals of the NN, as user's preference type, and advances learning of the NN.

Table 2 Example of preference type

Preference type	Weight of preference item		
	Traffic cost (0～1)	Traffic time (0～1)	Healthy side (0～1)
1(Sample)	1	0	0
2(Sample)	0	1	0
3(Sample)	0	0	1
4(Sample)	0	0	0
5(Calculation)	0	0.5	1

Table 3 Example of route candidate

Route candidate	Concrete values of item		
	Traffic cost (yen)	Traffic time (min)	Healthy side (kcal)
Route1	5.4	35	0
Route2	5.7	32	200
≀	≀		
Route14	5.5	34	200
Route15	5.2	31	5000

Table 4 Example of recommendation route

Preference type	Best agreeable route	Recommendation route	Concrete values of item		
			Traffic cost (yen)	Traffic time (min)	Healthy side (kcal)
1(Sample)	Route5	Recom.1	10	33	700
2(Sample)	Route3	Recom.2	5.5	30	300
3(Sample)	Route15	Recom.3	5.2	31	5000
4(Sample)	Route7	Recom.4	6	40	1000
5(Calculation)	Route10	Recom.5	5.4	33	2000

3. Procedure of study

The study consists of the following four procedures.

[1] Preparation of NN framework

[2] Questionnaire surveys about transportation mode choice

[3] Development of Learning System

[4] Analyses of transportation mode choice

First, we made the framework of the NN in procedure [1]. And, to complete the NN, we conducted a first questionnaire survey and a follow-up questionnaire survey in procedure [2]. Then, to complete the NN taken into the Learning System, we put the results of the first survey into the NN, and the NN learned them, in procedure [3]. Finally, in procedure [4], to improve the Learning System more, we did analyses of transportation mode choice by using the NN after learning.

4. Preparation of NN framework

The learning system is formulated as three-layered neural network. Fig.2 shows an example of graphical expression. Then learning was done with Back Propagation method. The data to be used for tuning and learning of the NN is obtained through questionnaire survey of which sample is inhabitants of a city located in suburbs of Osaka..

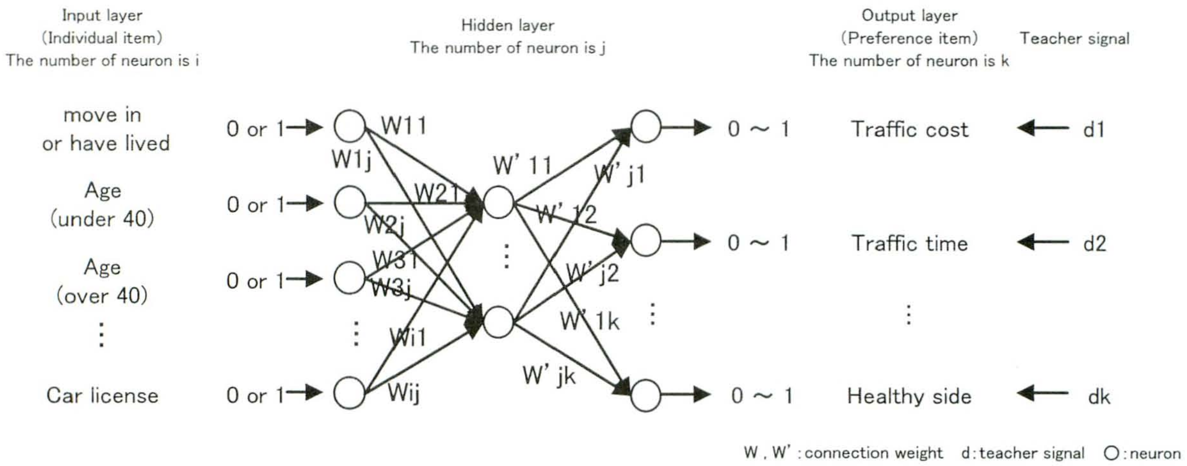

Fig.2 An example of three-layered neural network

5. Questionnaire surveys about transportation mode choice

5.1. Aim of the questionnaire surveys

The following two are aims of the questionnaire surveys.

- To complete and improve the NN, we aim to know "what kind of person" regards "which preference item" as "how values", in each of traffic purposes.
- To make the system more efficient, we aim to know a gap of the notion in choosing transportation mode between those who move in or remove and citizens who have lived, and whether the system, exclusively used by those who move in or remove, is useful or not.

5.2. Outline of the questionnaire survey

The questionnaire survey was executed for the *Izumi* citizens including those who move in or remove to there. The outline is shown in Table 5.

Table 5 Outline of the questionnaire survey

	The first questionnaire survey	The follow-up questionnaire survey
Number of distributions	200 (those who move in or remove: 11, citizens who have lived: 89)	39 (those who move in or remove: 22, citizens who have lived: 17)
Number of collections	85 (42.5%) (those who move in or remove: 50, citizens who have lived: 35)	24 (61.5%) (those who move in or remove: 12, citizens who have lived: 12)
Period	October 27, 2006 ~ November 28, 2006	January 12, 2007 ~ January 22, 2007
Place	*Izumi* City public office	–
Method	We handed the questionnaire, and collectedit then and there or by mail.	We mail the questionnaire, and collected it by mail.

5.3. Questionnaire items

In the questionnaire, we set three types of traffic purpose. Traffic purpose 1: Amusement, Traffic purpose 2: Shopping, and Traffic purpose 3: Commuting. The questionnaire items are summarized in Table 6.

Table 6 Questionnaire items

Individual attribute items	Preference attribute items
Sex	Traffic cost
Age	Traffic time
Occupation	Accuracy of Traffic time
Number of people of families	Comfort under movement
Spouse	Convenience of transfer
Car license	Healthy side
Motorcycle license	Environmental side
Car possession	Easiness of carrying luggage
Motorcycle possession	Companion's convenience
Bicycle possession	Presence of parking lot

6. Development of Learning System

6.1. Concrete structure of the NN

To advance the learning of the NN well, it is necessary to choose input items to some degree. The study analyzed the results of the survey by using Partial Correlation Analysis, and then chose the efficient items which determine the concrete structure of the NN. As a result, we modeled six variations of NN, *i.e.*, NNs1-NNs3 and NNw1-NNw3, in the paper. NNs1-NNs3 are the system which are exclusively for those who move in or remove, for each Traffic purpose 1-3. Similarly, NNw1-NNw3 are for all citizens. NNs1 is shown in Fig.3 and all NNs are shown in Table 7.

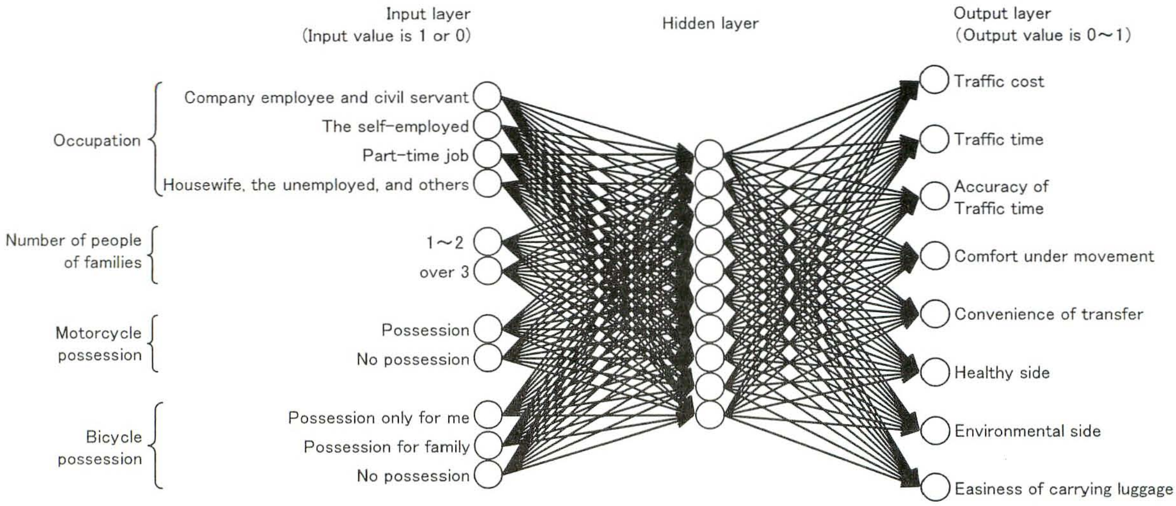

Fig.3 Concrete structure of NNs1

Table 7 Concrete structure of NNs1-NNs3 and NNw1-NNw3

	Item	The Number of neuron					
		NNs1	NNs2	NNs3	NNw1	NNw2	NNw3
Input layer	Those who move in or remove or citizens who have lived				2	2	2
	Age	–	3	3	–	3	3
	Occupation	4	–	4	4	–	4
	Number of people of families	2	2	–	2	2	–
	Motorcycle possession	2	3	2	2	3	2
	Bicycle possession	3	3	3	3	3	3
	The Number of input layer neuron	11	11	12	13	13	14
Output layer	Traffic cost	1	1	1	1	1	1
	Traffic time	1	1	1	1	1	1
	Accuracy of Traffic time	1	1	1	1	1	1
	Comfort under movement	1	1	1	1	1	1
	Convenience of transfer	1	1	1	1	1	1
	Healthy side	1	1	1	1	1	1
	Environmental side	1	1	1	1	1	1
	Easiness of carrying luggage	1	1	–	1	1	–
	Companion's convenience	–	1	–	–	1	–
	Presence of parking lot	–	1	–	–	1	–
	The Number of output layer neuron	8	10	7	8	10	7

6.2. Learning accuracy of the NN

Learning of NNs were conducted by using *MATLAB*[3)] (Learning rate: 0.5, Learning itelation: 5000). Table 8 shows learning accuracy of these NNs.

Table 8 Learning accuracy of the NN

Learning accuracy	NNs1	NNs2	NNs3	NNw1	NNw2	NNw3
Mean square error	0.231	0.277	0.159	0.230	0.283	0.152
Learning time (sec)	4073	4358	1839	11116	10247	4436
Agreement level (%)	67.0	68.8	73.7	65.6	68.2	78.6

7. Analysis of transportation mode choice

To develop an efficient system with a little uselessness, the study did two analyses.

7.1. Analysis of relation between input items and output items

The study clarified causal relation between input items, individual attribute items, and output items, preference attribute items, by examining the value of the connection weight. Then this result is able to be used as an index in saving the input items which don't influence the output items so much.

7.1.1. Method of calculating connection weight W_{ik}

Coefficient w_{ik} (connection weight between input and output layer) is obtained by putting the values of w_{ij} (connection weight between input and hidden layer) and w_{jk} (connection weight between hidden and output layer) in Eq. (1). Table 9 shows the results of NNs1.

$$w_{ik} = \sum_{j} \{ f(w_{ij}) \times f(w_{jk}) \} \quad , \quad \text{where } \left(f(x) = \frac{1}{1+e^{-x}} \right) \tag{1}$$

Here, the larger the value of a w_{ik} is, the more important are the items connected by the w_{ik}. So, Table 9 says the causal relation between 'over 3 families' and 'Convenience of transfer' is important, and the people who have large family make much of convenience of transfer most in amusement scene. Then this type of people, in amusement scene, take account of not only this item but also the other items. In addition, 'the self-employed' is also key item in NNs1.

In the same way, we view the other NNs. In NNs2, 'Motorcycle possession for family' and 'No possession of bicycle' are important items. In NNs3, 'over 50 of Age' and 'Part-time job of Occupation' are key items. Then, 'over 3 of Number of people of families' and 'Part-time job of Occupation' in NNw1, 'Motorcycle possession for family', 'Bicycle possession only for me' and '40~59 of Age' in NNw2, '40~49 of Age' in NNw3, are thought important items.

So, in the scene of the amusement, what kind of occupation a parson is and whether a people have large family or not are the key point in choosing a transportation mode. And, in the scene of the shopping, whether the people possess a motorcycle or bicycle is important. Then, in the scene of the commuting, how old a parson is and what kind of occupation a parson is are thought important viewpoint.

Table 9 Connection weight w_{ik} in NNs1 (Amusement)

		Preference attribute items							
Individual attribute items		Traffic cost	Traffic time	Accuracy of Traffic time	Comfort under movement	Convenience of transfer	Healthy side	Environmental side	Easiness of carrying luggage
Age	under 40	–	–	–	–	–	–	–	–
	40~49	–	–	–	–	–	–	–	–
	40~59	–	–	–	–	–	–	–	–
	over 50	–	–	–	–	–	–	–	–
	over 60	–	–	–	–	–	–	–	–
Occupation	Company employee and civil servant	1.19	2.49	2.81	2.34	3.23	1.39	1.88	2.96
	The self-employed	3.03	3.86	3.75	3.38	4.41	3.64	3.20	3.83
	Part-time job	2.70	3.34	3.62	3.46	3.83	2.25	3.80	3.59
	Housewife, the unemployed, and others	2.05	2.48	2.69	2.64	3.52	1.68	2.81	3.11
Number of people of families	1~2	0.66	2.31	2.09	1.89	2.31	1.41	1.37	1.95
	over 3	3.01	4.32	4.47	3.80	4.90	2.63	3.84	4.27
Motorcycle possession	Possession only for me	–	–	–	–	–	–	–	–
	Possession for family	–	–	–	–	–	–	–	–
	Possession	1.79	2.99	3.13	2.35	4.04	1.48	2.66	3.58
	No possession	1.42	3.47	3.45	2.62	3.97	1.61	2.27	3.38
Bicycle possession	Possession only for me	0.63	2.36	2.25	1.87	2.73	0.41	2.27	2.28
	Possession for family	0.98	1.55	1.97	1.84	1.93	0.66	2.11	1.80
	No possession	1.67	3.60	3.07	3.89	4.41	2.47	3.58	3.85

7.2. The necessity of the system exclusively for those who move in or remove

If there is a big gap of the notion between those who move in or remove and citizens who have lived, in selecting transportation mode, and this gap doesn't become small even after some months, their exclusive use system is needed. So the study analyzes the gap by using the results of the first questionnaire survey and the follow-up questionnaire survey in order to know whether the system, exclusively used by those who move in or remove, is useful or not.

7.2.1. Method of analysis

First, four types of the error shown in Table 10 are calculated. Then, they are compared (comparison types are also shown in Table 10). If there is no difference in them, it is judged, "Those who move in or remove can consider the citizens". Note that the error is the one between the output value and the teacher signal.

Table 10 The error of two patterns

Error①	**The resaluts of the first questionnaire survey** answered by those who move in or remove are input to NNw1-3 after it learn the ones of the first questionnaire survey as **"Moving in or removing parson's answer "**, and the error is calculated.
Error②	**The resaluts of the first questionnaire survey** answered by those who move in or remove are input to NNw1-3 after it learn the ones of the first questionnaire survey as **"Having lived citizens' answer"**, and the error is calculated.
Error③	**The resaluts of the follow-up questionnaire survey** answered by those who move in or remove are input to NNw1-3 after it learn the ones of the first questionnaire survey as **"Moving in or removing parson's answer "**, and the error is calculated.
Error④	**The resaluts of the follow-up questionnaire survey** answered by those who move in or remove are input to NNw1-4 after it learn the ones of the first questionnaire survey as **"Having lived citizens' answer"**, and the error is calculated.
Comparison①	Error② minus Error①
Comparison②	Error④ minus Error③
Comparison③	Comparison② minus Comparison①

5.2.2. The results of the calculation

Table 11-Table13 shows the results of the calculation of the error and comparisons.

Here, focusing the values of Comparison③ in each of Table 11-Table 13, it is understood that the Comparison② is smaller than the Comparison ① in almost all items of the preference attribute. So, it is thought that those who move in or remove and the citizens who have lived had a bigger difference between them when the first questionnaire survey was being done. Therefore, it can be judged that moving in or removing parson's exclusive use system is useful when they are moving in or removing.

Table 11 The calculation of the error and comparisons by NNw1 (Amusement)

Preference attribute items	At the first questionnaire survey			At the follow-up questionnaire survey			Amount of change
	Error①	Error②	Comparison①	Error③	Error④	Comparison②	Comparison③
Traffic cost	0.0588	0.1157	0.0569	0.0351	0.0739	0.0388	−0.0181
Traffic time	0.0089	0.0563	0.0473	0.0882	0.1172	0.0290	−0.0184
Accuracy of Traffic time	0.0310	0.2039	0.1730	0.1625	0.2189	0.0564	−0.1166
Comfort under movement	0.0212	0.1154	0.0942	0.0766	0.0796	0.0029	−0.0912
Convenience of transfer	0.0113	0.1679	0.1566	0.1305	0.2384	0.1079	−0.0487
Healthy side	0.0157	0.0627	0.0471	0.0484	0.1200	0.0716	0.0245
Environmental side	0.0157	0.1902	0.1745	0.0302	0.1720	0.1418	−0.0327
Easiness of carrying luggage	0.0095	0.1077	0.0981	0.0349	0.0930	0.0581	−0.0401

Table 12　The calculation of the error and comparisons by NNw2 (Shopping)

Preference attribute items	At the first questionnaire survey			At the follow-up questionnaire survey			Amount of change
	Error①	Error②	Comparison①	Error③	Error④	Comparison②	Comparison③
Traffic cost	0.0428	0.1563	0.1135	0.0622	0.2197	0.1575	0.0441
Traffic time	0.0163	0.0953	0.0789	0.1084	0.1689	0.0605	-0.0185
Accuracy of Traffic time	0.0150	0.0828	0.0678	0.0318	0.1602	0.1285	0.0607
Comfort under movement	0.0183	0.0958	0.0775	0.0614	0.1861	0.1246	0.0471
Convenience of transfer	0.0393	0.2810	0.2417	0.1545	0.3165	0.1619	-0.0798
Healthy side	0.0248	0.1147	0.0899	0.0408	0.0767	0.0359	-0.0540
Environmental side	0.0279	0.1731	0.1452	0.0392	0.1100	0.0708	-0.0744
Easiness of carrying luggage	0.0252	0.1952	0.1700	0.1041	0.1455	0.0414	-0.1286
Companion's convenience	0.0555	0.2705	0.2150	0.1076	0.3157	0.2081	-0.0070
Presence of parking lot	0.0296	0.0446	0.0150	0.0935	0.1042	0.0106	-0.0043

Table 13　The calculation of the error and comparisons by NNw3 (Commuting)

Preference attribute items	At the first questionnaire survey			At the follow-up questionnaire survey			Amount of change
	Error①	Error②	Comparison①	Error③	Error④	Comparison②	Comparison③
Traffic cost	0.0523	0.1631	0.1108	0.0619	0.2429	0.1810	0.0703
Traffic time	0.0145	0.2721	0.2577	0.1448	0.3164	0.1716	-0.0861
Accuracy of Traffic time	0.0113	0.0673	0.0559	0.1310	0.1331	0.0020	-0.0539
Comfort under movement	0.0222	0.0747	0.0524	0.1084	0.2241	0.1158	0.0633
Convenience of transfer	0.0629	0.4398	0.3769	0.2400	0.2432	0.0032	-0.3737
Healthy side	0.0166	0.2144	0.1978	0.1788	0.2393	0.0604	-0.1374
Environmental side	0.0148	0.1341	0.1192	0.0815	0.0878	0.0063	-0.1130

6. Conclusions

In this paper, development of learning system and analysis of the causal relationship between the individual attribute items and the preference attribute items are conducted by using the NN-based models.

As results, the NN with about 70% agreement level was obtained in the former. The latter calculated the index for analyzing the causal relation between the individual attribute items and the preference attribute items, which compose the NN. The utility of the system which is exclusively for those who move in or remove was examined based on the index.

References

1) N. Baba, T. Kojima and S. Ozawa, *Neural Network no kiso to ouyou (Base and Application of Neural Network)*, Tokyo: Kyouritu Shuppann, (1994)(in Japanese).

2) www.navitime.co.jp (accessed in Sep 10, 2007).

3) Y. Kamisaka, *MATLAB Puroguraminngu Nyumonn (Introduction to MATLAB programming)*, Tokyo: Makino Shotenn, (2000) (in Japanese).