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A Neural Network Approach to Website Design

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***Abstract*—This paper develops a neural network (NN) approach for examining how specific design elements of a website will affect users' perception of the website characterized by image words. An experimental study on 96 university websites is conducted based on the process of Kansei engineering. With a morphological analysis and a cluster analysis, the study identifies 7 influential website design elements and 33 representative websites as experimental samples for training and testing NN models. Four NN models are built to formulate the relationship between the 7 website design elements and three website image words including easy-difficult, clear-confusing, and realistic-fancy. The results of the NN models can be used to construct a website design database for determining the best combination of website design elements for matching a set of desirable website images as perceived by users. The result of this study provides useful insights in supporting the design of website elements that better meet users' specific expectations.**

***Indexed Terms*—Neural network applications, user centered design, Kansei engineering, website design.**

I. INTRODUCTION

WEBSITES have been used by companies or organizations as a means to communicate with their existing and potential customers or users. A good website design is convenient for users, while a bad website design can be disorientating to users [12]. The unclear hyperlinks or icons of a website may lead to users' operational failures, thus making the website unusable. Thus, the usability issue has to be addressed in website design in order to achieve its purpose. Usability studies have been developed as a research field for "addressing the relationship between tools and their users" [11]. It has been applied to create a highly usable system through a process that involves getting information from users who actually use the system, and makes it easy to learn, easy to use, easy to remember, error tolerant, and subjectively pleasing [11]. However, the subjectively pleasing feeling or perception of users is often a black box and cannot be precisely described. Moreover, the design information of a website is often difficult to obtain, particularly in relation to users' perception of the website.

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With their effective learning ability, neural network (NN) models have been widely used to examine the complex, non-linear relationship between input variables and output variables [10]. As such, in this paper we develop an NN approach for formulating the relationship between design elements of a website and the website images as perceived by users. The NN models developed can be used to determine the best combination of design elements for matching given website images. To collect numerical data for building and testing NN models, we conduct an experimental study on university websites using the process of Kansei engineering [8]. Kansei engineering has been successfully applied in the product design field to explore the relationship between users' psychological feeling or image (Kansei) of a product (characterized by pairs of image words) and the design elements of the product [3], [5], [6].

In subsequent sections, we first present the experiment study for extracting representative web page samples and for identifying key design elements of web pages using morphological analysis. We then describe an evaluation process for assessing the web page samples with respect to users' feelings characterized by three word pairs. Next we construct and evaluate 4 NN models based on the experimental data. Finally we discuss how the NN models can be used as a design database for supporting the website design process.

II. EXPERIMENTAL SAMPLES AND DESIGN ELEMENTS OF WEBSITES

In the experimental study, we first collected 96 homepages of university websites as experimental samples for extracting website design elements by morphological analysis. The morphological analysis involved two steps. In the first step, 6 design experts with at least 3 years of website design experience were asked to write down the influential design elements of the websites that will affect users' perception of websites, according to their knowledge and experience. In the second step, the 6 experts formed a focus group [1] to discuss the results and combine similar opinions or components. As a result of the morphological analysis, Table 1 shows the 7 influential design elements extracted from the 96 websites, together with their associated types.

Each design element has different types of its own, ranging from 3 to 5, as indicated by the type number 1, 2, 3, 4 or 5 in Table 1. For example, "Ratio of Graphics to Text (X_1)" means that the ratio between the area used by graphics and the area used by text on a web page. This ratio takes 5 values, corresponding to 5 different types, including "Above 3", "Between 3-1", "1", "Between 1-1/3", and "Below 1/3". The design element "Hyperlink Style (X_5)" has 3 types, including

"Only text", "Text and symbol", and "Text and icon", meaning that the hyperlink style is "only" text, or "adding" some symbols (e.g. small circles or square shapes without a specific meaning), or "adding" some icons (e.g. photographs or drawings with a specific meaning).

TABLE 1
EXTRACTED DESIGN ELEMENTS OF WEBSITES

Elements		Type 1	Type 2	Type 3	Type 4	Type 5
X_1	Ratio of graphics and text	Above 3	Between 3-1	1	Between 1-1/3	Below 1/3
X_2	Blank ratio	0% - 20 %	20% - 40%	40% - 60%		
X_3	Layout style	2 columns	3 columns	Multiple columns		
X_4	Frame style	Up and down	Left and right	Compound style		
X_5	Hyperlink style	Only text	Text and symbol	Text and icon		
X_6	Number of colors	Below 4 colors	4-7 colors	Above 7 colors		
X_7	Background color	Cold color	Warm color	Neutral color		

To facilitate the assessment process to be made by another group of subjects, we performed a cluster analysis on the 96 websites based on the result of morphological analysis. With the generation of a cluster tree diagram [4], we extracted 33 websites as the final representative website samples, including 27 training samples and 6 test samples for training and testing the NN models to be developed. Fig. 1 shows the first 12 representative experimental website samples. To collect numerical data for building NN models, the degree to which the 33 website samples match a given set of image words has to be assessed.

Fig. 1. Representative experimental samples of websites (Nos. 1-12)

With Kansei engineering, a pair of image words is often used to describe users' feeling or perception about a specific image of a product. Based on our previous study [2], we used 3 image word pairs for describing the images of websites, which were easy-difficult (E-D), clear-confusing (C-C), and realistic-fancy (R-F). 30 subjects were asked to assess the degree to which each of the 33 website samples matches the E-D, C-C and R-F images respectively using 5 scales (1-5) of the semantic difference (SD) method [13]. For example, each subject assessed each website sample for the E-D image on a scale of 1 to 5, where 1 is very easy to use and 5 is very difficult to use. For the C-C image, the value of 1 represents the website is very clear to follow, and 5 represents the website is very confusing. For the R-F mage, the value of 1 represents the website looks very realistic, and 5 represents the website looks very fancy.

The last three columns of Table 2 show the assessment results for the 33 experimental samples, including 6 test samples (asterisked). The E-D, C-C, or R-F image value shown is the average of the values assessed by the 30 subjects. For each representative website sample in Table 2, the first column shows the website number and Columns 2-8 show the corresponding type number for each of its 7 design elements, as given in Table 1. Table 2 provides a numerical data source for training and testing neural network models to be presented in the following section.

TABLE 2
ASSESSED IMAGE VALUES FOR 33 REPRESENTATIVE WEBSITES

Website No	X_1	X_2	X_3	X_4	X_5	X_6	X_7	E-D value	C-C value	R-F value
1	2	2	2	3	2	2	2	2.28	1.70	2.90
2	3	3	3	3	1	1	2	2.11	2.16	2.27
3	3	3	2	1	2	3	1	2.63	2.59	2.42
4	5	3	2	3	2	1	3	3.26	3.48	2.73
5	3	2	3	1	3	2	1	2.84	2.57	2.75
6	1	1	2	1	3	3	3	2.44	2.48	2.95
7	3	3	1	2	1	1	1	2.47	2.42	2.26
8	5	2	2	3	2	1	3	2.78	3.16	2.42
9	1	1	1	1	3	3	3	3.27	3.11	4.06
10	1	2	1	2	1	2	3	2.60	2.28	2.94
11	3	3	2	1	2	1	1	2.77	2.33	2.53
12	4	1	2	2	1	2	2	2.64	2.63	2.46
13	2	2	3	1	1	3	3	2.27	2.33	2.58
14	2	1	3	2	1	2	3	2.73	2.31	2.21
15	4	1	2	1	3	3	2	2.89	2.63	2.61
16	4	2	3	3	3	3	1	2.67	2.78	2.52
17	2	3	2	3	2	1	3	2.26	2.00	2.85
18	4	1	2	3	2	3	2	2.68	2.59	2.47
19	5	2	3	2	1	2	1	2.96	2.90	2.42
20	5	3	1	2	1	1	3	2.34	2.28	2.59
21	4	2	2	3	3	3	2	2.37	2.26	2.55
22	1	1	2	3	3	2	3	2.70	2.49	3.26
23	3	2	3	1	1	2	3	2.73	3.00	2.70
24	4	3	3	1	1	2	2	3.15	2.89	2.77
25	5	3	3	3	3	1	2	4.11	3.36	3.06
26	2	2	3	3	2	1	1	3.02	3.07	2.79
27	1	1	3	3	2	3	1	3.06	3.26	2.75
28*	2	2	2	1	3	2	2	2.80	2.20	2.27
29*	2	3	1	2	2	1	3	2.27	2.27	2.60
30*	1	2	2	2	3	2	3	2.80	3.07	3.80
31*	3	3	1	1	1	3	1	2.53	2.47	2.40
32*	2	1	3	3	3	3	1	3.60	3.40	2.80
33*	2	1	3	3	2	3	2	2.80	2.87	2.73

III. EXPERIMENTAL ANALYSIS OF NEURAL NETWORK MODELS

Neural networks (NNs) are non-linear models and are widely used to examine the complex relationship between input variables and output variables [9]. In this paper, we use the multilayered feedforward NNs trained with the backpropagation learning algorithm, as it is an effective and popular supervised learning algorithm [10]. In addition, the learning rule used is Delta-Rule and the transfer function is Sigmoid.

To examine the relationship between the 7 website design elements and the 3 website images, we built 4 NN models, called NN-1, NN-2, NN-3, and NN-4 respectively. These 4 NN models used 4 most widely used rules for determining the number of neurons in the single hidden layer respectively, listed below [10]:

(a) (The numbers of input neurons + the numbers of output neurons) / 2

(b) (The numbers of input neurons * the numbers of output neurons) ^ 0.5

(c) (The numbers of input neurons + the numbers of output neurons)

(d) (The numbers of input neurons + the numbers of output neurons) * 2

The 23 types of the 7 design elements in Table 1 are used as the 23 input variables for the 4 NN models. For each model, if a website has a particular design element type, the value of the corresponding input neuron is 1; otherwise the value is 0. The assessed values of the E-D, C-C, and R-F images are used as the output neurons. Table 3 lists the neurons of the 4 NN models, including the input layer, hidden layer, and output layer.

TABLE 3
NEURONS OF FOUR NN MODELS

The NN models	Input layer: 23 neurons for 23 types of 7 design elements
	Output layer: 3 neurons for the E-D, C-C, and R-F images
The NN-1 model	Hidden layer: 13 neurons, (23+3)/2=13.
The NN-2 model	Hidden layer: 8 neurons, (23*3)^0.5=8.31 8.
The NN-3 model	Hidden layer: 26 neurons, (23+3)=26.
The NN-4 model	Hidden layer: 52 neurons, (23+3)*2=52.

TABLE 4
RMS ERRORS OF 4 NN MODELS FOR THE TRAINING SET

Learning epochs	The NN-1 model	The NN-2 model	The NN-3 model	The NN-4 model
5000	0.0625	0.0643	0.0654	0.0676
25000	0.0496	0.0566	0.0440	0.0573
50000	0.0402	0.0466	0.0313	0.0459
75000	0.0372	0.0404	0.0276	0.0404
100000	0.0370	0.0400	0.0274*	0.0400

Each of the 4 NN models was trained by 810 inputs, including 27 website samples in the training set, each of which was assessed by 30 subjects. Each model was trained 5,000 epochs at each run. When the cumulative training epochs were over 100,000, the training process was completed. Table 4 shows the training epochs of each model run and their corresponding root of mean square (RMS) errors. As indicated in Table 4, the NN-3 model has the lowest RMS error (0.0274) among all 4 models.

IV. PERFORMANCE EVALUATION OF NEURAL NETWORK MODELS

To evaluate the performance of the 4 NN models in terms of their ability to predict the website image values for a new website with given website design elements, the 6 website samples in the test set were used. Rows 2-4 of Table 5 show the average assessed values of the three image word pairs on the 6 test samples given by the 30 subjects, and Rows 5-16 show the predicted values for the three image words by using the 4 NN models respectively. In comparison with the assessed values, the last column of Table 5 shows the RMS errors of the 4 NN models for the test set.

TABLE 5
PREDICTED IMAGES VALUES AND RMS ERRORS OF 4 NN MODELS FOR THE TEST SET

	Website image	Website sample no. 28	29	30	31	32	33	RMS error
Assessment	E-D value	2.80	2.27	2.80	2.53	3.60	2.80	
	C-C value	2.20	2.27	3.07	2.47	3.40	2.87	
	R-F value	2.27	2.60	3.80	2.40	2.80	2.73	
The NN-1 model	E-D value	2.42	3.21	2.86	2.25	2.67	3.14	0.2072
	C-C value	1.66	2.12	2.03	2.58	2.56	2.64	
	R-F value	3.23	2.87	2.52	3.13	2.93	2.76	
The NN-2 model	E-D value	2.55	2.89	2.59	2.23	2.69	2.94	0.2077
	C-C value	1.72	1.93	1.86	2.50	2.56	2.50	
	R-F value	3.26	2.81	2.46	3.08	2.93	2.74	
The NN-3 model	E-D value	2.50	3.09	2.97	2.25	2.70	3.08	0.2006*
	C-C value	1.67	2.00	2.13	2.66	2.63	2.60	
	R-F value	3.25	2.75	2.52	3.19	2.97	2.74	
The NN-4 model	E-D value	2.43	3.23	2.85	2.21	2.69	3.06	0.2076
	C-C value	1.65	2.14	2.01	2.55	2.59	2.58	
	R-F value	3.24	2.84	2.50	3.13	2.95	2.74	

As indicated in Table 5, the RMS error (0.2006) of the NN-3 model is the smallest among the 4 models, thus suggesting that the NN-3 model has the highest predictive consistency about the E-D, C-C, and R-F images of websites. This test result is consistent with the training result, where the NN-3 model has the best performance. However, the other three models also have a quite similar performance, as the difference between the RMS errors of the 4 models is insignificant. This seems to suggest that the number of neurons in the hidden layer has no significant impact on the predictive ability of the NN models in this study.

The NN models can be used to determine whether a specific design of website elements meets desirable website images. For examples, the website designer can individually input the values of website elements as "X_1=1, X_2=2, X_3=3, X_4=3, X_5=2, X_6=1, and X_7=1", or "X_1=4, X_2=1, X_3=1, X_4=2, X_5=3, X_6=1, and X_7=2" to the NN-3 model, shown in Table 6. Then the NN-3 model can predict the corresponding values of the three website images as "the E-D value is 2.46, C-C is 4.60, and R-F is 2.69", or "the E-D value is 2.46, C-C is 4.60, and R-F is 2.69" respectively. If the predicted values are not satisfied, the website designer can modify the combination of website elements until desirable image values are obtained.

TABLE 6
IMAGE VALUES OF GIVEN WEBSITE ELEMENTS

X_1	X_2	X_3	X_4	X_5	X_6	X_7			
Ratio of graphics and text	Blank ratio	Layout style	Frame style	Hyperlink style	Number of colors	Back-ground color	E-D value	C-C value	R-F value
Above 3 (1)	20% - 40% (2)	Multiple columns (3)	Compound style (3)	Text and symbol (2)	Below 4 colors (1)	Cold color (1)	2.46	4.60	2.69
Between 1-1/3 (4)	0% - 20% (1)	2 columns (1)	Left and right (2)	Text and icon (3)	Below 4 colors (1)	Warm color (2)	2.46	4.60	2.69

To help determine the best website design for meeting specific website images, all possible combinations of design elements can be input to the NN models for generating their corresponding image values. As a result, a website design database can be generated, consisting of 3,645 (=5×3×3×3×3×3) different combinations of website elements, together with their associated E-D, C-C, and R-F image values. Table 7 shows the website design elements with the largest and the smallest of the total E-D, C-C, and R-F image values respectively.

TABLE 7
THE LARGEST AND SMALLEST AVERAGE VALUE OF THREE E-D, C-C, AND R-F IMAGES

X_1	X_2	X_3	X_4	X_5	X_6	X_7	
Ratio of graphics and text	Blank ratio	Layout style	Frame style	Hyperlink style	Number of colors	Background color	Total value of E-D, C-C, R-F images
Below 1/3 (5)	40% - 60% (3)	2 columns (1)	Up and down (1)	Text and symbol (2)	4-7 colors (2)	Cold color (1)	12.01 (4.20, 3.72, 4.09)
1 (3)	40% - 60% (3)	3 columns (2)	Left and right (2)	Only text (1)	4-7 colors (2)	Warm color (2)	5.45 (1.99, 1.58, 1.88)

The website design database can be used to work out the best combination of website design elements for a set of desirable images specified by the website designer [7], [14]. The website designer can specify a desirable set of E-D, C-C, and R-F image values for a new website design, and the database can then work out the best matching design elements for the new website.

V. CONCLUSION

Web users have different feelings or perceptions about websites with different types of design elements. In this paper we have presented an NN approach for modeling the relationship between website design elements and a set of website images perceived by users, with an experimental study using Kansei engineering. The result of the study has demonstrated the advantages of using Kansei engineering and NN models for supporting the website design process in matching specific user-perceived website images. Although websites are chosen as the experimental study, the NN approach can be applied to the design of other user-oriented products or systems with a wide variety of design elements.

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