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Perceptional Retrieving Method for Distributed Design Image Database System

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In distributed multimedia database systems where database objects are organized by video, audio, graphics and text data and stored in multiple numbers of database servers on different locations over a wide area network, intelligent and flexible retrieval capability is required particularly for designers in various application fields who use a multimedia database for their CAD process. In this paper, we introduce a hypermedia-based distributed design image database system based on the perceptional retrieving method which allows each designer to make the best use of his or her creativity and originality and his or her style and sensitivity to beauty. The knowledge agent, utilizing the knowledge-base, creates links from perceptional word objects provided by the user to suitable design image objects among those stored on multimedia databases distributed across the network. These perceptional query words are then converted to equivalent color values and design patterns. Color value and design pattern are the means by which all stored design images are characterized. We have developed a Textile Design Image Database System (TDIDS) which aids designers using apparel CAD systems in difference locations, collaborating or working separately, in the design of clothes, including kimonos. Through the functional evaluation of the prototype system by the design school students, usefulness of the suggested perceptional retrieving method for distributed design image database system was verified.

1. Introduction

Multimedia database systems are very useful in many industrial application fields including the textile, car, building, housing, etc. industries. Particularly in the textile design field, such as dress, cloth, or kimono design, many different design materials with different colors, patterns, textures are required in their design process. There are a number of distinct traditions of textile, clothes, and kimono production sprinkled throughout the cities and small towns of Japan, preserving and continuing design traditions dating back centuries. The textures and design patterns of these products are still relevant and valuable in various design fields, not only traditional kimono design, but also more modern design industries, including the general apparel industry, dress making, interior design, etc. However, in order to obtain data on traditional Japanese textiles, one currently must visit various local textile industrial institutes, art galleries or museums. A database of traditional Japanese textiles not been established yet, perhaps partly due to the volume and complexity of the subject matter. To implement such a database, we propose a hypermedia-based textile design image database system, Textile Design Image Database System (TDIDS), consisting of database servers storing traditional textile images, distributed across numerous cities and towns, connected by a wide area network, and coordinated by a knowledge agent. Our TDIDS is a working prototype of just such a network. The perceptional approach to our TDIDS has evolved over the course of several years in response to our desire to develop more intelligent, human-centric computer interfaces. In previously published research, we introduced a Dynamic Hypermedia System (DHS) [1),2)] in which the links between a reference point and a corresponding object were dynamically determined using a knowledge-base, thereby attaining more suitable and flexible linking. Such hypermedia systems provide useful human interfaces for multimedia database systems, as users can interactively access databases, retrieving multimedia information with simple icon-driven mouse operations. We utilized a DHS interface in the first implementation of our TDIDS; users were able to directly access and manipulate the database by simple mouse operations. Conventional keyword retrieval methods, such as specifying materials, patterns or representative colors, etc. as keywords, or similarity

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retrieval methods, such as directly specifying color-values on the color-map, which are similar or representatives of the design images, were incorporated[3]. However, these conventional methods of design image database retrieval were often not sufficient from the point-of-view of the designers who served as our users. This was because users queries or only rarely retrieved images they felt were usable; they felt the system was rather hit and miss. Many of the designers expressed a wish for a more direct and subjective retrieval method.

From our own experiences and a review related research, we conceived that, in order to create a useful retrieval system, each image must be characterized by perceptional words. As the relationship between words and different design images changes depending upon individual perceptional, we came to the conclusion that design images cannot be objectively, statically characterized by perceptional words in a truly useful manner.

In order to overcome this problem, we have developed a subjective retrieval method based on a user model structure designed to reflect differences in perceptional between individual users. Our method is based on intelligent user models that model individual users perceptional by observing and adapting to users repeated acts of image retrieval. Users retrieve design images by simply selecting perceptional words, such as "ethnic", "elegant", "chic", etc. These perceptional word queries are converted into objective perceptional words by each user model, then interpreted into a color value (RGB, HUV or Munsell color), or a combination of multiple colors according to information stored in the knowledge-base. On the other hand, the design images are characterized by various components, such as color components, design patterns, materials, textures, etc.

In previous statistical evaluation test, we could derive the result that color components more strongly influence to users perceptions than other components[4]. We initially incorporated the color values and their corresponding area percentages to characterize the design images[5].

We also investigated the influence of shaped patterns to the human perception and derived the relationship between them.

The relationship between color and shaped pattern components and equivalent perceptional words can be cooperated as a knowledge-base in a knowledge agent. Therefore, by specifying color values or shaped pattern to the image database, nominated images can be retrieved, sent through the knowledge agent, and browsed on the users station.

Browsed images are then evaluated for user satisfaction; based on this evaluation, the parameter values of the user model[6] are adjusted to minimize the difference between the users subjective perceptional and the browsed images. The initial parameter values of the user model are informed by color image engineering, the experiences of professional designers involved in our project, and statistical data on the evaluation of typical design images by our user test group of designers. This experimental data is collected into the knowledge agent to serve as the knowledge-base, and is used to initialize the user model and convert perceptional words to an equivalent color combination. The learning process for a user model is repeated several times for each new user, enough times to allow convergence of parameter values during the initial retrieval stage. By combining this subjective retrieval method based on the user model, with a DHS based on the perceptional link method, the system performs far more flexible and perceptional retrievals of design images than that possible using more conventional database search methods.

This paper is organized as follows: The TDIDS from a users point-of view is described in Section 2. Our Dynamic Hypermedia Systems are briefly discussed in Section 3. The knowledge agent and its function are precisely described in Section 4. The system configuration of our TDIDS and our perceptional link method is described in Section 5. The user model and the method by which it is updated are described in Section 6. Our prototype TDIDS is described in Section 7. Evaluation of our prototype TDIDS is presented in Section 8. Our conclusions are presented in Section 9.

2. Textile Design Supporting Systems

Textile design, like other field of design, involves many hours of tedious research, trial and error. Such labor intensive design work is greatly aided by our multimedia database from which designers can simply and interactively retrieve textile images and patterns by specifying perceptional words (along with corresponding scales of intensity), then immediately pasting these textile images over three-dimensional ap-

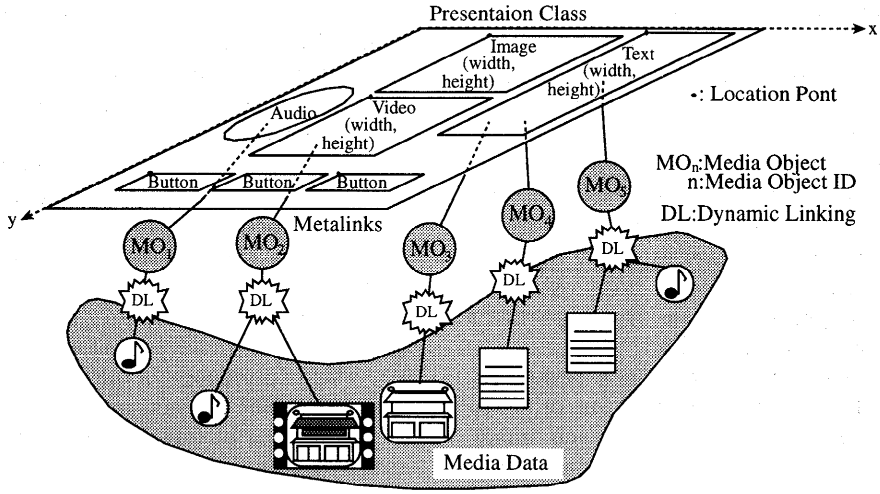

Fig. 2 Structure of metanode.

parel design images, thereby quickly creating finished design images. Examples of perceptional words are "ethnic", "elegant", "chic", etc. **Figure 1** illustrates how such a system works from a users point-of-view (see p.167).

In response to the users queries, images appear (transmitted from multimedia databases distributed throughout the network) in the browsing window (top left). The user chooses images of interest from among them, then pastes these images into the clip window (top middle). Manipulation of color and color intensity is performed in the color convert window (top right). The texture grid window (bottom left), contains images of fashion models wearing user-selected white neutral materials. These neutral materials include lines for shaping two-dimensional images into three-dimensional images. The user then creates finished images in the texture map window (bottom right) by pasting fashion model images from the texture grid window, then textile images from the window.

To achieve the level of performance described above, a multimedia database system should provide the following functionalities; 1) perceptional retrieval functions, so as to make best use of its users individual creativity. 2) Interactive access capabilities provided over a distributed database environment. 3) A simple but robust graphical user interface. 4) A user model which takes into consideration the differences between users perceptional. In the next section, we propose our model for a hypermedia system that provides the functionalities listed above.

3. Dynamic Hypermedia System

Reviewing the current state of design database systems, it is obvious that a more flexible, effective, a intelligent user interface is needed. We feel that hypermedia systems are essential to such improvements. In hypermedia systems, each information unit is directly connected to others and users can navigate simply over the linked information space using a GUI. Many researchers have developed several prototype applications that utilize hypermedia systems to access a multimedia database system. For example, World-Wide Web (WWW) is the most popular and world-wide hypermedia system. However, WWW system does not provide intelligent link operations that perform dynamic and automatic linkages from the users current reference point to the most suitable information unit(s) based on the users information retrieval goals.

In order to solve the problems inherent in current conventional hypermedia systems, we have developed a new Dynamic Hypermedia System, consisting of a Metanode, a Metalink and a Frass. A Metanode is defined as the semantically integrated information unit. Each Metanode is organized by video, audio, graphics, and/or text media as presented in **Fig. 2**, and manipulated as an ordinal node.

Individual media data are structured as files and stored on local database servers distributed over the network. Each local database management system, such as a relational database system, maintains the filenames of those media

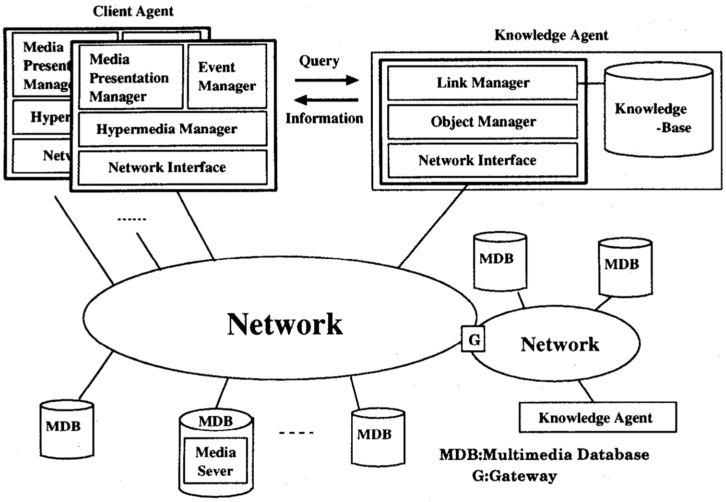

Fig. 5 Distributed design image database system.

data within its own database as a set of tuples. Currently our TDIDS, video and graphics data are not used. **Figure 3** describes an example of a Metanode that explains a "chic" image in the TDIDS (see p.167). In this example, the Metanode is organized by image data that shows its characteristics of the image, such as area percentage of each color component, evaluated score for satisfaction, vector component etc, and audio and text data that describe its material, pattern, texture and representative color components.

Larger units of information space, are organized as a Frass (Frame with class); a Frass is defined as a set of classified Metanodes semantically related to each other. For example, some of the design images in our TDIDS are characterized as "chic", others may be characterized as "elegant" although their degrees of impression may be changed for each image. Thus, those similar images are classified into a cluster of the whole images and defined as a Frass. A Frass has characteristics of both a class (as employed in object-oriented systems) and a frame (as employed in knowledge-base systems). A Frass can be easily implemented utilizing an object-oriented language and organized as knowledge-base. **Figure 4** shows an example of Frasses which are composed of a set of image data with the same attribute "chic" and "elegant" but the different attribute percentage values (see p.167).

A Metalink is defined as a virtual link between different Metanodes and/or Frasses. Unlike conventional links, multiple Metalinks from a reference point in the current information unit to subsequent Metanodes or Frasses are possibly connected to each other. Using the knowledge-base, the link manager in the knowledge agent, which will be explained in the next section, dynamically selects the most suitable Metalinked Metanodes and Frasses depending upon the users requests. This decision process can be repeated as long as any following node exists.

In order to allow the knowledge-base to be shared by multiple users, we divided the DHS into two parts. One part is the client agent, and the other is the object manager. A client agent containing the user model and performing I/O interface functions is located on each user station. The object manager is separated from the users stations and independently located as part of the knowledge agent.

4. Knowledge Agent

The TDIDS, as depicted in **Fig. 5**, consists of a number of user stations, multimedia databases and a knowledge agent distributed over an interconnected network consisting of multiple LANs and a WAN.

The knowledge agent performs various functions to aid intelligent information retrieval, acting as a users consultant and managing the databases distributed over the network. Users issue perceptional word queries (users may also issue conventional word queries) to the knowledge agent through the user interface in their individual client agents in Fig. 9. User queries to the knowledge agent are then converted into database queries and transmitted to all related multimedia databases using the multicast remote procedure call[7),8)]. The selected images from each database are sent to the knowledge agent. Then those image are classified and integrated into Matanodes and Frasses by object manager. The link manager in the knowledge agent creates links between those Matanodes and Frass using knowledge-base. At this time, the object manager selects the suitable images for the user, filters out any redundant images and send those selected images to the user station, organizing a suitable information space for the user. Thus, users can interactively browse and retrieve images without knowing the locations of the databases queried. From the user point of view, this information space appears as a seamless multimedia database space, as if it existed entirely within the knowledge agent even though the actual information is located within database servers distributed across the network and managed by multimedia database management systems localized within each server. In future large multimedia information systems based upon our perceptional approach, several knowledge agents will be able to coexist[9)]. Each knowledge agent will have its own knowledge-base and area where the knowledge agent can cover within the database servers. When information is requested of a knowledge agent about a subject for which it does not have a complete knowledge-base, it will communicate with other knowledge agents, inquiring whether they have information in their knowledge-base on the subject in question. Thus, by cooperating with each other, knowledge agents will be able to obtain new knowledge and create links to suitable Metanodes stored on database servers pertaining to other areas of information.

4.1 Knowledge-base

As mentioned before, the knowledge-base provides information to the knowledge agent that is used to determine links to suitable objects (Metalinked Metanodes and/or Frasses) depending upon users requests or interests. Each Metanode is classified depending not only upon its attributes, but upon the degree of those attributes. In the TDIDS, the attributes of Metanodes (in this case, textile images) are characterized as various perceptional attribute words or a combination of them. These perceptional attributes are quantified as independent perceptional vector values to express the degree of attribute. At the same time, each image is characterized by color and design pattern. Thus, the relationship between an images attributes, colors and pattern is stored as knowledge-base within the knowledge agent. In our TDIDS, 15 of the perceptional words including "pretty", "romantic", "dandy", "casual", "natural","formal", "dynamic", "elegant", "clear", "gorgeous", "chic", "cool", "ethnic", "classic" and "modern", which are frequently used in the kimono design field, are related to 130 Munsell color combination. An example of the knowledge-base is summarized in **Table 1** as the relations between the perceptional words, "chic", and the equivalent color components (see p.167). In this case, the perceptional word "chic" is related to 29 color components including Yellow Red with Dull tone (YR_DL), Yellow with Gray tone (Y_{Gr}) and so on. When executing textile image retrieval, the user can specify a combination of perceptional words and their degrees as a query. The knowledge agent then selects the best Metanode which match(es) from among the subsequently nominated Metanodes.

5. The Perceptional Link Method as Implemented in the TDIDS

In order to link the selected perceptional words (treated as objects by the system) to suitable design images, the relationships between perceptional words and design images are clearly defined. Design images within the TDIDS are generally characterized by representative colors, namely, color values (RUB, HUV or Munsell color expressions), and their area percentage of the whole image. In addition, most color values are characterized by one or several perceptional words. For example, bright red colors are generally characterized by perceptional words such as "dynamic", "casual" or "passionate". A combination of a brown color and a gray color is classified by perceptional words such as "classic" or "dandy". **Figure 6** shows an example of automatic indexing of the TDIDS (see p.168).

The best 5 dominated colors and their area percentages of the original image are extracted by calculating its color pixcel distribution. Then, the perceptional words equivalent to each extracted color are selected as depicted in Fig. 6.1. Next, a perceptional vector is formed

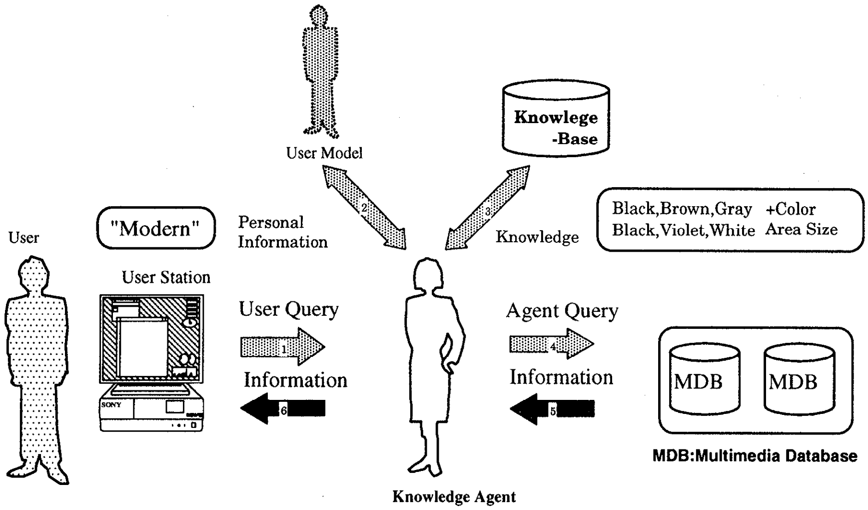

Fig. 7 Perceptional retrieval.

using the area percentages of the best 5 color components assuming that the degree of the perceptional is proportional to the area percentage of the equivalent color as shown in Fig. 6.2. Thus, by registering these vector values in advance as shown in Fig. 6.3, all design images can be indexed and stored in the databases distributed over the network. On the other hand, the initial or default relationships between color components and perceptional words are also stored in the knowledge agent as part of the knowledge-base. These default settings determine the relationship between perceptional words and color values as informed by color engineering, the opinions of professional designers involved in this research, and statistical data on the evaluation of sample design images by our user test group, even taking into account changes in fashion taste between different generations. These default relationships form the objective or average perceptional stored in the knowledge-base. Thus, as depicted in **Fig. 7**, users select perceptional words and send them to the knowledge agent where they are converted into equivalent color values based on the knowledge-base.

The knowledge agent then creates dynamic links from the users perceptional words to suitable design images. We call this as the perceptional link method. All design images are expressed by representative color values and color value area percentages. By registering these values in advance, all design images can be indexed and managed by a conventional database management system.

6. User Model

The perceptional link method includes two retrieving methods: the objective retrieval method and the subjective retrieval method. In the objective retrieval method, users send queries to the knowledge agent directly (bypassing the user model) which are then converted into database queries by the knowledge agent. This method provides general design image retrieving capabilities. However, as it is based upon the objective or average human perceptional stored in the knowledge-base, the retrieved images may not suit the users taste. They are an informed average, not a custom fit.

In the subjective retrieval method, the users subjective perceptional queries are converted into objective perceptional queries by the user model localized within the users client agent. The user model compensates differences between individual users perception and the objective perception stored in the knowledge-base. To organize the user model, we define a perceptional vector space consisting of N components. (Currently, we use 15 representative perceptional vector components out of more than two hundred similar perceptional words, as summerized in Table 2.) Since all of the design images can be characterized by several perceptional words, these are expressed by N vector components as indicated in **Fig. 8** (some of N components may be 0). Therefore, by specifying perceptional words as vector values Q, suitable design images R (matching the "objective" perceptional) can be retrieved. However, since

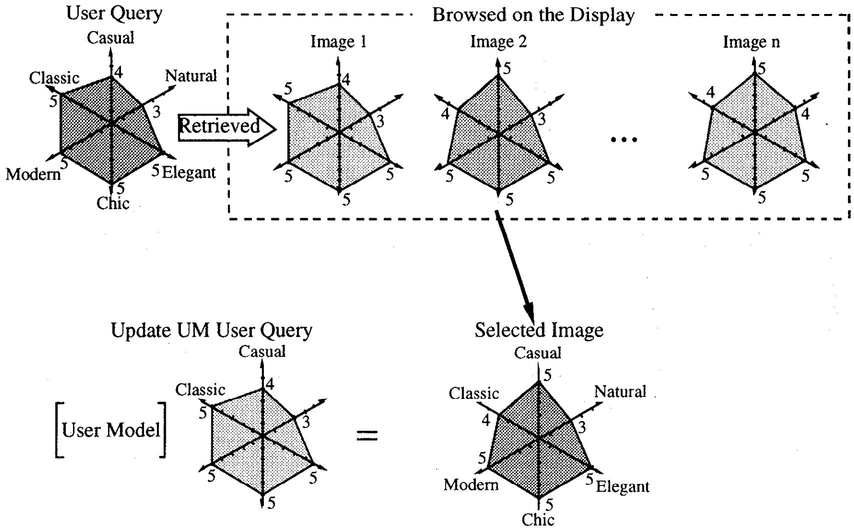

Fig. 8 Illustration of updating user model.

images R were selected based on the "objective" or "average" perceptional, the user will not necessarily be satisfied with these images. Therefore, the user model must compensate for the difference between Q and R according to the following equation:

$$R = UQ \qquad (1)$$

where U is the user model, as expressed by the $N \times N$ matrix. Since all the vector components of Q cannot necessarily be specified as a query, U cannot be determined by one attempt; however, by repeating evaluation of the retrieved images R_i, the modification of the user model U_i and the user's characteristic selection of perceptional words affects Q_i. Thus, the user model can be gradually conversed to a more correct value according to the following equation:

$$R_i = U_i Q_i \qquad (2)$$

The optimal U_{iopt} that minimizes the following error function E_i at each step i,

$$E_i = \frac{(U_i Q_i - R_i)^T (U_i Q_i - R_i)}{2} \qquad (3)$$

must satisfy the following condition:

$$\frac{\partial E_i}{\partial U_i} = 0 \qquad (4)$$

By finding the U_{iopt} and updating $U_i \leftarrow U_{iopt}$, the user model can learn the correct parameter value. This learning process for the user model is usually executed at the beginning of image retrieval, but can be repeated at any time after the model has been fixed. As the user models interact with the knowledge agent, the knowledge agent gathers statistics from them; thus they influence it on a dynamic basis. Through this process, the "objective" perceptional is changed. On our prototype system, to provide these statistics, users periodically perform image satisfaction evaluation. In future systems, the knowledge agent may gather statistics by more subtle and automatic means.

7. Prototype System

Our prototype system (as previously shown in Fig. 5), consists of several RISC-based workstations and file servers. The system is connected by FDDI, Ethernet and ISDN networks. Three SONY NWS-3870 workstations (equivalent to Sun SPARCstation 2) with color video interfaces serve as user workstations, and one SUN-4/670MP houses the knowledge agent. Several SONY NWS-3870s are used as multimedia database servers. The application programs were written in C language. The implementations of the Dynamic Hypermedia System and the knowledge agent were developed using a combination of C language and a knowledge-base language, IXLA [10]. **Figure 9** shows a sample output from a textile image retrieval prompted by the perceptional word "elegant" (see p.168).

8. System Evaluation

In order to evaluate the prototype of our TDIDS, we have employed a questionnaire method by which our test user group indicates his/her satisfaction with percentage (0–100%) when the retrieved images were provided. The user carried out the questionnaire five times for each perceptional word. 28 users composed our test user group, included 16 males and 12 females, all in their early twenties. **Figure 10** shows the average percentage of users satisfactions repeated five times in both cases where the retrievals were carried with and without user model, to study his/her perception using 15 perceptional words.

Although the user group could obtain higher satisfaction with "chic", "dandy", "classic" and "formal", they were not satisfied with other perceptional words. In order to clear those reasons, we investigated the deviation of perceptional vector values, especially about two perceptional words, "chic" and "clear" which indicated the best and the worst satisfactions when the user models for each person are updated five times (see **Figs. 11** and **12**).

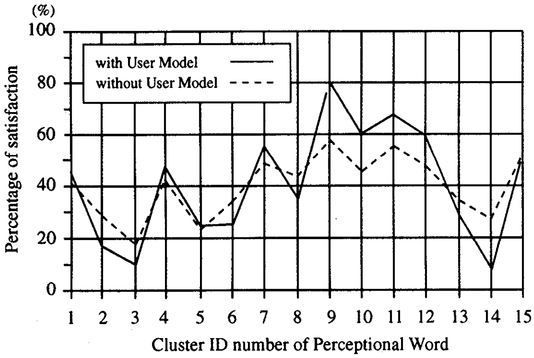

Fig. 10 The average percentage of satisfaction.

Here the horizontal axis indicates perceptional word ID numbers shown in **Table 2**, the vertical axis indicates perceptional vector values and 1st, 2nd, ... mean the updated number of each user model. The perceptional vector values of "chic" gradually converted into constant higher values as the number of updat-

Table 2 Perceptional words and cluster ID number.

ID No.	Perceptional Words
1	Pretty
2	Casual
3	Dynamic
4	Gorgeous
5	Ethnic
6	Romantic
7	Natural
8	Elegant
9	Chic
10	Classic
11	Dandy
12	Formal
13	Clear
14	Cool
15	Modern

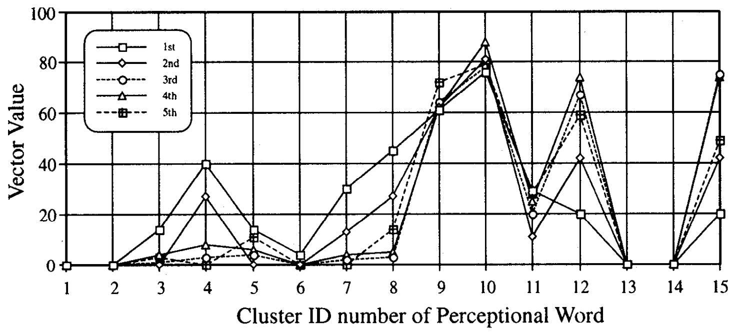

Fig. 11 Perceptional vector value of user model of "chic".

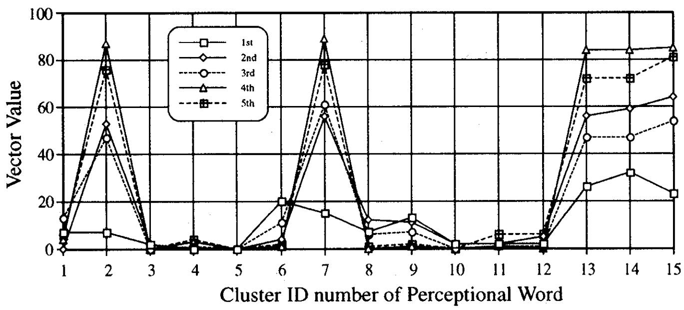

Fig. 12 Perceptional vector value of user model of "clear".

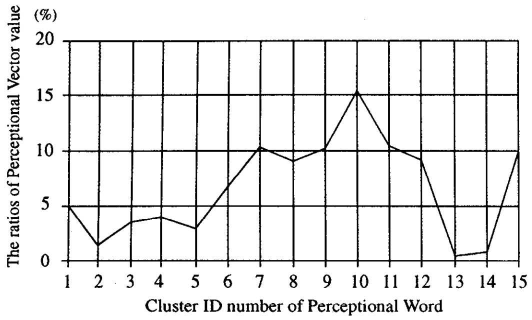

Fig. 13 The average distribution of color in TDIDS.

ing the user model increases. Thus user model performed very effectively to reflect the users perception. On the other hand, the perception vector values for "clear" remained to the lower values even though the user models are updated five times. The reasons for this result were estimated due to; 1) The database did not include all of the perceptional vector distribution. perceptional vector values in our TDIDS was not homogeneous. 2) The influence of the design pattern of the images to the users perception was not considered.

8.1 The Influence of Color Deviation

We investigated the average distribution of color for all of the design images in our TDIDS. The color components of the design image were converted into the equivalent perceptional words using knowledge-base. The ratios of the each perceptional vector value to whole value for the total images are indicated in **Fig. 13**. From Fig. 13 it is clear that our TDIDS did not contained the images which provide "casual" and "clear" as their perceptional vectors.

From this result, in order to perform the user model effectively, large number of the design images with each perceptional words is required.

8.2 The Influence of the Design Pattern

We have investigated whether the design patterns in images would influence to perception using questionnair. In our questionnair method, two kinds of design images including the original images with color components and only with edge detected images with black and white were employed. The same evaluation method as used in the previous section were carried out for those images. In this method, if the perceptional word indicated to the original color image is the same as its edge detected image, then this perceptional word could be influenced by its design pattern. The result of this test is summerized in **Table 3**. From this table, it is clear that some perceptional words are designed by not only color components but also patterns. The other words are influenced by the combination of both colors and patterns. Through this investigation, we could conclude that the design image have to be characterized the combination of both colors and patterns.

Table 3 The perceptional component correspond to original image.

Perceptional Words	Influencing Components to Perceptions
Pretty	neither
Casual	colors
Dynamic	neither
Gorgeous	colors
Ethnic	pattens
Romantic	neither
Natural	both
Elegant	neither
Chic	colors
Classic	colors
Dandy	colors
Formal	colors
Clear	colors
Cool	colors
Modern	pattern

9. Conclusions

In this paper, we have introduced a new intelligent human interface based on the concept of a Dynamic Hypermedia System utilizing the perceptional link method to provide simple and flexible user access to multimedia information networks. Metanodes, Metalinks and Frasses organize a dynamic hypermedia space wherein users can easily retrieve desired information objects by performing perceptional word queries. The knowledge agent utilizes information from the knowledge base to create links from perceptional word objects to suitable design images chosen from the various multimedia databases distributed over the network. The knowledge agent also performs query conversion from the users perceptional words to objective perceptional words using information from each users individual user model. In order to verify the functionalities of our proposed human interface, we have developed a prototype multimedia information network dubbed the Textile Design Image Database System. Through this prototype system, we have confirmed the usefulness of our proposed perceptional approach. We are currently in the preliminary stages of full

Fig. 1 Example of design CAD.

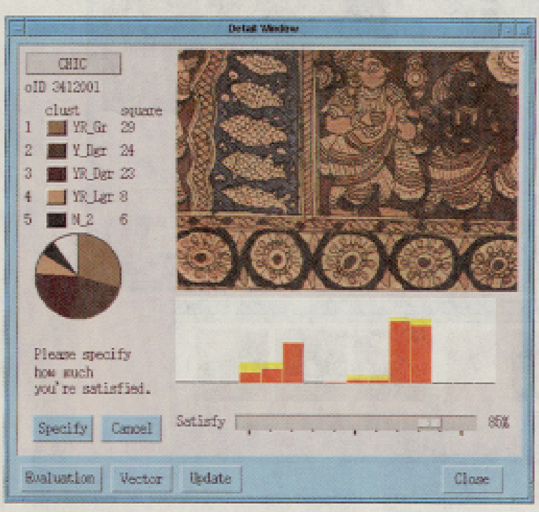

Fig. 3 Example of metanode.

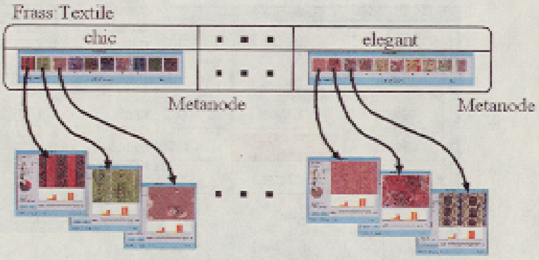

Fig. 4 Illustration of Frass.

Table 1 Example of knowledge.

implementation of an improved TDIDS on a prefectural-wide scale. This new TDIDS will also incorporate image pattern as an additional key for perceptional word selection. While we have developed the perceptional approach as an aid to designers, we feel it has potential for wide applications, for example, as the basis for a music database delivered over a high-speed network that would allow users to select music using perceptional words, adapting to their tastes over time. We feel it is significant that our perceptional approach requires little in the way of processor overhead; it is well suited for application utilizing current technology.

OID: 3200002

Figure 6.1. The Original Design Image

	38%	elegant	chic			modern
	16%	elegant	chic	formal	cool	modern
	16%		chic		cool	modern
	6%		chic		cool	modern
	4%	elegant	chic			
Perceptional Vector		{ 58 ,	80 ,	16 ,	38 ,	76 }

Figure 6.2. Best 5 Color Component and Perceptional Vector

Object ID	Best 5 Colors and Color Area Size	Perceptional Vector (pretty, elegant, chic, cool, modern)
3200002	38% 16% 16% 6% 4%	0 ...... 58 80 ...... 38 76
3200003	37% 28% 15% 6% 3%	0 ...... 65 37 ...... 28 15

Figure 6.3. Registration of Perceptional Vector in Knowledge-base

Fig. 6 Indexing of design image as perceptional vector.

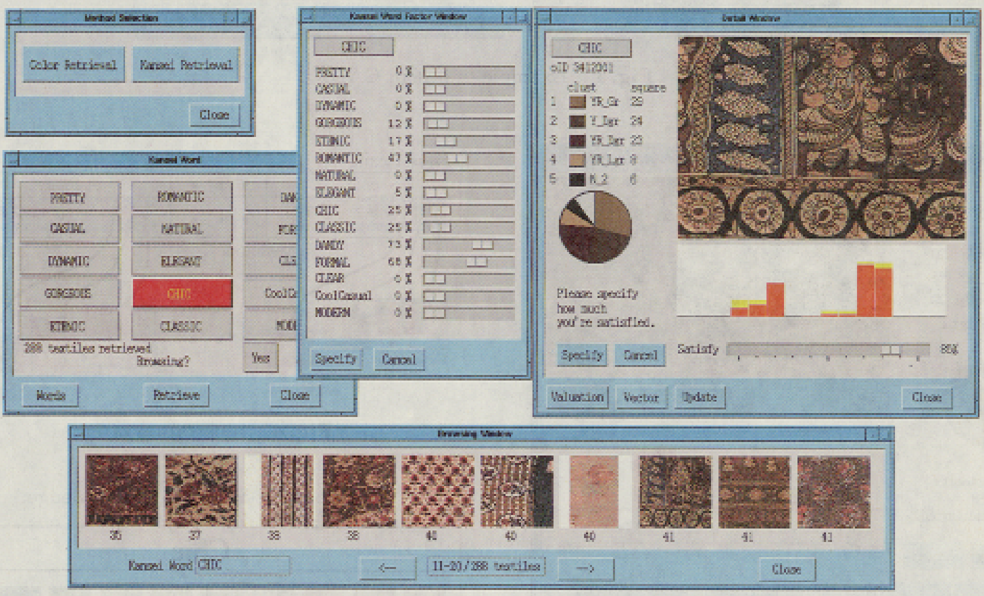

Fig. 9 User interface for textile design image database system.

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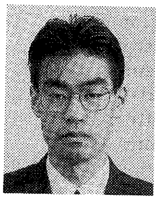

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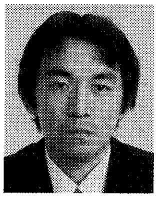

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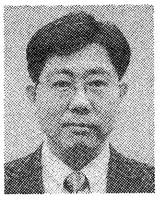

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