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A Framework that Supports Collective Creativity in Design using Visual Images

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ABSTRACT

The goal of our research is to develop computer systems that support designers' *collective creativity*; such systems support individual creative aspects in design through the use of representations created by others in the community. We have developed two systems, IAM-eMMa and EVIDII, that both aim at supporting designers in finding visual images that would be useful for their creative design task. IAM-eMMa uses knowledge-based rules, which are constructed by other designers, to retrieve images related to a design task and infers the underlying "rationale" when a designer chooses one of the images. EVIDII allows designers to associate affective words and images, and then shows several visual representations of the relationships among designers, images and words. By observing designers interacting with the two systems, we have identified that systems for supporting collective creativity need to be based on design knowledge that (1) is contextualized, (2) is respectable and trustful, and (3) enables "appropriation" of a design task.

Keywords

Computer support for collective creativity, Human-computer interaction, Visual images in creative insight, Knowledge-based approaches, Visualization

INTRODUCTION

The goal of our research is to develop computer systems that support designers' *collective creativity*. Such systems "trigger" individual designer's creativity by using design knowledge, or representations, created by other designers in the community. There are two types in the use of design knowledge in this approach. One is to present design knowledge itself for the designer's perusal, such as with case-based design support [6]. The other is to use design knowledge to retrieve information relevant to the designer's task at hand [8,15]. The research presented in this paper is based on the latter.

Designers rely on external information resources in their creative design. Industrial designers, for instance, often have "image albums" that hold a large number of visual images that they have accumulated over the years. In the early phase of the design process, the designer browses the album to find images that help them generate new ideas. We have developed two systems, IAM-eMMa and EVIDII, that support this process. The two systems aim at supporting designers in finding visual images that would be useful for their creative design task.

The first system, IAM-eMMa, uses knowledge-based rules, which are constructed by other designers, to retrieve images related to a design task. The system also infers the underlying "requirements" when a designer chooses one of the images. The other system, EVIDII, allows designers to associate affective words and images, and then shows several visual representations of the relationships among designers, images and words.

Although both systems aim at supporting designers in finding images that would be useful for their creative design task, EVIDII was welcomed more by professional industrial designers than IAM-eMMa was. Based on an analysis of observations of designers interacting with the two systems, we have identified that systems for supporting collective creativity need to be based on design knowledge that (1) is contextualized, (2) is respectable and trustful, and (3) enables "appropriation" of a design task.

In what follows, we first describe the notion of collective creativity and how computers may support the process. We then describe the use of visual images in support of collective creativity. The following section then describes the two systems, followed by a discussion on user studies conducted with the systems.

COMPUTER SUPPORT FOR COLLECTIVE CREATIVITY

The power of the unaided, individual mind is highly overrated. A creative activity is not only performed as an individual but placed in a social context [8]. Much of our intelligence and creativity results from the collective memory of communities of practice and of the artifacts and technology surrounding them --- what we call "*collective creativity.*" Though creative individuals are often thought of as working in isolation, the role of interaction and collaboration with other individuals is also critical [2].

A typical model for the creative design process consists of four stages: (1) collection of information, (2) incubation, (3) creative insight, and (4) evaluation [2]. Collaboration with other people, either directly, or indirectly via representations created by other people, takes place in all of the four stages except the third stage.

Most of researchers in the field of creativity agree that designers who are engaged in creative design tasks use external resources extensively [4,10,11]. Such external resources include a variety of "physical" and "logical" information, for instance, reading books, browsing photographic images, talking to other people, listening to music, looking at the sea, or taking a walk in the mountains. Sketches and other forms of external representations produced in the course of design are also a type of "external resources" that designers depend on [5]. Designers then "incubate" or "foster" such accumulated information.

During the incubation phase, the moment of "creative insight" emerges, when designers discover a "new" or "previously hidden" association between a certain piece of information and what they want to design [20].

Designers then apply the association to their design and produce a "potentially creative" design. They reflect on the design and decide whether they "like it or not" in the evaluation phase. They may use external resources in their evaluation.

These four process stages are repeated until designers are satisfied with the artifact they designed.

Our approach to support collective creativity is to design computational tools that can retrieve information that is "useful" for producing creative insight in such a process. While it is not consciously controllable for us to produce "cognitive leaps" in a designer's mind [3], we hypothesize that we can use design "knowledge" constructed by other designers to identify and retrieve "useful" information, which is prone to result in cognitive leaps.

Figure 1 illustrates our approach. There are two points to note here. First, the approach presented in this paper is not to deliver design knowledge itself that is produced by other designers. Instead, we use design knowledge to retrieve pieces of information (i.e., visual images) for a designer's perusal. Second, although we call design "knowledge" produced by other designers, it does not necessarily have to be in the form of formal knowledge representations, such as rules or cases. One of the approaches presented in this paper uses results of surveys filled by designers, which is similar to the approach employed in social information filtering [12,20].

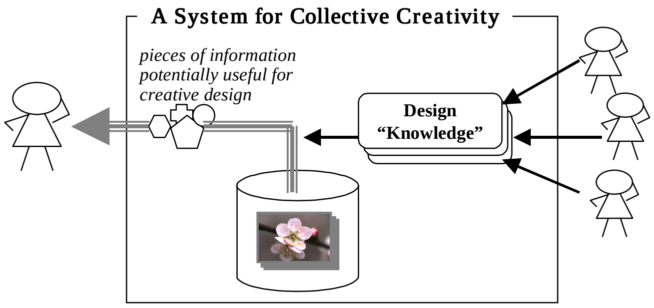

Figure 1: A System that Supports Collective Creativity

PRACTICE: HOW IMAGES ARE USED IN CREATIVE DESIGN

The particular type of information we are interested in retrieving in this approach is visual images. When we studied professional industrial designers, we found that many use "image albums," which each designer has created for him/herself. They used to fill these albums with illustrations they cut out from design journals and photo books. Nowadays, they use digital scanners and store the images on computers. Regardless of whether the images are in image albums or on computers, they use the visual images by simply browsing them in order to get "fresh ideas" for their design.

A Story

To illustrate this point, we now present an anecdotal story of one of the industrial designers who collaborated with us. While designing a chair, the designer browsed images in his image album seeking for some that would be "useful" for his design. Although he did not have a clear goal in mind while browsing, he was vaguely thinking of objects that have the same functionality as a chair. When he saw a picture of plum flowers (see Figure 2), the image "clicked." He thought that the round bowl-like shape could be used in the design of his chair.

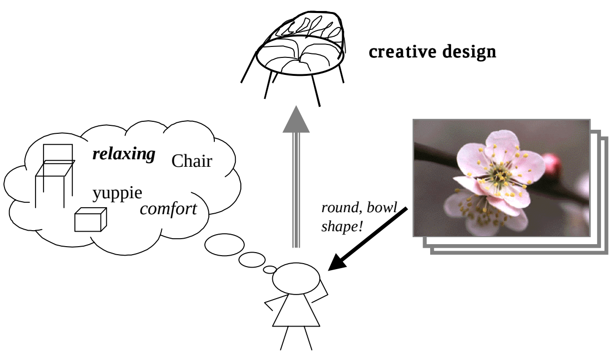

Figure 2: Visual images in the creative design process

Figure 2 illustrates the process. When he was browsing images in his image album, he already had a vague understanding about his design: that he needed to design a chair, implying functional requirements like “seatability.” Other concepts, such as comfort, relaxation, or a potential targeted user group (e.g., yuppies) may also have been on his mind. When he looked at the plum image, it literally “clicked”--- the moment of creative insight. When he first encountered the image, he was not aware of why or how the image was related to his design. Then he thought about why the image interested him. Then he noticed that the round bowl-like shape of the plum could be useful for his chair design. He applied the shape to his design, and designed a chair that looked like a plum flower to him. It is important to note that he was drawn to the picture before he became aware of the possible connection to chairs via the rounded bowl shape of the flower. At first, he liked the picture “for no apparent reason.” Then properties such as its shape became apparent and helped explain why he liked the image and how he could use the picture for his design.

Creative Process using Visual Images

Many of the designers we interviewed stated that browsing image albums is a process of seeking for a “metaphor” [13]. Especially in the domain of industrial design, designed artifacts need to be creative: both innovative and useful [14]. For example, in chair design, one needs to design a chair that has never existed; but at the same time, the produced artifact needs to function as a chair --- one needs to be able to seat oneself on the artifact. When browsing image albums, designers seek for a metaphor for the “connotation” of the chair --- abstract concepts that make objects function as “chairs.” When a designer finds a metaphor, then the designer analyzes what is common between the found metaphor and the connotation, namely, what is to be designed. A metaphor is an association between two concepts [13]. Two concepts are metaphorically related if there are properties that are common to both concepts. When people use a metaphor to describe a concept, they usually are not aware of which properties are in common. For instance, take an example of “Argument is War” metaphor used throughout in Lakoff and Johnson [1980], one can then know that both activities involve two parties who oppose each other. Such common properties, however, came to mind only after one uses the metaphor.

In the same manner, when a designer uses the plum flower picture as a metaphor for his design, the designer finds that the picture has “something in common” with his design task. Then upon further reflection, he finds that one property of the plum flower, the round, bowl like shape is related to the seat in his chair design.

What he found is a way to use the picture of a plum flower as a *metaphor* of chairs. He combined a property that he “discovered” from the picture with the properties of the design of a chair he already had in mind; for instance, the typical shape of a chair and perhaps functional and behavioral requirements.

As Figure 2 indicates, the creative design process depends on the designer’s ability to discover this association between two as-yet-unrelated things, the developing design and a specific visual image.

Computer Support for the Process

Figure 3 illustrates a cognitive model of the use of visual images in the creative design process as described above.

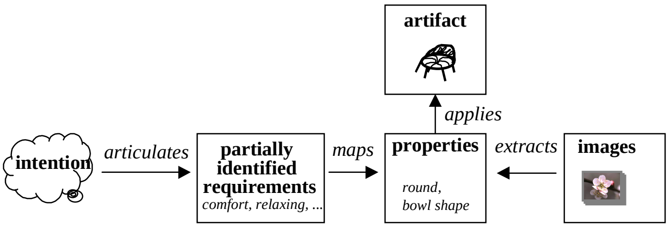

Figure 3: A Cognitive Process Model in Using Visual Images

Based on this cognitive process model, there are two approaches to help designers use visual images for their creative design task:

1. by identifying and delivering *images* that might be useful for the designers, and/or
2. by identifying *properties* that can be mapped from partially identified design requirements to those of visual images.

Both approaches are related to the issue of information delivery in supporting creative design [15]. There are tensions related to types and properties of information that can be weaved into a creative product. Often, information that leads to a creative product is regarded as a result of serendipitous encounter [19]. However, studies have shown that information necessary for a creative product is often deeply related to the problem that one is coping with. From our experience working with industrial designers, each designer has his/her own “image albums” and favorite design journals. It was not that they browse arbitrarily pictures. In terms of the importance of the information, if the importance is so obvious, it is likely to lead to a well-known solution - not creative. On the other hand, whether the information can be important for creativity cannot be known a priori. Following orderly rules based on some traditional approach tends to lead to a product that is useful, but not necessarily innovative. To transcend tradition, one needs to take a chaotic approach by breaking rules, which, however, has less chance of producing a useful product. Finding the right balance between these tensions is a challenging research question.

In our previous research, we have studied knowledge-based critiquing systems, which can help designers become aware of implicit aspects of a visual image [9,15]. For instance, given a picture of plum flowers and rules about geometric shapes, a system could conceivably notify designers that the picture is related to shapes like circle, oval, or bowl.

This paper presents two systems that support designers in the use of visual images for their design tasks, based on two radically different approaches.

IAM-eMMa uses knowledge-based rules that represent relationships between a color property of an image and impressions; for instance; “yellow is good for images intended for children because it is often their favorite color.” The system analyzes color properties of images, and infers whether the picture is good for kids based on the amount of yellow in the image.

EVIDII, in contrast, does not use rules to assist designers in finding images appropriate to a given task. Instead, it displays relationships between designers and the words they associated with images. It represents the result of surveys of individual designers asking what words they associate with each of a set of given images. The system then provides an interface that displays relationships among people, images, and words in two- and three-dimensional space.

The next section describes how each system is used by designers.

THE TWO APPROACHES

The IAM-eMMa System

IAM-eMMa (Interactive Abduction Mechanism in an Environment for Multimedia Authoring) is a system that helps designers select an image from a large image library given vague initial requirements [21]. This section provides an overview of the system and how it is used by designers. Detailed mechanisms are described in [21] and in [17].

The eMMa-SPEC component of IAM-eMMa allows designers to express conceptual requirements of their design task. A specification in eMMa-SPEC is a set of aspect-value pairs. Aspects represent categories of requirements for an image search task. Aspects include: *Age*, *Atmosphere*, *Audience*, *Media*, *Objects*, *Purpose*, *Style*, and *Topic*. Possible values for each aspect are defined in the system a priori: for instance, the aspect *Atmosphere* has, *cheerful*, *sad*, *warm*, and *cold* as possible values.

The system uses “knowledge” about color and image usage as production rules. Each rule represents an interdependence between an aspect-value pair and an image attribute. Image attributes are physical characteristics, such as color values and brightness that can be computed from a digital image. Image attributes include *ThemeColor* and *Brightness*.

For example, the following rule:

Atmosphere(*warm*) -> *ThemeColor*(*red*)

represents “ *if you want a warm atmosphere, consider red as the theme-color*.”

In using IAM-eMMa, a designer first specifies his/her design requirement using eMMa-SPEC (see Figure 4-(a)). The system then identifies necessary image properties by making inferences using its rules (see Figure 4-(b)). Based on the identified properties, the system orders images in its library according to these attributes and presents them (see Figure 4-(c)).

When the designer selects one of the presented images using eMMa-ImageSelector (see Figure 4-(d)), the system computes attributes of the image; the predominant color and average brightness. Using this information and the system’s rule-bases, the system suggests necessary requirements derived from those computed attributes of the selected image (Figure 4(e)).

For example, when a designer has a design task related to “*middle-aged* customers,” and wants to design something with a “*warm*” atmosphere and so on, he/she can represent the requirements using eMMa-SPEC as shown in Figure 4-(a). The system then suggests that images which have certain brightness and red and blue as theme colors, would be useful for the design task as shown in Figure 4-(b). Figure 4-(c) displays ordered images based on the identified image properties. Designers can browse these ordered images hoping to find something useful for their creative design.

When the designer finds an image that interests him/her, he/she can tell IAM-eMMa which image interests him/her by selecting the image. For instance, when the designer selects a rose image as shown in Figure 4-(d), IAM-eMMa suggests that the selected image has properties related to “*old*” customers, “*sad*” atmosphere, and “*engineer*” setting and “*American*” nationality. It is up to designers whether to agree with, disagree with, or ignore the system’s suggestion. If the designer agrees with any of the suggestions, he/she can accept them and the system modifies the specifications in eMMa-SPEC to include the new aspects.

The designer can repeat this process until he/she finds images that are useful for the creative design task.

The EVIDII System

The EVIDII (Environment for VIsualizing Differences of Individual Impressions) system [16,18] allows designers to conduct surveys on how one associates images with adjectives, such as “*warm*,” “*refreshing*,” or “*pretty*.” The system then displays the results of the surveys in two- and three-dimensional spaces so designers can explore who thinks of what images in what ways.

The EVIDII system uses the three elements of person, image, and word to represent the space of association. $S(P,I,W)$ represents a set of triplets $\{(p, i, w)\}$ where p is a person identifier, i is an image identifier, and w is an affective word, e.g. “*clear*” or “*soft*”. For example, (Jack, Image#31, refreshing) represents "*Jack associated refreshing with Image#31*." The goal of the representation is to allow people to explore how the three elements are related.

EVIDII has the following components: Data collection, Word-based map, and Image-based map.

The data collection interface is used to collect data *(p, i, w)* that are visualized in the word-based and image-based maps. Given a set of images and a set of impression words, which are set up by a designer a priori, EVIDII asks each designer to associate words with each image, or vice versa.

The word-based and image-based maps allow a designer to explore the space of relationships among persons, images and words, derived from the collected data.

Figure 5-(a) shows a two-dimensional implementation of the word-based map interface. The left three windows are used to operate the display in the right window. The top-left window allows designers to specify which "word-based map" to use in the right window. A "word-based map" is a map where words are distributed in a two-dimensional space. Designers can construct their own maps and assign meanings to relations among words through their positioning. For example, if one thinks that "*cool*" and "*warm*" have opposite meanings, one can position the two words far from each other.

There are two types of views for the word-based map interface through which the designer can explore the relationships. The image-view is displayed by selecting one of the images listed in the middle left window, showing who associated which word to that particular image (person icons are displayed in the position of the corresponding word in the map). The person-view is displayed by selecting a person from the bottom left window, resulting in thumbnails of images that this particular person associated to each word. Designers can also go back and forth between these two views by selecting a person icon or a thumbnail image in the right window.

Figure 5-(b) shows a three-dimensional implementation of the image-based map interface. This is similar to the word-based map interface except that the right window shows an image-based map, where each image is allocated in a three-dimensional space. While user extension is possible, the current version of EVIDII provides two types of image-based maps, the HSB map, which positions each image according to the Hue, Saturation and Brightness values of the most used color in the image, and the RGB map, which positions each image according to its RGB values. The image-based map interface operates in a manner similar to the word-based one with two types of views. The middle left window allows designers to select a word to display who associated the word with each image (word-view). The bottom left window allows designers to select a person to show what words the person associated to each image (person-view).

Using EVIDII, designers explore how other designers "see" visual images. For instance, when a designer Joe finds that another designer Tim associated a particular kitchen picture with a word "pretty" while no the other designers who participated in the survey associated the word with the image, Joe finds it interesting and looks at the kitchen image more carefully. Then, Joe finds that the ventilator hood of the kitchen is rounded. Joe then understands why Tim found the kitchen image "pretty" because of the round shape of the ventilator hood. Now Joe wants to how Tim thought of other images, so he clicks on the Tim icon in the word-based space and further examines how Tim made associations between images and words.

DISCUSSIONS

While the above two systems are based on two totally different approaches, both were intended to support designers in their creative design by using visual images. By observing both novice and expert designers interacting with the two systems, we have identified that systems for supporting collective creativity need to be based on design knowledge that (1) is contextualized, (2) is respectable and trustful, and (3) enables "appropriation" of a design task. Each point is discussed below.

Design knowledge needs to be contextualized. IAM-eMMa supports designers by delivering images based on knowledge-based rules and inferring underlying properties from a selected image. Such rules are stored by other designers in the community, who used the IAM-eMMa system IAM-eMMa supports designers:

- by retrieving images relevant to the partially specified requirements in the eMMa-SPEC;
- by inferring implicit requirements based on color properties extracted from a selected image in eMMa-ImageSelector; and
- by presenting rationale (i.e., rules stored by other designers) for the above two types of the system's behavior.

In user studies of IAM-eMMa, designers were observed to almost always ask for rationale for the system's behavior. While novices reported that they have learned some domain knowledge in this presentation of rules, experts often did not agree with the rules completely and argued that the rules were too much detached from the context. That is, rules of IAM-eMMa are about associations between words and color properties, and the designers thought that such color properties heavily depend on the context. It is too trivial to say that "*yellow is liked by children therefore yellow pictures are related to children.*" Experts often asked the experimenters whether they could view original images from which those rules were extracted (note that the current implementation does not support this) to answer questions such as "*which picture's yellow is liked by children*."

Design knowledge needs to be respectable and trustful. EVIDII, on the other hand, supports designers in finding images that interest them by allowing them to find how other designers think of images. EVIDII allows designers to ask questions through interaction such as:

- who thinks this image as "cute?";
- does this person find this image "gorgeous?"; or
- what other designers think of this image?

In our user studies, designers, especially experts, were found to prefer EVIDII to IAM-eMMa. They found EVIDII useful because it allowed them to "browse inside of the brains of other designers." For designers, talking to other designers is very important. They appreciate design meetings and comments made by their peers on their designed artifacts. By using EVIDII, they can view how their colleagues think of images in what ways. Just like they appreciate their colleagues' opinions, they respect associations made by their colleagues using EVIDII.

Interestingly, experts wanted to view only associations made by other expert designers, not ones made by novices. When confronted with discrepancies between their associations and those of another peer designer, they became interested in possible underlying properties that explain the associations. This challenging thought process has led them to creative design.

In contrast, because the expert designers found that IAM-eMMa's image ordering is too trivial being based on too simplistic rules that are detached from its context (as discussed above), they were not motivated to examine suggested pictures by IAM-eMMa.

Design knowledge needs to enable "appropriation" of a design task. "Appropriation" is a principle that is related to the motivational issue [1]. By appropriation of a design task, one can "fall in love with what they are doing" by making activities their own and by caring about their work [by Papert in 7]. Affection and appropriation are two important aspects of engaging people in creative activities [7; p.293].

This aspect explains why IAM-eMMa's inference on the underlying association from the selected image was even less welcomed by the expert designers. It was the designers' task to point out what properties can be derived from an image. It is the core of the designer's task to identify common properties between an image that interested them and their design task. Computer systems' helping them in this process deprives them of the feeling of having the activity their own. They were not interested in being told by the systems especially if they are based on rather simple decontextualized rules.

CONCLUSION

In summary, The EVIDII system has demonstrated that it can support creative design not by automating image analysis, but by opening the door to other designers' associations. Our user studies showed:

- *Computer systems can help designers in their creative design by using visual images.* EVIDII was found helpful by professional designers and has demonstrated a potential that leads them to creative design.
- *Delivery of images is helpful as long as the delivery is based on the "rationale" that the designers consider meaningful.* The designers liked EVIDII because it displays associations made by their peers and not based on some trivial rules.
- *Mechanisms for supporting collective creativity need to be carefully designed so that they will not deprive them of the feeling of having the design activity their own.* It is the core of the designer's task to identify common properties between an image that interested them and their design task. The designers do not feel a need for computer systems to help them in this process.

These findings corroborate results from other knowledge-based design support studies. In our previous studies, we found that a key to successful critiquing was to provide rationale for the system's behavior. The rationale needed to be convincing enough for professional designers [15]. The problems we found with IAM-eMMa may not be due to the architectural design of the system but be due to the lack of considerations of the three aspects discussed in the previous section.

Our future research issues include how to design systems that allow designers to better communicate with design "knowledge," or representations, created by others in the community. Keys to successfully addressing these issues are contextualizability, respectability, and motivation.

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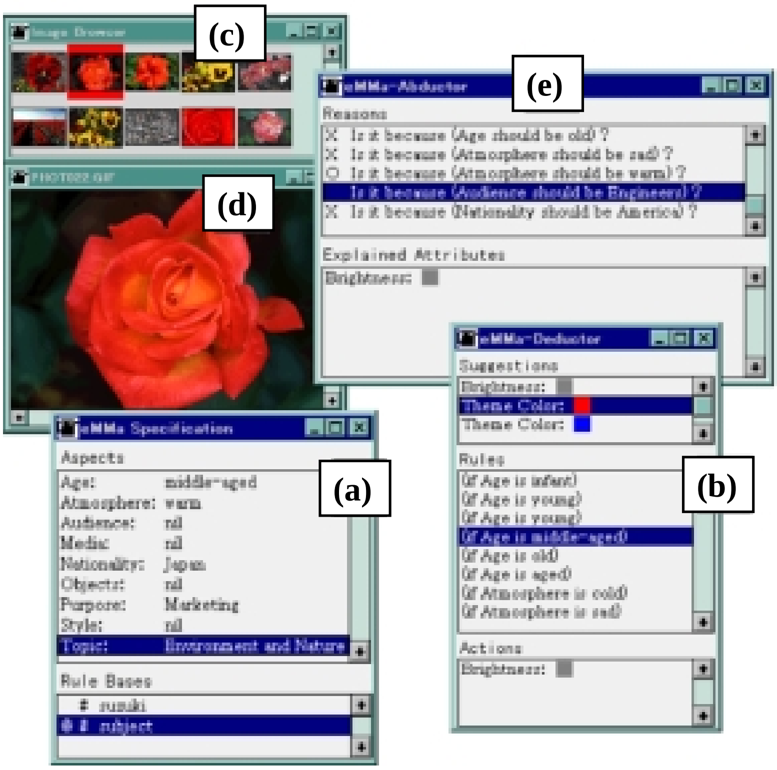
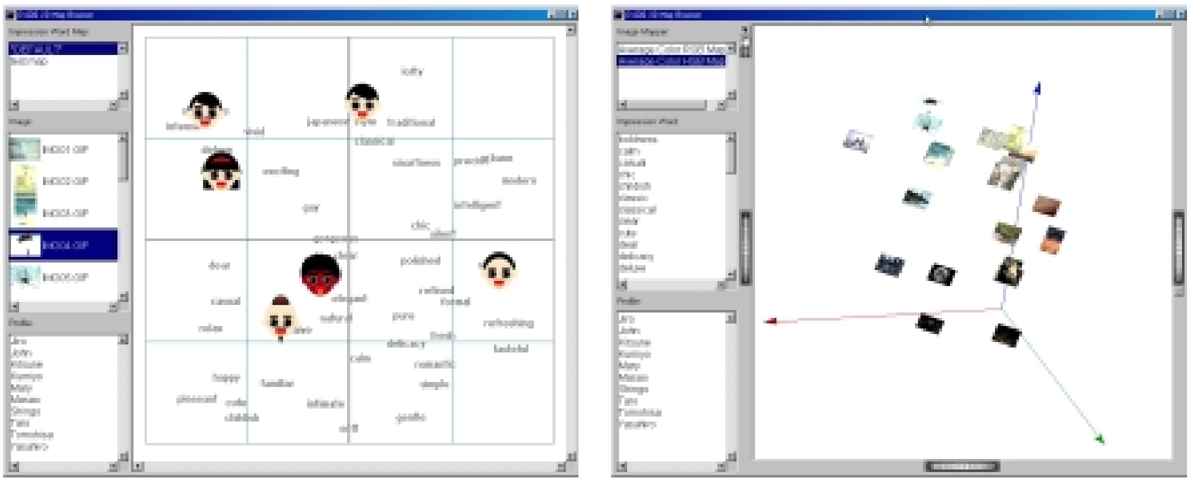


Figure 4:The IAM-eMMa System



(a) (b)

Figure 5: The EVIDII System