Artificial Intelligence for Engineering Design, Analysis and Manufacturing (2001), *15*, 433–440. Printed in the USA.

Creative stimulator: An interface to enhance creativity in pattern design

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(RECEIVED June 20, 2000; ACCEPTED April 29, 2001)

Abstract

Creative Stimulator (CreaStim) is an intelligent interface for pattern design that behaves as a semiactive partner to human designers rather than as a passive graphical or computational tool. By making adjustments to psychological differentials and/or design parameters, CreaStim is able to help designers to explore innovative pattern designs and to get inspiration, producing different types of novel designs. In this article, the mechanism, the technique, the implementation, and the testing of CreaStim are described. The basic principle of CreaStim is the catastrophe theory, which implies that sudden realization in the thinking process of design may lead to creativity. CreaStim tries to stimulate and/or impact designers' creativity in design process using the output of it, rather than to simulate the sudden realization. The core of the CreaStim is a neural network-based imagining engine, a data repository, and its learning strategies considering psychological factors. The psychological factors, which are thought one of the key influences to creative design, are based on the questionnaires completed by designers about the existing successful designs. The repository contains not only a traditional database storing functional attributes, economic attributes, graphic description, structural description, and psychological attributes, but also methods, rule-based knowledge, and pattern-type knowledge. And it is managed by an application program called Design Template Group (DTG) manager. Trained with 12 pieces of successful pattern designs and 528 pieces of pseudo-examples produced and evaluated by the authors, CreaStim is implemented for a PC and an evaluation poll from five designers shows that designers may most likely get some inspiration from the produced patterns and some of them can even be adopted as the design alternatives directly.

Keywords: Creative Design; Neural Networks; Pattern Design; Psychological Differentials

1. INTRODUCTION

Behaving as a semiactive partner to human designers rather than as a passive graphical or computational tool, Creative Stimulator (CreaStim) is an intelligent interface helping designers to explore innovative design by producing different types of novel designs and getting inspiration according to the adjusting of psychological differentials and/or design parameters. Here, the word "semiactive" means that the results of CreaStim can be used to stimulate or impact the designers' creativity in the design decision process, and satisfactory results can be learned by CreaStim under supervision of the designers.

Creativity is crucial to pattern design that is widely used in the area of textiles and decorating. The term "pattern" here is defined as the natural outgrowth of floral and geometric repetition (Stevens, 1980). A pattern design generally depends on the following aspects: imitation and translation, memory and imagination, old-time content with tradition, modern self-consciousness, originality, condition of today, inspiration, enlightenment of nature, use of old work, designer's domain, and designer's personality (Day, 1979). To create innovative pattern design is an intuitional, divergent and nonlogical thinking process that is strongly affected by psychological factors and requires a trial-and-error process (Lawson, 1997). These factors are influenced by cultural, natural, and economic elements.

Existing CAD systems rely on precise geometric information to specify the model of an artifact. They are not very well able to support computer-aided pattern design at

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Editor's Note: Due to communication difficulties, the proof copy for this article was not reviewed by the authors. Every effort has been made to eliminate errors, but the publisher cannot assume responsibility for the accuracy of this article.

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the originating stage because the geometry of an artifact is not sufficiently definite and it only becomes available when the design has advanced to the detailed stage (Pugh, 1989; Smithers et al., 1990). Simulating the designer's logical thinking process in conceptual design, Intelligent Computer Aided Design (ICAD) systems, which stem from the combination of AI and CAD techniques, seems exaggerated and has accepted the major complaints about their fragility (Gero & Sudweeks, 1998). In general, existing expert design systems are usually very good at what they are programmed to do, but respond in unintelligent or odd ways when faced with novel situations. The main reasons for this are the bottleneck of knowledge acquisition and representation, the difficulties in the spatial layout, and weakness of the inference engine. To enlarge this bottleneck, further study on ICAD is carried out by using both Artificial Intelligence (AI) and Artificial Neural Networks (ANN) to simulate the rational thinking process of design (Wang, 1996). Based on learning of successful design examples, thinking with mental imagery can be simulated by trained multilayer perceptrons implementing mapping between design requirement and the design sketch. However, this kind of simulation is considered to be difficult in creating innovative designs. Some researchers have paid attention to the study of principles and models of creating innovative designs (Gero, 1994, 1996; Coyne, 1997; Nigel, 1997). But, the mechanisms for an innovative design process are still not fully understood, and simulating creating an innovative design process is rather difficult (Boden, 1991; Petrovic; 1996; Athavankar, 1997; Goel, 1997).

In this article, applying catastrophe theory (Castrigiano, 1993), psychological differentials, which are actually a set of parameters for quantitatively defining psychological factors, as well as a neural network imagining engine, we try to stimulate a designer's creativity by helping him catch sudden realization (inspiration) rather than to make the computer simulate the innovative design process. Trained with 540 existing designed patterns of different styles, CreaStim can produce novel patterns very quickly by altering the psychological differentials. The produced patterns can then be used to stimulate designers' inspiration, to impact designers' design process, or to be alternatives of design output.

2. WORKING MECHANISMS

The idea of CreaStim comes for simulating of the thinking process of expert designers in the conceptual design phase. Thinking in design is classified into three kinds: logical thinking, thinking with mental imagery, and sudden realization (Qian, 1986; Yan, 1989; Pan, 1991). An actual thinking of design is the alternating among these three processes. The brain is recognized as an open system with self-organization behaviors. The behavior itself is called consciousness. The brain works when the system has interaction with environment. The behavior of the brain depends not only on natural elements such as logical inference of determinate facts and rules but also on economic and social (or cultural) elements which influence psychological factors subjectively. According to the catastrophe theory (Castrigiano, 1993), when the state of a self-organized system is far away from its equilibrium point, it is much easier to have a phase change. For the thinking process in creating innovative design, from the point of view of cognitive psychology (Medin, 1992), the phase change is something like sudden realization in the brain after some successful stimulation given by the environment.

Simulating logical thinking, a rule-based expert design system used logical inference and abstract knowledge, which deviates from designer's thinking and decision process. The crux of the deviation is the lack of thinking with mental imagery ability process (Wang, 1996). For example, when an experienced designer undertakes a design task for product, according to the design requirement and his knowledge, he can immediately get the sketch of the product in his mind by thinking with mental imagery. It is noticeable that a lot of things at this stage are regarded as default, which may cause trouble when representing the problem in a rule-based system. Based on learning of successful design examples, this kind of thinking with mental imagery can be simulated by trained multilayer perceptrons implementing mapping between design requirement and the design sketch. Without considering the impact of psychological factors that are much related to inspiration for creativity, this kind of model is not able to create innovative designs (Wang, 1996).

On the other hand, the role of psychological impact during the early creative phase in design problem solving is neither fully understood nor recognized (Boden, 1991; Athavankar, 1997). Many researchers think psychological factors are too subjective to be a scientific research topic, especially in the AI field. But from the phenomenon of some experienced designers' design process, sudden realization does appear sometimes when designers are stimulated by the underlying environment (Lawson, 1997).

In the authors' opinion, creativity is a subjective activity that depends on the thinker's natural talent, background, personality, and environment that stimulates his/her inspiration. It is not realistic to simulate creativity by a computational model, but it is possible to stimulate the thinker by altering the underlying environment. Therefore, in addition to the simulation of logical thinking and thinking with mental imagery, CreaStim is proposed to stimulate designers' creativity on design process by controlling psychological factors. Psychological differentials, which are used to describe the gradient extent of psychological factors, are used as the psychological state descriptions in this study. By producing different types of novel designs according to the altering of psychological differentials and/or design parameters, rather than to simulate the sudden realization by computer, Creative Stimulator is used to help designers to get new inspiration. Thus, creativity could be enhanced by stimulating designers and by allowing them to explore innovative designs more easily.

Considering psychological factors as part of the inputting parameters, we propose an ANN-based imagining engine for designing patterns. The imagining engine is one of the cores of the CreaStim. The way information is processed in an imagining engine is similar to that in the human brain in the aspects of functional and structural similarities. An ANN system is a highly nonlinear dynamic system. Although the structure and performance of a single neuron is very simple and limited, the network system consisting of large amount of neurons can implement extremely rich behavior. Through adaptive learning, an ANN can gradually acquire knowledge about the attributes and mutual relation of objects in an environment, and can adapt to changes of the object, that is, can achieve pattern association. The storage and processing of information are combined into one in an ANN system. The information is stored distributively between the connection of neurons, and is processed by the way of parallel distributed processing. The behaviors of large numbers of neurons which transfer information among each other forms the overall performance of the imagining engine. This makes it possess features such as synergeticness, robustness, and fault tolerance.

Figure 1 shows the working mechanism diagram of CreaStim for pattern design. Given a design task that is described as design requirements on functional, economic, and aesthetic aspects, a designer is asked by CreaStim's pattern abstraction engine (PA-engine) to input essential parameters and preferences such as structural description, image description, and psychological factors. These inputs will be coded as a kind of internal data structure that is handled by the Design Template Group (DTG) Manager. Knowing the design requirements, the DTG manager will make pattern searching and matching in the design template group to decide what style or type of design may most satisfy the current design requirement. Here, the style of a pattern is defined as a semantic description of its design concepts represented by psychological factors and topology features. The precondition of searching and matching is a well-organized previously completed data repository which contains not only a traditional database storing functional attributes, economic attributes, graphic description, structural description and psychological attributes, but also pattern transform methods, rules and facts (rule-based knowledge), and pattern-type knowledge (P-T knowledge). Here, P-T knowledge is the new feature of this system. It is ANN based and is the major resource of the imagining engine (I-engine). After the style or type of design is decided, the DTG manager will fit the selected pattern to the current agenda and send it to the imagining engine to create image and structural descriptions. The mechanism of the imagining engine is a kind of feed-forward calculation of trained neural network (Rumelhart & McClelland, 1986). According to pattern-type knowledge acquired by training neural

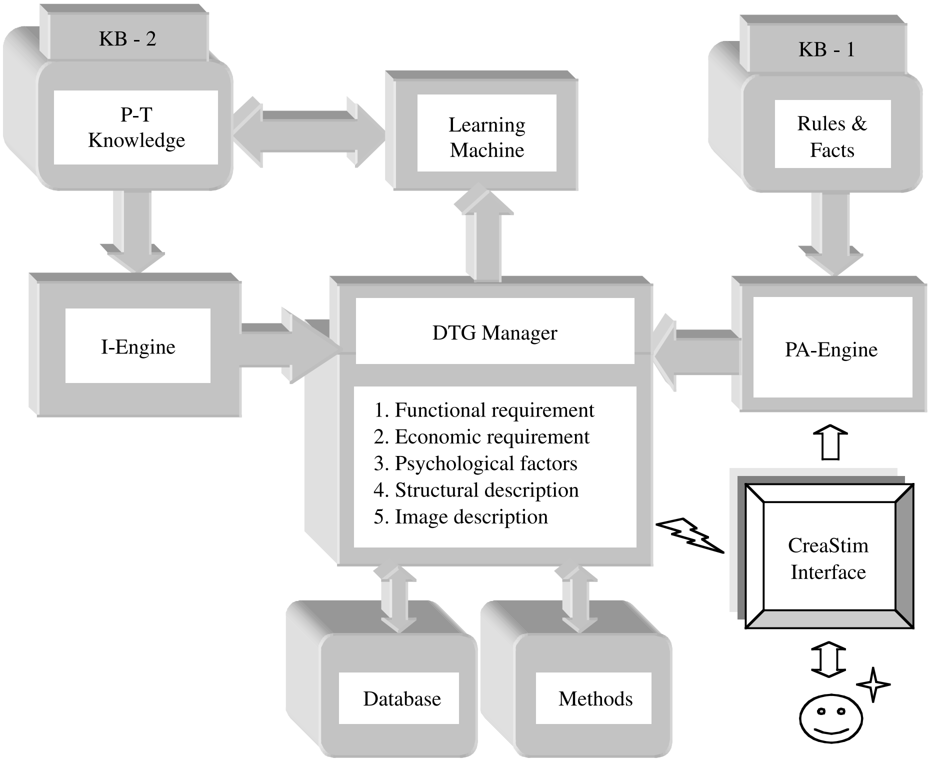


Fig. 1. Diagram of the working mechanism of CreaStim for pattern design.

networks, input with design requirement parameter sets and psychological differentials, the imagining engine can output a new parameter sets that can be used to produce an image. From the new parameter sets and pattern transform methods, new patterns are then visualized as design alternatives. On the right side of Figure 2, the PC implementation interface of CreaStim for pattern design, three produced patterns are shown as the design alternatives recommended by CreaStim. Seeing the design alternatives, the designer will choose one of the following two things to do:

1. drive the DTGM to generate more design alternatives through the imagining engine by altering the psychological differentials and design parameters, as well as by synthesizing two or more different styles of existing designs;
2. improve the pattern-type knowledge base by directing a supervised training, when the designer thinks that a design alternative is an ideal one or one worth recording;

Doing item (1) repeatedly will produce more and more novel design alternatives. These design alternatives can be used to stimulate the designer's creativity.

3. IMPLEMENTATION STEPS AND TECHNIQUES

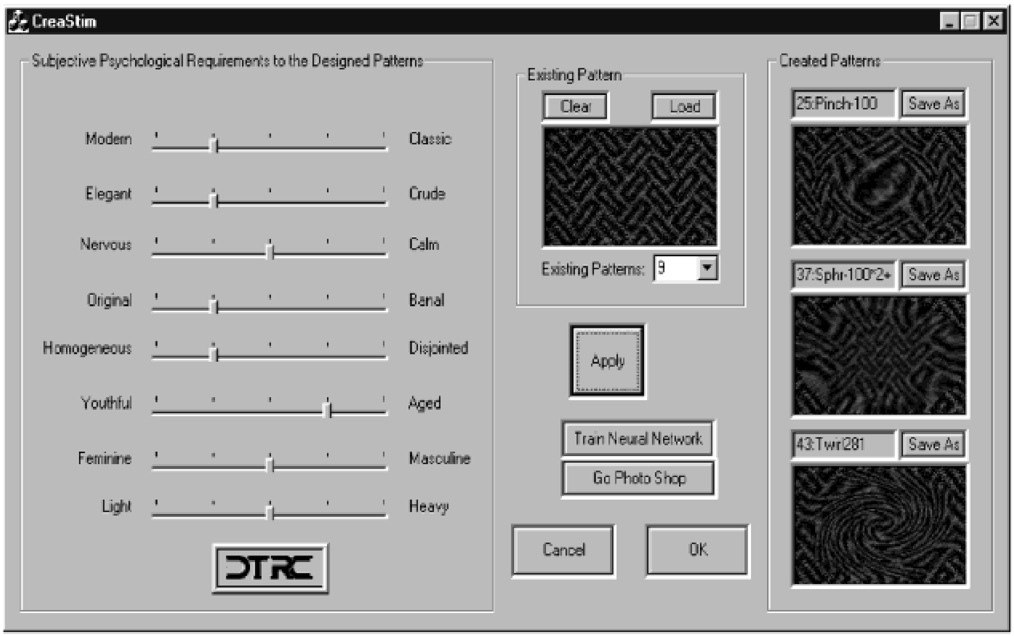
The implementation of CreaStim for pattern design includes the following four phases:

1. Classification of different design styles of patterns into a design template group;
2. Knowledge acquisition and representation by rules, facts, and training of neural networks, database organization, and methods collection (this forms the system repository that is handled by the DTG manager);
3. System sensitivity analysis and validation;
4. Supervised training.

The design style of an existing pattern is classified by psychological differentials and topology features of a pattern stored in the DTG. This classification is not made by criteria of semantic description but by a trained neural network classifier without semantic explanation. The DTG is a group of design templates which contain the following information:

1. Functional attributes
2. Economic attributes
3. Psychological attributes
4. Structural description
5. Image description.

The functional attributes and economic attributes describe the functions and cost factors of the designing pattern. Psychological attributes are evaluated by psychological questionaries answered by the designer and/or users of the existing successful patterns. Structural description stands for the materials under use and topology of the internal structure if any. Image description stands for the appear-



Existing Patterns: 9

25:Pinch-100

37:Sphr-100*2+

43:Twirl281

Fig. 2. The PC implementation interface of CreaStim for pattern design.

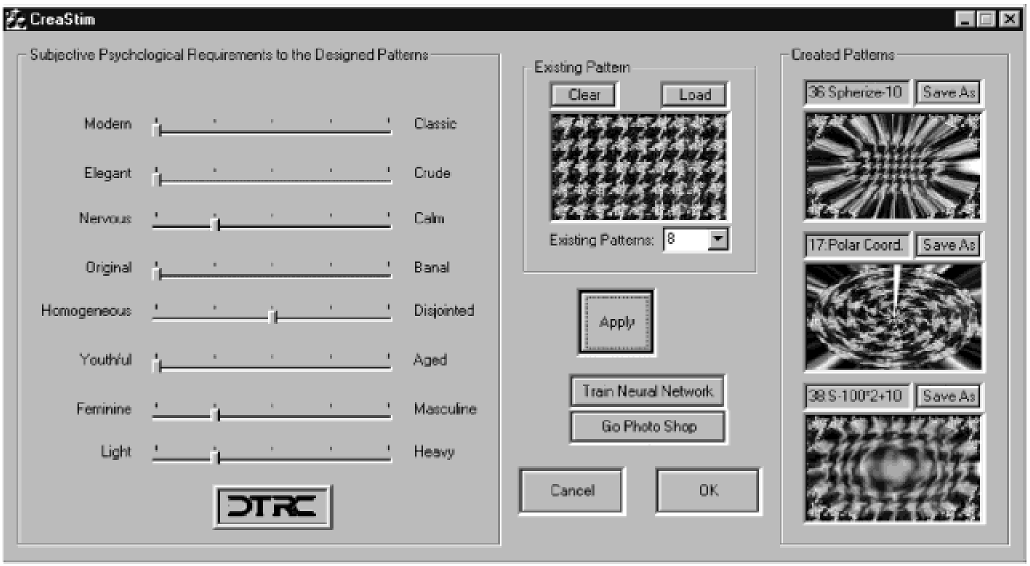
ance of a pattern such as bitmap images viewed from different specific directions. To classify different pattern design styles into a design template group and to be universalized, CreaStim also conforms to theory of ontology engineering (Meersman, 1999). That is:

1. It should be adaptable to the environment, that is, it should have some kind of intelligence.
2. It should be formulated in a conceptualization way.
3. It should conform to the conception of standardization.
4. It should be reusable.

The knowledge base of CreaStim is divided into two types: KB-1 and KB-2. KB-1 contains rules and facts for pattern abstraction that codes the design requirement into an internal data structure. KB-2 contains pattern-type knowledge, which is ANN based and is used by the imagining engine for classification and association of pattern styles. Like a general knowledge-based system, KB-1 is obtained by experiential questionaries answered by experienced designers. KB-2 is obtained by training the neural network (supervised learning module) with coded existing successful design examples. Compared with a general representation of a conceptual design, the content of these examples in CreaStim includes not only the basic information, such as functional attributes, economic attributes, structural description, and image description but also the psychological attributes. The psychological attributes will play an important role in creating new designs with multiple psychological needs, especially if the aesthetic requirement is of more concerned in the pattern design. The frame of these examples are represented by the design templates in the DTG, and the data as well as pattern transforming methods of the examples are stored in the repository. The data stored in the repository can be used not only for pattern matching and recommending but also for training of neural networks. When the number of examples in the repository is too few to train the neural network, for the training purpose, it is necessary to produce some pseudo-examples. Pseudo-examples are examples that are not in real use but are created for training of the neural network only.

The psychological differentials using slider controls shown on the left side of Figures 2–5 are summarized for a pattern design of textile. According to the combination of psychological differentials and design parameters, various transformation algorithms can be recommended to produce images by synthesizing existing images in the repository. These algorithms are actually the pattern transforming methods in the repository such as distorting, blurring, pinching, and twirling to the existing patterns or a combination of these methods (Table 1).

It is crucial to make sure that the system is robust enough so that it can deliver acceptable and reliable generalizations under the incomplete and ambiguous inputting information. The robustness of the underlying system is mainly decided by the pattern-type knowledge used. According to the author's study (Wang & Du, 1993), the robustness of pattern-type knowledge, which actually is the records of weight matrix, network structure, and its activation function parameters of the neural network, is dominated by the sampling of training examples, network structure, and the shape of activation function. Sensitivity analysis is one of the most effective measures that can be used to evaluate robustness of a system (Choi & Choi, 1992). To assure the robustness of the system, a sensitivity analysis module is set up



Existing Patterns: 8

36 Spherize-10

17:Polar Coord.

38 S-100*2+10

Fig. 3. Patterns produced by CreaStim under different combinations of psychological differentials.

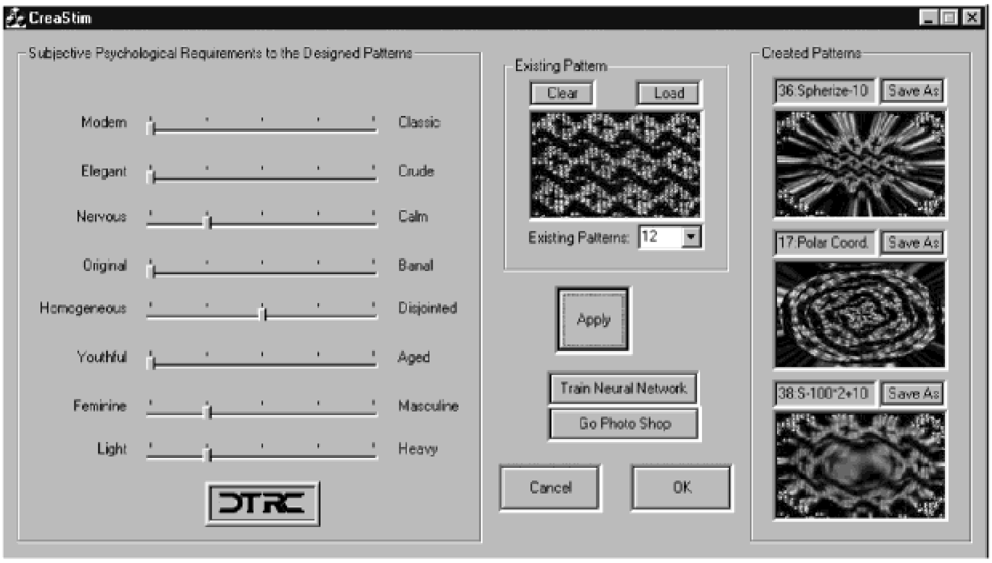


Fig. 4. Patterns produced by CreaStim under different combinations of psychological differentials.

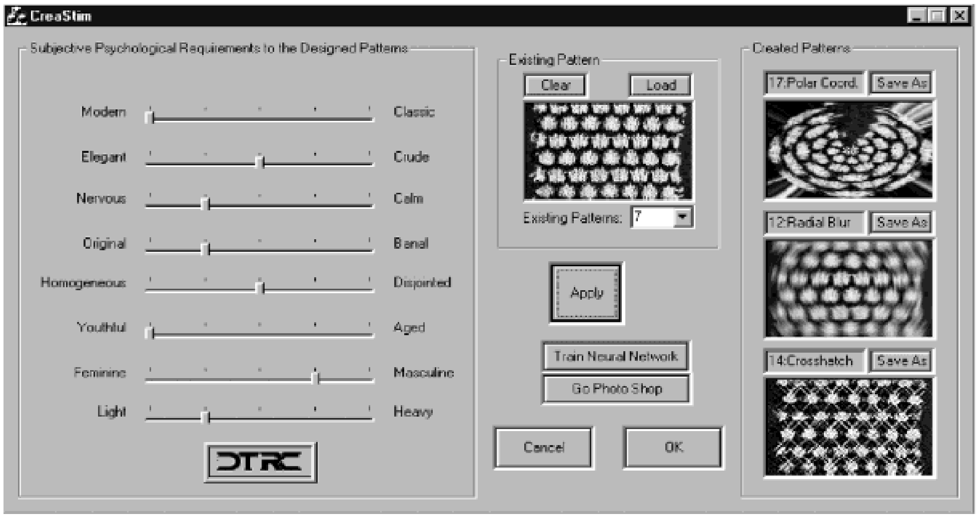


Fig. 5. Patterns produced by CreaStim under different combinations of psychological differentials.

Table 1. *Transformation algorithms adopted by CreaStim for pattern design*

00: Current
01: Invert
02: Chrome
03: Pinch +100+ Difference Clouds
04: Desaturation
05: Colored Pencil
06: Cut-out
07: Paint Daubs
08: Rough Pastels
09: Smudge Stick
10: Sponge
11: Gaussian Blur
12: Radial Blur
13: Accented edge
14: Crosshatch
15: Dark Stroke
16: Sumi-e
17: Polar Coordinate
18: Crystallize
19: Facet
20: Reticulation
21: Glowing Edges
22: Patchwork
23: Stained Glass
24: Pinch+100
25: Pinch−100
26: Pinch+50
27: Pinch+50+100
28: Pinch−100−100
29: Shear+50
30: Shear Sin+50
31: Shear−50
32: Shear Cos+50
33: Shear Sin+100
34: Spherize+100
35: Spherize−100
36: Spherize−100 ∗ 2
37: Sphr−100 ∗ 2+100
38: Sphr−100 ∗ 2+100 +Pinch+100
39: Twirl−999
40: Twirl−182
41: Twirl+l72
42: Twirl−293
43: Twirl+281
44: ZigZag+10+20

not only for evaluating but also for finding higher robustness pattern-type knowledge.

After validating the system, when the system in its service stage, it is very important that the system should have the ability to learn something new. The supervised learning module allows designers to teach the system by providing some new examples produced by the system or elsewhere, which makes the system more and more profound, intelligent, and personalized. The learned pattern-type knowledge is stored in the private reservoir of the repository. The mechanism of the supervised learning is to retrain the neural network by providing new examples which the designer thinks excellent.

4. IMPLEMENTATION AND TESTING

Twelve pieces of successful pattern designs with corresponding attributes and descriptions are evaluated and stored in the data repository. Another 528 pieces of pseudo-examples are produced and evaluated for training of neural networks by the authors. A three-layer feed-forward neural network with 8 input neurons, 100 hidden neurons, and 45 output neurons is selected for constructing the imagining engine for the testing. After a 96-hour training period, the pattern-type knowledge base KB-2 is learned using the Leaning Rate Matrix (LRM) method (Wang, et al., 1993). Table 1 shows the stimulating algorithms adopted by CreaStim in the testing. Integrated with PhotoShop 5.0 and LRM training algorithm for neural network, an implementation of CreaStim in PC, CreaStim v1.01, is shown in Figures 2–5.

After loading an existing pattern from a bitmap file or CreaStim's pattern list and supposing preferences in psychological differentials by altering the slider controls on the left side of the interface interactively, three stimulating algorithms, which CreaStim thinks are most eligible for fitting the psychological requirements, will be recommended by simply pressing the "*Apply*" button. And three novel patterns generated by applying the proposed stimulating algorithms will be shown immediately in the three windows on the right side of the interface. Figures 2–5 are some patterns produced by CreaStim under different combinations of psychological differentials. An evaluation poll from five designers (two of them are faculty members with professional experiences in design, two of them are brilliant senior students majoring in industry design, another is a professional designer in fashion design) has been made with six questions such as "do you think CreaStim can give you inspiration in pattern design?", "are the results created by CreaStim useful?", and "what do you think CreaStim should improve?" Results of the poll show that four of the designers think they may most likely get some inspirations from the produced patterns and some of them can be adopted as the design alternative directly. The other one thinks CreaStim could be more useful if the system had learned more design examples.

5. CONCLUDING REMARKS

Conclusions drawn from the study and implementation of CreaStim for pattern design are shown as follows:

1. Conforming to catastrophe theory, it is possible to catch sudden realization by stimulating designers with the production of quaint designs which are based on the psychological evaluation of the existing designs.
2. Psychological factors, which are able to be represented using psychological differentials, can be considered and learned by the ANN-based imagining engine that will be used to generalize new patterns with different psychological requirements.
3. The proposed intelligent interface for pattern design looks simple, but the mechanism and the underlying techniques for implementation are worthy of study. The data repository should be well organized when being implemented, because very professional work should be done on classifying examples and training neural networks to get the pattern-type knowledge.

The results of the testing and an evaluation poll show that it does give some inspiration to designers. This is quite useful in enhancing creativity in pattern design. The outcome of this article can be also applied to innovative product design that involves much more complicated data structure in the repository and different kind of stimulating algorithms. This will be considered in future works.

ACKNOWLEDGMENTS

The current research on the Study of the Integrated Computer-based Design Support System is supported by CERG grant (No. Q271) from the Research Grant Council of the Hong Kong Government.

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