Research Article

The concept of EmPatGen (Emotional Pattern Generator)

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Abstract

Nowadays, the aesthetic appearance of a product becomes more and more important in several industries. Psychologic studies and researches highlighted that beside the functionality of a product, aesthetic appearance is one of the key factors of the decision-making process before buying a product. The geometric properties—such as basic geometries and lines—of patterns that are simple structures, usually consist of replication of simple elements or their mathematically described modifications. These are all in connection with human emotions. A software called EmPatGen (Emotional Pattern Generator) has been developed that creates patterns automatically based on user preferences. The focus of this research is to support the work of product designers in the automotive industry. With the aid of this program, they are able to design the most aesthetically pleasing car interiors and fulfill specific customer requirements in a much easier manner. This study focuses on the connections of basic geometries and lines created with the introduction of a novel pattern generator program and mathematical model which is based on fuzzy logic.

Keywords Geometric patterns · Pattern generator · Emotional design · Fuzzy logic

1 Introduction

In the past decades, many branches of product design examined and utilized emotions. One of the first was the Kansei engineering which was invented by Mitsuo Nagamachi in the 70s. The Japanese people are using the word Kansei for the feeling that users think of the product, for example, when they say that their car should be fast, easy to control, stylish, and so on. Kansei Engineering aims to develop or improve products or services by transforming users’ emotions and needs. It creates a link between physical and psychological responses and product features [1].

In the mid-1990s, the user experience expression was introduced by Donald Norman. It means the effect of the product on the user. An emotional interaction that is practically determined by what people feel and remember after using the product. The purpose of the UX is not only to make the product beautiful, but also to provide experience by using it. Since the experience is based on the emotion that can be associated with psychology, it’s hard to predict [2]. The emotional design expression was also introduced by Norman in the 2000s [3]. Studies have proved that emotions that affect users play a significant role in decision making and information processing. Furthermore, it turned out that the aesthetic appearance is more important than functional capability [2, 4].

Nowadays (according to the facts mentioned above), dealing with emotions is becoming more and more important in the operations of product producing companies. This study supports this goal by examining patterns from the viewpoint of evoking emotions, and also by introducing the concept of a program named Emotional Pattern Generator (shortly EmPatGen), where the relationships between emotions and patterns, the algorithms of the pattern development process and the mathematical model are demonstrated as well. The hypothesis of this study is that for product designers, the task of creating a more
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aesthetically pleasing car interior design for consumers can become easier with EmPatGen.

Since this paper contains only a part of our study, it is important to introduce the whole methodology of this research and also to clarify the stage of the current state. For this research, a method called function-behavior-structure (FBS) model [5] was adopted; however, a few changes were necessary to be made to apply FBS to this specific task, and Fig. 1 represents the modified FBS model, where the following notation was used:

The 1. action is a process of gaining data from consumers by both qualitative and quantitative research techniques, in order to discover the full picture of the study [6]. “Be” is a collection of emotions, feelings, moods and attitudes that are connected to basic geometric elements and functions. The 2. action is to program a mathematical model and pattern generating system. “T” is a tool that creates patterns according to the given preferences. The 3. action is an emotion-based evaluation of shape and pattern. For this, different types of techniques will be used, for instance, eye tracking, face detection software and physiological signal meters. This information should be transformed into pairs (“Bs”) similarly to the case of “Be”.

The 4. action is a comparison between “Be” and “Bs”. Action 5 is the documentation process of the results. In action 6, it is necessary to test the program with designers, in order to improve the model according to their insights. In the 7. the subdivisions of emotion groups were modified. [7] At this stage, the 2. action was completed, and this paper introduces the concept of T (Tool).

2 Geometric patterns of using EmPatGen

This study is dealing with geometric patterns, where the basic geometries are in connection with emotions. An automated pattern development program called EmPatGen (Emotional Pattern Generator) was created where the inputs are emotions, feelings and the output is a 2D pattern. Figure 2 shows the concept for that with the imagined interface, where the user can change the rate of the sliders, and the program automatically generates a 2D pattern based on these preferences. Previous researches have proved that, in the case of patterns, not only the Basic Geometry has impact on consumers, but also the spreading type of the pattern. This was named

![Fig. 1 Modified FBS](image1)

![Fig. 2 Concept of EmPatGen](image2)
Pattern Space. Basic Geometry and Pattern Space have different parameters that are explained later of this paper, however, in order to introduce EmPatGen, at 2. Figure, 1-1 dimension of both Basic Geometry and Pattern Space is shown. From the parameters of Basic Geometry, in this example, the number of sides of a shape is considered, from the parameters of Pattern Space the variable is the dynamic scale of the elements building up the pattern. For the example of Sporty-Youthful-Feminine pattern, the Basic Geometry is a circle, since round shapes are much more fitting for the feeling of Feminine than sharp edges shapes. For Elegant-Classic-Masculine pattern, the basic geometry is a square since it generates a more masculine sense. In the matter of Pattern Space, scaling only can be seen in the first example, since while sporty and youthful both have dynamic and active sense that evokes this change, elegant and classic style provides calm and stable sense that does not require dynamic variables. (Naturally, the program has more factors, and also the consumer can set the rate of the transition between the two borders on the slider, examples of Fig. 2 serve only the better understanding was the goal.)

The program automatically generates the pattern, which method belongs to an area called parametric or generative design (also called algorithmic design). It essentially that the design was created by computer and mathematical relationships. The result is generated by algorithms. Unlike traditional design, the design process was controlled step by step and the consequences of manipulation right away. With the help of this new approach, making multiple versions of a product can be accomplished very quickly. This is because changing a parameter causes the whole body to transform. Generative design has the possibility of a great future because customers can create unique pieces of their own. This will generate increased customer satisfaction.

Patterns are desired features in many different industries such as in textile, homeware and decorations, jewelry, interior design, food products, stationery, etc. (Fig. 3).

In order to design EmPatGen appropriately, the automotive sector as an industry was selected to qualify the research. The reason for this is that it is readable in more and more forums [8–11] that the research into the mood/effect of the customers has become more emphasized in the car design process, which fits very well with this research objective. This study is dealing specifically with the patterns of decoration elements in the inside of the car. The left side of Fig. 4 [12] shows the types of panels and trim elements, and the right side of it, the implementation of a few patterns [13].

To summarize the application of EmPatGen in the field of automotive industry, the idea is that:

1. Consumers can provide their preferences via a similar platform shown in Fig. 2 (even in the car dealership), where the EmPatGen program automatically generates the 2D pattern (in DXF file).
2. In the second phase of the application of EmPatGen, with appropriate technology (for instance, with laser-texturing), this pattern could have been placed on the required car interior trim element.

With this system, EmPatGen Tool would help the product designer's job, and it is easier to reach the satisfaction of consumers. In the next section, the background of EmPatGen is presented.

### 3 Background of EmPatGen

There is no similar application to create a geometric pattern automatically. There are studies that tried to write a few patterns with mathematical language [14], however,
the steps are mainly manual (for example [15]). In a usual software such as Adobe Illustrator, Inscape and so on, it is possible to produce geometric pattern, but only a few types of them, and still in some cases, you should generate it manually. Because of this lack, a new approach of pattern generation process was needed.

Figure 5 shows the main milestones of this study. In this study, it was essential to find relations between emotions and geometries, and also an algorithm to develop a pattern automatically. And last but not at least the mathematical model that connects these and finalize the pattern.

3.1 Relationship between emotions and geometries

Design has 8 basic elements: line, shape, color, texture, tone, form, space and depth. [16] Since the output of EmPatGen is a pattern, the research focused on lines and shapes.

Basically, the idea is to create connections between geometric elements and emotions in order to create patterns based on consumer preferences. The previous primer researches have shown that in case of patterns, not only the basic geometries, but also the spreading of the patterns has impact on us, that is why literature studies have been made in the field of lines (that could define the spreading type of the patterns) and basic geometries as well.

Lines can express different feelings, moods based on their movement, that has been analyzed in many fields where it is relevant, for instance, in typography [17], in visual arts [18, 19] and architecture as well [20]. Figure 6 presents a collection from Landscape Architecture by John Ormsbee Simonds, that contains 48 Mood Lines. This collection is the most completed, and also validated by Zeven Design [21] with plenty of examples in the field of movie posters, paintings, photographs, game layouts and products.

There are studies about basic geometries as well [22, 23], and researchers have shown similar results about their meaning. Table 1 introduces the main geometries such as square, triangle and circle.

Besides these researches, own studies confirmed and expanded the information [7, 24] 3.1.1 and 3.1.2 chapters summarize this information, that was used to create input and output parameters.

3.1.1 Input parameters

1. First of all, attributes were collected that could connect to geometries according to the primer and seconder...
researches that have been introduced in the previous phase. Considering the mood lines and the meaning of shapes, the following parameters are distinguished:

- Dynamic/interesting
- Calming
- Aggressive
- Stable, organized
- Feminine
- Masculine, strong

2. Second of all, these attributes were collected under the moods: elegant—sporty, classic—youthful, feminine—masculine; because these feelings are mostly in connection with cars [9]. Elegant is calming and stable, and feminine, while sporty is dynamic, aggressive and masculine and so on.

### 3.1.2 Output parameters

To build a pattern, the following attributions were distinguished (Fig. 7):

1. Uniform scale ($r$)—Scale all sides of the geometry equally.
2. Non uniform scale (e)—Scale sides of the geometry.
3. Side (n)—Number of sides of the geometry.
4. Rotation (rot)—Rotate the geometry.

Related to pattern space
5. Row distance (VStS)—Distance of the rows of the pattern.
6. Amplitude (A)—The height of periodic waves in a row.
7. Dynamic Range (dRng)—The number of varying pattern members.
8. Dynamic shift (dSft)—The distance between same pattern members in neighboring rows.
9. Dynamic uniform scale (dScU)—The number of varying uniform scaled pattern members.
10. Dynamic non-uniform scale (dSnU)—The number of varying non-unif. scaled pattern members.
11. Dynamic rotation (dRot)—The number of rotated pattern members.

3.2 Mathematical model of EmPatGen

The mathematical model should be dealt with human factors, language tools, words, as well as soft borders in order to accomplish the concept presented above. For this, fuzzy logic is appropriate, which is one of the artificial intelligence methods [25].

Here are the steps for applying fuzzy logic, which are done in a software called MATLAB.

1. Specify input and output parameters as well as membership functions.
2. Set up a fuzzy rule set.
3. Process the input data.
4. Defuzzification of processed data.

Figure 8 shows the membership functions. Now in EmPatGen, it is possible to give input values from 1 to 10. Rating scale has been set considering simplicity for users. Other scales are to be further examined and revised in the future, since there are advantages for both of 1–10 and 0–10 and possibly other rating systems as well.

In the case of dynamic inputs, 1 is elegant and 10 is sporty. Between them, a linear transition can be seen. For outputs, here is an example that is showing the number of sides of basic geometries, that is a parameter related to Basic Geometry. For instance, this is set to be small from 3 to 5 sides, medium between 3 and 9 sides, and large in the case of more than 8 sides. In other cases, also trapezoidal and triangular functions were applied.

Figure 9 shows that the system has

- 3 inputs: dynamics, style, orientation
• 11 outputs: 4 for Basic Geometry and 7 for Pattern Space
• and 8 rules: that were created to cover all rages of inputs

For example, this is a 1 value of dynamic—which means absolutely elegant-, 1 value of style—which means totally classic- and also 1 value of orientation—which means a totally feminine- rule. Let me draw your attention to the other rules, that in this set do not live.

Thus, there are rules of sporty–youthful–masculine or elegant–youthful–feminine and so on.

The effects of providing an intermediate value are visible in Fig. 10. In this particular case, 2 rules are active since an AND connection works in the fuzzy system. It means that the rule will work if all the membership functions are applied. After reviewing the orientation input, it is clear that there are values only under the intersection of a red line (at the input value) and the membership function. In the Mamdani control algorithm, the lowest value is taken over by the output membership function. The area below the membership functions is summarized in the bottom line. It compares the active membership functions and takes the highest value. Defuzzification here is bisector.
Fig. 10  Fuzzy rule set and defuzzification 2

Fig. 11  EmPatGen example

type, which means that the two areas intersected by the red line have the same size. The red lines indicate the output values.

Figure 11 shows a result of EmPatGen with the following inputs: Dynamic = 5. Style = 5. Orientation = 6

4 Summary

With the software of EmPatGen, the goal is to create the most aesthetically pleasing geometric pattern based on the preferences given by consumers. The algorithm is basically able to make connection between emotions and geometric properties.

Previous studies have shown that in the case of geometric patterns, not only the basic geometry has an impact on people, but also the structure of the arrangement influences the consumers. This was called pattern space. Because of that, EmPatGen has rules for basic geometries—such as number of sides of the geometry or the angle of the rotation of the geometry—and for the pattern space—for instance, the distance of rows of the pattern or the angle of rows—at the same time.

At the future work, it is essential to validate the result patterns, that is why, physiological signs will be measured during the testing process.

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Compliance with ethical standards

Conflict of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

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