

ISASE 2020

System Advised Drawing of Tessellation based on Artful Thinking Process

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Abstract: Tessellation, as a regular pattern performance, is useful for aesthetic appreciation or commercial purpose due to its special visual affect. However, creating a tessellation is not a simple matter, especially for those non-professionals. Based on the visual patterns surveyed from existing samples, we firstly define an artful thinking process to guide the creation of tessellation. Secondly, we demonstrate a prototype system to advise the drawing according to the visual patterns recognized from the current drawing. The case study is applied with help from student volunteers: the defined artful thinking process is practical for non-professionals to follow. The demonstration system is able to classify drawings and give drawing advice based on classification results. In order to make the drawing advices more abundant and affective, we plan to add more categories including the associated emotions, and enlarge the drawing dataset.

Keywords: *Tessellation Visual Patterns, Artful Thinking Process, Drawing Classification, System Advised Drawing*

1. INTRODUCTION

Tessellation is a regular pattern performance. The created pattern has special visual effect and aesthetic experience. This aesthetic feeling can have a wide range of applications, and can be used in many kinds of business, such as the design of advertisement, product packaging, trademark, architecture, and mall event. There are certain difficulties to design or draw a tessellation that conforms to a certain visual pattern, either for those experienced professionals or the non-professionals. To overcome the difficulties, it is a challenge to help the non-professionals create tessellations in a practical way. In this paper, we propose an artistic practice of creating tessellation via system advised drawing based on artful thinking process.

Escher, a famous artist in tessellation, and also his followers, have created many impressive tessellations [1]. Their tessellations have many visual patterns inside, such as to replicate, transform, associate the visual elements. These patterns are exquisite but complex, requiring some aesthetic experience or ability that most people are weak at, thus not easy for them to practice. We survey the tessellation design patterns, then try to break down the drawing process by considering the practicability from simple to complex levels and define the hints to continue the drawing in steps.

Aesthetic experience is important, especially when

people encounter the opportunity to apply art either in work or daily life. Through a series of practice in methods, such as drawing tessellations, people could experience the joy or accomplishment of art. And their continuous aesthetic could make them deeper into art.

For this motivation, we propose system advised drawing of tessellation to alleviate the difficulty of people's drawing practice. To this end, we need to solve several problems: (1) to digitalize the drawings; (2) to learn and recognize the drawings, (3) to give system advice of drawings. In Section 2, we surveyed the visual patterns in exiting tessellation examples, and define an artful thinking process to guide the creation of tessellation. In Section 3, we demonstrate a system to classify the drawings, and give system advice based on the result of classification. The experiment is applied via the help from volunteering students: they practice the drawing by following the artful thinking process, and also provide images of their own drawing samples as the training data for us to build the model of drawing classifier. We further investigate the merits of application in Section 4, and finally discuss the remaining issues for future work in Section 5.

2. Artful Thinking in Creating Tessellation

In this section, we research on the visual patterns in tessellation, and the propose methods to create tessellation.

2.1 Related Work

The tessellation is a drawing or printing of combined tiles on surface; those tiles are usually geometric shapes with paintings filled inside. The study on tessellation is popular in fine arts, geometrics or computer graphics, to analyze the visual patterns of the structures, to tell the meaning or story hidden inside, or to create novel tessellation design.

Creating a tessellation is a challenging practice, which may involve the utilization of mathematical principles or visual patterns, and the user's personality such as their aesthetic experience and emotional inspirations. Escher created many famous tessellations [1], but his tessellation is not easy to learn or practice. David Bailey [2] studied Escher's artwork, and then used geometric gradient combinations to quickly decompose geometric figures into countless geometric pictures; he also mentioned some similarities between the Penrose puzzle and Escher's artistic graphics, and simplified the geometric tiles, such as triangles and squares. David Bailey's work is a simplification of creating tessellation. For example, he proposed a simple way of drawing birds inside the tessellation tile. His tessellation samples are mostly symmetric visual patterns, but has difficulty to support other patterns. After creating the shape of tiles, he suggests the last step to imagine a motif or suitable image to be filled into the tile. This is still a challenging practice for people who the lack aesthetic experience.

Computer as a tool has been widely used in graphic design, but could it assist the creation or imagination of new tessellation is an open question. Computer is not be able to perform better than humans in creativity. It might be difficult to tell the meaning of images generated by computers without the supervision by human beings. The supervision such as by manual corrections and improvements are still needed. On the contrary, computers can assist human to complete and give certain planning opinions. By interacting or simulating with computers, users can take the system advised drawings based on their feelings. We denote this as the system advised drawing, which is semi-automatic and user feeling oriented.

2.2 The Proposed Methods of Creating Tessellation

In order to realize the system advised drawing of tessellation, we propose semi-automatic methods to utilize computer technology for drawing. The drawing of tessellation from sketch will involve the creation of tessellation tiles and combination of tiles. To generate the geometric skeleton of the tile, we can start from drawing the edge, then divide the area bounded by the edge, and

then add or review drawings within the divided regions. And finally, is to represent the story after combine the tiles into a tessellation.

The tiles' edge will determine the boundary relationship when the tiles are combined into a tessellation. Since it is required to be less or no gap between the edge of the tiles, we have determine the edge (such as to form a symmetry tile) by imaging the tessellation overview. This can be a geometric shape with bended edges originate from a square. Computer could assist the drawing of tile's edge, for example by recognizing the shape of initial drawing, and provide a similar shape which has more elegant curve.

To further form the skeleton of the tile, we need to divide the edge-bounded region into several sub regions. We introduce a method which is different with David Bailey's way [2]. To integrate the proposed semi-automatic methods, we firstly try to find the center of the tile, and then draw new curves passing through the center of each side to form a twisted pattern. The number of curves, and the curves with different radians could produce various symmetric visual patterns. We can also create unsymmetrical visual patterns by applying irregular curves, and this curve could either passing through the center or crossing an arbitrary point within the tile so as to create an imagined skeleton.

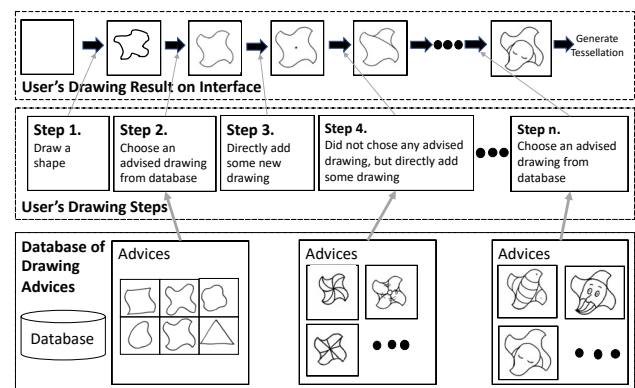


Fig. 1. Artful Thinking Process in Creating Tessellation

Based on the proposed method, we propose the artful thinking process (in Fig. 1) by utilizing the system to alleviate the difficulty of drawing tessellation. At first, the user can select the tessellation graphic shape on the interface, add a few strokes to the graphic after confirmation, and the system will give some design suggestions (some finished styles), and then modify the design of graphics based on the suggested samples. Finally, the user can modify it repeatedly. It will also give the closest graphic suggestion based on the added strokes, the user also can choose another type of tessellations, until

getting the graphic that the user who is satisfied with. User can also add and design a motif that fits the shape of the graphic in the selected graphic. In this paper, we do not solve the problem of internal tessellation. Although we tessellate the same shape graphics, the patterns in the graphics are not necessarily the same.

It is a research issue here to recognize the initial skeleton of the drawing and recommend modification of the skeleton. Once the skeleton of the tile is created, we shall have a brief image what it would look like, and then fill the motif into the sub-regions. It is necessary user to judge whether it is a good and effective tile shape. There are also some rules can be followed, firstly to make the tile as an enclosed geometry shape, no drawings or lines exceeding out of the edge; secondly, the filled motif shall match with divided regions; thirdly, the combination of multiple tiles needs to ensure the integrity. And final, the tessellation shall represent some story, such as to reflect the affective expressions of the creator.

3. System Advised Drawing of Tessellation

In this section, we train a drawing classifier to recognize the visual objects in drawing, and demonstrate a system advised drawing based on the classification result.

3.1 Drawing Classification

We set up three drawing categories of tessellation tiles to perform the experiment of drawing objects recognition. There are 100 samples in each category, and 90% will be used for training and 10% for evaluation.

Tab. 1. Drawing Categories of Tessellation Tiles

ID	Shape	Border	Filled Painting	Amount
1	Circle	Black	Arbitrary	100
2	Flag	Black	Arbitrary	100
3	Propeller	Black	Arbitrary	100

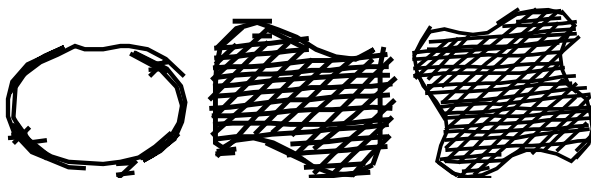


Fig. 2. Vectorized Drawing of Tessellation Tiles in Training Dataset

The data set preparation is done by following steps below. Experiment volunteers provide images of their drawing in PNG format. Every PNG is vectorized into vectors [3] in SVG format. The vectorized drawing samples is given in Fig. 2. Vectors in each SVG file is re-

scaled so that its maximum coordinate does not exceeds 255. The scaled vector and its category information is then output into JSON file. And the JSON files in every category are merged and converted to a NDJSON file, which is same to the format defined by the Quick, Draw! Dataset [4]. In this dataset, there are only categories and coordinators of drawing path, no time series of drawing. But this will not affect the classification result too much.

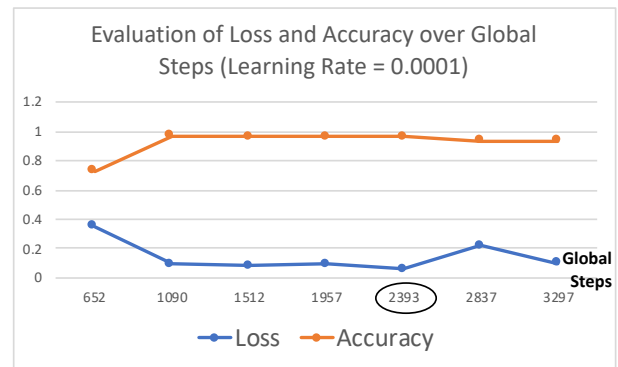


Fig. 3. Evaluation of Loss and Accuracy over Training Interactions (A Sample Experiment)

Based on the tutorial in [5], we re-implemented a neural network model based on TensorFlow framework to classify the drawings. The model is trained in a MacBook computer with 1.4 GHz Intel Core i7 processor. The training experiment (see Fig. 3) evaluation reports that the of accuracy reaches over 95%, which accuracy is sufficient to demonstrate the drawing classification of a small number of categories.

3.2 Drawing Advice based on Artful Thinking Process

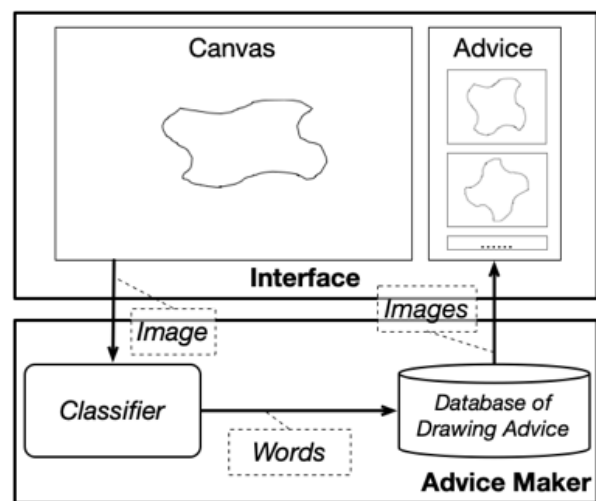


Fig. 4. Components for System Advised Drawing

Fig. 4 illustrates the components for the system advised

drawing, including the system interface, advice maker, and advice operator.

The system interface consists of a canvas panel and advice panel. When a user draws on the canvas, the system keeps on updating the advices accordingly. The interface periodically monitors user's drawing, and then send it to the advice maker. The advice maker generates the advice for next drawing action based on the classification results. For example, in Fig. 5, the system can recognize user's initial drawing in Fig. 5-a as propeller, and then recommend user to draw petals and then a flower in steps as show in Fig. 5-b and 5-c. Once the unit design is picked, a tessellation can be generated as shown in Fig. 5-d.

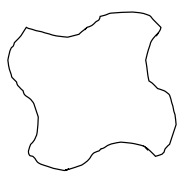


Fig. 5-a. Propeller



Fig. 5-b. Petals

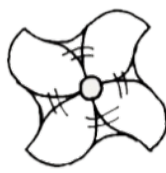


Fig. 5-c. Flower

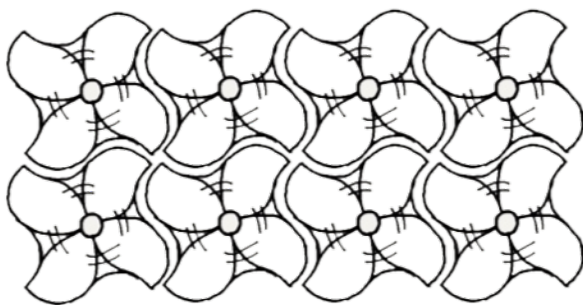


Fig. 5-d. Sample of Generated Tessellation

Fig. 5. Drawing Advice based on the Artful Thinking Process

The current designed artful thinking process defines the advice generation based on the random selection of images which are associated with the words output the classifier. The advice operator contains the function to add changes to the canvas according to the advice, such as replacing the current drawing by the recommended image. After finishing the drawing of the tessellation unit, the system then reproduces the unit of tessellation design into a tessellation artwork.

Giving the advice for drawing in this system is the different function from the Google's Quick Draw prototype. The current demonstration system has only limited number of recognizable drawing categories, and the advice database is also limited. These two limitations can be solved by the following approach. Besides collecting more drawings from the volunteers, other exiting drawing datasets can be utilized to train the model for recognizing more drawings. And people who are good

at drawing could contribute the images to enrich the advisable database. Based defining more association between words and images, learning from users' behavior can also be a feasible direction to make the advice more personalized.

4. Discussion and Future Works

This work shows a practice of system advised drawing of tessellation. According to a series of methods, tessellation can also be integrated into life, such as commercial advertising, shopping mall marketing, extracting features of product images. Based on the related work study, we propose our semi-automatic methods of drawing tessellation by utilizing system support, which includes the digitization of the drawings, the recognition of the drawings, and the advising to the next drawings.

The case study is applied with help from student volunteers: the defined artful thinking process is practical for non-professionals to follow. The demonstration system is able to classify drawings and give classification-based advice. As for future work, we plan to revise the artful thinking process in a more fine-grained way and train the classifier to recognize more drawing patterns to advance the system advice. We can also enrich the existing category in database by adding emotion tags to the drawing samples to make the affective system advice to users' drawing as a future application.

ACKNOWLEDGMENTS

We want to give thanks to the volunteering support provided by the students from Computer Network Laboratory in the University of Aizu.

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