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Connected Three and Four Straight Lines Composition in IFS Fractal Model with Unique Color inside Unique Shape of Closed Areas as an Artistic Symmetrical Image Pattern

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ABSTRACT

A symmetrical image pattern can be generated in an IFS fractal model with a unique color inside a unique shape of closed area by means of a random iteration algorithm in two modes, the inverse problem and decoding modes. The inverse problem mode of the algorithm can be used to generate connected straight lines that can represent any characters in the form of IFS code. After decoding the IFS code into a fractal object that has several neighborhoods with a closed area then a pattern of colors with unique color inside each unique shape of the closed area can be applied to have the artistic symmetrical image.
Keywords: *IFS fractal model, symmetrical image pattern, straight lines composition, random iteration algorithm, inverse problem*

1. INTRODUCTION

An artistic symmetrical image can be generated easily by means of inverse problem or encoding algorithm then by generating or decoding algorithm, the designs decoded into images based on iterated function system (IFS) fractal model. In general, the term of inverse problem is a reverse process from a prototype of output into generic form of input, so based on the feedback finally the inverse problem gives the desired generic form of input after repeating the process by the try and error efforts. In this case, there are two basic steps. The first step is how to design the appropriate templates or patterns in the form of lines as boundaries of several neighborhoods of closed areas to be filled in by chosen desired colors uniquely according to the shape of the area. The second step of course is how to generate the images of fractal objects from those design patterns. In the decoding process itself there are several phases depending on how dense the resolution or how big the dimension of the images in pixels horizontally and vertically.

In this paper as examples there are three models, the first two models represent two different characters-like represented by three and four connected straight lines and the last model is the combination of the two characters-like consists of seven connected straight lines. In the first phase the dimensions of the image are 500 to 500 pixels and every next phase the dimensions are doubled. In the case of the third model that is more attractive is proceed until phase 3, so the dimension of the final artistic image is 2000 to 2000 pixels with six colors applied into six uniquely shape of areas as the last chosen example.

At least there are 22 related works to the topic of this paper. Umar et.al. published their research result on creation of fractal objects by iterated function systems model in two algorithms, the deterministic and the random iteration algorithms [1]. Darmanto et.al. was presented his and their research results in animating fractal objects based on IFS fractal model by implementing random iteration algorithm [2, 3, 4]. Zhang et.al conducted research on IFS fractal image generation method based on Markov random process that has better controllability parameter model using double random process [5]. Yue used a new method to magnify the partial image based on the IFS fractal model that has details at every scale [6]. Tao et.al. analyzed the influence of the generation of each affine transformation of IFS code on the appearance of the fractal image by controllability parameters to simulate different forms of fractal trees that can be used as information stenography [7]. Ye and Li generated a plain image content dependent pseudo-random sequence to change pixels' positions to design an adaptive image encryption scheme with a permutation-diffusion structure [8]. Rama et.al used boundary-tracking algorithm and the output is shaded using Z-buffer algorithm to create and reveal the 3D IFS fractal images as actual time image representation [9].

Prasad and Katiyar proposed rational Bezier derived from the de Casteljau subdivision algorithm curves as attractors of some iterated function systems [10]. Dym et.al. used IFS extensively to generate natural-looking landscape textures in artificial images as well as for compression of natural images that human visual systems may lock in on self-similarities and combine with the capacity of deep neural network (DNN) to efficiently approximate the IFS [11]. Zhao and Liu introduced a new technique in the image compression field based on affine contractive transforms as a review [12]. Qiang provided a new fractal encoding method based on minimum iterated function systems by using minimum block set to reduce the redundant domain block set and removing the constraints on scaling coefficient [13]. Sheikh et.al. explored the use of genetic algorithms in the field of fractals generation and focused on handling and manipulating the point in 2D space based on the principles of genetics to search for hidden similarities apparent among the data points [14]. Zhuang et.al. proposed morphing IFS fractal method by calculating local attractor's course convex-hull and selecting rotated matching between two IFS codes [15].

Amrutha and Gayathri designed microchip antenna by using fractal geometries by IFS model [16]. Galvez and Iglesias constructed 2D fractal image by modified memetic self-adaptive firefly algorithm with three additional features for better performance [17]. Varghese and Krishnakumar suggested the importance of parallel computation techniques such as general-purpose graphical processing unit (GPGPU) and compute unified device architecture (CUDA) in fractal-based image compression algorithms that can reduce the encoding time significantly [18]. Van Loocke proposed polygon-based fractal image of compressed IFS to generate various fractal textures as a new version of recurrent IFS method [19]. Zhu and Chen surveyed the research on fractal image coding methods focused on coding time by combining DCT or wavelet method and block-based division [20]. Huang et.al investigated a fractal-based number generator that has extremely high similarity with the original input curves or folds consistently [21]. Saidi and Ali proposed a new technique based on a fractal dimension that represents image complexity to be used as an index for the domain blocks, to facilitate the searching process for each range block for enhancing image compression performance [22]. To be compare with the previous publication as the baseline of this paper, Darmanto had studied IFS fractal model to generate the tiling motif designs by means of just two and three generic lines composition [23].

2. METHODOLOGY

In the iterated function system of fractal model, the fractal objects are represented as a collection of iterated function system code (IFS code) as the result of an encoding process. The IFS code set actually is the collection of affine coefficients of the fractal object that consist of six coefficients alphabetically from 'a' to 'f'. The code can be generated by the rule iteratively represented by the collage theorem to become the fractal object image as the result of the decoding process. The collage theorem is related to the recursive design process and self-similarity as the main key of the fractals itself, any parts of collage area resemble the whole in miniature fashion. The methodology discussed in this paper is based on the purpose of the research, that is to create the artistic symmetrical pattern of image based on the collage theorem of fractal in which coloring the neighborhood unique areas inside a closed boundary plane by several different colors is necessary.

To accomplish that purpose, then there is a need to design a composition of at least three straight lines crossing one to another as the boundary of a simple area. In the case of creating an interesting example, the methodology at least consists of two things. The first thing is how to compose several straight lines in which there are one, two or more lines crossing to others, and forming two known characters. The second thing is how to combine the two characters into one composition as a word. To the point, there are three examples chosen to be discussed in this paper. The first example consists of 3 straight lines forming an "H-like" character. The second example consists of 4 straight lines forming an "E-like" character. The last example combines the two characters into a word "HE".

The design formation of the thick lines can be seen in Figure-1 and Figure-2, as the first and second example representations. By means of the collage theorem, the area to be covered by collage members can be fulfilled by non-void fractal objects in the form of lines. To do this effort, there is at least one strategy as a design way in composing the collage members. The way to have the symmetrical pattern in first step is by positioning three slim rectangle as collage members for an "H" design and an "E" design each in a quarter area, for instance the first step is starting form the third quarter area in southwest direction from the center as can be seen in Figure-1 and Figure-2 mentioned above. The second step is mirroring the third quarter area to the fourth quarter area in the southeast direction from the center. The third step is mirroring the two quarter areas mentioned above to the north direction as the first and second quarter areas in the northwest and northeast positions from the center respectively as can be seen in Figure-3 and Figure-4 as the intermediate results of both examples. The results can be obtained at least in three phases as discussed in detail in the result and discussion section.

The two results also can be represented by two sets of IFS code as can be seen in Table-I on the left side and Table-I on the right side. The resulting fractal object fully occupies the whole area if there are several straight lines reaching to the edge of the whole area that consists of four quarter areas mentioned earlier. The results in Figure-3 and Figure-4 look like two compositions of several thick lines. To have the formation of several thin lines rather than thick lines, then the coefficient- 'a' and coefficient- 'c' in an IFS code as a collection of affine coefficients of Table-I at left side and Table-I at the right side are updated into a collection of zero values or then only the vertical factors of collage members are preserved and also the other coefficients are normalized in order to have the perfect shapes of fractal objects. The combination of the "H-like" and "E-like designs" becoming a new "HE-like" design in original and normalized versions of IFS code sets are displayed in the Table-II and Table-III at the Appendix

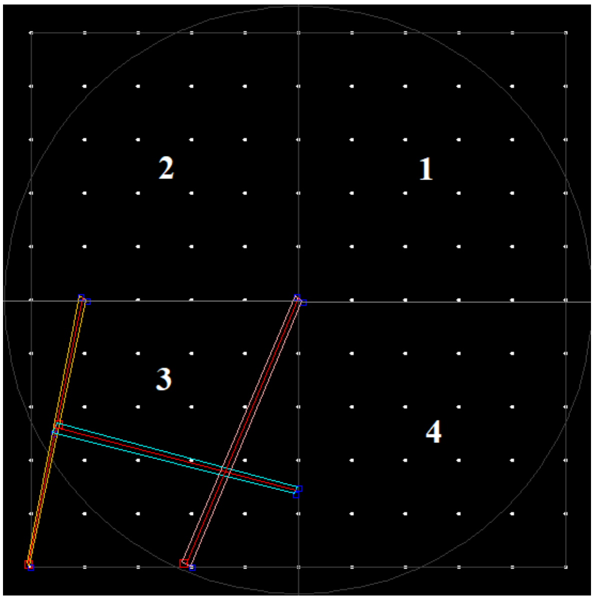

Figure-1. “H-like” design composition consists of three collage members in connected slim rectangles form inside the South-West quarter area from the center of area

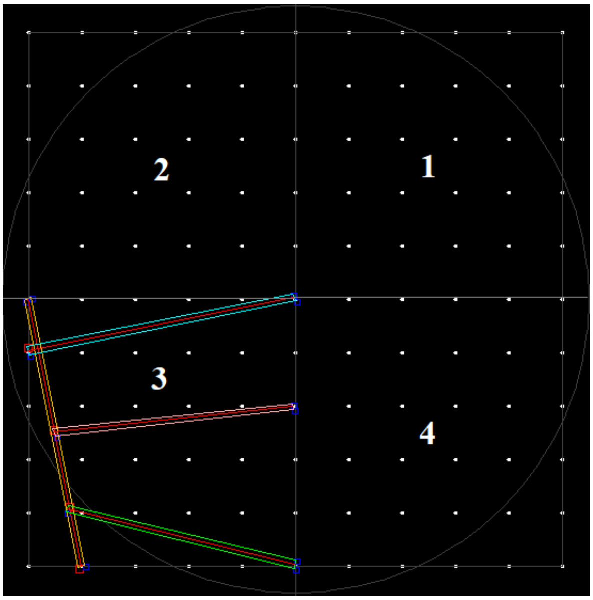

Figure-2. “E-like” design composition consists of four collage members in connected slim rectangles form inside the South-West quarter area from the center of area

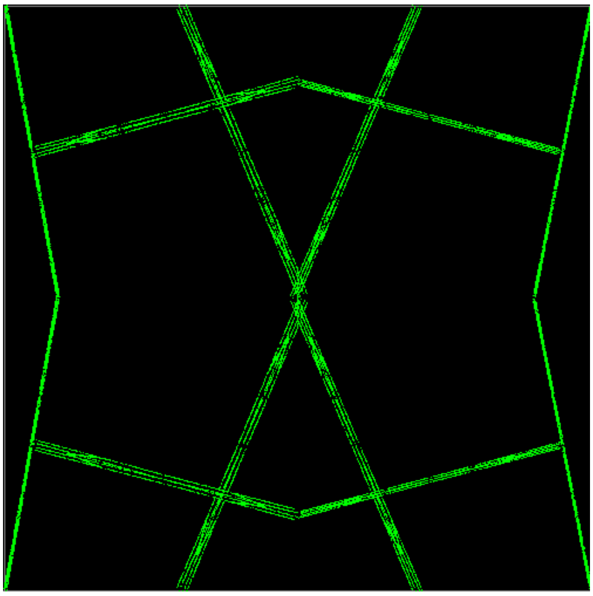

Figure-3. Four quarter areas implementation of “H-like” design composition in Figure-1

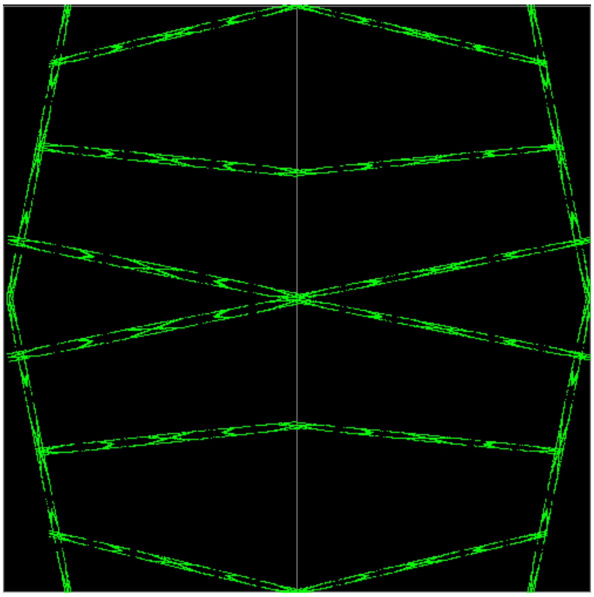

Figure-4. Four quarter areas implementation of “E-like” design composition in Figure-2

3. RESULTS AND DISCUSSION

To have the artistic symmetrical images generated in a fractal model can be accomplished in several phases of the after-design process. At least three phases are needed, for example in phase-1 the obtained image has the dimension property in 500 to 500 pixels, in phase-2 by mirroring process based on x axis and y axis the new image then will have the dimension property in 1000 to 1000 pixels. Finally, in phase-3 the new image will have the dimension property in 2000 to 2000 pixels with the same scheme mirroring process, and so on as final resolution of image is required. The choice and combination of colors applied into the unique shape of bounded area is another factor that affecting the result as can be seen in Figure-12 with the highest number of colors as the final model.

The resulting fractal images of the “H-like”, “E-like” and “HE-like” designs generated by the IFS decoding process can be seen in figures in sequence starting from Figure-5 until Figure-12. Figure-5 shows the "H-like" of the three colors version resulted in phase-1. Figure-6 shows the "E-like" of the three colors version resulted in phase-1. Figure-7 shows the "H-like" of the three colors version resulted in phase-2. Figure-8 shows the "E-like" of the three colors version resulted in phase-2. Figure-9 shows the "H-like" of the three colors version resulted in phase-3. Figure-10 shows the "E-like" of the three colors version resulted in phase-3. Figure-11 shows the "HE-like" of the four colors version resulted in phase-2, and Figure-12 shows the "HE-like" of the six colors version resulted in phase-3 respectively.

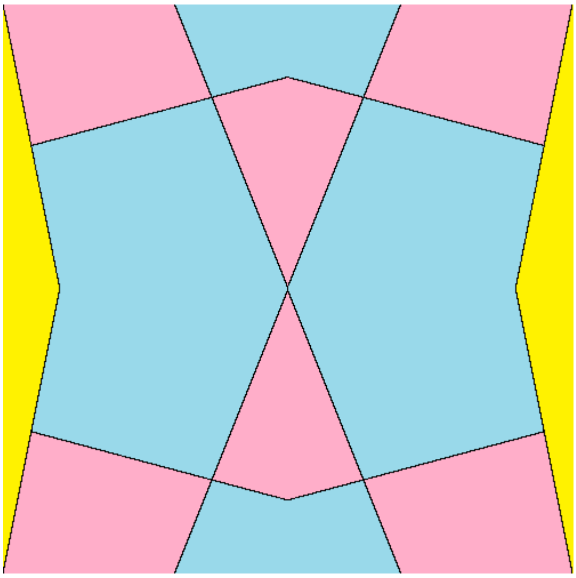

Figure-5. **Three colors version of "H-like" normalized version in phase-1**

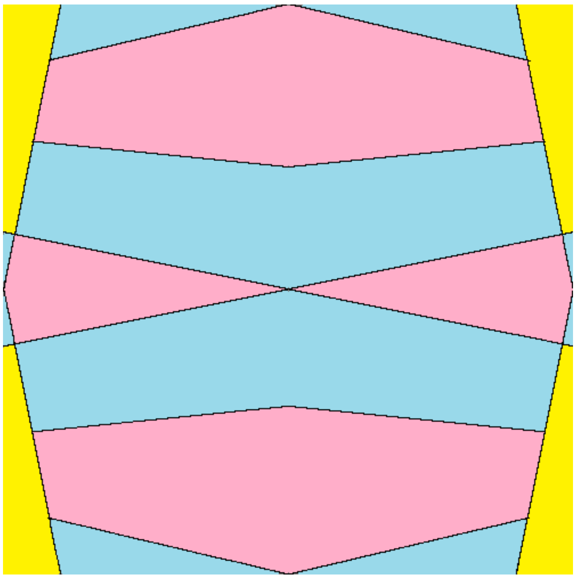

Figure-6. **Three colors version of "E-like" normalized version in phase-1**

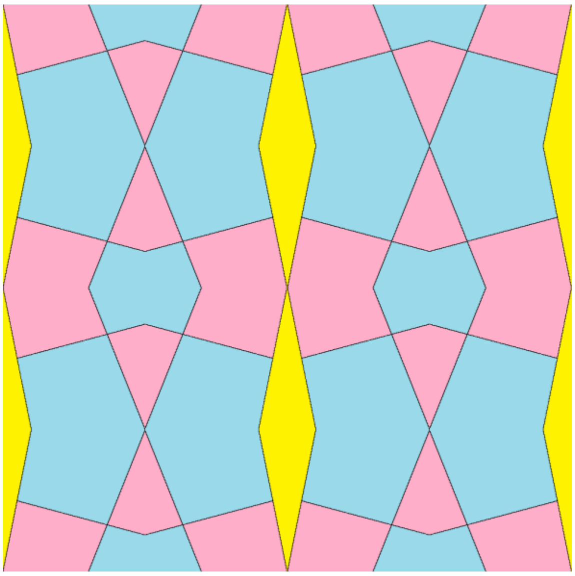

Figure-7. Three colors version of "H-like" normalized version in phase-2

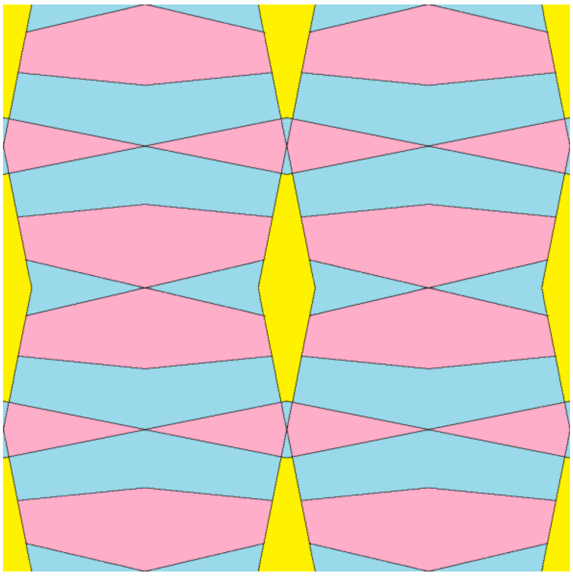

Figure-8. Three colors version of "E-like" normalized version in phase-2

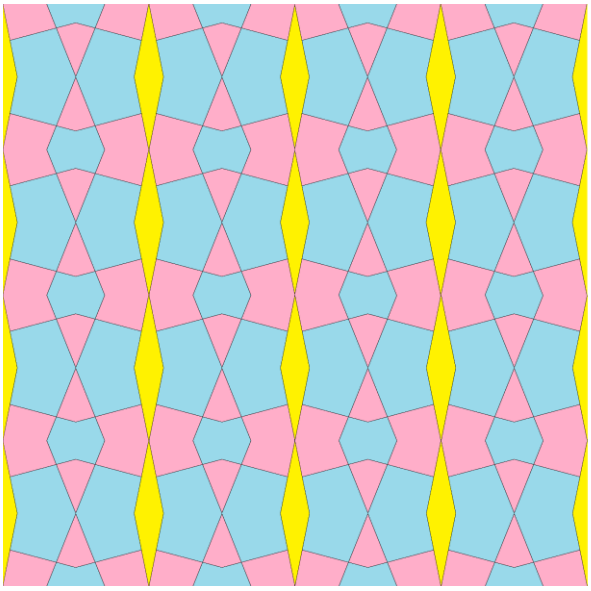

Figure-9. Three colors version of "H-like" normalized version in phase-3

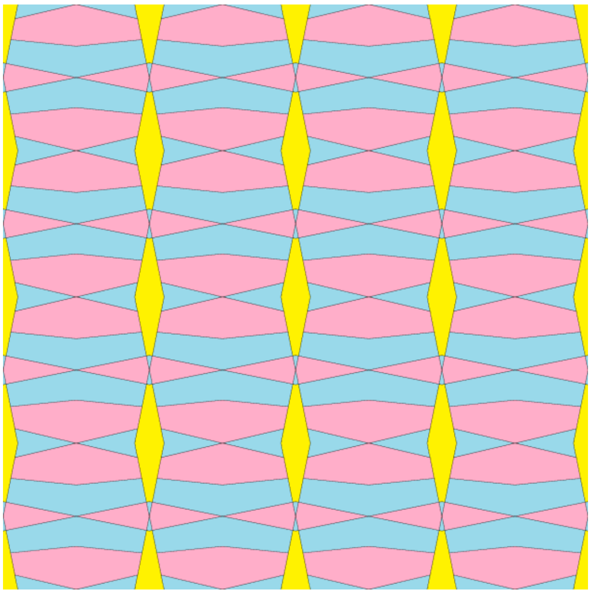

Figure-10. Three colors version of "E-like" normalized version in phase-3

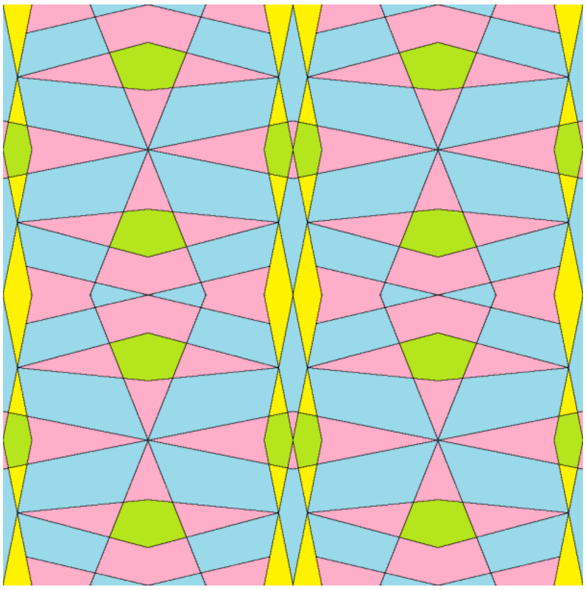

Figure-11. Four colors version of “HE-like” normalized version in phase-2

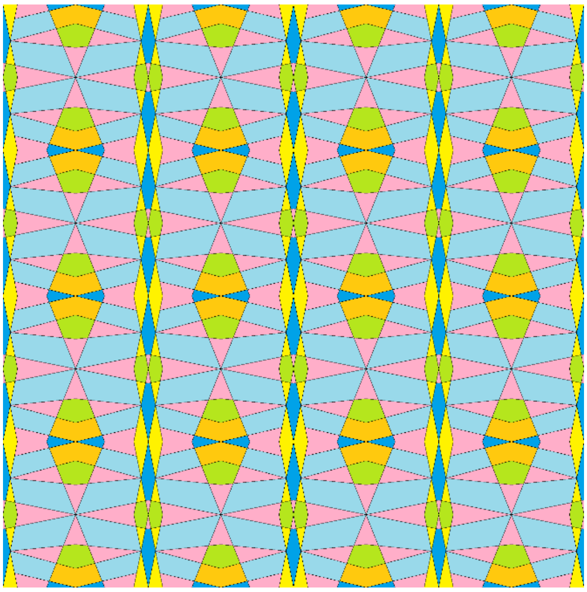

Figure-12. Six colors version of “HE-like” normalized version in phase-3

4. CONCLUSION

To have unique closed areas in neighborhoods fashion delimited by straight lines in phase-1 of generating composition straight lines, the lines should be reached the edge of the image or connected to other lines, then a unique color can be applied by the algorithm of color flood without leaking. The easiest way to have the symmetrical image generated by random iteration algorithm to decode IFS code of straight-line composition, is by mirroring the image from previous phase vertically and horizontally, so the result is as a composition of four tiles or has double dimension. The number of chosen unique colors can be increased in the next phases with double dimension. The number of phases needed depends on the chosen requirement. In general, the IFS fractal model can be used to design the artistic symmetrical images better than conventional ways that the IFS fractal model can be repeated and modified any time efficiently, because it is not necessary to start over again from a scratch.

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Appendix:

Table-I. IFS code as a set of affine coefficients (a to f) of the "H-like" design (left) and the "E-like" design (right) in a quarter area

a	b	c	d	e	f	a	b	c	d	e	f
0.004	-0.09	0.005	0.500	-0.50	-0.001	0.012	0.10	-0.001	0.500	-0.39	0.003
-0.001	-0.45	0.018	-0.12	-0.45	-0.250	0.003	-0.49	0.016	0.098	-0.49	-0.40
0.016	-0.21	0.008	0.498	-0.20	-0.001	0.006	-0.44	0.014	0.045	-0.44	-0.24
						0.001	-0.42	0.012	-0.10	-0.42	-0.10

Table-II. A set of affine coefficients of "HE-like" design in pair of four quarter areas: Original (thick lines formation) version

a	b	c	d	e	f	Note: 4 Quarter areas in pairs
0.004	0.09	-0.005	0.5	-0.409	-0.500	Affine coefficients of "H-like" collage members in NW area from center
-0.0	0.45	-0.018	-0.12	0.0	-0.869	
0.016	0.21	-0.008	0.498	0.0099	-0.502	
0.012	-0.1	0.0	0.5	-0.49	-0.503	Affine coefficients of "E-like" collage members in NW area
0.003	0.49	-0.016	0.098	0.0	-0.502	

0.006	0.44	-0.014	0.045	0.0	-0.714	from center
-0.0	0.42	-0.012	-0.1	0.0	-1.000	
0.004	-0.09	0.005	0.5	0.4099	-0.500	Affine coefficients of "H-like" collage members in NE area from center
-0.0	-0.45	0.018	-0.12	0.0	-0.869	
0.016	-0.21	0.008	0.498	-0.009	-0.502	
0.012	-0.1	0.0	0.5	0.49	-0.503	Affine coefficients of "E-like" collage members in NE area from center
0.003	0.49	-0.016	0.098	0.0	-0.502	
0.006	0.44	-0.014	0.045	0.0	-0.714	
-0.0	0.42	-0.012	-0.1	0.0	-1.00	
0.004	-0.09	0.005	0.5	-0.50	-0.00	Affine coefficients of "H-like" collage members in SW area from center
-0.00	-0.45	0.018	-0.12	-0.45	-0.25	
0.016	-0.21	0.008	0.498	-0.20	-0.00	
0.012	-0.1	0.0	0.5	-0.39	0.003	Affine coefficients of "E-like" collage members in SW area from center
0.003	0.49	-0.016	0.098	-0.49	-0.4	
0.006	0.44	-0.014	0.045	-0.44	-0.24	
-0.0	0.42	-0.012	-0.1	-0.42	-0.10	
0.004	0.09	-0.005	0.5	0.5	-0.0	Affine coefficients of "H-like" collage members in SE area from center
-0.0	0.45	-0.018	-0.12	0.45	-0.25	
0.016	0.21	-0.008	0.498	0.2	-0.0	
0.012	-0.1	0.0	0.5	0.39	0.003	Affine coefficients of "E-like" collage members in SE area from center
0.003	0.49	-0.016	0.098	0.49	-0.4	
0.006	0.44	-0.014	0.045	0.44	-0.24	
-0.0	0.42	-0.012	-0.1	0.42	-0.1	

Table-III. A set of affine coefficients of "HE-like" design in pair of four quarter areas: Normalized (thin lines formation) version

a	b	c	d	e	f	Note: 4 Quarter areas in pairs
0.0	0.1	0.0	0.5	-0.4	-0.500	Affine coefficients of "H-like" collage members in NW area from center
0.0	0.45	0.0	-0.12	0.0	-0.869	
0.0	0.2	0.0	0.5	0.0	-0.500	
0.0	-0.1	0.0	0.5	-0.5	-0.500	Affine coefficients of "E-like" collage members in NW area from center
0.0	0.5	0.0	0.1	0.0	-0.500	
0.0	0.45	0.0	0.045	0.0	-0.714	
0.0	0.425	0.0	-0.1	0.0	-1.000	
0.0	-0.1	0.0	0.5	0.4	-0.500	Affine coefficients of "H-like" collage members in NE area from center
0.0	-0.45	0.0	-0.12	0.0	-0.869	
0.0	-0.2	0.0	0.5	0.0	-0.500	
0.0	-0.1	0.0	0.5	0.5	-0.500	Affine coefficients of "E-like" collage members in NE area from center
0.0	0.5	0.0	0.1	0.0	-0.500	
0.0	0.45	0.0	0.045	0.0	-0.714	
0.0	0.425	0.0	-0.1	0.0	-1.000	
0.0	-0.1	0.0	0.5	-0.50	0.0	Affine coefficients of "H-like" collage members in SW area from center
0.0	-0.45	0.0	-0.12	-0.45	-0.25	
0.0	-0.2	0.0	0.5	-0.2	0.0	
0.0	-0.1	0.0	0.5	-0.4	0.0	Affine coefficients of "E-like" collage members in SW area from center
0.0	0.5	0.0	0.1	-0.5	-0.40	
0.0	0.45	0.0	0.045	-0.45	-0.25	
0.0	0.425	0.0	-0.1	-0.425	-0.10	
0.0	0.1	0.0	0.5	0.5	0.0	Affine coefficients of "H-like" collage members in SE area from center
0.0	0.45	0.0	-0.12	0.45	-0.25	
0.0	0.21	0.0	0.5	0.2	0.0	

0.0	-0.1	0.0	0.5	0.4	0.0	Affine coefficients of "E-like" collage members in SE area from center
0.0	0.5	0.0	0.1	0.5	-0.40	
0.0	0.45	0.0	0.045	0.45	-0.25	
0.0	0.425	0.0	-0.1	0.425	-0.10	