EYE TRACKING BASED ANALYSIS OF EFFECTS OF MOTIF COMPOSITION ON IMPRESSIONS OF PAINTINGS

In the case of Katsushika Hokusai's "Thirty-six Views of Mount Fuji"

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Abstract: The presence of pictures that people recognize as great beyond the borders of cultural differences over 100 years could suggest that such paintings would have certain aesthetic elements in common, and if people are able to recognize them through a shared sense of beauty, it might be able to study what kinds of properties influence people's evaluation of paintings. This paper investigates influences of motif compositions on impressions of pictures. In the first experiment, participants were asked to answer their impressions of the printings using two kinds of rating scales: information rate scale and semantic differential scale, where "symmetry", "complexity" and "order" are defined as the elements of "beauty". Results showed that these three perceptual features influence strongly on people's impressions. However, this experiment poses some questions. Do participants sense the existence of the golden ratio from motif composition? In recognizing that the ratio had been broken, did their impressions change as a result? Do their impressions change according to degrees of symmetries of motif, no matter if the golden ratio exists? To find answers to these questions, we conduct the second experiment to analyze the relationship between motif compositions and gaze movements detected by an eye-tracking system.

Keywords: Beauty of Paintings, Motif Composition, Golden Ratio, Eye-tracking

INTRODUCTION

BACKGROUND AND PURPOSE

There are pictures that have been almost universally recognized as great for over 100 years, such as Da Vinci's "The Last Supper" and Monet's "Water Lilies." Their existence suggests that there are certain common aesthetic elements among great paintings, and if people can recognize them through a shared sense of beauty, we can identify the properties that influence people's evaluation of paintings.

Many theorists dating back to ancient Greece saw that "one of the factors of beauty is symmetry" [Arnheim(1974),Birkoff(1933),Gombrich(1984),Humphery(1997)], and symmetry-based order is also a factor [Birkoff(1993)]. Birkoff, who described the two defining features of beauty, complexity [Eisenman(1967),Berlyne((1970),Jacobsen(2002)] and order [Birkoff(1933)] as the aesthetic properties, suggested that perceptual features and beauty are closely related. With regard to "symmetry," recent research found that "sexual attractiveness is strongly related to the degree of body symmetry as sex-typical bodily characteristics function as a signal of underlying developmental stability, and such research therefore predicted that these characteristics would negatively correlate with FA in bodily features in general" [Brown(2008)]. From this theory, one may assume that people would have innate criteria of "beauty." The argument of this theory is that there can be no existence of a perfect bilaterally symmetric body, but humans know instinctively that a high degree of body symmetry indicates its underlying genotypic quality, hormonal and health status, competitive ability, reproductive potential, or some combination of these factors; thus, people tend to be attracted to another sex peer with a highly symmetric body. One may then assume that people always instinctively judge whether the object is bilaterally symmetric when they see anything. If bilateral symmetry can be considered one of the factors of beauty [Arnheim(1974), Birkoff(1933),Gombrich(1984),Humphery(1997)], people would have instinctive judgment of whether the target is beautiful; moreover, this judgment should be instinctively based on competition for survival. One theory holds that a perceptual feature such as symmetry is processed during the initial phase in the psychological model of the aesthetic experience judgment [Leder(2004)].Based on these issues, one may think that judgment of the aesthetic level of beauty should be decided within a few seconds, at the initial sight.

In this study, we hypothesize that beauty should be easy-to-understand, super-rational, implicit knowledge, and the purpose of the study is to construct an automatic recognition model of aesthetic evaluation that can measure the level of beauty underlying systematic algorithms. First, focusing on a visual art such as a painting, we investigated which elements make paintings beautiful.

We adopted the "golden ratio" as one of the scales of beauty; this ratio (1:1.618) widely exists throughout nature and in the arts, such as in the Khufu Pyramid of Egypt (the ratio of the height of its triangular face to half the side of its base), the Venus de Milo (the ratio of its body proportions), the chambered nautilus shell (the ratio of its spiral structure), and so forth. The golden ratio has been introduced into much research that discusses the nature of beauty; for instance, in various art domains, researchers confirmed the existence of the golden ratio by adding auxiliary lines into compositions that used it [Livio(2003)]. In the Oriental art domain, researchers used it for analyzing the structural ratio of Buddha statues [Matsubara(2008)], and Kansei engineering adopted it to analyze the properties of the attractiveness of a human smile [Sugawara(2004)].

The psychological model of aesthetic experience judgment [Leder(2004)] showed that affective processing is defined in five steps: perceptual analyses, implicit memory integration, explicit classification, cognitive mastering, and evaluation. These affective evaluations are sequentially processed. Perceptual features like symmetry, complexity, and order are processed in the initial phase. The processing of these perceptual features tends to elicit positive emotions because of a significant feature they hold, which is an "easy to identify stimuli's physical properties" [Reber(2004)], as indicated by psychological and physiological findings. We followed these traditional theories, and the focus of this experiment was to explore correlations between the perceptual features and affective state induced by stimuli.

This study investigated the influence of motif composition on people's impressions of Hokusai's paintings, particularly focusing on their perceptual features. In this analysis, we adopted the perceptual features symmetry, complexity, and order. As relevant research suggests, "beauty induces pleasurable experience" [Herzberger(1989), Santayana(1995), Tatarkiewicz(1970)]; therefore, we used "pleasant-unpleasant" as the affective state factor, and "aroused-unaroused" as the influential factor that causes a change in feeling. We asked participants to evaluate the original picture and a re-worked version, in which the motif composition had been changed, to analyze the relation between perceptual features and affective impressions of paintings.

If a relationship is revealed, the processes behind the human aesthetic experience is further clarified and enables construction of an automatic recognition of aesthetic evaluation that can measure the level of beauty underlying systematic algorithms as the final goal of our study. First, in focusing on a visual art such as painting, we investigated which elements make paintings beautiful.

1. STANDPOINT OF BEAUTY

As the factors of the beauty of paintings, two aspects: physical properties make people sense beauty and psychological properties make people feel physical responses such as "beautiful." In this study, we defined physical factors as attributed to material nature, and psychological factors as attributed to psychological nature. Thus, psychological factors can be considered perceptual factors that recognize objects as creating meanings such as symmetry, complexity, and emotional factors such as pleasantness caused by perceived features. We defined "measure" as the level of influence of effect for the impressions of beauty caused by physical and psychological factors.

1.1. Hokusai's painting style

Previous studies evaluate Hokusai's paintings as having "elements of surprise," being "full of wit" and "unpredictable" [Fukumoto(1947), Narasaki(1980), Tsuji(1972), Ukiyo-e Society(1994), Yanagi(1957)]. We believed that such evaluation would result from his works having certain influential factors that arouse such positive responses.

Strong relationships exist between positive awareness and pleasantness [Fujimoto & Suzuki(2007), Russell & Block(1985)], and so one could say that Hokusai's works somehow cause pleasant feelings. Haltmann, who proposed a structural analysis of beauty, said that the basic structure of the acceptance effect in aesthetic experience comprises sensuous and inner intuition, and only when people sense pleasantness from these factors' interaction, does the object become beautiful [Haltmann(2001)]. Because intuition is in the basic structure of aesthetic experience and pleasantness, and the pleasantness feeling based on that institution and perception of beauty are explained as very close in this research, the psychological factor that Hokusai attempts to elicit should be "pleasantness." Let us examine how he attempted to convey "pleasantness" in his work.

1.2. Hokusai's method

For Japanese woodblock artists, the artistic process or technique was a valuable secret, so that most of them were reluctant to show it, but Hokusai, who was not only a gifted woodblock artist but also a talented educator, published many text books such as "Hokusai manga" to mentor many pupils. Through these teaching books he revealed his distinguishing characteristic method of composition. For instance, according to "Ryakuga-Haya-Shinan" (One point lessons for rough drawing), published when he was 53 years-old, he described the method of drawing with a compass and scale, based on the fundamental rule that the basic shape can be a circle and triangle [Yanagi(1957)]. Researchers have noted that in "Thirty-six views of Mount Fuji," he tried to resolve natural forms to perfect geometric figures [Tsuji(1972)]. Thus, his practice concurs with Cezanne's famous words, "The whole configuration can be summarized as circles, circular cones, and circular cylinders" [Zeki(2000)]. For Hokusai, there is no doubt that the geometrical composition was his vital strategy to create his characteristic work.

Regarding his composition method in "Thirty-six views of Mount Fuji," of a total of 46 pictures, 2 adopted 2-part-segmentation, 17 adopted 3-part-segmentation, 8 adopted both odd-even segmentation, and others adopted Hokusai's distinctive method called "Hokusai's 3-part-segmentation", "telescopic method", "back and forth placement of triangles", "circle and triangle composition", and so forth [Yanagi(1957)].

The "telescopic method" is the manner of using certain motifs such as barrels, waves, and bridges to resemble a peephole, and set Mount Fuji inside the hole, to make the mountain appear from the small place. "Back and forth placement of triangles" describes triangle motifs such as house roofs allocated back and forth to create a rhythm [Fukumoto(1947)]. "Hokusai's 3-part-segmentation", especially as adopted in many instances, arranges screens in 3 partitions: top, center, and bottom, and sets the sky or land in one-third of the area, which is obviously affected by Western methods. To be precise, in "Thirty six views of Mount Fuji," we observe "Koshu-Mishima-Etsu," whose layout is "Hokusai's 3-part-segmentation" [Figure 1].

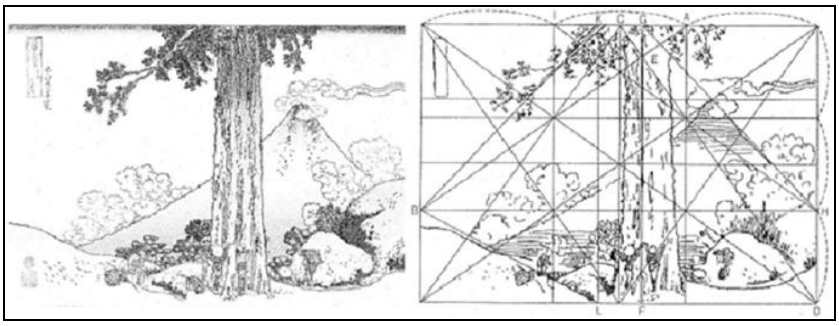

Figure 1: The composition of "Koshu-Mishima-Etsu"

"The Great Wave," [Figure 2] probably his most iconic work, draws a tiny Mount Fuji in the distance among massive waves. Authorities have said that each motif is defined by 2 diagonal lines and 19 circles [Yanagi(1957)].

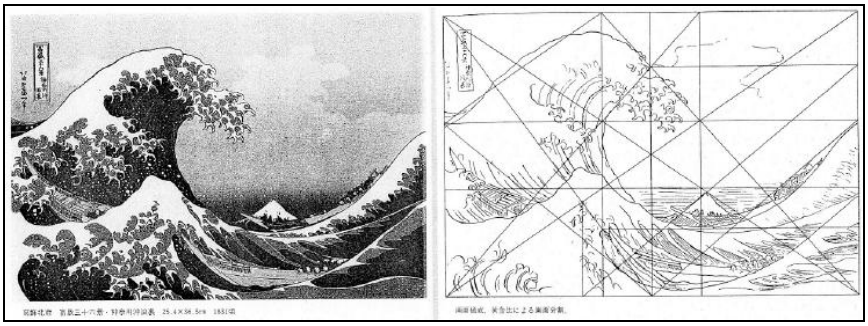

Figure 2: The composition of “The Grate Wave”

Based on these geometric composition rules, the following 4 features are noted [Yanagi(1957)]:

1. Direction and movement. - Set the key motif, Mount Fuji, on the edge of the screen and let painted people point fingers toward the mountain to create a sense of depth.
2. Contrast of color and shape - Drawing Mount Fuji quite small to focus attention.
3. Double motifs. - Although drawing ships and a bridge in the distance, two motifs are similar in shapes and this repetition creates the effect of harmony.
4. Allocation of humans and animals - Allocate living creatures such as humans and many types of animals to cause the feelings of uplift and vitality.

Given these issues, we can consider that Hokusai’s method is to create 4 effects through underlying geometrical rules of composition and motif allocation.

1.3. Aspects of “Thirty-six Views of Mount Fuji”

Various theories explain why Hokusai made Mount Fuji the main motif of this series. There are many records of the facts that during the Edo period, the pilgrimage to Mount Fuji was a great event in everybody’s life. People build miniature Mount Fuji mounds to revere and pray for protection from natural threats. Nothing was higher than Mount Fuji, and so its greatness was remarked by everyone as a symbol of awe to be revered by the Edo people, the most successful people in the country. Thus, Mount Fuji should symbolize Japanese pride and such concepts. In this series, Mount Fuji is not only a motif but also a special symbol with many meanings such as Japan itself, Japanese culture, the greatness of nature, awe, and there being but one unique existence. Mount Fuji is an image with an informational function [Tsuji(1972)]; therefore, it is a special symbol that attracts people’s attention. Hokusai would have been deeply aware of this fact and used this motif as a tool to achieve the purpose of his works.

2. ANALYSIS FINDINGS OF THE PREVIOUS EXPERIMENT

We designed the analysis point of this experiment based on the tentative theory that if people experience beauty upon seeing a golden ratio in a motif composition [Nojo, Muramatsu, Kojima & Matsui(2012)]. In the first experiment, participants were asked to answer their impressions of the printings using two kinds of rating scales: information rate scale (IRS) and semantic differential (SD) scale, where “symmetry”, “complexity” and “order” are defined as the elements of “beauty”. Results showed that these three perceptual features influence strongly on people’s impression of "beauty" of printings. Moreover, the results showed that the three properties of motifs that most influence our impressions are (1) motif size, (2) the ease of recognition of motif composition, and (3) the balance of motif composition.

3. ANALYSIS POINT OF EYE-TRACKING EXPERIMENT

There remain some questions—in the first place, do participants sense the existence of the golden ratio from motif composition? In recognizing that the ratio had been broken, did their impressions change as a result? Alternatively, was their change in impression not related to the ratio? Did their impressions change due to a change in the symmetry of motif composition? How did they perceive the edge lines of each motif, and is this a result of recognizing them? To find answers to these questions, we use an eye-tracking system to confirm the following three points.

1. Whether people watch the center point of the large motifs such as Mount Fuji or others.
2. Whether the eye-line moves to check size of motifs (height and width).
3. Whether the eye-line moves to check the distance of the motif's center point from the screen edge.

If the subject recognizes the golden ratio as we established in the previous experiment, the result would demonstrate that the eye movements concur with the above three points, but if not, we can conclude that other factors affect the impression of beauty.

4. REVIEW OF LITERATURE

4.1. Studies of the physiologic function of eyesight

It has been observed that in screen watching, the eyesight tends to move in the horizontal direction and returns to the same point just before it observes, in reaction to the screen. [Shioiri(2007)]. Further, the distance between objects (distance or background) affects the functions of the neuropsychology of eyesight. Kovacs, Feher, and Julezs found that the sensitivity of brightness contrast becomes high around the medial axis point of a figure [Ogawa & Inui (2011)]. One visual feature is the "attention model", which shows that intentional selection is caused by changing contrast sensitivity, space frequency, or brightness [Ogawa & Inui (2011)]. Humans have been observed to possess space coordination, called human-object-centered coordinates, which exists in the brain's right PMv, with a visual perspective point called the "cyclopean eye" [Ogawa & Inui (2011)]. Human can optimize their behavior space with much stronger sense of horizontal direction than vertical [Gregory(1997)].

4.2. Early studies related to visual issues and paintings

During picture appreciation, eye movement shows a "wide search", which glances around the entire picture and "specific search" (stay time is more than 300 ms) [Shioiri(2007),Solso(1994)]. A study of attention selection based on objects found that each unit of selection is an object [Taketani(2011)]. In the aesthetics domain, regarding visual images and paintings, there is a "right-half side matter" that insists "the most important content exists on the right-half side of the art painting" [Restak(1979), Nakatani & Fujimoto(2002)]. Related to this issue, in psychological fields focusing on the visual gap caused by cerebral hemispheric asymmetry, and based on many experiments, Restak noted that the main factor of the visual gap can be explained as hemispherical asymmetry, and people tend to be more attracted to the picture that has a major emphasis on the right side of the screen [Nakatani & Fujimoto(2002)]. Moreover, later research found that when the picture has some directional meaning, people are attracted to a picture drawn with the primary motifs on right side, but direction has preference from left to right [Nakatani & Fujimoto(2002)].

4.3. Psychological study of visual information

According to the early study, human faces have an especially strong property of drawing attention. This is a baby's innate function based on the survival instinct to identify its mother [Gregory(1997)]. In addition to the human face, animal motifs or characters have the same property. The same study found that babies have an innate ability to grasp spatial features such as depth; therefore, it is a genuinely innate ability to accurately perceive distance in motifs drawn on pictures [Gregory(1997)].

5. THE PRESENT EXPERIMENT

5.1. Experiment design

We use Tobbi technology's T60 Eye tracker which provides a 23.5 inch LCD monitor with an integrated eye-tracking system. It performs binocular tracking at 60 Hz and allows for head movement within a 44 × 22 × 30 cm volume centered 70 cm from the camera. The distance from the eye to screen is 53 cm, displayed gray-scale 1920 × 1080 pixel images on the screen. The participants are 19 students (3 females and 16 males) aged from 23 to 50 years, who viewed the 8 stimuli presented on the screen for 30 second each.

5.2. Materials and methods

We totally prepared 8 pictures including 4 original and 4 reworked pieces from the previous our experiment [Nojo(2012)], at the evaluation scores of the 1st experiment, they showed obvious differentials in 3 psychological factors such as "Symmetry", "Order" and "Complexity", between the original and the worked.

In this experiment, we saw the golden ratio as "a visual balance which is created by dividing an area" [Livio(2003)], with two underlying rules: (1) the ratio of the lesser segment to the greater segment should be 1:1.618 and (2) the dividing point of either the greater or lesser segment should be on the center line of the Mount Fuji motif. Figure 3 shows the original picture on the left side, which has the golden ratio indicated by a solid arrow and dashed arrow, and the re-worked picture on the right side in which the Mount Fuji motif was moved to disrupt the ratio.

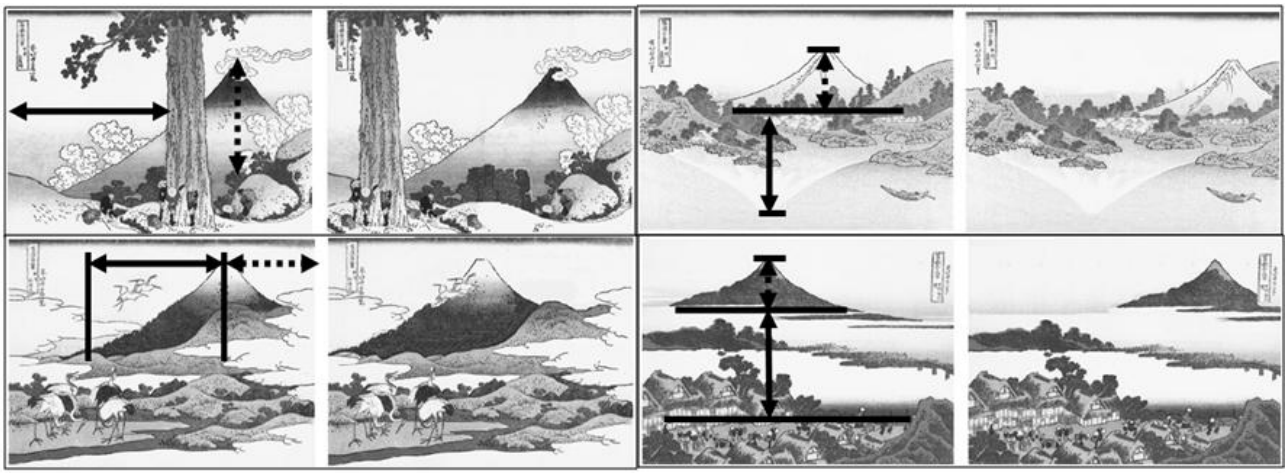

Figure 3: The 4 pairs of stimuli. Originals on the left, re-worked on the right.

"Koshu-Mishima-Etsu," the ratio is found in the spaces to the left and right of the tree and the height of Mount Fuji; we disrupted it by moving the tree farther to the left. This stimulus also has

another golden ratio in the distance from the foot of Mount Fuji and its height. “Soshu-Umesawa-Hidari” shows the ratio in the distance from the beginning of the slope of the mountain to its top, and the space between the top and the right edge of the picture; we moved Mount Fuji to the center to disrupt the ratio. In “Koshu-Misaka-Suimen,” the ratio is found in the height of Mount Fuji and the height of Fuji’s reflection on the lake; we moved the Fuji motif. “Koshu-Isawa-Akatsuki” shows the ratio in the height of Mount Fuji and the distance from foot of the mountain to the village road; we moved Fuji again to the right side to disrupt the ratio. And using the free software Ogama, we analyze the results.

6. RESULTS

To validated the three hypotheses listed in Section 3, we extracted a 300 [ms] retention point from the result of experiment, based on previous research [Yoshitka,Nishida&Hirashima(2009)]. Due to the error, 2 participant data was unable to use, therefore totally 17 data was based on following result.

KOSHU-MISHIMA-ETSU (ORIGINAL / WORKED)

The distinctive findings were in the original, people gaze at the center point of the picture (Figure 4), even though there seems nothing particular about the motif without serried bore lines with a bit of dark contrast. As shown in figure1 in the section 1.2, this point is just the geometrically center of this painting. In the worked version, it did not occur. In both cases, the point receiving the most attention was the center -positioned-person among the pilgrims, the person drawn third (5.0%) from the left side in the original, and in the worked, it is the fourth person (5.9%) from the left [Table1]. In the case of existing same kind of motifs in the horizontal way, such as pilgrims in this case, people tend to check the center positioned motif among the motif group. The little person drawn first from the right side, leaning on a giant rock located at just under the crest was gazed almost as same times as top of Mount Fuji, a vertical connection lines between this person and the top of Mount Fuji were especially prominent. The eyes traced over the line from the crest to the left side of the mountain skirts. Triangle lines connected the top of Mount Fuji, the end point of the mountain skirt, and a giant rock located at the lower right. Triangle-like eye trace lines were also found between the signature, top of Mount Fuji, and the end of the mountain skirt.

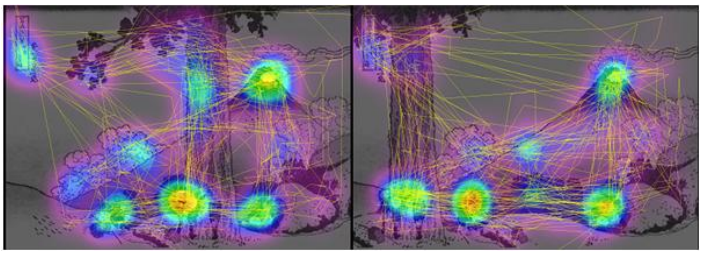

Figure 4: The result of “Koshu-Mishima-Etsu”. (original on the left, worked on the right.)

SOSHU-UMESAWA-HIDARI (ORIGINAL / WORKED)

In the original, the top fixation point was flying cranes. The horizontal connection lines from

this point to the signature and to the top of foreground mound were incessantly caused. Two standing cranes abreast on the alley were gazed at almost same times each other. In the worked, the top gazed point was the rightmost standing crane. It was prominent that the vertical eye-tracking lines between the flying cranes and the center point of this screen were incessantly occurred. And the fixation rate of the top of Mount Fuji was the lowest (1.2%) in this experiment [Table1], people watched the flying cranes (6.4%), allocated foreground of Mount Fuji.

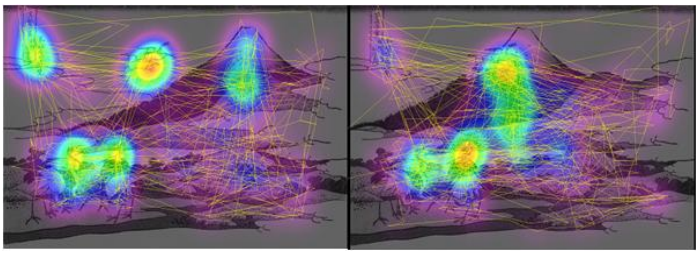

Figure 5: The result of “Soshu-Umesawa-Hidari”. (original on the left, worked on the right.)

KOSHU-MISAKA-SUIMEN (ORIGINAL / WORKED)

This picture has a strong symmetric composition with two images of Mount Fuji, rising from the ground and mirrored on the lake (Figure6). All participants gazed at the center point of these symmetric motifs many times in the both the original and worked versions [Table1]. It found many eye derivations, from the top of Mount Fuji to the top of mirrored, through the center point. The triangle zone comprising the top of Mount Fuji, the center point, and right side of the center the end point of the slope of the foreground mound. A very tiny triangle figure allocated on the edge line of the left side of lake, was gazed in both cases. In both cases, eye moved on very the line of slope of Mount Fuji. The fixation time of signature was very much less than the center point.

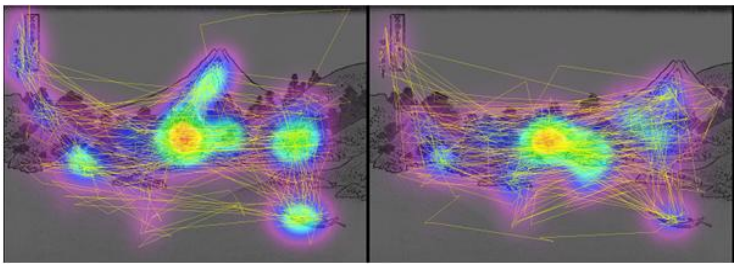

Figure 6: The result of “Koshu-Misaka-Suimen” (original on the left, worked on the right.)

KOSHU-ISAWA-AKATSUKI (ORIGINAL/WORKED)

In the original, top of Mount Fuji and the long islands which is allocated vertical below of Mount Fuji, and pilgrims were traced in all cases. The horizontal line from the signature to the top of Mount Fuji was caused in many cases. In the worked, the eye derivations between the center point of Mount Fuji and the other each high-contrasted motif were occurred. Gazing at left side of Mount Fuji, even where there is no motif was confirmed. The center of Mount Fuji, not the top, was gazed many times in the worked. In both cases, slanting movements from the top downward particularly occurred, and tended to move to the point with high contrast in a top-downward direction.

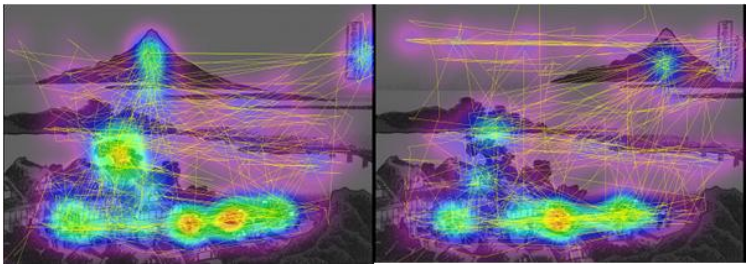

Figure 7: The result of “Koshu-Isawa-Akatsuki”. (original on the left, worked on the right.)

Regarding to several feature points where people gazed at very frequency, we analyze its efficiency based on the number of fixations as follows;

		Feature points										Other Fixation Points	Total Fixation Points
		Mt.Fuji							Koshu-Misaka-Suimen				
		Top	Signature	Humans, Animals					Mirrored Mt.Fuji	Center Point			
Koshu-Mishima-Etsu	No. of Fxation	72	129	80	88	94	46	80	-	-	669	1,194	1,863
Original	No.of Fix / Total	3.9%	6.9%	4.3%	4.7%	5.0%	2.5%	4.5%	-	-	35.9%	64.1%	
Koshu-Mishima-Etsu	No. of Fxation	104	164	79	73	35	115	78	-	-	673	1,286	1,959
Worked	No.of Fix / Total	5.3%	8.4%	4.0%	3.7%	1.8%	5.9%	4.4%	-	-	34.4%	65.6%	
Soshu-Umesawa-Hidari	No. of Fxation	66	124	62	147	46	44	105	-	-	625	1,159	1,784
Original	No.of Fix / Total	3.7%	7.0%	3.5%	8.2%	2.6%	2.5%	5.9%	-	-	35.0%	65.0%	
Soshu-Umesawa-Hidari	No. of Fxation	23	96	48	106	56	44	123	-	-	496	1,412	1,908
Worked	No.of Fix / Total	1.2%	5.0%	2.5%	5.6%	2.9%	2.3%	6.4%	-	-	26.0%	74.0%	
Koshu-Misaka-Suimen	No. of Fxation	53	66	55	60	-	-	-	8	245	582	1,299	1,881
Original	No.of Fix / Total	2.8%	3.5%	2.9%	3.2%	-	-	-	0.4%	13.0%	30.9%	69.1%	
Koshu-Misaka-Suimen	No. of Fxation	26	68	42	88	-	-	-	17	179	476	1,371	1,847
Worked	No.of Fix / Total	1.4%	3.7%	2.3%	4.8%	-	-	-	0.9%	9.7%	25.8%	74.2%	
Koshu-Isawa-Akatsuki	No. of Fxation	60	153	80	69	85	51	-	-	-	517	1,339	1,856
Original	No.of Fix / Total	3.2%	8.2%	4.3%	3.7%	4.6%	2.7%	-	-	-	27.9%	72.1%	
Koshu-Isawa-Akatsuki	No. of Fxation	48	155	95	60	63	68	-	-	-	526	1,399	1,925
Worked	No.of Fix / Total	2.5%	8.1%	4.9%	3.1%	3.3%	3.5%	-	-	-	27.3%	72.7%	
Average	No. of Fxation	63	118	75					8	245	598	1,248	
Original	No.of Fix / Total	3.4%	6.4%	4.1%					0.4%	13.0%	**32.4%**	**67.6%**	
Average	No. of Fxation	50	121	73					17	179	543	1,367	
Worked	No.of Fix / Total	2.6%	6.3%	3.8%					0.9%	9.7%	**28.4%**	**71.6%**	

Table1: Analysis of feature points

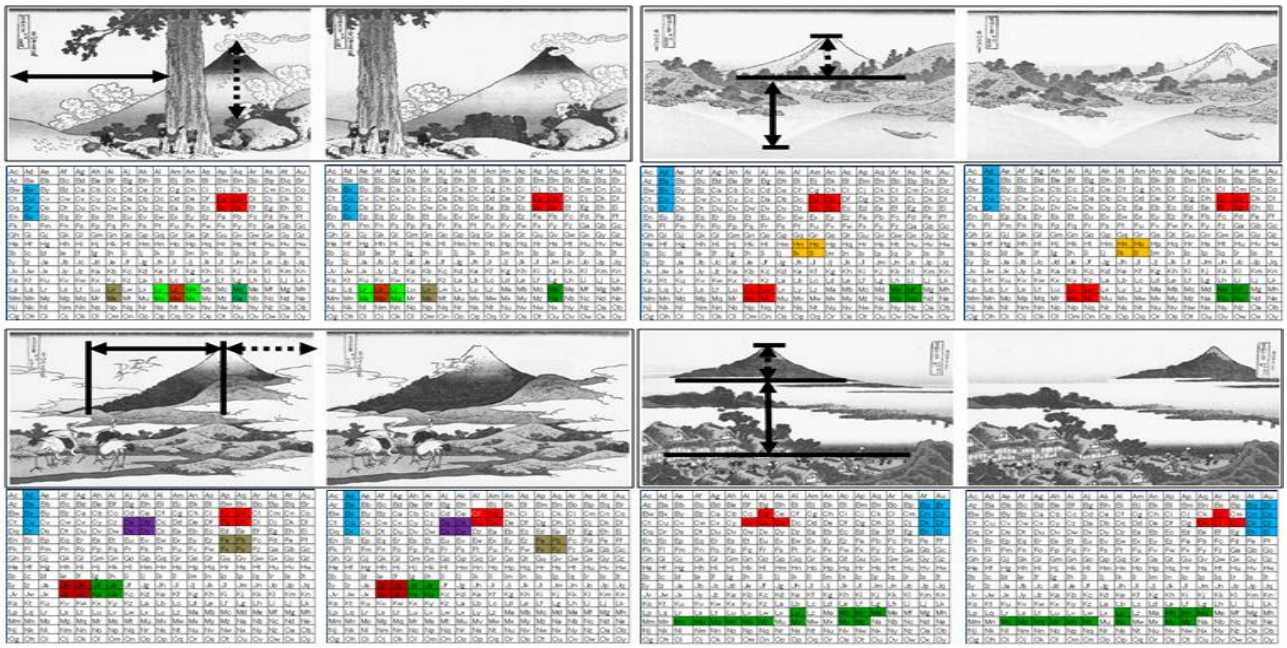

Figure 8: The base data of analysis of feature points. (original on the left, worked on the right.)

This result shows that in the totally around 1,800 fixation points in each picture, in the original, several feature points that we proposed in this paper were account for 32.4 %, Mount Fuji was gazed average 3.4%, signature 6.4%, humans and animals 4.1%. Of special note is in Koshu-Misaka-Suimen, its center point was gazed at over 13.0%, this is the top percentage within other feature points.

7. DISCUSSION

From these results, we confirmed the three purposes of the current experiment, as described below.

1. WHETHER DO PEOPLE WATCH THE CENTER POINT OF THE LARGE MOTIFS SUCH AS THE MOUNT FUJI OR OTHERS, OR NOT.

Without one case, there was no case that people gazed the center point of the large motifs. People tend to watch the feature points (top of Mount Fuji) or feature motifs (animals, humans, signature) in every case. Only the case of worked of Koshu-Isawa-Akatsuki, we could confirm that people gazed at the center point of Mount Fuji. And in this case, there happened many connection lines from this point to other motifs. This eye movement indicating that as if participants were confirming the interspace distances between several motifs suggest that people see motifs' comparative positioning and may want to understand the overall balance of motifs in the picture. Not the center point of the large motifs, but in the case of the originals of Koshu-Mishima-Etsu and Koshu-Misaka-Suimen, people gazed the center of the pictures and this findings may hold a special meaning for viewers.

2. WHETHER THE EYE-LINE MOVES TO CHECK THE SIZE OF MOTIFS (HEIGHT AND WIDTH).

In all original cases, it was confirmed that eyes traced the center line of Mount Fuji, from the top to something feature motifs allocated its vertical lower point. This movement makes viewers check the height of Mount Fuji. But regarding other motifs, there seems nothing particular feature motif to trigger such a movement. This fact suggested that perhaps Hokusai would intend to make viewers sense the perspective of paintings by recognizing the real size of Mount Fuji, —as mentioned in subsection 4.3, we can sense the distance or depth of an object instinctively. — It would be possible if people know its' real height in common. However, in all cases, eye did not moved from this point to the certain end point as we defined as the distance of golden ratio.

3. WHETHER THE EYE-LINE MOVES TO CHECK THE DISTANCE OF THE MOTIF'S CENTER POINT FROM THE SCREEN EDGE.

In all cases, there was no movement to the screen edge. This fact suggested that perhaps people would be able to sense the overall size of the object without explicit eye movement, or the balance of feature motifs would be more important than checking the distance from the edge.

This experiment's results enabled us to confirm how Hokusai's motif composition affects the viewer's eye movements and impressions of paintings.

KOSHU-MISHIMA-ETSU

The result shows that perceiving the “center” should be quite important. If Hokusai intended to make the viewer’s eye movement triangle-like way based on motif allocation, —a triangle is important figure in his method— it succeeded. In this picture as well, most motifs were located at right side. Thus, from the perspective of the previous theory—the “right-side problem” mentioned in Section 4—this picture has many properties that make people perceive this picture as an example of “beauty.”

SOSHU-UMESAWA-HIDARI

There are rhythmical line-position from top of Mount Fuji to foreground mound, and double-motifs such as flying and standing cranes, if Hokusai intended right-left, upper-lower eye movement by these motifs, he did succeed. By the fact that flying cranes were more gazed than the top of Mount Fuji, its weight of importance as motif should be heavier than Mount Fuji.

KOSHU-MISAKA-SUIMEN

According to the fixation analysis [table1], perceiving the center point of the object (13.0%) seems to be much more instinctively important than doing top of Mount Fuji (2.9%), this presumed the existence of “cyclopean eye” as mentioned in section 4.1, search for the symmetric property; thus, humans tend to react easily to symmetry. It means that the symmetric composition should be a physical factor which gives strong influences for the psychological factor of impressions of paintings. This evoked Brown’s theory mentioned at the beginning of this paper, and this picture should give strong impressions of “beauty”.

KOSHU-ISAWA-AKATSUKI

Only a material among 8 pieces in which Hokusai’s signature was allocated at the top right. It seems that Hokusai intended to allocate his signature at a longer distance from Mount Fuji. This suggests that Hokusai treated his signature as one tricky motif to induce eye movement as he intended. Hokusai’s signature, in particular, is a brand symbol, which means that “this picture is not drawn by somebody unknown, but is drawn by Japanese great woodblock printer, Katsushika Hokusai, who has a significant talent with profound skill; this is a very special picture and different from the others” that makes viewers perceive it positively. Also, this signature has a role to enhance the stability of the picture’s left-right and up-down directions; when people observe this picture from the top down, they can recognize the mountains with correct direction and understand that “this is an inverted image.” Therefore, in the series of “The Thirty-six Views of Mount Fuji,” the signature is quite effective as an informatic signal.

These results confirmed that on Hokusai’s geometric motif allocations, 4 effects have occurred as mentioned in Section 1.2, and further confirmed that the special motifs cause eye derivations. As mentioned in section 1.1, If Hokusai attempted to elicit “pleasantness” by his systematic tricky composition method, it seems to be quite succeed. And the outcome suggested that for impressions of beauty of paintings, people would understand the motif balance on the basis of a much simpler ratio, not a subtle ratio such as golden ratio.

8. SUMMARY

For the final target of our research, “construct a system of automatic recognition of the aesthetic level of pictures,” we adapted the golden ratio as the aesthetic measure that affects physical and psychological properties; we also confirmed its availability using an eye-tracking system. However, the results suggest that the golden ratio seems an ineffective influence on the impression of a painting’s beauty. If the golden ratio is adopted as a composition rule, the issue remains for further study.

Based on above results, we suggest 2 physical factors which give influences of impressions of “beauty” of paintings. The first physical factor, which effects for the perceptual feature “symmetry” would be feature motifs and feature points, and the second physical factor, which gives influences for the perceptual factor “order”, can be Hokusai’s unique motif composition rules.

Instead of the golden ratio, what should be adapted as the next “measure” as the level of influence of effect for the impressions of beauty caused by physical and psychological factors. Determining the match rate of composition rules and motif allocations, and the match rate of a motif’s shape and ideal motif shapes? First, when considering the motif’s ideal shape, we adopt Leibniz’s theory of pre-established harmony to the issue of the motif’s figure to assume that “all motifs should have an ideal shape.” Further, from the concept of pregnant figures in Gestalt psychology, Hokusai said in his textbook that triangles and circles are the basic shapes of whole things. In 90 figures that Birkoff displayed as degrees of aesthetics, the top was a square, followed by a rectangle. Cezanne, who set great store on composition, said that everything can be expressed by a circular cone. These theories suggest that the ideal shapes are basic figures such as square, rectangle, triangle, and so forth. If one compares the degree of the matching rate of composition and motif allocation, and the rate of the motif figure and the ideal shape, one could validate this “measure.”

Research in recent years, visual structure has both statistical self-similarity and common predisponency. To benefit from Kant’s words, “art is nature’s copyism” [Kant(1790)], we assume that the properties of “Beauty” would also relate to nature, and we intend to continue our research at that level.

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