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"Utopia": an Interactive Visual Experience

--- Equal and Borderless World,
from a Semantic Concept of a Painting to a Comprehensive Eye-Guidance ---

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Abstract

"Utopia" is a novel artistic representation with an interactive visual experience. It consists of a painting that depicts an imaginary neighborhood in which all residents are living together, happily, and peacefully. The aim of "Utopia" is to provide a viewer an interactive experience of appreciating a painting that is technically and semantically designed to represent an equal and borderless world. In order to create such an experience, in addition to conveying the Utopia's concept by illustrations such as people of all ages and descents, etc., we aspired to design and created a structure that induces the viewer's eyes on the whole painting ceaselessly and in a uniform manner. Thus, every painted element has an equal chance to be seen. For the first step, we applied artists' conventional eye-guiding techniques and painted and arranged the visual elements and cues considering the proposed affordable guidance method. Secondly, we designed an interface that displays a painting on a monitor connected to an eye camera that allows the viewer to interact, zoom and move the painting within the frame only by eyesight flow. The interface also provides a loop structure in all directions to realize borderless world, that helps the viewer to observe the painting without any interruptions. To reinforce the ceaseless interaction and guidance, we added animation and auditory effects that induce corresponding eye movements. Finally, the afford of applied visual elements and cues to guide the viewer's eye and the feasibility of the designed system, for the proposed concept of equality was examined and evaluated by experiments. The results of the experiments show that the implemented features of the system and the designed eye navigation, generated a uniform distribution of the gaze in the painting and the viewers could have a comprehensive experience of appreciating a painting while every element of the painting has been visited.

1. Introduction

1.1 Background and Purpose

Geographical determinism, boundaries, physical limitations, and discrimination are all issues that led me to create this work as an immigrant artist. In our real world, restrictions are in the form of borders between countries, racial differences, and discriminations, etc. In the world of painting, we still face constraints; the frame in the painting works as a border that separates the outside world from the painting's world[1], the surface of a painting is also limited according to the physical laws. These constraints often force the artists to choose from the vast possibilities of the outside world's sceneries, imaginary or abstract inner world and prioritize the images they would like to represent. These images would be an old story needs to be told, a narrative of a circumstance, a depiction of an important character, a scenery of a tree on a distance nature, or even a still life composition, etc.

To convey the painting's topic, artists often take advantage of eye-guidance techniques and compose the visual elements and cues in their paintings in a way that draw attention and direct viewers' eyes to a selective areas on the available surface regarding their priorities[2][3]. These visual cues can vary from the low-level saliencies with subtle characteristics such as color, size, and orientation to higher-level attractions by conspicuous objects such as a human face, a pointing finger, or even an image with high contrast. New technological advances and scientific researches on the human cognitive systems and viewing behavior helped us to understand the eye movements and the gaze-guiding techniques better. Figure 1 is a sample image of a study on eye movements that shows gaze points and viewing path of a viewer on Ilya Repin's painting "unexpected visitor"[1].

Another constrain of the classic the 2D paintings is the limitation of interaction to the act of observation only. Desire of viewers, who are not the creator of the content, to interact with the world inside the frame and

[1] Figure one is an example image extracted from famous research on eye movements and vision by Yarbus used in a blog post which is a discussion over composition specifically about the usage of directional lines and shapes to lead the eye to the focal point [4][5].

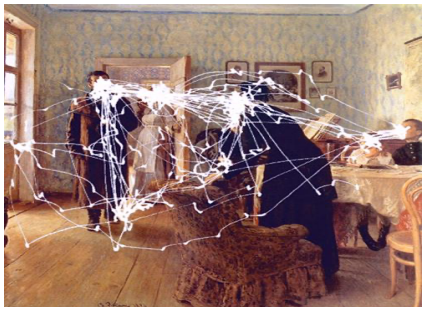


Figure 1 Eye tracking scan path on Repin's painting [5]

have an impact on it was eventuated by flourishing the computer systems[2]. Currently, Eye-tracking technology as a tool for interaction is used in a wide range of fields, from entertainment fields such as video games, VR devices, and artworks to medical and welfare fields such as input devices for patients with general incapacity.

The purpose of this study is to depict an equality concept in an interactive painting using conventional eye guidance techniques and by means of new technological achievements. We are challenging the composition and display style of 2dimentional paintings, examining the capability of visual and audial elements and cues on gaze guidance, and applying features that would result in reducing the existing restrictions, improvement of the interaction between the artwork and the viewer, and gradually provides an artistic concept of "equality and borderlessness" as in a form of interactive experience.

1.2 Concept of "Utopia"

utopia; (/juːˈtəʊpɪə/): "An imagined place or state of things in which everything is perfect."

"Utopia" is a place with no borders and boundaries, where all its residents are living equally, together happily and peacefully. A place that no individual is superior to another, and the land is free of hunters and hunts. A place in its most beautiful state that an ordinary moment worth eternity. In utopia, although every resident is a small beam of a whole, they can shine and be seen individually.

The concept "Utopia" of this study is that we simultaneously give an experience of an equal and borderless world, i.e., the sensational concept of utopia, by utilizing technical functionalities in addition to conveying the semantic concept of utopia by illustrations. "Utopia" gives a seamless interactive experience with a content that every element has an equal chance to be seen. We try to reduce the physical limitations of painting by not only the artists' conventional techniques of eye-guidance but also realizing a loop structure of a painting to a borderless appreciation by assistance of new technological achievements.

The considered features are a comprehensive eye-guidance that are provided by visual elements[3] and audial cues that will result in a uniform distribution of eye-fixations to represent equal world, a loop structure for a seamless and borderless experience and interaction design that realizes equal and borderless world by using an eye-tracking camera.

To implement the visual experience of "Utopia," first, we painted a neighborhood consisting of people, animals, and urban elements, etc., considering the desired eye-guidance techniques. Even though the painting is still obligated to be inside the rectangular structure of the frame, we painted it on a square surface. This allowed us to occupy a rather larger space than the display frame. Therefore, the viewer can explore and see more of the painting that resides outside the frame. Second, by utilizing the available functionalities of computers, we designed an interactive system for the painting. This system moves the painting, corresponding to the viewer's eyesight flow using an attached eye-tracking camera. For a ceaseless experience, we provided a loop structure both horizontally and vertically that allows the viewer to observe the painting whiteout any interruptions. In such a system, every painting element would be located on the focal point eventually and have an equal chance of being seen. Additionally, to fulfill the proposed guidance approach, we added animated moves and sound effects.

2. "Utopia"

2.1 Painting's Content and Visual Elements for Eye-guidance

The painting was created by several layers using the Procreate app, Apple Pencil, and Adobe Creative Suites. The background layers are including: the buildings, trees, urban elements, and the ground, with the original resolution of 4,000 pixels x 4,000 pixels. The image of the residents, including the people and animals was created in the original resolution of 3,508 pixels x 2,480 pixels each. The technique is a digital equivalent of colored pencils, the colors selected for the work are earthy and mostly in warm tones. The ambiance, lights, and shadows are depicting a pleasant afternoon at the beginning of autumn. Old-style buildings with geometric shapes are staying strong in multiple parts of the layout; people from different descents and ages, animals, and objects are flowing with organic shapes which are depicting an apparent contemporary environment.

The painting's content, visual cues, and the composition for eye-guidance were painted, considering the structure of the system, displaying style, and its interaction with the viewer. Hence a top-down approach was considered. First, the background and spatial and urban elements were painted and arranged at a corresponding interval. Buildings in this painting are proportional in terms of visual weight and

[2] The introduction of the mouse cursor realized the first engagement with visual contents inside a frame. Devices such as electronic pens, cameras, etc. are some of the more advanced tools for responding to the need for interaction.

[3] The elements and principles of painting are the visual tools that the artist uses to create a composition. These are line, shape/form, color, value, form, texture, and space. The principles of painting represent how the artist uses the elements of art to create an effect and to help convey the artist's intent. These principles are harmony, balance, proportion, contrast, emphasis, movement, pattern, rhythm, and unity/variety. Artists have intuitively understood this phenomenon and have expressionistically recreated the technique in paintings by strategically organizing the elements within a work of art to attract the attention and navigate the viewer's eye[6].

do not differ in contrast or dimensions drastically. The power cables, threads, and urban ornaments were designed to develop movement effect in the painting.

Worth mentioning that the building's structures and the perspective style, are the re-creation of some of the masterpieces in Persian paintings. Also, utilization of oriental motifs is prominent. The images of the residents are also painted on the same scale with no perspective and are placed at approximately uniform distances. This approach was considered and applied in the composition of the elements in all the main views. Figure 2 shows a flattened image of the main view of the painting.

Figure 2 Image of the main view of the painting with 4,000 pixels 4,000 pixels

Images of the residents are depicted in a way to refer to a direction to guide the viewer's eyes. Faces are especially powerful attractors of attention, and when a picture contained a face, the viewer's gaze was drawn to it immediately. Eyes are essential and viewers fixated on the eye region of the faces in a depicted scene within the first one-fifth of a second of viewing[7] Also, body gestures, elements showing a movement can attract and direct the eyes. For example, a couple looking from a balcony to a distant point creates a tendency for the viewer to check the pointed area. Worth mentioning, people are interested in the details that explain the narrative of the image: the eyes gravitate towards the clues that help decode the meaning of a painting[8]. Figure 3 shows some of the residents in "Utopia". Therefore, every element in this painting is connected in a sense and arranged to stimulate the viewer's eye to move all around the painting and observe every detail.

The artist's intention is not to highlight a storyline or emphasize a specific element; conversely, the artist is eager to portray a utopian neighborhood, that every element of the painting is equally important therefore, it is important to guide the viewer's eye throughout the whole image and encourage the viewer to explore all the painting to observe every detail. According to the primary findings on the effects of images on visual guidance shows that empty or uninformative parts of the scene are rarely fixated. Instead, viewers concentrate their fixations on the most informative and interesting parts of the scene[9]. Therefore, the authors expect relatively less eye fixation on the urban elements in the background and much less/no fixation and the empty ground areas.

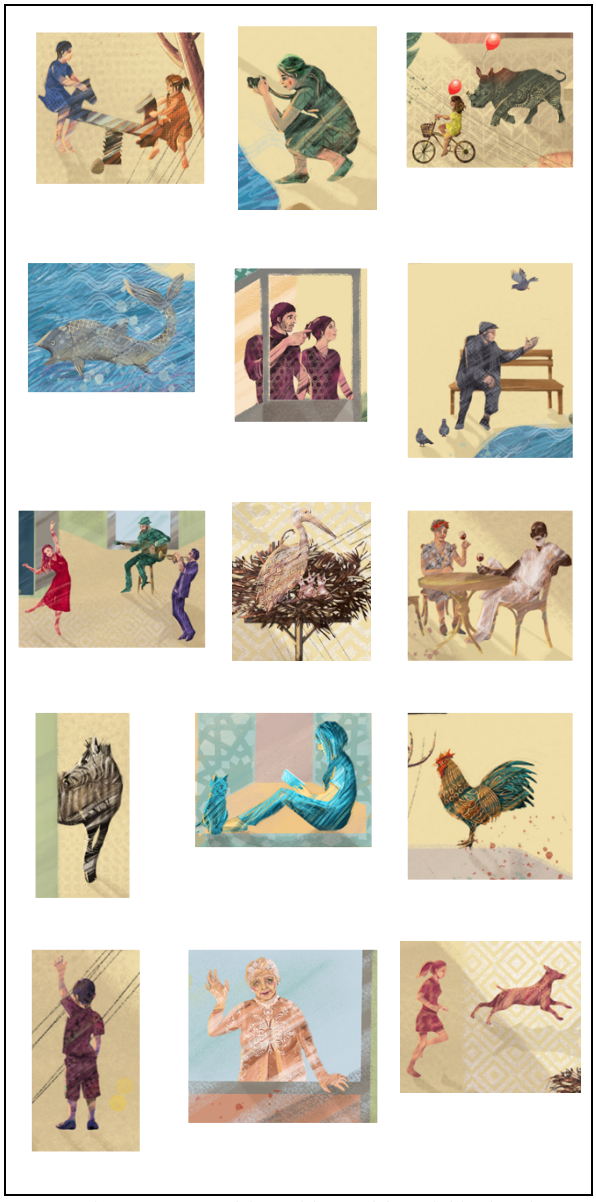
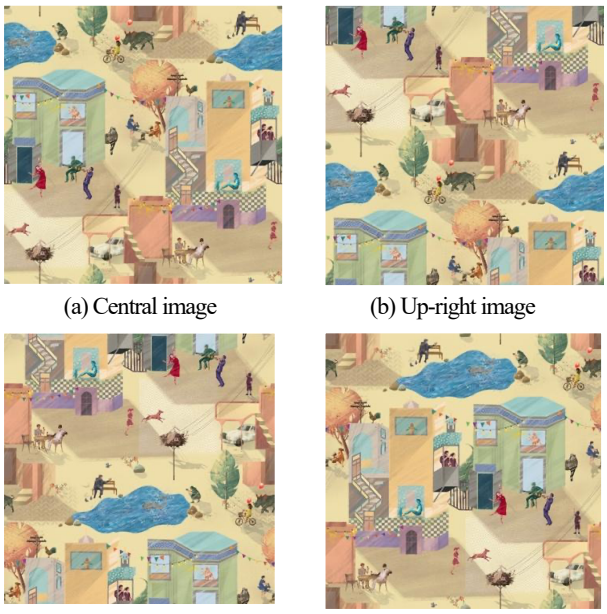


Figure 3 Image of the residents of the neighborhood

Since the eyes are often drawn to the most salient regions of the scene, which correspond to the areas containing the highest density of features or having the highest local contrast, more fixations are expected for the lake because of the sharpest edges and the color contrast[10]. Studies are also suggesting that the sky on the painting is usually be ignored, and perspectives do not essentially have effects on navigating the eyes. To avoid having areas with no eye fixation or making the composition complicated, I intentionally did not paint the sky, and I also did not apply any perspective effect. Knowingly that there is a general tendency for viewers to fixate the center of a framed image, regardless of its

content[11], a loop structure, that will be described in section 3.2, is defined for the system. Because of the looped structure, we painted the image, in such a way like the drawings of Mauritius Escher or pattern designs that no borderline would be felt or noticed while passing the sides, and the viewer can have a ceaseless experience. Therefore, every element has the chance of being in the central part of the frame, that is the area with the most eye fixation, and to be seen equally. In Figure 4 you can see the probable four main views of the painting and the adjustment of the images in the central part cause by the viewer's eye movements.



(a) Central image (b) Up-right image

(c) Up-left image (d) Down-right Image

Figure 4 The four main views of the depicted neighborhood

2.2 Audial References and Short Animated Effects

Two additional features including audio play and animated moves are applied in designing the "Utopia". The audio feature is a faint ambiance sound effect plus the residents' related sound effects, i.e., kids laughing sound, or water splash sound, etc. Table 1 shows the full list of the sound effects. The audio changes imperceptibly corresponding to the painting's move by the viewer's eye. Also, the intensity of the sounds changes according to the state of the zoom operations. Details are described in section 3.3. The intention of arranging the audial cues was following the distribution of the visual cues regarding the aim of the painting for comprehensive eye-navigation. It is also supposed to help the experience's engagement level.

The other mentioned feature is the animated moves. A gesture, moves, or action of the residents are highlighted in the form of a repeating short animation. These animated effects, exhibit a non-end, ordinary and joyful moment, and are toward the direction in which the character i

Table 1 List of the sound effects

1	Kids playing and laughing sound
2	Street musician's performance sound (Autumn leaves song)
3	Rooster crowing sound
4	Cat meowing sound
5	Cycling sound
6	Water splash sound
7	Camera shutter sound
8	Pigeons wing flap sound
9	Wine glass toast sound
10	Running steps sound

Figure 5 Animated gesture of the musician

3. System Design

The system design of "Utopia" for a ceaseless experience was inspired by Japanese handscroll paintings. The system has developed in Unity. An eye-tracking method is enabled using Tobii Eye Tracker 4C camera[4], attached to a PC monitor. Operations on Unity are linked with eye-tracking include image scrolling, zoom-in and zoom-out operations. We considered a loop structure for every all directions, i.e., vertical, horizontal, and diagonal cases, of the painting.

3.1 System Configuration

Figure 6 shows a schematic diagram of the system configuration. We used Tobii eye tracking for input and Unity for CG processing[12]. Internally, each object, building, and background are placed on a layer and drawn in parallel projection.

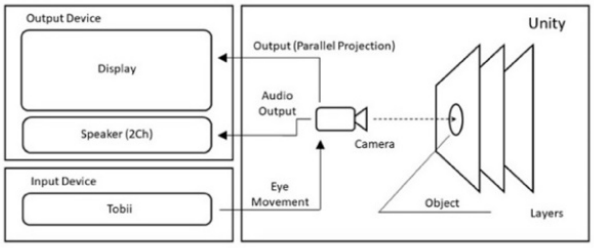


Figure 6 System of Utopia using the camera in Unity

The system uses the camera in Unity, we considered changing the camera angle depending on the coordinates of the gaze-point. The camera angles are expressed as the matrix that follows the 4 laws shown below.

[4] First, a near infrared ray is applied to the eye, and the eye is photographed with an eye camera to calculate and generate an eyeball model. By applying the display and the calculated eyeball model in a fictitious 3D space, the point where the line-of-sight forms on display is estimated.

1. On the vertical line, horizontal line, and diagonal line, the camera angles are 0 degrees.
2. The more leave from the center of the image, the more increase the camera angles.
3. Regarded center of the image as origin, there is the point symmetry about camera angles. And there is the line symmetry about the vertical line or horizontal line.
4. If the point of view is on the edge of the image, the camera angle follows the previous angle.

About these conditions, we calculated the optimal matrix. For the calculation of the matrix, we used Genetic Algorithm (GA). On-screen, the transition of the gazing point causes the eye-tracking movement, and the painting moves inside the frame. Since the painting was created on a square structure and displays on a rectangular frame, the resides part of the painting outside the visible display area moves and showed regarding the operation of eye movements. A schematic diagram of the movement of the eyesight is shown in Figure 7. The black circle in the Figure represents the center of the screen, and the white circle represents the gazing point. The arrows in the Figure represent the vector from the center of the screen to the gazing point. When scrolling the painting, a force proportional to the vector in the Figure is applied to the camera to move it.

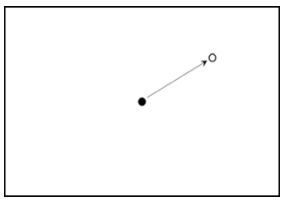


Figure 7 Moving of the eye sight; black circle: center of the screen, white circle: gazing point

3.2 Loop Structure

The image is displayed in a loop up-left, up-right, down-left, and down-right. A schematic diagram is shown in Figure 8. Image objects can be divided into two types. These are an image object located directly in front of the camera and image objects installed around the centered image object, respectively. The image object in the center holds the information of the eight image objects around it. The peripheral image objects hold the information of the central image object. When the camera moves and the central image object changes, the new central image object creates an image object around itself. Previously the central image object deletes the surrounding image objects and its image object.

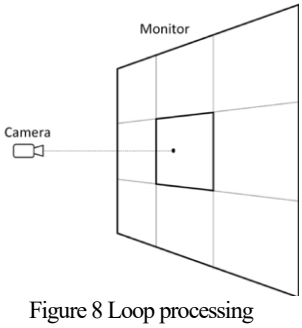


Figure 8 Loop processing

3.3 Zoom-in and Zoom-out Operations

The enlargement/zoom-in operation is utilized by gazing at a point, and the zoom-out is by averting from the gazing point. Concerning the movement of the eyesight and the zoom-in/out, the parameters are sensuously and smoothly changing[13]. The process is divided into three phases. The respective phases are zoom-out, zoom-in and neutral phases. Each phase transits to the other phase when a certain condition is met in each phase. Basic processing is common throughout each phase. The base point is set/updated at the coordinates of the current gazing point regularly in every one second. If the distance between the current gazing point and the base point exceeds or falls below a certain value, and if that state continues for a certain period, the current phase transits to the other phase. The zoom-in phase transits to the zoom-out phase if the distance is greater than 0.08 of image width and it keeps more than 0.5 second. The zoom-out and neutral phase transit to the neutral and zoom-in phase if the distance is smaller than 0.125 or 0.15 of image width and it keeps more than 1 or 2 seconds, respectively. Figure 9 shows the maximum and minimum zoom situations regarding the ratio of the display.

(a) Maximum zoom-out situation

(b) Maximum zoon-in situation

(c) Rectangular vision in (b)

Figure 9 Ratio of display frame to the painting

3.4 Sound Interaction

The audio output is controlled according to the distance to the camera and the degree of zoom. The distance between the point where the perpendicular line from the camera to the image intersects the image, which is referred to as the camera origin, and the coordinate at which the volume of each voice is maximized, which is referred to as the voice coordinate, is calculated for each sound coordinate. Since the image, loops up-left, up-right, down-left, and down-right, considering each loop destination, calculate nine distances to the voice coordinates for each coordinate shown in Figure 10, and select the smallest one from each voice coordinate distance. The volume of each voice increases or decreases depending on the distance and the degree of zooming. When

the line of sight is used for the system, the volume also increases or decreases depending on the point of gaze. The increase/decrease in volume follows a bell curve, i.e., Gaussian function. The maximum volume, minimum volume, and sound spread are given for each voice. Note that the sound spread is controlled according to the zoom. A low-pass filter that suppresses high frequencies is applied to each sound, and its cutoff frequency is changed according to distance and zoom. This filter is used to give a muffled sound.

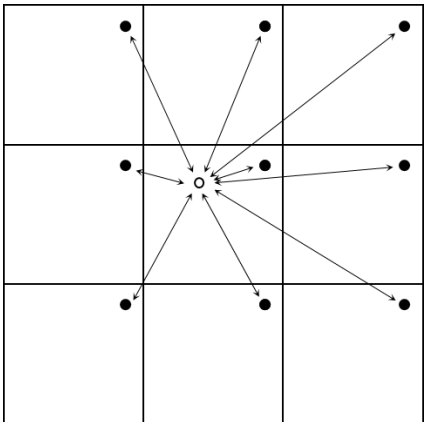


Figure 10 Calculation of the distance to voice coordinates; white circle: camera origin, black circle: loop destination voice coordinates

4.Experiment and Evaluation

4.1Experiment Conditions and Cases

To examine the feasibility of the implemented designs for comprehensive eye-guidance and to evaluate the images and audios' effects on gaze guidance, also to observe the viewer's visual path and, the distribution of gaze points, we conducted an experiment.

The experiment was divided into five cases. In each case, a new feature or layer was added. This allowed us to take measures of what cues attract the attention and the most gazed areas of each case, these measurements are later in section 4.4 compared with each other also with our suggestions to determine if the implemented features did have the proposed influences or not.

The experiment's conditions were as follows: the painting was displayed on a 942mm x 549mm Philips's monitor with 3,840 pixels x 2,160 pixels attached Tobii4C eye-tracking camera. The painting was displayed in an empty room, only one viewer would observe the painting at each time. The viewing distance from the painting was within 50 to 80cm. The setting suits that a viewer of 20/20 vision[5] can percept almost one pixel on the monitor[6]. Ten examinees ranging from 20 to 30 years old took part in this experiment. Each examinee was asked to observe the painting in five different cases, each case for 2 minutes. Figure 11 shows an examinee observes the painting.

Figure 11 An examinee is observing the painting

Figure 12 Case1: images of background and urban elements

Figure 13 Case2: the images of the residents

[5] 20/20 vision equals to score 1.0 of visual acuity test in Japan.

[6] 20/20 vision is defined to perceive a gap of 1.454mm in Landolt C with the diameter of 7.272mm from 5m distant. In Japan, the gap and the diameter are defined to 1.5mm and 7.5mm, respectively. The physical size of one pixel is 0.245mm x 0.254mm = 942mm/3,840pixels x 549mm/2,160pixels. If viewing distance is 80cm, a viewer of 20/20 vision can perceive 0.232mm, i.e., 0.24mm in the Japanese standard. Therefore, the setting was set to the most of all viewers can perceive one pixel.

It worth mentioning that, in all the five cases, the system uses the loop structure and same zoom in/out features, however, the displayed images and animation and sound effects were different depending on the experimented case. The experimented "five-cases" are as following:

1) In the first case as shown in Figure 12, we have only displayed the images of background and urban elements, including buildings, trees, the car, the lake, and electric posts.
2) For the second case illustrated in Figure 13, the images of the residents including the images of the people and animals were displayed.
3) Figure 2 is the third case, we had the complete painting.
4) For the fourth case, the short-animated moves of the residents were added.
5) On the fifth case which is the finalized version of the painting we added the sound effects.

In the end, a survey about the painting's System and content is done by questionnaires.

4.2 Visualization of the Experiments

We visualized each examinee's eye moves and fixations while observing the painting on all the 5 experiment cases. Figure 14 is a sample image of the visualization of the eye movements of an examinee. The order of the eye fixations, and the zoomed areas were recorded and analyzed. The order of the viewed areas that are assigned with color gradients is as following; the first area: Blue, the second area: Cyan, the third area: Green, the fourth area: Yellow, and the fifth area: Red. The number of colors and the number of divided areas is assigned arbitrarily. As it was mentioned we have suggested a corresponding schema that shows how the elements of the painting are supposed to attract the attention of the viewers and how the distribution of the elements will work for the proposed eye-fixation on the painting. Figure 15 shows the case2 painting with red circles which are the Area Of Interest (AOI), showing the most salient elements of the painting, suggested by the authors. Figure 17 is the visualization of the gaze points of an examinee in all 5 experiment cases and the AOI circles.

4.3 Questionnaire Survey

After each of the five experiment cases, we asked the examinees to complete a questionnaire by answering a set of questions about the content and their experience. Questions 1-3 and 4-8 were asked to give a score on a 5-point scale. Score number 5 is the highest of the rating for the highly interesting impression, and score number 1 is the lowest rate as the not interesting impression. They were also asked to give their overall opinion about the content and their experience of the appreciation style of Utopia. It is worth mentioning that the authors did not provide the viewers any information regarding the system's structure, eye camera, and the concept of Utopia for an equal and borderless place.

Below is the list of the questions.

1. Did you enjoy appreciating the painting?
2. Is it easy to appreciate the picture while scrolling the screen by your line of sight?
3. Is the interactive experience and the scrolling of the screen by the line of sight happening naturally?
4. Which do you like the most: illustrations, animations, and sounds in the picture?

Please add comments freely.

5. Do you think if the design of the painting is creative?
6. Do you think if the painting is beautiful or attractive?
7. Does the design look professional and high-quality?
8. Overall impression: Do you like or dislike it?
9. Have you ever seen artwork like this? Yes, No

If yes, please write the information about it.

10. Feel free to write your thoughts.

Figure 14 Visualization of the eye-fixation points of an examinee on the painting. Order of the fixations are as Blue, Cyan, Green, Yellow, Red, also the "zoom-in/out" positions

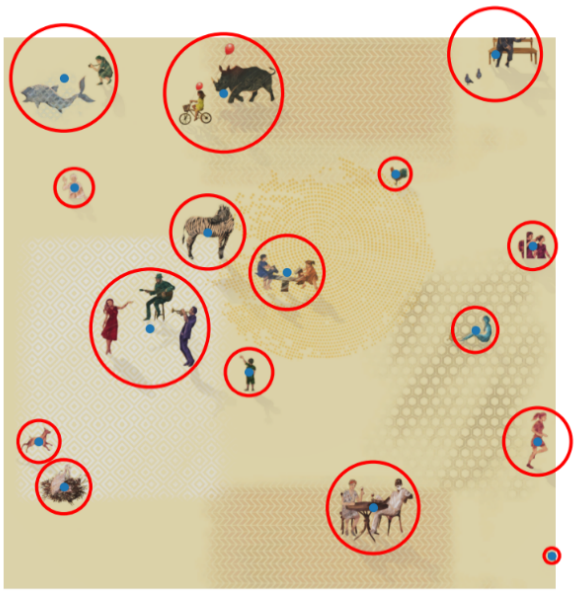
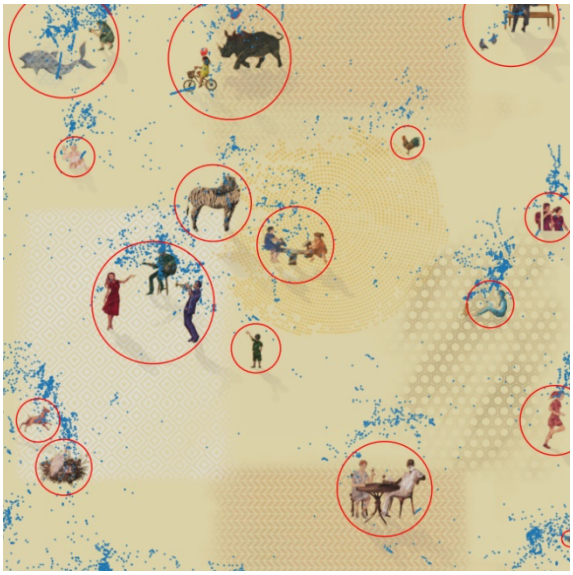


Figure 15 Red circles are representing the AOI

(a) Case1



(b) Case2

(c) Case3

(d) Case4

(e) Case5

Figure 16 Visualization of the gaze points of examinee 4 in all five cases. Blue dots are the gaze points of an examinee and the red circles are the authors' suggested AOI.

Example comments, made by examinees after the case 1

(1-1) It was interesting to be back in the same place before I knew it.

(1-2) It was fun after I realized that it was moving according to my line of sight. My eyes moved according to the electric wire. I think it would be another move if there were no wires.

(1-3) The illustration of a buildings seems to have a strange sense of direction as you look at it

(1-4) It was difficult to zoom in.

Example comments, made by examinees after the case 2

(2-1) There was a feeling that what I was trying to see was passing by

(2-2) It would be nice to have animation to make it lively

(2-3) It was interesting. If there were more pictures, I could watch it longer.

Example comments, made by examinees after the case 3

(3-1) Although I felt some resistance to moving my eyes, I could see what I wanted to see

(3-2) The scenery was exotic, yet somehow Japanese.

Example comments, made by examinees after the case 4

(4-1) It is fun to see the picture in motion. Every time I moved my eyes, I could see the animation, and I never got tired of it

(4-2) I was constantly zoomed in while watching the animation, but I think that is how much I was drawn to the work.

(4-3) Just the addition of the animation changed the impression considerably.

Example comments, made by examinees after the case 5

(5-1) I think the music gave it a unified feel all at once. The pictures and sounds reacted to each other, and it was a lot of fun to watch

(5-2) It was interesting to hear the sounds of the places we focused in

(5-3) When there was no sound, it felt like you were moving your eyes to look at the picture, but now that the sound is on, it is like, "Where is this sound coming from? My eyes naturally moved, thinking

(5-4) I liked the way the sound moved away from us as we left.

In addition, Figure 17 shows the examinee's average score with the seven questions for each of the five experiments.

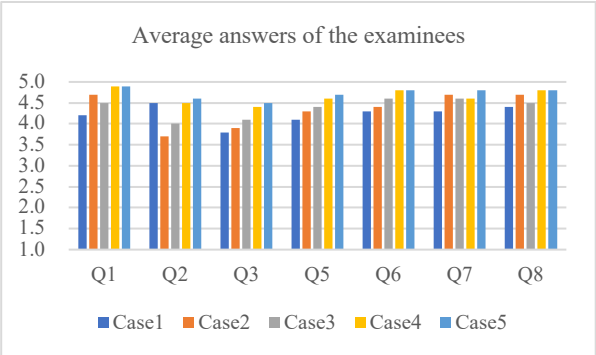


Figure 17 Examinee's average scores for the seven questions about the total interest rate

4.4 Discussions

From the results of the 5 experimental cases, we could observe the viewer's eye movements and their gazed areas.

In the case one which is the painting with only buildings and urban elements as shown in Figure 16(a), we can observe that the viewer's attracted to the areas with higher contrast and move their eyes according to the directions that are indicated by the wire lines and lamps, etc.

From case 2 which is the painting with images of residents, shown in Figure 16(b), we can trace the aggregation of eye fixations mostly, on the areas that the residents are depicted as the same areas defined as AOI by the authors.

In case 3 by reappearing the buildings and the urban elements denoted by Figure16 (c), we can see that gaze points distribution expands in search of the relation between the residents and the neighborhood. By adding the animation effects in case 4 and sound effects in case 5 depicted in Figure 16 (d) and (e), respectively, we can see that examinees get attracted to residents' images again and we have a noticeable increase in the number of the fixation points in AOIs.

Figure 18 shows the average percentage of examinees' fixations on the AOIs in all 5 cases. By comparing the results, we can observe that the animation and sound effects induce a significant factor in attracting and guiding the viewer's eyes. The average percentage of eye fixation in case 3, which includes not only the residents but also backgrounds, decreases comparing with that of case 2. Although background elements attract viewer's eyes, the animation and sound effects guide their attention to the residents.

Although we can also observe that each examinee's viewing path and order are different based on these results with visualization of the eye movements as shown in Figure 14, it appears that suggested elements of composition influence viewers' eye movements therefore the arrangement of the salient elements has resulted in an even distribution of the eye fixations.

From these results mentioned above, we can understand that with the average percentage of eye fixations in the AOIs, the considered loop feature and the arrangement of the painting elements according to Utopia's concept of equality is feasible and every resident of the depicted neighborhood has an opportunity to be observed. It worth mentioning, we are not expecting a linear distribution of eye-fixations, and of course, there are aggregation of eye fixation on some areas and less/no fixation on areas with non-informatic areas such as empty ground places.

The survey's results in Figure 17 shows that the examinees rated all the questions about engagement, creativity, and interest level above the average score of 3.5. Also, the average answer for question 8 which was about the like and dislike of the work is above 4.5 which means the examinees have found the work fun, interesting, and high quality, and of course, they have liked it.

Interestingly we can learn from the comments (1-1&2), (5-3) of the viewers that they were unconsciously drawn to the picture, cues, and sound effects and get familiar with the system's structure and its navigation style. These answers and comments helped us to understand the experiment's results better. From the added comments of the survey,

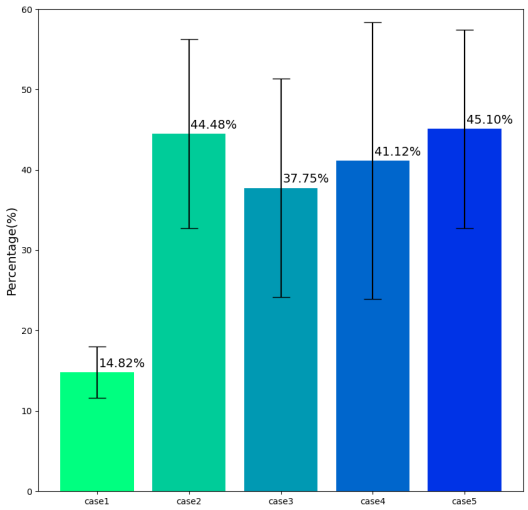


Figure 18 Average percentage of the all-examinees gaze in AOI

examinees mentioned that they have never had such an interactive visual experience. They also admitted that the way they can smoothly observe the painting and return the originated point by loop structure is interesting. The viewers also find images with a surrealistic concept more interesting, for example, the rhino with a balloon and a giant fish are the most mentioned elements. They have a positive intention toward the zoom-in and zoom-out feature and animated moves, and they think that these features improved the interactions with the painting and increased the engagement level. From the comments on sound effects, examinees mentioned a lot about the animals' sound effects and particularly mentioned the rooster sound that they found, nostalgic. From the viewers' comments, sound effects did complete the painting and are quite satisfying.

Worth mentioning, we are quite aware that there is a big chance that viewers would overlook the concept of such an interactive painting for a utopian neighborhood that tries to depict an equal world semantically and technically. Still, from the results and the comments of the examinees, we understand that the proposed eye navigation and the implemented strategies for a ceaseless experiment of appreciating painting are feasible and this feasibility supports the author's concept of artwork with equality and borderlessness concept.

5. Conclusion and Future Works

Utopia is an interactive visual experience. As it comes from the name, in Utopia, the aim was to provide an experience of appreciating a painting, which is interactive and compatible with the idea of Utopia for a borderless and equal world. For the implementation of the Utopia, in addition to semantically conveying the concept by illustrations, we proposed a comprehensive navigation method using the artist's conventional techniques for eye-guidance. Also, we provided a system with a loop structure for a ceaseless viewing experience and applied an eye-tracking camera as a tool of our interaction feature. The painting of our "Utopia" is a depiction of an imaginary neighborhood, a place with no borders and boundaries, where all its residents are living happily and peacefully together. Visual elements and cues, such as: a character looking into a distance, etc. are painted and arranged considering the system's structure and the concept to guide the viewer's eye in a uniform manner all around the painting. A system designed and developed in Unity. The display device is a monitor connected to an eye-tracking camera and speakers. The viewer's gaze-point is detecting by the eye camera, and the image moves/enlarges/reduces according to the movement of the gaze-point. For a ceaseless experience, we provided a loop structure in all directions that allows the viewer to observe the painting whiteout any interruptions. In such a system, every painting element would be located on the focal point eventually and have an equal chance of being seen. Additionally, to fulfill the proposed navigation method, we added animated and sound effects. Later by experiments and questionnaires, the effect of primary visual elements and principles, to introduce uniformity in different viewers' eye fixation patterns by directing attention to particular areas was examined and evaluated. The results of the experiments and comments of questionnaire are aligned with the author's' design and utilized features for a ceaseless navigation. In summary, we found some common fixation points and viewing patterns in the way examinees look at and interact with Utopia as it was expected. The results prove that the idea of creating a painting that every element could have a chance to be seen, shine individually, and be treated equally as well as overcoming the restriction of being inside the borders obligated by frame is possible. Still, a small variability regarding the viewing behavior depending on the viewer's interests, artistic appreciation, and knowledge exists. It is indeed challenging to find a clear explanation, but this is perhaps one reason that makes art so unique, personal, and fascinating.

Aiming for improvement of interaction, image quality, and creation of new artistic genres, we are eager to continue the path, proceed with additional research on visual and eye guiding fields. By connecting artistic knowledge and senses with the utilization of higher-level tools and by combining traditional and conventional artistic methods with new technologies we are going to create various interactive and contemporary contexts in near future.

Author Contributions

Design of the research, concept of the artwork and creation of the painting, data analysis and drafting the paper was done by Negar Kaghazchi.

System implementation and data acquisition by Yuto Kobayashi. Revising the paper critically and data analysis and final approval of the version to be published by Hiroki Takahashi.

Contributions to the conception and interpretation of data of the work by Sachiko Kodama.

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