

# Interpretation through Digital Imaging: Reflectance Transformation Imaging(RTI) as a Tool for Understanding Paintings

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**Abstract:** This paper presents Reflectance Transformation Imaging (RTI) as a tool to support the study of paintings and authentication. Manufacturing techniques of the artist are reviewed through the comparison between liberal perspectives and digital imaging techniques. In this study, RTI was applied to focus on the detailed textural information of eight paintings by Korean artist Lee Ji-ho. The RTI result visualizes shallow reliefs of brush strokes and different mediums on the surface technically enhanced through imaging filters, and these morphological textures on the surface act as a key factor in understanding the characteristics of the artist. The surface morphology and art criticism work as qualitative indicators to analyze the change of artistic techniques through time, and the usage of different mediums. The results of this study confirm that the RTI technique can be used as an analysis device in the study of paintings.

**Keywords:** reflectance transformation imaging (RTI); painting analysis; art appreciation; art interpretation; surface morphology

## 1. Introduction

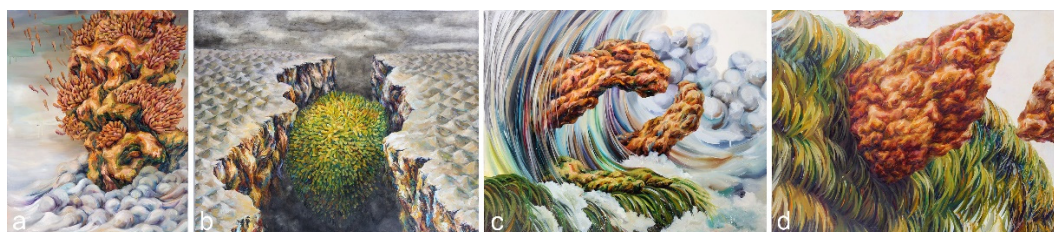
Lee, Ji-ho, a South Korean female artist was selected for the digital imaging examination to consider the applicability of studying the artist's methods and techniques [1]. The brushstroke of the artist may change due to many different reasons. Lee's painting has recently shown a noticeable change among the approximate range of five years. Her series which were produced till the year 2016 focus on expressing the slow and steady development of the consistent growth of nature. However, recent works, while maintaining the same subject, demonstrate the grandeur of nature expressed in different styles and different textures. The aim of this digital imaging analysis is to extract information regarding the brushstroke patterns and mediums to provide qualitative assessment for interpretation of the artist and her works. Through interactive re-lighting of RTI, shallow reliefs made by the brush strokes were visible. The surface morphology and art criticism altogether work as a qualitative indicator to analyze the changes of technique upon different times of production and usage of different mediums and materials.

## 2. Materials and Methods

A two-step method is applied for the development of this study: her artworks are carefully reviewed together before acquiring digital image data by an art historian who had previously studied her works, then for digital imaging, RTI is applied to examine the morphological images of the brush strokes.

### 2.1 Artwork

The artist Lee Ji-ho had focused on the individual detailed motives till the year 2017 (Figure 1). Elements of nature such as plants, rocks, clouds, grass, land etc. were described resembling body organs and by this effort she naturally stresses on replicating the detailed features. One interesting factor is while her description of plants, leaves, clouds uses a relatively thin brush following the underneath sketch, rocks and cliffs were expressed with strong informal strokes. Due to the differentially emphasized motifs, the individual characteristic of each is strongly revealed, allowing them to obtain an individual position, altogether leading to strengthen the dynamism of nature.



**Figure 1.** (a) Scattering space #8, oil on canvas, 90.9×72.7cm, 2013, (b) Soaring bush, oil on canvas, 72.7×90.9cm, 2013, (c) Scattering space #6, oil on canvas, 80.3×100.0cm, 2013, (d) rising rock, oil on canvas, 72.7×90.9cm, 2013

Since 2017, the rigid texture has changed through the addition of light, wind and air to create an atmosphere instead of clouds that have been a subject for reproduction itself (Figure 2). The intangible natural elements, such as air, wind and light, with an indistinctly constant direction, are utilized for the sentimental elements of the work itself. Therefore, the entire screen is encompassed altogether without the hierarchy of motifs and backgrounds. Still, the consciousness remains focused on reproduction of the vitality of nature. However, the texture of the body tissue-like expression disappears and a tendency to become abstract appears in the images of nature.



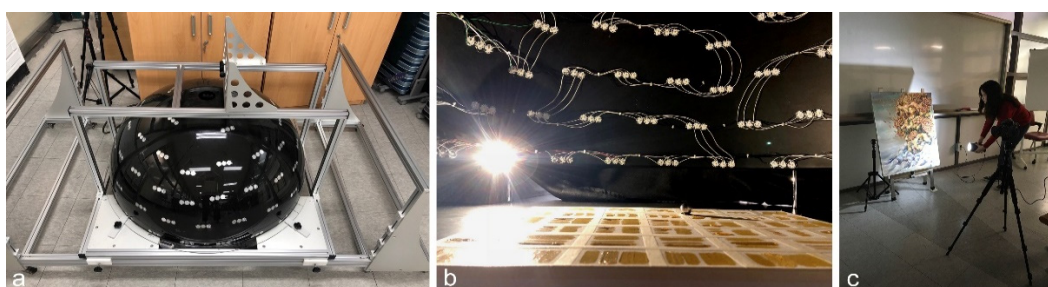
**Figure 1.** (a) Between, oil on canvas, 116.8×91.0cm, 2018, (b) Stump, oil on canvas, 72.7×53.0cm, 2017, (c) Emptying and Filling, oil on canvas, 90.9×65.1cm, 2017, (d) Sprout, oil on canvas, 65.1×50.0cm, 2018

## 2.2 Digital Imaging

Images have long been introduced as a documenting tool for paintings such as raking light photography which uses a low angle light source to examine the surface topography of a painting. Although various textures are visible, the still image has an inevitable limit to obtain the many characteristics of the painting which can be infinitely diversified through different angles of light. A digital imaging tool, similar to the basic idea of raking light named Reflectance Transformation Imaging (RTI) based on Polynomial Texture Map (PTM) was developed by Malzbender et al. [2]. This technology is a non-invasive, non-destructive surface examination tool based on computational algorithmic rendering [3]. RTI has been well known and used in the fields of archaeology [4] and to study the morphological texture of the surface [5] and trace manufacturing techniques [6]. Recently, RTI has also been applied in the field of paintings for conservation [7, 8] and documentation [9], [10] Imaging brush strokes, pigment and mediums of the painting has been done using RTI [11] and approaches towards applying RTI for art authentication [12] are in progress.

The aim of this paper is to examine the applicability of studying paintings through RTI and reviewing the potential advantages of using RTI to analyze the surface morphology such as brush strokes. While the surface

characteristics appear hidden under the distortion of light and shadow, they are revealed through RTI by illuminating the object from different directions and emphasizing the image by using a variety of RTI filters. This provides the opportunity to examine the painting techniques and also allows stylistic comparison. A Dome type RTI was developed for section imaging and a Highlight RTI was used to capture the entire image (Figure 3). The Dome RTI equipment is suitable for obtaining data through accurate light source placement in a geodesic shape, using a color temperature value of 4000k lighting LED. A total of 80 LEDs were placed on the interior of the black acrylic dome and Nikon D850 camera with AF-S Micro Nikkor 105mm 1:2.8G ED micro lens was used for the shooting for 80 sets of images in accordance with the number of LEDs. Rail structures were developed to promote the safety of the painting while moving the dome from one section to another. Images were captured as a raw image file and were converted into jpg files. The acquired images were then sent to the RTI Builder program, which is an open source offered by Cultural Heritage Imaging, a non-profit organization. [13] The finished files, produced as a polynomial texture map file (ptm.) are then operated through the RTI Viewer program [14] providing different images through dynamic lighting and various filters. Interpretation can be made through edge contour filters and specular enhancement filters which emphasize smooth texture and reflectivity of the original image (Figure 4).



**Figure 2.** (a) Dome RTI with rail structures, (b) Inside of the operating Dome (c) Highlight RTI operation



**Figure 3.** Different rendering filters from the RTI Viewer program, (a) Default Image, (b) Diffuse Gain (c, d) Specular Enhancement, (e) Normal Unsharp Masking, (f) Image Unsharp Masking, (g) Luminance Unsharp Masking, (h) Coefficient Unsharp Masking, (i) Normal Visualization

### 3. Results

In this section, results obtained by the analysis of the brushstroke and by the interpretation of art criticism will be presented.

#### 3.1 Surface Analysis

RTI results visualize the progress of change in the brush strokes and styles of the artist. The former period (before year 2017) reveals the original characteristics of the artist through body tissue like plants, rocks along with clouds, cliffs and long grass leaves. First of all, body tissue like plants are drawn in a two-stage method, using one brush with bright colors and another with dark colors (Figure 5b, 6b). Then, these colors are mixed together forming a gradation. Lastly, the brightest color is added as a highlighting factor in the end. The rocks are also performed in this regard accordingly (Figure 5c, 7b, 8b). Clouds are also done in the same process however flat brushes are applied instead (Figure 5d, 7c). As for the cliffs, they are expressed in a more abstract and informal manner compared to the former motifs. Some areas on the cliff have very thick painting layers and knife marks are also visualized through RTI filters (Figure 6c). Several locations in the cliff indicate sign of further modifications to change the boundary of the cliff. These underneath strokes assume to be Pentimenti (change of mind), which are previous brush strokes of the initial upper boundary of the cliff. Thus, in the initial sketch, the top of the cliff would have been narrower than it is now (Figure 6d). The low mountains above the cliffs reveal strokes that are not easily observed with the naked eye (Figure 6e). The long grass is expressed using a flat brush to draw a leaf in one stroke and the white areas painted into white layers are intentionally



added by the artist to show an empty space (Figure 7d, 8c). The background of the work painted with a single brush stroke is worth comparing to other techniques artist has utilized for different motifs (Figure 5b).

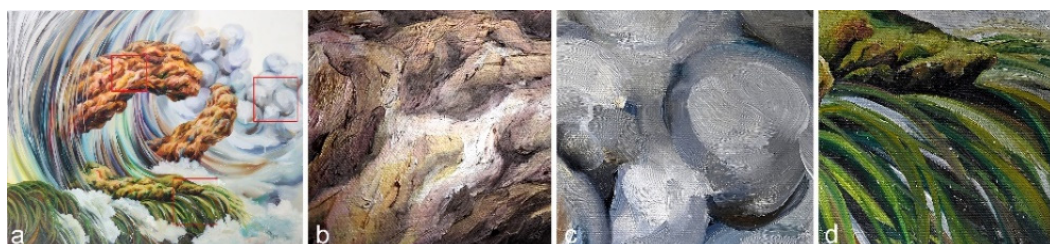
The RTI results of the recent works (produced after year 2017) indicate abundant usage of medium compared to the former stages of works. Significant change is noticeable by examining the stages the artist went through to apply the roughly textured medium on to the surface (Figure 9b). Through observing the descriptions of motifs, RTI image reveals that the paint layer and the gritty medium was first bountifully applied to the surface and then the depictions of the specific images were added using brushes and knives. Another interesting factor is the ambiguity of the border between the background and the motifs. Brush strokes overlap the background and the image mixing the colors together (Figure 10). Also, the paint layer of the background has increased revealing strokes amongst the surface. These are greatly comparable figures with regard to the earlier stages of the background painting. The backgrounds were equally painted along with the main motifs which make the background itself another motif with equal importance. RTI Filters also reveal an area which later was informed by the artist that she has used ceramic paint to give a smudging, reflecting effect on the surface (Figure 9c). The smudge layer had different reflectivity compared to the paint therefore revealed the applied area through a specular enhancement filter. Also, oil bars had different reflectivity compared to the surrounding oil painting surface (Figure 11).



**Figure 4.** (a) Figure 1a, (b) Detail image of body tissue like plants with Diffuse Gain, (c) Detail of the rocks with Diffuse Gain, (d) Detail of clouds with Image Unsharp Masking



**Figure 5.** (a) Figure 1b, (b) Body tissue like plants with Diffuse Gain, (c) Cliffs with Specular Enhancement, (d) Repainted area of cliffs with Image Unsharp Masking, (e) Mountain peaks with Specular Enhancement

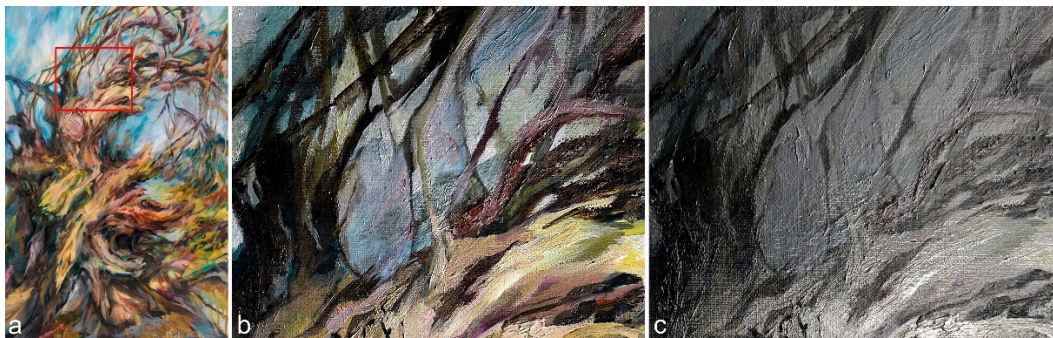


**Figure 6.** (a) Figure 1c, (b) Rocks with Specular Enhancement, (c) Clouds with Image Unsharp Masking, (d) Long grass with Diffuse Gain

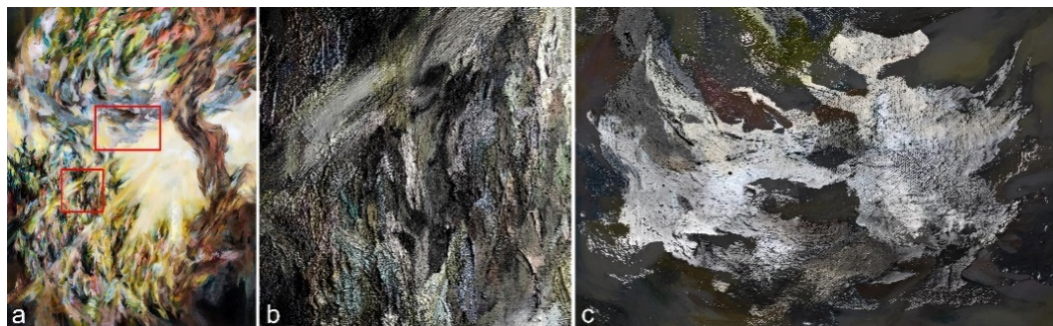




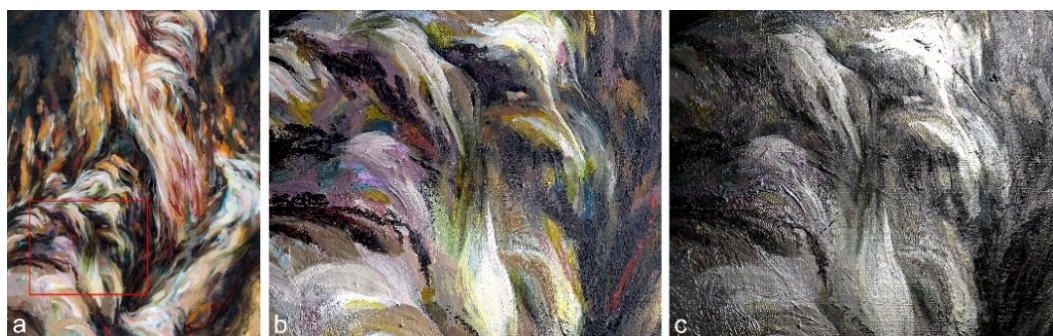
**Figure 7.** (a) Figure 1d. (b) Rocks with Specular Enhancement, (c) Long grass with Image Unsharp Masking



**Figure 8.** (a) Figure 2a, (b) Bushes with Specular Enhancement, (c) Ceramic paint with Specular Enhancement



**Figure 9.** (a) Figure 2b, Details of the twigs and overlapping background with (b) Image Unsharp Masking and (c) Specular Enhancement



**Figure 10.** (a) Figure 2d, Details of oil bar with (b) Image Unsharp Masking and (c) Specular Enhancement

### 3.2 Art Interpretation

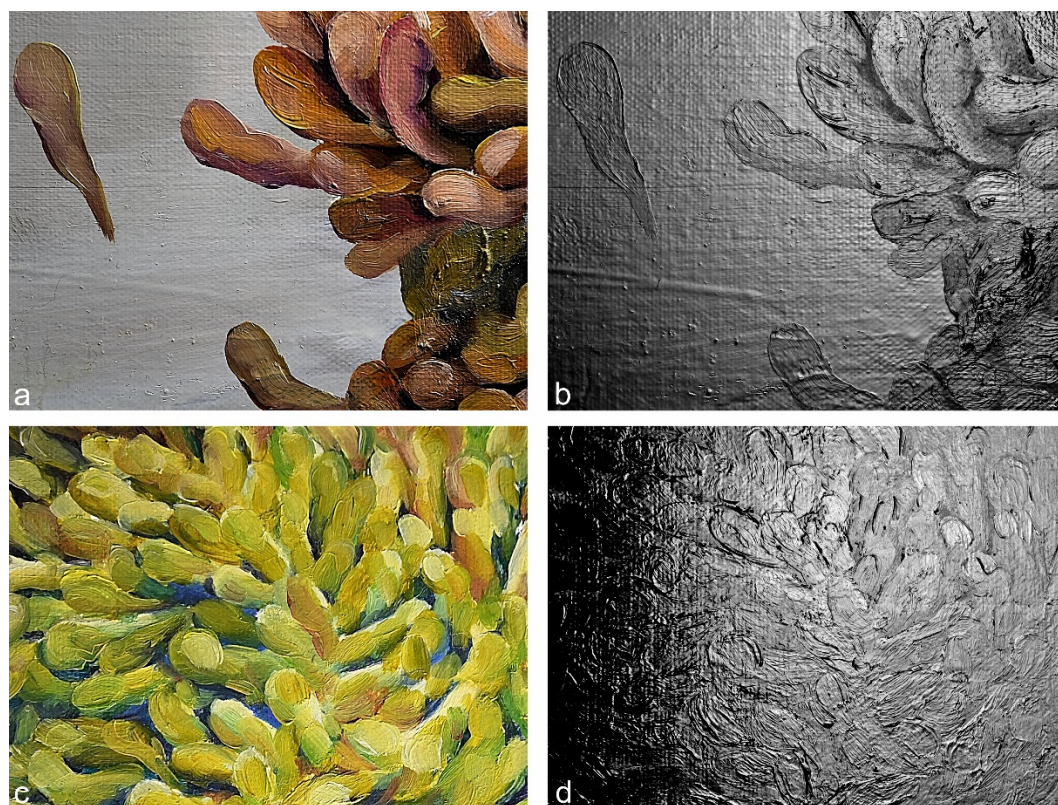
The combination of brushstroke analysis and art criticism was performed on 8 paintings of Figure 1 and 2. Comparing the repeated motifs and the background of the paintings along with the usage of mediums in different periods was chosen as a method for interpretation.

For the works before 2017, each 'body tissue' like leaf (see Figure 12) can be identified to be produced by repetitive brush strokes. This expresses the artist's concentration on producing repetitive and elaborate work based on the sketch underneath. The bright area increases its density through a final thick touch of white color



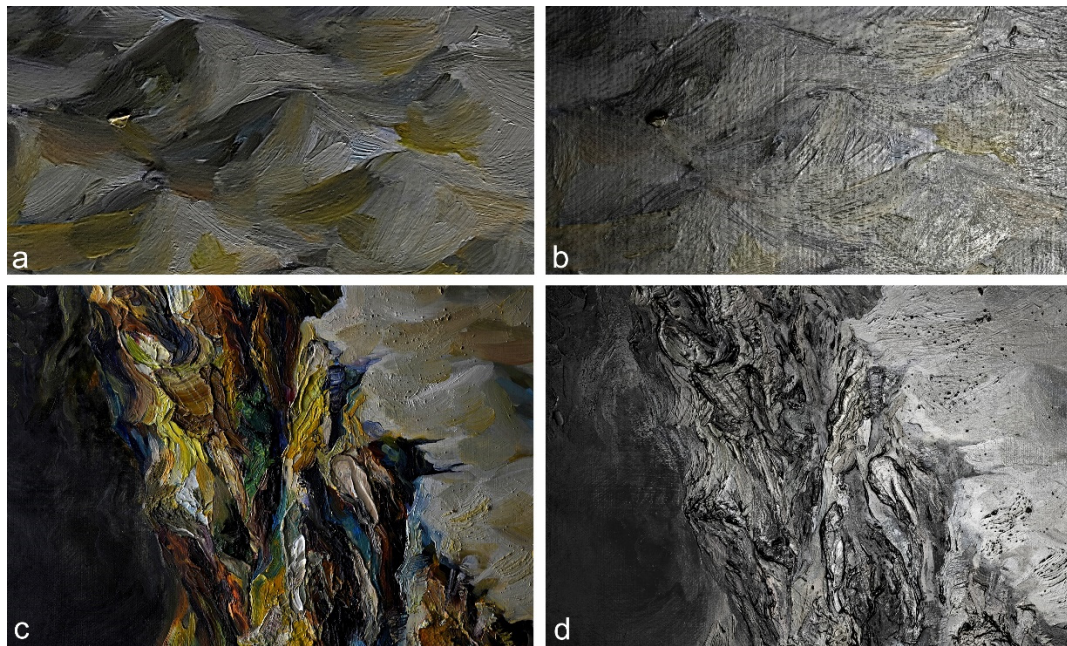
paint. The background shows no touches that can be compared to the touches of the major motifs indicating that the artist did not regard the background as a motif of her work. RTI also revealed the fact that the dark, shadowed area equally focuses on expressing its detailed features. The cliff can be another example. Relatively thick painting layers compared to the main motifs are notifiable despite being in the dark, not as a main motif. Also, the paints are applied directly on to the canvas and mixed upon the surface (Figure 13c). This can be compared to later works to reveal more significant results of understanding the stylistic changes. The mountain peaks (see Figure 13a, 13b) are expressed by using refined brush strokes to trim the overall shape of the surface of the peaks repeating several times. These strokes were examined through specular enhancement images showing a result that may indicate the painting progress of an artwork. The same area was observed to be a stroke colored with light yellowish hue. This seems to be the artist's last touch in determination to prevent the balance of colors from being broken and to give a sense of unity by using green and yellow in terms of grass masses and cliffs, on the top side of the gray peak. The additional yellow on the gray zone makes the description more lifelike.

Among the other features of the early work, the floating rocks are characterized by refined brush strokes, unlike the side of the cliff in other paintings although they are approximately similar rocky material (Figure 14). The probable explanation would be that the rocks are the main motif of the work. Long grass is completed by repeatedly applying long brush strokes, with white paint being the final color to be applied (Figure 15). This can be seen as one of the characteristic elements of the artist. Another feature of the early work is that dark areas have same intensity as the bright areas. In general paintings, the dark, shadowed areas are less described compared to bright areas. This equality in expression of bright and dark areas is what makes Lee Ji-ho's painting unique.

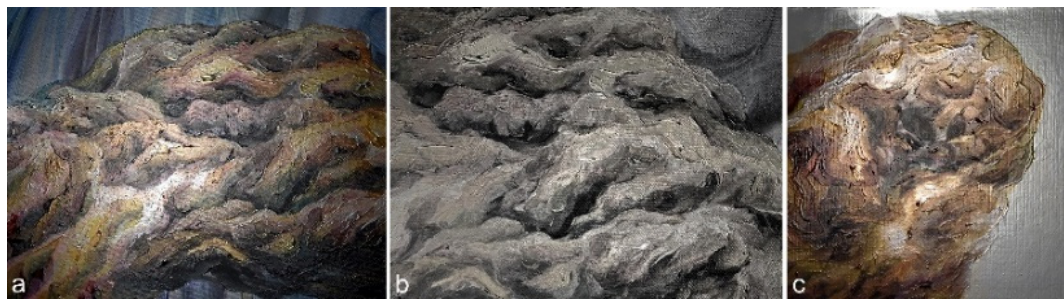


**Figure 11.** Body tissue like plants with Image Unsharp Masking (a), (c), and Specular Enhancement (b), (d)





**Figure 12.** Brush strokes of the mountain peaks with (a) Image Unsharp Masking and (b) Specular Enhancement (c) Cliff with Image Unsharp Masking and (d) Specular Enhancement



**Figure 13.** Rocks with Specular Enhancement (a), (c) and Specular Enhancement diffuse color filter rendering mode (b)



**Figure 14.** Long Grass with Image Unsharp Masking different light angles (a), (b)

All of the latest works depict strangely grown trees. The images were collected while the artist was traveling to Sri Lanka and Myanmar. If the early works were reproduced based on the author's imagination, the recent works were recreated based on empirical image. Nevertheless, the author does not see this as something that needs to be carefully reproduced. Magnified images present brush strokes that are strong enough to be felt like a part of an abstract painting. The biggest distinguishable features of the early and recent works are that the ecology-world created by the author being dismissed. If the previous works have been the mixture of plant and animal characteristics with unfamiliar and uncomfortable feelings being aroused by unfamiliar colors, the latest works depict scenes found in nature, such as in mountain sides quickly painted with rough brush touches and



mediums. Through this, the works evoke mysterious and fantastic emotions. If the former style of works had a clear distinguished method of description according to each motif, the work produced from year 2017 does not have a clear identification between the motifs and also the background behind it as in Figure 9. It has also diversified the way of producing paint layers by making a rich use of mediums as in Figure 8. The tree bark motifs, which were not featured in early works, are now being more actively presented. In the early works, rocks were expressed with repeated strokes with relatively short brush applied to fit the shape of the sketch. Recent works show that the shapes are expressed with longer brush strokes and the color used in one motif has become more abundant (Figure 16). This form of brush strokes or coloration resembles the brushwork that appears when describing the cliff side section of the early works as in Figure 15d. It is noteworthy that the brush strokes and thick paint layers shown in the cliffs of early works have been a constant interest to the artist since the beginning, and it is confirmed that she is trying to express them more actively in recent years. Therefore, despite the big difference of painting styles of her early and recent works, the painting patterns of her early works can be seen. This is also evident in the recent work, which uses additional medium to form thick layers of paint. This sufficient stacking of paint layers followed by later descriptions of motifs, leaves little importance for the under layer sketch. RTI analysis also visualizes the usage of mediums and knives to build up painting layers and other where the artist used a certain type of ceramic pigment as in Figure 8. This peculiarity cannot be identified through the naked eye due to the dark coloring areas with the distortion of light.



**Figure 15.** Tree Trunk with Image Unsharp Masking different light angles (a), (b), (c)

#### 4. Discussion

It can be said that there has also been a change in the artist's attitude toward non-material natural elements. In the early works, the author depicted non-material elements as a firm material with strokes shown in the examples of clouds, or toned down with thin, wide brush strokes as in the background sky as in Figure 12a. Compared to this, the author describes non-material elements such as sky and light using colorful colors and lively brush strokes to give similar hierarchy, allowing observers to feel the lively features of nature on the whole area of the screen. It seems that the author, who felt the power of nature while experiencing nature, has come to focus on portraying the whole atmosphere in order to fully convey the experience. Another example can be the image of light entering the bushes in Figure 8. The trees are covered with light and spread out in a variety of colors. In the early works, the light was not the subject of expression, but it is now chosen to be a main motif of the work by expressing strokes of light rays. An additional change of manner can be observed through the description of the knots, twigs and the sky overlapping each other in Figure 9. This shows a major change in the artwork where early works completely separate the background and motif. The recent works differ in that the background and motif are done at the same time. This paper has presented RTI as a method for studying the morphological data of the artist Lee Ji-ho's painting and for interpreting the characteristics of the artist. RTI enables an advanced understanding of surface information which offers an insight to understand the methods of description methods on the main motifs and materials of the painting. Overall, the evolution of expressions of the artist were able to be interpreted together with art criticism to understand how the intentions and ideas influence the manners of expressing nature through the brush strokes in her painting. RTI rendering filters allowed obtaining image results with enhanced edges, increasing or decreasing reflectance, color, along



with the control of the direction of light. This compensates limitation of the visual examination which would be generally insufficient and enables acquiring knowledge of unrecognizable information such as reflectivity and surface vectors. Reflectivity and light direction allows to observe changes in the curvature of the surface even in dark colors. This aids the interpretation of painting tools, styles, materials, and pentimenti. In addition, special mediums such as ceramic paint were visualized through different reflectance coefficient. This can be applied with further chemical analysis to support scientific examination. Overall, the results show the applicability of RTI to be used as a tool for preservation and documentation by archiving morphological information in terms of diagnostic examination, periodical condition check and transportation. The obtained images also open a possibility of RTI serving as a supplementary measure for the study of art history, art criticism and authentication in long term. For the future works, we plan to explore the application of other surface examination methods such as three dimensional imaging, photogrammetry and multispectral imaging to enhance the qualitative information of the data.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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