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Controlling color regions of leaves with painting techniques for landscape arts

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Abstract

In this paper, we propose a non-photorealistic rendering (NPR) framework for creating landscape art in traditional animation. The proposed method is based on painting techniques for landscape arts, which enables a user to reproduce features of the target work of art and its style. Landscape (background) arts is generally used in animation productions. One image of landscape art and multiple layers of moving characters compose a scene. Landscape art is one of most important factors for making the impression of an animation. We propose a NPR technique that reproduces painting techniques for landscape arts such as leaf painting based on just a few colors, shading to produce a spherical effect. The technique developed by the authors generates dynamic landscape art having a swaying motion in the wind by applying the animation generation technique for swaying trees to it.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 [Computer Graphics]: Three-Dimensional Graphics and RealismAnimation I.3.7 [Computer Graphics]: Three-Dimensional Graphics and RealismColor, shading, shadowing, and texture I.3.4 [Computer Graphics]: Graphics UtilitiesSoftware support

1. Introduction

In production processes of animation film, creators are required to have the expertise of painting and a lot of working hours for painting realistic landscapes, and smooth character animations. To create a landscape animation that has natural motion, an amount of time and effort is also required. Therefore, landscape paintings in animation, which are used for backgrounds of scenes, mostly just have simple motion or are static. In this paper, we propose a non-photorealistic rendering (NPR) technique for generating landscape art in animation. The proposed method is based on traditional painting techniques for landscape arts, which enables the method to pick up features of the target work of art and to reproduce its style.

1.1. Previous Work

There are many studies on modeling and rendering natural landscapes. For static modeling of plants, Lintermann et al. proposed an interactive design method for plants [LD99]. This method controls leaf arrangement, branching rules, and shapes of flowers. To generate realistic shapes, a growth simulation method [HBM03] was also proposed. Because the tree models used in these paper are based on L-System, the models have a link structure (parent-child relationship) of branches . In other studies on dynamic animation of plants [GCF01, SO99, PC01, CKS*93], many tree models used for animations also have the link structure for bending branches.

Creators of cartoon animation usually do not require photorealistic graphics, but NPR techniques [RTF*04, SBZ04, MMK*00, OK05]. NPR techniques can render paint-like styles (brush styles, inflated shapes, and cartoon shading) that are required by creators. Coconu et al. proposed pen and ink style shading for trees by controlling the complexity of a tree's outline and leaf location [CDH06]. Luft et al. proposed a water-color style rendering method, in which normal vectors of leaves are calculated from an implicit surface enveloping foliage [LD05,LD06,LBD07]. Since the method of generating the implicit surface is based on metaballs, the shape of the implicit surface and distributions of normal vectors can be easily controlled with a threshold value of a den-

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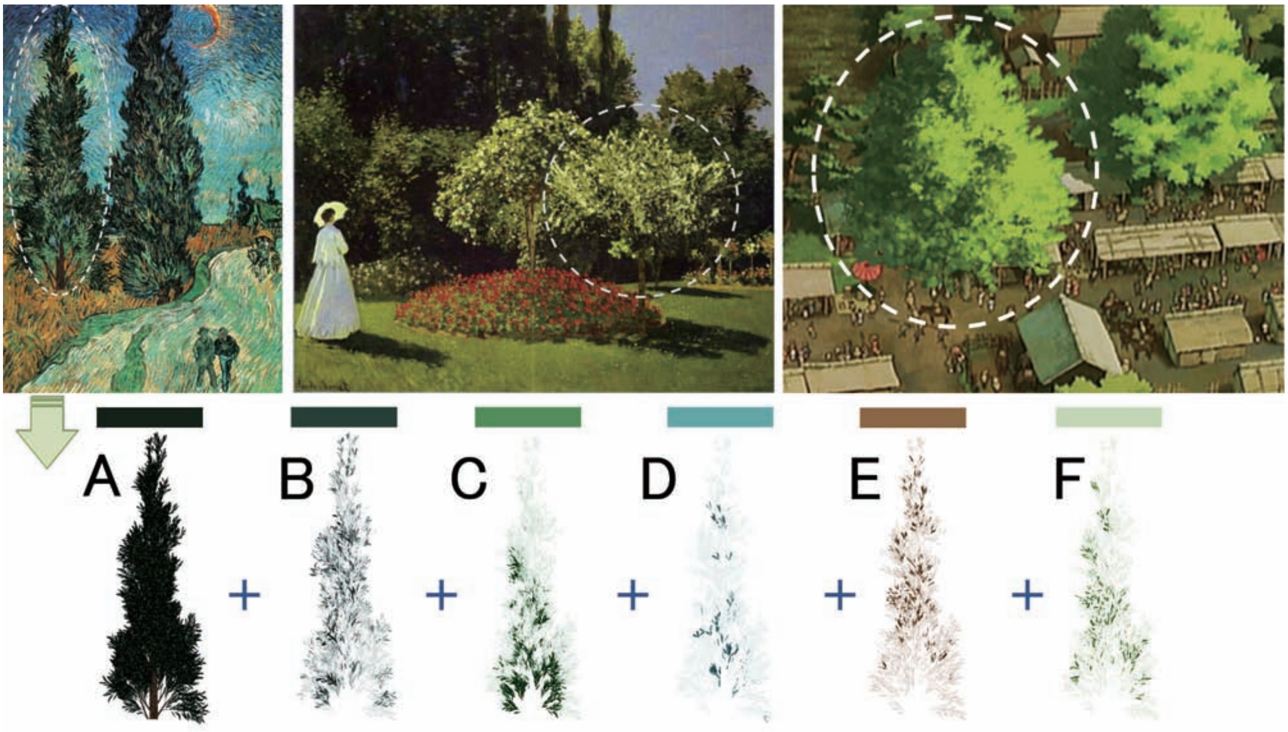

Figure 1: *Upper side: Each picture has an additional tree that is generated by our technique in a dotted circle. Lower side: Layers of color region (A B) and mapping colors in the left result.*

sity field and by raising the value of the parameter it comes closer to a sphere. This method has a merit that it can easily control shading styles with few kinds of parameters. Wilson et al. proposed pen and ink style rendering method which is based on brightness (grayscale) regions of complex objects [WM04]. This approach is similar to ours in considering the shapes and the shading result of 3D tree model. However, it is difficult to represent features of specific artworks with the method, because the degrees of freedom to control shading styles are too low.

On the other hand, there is another approach [CSUN04] for analyzing the coloration of specific art styles. The result of analysis can be used to generate new drawings or modify other drawings in/to the style of the analyzed art style. However, it is not so easy to apply the result to 3D tree models and rendering.

1.2. Approach

We aim to propose a novel rendering method for 3D tree models that can easily control shading styles. The feature of our method is in that we refer to the painting process of landscape including oil and watercolor painting. First, painters usually draw trees in landscape arts by using just a few colors of paints [Oga05]. We apply this to using layers of color rigions as will be mentioned in section 3. An example of color region is shown in the lower side of Figure 1. Next, in a commonly used shading technique for painting trees, the shape of a tree is often modeled as a combination of spheres enveloping not only a whole tree but bunches of leaves. We apply this to clustering of leaves and color-region-based rendering as will be mentioned in section 2 and 3. The results that have been generated with our method are shown in the upper side of Figure 1.

2. Clustering of leaves using generations of branches

In this section, we describe a preprocessing step for clustering of leaves. The typical structure of a tree model in animation is composed by segments and links of branches and leaves [TZW*07]. Because the segments-links structure enables the tree model easily to deform its shape by computing joint (link) rotations, this suructure is commonly used.

Our method uses this suructure in the preprocessing step. It groupes leaves into several clusters which correspond to each generation of branch (Figure 5). The number of generation increases every time branching occurs, where the number of generation for a trunk is 1. Since higher generations (number of generation > 4) have too much complicated a structure it is not suitable for landscape arts, we just use the numbers of generation from 1 to 4. A sphere enveloping each cluster of generation is obtained from positions of leaves and every sphere is used to calculate normal vectors of leaves.

3. Color-region-based rendering of trees

In this section, we describe a rendering technique to control color regions of trees. Section 3.1 shows that typical landscape arts are drawn by overpainting a few colors. In section 3.2, we propose a method of segmenting color regions, into which we define shading layer functions (SLFs) with tree parameters.

3.1. Painting techniques for landscape arts

In the process of painting a tree with a brush, leaves are shaded to present the volume of a tree. A painter usually paints a base outline first and overpaints detailed leaves with just a few colors [Oga05]. An example of color regions in

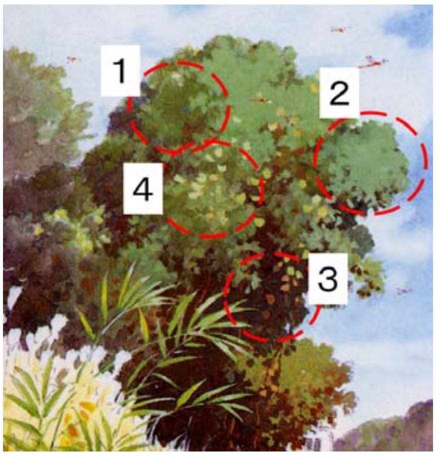

Figure 2: *An actual example of color scheme.*

landscape art is shown in Figure 2 . The concepts of each color region in the figure are as follows:

1. base color of overpaints
2. shiny side of leaves
3. shaded side of leaves
4. highlight

These regions are determined by abstracting the continuous transition of brightness on leaves. The method of abstraction determines the feature (style) of an art.

3.2. Shading Layer Functions (SLFs)

In our framework, we generate color regions which are similar to a target artwork. We propose five types of SLFs to easily control the shape of color regions. SLFs generate color regions as grayscale images with tree parameters (positions of leaves, center positions of clusters, a light direction and some coefficient values) (Figure 9). Grayscale images are assigned with paint colors that are used in the target artwork and synthesized to a fainal image. In the following section, we describe the detail of each SLF.

3.2.1. Diffuse Shading Function

This section shows the simplest function named the "diffuse function," which is well known as"diffuse lighting." In the case of the diffuse function, creators control color regions of trees by changing light direction. The result of synthesizing

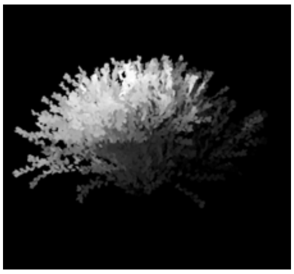

Figure 3: *Rendering result of a shading layer with the diffuse function.*

Figure 4: *Mapping a green color to the shading layer image.*

Figure 3 from a base color is shown in Figure 4. Figure 4 is the same result as that of diffuse lighting. In this case, we use this image for representing the color region of the sunny side of the tree. Because normal vectors of leaves have various directions, the diffuse function generates a detailed color region which is used for a near distance and a realistic style. In the following section, we describe a suitable shading method for landscape art.

3.2.2. Spherical Shading Function

We propose the "Spherical Shading Function" which generates normal vectors of leaves considering the distribution of leaves. The previous study [LBD07] generates a normal vector of a leaf from implicit surfaces in a preprocessing step. In our method, the normal vector is directly calculated from each position of a leaf and center positions of the bunches of

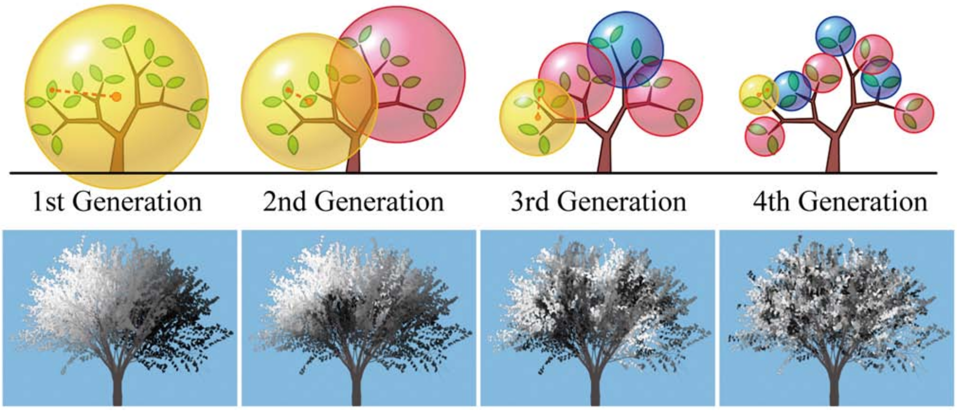

Figure 5: *Upper side:Spheres of each generation. Lower side: Shading layers generated with Spherical Shading Function.*

leaves. The center position $\vec{C}_{j,g}$ belonging to a cluster(j) of generation (g) are defined by the following equation:

$$\vec{C}_{j,g} = \frac{1}{L_{num}} \sum_i \vec{L}_i \quad (1)$$

$$L_{num} : number\, of\, leaves\, in\, the\, cluster(j)$$
$$\vec{L}_i : positon\, of\, the\, leaf(i)$$

By using $\vec{C}_{j,g}$,spherical distributed vectors of a leaf (i) $\vec{V}_{i,j,g}$ are calculated by the following equation:

$$\vec{V}_{i,j,g} = \vec{L}_i - \vec{C}_{j,g} \quad (2)$$

Next, we perform weighting according to distance based on normal distribution N and synthesize over all clusters(j) to obtain normal $\vec{N}_{i,g}$(eq. 3).

$$\vec{N}_{i,g} = \sum_j \vec{V}_{i,j,g} N(|\vec{V}_{i,j,g}|/R) \quad (3)$$

$$N(x) : Normal\, Distribution$$
$$R : Radius\, of\, the\, cluster(j)$$

Trees in landscapes are drawn with various details of shade that are determined to their distance from a viewpoint. To control the details, we use four weight values (W_g) of each generation (g) to computing each SLFs Then, we normalize the obtained normal $\vec{N}_{i,g}$ and synthesize over all generations using weight W_g of each generation (eq. 4). After that, we apply diffuse lighting to this normal and determine leaf brightness. W_g controls the details of shadow (Figure 5).

$$\vec{NC}_i = \sum_g W_g \vec{N}_{i,g}/|\vec{N}_{i,g}| \quad (4)$$

The dot product of a spherical normal ($\vec{NC}_i$) and a light vector $\vec{N}_{Light}$ is a brightness on a leaf BC_i.

$$BC_i = \vec{NC}_i \cdot \vec{N}_{Light} \quad (5)$$

The normal of a leaf is spherically distributed with a center of clusters, as shown in the upper side of Figure 5. The difference of shading complexity between different generations of clusters is shown in the lower side of the figure. The previous study [LBD07] controls the smoothness of shadow with a threshold parameter. In our approach, by increasing weight values of lower generation (ex. W_0), the shadow of leaves is closer to the shadow of a sphere.

3.2.3. Shading Function based on distance from center of a cluster

The central portion of a tree is drawn by using dark colors because the leaves shade the light. Therefore, the function (eq6) is introduced for representing this shading effect. $|\vec{V_{i,j,g}}|$ (eq. 2) are distances from the centers of a cluster (j,g) to the position of a leaf (i). After that, by searching the maximum distance ($MaxL_g$) in $|\vec{V_{j,g}}|$ and normlizing, the brightness of a leaf BG_i is comuputed. A result obtained by using this function is shown in Figure 6 (A).

$$BG_i = \sum_g W_g |\vec{V}_{i,j,g}|/MaxL_g \quad (6)$$

3.2.4. Shading Function based on a age of a leaf

Leaves have many colors that are attributable to age. Younger leaves often cover the outside of a tree and have a lighter color than older leaves. We calculate a virtual age of a leaf from a link structure of branches. First, we calculate distances (along branches) of leaves to the root of a tree (DL_i). Next, the age of leaves $Youth_i$ is calculated by the following equation:

$$Youth_i = 1 - \frac{DL_i - MinDL}{MaxDL - MinDL} \quad (7)$$

$$MaxDL : maximum\, value\, of\, all\, distances$$
$$MinDL : minimum\, value\, of\, all\, distances$$

This function sets brightness to leaves as $Youth_i$. Figure 6 (B) shows the result example of this function .

3.2.5. Shading Function based on viewing distance

In landscape arts, a technique named “aerial perspectiv” is generally used for representing diffusion of light that occurs due to atmospheric influence. The aerial perspective draws the color of leaves at the far side gradated to a sky color according to the viewing distance.

$Depth_{i,g}$ is a distance factor from scean camera to centers of a cluster $\vec{C}_{j,g}$. The BD_i is a brightnesse that is normalized $Depth_{i,g}$ by maximum ($MaxD_g$) and minimum ($MinD_g$) distance of each generation (eq. 8). When $g = 1$, these distances are searched in all trees and brightnesses are computed with positional relation of whole trees. In other generation ($g > 1$), the distances are searched in leaves that have a common parent branch (searched in the own tree). A result obtained using this function is shown in Figure 6 (C).

$$BD_i = \sum_g W_g \frac{Depth_{i,g} - MinD_g}{MaxD_g - MinD_g} \tag{8}$$

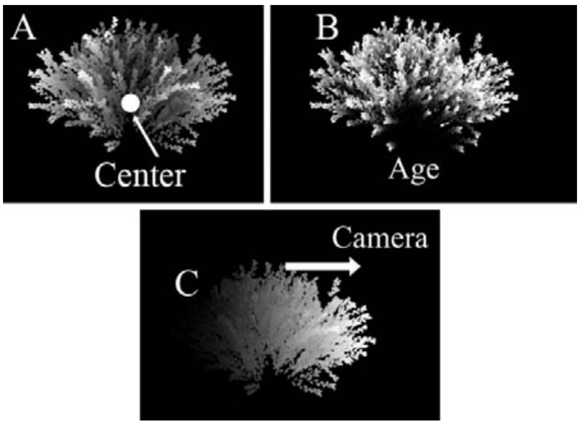

Figure 6: *Rendering result of each shadow–function.*

3.3. Controlling the contrast of a color region

Even if a color region is painted by one color, the variance of color density is appeared. For example, water color has a large color gradient and oil painting has clear edges. To control the styles of gradation, we control the contrast of the brightnesses of leaves (Fig. 7). This control function is declared by using maximum and minimum points of brightness.

3.4. Synthesis of mask images

Mask images that are rendered to represent particular regions of a color with SLFs are synthesized in one image. This method can be performed by the following procedure:

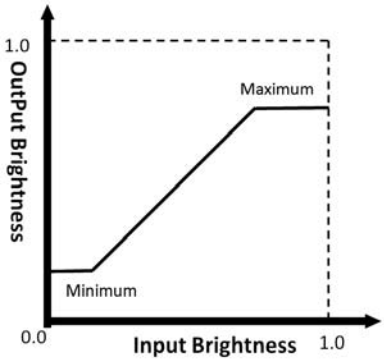

Figure 7: *A control function for the contrast of leaves.*

1. Setting the colors of each mask images.
2. Setting the order of synthesis.
3. By using mask images as a map of alpha values, each plane (that has the color of each region) is synthesized using the alpha-blending.

These are color-region-based rendering techniques for landscape arts. The rendering results are shown in section 4.3.

3.5. Direction control of a leaf

The shape of a leaf in landscape arts is different from that in nature. The difference is mainly caused by the limitation in the fineness of a paint brush. The shapes of leaves are usually drawn as though they are flat because of the limitation of a paint brush. In contrast, a 3D tree model usually has various direction of the face of a leaf caused by complex branch structures. Therefore, when our system renders a tree, leaves are changed to face the scean camera with a facing rate. The facing rate is a weight value (0.0 1.0) for a rotation angle between an orignal direction to camera direction. In the Figure 1, values of each result are { $left = 0.36, center = 0.87, right = 1.0$ }. With increasing the facing rate, the impression (painting style) of a tree resembles water color style (by the character/limitation of a brush and paints, this style is difficult to draw thin lines). To prevent an over rotation, the rotation angle is less than 180°.

4. Results and discussions

In this section, we show results of our technique for approximating actual arts and discuss the effectiveness of shading functions.

4.1. Results of approximating to arts

In Figure 1, trees generated with our method are added on the original drawings. These results are approximated with two oil paint pictures ([Gog90], [Mon67]) and an animation

Table 1: *Weight values of each layer.*

	Layer									
	B		C		D		E		F	
SLF Type	sphere	0.78	age	0.45	sphere	0.0	center	0.37	sphere	1.0
		0.0		0.15		0.80		0.81		0.0
		0.40		0.24		0.52		0.54		0.0
		0.20		0.73		1.0		0.32		0.0
	age	0.11	-	-	view	0.0	age	0.11	center	0.10
		0.31		-		0.26		0.31		0.43
		0.82		-		0.46		0.82		0.01
		0.63		-		0.87		0.63		0.64

picture ([Ghi97]). The user interactively controls the color region of leaves by changing weight parameters of each SLF (Table 1) in conformance with target pictures. However, this operation averagely takes one - two hours. These results received the following comment by an expert in animation film.

"I get the impression that the results accurately represent the artistic style of the original works. In particular, it is estimable that features of paint brush and color regions are able to represent as well as colors features. However, the matiere (material) of branches is not represented, so the original works are not completely recreated. I feel this technique has more potential for development of art research than just imitation of art style."

Therefore, our technique enables reproduction of the color region of leaves in arbitrary artistic styles. However, the rendering technique for branches is an issue to be studied in the future.

4.2. Parameter adjustment

Out method requires a user to adjust parameters which are four weight values of each SLF and a light direction (it is required in diffuse and spherical shading function). The total number of parameters is 32 (5 SLF $\times$(4 weight values $+$ 2 values for contrast)$+$ degrees of latitude and longitude of a light sorce $\times$ 2). Therefore, if user configures all parameters, it takes considerable time to choose values. However, the number of SLFs which are required to create a similar color region is sufficient in two types or less. The left image of Figure 1 is generated with using two types (or less) of SLF. Table 1 shows the types of SFLs and weight values of SLFs which are used to generate Figure 1. Our method still takes some time to set up parameters. However, there are benefits in creating and editing tree animations. Once parameters are decided, our method can generate arbitrary scenes (adding motions, another camerawork and minor changing of the shape) with keeping the style of a target artwork.

On the other hand, to adjust parameters, it is requires some artistic ability to analyze the color region of a target artwork. In the case of creating animations for commercial use, creaters usually have such an ability. For a general user who is not expert in art, our method provides a interactive controllability of parameters. In other words, the user can interactively compare the result of controling to a target artwork and improve it.

4.3. Division of color region

The color region (mask images) that is approximated to the image of an animation [Ani91] (Figure 8) is shown in Figure 9. This result has nine types of paint colors for representing each region (Table 2). The color values of each region and their composition order are decided by the user. This result suggests that the composition of a few color layers can reproduce the target artistic style and give a 3D appearance to trees. In particular, by using the Spherical Shading Function, the thick growth of leaves is naturally shaded. The function of contrast controlling is useful for clipping a small area like E-I in Figure 9.

Figure 8: *Target image of approximation.*

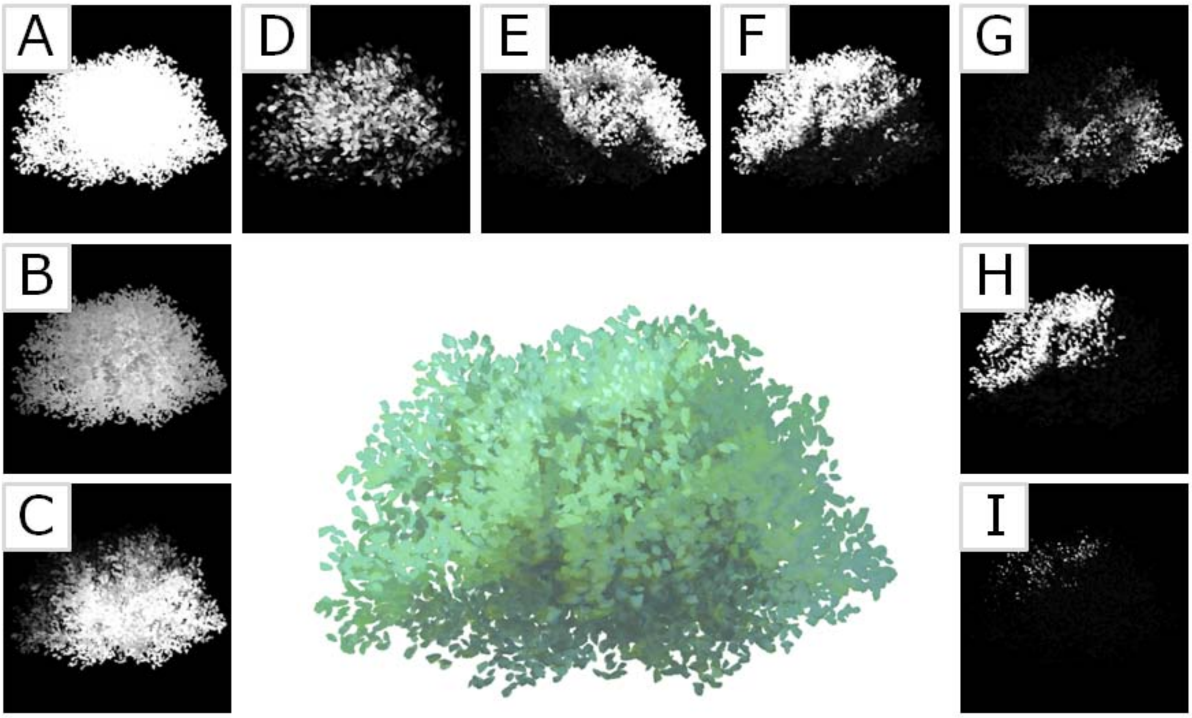

Figure 9: *Mask images of each color and synthesized result.*

Table 2: *Intentions of color schemes and color values*

Image	Expressive intention	Color(RGB)		
A	Ground Color	118	165	120
B	Under Darkness	24	27	29
C	Inner Area	3	72	68
D	Accent Light	217	221	107
E	Shaded Side	86	132	95
F	Deep Green	89	128	89
G	Accent Shadow	87	126	120
H	Light Side	107	171	136
I	Highlight	178	225	212

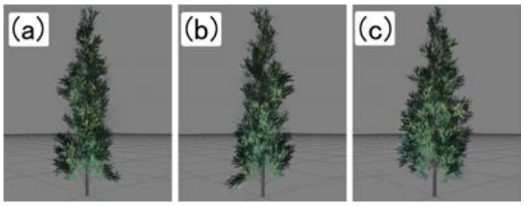

Figure 10: *Results of a tree (upper left of Figure 1) which is viewed from other directions.*

(a) viewed from the left side
(b) viewed from the back side
(c) viewed from the right side

4.4. Rendering results from other views

In this section, we show some rendering results from other views. Figure 10 and 11 show the rendering results for the trees shown in the upper left side and right side of Figure 1, respectively. Both represent natural effect that corresponds to each shading style.

5. Conclusions

We achieved a novel framework for creating landscape arts that have arbitrary styles of animation. By synthesizing SLFs, we parameterized a target artistic style and rendered a 3D tree model with its style. Various experiments were performed to compare landscape arts in animation to the original image.

References

[Ani91] ANIMAGE: *THE ART OF ONLY YESTERDAY*. Tokuma Syoten, 1991.

[CDH06] COCONU L., DEUSSEN O., HEGE H.: Real-time pen-and-ink illustration of landscapes. In *Interna-*

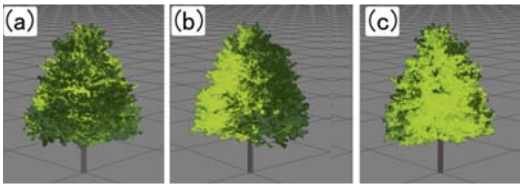

Figure 11: *Results of a tree (upper right of Figure 1) which is viewed from from other directions.*

(a) viewed from the left side
(b) viewed from the back side
(c) viewed from the right side

tional Symposium on Non-Photorealistic Animation and Rendering (2006), ACM Press, pp. 27–35.

[CKS*93] CHIBA N., KONO N., SATO Y., MURAOKA K., SAITO N.: Image generation method for swaying branches by wind. *Journal of IIEEJ 5*, 27 (1993), 475–483.

[CSUN04] CHANG Y., SAITO S., UCHIKAWA K., NAKAJIMA M.: Example-based color stylization based on categorical perception. In *ACM Symposium on Applied Perception in Graphics and Visualization* (2004), ACM Press, pp. 91–98.

[GCF01] GIACOMO T., CAPO S., FAURE F.: An interactive forest. In *Eurographics workshop on computer animation and simulation* (2001), Eurographics, pp. 65–74.

[Ghi97] GHIBLI S.: *The art of the Princess Mononoke*. Tokuma Syoten, 1997.

[Gog90] GOGH V. V.: Road with cypress and star, 1890.

[HBM03] HART J. C., BAKER B., MICHAELRAJ J.: Structural simulation of tree growth and response. *The Visual Computer*, 19 (2003), 151–163.

[LBD07] LUFT T., BALZER M., DEUSSEN O.: Expressive illumination of foliage based on implicit surfaces. In *Eurographics Workshop on Natural Phenomena (EG-WNP)* (2007).

[LD99] LINTERMANN B., DEUSSEN O.: Interactive modeling. of plants. *IEEE Computer Graphics and Applications 1*, 19 (1999), 56–65.

[LD05] LUFT T., DEUSSEN O.: Interactive watercolor animations. In *PG '05: Poster Proceedings of the 13th Pacific Conference on Computer Graphics and Applications* (2005), pp. 7–9.

[LD06] LUFT T., DEUSSEN O.: Real-time watercolor illustrations of plants using a blurred depth test. In *International Symposium on Non-Photorealistic Animation and Rendering (NPAR)* (2006), pp. 11–20.

[MMK*00] MARKOSIAN L., MEIER B. J., KOWALSKI M. A., HOLDEN L. S., NORTHRUP J. D., HUGHES J. F.: Art-based rendering with continuous levels of detail. In *First International Symposium on Non Photorealistic Animation and Rendering* (2000), ACM Press, pp. 59–66.

[Mon67] MONET C.: Woman in the garden, 1867.

[Oga05] OGA K.: *Kazuo Oga - Art Collection 2*. Studio Ghibli, 2005.

[OK05] OLMOS A., KINGDOM F.: Automatic non-photorealistic rendering through soft-shading removal: a colour-vision approach. In *2nd International Conference on Vision Video and Graphics* (2005), Eurographics, pp. 203–208.

[PC01] PERBET F., CANI M.: Animating prairies in real-time. In *Proceedings of the 2001 symposium on Interactive 3D graphics* (2001), ACM Press, pp. 103–110.

[RTF*04] RASKAR R., TAN K.-H., FERIS R., YU J., TURK M.: Non-photorealistic camera: Depth edge detection and stylized rendering using multi-flash imaging. *ACM trans. Graph 3*, 23 (2004), 679–688.

[SBZ04] SYKORA D., BURIANEK J., ZARA J.: Unsupervised colorization of black-and-white cartoons. In *Proceedings of the 3rd international symposium on Non-photorealistic animation and rendering* (2004), ACM Press, pp. 121–127.

[SO99] SAKAGUCHI T., OHYA J.: Modeling and animation of botanical trees for interactive virtual environments. In *Symposium on virtual reality software and technology* (1999), ACM Press, pp. 139–46.

[TZW*07] TAN P., ZENG G., WANG J., KANG S. B., QUAN L.: Image-based tree modeling. In *SIGGRAPH '07: ACM SIGGRAPH 2007 papers* (New York, NY, USA, 2007), ACM, p. 87.

[WM04] WILSON B., MA K.-L.: Rendering complexity in computer-generated pen-and-ink illustrations. In *NPAR '04: Proceedings of the 3rd international symposium on Non-photorealistic animation and rendering* (2004), pp. 129–137.

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