

## SHADING ESTIMATION METHOD FOR CEL-ANIMATION STYLE 3DCG ANIMATION

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### ABSTRACT

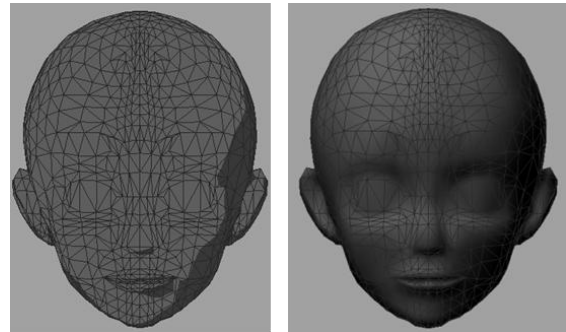
Traditional cel-animation style works are popular in Japan. Today, some of such works are produced from 3DCG with cel-shading techniques which convert ordinal shading effects into simple bi-level shades. However, this process often generates unsuitable shades with complicated shapes, and manual refinement of these shades disturbs efficient production process. In this study, we try to estimate hand-drawn facial shading style in each frame from multiple shading examples. Here, the shading examples correspond to several different camera angles are drawn by an animator. Then, shading pattern in each frame is calculated by using example shades from adjacent camera angles.

### 1. INTRODUCTION

In animation works, traditional cel-animation style is popular in Japan. In cel-animation style, several abstraction techniques are used. Color tone change caused by shades and shadows are expressed as bi-level (light and dark) tone painting with simple border shapes, instead of photorealistic graduation. Today, many animation works are produced by using computers, and some of them utilize 3DCG. To realize cel-animation style with 3DCG, cel-shading (or toon shading) technique is used, where the color at each pixel calculated by ordinal shading process is converted to either of bi-level colors by simple thresholding (Fig. 1).

However, by using conventional cel-shading technique, shading result is often unsuitable, because it has complicated or dirty border shapes. In such case, it is necessary to simplify the shading result in each frame by hand, which is time consuming. To reduce this effort, several methods have been proposed. Todo *et al.* proposed a locally controllable stylized shading techniques [1]. Here, user can modify the shape of a shaded area in a key frame. Then, the shaded area in the other frames are automatically corrected by using an offset function for shading calculation. Nakajima *et al.* proposed a method that manipulates shading result by placing an invisible object in front of the character model [2]. DeCoro *et al.* presented stylized shadow generation by controlling some parameters such as softness and abstraction [3].

In this study, we aim another shading method for cel-animation style 3DCG. For rendered images of a character face from several camera angles, user draws shape of shaded areas. Then, system estimates the shaded areas in the image from another camera angle. In this paper, we propose a method to estimate the positions of shaded areas in the camera angle set by the user.



(a) cel-shading (b) photorealistic shading  
Figure 1 Cel-shading technique in 3DCG

### 2. SHADING TYPE IN CEL-ANIMATION

In this section, characteristics of shading styles in existing cel-animation works are analyzed.

#### 2.1. Shading at each part of character face

In cel-animation works, shading is often applied to parts of a character face, such as the nose, eye socket, or mouth. This shading emphasizes the feature of the character face. Whether shading is applied or not for each part mostly depends on animation works rather than characters. An example is shown in Figure 2, where two male characters and two female characters in an animation work are shown. Although they are different characters with different expressions, shading is applied to the same parts, *i.e.* nose side and the eyebrows of each character. It is difficult to realize such shading effect in conventional 3DCG.



(a) male,  
Embarrassment

(b) male  
smile



(c) female  
normal

(d) female  
anger

Figure 2 Shading style in the same cel-animation work  
“Syokugeki no Soma” ©J.C.STAFF

## 2.2. Little effect of character rotation

There is another feature in shading style of cel-animation works. Excluding the parts such as nose and eyes, shades on facial surface is little affected by head rotation. In an example animation sequence shown in Figure 3, the head of the character is rotating. In the first frame, the character face is drawn as a side view. Here, the face is totally illuminated while the back side of the head is shaded. It means that the light source is in right side of the scene. In the last frame, the character face is drawn as front view. If the light source is fixed, left half of the face should be shaded. However, the face is still totally illuminated in this example. To realize this shading result with conventional 3DCG, the light source for the character must be moved according to head rotation, while the light source for background should be fixed. Therefore, character rotation does not much affect shading result.

This feature is not true for shading of parts. In Fig.2, position of shaded area near nose is different; it becomes left or right side according to head rotation.



Figure 3 Shading of facial surface  
from different camera angles  
“PHANTASY STAR ONLINE 2 THE ANIMATION”  
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## 3. ESTIMATION OF SHADING

In this section, we present a shading method for cel-animation style 3DCG.

### 3.1. Overview of the procedure

The overview of our shading method is as follows.

#### (1) Modeling and motion generation with 3DCG

By using conventional 3DCG software, characters and background objects are modeled. Also, character motion, camera position, and lighting condition are defined.

#### (2) Manual drawing of shading examples

For each character face, 2D images are rendered with 3DCG by setting several camera angles. Then, user manually draw shaded areas on each 2D image.

#### (3) Estimation of shading for each part

For each frame, the system estimates shaded area existence of each part of the face according to the camera angle at the frame.

#### (4) Shape interpolation of shaded area

The system interpolates the shape of each shaded area from shading examples. This interpolation is done in 2D texture plane, and the result shape is stored as texture image.

#### (5) Rendering with 3DCG

Finally, the image of each frame is rendered with conventional 3DCG software. Stylize shading is realized with texture mapping, which has also been attempted in the study of Adam *et al.* [4].

Currently, we have not completed shape interpolation (4) yet. In this paper, shading example (2) and estimation of shading part (3) is described in the following subsections.

### 3.2. Shading examples

To obtain the shading result that the user (animator) satisfies, the user manually gives shading examples for several camera angles. The camera angle is treated as follows. Here, the origin of the coordinate system is at the centroid of the character head,  $x$ -axis is horizontal (side) direction, and  $y$ -axis is vertical (upward) direction. Then, camera angle can be defined with two angles  $X$  and  $Y$  which correspond rotation around  $x$ -axis and  $y$ -axis, respectively. Then, the shading examples are given at several interval of  $X$  and  $Y$ . In our experiment, we choose 30 degrees interval. In this study, the angle of the sample is set to 30 degrees, but this angle can be set arbitrarily by the user. If the character model is bilaterally symmetric, negative  $Y$  angle can be omitted because shading example at  $(X, -Y)$  can be obtained as the mirror image of one at  $(X, Y)$ . Figure 4 shows an

example combination, where user needs to draw 7 shading examples.

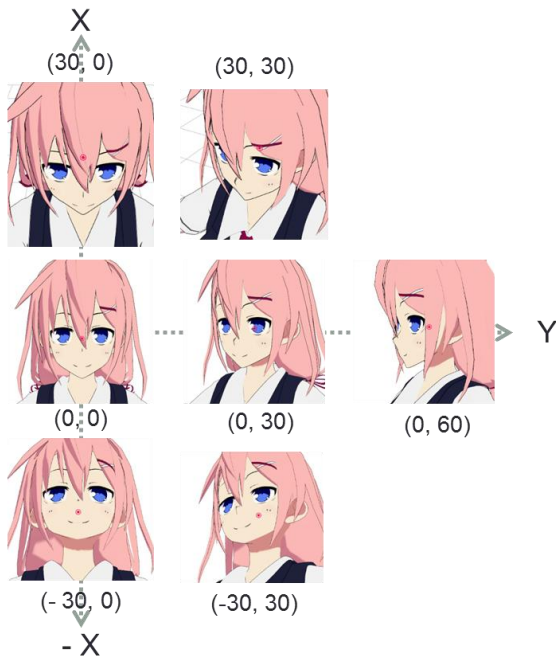


Figure 4 Shading examples

Example made by MMD model “syatiku chan” ©vitaone  
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### 3.3. Estimation of shading parts

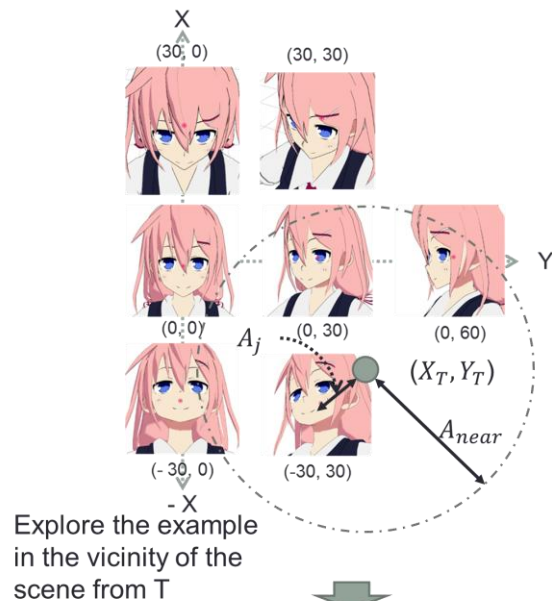
In order to estimate which part should be shaded in a certain scene T, we calculate shading utilization number  $P_i$ , where  $i$  is assigned to each part of the face. For the scene T, camera angle  $(X_T, Y_T)$  is calculated. The camera angle  $(X_T, Y_T)$  is the difference between the angle at which the face faces and the angle at which the camera faces. Then, check the camera angle  $(X_j, Y_j)$  of each shading example whether the angle  $A_j$  between two directions  $(X_T, Y_T)$  and  $(X_j, Y_j)$  are within a threshold value  $A_{near}$  (Fig. 5), and collect shading examples with closer directions  $(X_j, Y_j)$  if  $A_j < A_{near}$ . Let the number of collected shading examples be  $E$ . Among the collected shading examples, count the number of times  $P_i$  that  $i$ -th part of the face is shaded. If  $P_i/E$  is larger than a threshold value  $S$ , then  $i$ -th part of the face in scene T will be shaded, otherwise it will not be shaded.

## 4. RESULT

### 4.1. Head rotation

An example of the estimated result is shown in Figure 6. In this sample, shade arises at nose, eyebrows, cheek and mouth. For the input sequence of horizontal rotation, output image shows that shade existence of each part is correctly estimated.

switched from right to left. Shade of the cheek is shown in the appropriate side, and is omitted in the front view.



Explore the example in the vicinity of the scene from T

| Example      | nose right | nose left | eyebrow right | ... | lips  |
|--------------|------------|-----------|---------------|-----|-------|
| A            | 0          | 0         | 1             | ... | 1     |
| B            | 1          | 0         | 0             | ... | 1     |
| C            | 0          | 1         | 1             | ... | 1     |
| ⋮            | ⋮          | ⋮         | ⋮             | ⋮   | ⋮     |
| Num of times | $P_1$      | $P_2$     | $P_3$         | ... | $P_n$ |

Figure 5 Estimation of shading parts

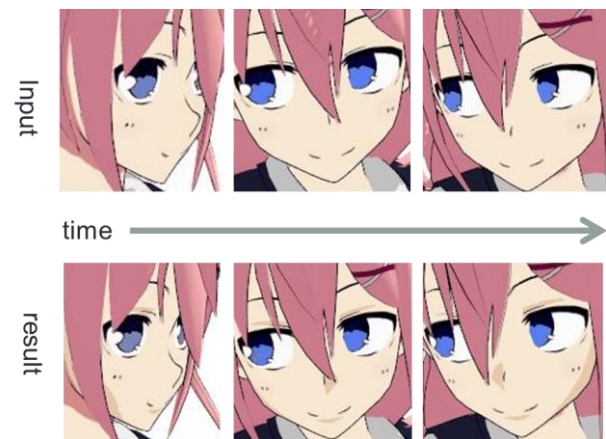


Figure 6 Estimation result

### 4.2. Facial expression

If the scene has change of facial expression, shading deformation may occur. Figure 7 shows an example, where shading of the eyebrows is badly deformed by winking. This is because of the deformation of texture coordinate on 3D model. Therefore, additional treatment is required in such facial expression change.

One solution for this problem is to prepare shading sample for each facial expression. In the case of Fig. 7, shading examples for both open and closed eye are

required. However, the number of samples increases for various facial expressions.



Figure 7 Problem that shading is deformed  
Example made by MMD model “Hatsune Miku”  
©Crypton Future Media INC. www.piapro.net

### 4.3. Expected effect

Shading samples in this method can be created by using conventional texture drawing method. Also, this method expresses shading with multiple texture images. By preparing small number of shading samples, our method can express shading like conventional animation. However, more detailed verification is required.

## 5. CONCLUSION

In this paper, we have presented a shading method for cel-animation style 3DCG. From multiple shading examples drawn by user, we try to estimate whether each part of face is shaded or not.

For future studies, we will develop the algorithm for interpolating shape of shaded areas. Also, we would like to extend the proposed method so that it is applicable for various situations such as facial expression change.

## REFERENCES

- [1] Hideki Todo, Ken-ichi Anjyo, William Baxter, Takeo Igarashi, Locally controllable stylized shading, ACM Transactions on Graphics, Vol.26, No.3, Article 17 (2007).
- [2] Hidehito Nakajima, Eiji Sugisaki, & Shigeo Morishima, An Interactive Tool for Editing Shadows in Cartoon Animation, Journal of the Institute of Image Information and Television Engineers, Vol.62, No.2, pp.234-239 (2008).
- [3] Christopher DeCoro, Forrester Cole, Adam Finkelstein, Szymon Rusinkiewicz, Stylized shadows, Proc. NPAR 2007, pp.77-83 (2007).
- [4] Adam Lake, Carl Marshall, Mark Harris, Marc Blackstein. "Stylized rendering techniques for scalable real-time 3D animation." Proceedings of the 1st international symposium on Non-photorealistic animation and rendering. ACM, 2000.