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Converting the Images without Glossiness into the Images with Glossiness by using Deep Photo Style Transfer

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In this paper, we propose an image conversion method to transfer the images without glossiness into the images with glossiness by using deep photo style transfer technique. The deep style photo transfer can be expected to reproduce a desired image with metallic appearance based on the texture transfer technique. Our practical challenge was performed to create the gold metallic image by transferring a style image of the gold ingot. Two kinds of stile images where one gold ingot and assembled mass of gold ingots were tested to verify how degree of complexity in style image is appropriate for our propose using deep neural network. In order to avoid an excessive loss of color balance, we also applied the YC_rC_b separation technique and used only Y component to learn the only style of gloss appearance. Moreover, the luminance and saturation of the style image were changed to investigate the influence into the converted appearance, since the converted appearances are expected to have the dependence with the contents of the images. These transferred results by changing the luminance and saturation of style image were evaluated by subjective evaluation using semantic differential method. As the results, it is found that the style image with an appropriate amount of contrast change is suitable for appropriate gloss appearance, then showed that there is appropriate selection of contrast in style image depending the contents of original images.

1. Introduction

Recent progress of 3D printer has a possibility of drastic change for manufacturing process. The product by 3D printer can reproduce the shape and tactile perception as same as real object. A further development for colored 3D printer are useful for a rapid proto-typing of final product with renewed attention of color management techniques. Unfortunately, the only fault of present 3D printer are hard to avoid the use for limited material such as Acrylonitrile Butadiene Styrene and Polylactic Acid. Therefore, an additional post-processing of surface fabrication and chemical manipulation is necessary to produce the final proto-type of product by using the 3D printer.

Especially, a plate processing was the only way to post-process an appearance of metallic surface on the product of 3D printer, since the development of metal 3D printer takes long time at the present technology. On the other hand, a metallic ink jet printer have received a lot of attention by 3D printer maker in recent years. This method has an advantage for easy and low cost process as post processing for 3D printer. However, it is difficult to control an amount of coating for reproducing the metallic appearance on the 3D object. Moreover, it is necessary to develop the gloss and color management to simulate the desired appearance, since this coating by metallic ink jet causes slightly transparency of the foundation which is materials of 3D print.

As mentioned, metallic ink such as silver ink used in a ink jet printer with silver ink makes it possible to control the surface appearance of the printed paper. When using this printer with silver ink, we need to prepare or create the design which can take the advantages of silver ink for gloss appearance. However, those procedure demands designing skills and experience, so it's very difficult problem to make an acceptable design in general. Thus, it is beneficial we have a method to convert any image into the image with glossiness.

In this paper, therefore, we propose an image conversion method to transfer the images without glossiness into the images with glossiness automatically by using deep photo style transfer technique. The deep style photo transfer can be expected to reproduce a desired image with metallic appearance based on the texture transfer technique.

2. Related works

Recently, the neural network is continually used for the image analysis and image reproduction. As one of remarkable researches, Gatys[1] et al. have proposed a style transfer technique by using convolutional neural networks. They adopted neural network model called VGG19[2]. VGG19 is used as a decomposer into the content of an image and the style of an image. This content represents the shape and arrangement of the objects in an image. The style represents texture information and appearance features in an image. The structure of this method is showed in Fig 2.1. In Fig 2.1, the style transfer method is briefly explained as follows. First, passing all of the content image, style image and white noise image as the initial image through the VGG19, These three images are decomposed into each contents and styles. Next, error rates between each contents and each styles is minimized with the iterations. After the minimization of the error rates, a new image is generated where the new image has the shape and the arrangement of content image, and the texture and appearance features of style image.

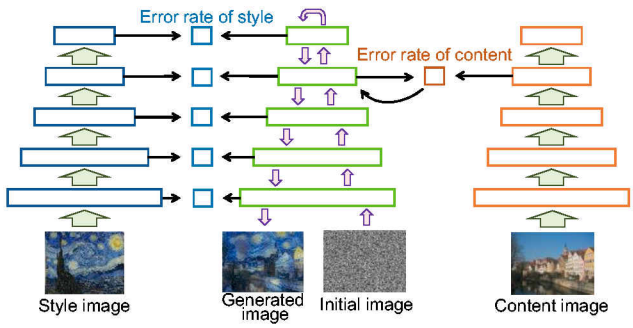


Figure 2.1 The structure of style transfer

Their method aims to extract the features from paintings and make the target image like painting. On the other hand, Luan[3] et al. extended this technique and they made new method called Deep photo style transfer, which can be applied even to the improvement for photographic processing. In this technique, they constrained the transformation from the input to the output to be locally affine in color-space. The approach successes to suppress the geometric distortion in photograph.

As shown in Fig 2.2, output image is newly generated from two input images in style transfer. Style transfer makes it possible to generate aesthetic image whose style is similar to the style image, while preserving the impressive constituent element in the content image.

Comparing the left content image with the right processed image in Fig 2.1, it is obvious that only the style of the image changed without changing the shape of the content object in the image. And also obvious that distortion and unnatural change are hard to generate. Besides, the transfer respects semantics of the scene. This means that in this case of the style transfer, the sky matches to the sky, clouds to clouds, and land to land in Fig 2.1.

In this paper, the deep photo style transfer is used to reproduce a desired image with metallic appearance based on the above texture transfer technique.

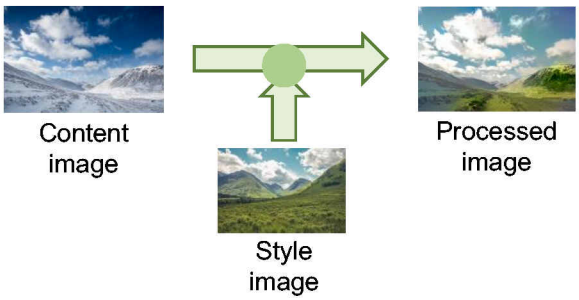


Figure 2.2 interpretive example of style transfer

3. Generation of gloss by using style transfer

3.1. Generation procedure

We apply the deep photo style transfer to convert the images without glossiness into the images with glossiness. In generating the gloss, we adopted the procedure shown in Fig 3.1.

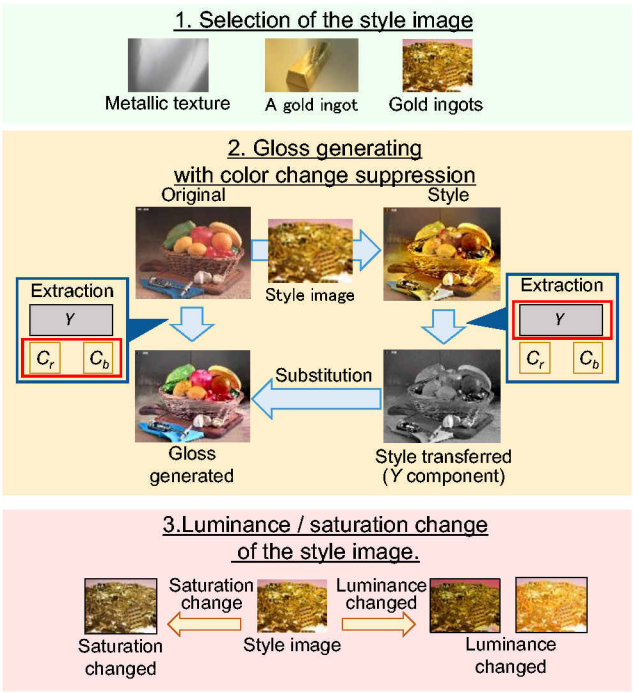


Figure 3.1 Gloss generation procedure

3.2. Selection of the style image and consideration of color change

Comparing the images in Fig 3.3, the image of (a) and (b) shows objects which are as if enveloped in the mist and they do not have metallic-liker appearance. On the other hand, the image of (c) seems to have metallic-like material appearance and most appropriate. Although color seems to have a major role as an element of gloss, the influence of color information in style image is too tremendous in this results. Therefore, we consider the improvement method of style transfer that suppresses extreme color change.

Comparing the images among Fig. 3.2, 3.3, and 3.4, we found that the image after applying Deep Photo Style Transfer was greatly affected by the color of the style image. Therefore we ignore the gloss addition by changing color in this study, although some changes in color has slight influence to the perception of gloss[4]. For the suppression of color change, we consider the limited processing only to use the luminance component of the style image for suppressing color change. In extracting luminance components, we employ the color transformation in YC_rC_b color space, whose Y channel indicates only a luminance. It is obvious that no color change occurs when processing is performed only on the luminance channel. Therefore, we adopt the approach as follows to carry out the color change suppression. First, we applied Deep photo style transfer. Second, we extracted only the luminance channel from the image. Finally, we assigned the extracted component to the luminance component of the original image. Figure 3.5 shows the result of style transfer with color change suppression by using the Fig 3.2(c) as the style image.

(a) texture of metal (b) One gold (c) Some golds

Figure 3.2 three kinds of a style image to generate the gloss

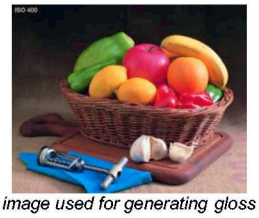


Figure 3.3 a content image used for generating gloss

(a) texture of metal (b) One gold (c) Some golds

Figure 3.4 the results of style transfer with generating the gloss

Figure 3.5 the result of style transfer with color change suppression

Comparing the result in Fig. 3.5 and content image in Fig. 3.3, it is clear that only the gloss appearance is generated while suppressing the influence of color information in style image.

3.3. Brightness / saturation changes of a style image

When the gloss appearance is generated by using deep photo style transfer, it is noted that a better gloss generation result can be obtained by adjusting the degree depending on the tone of style and content image. Therefore, we control the saturation and brightness of the style image as shown in Fig 3.2 (c) to investigate the influence into the converted appearance. Here, it is obvious that this style image already had a sufficiently high saturation. Consequently, we only reduce the saturation in three step of -20%, -40%, and -60%. On the other hand, the luminance of style image has acceptable range for changing in up and down. Therefore, we applied the luminance change in four steps of 30%, -30%, 60%, and -60%. Adding the original style image without change both saturation and luminance, eight kinds of style images were prepared. Fig 3.6 shows the style images with saturation change and Fig 3.7 shows the style images with luminance change.

Fig. 3.8 shows the content images which are applied the style transfer by using the style images shown in Fig. 3.6 and Fig. 3.7. A total of 32 images are created from the combination of content and style images. The examples of the style transfer results are shown in Fig 3.9. As a result, the luminance of processed image after generated are influenced by the luminance and saturation of the style image. Namely, according to the increment of the luminance in style image, the luminance of processed image is also increase with generation of gloss appearance. Moreover, the same proportional change is found at the case of luminance decreases. Therefore, it is clarified that the degree of gloss emphasis can control according to the tone change of style image.

Seeing the images in Fig 3.9, some of the images are blown out highlights and some are blocked up shadows. From these points, it needs to adjust the style image with an appropriate amount of contrast change depending on the contents of original images.

(a) saturation -20%

(b) saturation -40%

(c) saturation -60%

Figure 3.6 style images reduced the saturation

(a) luminance +30%

(b) luminance +60%

(c) luminance -30%

(d) luminance -60%

Figure 3.7 style images controlled by the luminance

(a) chain

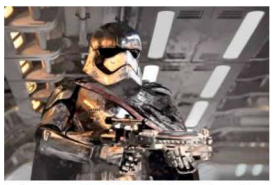
(b) soldier

(c) Gold illustration

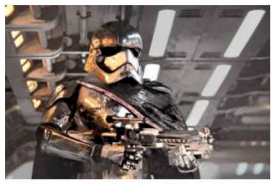
(d) Buddha statue

Figure 3.8 content images for generating the gloss appearance with various changed style image

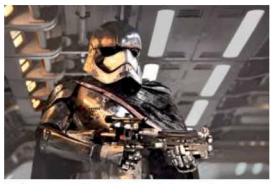
(a) the result obtained by using the style image of original



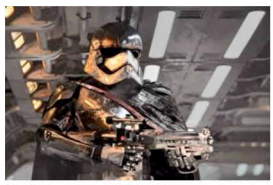
(b) the result obtained by using the style image of saturation -20%



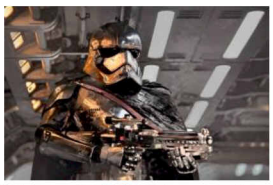
(c) the result obtained by using the style image of saturation -40%



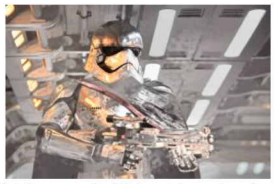
(d) the result obtained by using the style image of saturation -60%



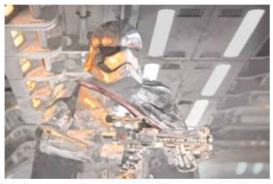
(e) the result obtained by using the style image of luminance -30%



(f) the result obtained by using the style image of luminance -60%



(g) the result obtained by using the style image of luminance +30%



(h) the result obtained by using the style image of luminance +60%

Figure 3.9 The examples of the style transfer results

4. Evaluation for gloss generated images

Proposed method in the previous chapter can generate various images with gloss appearance by applying the Deep photo style transfer. Here, it is obvious that these images depend on the luminance and saturation of the style image. However, as mentioned before, there contains inappropriate results. Therefore, in this chapter, we execute a subjective evaluation, which is performed to examine the highly evaluated images from a view point of gloss emphasizing.

4.1. Semantic differential method

In the experiment, we used a semantic differential method (SD) [5] to evaluate the metallic appearance of emphasized image generated by the proposed method. This method can measure the impression of image with multiple adjective pairs, which have an opposite meaning.

The subject is asked to choose where his or her position lies, on a scale between two polar adjectives. For example, as shown in Fig. 4.1, subjects select the adjectives with seven scale from "good" to "bad" at the ends of the scale. The subjects can score the dimension using a middle value if they feel "neither" of polar adjectives. SD method can be used to measure opinions, attitudes and values on a psychometrically controlled scale of the connotative meaning of objects, words, and concepts.

Then, we calculate the mean value of the adjective pair based on the evaluated value, and the same processing is performed for all the adjective pairs.

Next, factor analysis[6] is performed based on the obtained value. Factor analysis is one of a technique of multivariate analysis and that is a technique to find what kind of potential variables is influenced about the answers to the questions.

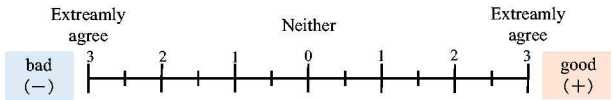


Figure 4.1 seven scale of adjective pair

4.2. Procedure of subjective evaluation

A list of adjective pairs used in this evaluation is shown in Table 4.1. Figure 4.2 shows the setting and condition of the experiment, and this experiment environment was executed in the dark room. The participants are 5 males and 5 females, and they evaluate the impression of processed image without time restriction. Figure 4.3 shows an example of image stimulus in our display.

Table 4.1 A list of adjective pairs used in our experiment

Inconsistent with the original glossy part	Consistent with the original glossy part
Unfavorable	Favorable
Decrease of gloss	Increase of gloss
Aversion	Acceptable
Unnaturalness	Naturalness
Hard to see	Easy to see
Ugliness	Beauty
Discomfort	Pleasant
Flimsy	Heavy
Reduction of the presence	Increase of the presence
Reduction of the profoundness	Increase of the profoundness
Poor	Luxury

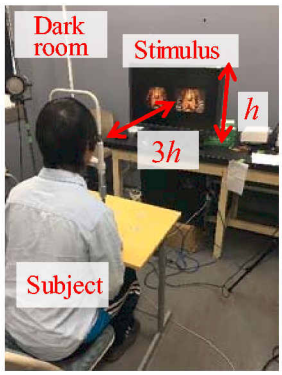


Figure 4.2 experimental condition

Figure 4.3 an example of image stimulus in our display.

4.3. The result of evaluation experiment

Figure 4.4 shows the results of factor analysis by averaging the evaluation values among subjects. In this factor analysis, statistical analysis software SPSS developed by IBM was used. For the factor extraction operating, the maximum likelihood method and a promax rotation was used.

In factor analysis, two factors were mainly extracted as shown in Fig 4.4. The first factor concentrated on presence, luxury, heaviness, increase and decrease in gloss. The other factors such as naturalness and beauty were concentrated in the second factor. Therefore, we defined as "gloss factor", which concentrated on the horizontal axis. Also, we defined as "subjective factors", which concentrated on the vertical axis.

After the evaluation values obtained, we next focused on the "gloss factor", which was related to the gloss appearance mainly. To calculate the score from the "gloss factor", a weighted average was derived from the calculation of correlation coefficient in each question item, which was concerned about the first factor. Table 4.2 shows the good results of combination between the content image the style image with the highest gloss score.

The gloss generated images with high gloss score is shown in Fig. 4.5. Comparing Fig. 3.7 with Fig. 4.5, it is found that good result was obtained by using the balanced combination between original and style image in term of luminance value. Conversely, unbalanced combination of luminance in each image invokes unfavorable result. For example, the combination between bright style image and luminous content image was evaluated as low score, since the luminance of processed image became too high.

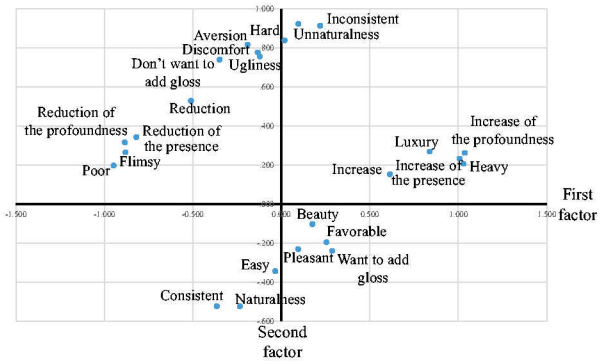
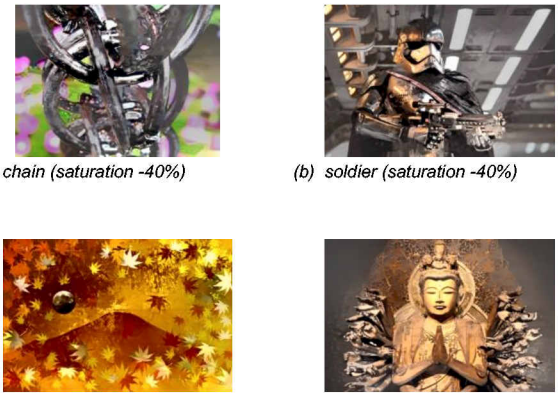


Figure 4.4 the results of factor analysis

Table 4.2 Combinations of images with the best gloss score value in subjective evaluation

Content image	Chain	Soldier	Gold illustration	Buddha statue
Change of luminance / saturation	Saturation -40%	Saturation -40%	Saturation -40%	Original content image
Score	2.5	2.3	2.0	2.2



(a) chain (saturation -40%) (b) soldier (saturation -40%)

(c) gold illustration(saturation -40%) (d) buddha statue(original)

Figure 4.5 The gloss generated images with high score

5. Limitations

The performance of transformation using this method is heavily dependent on the selected style image. For this reason, there would be many cases in which this method doesn't work as desired. Furthermore, to perform the proposed processing, suitable style image has to be chosen manually, and evaluation method for results also should be given appropriately depending on the purpose.

6. Conclusion and Future works

In this research, we proposed a method to convert the images without glossiness into the images with glossiness by using deep photo style transfer technique. This method can generate the gloss appearance of the objects in images as the result. Thorough the subjective experiment, it is found that the style image with an appropriate amount of contrast change is suitable for appropriate gloss appearance, then showed that there is appropriate selection of contrast in style image depending the contents of original images. It is possible to automatically obtain the processed image with the most natural gloss generation by selecting the appropriate gloss-generated image as the style image. Our method was verified by using a few images. In fact, we have to select the most suitable image from a lot of style image candidates.

Therefore, as a future work toward practical application of this technology, it is necessary to automate the selection of images the most suitable as a style image from many images. This selection is very important to obtain the generated gloss appearance with full respect for user's intent.

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References

[1] L.A. Gatys, A. S. Ecker, and M. Bethge, "Image style transfer using convolutional neural networks", Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, 2016.

[2] Karen Simonyan, and Andrew Zisserman "Very Deep Convolutional Networks for Large-Scale Image Recognition", FarXiv:1409.1556

[3] F. Luan, S. Paris, E. Shechtman, and K. Bala, "Deep Photo Style Transfer", Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition, 2017.

[4] S. Serikawa, T. Shimomura. "An Investigation of Effect of Color on Glossiness", IEEJ Transactions on Electronics, Information and Systems113.11, pp.1013-1022, 1993. (Written in Japanese)

[5] Osgood, C. E., Sugi, G. J. & Tannenbaum, P. H. : The measurement of meaning. University of Illinois Press, Urbana, 1957.

[6] T. Nakamura, "Usage of factor analysis in creating psychological measure", The Annual Report of Educational Psychology in Japan, Vol.46, pp.42-45, 2007. (Written in Japanese)