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A PROPOSAL OF IMAGE COLOR PRE-CONVERSION FOR ELDERLY EMPLOYING NEURAL NETWORKS

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Abstract. *Performance of elderly visual functions is gradually changing with age. As one of those changes, aged eyes have a different property in perceiving colors from younger eyes. In general, the elderly perceive images differently from the younger. To give the same perception for the same image as the younger, a different image from an original image needs to be displayed to the elderly. In this paper, a method of generating an inverse characteristic of the elderly image filter for color conversion is proposed. To this end, a neural network model is employed. The neural network is composed of 5 layers. The 5-layer neural network is divided into 2 blocks on the aspect of function. The lower and the upper layers play a role of simulating the image conversion and obtaining its opposite characteristic, respectively. The performance of the proposed framework is evaluated by the experiments on the image color pre-conversion for the elderly.*
Keywords: Elderly vision, Color conversion, Neural networks, Inverse transform

1. **Introduction.** Color conversions for image have been addressed in order to improve the visibility and to change the impression of images. Various color transformation models have been proposed [1, 2, 3, 4]. On the other hand, it is useful to obtain an inverse characteristic of the existing color transformation model. For example, we assume that we have an inverse characteristic of the elderly color conversion model. By applying the transformation of the inverse characteristic to the image in advance, it is expected to obtain an improved image with respect to the visibility of the elderly. In this study, we discuss an inverse model generation for the elderly as an example to generate inverse characteristics for image color conversion models.

Elderly vision is changed by a presbyopia [5]. In the presbyopia, an accommodation power of focus is deteriorated by a decrease of lens elasticity. This produces a phenomenon that proximal objects are difficult to see. There are reading glasses for dealing with the presbyopia. The reading glasses can help the elderly to adjust the focus. It is, however, difficult for the glasses to improve age-related changes in color vision. A senile miosis and a lens yellowing bring a yellower and darker vision to the elderly [6, 7]. The senile miosis is a phenomenon that a pupil changes smaller according to aging. Commonly, it is possible for us to expand a pupil diameter and to increase an entering light to the eyes in the dark environments. However, since the elderly's adjustment ability for the pupil is weaker than that of the young people, the field of view is kept dark. In addition, the amount of light is also decreased by the age-related changes of crystal lens. By age-related changes in the lens, the transmittance of the lens is reduced. Since the transmittance of short wavelength is especially reduced, the field of view for the elderly becomes yellower. According to the result of experiments with respect to the color appearance of the elderly, it is reported that changes of hue have not occurred [8]. In the vision of the elderly, it is considered that the compensation effect of long-term color adaptation has occurred in some nervous system. In the same experiment, a result that color saturation decreases has also been reported. As a result, it is considered that the field of view becomes darker by the reduction of the light amount that is captured without color changes. In any case, the elderly's darker view causes inconvenience to the elderly.

As a method to cope with this problem, a brightness conversion method of images has been proposed as a technique for obtaining an image giving the same impression for both the elderly and the young [9]. Indeed this method can generate an intermediate image that is valid for both the elderly and the young to see, but it is not optimized for the elderly. As a result, the conventional method has a drawback that it is not possible to present a more visible image to the elderly. Another method to cope with elderly color perception problem has been reported [10]. In this color compensation method, color signals involved in an image are amplified globally. This brings a possibility to exceed the color range for a display (0 to 255). This phenomenon might cause some intensity saturations in a resultant image. The effects of this phenomenon for various images have also been studied in particular [11].

In this study, we propose a novel color compensation method for the elderly. To this end, a neural network model is employed. The neural network is composed of 5 layers. The 5-layer neural network composed is divided into 2 blocks on the aspect of its function. The lower and the upper layers play a role of simulating the image conversion and obtaining its opposite characteristic, respectively. The performance of the proposed framework is evaluated by the experiments on the image color pre-conversion for the elderly.

This paper is organized as follows. In Section 2, we describe the neural network model we use, and we derive our learning procedures to generate an inverse characterisctics of given filter property. Then, we test our algorithm in Section 3 and finally draw some conclusions in Section 4.

2. **Proposed Method.** To let the elderly perceive an image as the young does, an appropriately transformed image needs to be presented to the elderly. Figure 1 shows a schematic overview of the proposed framework. In Figure 1, the transformation model represents a color perception model of the elderly. In this study, it is assumed that the perception model is given, and the elderly perception model from the previous study [7] is used. A major issue is to generate an inverse transformation model representing the inverse perception model of the elderly. To this end, we construct a cascaded neural network connecting a simulated model of elderly perception and an inverse model for the elderly visual characteristics. Inputs and outputs of the neural network are RGB brightness values of the image, and the neural network is learned in the manner of back-propagation [12].

2.1. **Simulated model of elderly vision.** At first, a filter which simulates both the yellow change of senile miosis and the lens of the elderly is prepared for obtaining the elderly simulated image which is described as the transform image in Figure 1. Next, an original image to let the elderly perceive and its simulated elderly image are fed to a 3-layer MLP neural network for training as inputs and teachers, respectively. As a result of learning for the input-output pairs, a simulated model of elderly vision can be obtained as shown in Figure 2. As shown in Figure 2, the RGB components are learned by independent networks one another, i.e., each neural network model has one input and

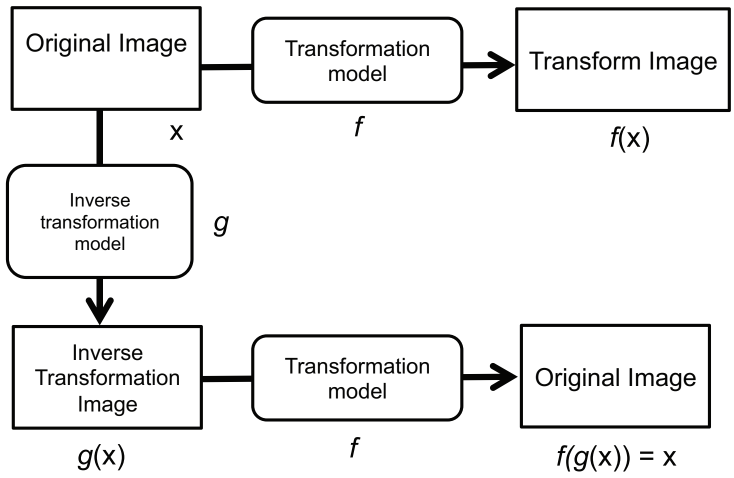


FIGURE 1. Overview of the proposed framework

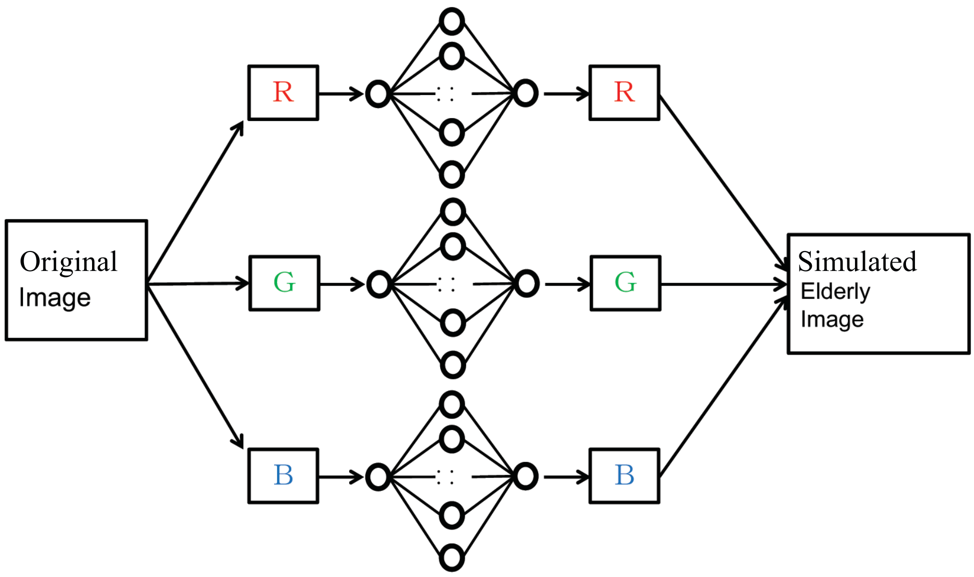


FIGURE 2. Simulated model of elderly vision

one output. In other words, a relationship between the luminance values of each color plane in the original image and the simulated elderly image is mapped to the network.

2.2. **Luminance correction model of image.** Luminance correction model can be obtained by using a 5-layer neural network involving the simulated model of elderly vision constructed in the previous process. The parameters of the neural network, i.e., weights and biases, from the third layer to the fifth layer in the 5-layer network are assigned by the use of the simulated model of elderly vision. The assigned parameters are not updated during the following training. By applying the original image as both input and teacher, respectively, a luminance correction model can be generated between the first layer and the third layer of the network. As shown in Figure 3, training is performed for a whole neural network connecting the luminance correction model with the simulated model of elderly vision. In the training phase, the neural network is trained by the same learning method as constructing the simulated model of elderly vision. By picking up the values from the third layer, a luminance-corrected image to be presented to the elderly can be generated. By presenting the luminance-corrected image to the elderly, it can be expected for the elderly to perceive the similar appearance as the original image.

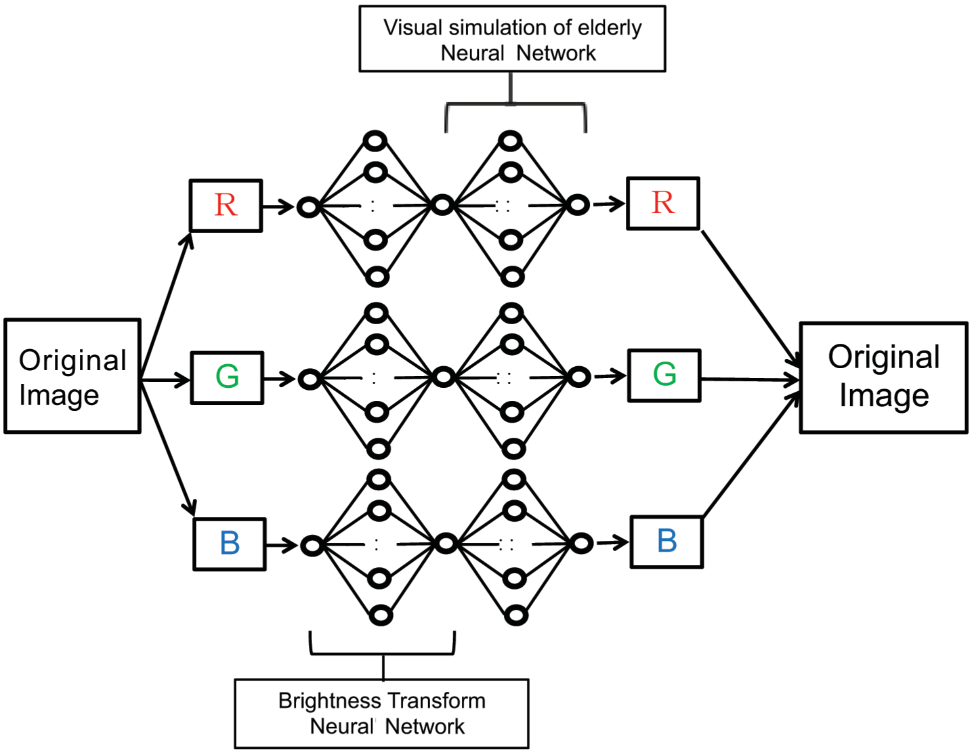


FIGURE 3. Luminance correction model of image

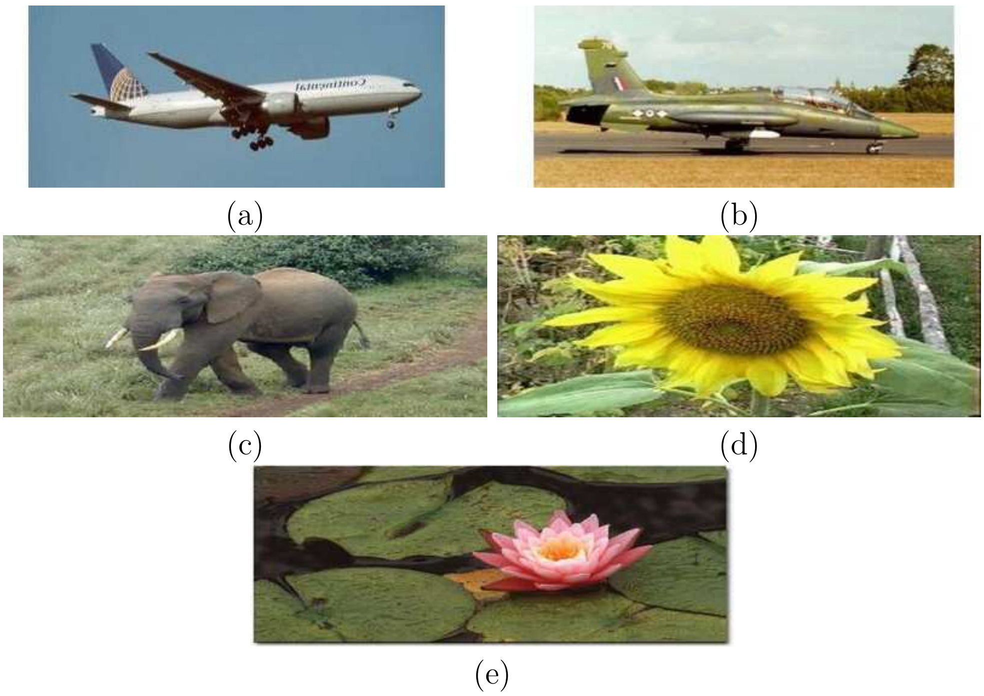
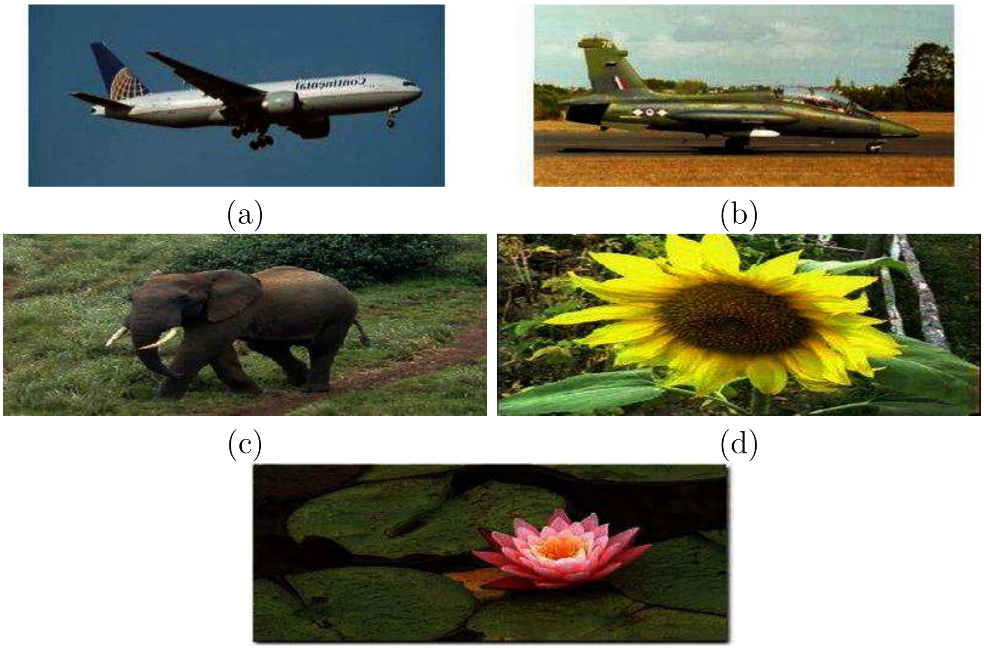


FIGURE 4. The images used in the experiment. (a) *airplane*, (b) *battle-plane*, (c) *elephant*, (d) *sunflower*, (e) *lotus*.

3. **Experiment.** The images used in the experiment shown in Figure 4 are all 150×400 24-bit color. By applying the mathematical model of elderly perceptual simulation, these images are transformed as shown in Figure 5. All simulated images are darker than the original images.



(a) (b) (c) (d) (e)

Figure 5. The images after the application of elderly perceptual simulator by the mathematical model. (a) *airplane*, (b) *battleplane*, (c) *elephant*, (d) *sunflower*, (e) *lotus*.

In the experiment, the image *airplane* is used as a training data for both elderly simulation model and luminance correction model. The number of units in each layer for the 3-layer neural network is one for input layer, 10 for intermediate layer, and one for output layer, respectively. In addition, the number of units in each layer for the 5-layer neural network connecting the luminance correction model with the elderly visual simulated model is one for input layer, 10 for the second layer, one for the third layer, 10 for the fourth layer, and one for the output layer, respectively. Since the brightness correction model is located in the 1st to the 3rd layer of the 5-layer neural network, the number of units of each layer is 1 for the input layer, 10 for the intermediate layer, and 1 for the output layer, respectively. Sigmoid functions are used as a threshold function for each model.

By elderly simulation model learned by the image *airplane*, simulated elderly perception images are obtained as shown in Figure 6.

Pre-converted images obtained by luminance correction model and its simulated perception images through the mathematical model are shown in Figures 7 and 8. As shown in Figure 7, the images obtained by the luminance correction have become brighter than the original images. As a result, the images in Figure 8 are almost similar to the original images in Figure 4. This means the pre-converted image can make elderly perceive similar appearance.

In order to evaluate the proposed image pre-conversion method numerically, root mean square error (RMSE) between the original image and the perceptual simulation image of pre-converted image for each image is calculated. The RMSE is defined as follows:

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \hat{x}_i)^2}, \tag{1}$$

where N is the number of pixels, x_i is the intensity value of the original image, and $\hat{x}_i$ is the intensity value of the perceptual simulation image of pre-converted image.

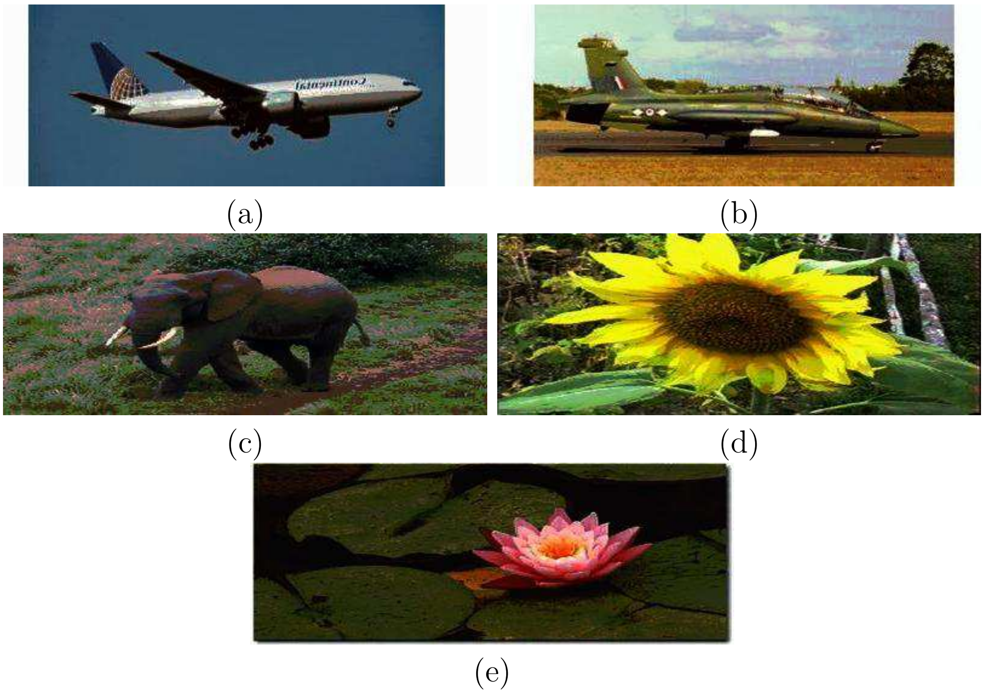


FIGURE 6. The simulated elderly perception images obtained by the elderly simulation model trained by image *airplane*. (a) *airplane*, (b) *battleplane*, (c) *elephant*, (d) *sunflower*, (e) *lotus*.

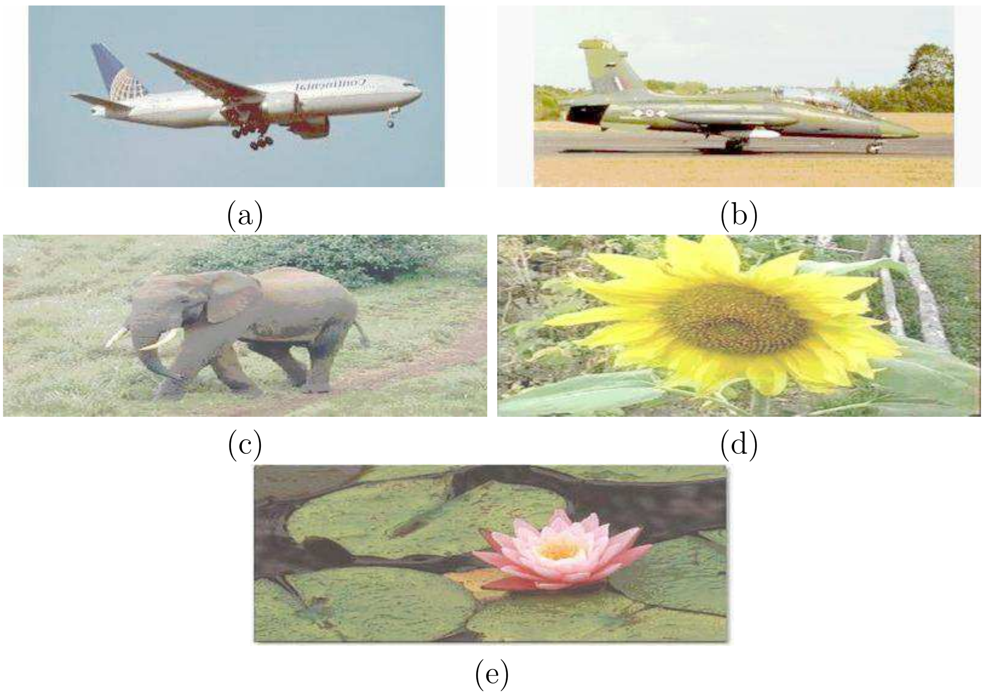


FIGURE 7. The pre-converted images obtained by the proposed method. (a) *airplane*, (b) *battleplane*, (c) *elephant*, (d) *sunflower*, (e) *lotus*.

To examine the effect of a training data, experiments using each image as a training data are performed and the RMSEs between the original image and the elderly perceptural simulation image are calculated. As a result, the RMSEs are summarized in Table 1.

As a reference, the RMSEs between the simulated elderly perception images from original images and ones from pre-converted images are shown in Table 2.

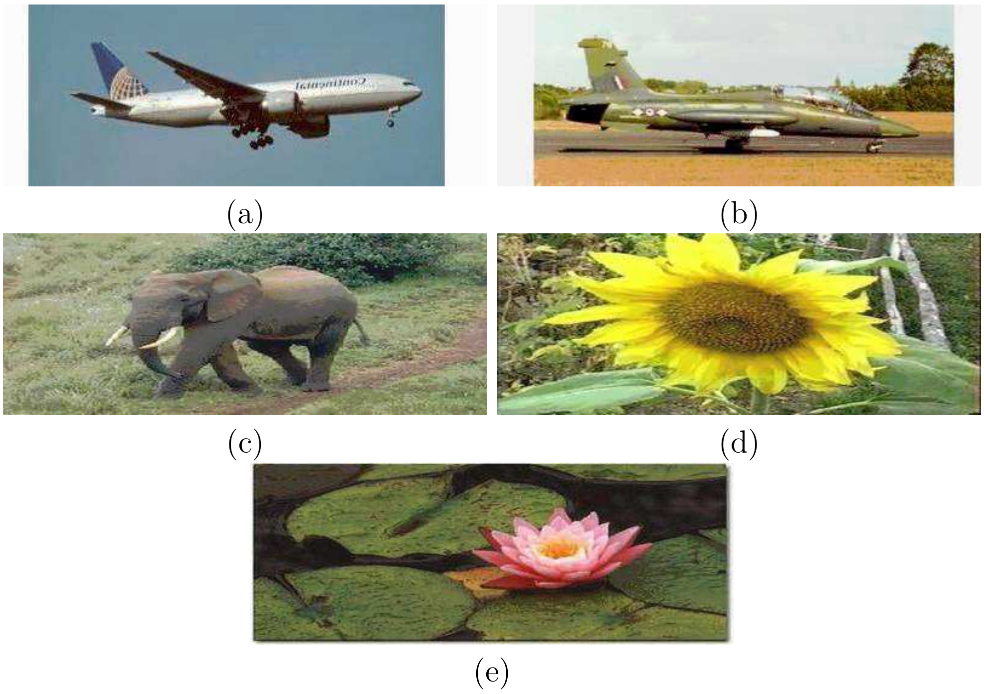


Figure 8. The elderly perceptual simulation obtained by applying the mathematical model to the pre-converted images obtained by the proposed method. (a) *airplane*, (b) *battleplane*, (c) *elephant*, (d) *sunflower*, (e) *lotus*.

Table 1. RMSEs between the original image and the elderly perceptual simulation image for each training data

		test image				
		airplane	*battleplane*	*elephant*	*sunflower*	*lotus*
training image	*airplane*	5.61	8.53	7.97	7.90	6.37
	battleplane	9.95	6.82	7.33	8.76	6.10
	elephant	9.40	11.20	7.08	8.83	6.29
	sunflower	9.28	8.02	8.60	8.55	6.23
	lotus	9.19	18.39	8.50	12.28	5.90

Table 2. RMSEs between the simulated elderly perception images from original images and ones from pre-converted images

	RMSE
airplane	53.76
battleplane	43.46
elephant	58.28
sunflower	48.97
lotus	49.40

By comparing Table 1 with Table 2, it is verified that pre-converted images can bring the elderly better perception than original images numerically.

4. **Conclusions.** In this study, a method to generate an inverse characteristic of elderly simulation model was proposed. The proposed method uses five-layer neural networks cascading a color transform model and its inverse model. As a result of experiments, we confirmed the proposed method could successfully obtain an inversely transformed image with respect to the color transform characteristics. Future work involves a development of

application to other color transform cases. And also, our proposed method can generalize to restorations of image deteriorations such as image super-resolutions [13].

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