Digital Face Beautification Utilizing TV Filter and Super-Resolution Technology

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Abstract—***In this paper, we apply a total variation (TV) filter and super-resolution technology to the image processing of human face beautification. We focus on two aspects: one is smoothing of the facial skin; the other is emphasizing the parts of the face. Facial skin smoothing has already been addressed using nonlinear filters, but the effective removal of moles and stains was not successful. We solved this problem utilizing a TV filter, and obtained good results. For emphasizing face parts, we utilize the face-part detection and super-resolution technology that we have developed for 4K-HDTV. This work is not computer graphic technology that modifies face shape, but can be addressed as a digital cosmetic using recent state-of-the-art image signal processing technologies.***

Keywords—Face beautification, TV filter, Super-resolution, Facial part extraction, Digital cosmetic

I. INTRODUCTION

Human face is very important in many photographs taken by digital cameras or smart phones. People are typically happier if their faces can be edited to be more attractive and to present a better impression to other people. This is particularly true for photographs of resume or identification card. And it would be useful in social networking sites such as Facebook or Twitter, if these face image processing can be available by a software application.

Face image processing is categorized into two parts: skin smoothing and enhancement of face-part details. The skin-smoothing attempts were performed using an ε-filter to remove the wrinkles on the face [1]. It did successfully remove wrinkles. However, it had difficulty removing stains, moles, and freckles on the face. This is because the ε-filter is a type of low-pass filter that removes impulse-shaped noise, and it cannot remove small flat rectangular waves. In this paper, we propose to use a total variation (TV) regularization filter to solve this problem. We compare the effects of using ε-filter, bilateral filter, and TV filter.

Face-part enhancement has been performed using contrast enhancement [2]. However, this approach is inadequate because it does not adopt face-part detection. Further, contrast enhancement is not the best solution for face part enhancement. In this paper, we firstly detect and extract face parts, such as eyes and hair [3], and then apply our super-resolution technology [4] to each face part. We apply these functions to each face part and obtain good enhancement effects.

II. SKIN SMOOTHING

A. Nonlinear Filters

We examine three non-linear filters that can remove small pulse signals without losing edge sharpness. They are the bilateral filters [5], the ε-filters [6], and the TV (total variation regularization) filter [7]. The bilateral filter and the ε-filter are basically low-pass filters that effective for small level signal without effecting large level difference signal such as the edge portion.

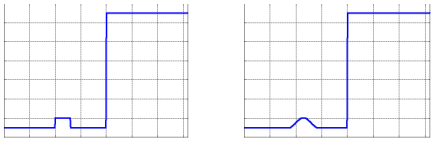
The total variation (TV) regularization filter has different characteristic for small level signals. It is a non-linear filter which output is obtained by solving the following minimization problem.

$$\inf_u F(u) = \sum_{i,j} \nabla\left|(\mathrm{u})_{i,j}\right| + \frac{1}{2\lambda}\sum_{i,j}\left(u_{i,j} - x_{i,j}\right) \tag{1}$$

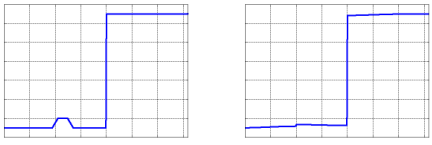
$$p_{i,j}^{n+1} = \frac{p_{i,j}^{n} + \tau\left[\nabla\left(\mathrm{divp}^{\mathrm{n}} - x/\lambda\right)\right]_{i,j}}{1 + \tau\left|\nabla\left[\left(\mathrm{divp}^{\mathrm{n}} - x/\lambda\right)\right]_{i,j}\right|} \tag{2}$$

$$u_{i,j} = x_{i,j} - \lambda divp_{i,j} \qquad v_{i,j} = x_{i,j} - u_{i,j} \tag{3}$$

F(u) is the evaluation function for input signal x, and Eq.(2) is an iteration algorithm that gives the solution of Eq.(1) [7]. Signal u is called the structure component, and v is called the texture component. Here, we call it the TV filter that obtains the structure component u from the input x. The interesting characteristic of the structure component is that it consists of all edge components but roses all small level signal even if it is pule or rectangular signal.



(a) Input signal (b) Bilateral filter output



(c) ε-Filter output (d) TV filter output

Figure 1. Rectangular wave noise removal

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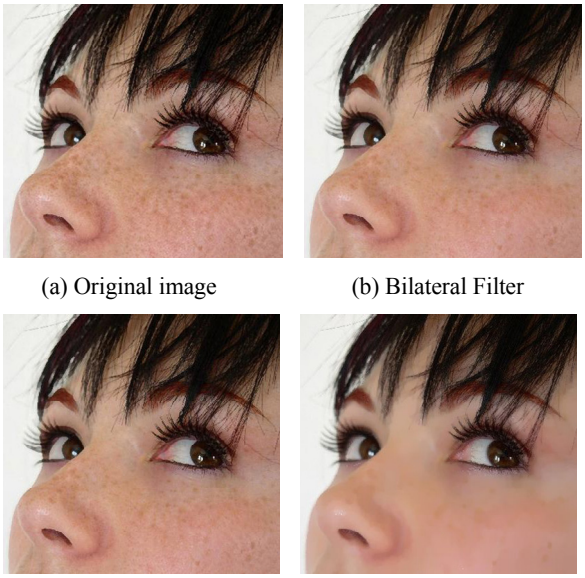
Figure 1 shows the out-put signal of each filter for the input signal of a large step signal and a small rectangular wave. We can see only the TV filter can remove small rectangular wave.

Figure 2 shows the result of face image processing by each filter. The original image has stains on face. We can see only the TV filter removes the stain completely without losing any edge sharpness of the face picture. There is no space to show , but the wrinkles, moles, and freckles can be removed in the same manner, while other filters cannot do it



(a) Original image (b) Bilateral Filter

(c) ε-Filter (d) TV Filter

Fig.2 Stain removal by the three filters.

III. FACIAL-PART ENHANCEMENT

A. *Facial-part extraction*

In this work, we focus on facial parts such as eye, eyelash, lip, and hair. Before signal processing, we have to detect these parts. This is achieved by the high precision automatic extraction of facial features [3]. The hair is extracted by using the combination of a contrast filter. For eyes, firstly pupils are extracted as the pair of circles by using the circular filter.Then the neighbor of eye area centered at each of the detected pupils is transformed from Cartesian coordinates to polar coordinates, and third order Bezier curves are fitted to contour of eyelid based on the analysis results of luminance level distribution. .

B. *Super- resolution system*

In this work, we adopt our super-resolution technology that was originally developed for image enhancement of magnified images such as the 4K-HDTV display. Figure 3 shows the block diagram of our super-resolution system [4]. It uses the TV filter and decomposes the input signal into the structure component and texture component as shown in Eq.(3). The structure component is enhanced by the shock filter and the texture component is enhanced by the pulse enhancement filter (PEF).

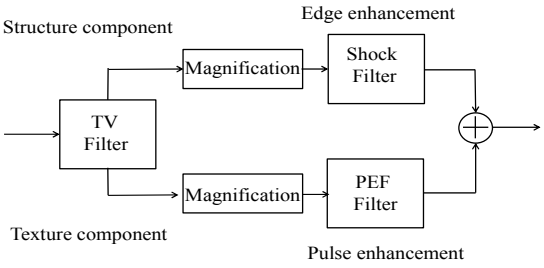
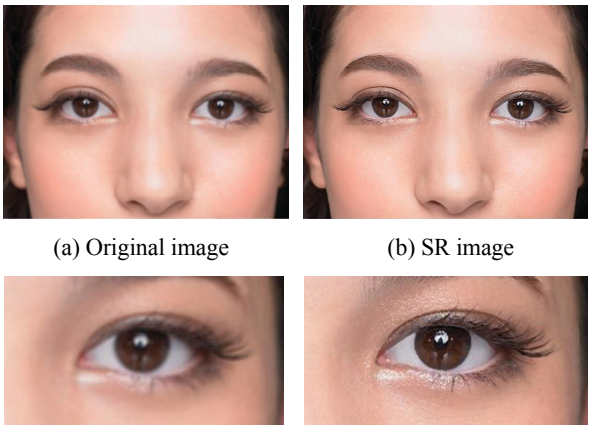


Fig.3 Super-resolution system

C. *Experimental Result*

Figure 4 shows the results of the super-resolution (SR) process for eye part of a face picture. The pupil becomes clear and brilliant. The eye line becomes clear and the eyelashes are emphasized. The hair enhancement is also achieved that is not shown because of the space limit.



(a) Original image (b) SR image

(c) Original image (d) SR image

Fig.4 Eye enhancement.

IV. CONCLUSION

We show the remarkable effects of the TV filter and super resolution for the human face image processing.

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