VIEWING EFFECT ALGORITHM FOR IMAGE EXPANSION

Joseph Y. Pai and *Lori Lucke*
Department of Electrical Engineering
University of Minnesota, Minneapolis, MN 55455

Abstract – Color image expansion is necessary for printing images on large format printers. A new Viewing Effect Algorithm is introduced for image expansion in this paper. The algorithm is developed to measure the viewing quality of the expansion results from various image expansion techniques. The principle behind the algorithm is based on viewing angle and distance to the image to calculate a viewing effect number. The viewing effect number is used to compare the expansion quality among various popular expansion techniques. Simulation results show this algorithm can provide qualitative comparisons for the various expansion techniques.

1. Introduction

Image expansion is essential for large format printing especially when the original image is in low resolution mode. Expansion creates many new, non-existent pixels that can lead to a significant degradation in image viewing quality. Some expansion schemes have been introduced in [1], [2], [3], [4], [5], and [6] that include pixel replication, interpolation, area sizing, fractal, and fuzzy expansion techniques. Simple pixel replication may cause loss of image detail when expanding an image. Linear interpolation should improve the image viewing quality over simple replication. Nonlinear techniques such as area sizing and fractal expansion should generate even better results. Fuzzy expansion tries to maintain the edge information and minimize detail loss through fuzzy judgement. Area sizing expands an image dependent on local area parameters.

Many techniques exist to measure image quality or distortion. Typically these techniques are developed for a particular application. For example, when removing noise from an image or judging the effects of lossy compression, it is possible to use a set of training images. The processed image and the original image can be compared using image quality metrics such as peak signal to noise ratio, or the mean absolute difference, or more complicated metrics based on the human visual system [7]. Image distortion measurements are also commonly used to guide the compression of an image [8], [9]. However these techniques are not easily applied to image expansion due to the generation of many new pixels. Instead aesthetic analysis is typically used to judge the expanded image quality. A qualitative technique to measure the expanded image quality would be very useful. In this paper we present a new ***Viewing Effect (VE)*** algorithm to measure the quality of the expanded image. This algorithm can be applied to both grayscale and color images. It can also be used to guide the expansion technique. We demonstrate its ability to qualitatively measure the results of various expansion techniques.

2. Viewing Effect Algorithm

In the following we develop an image quality metric which can be applied to image expansion algorithms to judge their effectiveness.

Assume the viewing resolution for a human's eye is θ degree. At a distance of l from a picture, the resolution of viewing width is approximated to $l\theta$ since θ is very small. In a grayscale or one plane of a color picture, let P represent the pixel value, where P = 256 for black and 0 for white in an 8-bit stored format. Therefore the viewing effect function (VEF) in the ***normal*** distribution for a pixel P can be described as

$$\mathrm{VEF} = P \times e^{-x/(l\theta)} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

where x is the distance of any point from center of pixel P when $x \le l\theta$ for dominance.

For two adjacent pixels P_1 and P_2 the right and left viewing effect functions are expressed as

$$\mathrm{VEF}_{1R} = \boldsymbol{P_1} \times e^{-x/(l\theta)} \text{ and}$$
$$\mathrm{VEF}_{2L} = \boldsymbol{P_2} \times e^{(x-l\theta)/(l\theta)} \quad \text{............. (2)}$$

where P_1 and P_2 are pixel values and x is distance from the center of each pixel.

For the original picture, the viewing effect for these two pixels can be written as

$$\mathrm{VEF}_{org} = \mathrm{VEF}_{1R} + \mathrm{VEF}_{2L} = P_1 \times e^{-x/(l\theta)} + P_2 \times e^{(x-l\theta)/(l\theta)} \quad \text{..... (3)}$$

The viewing effect number of an image of $m \times n$ pixels can be derived as follows: Let $P_{m,n}$ be the pixel value of one color layer of an image at the position of m and n in the 2-D plane. The accumulated row effect of $P_{1,n}$ to $P_{m,n}$ is

$$\mathrm{VEF}_{row} = \sum_1^n \sum_1^{m-1} \int_0^{l\theta} (P_{m,n} \times e^{-x/(l\theta)} + P_{m+1,n} \times e^{(x-l\theta)/(l\theta)})\, dx \quad \text{.....(4)}$$

and the accumulated column effect of $P_{m,1}$ to $P_{m,n}$ is

$$\mathrm{VEF}_{col} = \sum_1^m \sum_1^{n-1} \int_0^{l\theta} (P_{m,n} \times e^{-x/(l\theta)} + P_{m,n+1} \times e^{(x-l\theta)/(l\theta)})\, dx \quad \text{...(5)}$$

Therefore the entire image viewing effect number can be calculated using

$$\mathrm{VEF}_{image} = \mathrm{VEF}_{row} \times \mathrm{VEF}_{col} \quad \text{.................. (6)}$$

The expansion distortion of viewing effect between a ×2 expanded image and original image can thus be easily expressed as

$$\mathrm{VEF}_{dist}(\%) = \{[\mathrm{VEF}_{image(org)} - (\mathrm{VEF}_{image(x2)}/16)]/\mathrm{VEF}_{image(org)}\} \times 100 \quad \text{........(7)}$$

where $\mathrm{VEF}_{image(org)}$ is the entire image viewing effect of the original image and $\mathrm{VEF}_{image(x\,2)}$ is for the ×**2** expanded image. The division by 16 accounts for the ×4 factor in the accumulated row (Eq. 4) and the ×4 factor in the accumulated column (Eq. 5).

The above viewing effect number can easily be used to judge the expansion quality for various expansion techniques. For example, the distortion in an expanded edge can be compared as follows. For edge detection in a ×**2** expanded image, a ratio of edge pixels is used to determine the new inserted pixel. Let r = edge ratio, where $0 \le r \le 1$. Therefore new pixel $P_n = r \times (P_2 - P_1) + P_1$ in an expanded image. The expanded edge viewing effect of P_1 and P_n then can be derived from equation (3) as

$$\mathrm{VEF}_{edge} = P_1 \times e^{-x/(l\theta)} + (r \times (P_2 - P_1) + P_1) \times e^{(x-l\theta)/(l\theta)} \quad \text{.. (8)}$$

The viewing effect difference VEF_{diff} of VEF_{org} and VEF_{edge} is then

$$\mathrm{VEF}_{diff} = ((1-r) \times P_2 + (r-1) \times P_1) \times e^{(x-l\theta)/(l\theta)} \quad \text{.. (9)}$$

3. **Viewing Effect Results**

Using the Viewing Effect Function developed in the last section, we demonstrate its ability to judge the distortion in an expanded image.

For linear interpolation r = 0.5 and for fuzzy expansion, r > 0.5 when an edge is detected. Therefore the viewing effect difference (equation 9) for fuzzy expansion is always smaller than that of linear interpolation. Thus fuzzy expansion will always have less VEF distortion than linear interpolation. This agrees well with aesthetic analysis.

The sample image shown in Fig. 1 demonstrates the usefulness of the viewing effect calculation. Here each pixel is represented by a grayscale value. The original image is expanded ×2 using several expansion techniques [1,2,3,4,5,6].

(a) original	(b) replication	(c) area sizing	(d) edge detection	(e) fuzzy expansion
64 128 130	64 64 128 128 130	64 96 128 129 130	64 107 128 129 130	64 107 128 129 130
75 120 192	64 64 128 128 130	70 97 124 143 161	70 100 124 143 161	70 103 124 154 161
64 128 255	75 75 120 120 192	75 98 120 156 192	75 98 120 156 192	75 98 120 178 192
	75 75 120 120 192	70 97 124 174 224	70 97 124 174 224	70 97 124 237 224
	64 64 128 128 255	64 96 128 192 255	64 96 128 192 255	64 96 128 254 255

Figure 1: Expansion of an image using several algorithms.

The effectiveness of the expansion techniques in Fig. 1 can be measured using the Viewing Effect Function. Assume the viewing distance, l, is set to 1 foot and the viewing resolution, θ, is 1 arc second (which corresponds to approximately 300 dpi). Therefore the viewing width $l\theta$ is about 0.0033 inch or 3 mil. ($\tan(\theta) \approx \theta$ when $\theta = 1$ arc second; $l\theta \approx 0.0033"$). The results are shown in Table 1.

Table 1: The comparison of Viewing Effects for different expansion schemes

	Original	Replication	Area sizing	Edge detection	Fuzzy expansion
Row Effect VEF_{row}	2.905	8.382	9.594	9.655	10.350
Column Effect VEF_{col}	2.927	8.550	9.733	9.765	10.258
Image Effect VEF_{image}	8.503	71.666	93.378	94.281	106.170
Distortion VEF_{dist} (%)		47.32%	31.36%	30.70%	21.96%

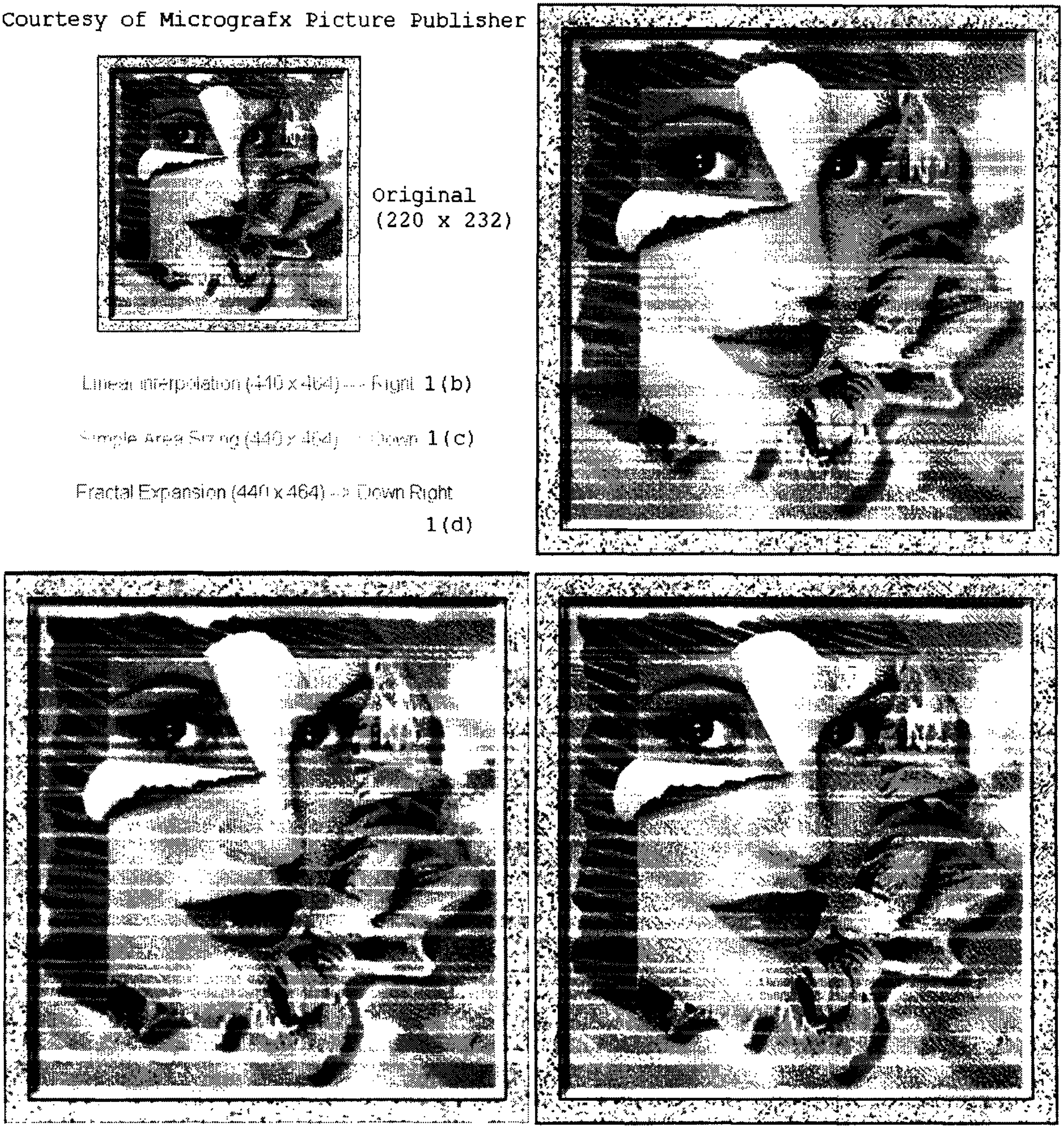
These results show decreasing distortion of VEF for the nonlinear expansion techniques and agree with aesthetic analysis. We have tested the VEF on several 'real' color images with similar results.

For color images, the VEF for each plane can be calculated. The total VEF for the color image is the sum of the VEF for each plane.

$$VEF_{color\_image} = VEF_{plane1} + VEF_{plane2} + VEF_{plane} \cdots \quad (10)$$

Other techniques, such as averaging, can be used for the combination of the VEFs for each plane. However we have found that simple addition provides good results.

In Fig. 2, three different ×2 expansions from an original image (220 × 232) are compared. In Fig. 2(b) linear interpolation is used causing blocky details particularly around the face and eyes. In Fig. 2(c) area sizing expansion is used which smoothes details and color blurring in the red-yellow frame. Fractal expansion is shown in Fig. 2(d). It does a much better job expanding the image edges and details but tilt line noise shows up on the face and other places. The VEF algorithm can be used to calculate the distortion in the entire expanded image or on selected areas of the image. For example, the distortion in the smooth areas of the face in the image in Fig. 1 could be compared to the distortion in the background of the image. Thus the VEF can be used to guide the expansion of an image. Multiple expansion methods can be applied to different areas of an image to improve the overall expansion as guided by the VEF numbers.



(c) Area Sizing

(d) Fractal Expansion

Figure 2: Comparison of Expansion Techniques

4. Viewing Effect Function Extensions

The Viewing Effect Function can also be used to optimize the expansion of an image. An image can be subdivided into blocks. Each block can be expanded using multiple expansion techniques. The Viewing Effect Function in equations (6) and (7) can be used to choose the best expanded block for use in the final image. We have applied this technique to several images with good results. The resulting image contains a combination of expansion techniques. For example, fractal expansion would be used in the areas of an image with a lot of detail while area sizing would be used in the smoother areas of the image. The overall VEF for the final image is lower than that of any of the individual expansion techniques.

Another useful application of the Viewing Effect Function is to calculate the viewing distances for an original and expanded images which appear to have the same viewing effect. For example, an image viewed at 1 foot using fractal expansion could be judged to be similar to an image viewed at 2 feet using simple linear interpolation. Thus the simpler interpolation scheme could be used for larger viewing distances.

5. Conclusion

A new tool for judging the quality of image expansion has been introduced in this paper. Experimental results have demonstrated the efficiency of the proposed algorithm. It helps to preserve the detail and chromaticity of an expanded image from the original. That is very important in visual perception of color images. We have demonstrated its ability to judge the distortion in an expanded image and also to guide the expansion process.

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