# IMAGE ENHANCEMENT BY EDGE-PRESERVING FILTERING

*Yiu-fai Wong*

Institute for Scientific Computing Research, L-416
Lawrence Livermore National Laboratory
Livermore, CA 94550
Email: wong@redhook.llnl.gov

## ABSTRACT

Image enhancement is useful when the details in an image are lost due to various reasons. It is common to subtract a mask from a given image to enhance the details. The trick is how to obtain a good mask. We describe here how an edge-preserving filter can be used to generate a mask which is smooth over areas with fine details, yet preserving most of the edges. Experiments with real images show that our scheme is very effective.

## 1. INTRODUCTION

Image enhancement is needed when the dynamic range of a recording/display media is smaller than that of the signal it is exposed to. The media can be film, monitors and printers. Without any postprocessing, the visibility of important details in both the light and dark areas is greatly reduced. Such areas may appear flat or washed out (see [1] for an excellent review). This can also occur in other imaging modalities such as Magnetic Resonance Imaging.

A common procedure for enhancement is to subtract a low-passed version of an image from the original, increasing the high-frequency components. But it is known that unpleasant effects, overshoots which look like bright and dark bands near the edges, can be created. Thus, sharp masks are needed. An expensive and time-consuming way to obtain good quality pictures is to have photographers under-expose or over-expose the scene [2].

In this work, we propose and demonstrate the use of an edge-preserving filter called *clustering* filter for image enhancement [1]. The filter will be briefly described below and the details can be found in [3, 4].

---

[1] We are partly motivated by the work in [5] in which a saturating resistive grid was used to generate a mask.

Let $\mathbf{x}_i$ be the coordinate of $i^{th}$ pixel[2] and $y_i$ its gray level. The output $y$ at pixel location $\mathbf{x}$ is given by

$$y = \sum_i \frac{y_i w_i e^{-\beta(y_i - y)^2}}{\sum_j w_j e^{-\beta(y_j - y)^2}}, \qquad (1)$$

where $w_i = e^{-\alpha \|\mathbf{x}_i - \mathbf{x}\|_2^2}$. $\alpha$ is the scale in the input space and governs the effective neighborhood of data used in the filter. Given $\alpha$ and the data, $\beta$ is computed as follows: Let $\bar{y} = \sum_i y_i w_i / \sum_i w_i$ and $\sigma_y^2 = \sum_i (y_i - \bar{y})^2 w_i / \sum_i w_i$. One then chooses $\beta = (2\sigma_y^2)^{-1}$. Select $y_0 = \bar{y}$; iterate equation (1) a few times. The converged $y$ is the filtered output. As demonstrated in [3, 4], the clustering filter is capable of 1) preserving edges, 2) removing impulsive noise and 3) providing improved smoothing of nonimpulsive noise.

## 2. ENHANCEMENT SCHEME AND RESULTS

A good mask should be smooth in areas with fine details, yet has sharp edges between the larger-scale structures. Subtracting this mask from the original image and rescaling will enhance the details while avoiding the halos around the edges. This is the essence of the scheme below using the clustering filter:

1. Filter a given image $I$ using $\alpha = 1/2$ recursively $k$ times to obtain $I_i$. $k = 5$ in our case.

2. Compute the difference signal $I_d = I - I_i$.

3. Compute the local mean $M$ and variance $V$ for every pixel of $I_d$. The size of the local neighborhood is $40 \times 40$ pixels in all our examples.

4. $I_m(\mathbf{x}) = \begin{cases} I_i(\mathbf{x}) & \text{if } |I_d(\mathbf{x}) - M(\mathbf{x})| < 2.5V(\mathbf{x}) \\ I(\mathbf{x}) & \text{otherwise.} \end{cases}$

5. Compute $I_o = I - sI_m$; $s = 0.5$ in our experiments.

---

[2] $\mathbf{x}_i = (i, j)$ for an image with rectangular grids. We use this notation for simplicity.

6. Rescale $I_o$ appropriately. For example, let $m$ and $v$ be the mean and variance of $I_o$. $I_o$ is stretched to the range between $m - 2.5v$ and $m + 2.5v$.

Let us explain each of the steps above. Step 1) is used to generate a smoothed version of the image to serve as an initial mask. The mask is such that local details are smoothed while edges are preserved. However, smoothing means that not all useful signals can be preserved. For example, bright/dark spots can be removed completely by the filter; edges of smaller scale can be smoothed out; corners of edges can be rounded to some extent. Thus, the difference image computed in step 2) contains the signal which needs to be restored in the mask. To decide which difference signal should be added to the initial mask $I_i$, we compute the local means and variances of $I_d$ in step 3). At corners and bright spots, the difference signal will be large compared to their local variances. Step 4) restores these signals to the mask by thresholding. After subtracting the mask from the original image in step 5), rescaling in step 6) brings the image to its full dynamic range.

Figures 1a, 1b and 1c show the Cameraman, the mask $I_m$ and the enhanced image $I_o$ respectively. One can see that the coat and the ground (grass) are enhanced while the brightness relations of the local areas are preserved, which is really important in image enhancement [1]. The scenes on the background also appear sharper. To demonstrate the use of our procedure for dynamic range compression, Figure 2a shows an original 8-bit MR image. Figure 2b shows the result when only 4 bits are used, which is obtained by quantizing $I_o$ after step 6). It is seen that the anatomical structures become much more visible. In both cases, the enhanced images are visibly more pleasant than those obtained by histogram equalization or adaptive histogram equalization, which are not shown here. The experiments demonstrate that the clustering filter is suitable for dynamic range compression and image enhancement.

## 3. SUMMARY

We argue that edge-preserving filtering is essential for generating a mask such that halo effects can be avoided in image enhancement. We further demonstrate that the clustering filter can do a very good job of generating a good mask due to its nice smoothing and edge-preserving properties. Results on real images show that our scheme is very effective.

## 5. REFERENCES

[1] W.F. Schreiber, "Image Processing for Quality Improvement," *IEEE Proc.*, Vol. 66, No. 12, 1978.

[2] J.A.C. Yule, *Principles of Color Reproduction.* New York, Wiley, 1967.

[3] Yiu-fai Wong, "Saddle-node Dynamics for Edge-preserving and Scale-space Filtering," *Proc. IEEE Intl. Conf. Image Processing.* November, 1994.

[4] Yiu-fai Wong, "Nonlinear Scale-space Filtering and Multiresolution System," to appear in *IEEE Trans. Image Processing.*

[5] A.J. Moore, *Spatial Filtering in Tone Reproduction and Vision,* PhD Thesis, California Institute of Technology, 1992.
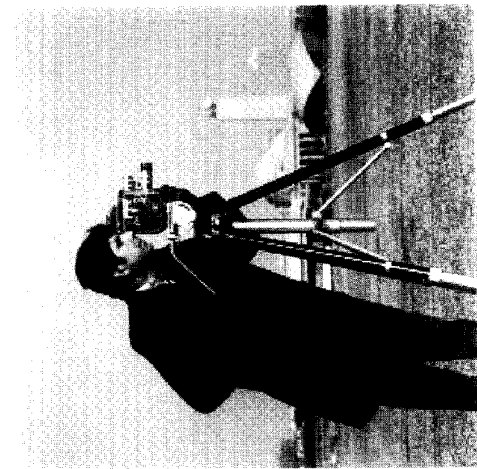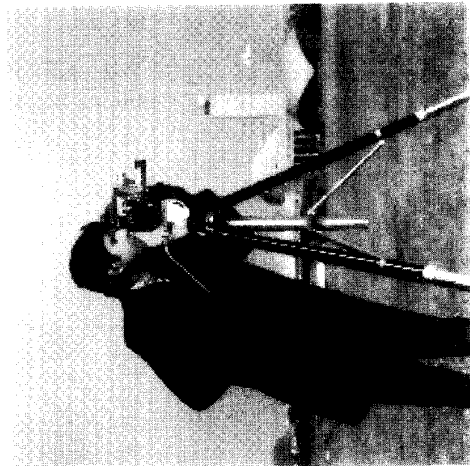
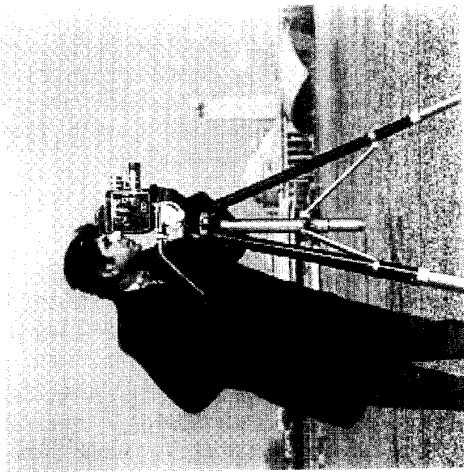Figure 1a. Original cameraman.

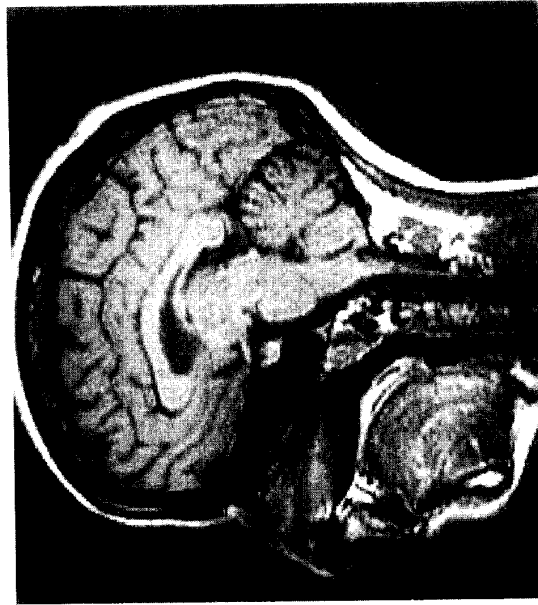Figure 1b. Generated mask.

Figure 1c. Enhanced Image.

Figure 2a. Original 8-bit MR image.

Figure 2b. Enhanced 4-bit MR image.