# Image Detail Enhancement Using $L_0$ Gradient Minimization

Prakash R. Gadekar[1], Shradha B. Hedgire[2], Rajan S. Jamgekar[3]
[1] Assistant Professor, *SKNSCOE, Korti, Pandharpur, Solapur University, Solapur, India*
[2] ME- CSE, *SKNSCOE, Korti, Pandharpur, Solapur University, Solapur, India*
[3]Assistant Professor, *NBN SCOE, Solapur, Solapur University, Solapur, MS, India*
[1] gadekar.prakash@gmail.com, [2] hedgire_shradha@rediffmail.com, [3]rs.jamgekar@gmail.com

***Abstract*— Image enhancement is required to improve the image quality so that the resultant image is better than the original image for a specific application or set of objectives. Image enhancement is the task of applying certain alterations to an input image like as to obtain a more visually pleasing image. Many images such as medical images, remote sensing images, electron microscopy images and even real life photographic pictures, suffer from poor contrast. Therefore, it is necessary to enhance the contrast. The purpose of image enhancement methods is to increase image visibility and details. Two major classifications of image enhancement techniques are spatial domain enhancement and frequency domain enhancement. However, these techniques bring about tonal changes in the images and can also generate unwanted artifacts in many cases, as it is not possible to enhance all parts of the image in balanced manner***

***Keywords*— Image Smoothing, Image Enhancement, Image gradient, Spatial Domain Enhancement , Frequency Domain Enhancement***

## I. Introduction

Image contains lots of features like edge, color, contrast and brightness etc. the process of changing or modifying certain features that meet application requirement is called Image Enhancement. It can also be defined as:

1. Processing of an image to bring out specific features of an image
2. Highlight certain characteristics of an image
3. To process an image so that result is more suitable than original image for a specific application.

The image enhancement filters [2] are broadly divided in to following categories: -

1. Spatial Domain: - based on direct manipulation of pixels in image.
2. Frequency Domain: - based on modifying Fourier transform of an image.

Image detail enhancement algorithms can increase visual appearance of images. They enhance fine details while avoid halo artifacts and gradient reversal artifacts around edges. Existing detail enhancement algorithms are based on edge-preserving decomposition algorithms. A source image is first decomposed into a base layer which is of homogeneous regions with sharp edges and a detail layer which is composed of fine details or textures via decomposition algorithm, then a detail-enhanced image is produced by amplifying the detail layer.

Bilateral filter [4] is non-linear and non-iterative filter that preserve the edges by mean of combining the nearby pixels values in image. They used the technique to combine the gray levels or color based on their geometric closeness and their photometric similarity in both range and domain. In [9], an iterative median filter was used as an edge-preserving decomposition tool in a generalized unsharp masking algorithm.

F. Durand and J. Dorsey [6] presented a technique for the display of high-dynamic-range images, which reduces the contrast while preserving detail. Xu, L., Lu, C.et al. [8] have proposed the technique of image smoothing with $L_0$ gradient minimization method. This method is based on the spatial changes in which a restriction is placed upon the total number of non-zero gradients between pixels so that to globally enhancing the prominent edges, even if the boundaries of objects are much contract. In [11], an iterative median filter was used as an edge-preserving decomposition tool in a generalized unsharp masking algorithm. Pietro P., and Malik J. [3] proposed a new scale-space and edge detection algorithm using anisotropic diffusion method. M. Son,Y. Lee,et al.[12] presented a novel method for enhancing details in a digital photograph, inspired by the principle of art photography.In[7]an algorithm was presented for removal of noise from an image. Two-scale tone management for photographic look was used in [10].

A new detail enhancement algorithm is proposed to produce a detail-enhanced image. With the proposed algorithm fine details can be amplified by enlarging all gradients in the source image except those of pixels at edges. The algorithm is derived by solving a newly formulated norm based global optimization problem.

## II. Proposed Algorithm

Image is composed of base and details layers. Fig.(a) shows input image taken for enhancement. The based layer is responsible for structural properties of an image. The human perceptional system can able to recognize the object because of based layer. For example, by looking at Fig. (b), we can classify it has a rose object even though it's details are missing. Fig.(c)shows details layer and Fig.(d) shows detail enhanced image.

Now a days, people are using mobile camera to capture an image. Since mobile camera have small aperture hence they are able to capture few details resulting decreased in image quality. Thus requirement to Enhanced details part of an image increases.

To enhance details part, we need to first extract it as shown in eq. 1

$$D = I - S \qquad (1)$$

Then Enhanced image can be obtain by eq. 2

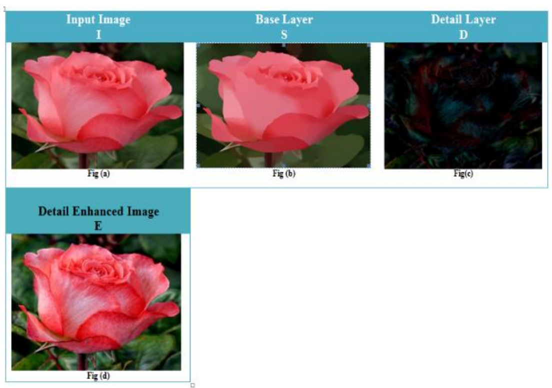


Fig.(a) Input image Fig(.b) Base layer Fig.(c) Details layer Fig.(d) Detail enhanced image

$$E = I + K \times D \qquad (2)$$

where K is positive integer used to control degree of details enhancement. The $L_0$ norm can be used to obtain based layer S.

The algorithm for $L_0$ norm is outlined below.

Algorithm $L_0$ Gradient Minimization

Input: image I, smoothing weight λ, parameters $^{\beta}{}_{0}$, $^{\beta}{}_{max}$ and rate k

Initialization: E ⟵I, $^{\beta} \longleftarrow {}^{\beta}{}_{0},\ i \longleftarrow 0$

repeat

With $E^{(i)}$,solve for $h_p^{(i)}$ and $v_p^{i}$ in Eq.(4)

With $h^{(i)}$ and $v^{(i)}$solver for

$E^{(i+1)}$ $with\ Eq.$(5)

$^{\beta} \longleftarrow k^{\beta}, i++$

until $^{\beta} \geq {}^{\beta}{}_{max}$

Output: result image E

The smoothing can be achieved by using energy function(3)

$$\min E\{\textstyle\sum_p (E_p\text{-}I_p)^2 + \lambda . C(E\text{-}KoI)\} \qquad (3)$$

Where E is the detail-enhanced image, I is the input image, p is the pixel index of the images, o denotes the element-wise product operator. C(E-KoI) is the $L_0$ norm of the gradient field, which equals the number of non-zero elements of the gradient field.

The Eq.(3) involves a discrete counting metric. It is difficult to solve because the two terms model respectively the pixel-wise difference and global discontinuity statistically. Traditional gradient decent or other discrete optimization methods are not usable. We adopt a special alternating optimization strategy with half quadratic splitting, based on the idea of introducing auxiliary variables to expand the original terms and update them iteratively. Thus it degenerate in two sub problem: first estimating $(h_p, v_p)$ as shown in Eq. (4) and second estimating E shown in Eq. (5).

$$(h_p, v_p) = \begin{cases} (0,0), & if\ \partial_x(E_p - \hat{I}_p)^2 + \partial_y(E_p - \hat{I}_p)^2 \le \frac{\lambda}{\beta} \\ (\partial_x(E_p - \hat{I}_p), \partial_y(E_p - \hat{I}_p)) & otherwise \end{cases}$$

(4)

$$E = F^{-1}\left(\frac{F(I)+^{\beta}\left(F(\partial_x)F(h+\hat{I})+F(\partial_y)F(v+\hat{I})\right)}{F(1)+^{\beta}\left(F(\partial_x)^{*}F(\partial_x)+F(\partial_y)^{*}F(\partial_y)\right)}\right)(5)$$

## III. EXPERIMENTAL RESULTS

In this, we first evaluate the choice of λ . As shown in Fig. 1, λ controls the degree of the enhancement. With a smaller λ, the final image will be more similar with the input image; with a larger λ, the result image will be sharper. Then experimental studies are conducted to compare the proposed algorithm with the $L_0$ norm based algorithm in [8], the GIF in [5] and the BF in [4].

We first compare their overall performances. The images in Fig. 2(a) and Figs. 2(c)–(e)are resulting images by four different algorithms, obtained by adding 4 times of the detail layer to the input image. The result images of $L_0$ norm based algorithms are less dependent on local features. It is observed that the resulting image of $L_0$ norm based algorithms are sharper and have more details than both the GIF and the BF.

Then we compare the images by observing the zoom-in patches of the result images. The zoom-in patches of Fig. 2(a) and Figs. 2(c)–(e) are presented. It is shown that both the $L_0$ norm based filter in [8] and the BF in [3] suffer from the gradient reversal artifacts and the GIF in [5] suffers from halo artifacts. Both artifacts are significantly reduced by our proposed algorithm.

Fig. 1 Comparison of enhancement result of image “tulips” with different selections of λ, k = 4 for all λ. (a) Input image. (b) λ=0.016 (c) ) λ=0.032.(d) ) λ=0.08. (e) ) λ=0.32.

Fig. 2 Comparison of enhancement result of image “tulips”. a) Original $L_0$. (b) Edge aware factor. (c) Proposed algorithm. (d) GIF. (e) BF.

## IV. CONCLUSION

The proposed detail enhancement uses an $L_0$ norm based optimization algorithm. This algorithm will not only preserve the sharp edges but also produce a detail-enhanced image.

Experimental results show that our algorithm produces images with better visual appearance than the existing norm based and several other detail enhancement algorithms, especially around edges.

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