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Chrominance Assisted Sharpening of Images

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Abstract

This paper presents a method to sharpen an image with less amplification of the noise than conventional methods. The proposed design method uses unsharp filtering for the sharpening part and differences in the chrominance data to decide if sharpening should be performed or not. The basic idea is to only do the sharpening if there are any changes in the chrominance information. Examples are included of sharpened images with less amplification of the noise.

Introduction

Different image sharpening methods have been known for a long time and can be studied in [1], [2] and [3]. In the literature the sharpening is often performed with either a high pass filter or by an unsharp filter or mask. One problem with these methods is that the sharpening is applied to the entire image. This can result in that not only contures but also unwanted noise gets amplified. In an image there is often areas which are not desired to sharpen e.g. clothes, blue-sky, buildings etc. Generally textures like these have the same color over the whole region and even if there is a change it is of a low-frequency characteristic. This makes it possible to use the chrominance components in the decision step.
To be able to perform this the image, which is commonly represented in RGB (red-green-blue), must be represented in a format which separate the luminance and chrominance components, e.g. YC_bC_r where Y represents the luminance, C_b the chrominance blue and C_r the chrominance red. In this format the sharpening can be performed on the luminance, Y, and the decision to sharp or not can be performed using the chrominance, C_b and C_r, where sharpening is excluded when there is little variation in the chrominance components.

In Section 1, a description of different sharpening methods is given. Section 2 presents the method using the chrominance data to decide if sharpening should be performed or not. Section 3 presents the results including image examples. The report ends with a conclution in section 4.

1 Sharpening

To perform sharpening there are two basic methods: highpass filtering and unsharp filtering which are presented in [1], [2] and [3]. These can be used in different ways presented in this section.

1.1 Highpass Filtering

The simplest way to sharpen an image is to use a high-pass filter, which emphasizes the high frequencies components and reduces the low frequencies. Some typical examples of highpass masks used for contrast enhancements are shown in Eq. 1

$$\begin{aligned} h_{HP} &= \begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix} \\ h_{HP} &= \begin{bmatrix} -1 & -1 & -1 \\ -1 & 9 & -1 \\ -1 & -1 & -1 \end{bmatrix} \\ h_{HP} &= \begin{bmatrix} 1 & -2 & 1 \\ -2 & 5 & -2 \\ 1 & -2 & 1 \end{bmatrix} \end{aligned} \tag{1}$$

A drawback of this approach is that the results from areas with constant or slow variation will be very small; this will result in an image with enhanced edges over a rather dark area. To preserve the low-frequencies parts of the image it is significantly better to us an **unsharp filter**.

1.2 Unsharp Filtering

Unsharp filtering or unsharp masking has been used by photographic artists and printing industries for a long time. The method is a simple way to enhance the edges and other high frequency components but with the possibility to keep the basic low frequencies in the image.

This is performed via a procedure where the original image first is blurred, *unsharped*, and then subtracted from the original to produce an edge image $g(x, y)$. This can be expressed as

$$g(x, y) = f(x, y) - f_{blurr}(x, y) \tag{2}$$

where $f(x, y)$ is the original image and $f_{blurr}(x, y)$ is the blurred or unsharped version of $f(x, y)$. This image can then be used for sharpening if it is added back into the original image

$$f_{sharp}(x, y) = f(x, y) + m * g(x, y) \tag{3}$$

where m is a scaling factor that decides the amounts of sharpening. The blurred version $f_{blurr}(x, y)$ of the original image can be generated by convolution with a 2-D Gaussian filter where the discrete Fourier transform of it is expressed as

$$G(n_1, n_2) = \frac{1}{2\pi\sigma^2} e^{-\frac{n_1^2+n_2^2}{2\sigma^2}} \tag{4}$$

and σ represents the Gaussian filters spread factor. In Eq. 5 a suitable integer-valued convolution kernel that approximates a Gaussian with a σ of 1.0 is shown.

$$h_{gauss} = \frac{1}{273} \times \begin{bmatrix} 1 & 4 & 7 & 4 & 1 \\ 4 & 16 & 26 & 16 & 4 \\ 7 & 26 & 41 & 26 & 7 \\ 4 & 16 & 26 & 16 & 4 \\ 1 & 4 & 7 & 4 & 1 \end{bmatrix} \tag{5}$$

The blurred version $f_{blurr}(x, y)$ can also be generated by using a common lowpass (LP) filter as illustrated in Eq 6.

$$\begin{aligned} h_{LP} &= \frac{1}{9} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \\ h_{LP} &= \frac{1}{10} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & 2 & 1 \\ 1 & 1 & 1 \end{bmatrix} \\ h_{LP} &= \frac{1}{16} \times \begin{bmatrix} 1 & 2 & 1 \\ 2 & 4 & 2 \\ 1 & 2 & 1 \end{bmatrix} \end{aligned} \tag{6}$$

which are common for image enhancement.

A more common way to perform the unsharp filtering is to generate $g(x, y)$ by using the negative Laplacian, the second-order derivative, operator. The Laplacian $L(x, y)$ of an image with pixel intensity values $I(x, y)$ is given by:

$$L(x, y) = \frac{\partial^2 I}{\partial^2 x^2} + \frac{\partial^2 I}{\partial^2 y^2} \tag{7}$$

Three commonly used discrete negative Laplacian kernels are shown in Eq. 8.

$$\begin{aligned} h_{Laplacian} &= -1 \times \begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix} \\ h_{Laplacian} &= -1 \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix} \end{aligned} \tag{8}$$

$$h_{Laplacian} \quad = \quad -1 \times \begin{bmatrix} -1 & 2 & -1 \\ 2 & -4 & 2 \\ -1 & 2 & -1 \end{bmatrix}$$

By using these negative Laplacian filters $g(x,y)$ can be generated direct by convolution and Eq. 3 can then be used.

2 Chrominance Assisted Sharpening

In a sharpened image the high frequencies of the image are amplified. This results in an image where contours and edges will be more prominent. The problem is that this, most likely, also will amplify unwanted high-frequency noise in the image. In this section the sharpening is only applied on the luminance component for pixels, where there are difference in the chrominance component compared to the surrounding pixels.

2.1 Chrominance Variations

To decide if there is a variation in the chrominance some measure must be used. If the two chrominance components C_b and C_r are seen as two axes in a 2-D plane the chrominance distance between two pixels can be calculated as

$$d = \sqrt{(C_{b_1} - C_{b_2})^2 + (C_{r_1} - C_{r_2})^2} \tag{9}$$

The distance d shall then be compared with some threshold k. This distance calculation is performed for the nearby neighbors for each pixel in the image and the maximum is chosen to be compared with k. To decide the threshold k some empirical tests must be performed on the camera which generates the images, due to the different characteristics between cameras. Thus, different cameras generate different amount of noise in the luminance and chrominance components.

2.2 Pre-filtering

Depending on the characteristics of different cameras the amount of noise in luminance and chrominance components will differ. For cheaper cameras the amount of noise is essential higher in the chrominance components and since the decision is based on variation in the chrominance components it can be profitable to do some pre-filtering before the decision is taken. This will not influence the subjective result since the filtered components are only used for the decision-making.

The pre-filtering can be done by both a common LP-filter like the mean filter; the filter mask is shown in Eq. 10, or a median filter.

$$h_{LP_{mean}} = \frac{1}{9} \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix} \tag{10}$$

The mean filter attenuates high frequencies present in the image, but if the noise includes single very unrepresentative value this can significantly affect the mean value of all the pixels in its neighborhood. The filter will also blur edges, which can affect the result of the decision to sharpen or not. An alternative is to use a median filter, which is more robust for single very unrepresentative values of the components. The median filter sorts the components in the surrounding of the chosen component and then replaces it with the middle component value. As a result of this the filter will not create new unrealistic values when an edge is filtered. What to choose depends on the type of noise the image includes.

2.3 Implementation

This section shows a flow chart of the method, see Figure 1.

3 Results

In this section the results on images from three different cameras are shown. The unsharp filtering method is used for all three cases. The different cameras demand different setups of pre-filtering strength on the sharpening, f, and threshold, k. Also, both common LP filtering as negative Laplacian filters have been used to generate $g(x,y)$. The LP filter used is shown in Eq. 11

$$h_{LP} = \frac{1}{25} \times \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} \tag{11}$$

and the negative Laplacian filter usedd is shown in Eq. 12.

$$h_{Laplacian} = -1 \times \begin{bmatrix} 1 & 1 & 1 \\ 1 & -8 & 1 \\ 1 & 1 & 1 \end{bmatrix} \tag{12}$$

Image one, Vacation, is taken with a Canon Ixus 400, the second, Flowergirl, with a Canon S10 and the third, House, with a SonyEricsson 610 mobile phone. It has not been possible to calculate any PSNR so just subjective evaluation has been used to tune in the different parameters in the method.

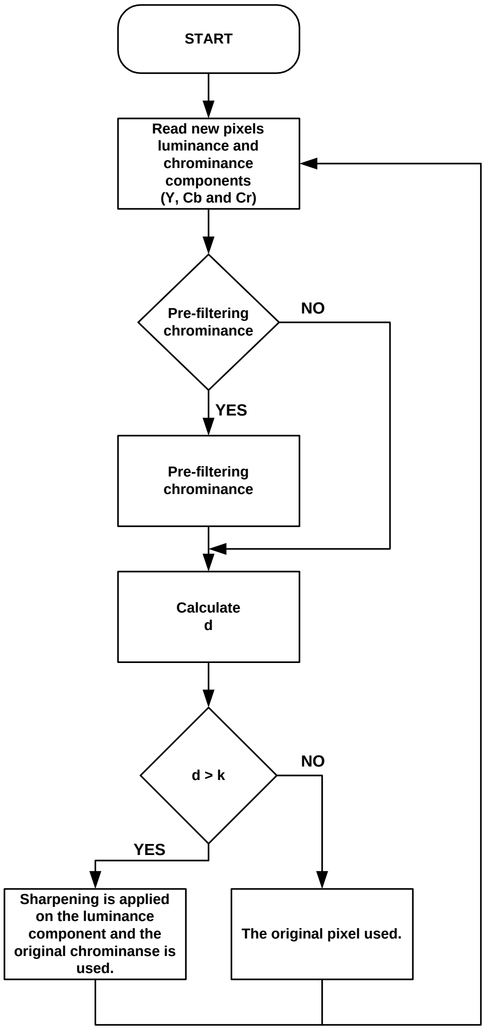
START
Read new pixels luminance and chrominance components (Y, Cb and Cr)
Pre-filtering chrominance
NO
YES
Pre-filtering chrominance
Calculate d
d > k
NO
YES
Sharpening is applied on the luminance component and the original chrominanse is used.
The original pixel used.

Figure 1: *Flowchart describing the selective sharpening filter.*

3.1 Vacation

The original image is shown in Figure 2. The sharpened image with both LP filtering and Laplacian filtering is shown in Figure 3. In Figure 4 the mask that illustrates where the sharpened pixels are used is shown. The final results are shown in Figure 5. No pre-filtering on chrominance is used.

3.2 Flowergirl

The original image is shown in Figure 6. The sharpened image with both LP filtering and Laplacian filtering is shown in Figure 7. In Figure 8 the mask that illustrate where the sharpened pixels are used is shown. The final results are shown in Figure 9. No pre-filtering on chrominance is used.

3.3 House

The original image is shown in Figure 10. The sharpened image with both LP filtering and Laplacian filtering is shown in Figure 11. In Figure 12 the mask that illustrate where the sharpended pixels are used is shown. The final results are shown in Figure 13. LP pre-filtering has been performed on the chrominance components with the same filter, h_{LP}, used to generate $g(x, y)$.

4 Conclusion

This report presents a method where chrominance components are used to decide if sharpening is required or not. The sharpening has been performed in a general way using unmask filtering with lowpass filters or negative Laplacian filters. The decision-making has been performed by calculating the variation in chrominance component. No sharpening has been performed if there is little variation in the chrominance components.

In section 3 the results from three different cameras are presented. In the two first examples, Vacation and Flowergirl no pre-filtering of the chrominance components has been performed, depending on the low noise contribution from the cameras. In the third example, House, the result from a much cheaper camera is shown where it is a much higher noise contribution. Therefore, pre-filtering has been used in this example. The threshold k is different for all three cases to avoid amplifying of the noise. If k would be reduced a much higher amount of noise would be included in the image which would lower the subjective result.

In all examples it can be seen that with the "chrominance assisted sharpening" method a smoother sharpening is performed and no or little noise is amplified. The evaluation and parameter tuning has been performed based on subjective opinions.

References

[1] William K. Pratt, *Digital Image Processing: PIKS Inside, Third Edition,* 2001, John Wiley & Sons, Inc.

[2] Jae S. Lim, *Two-Dimensional SIGNAL and IMAGE Processoing,* 1990, Prentice Hall PTR.

[3] Rafael C Gonzales, Richard E. Woods, *Digital Image Processing,* 1993, Addisio-Wesley Publishing Company

Vacation

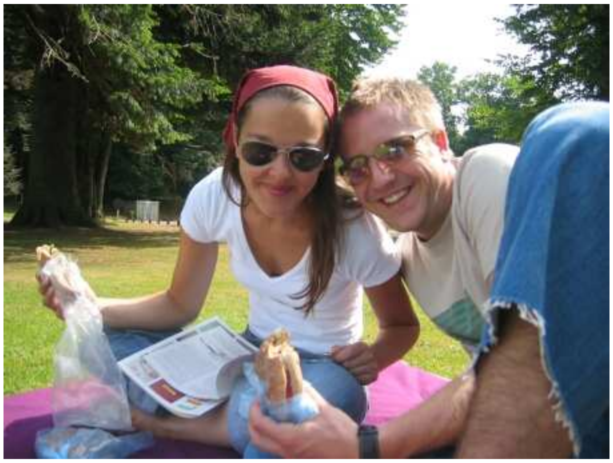

Figure 2: *Original image.*

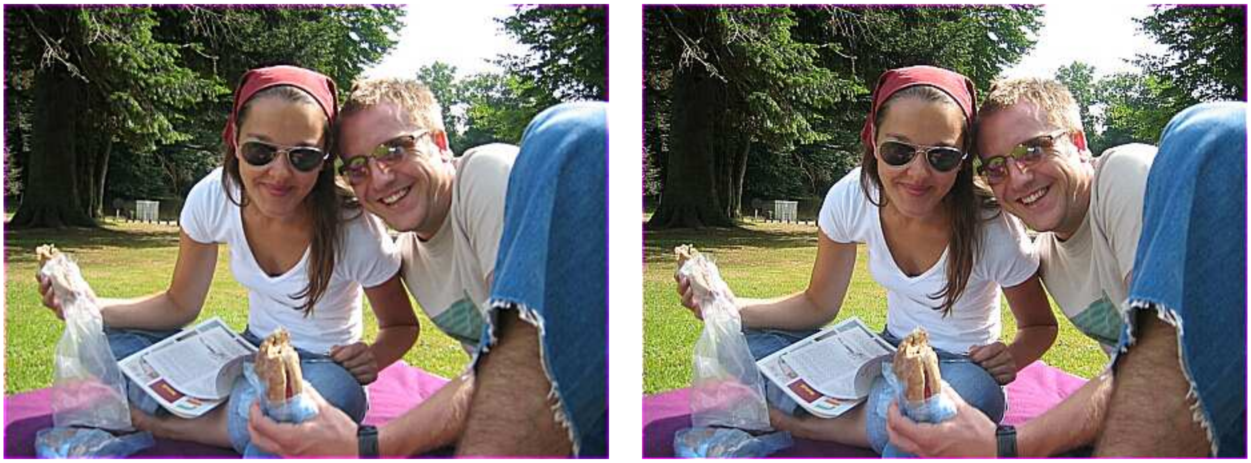

Figure 3: Left *Sharpening with LP filter.* **Right** *Sharpening with Laplacian filter.*

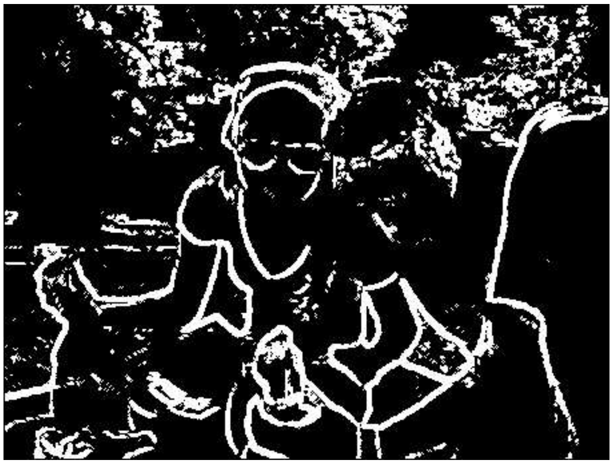

Figure 4: *The resulting Mask, showing where* $d > k$.

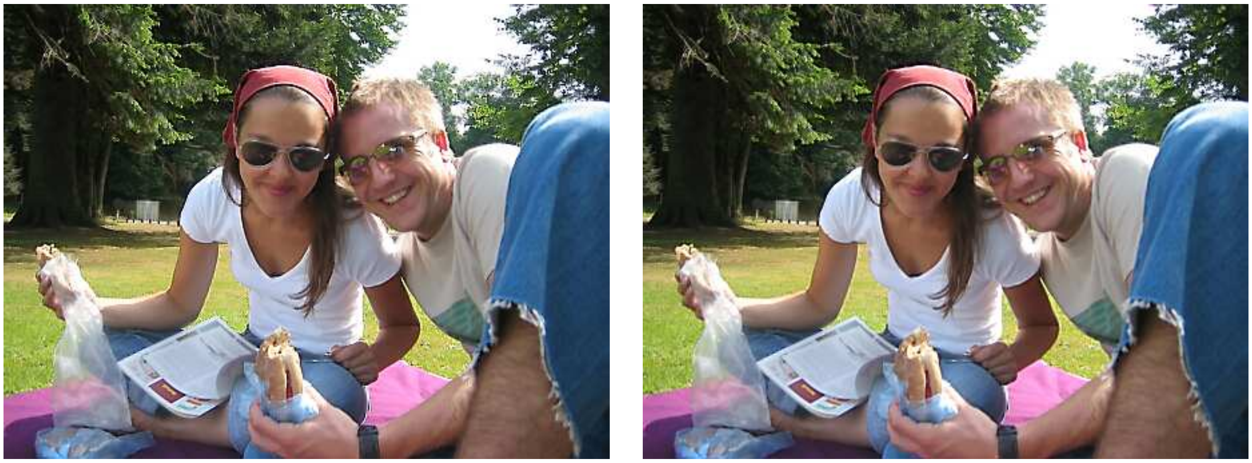

Figure 5: Left *Assisted Sharpening with LP filter.* **Right** *Assisted Sharpening with Laplacian filter.*

Flowergirl

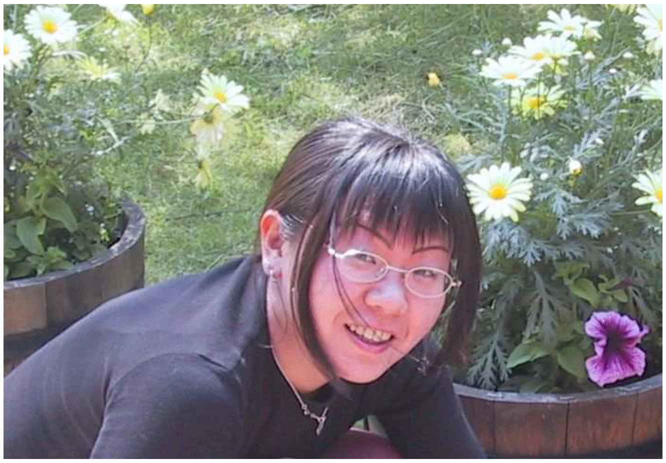

Figure 6: *Original image.*

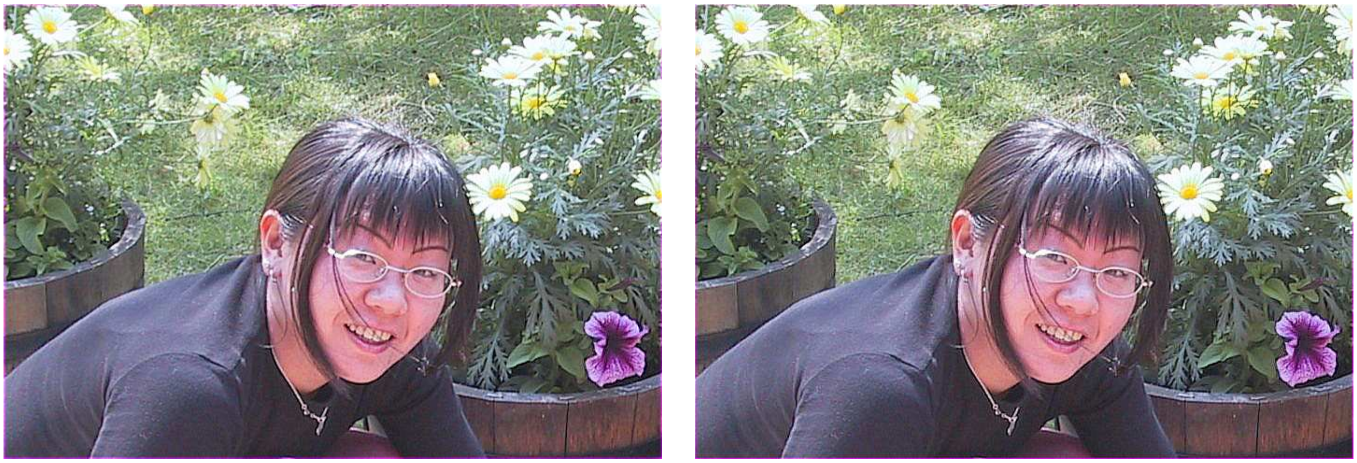

Figure 7: Left *Sharpening with LP filter.* **Right** *Sharpening with Laplacian filter.*

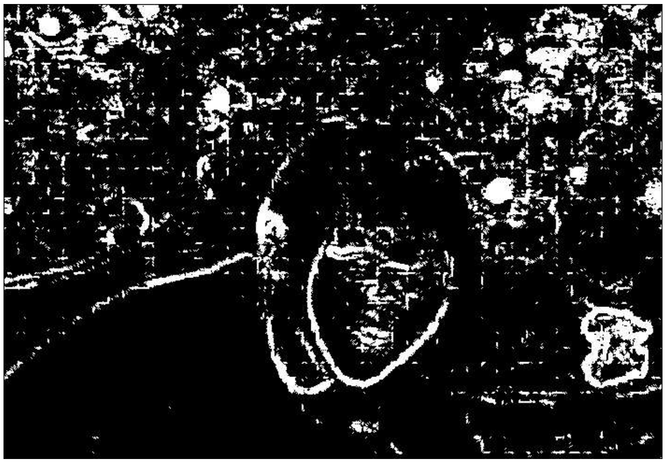

Figure 8: *The resulting Mask, showing where $d > k$.*

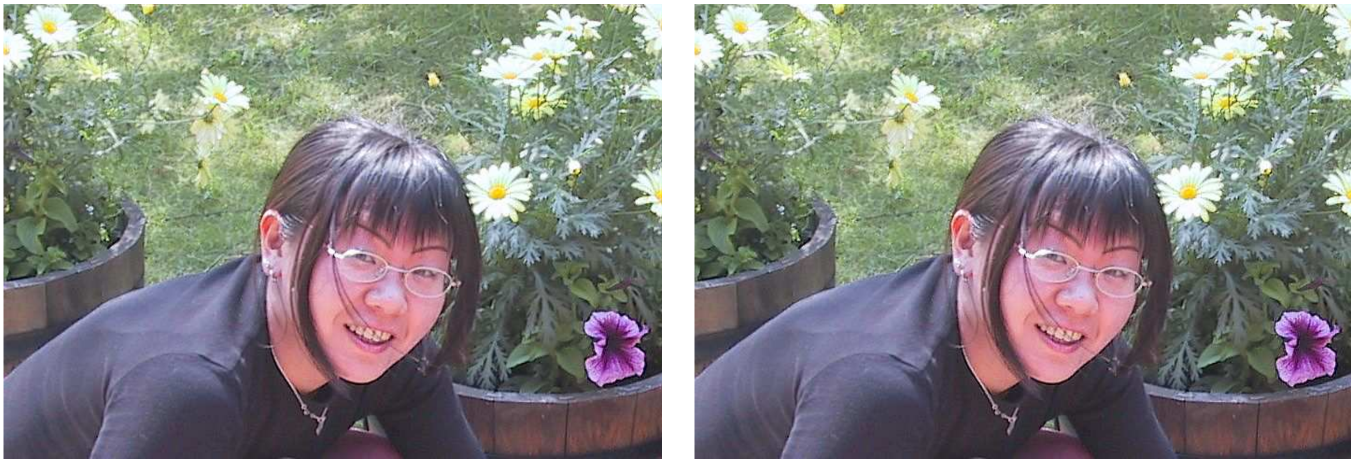

Figure 9: Left *Assisted Sharpening with LP filter.* **Right** *Assisted Sharpening with Laplacian filter.*

House

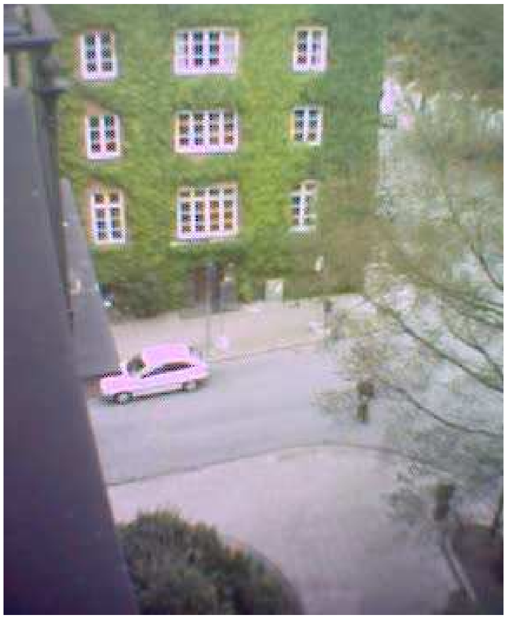

Figure 10: *Original image.*

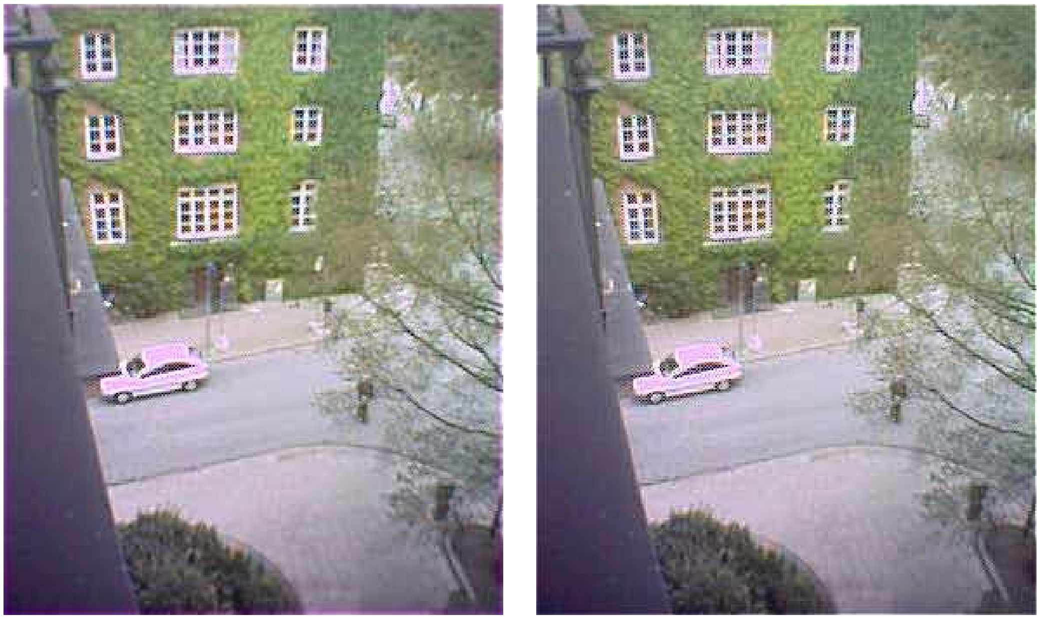

Figure 11: Left *Sharpening with LP filter.* **Right** *Sharpening with Laplacian filter.*

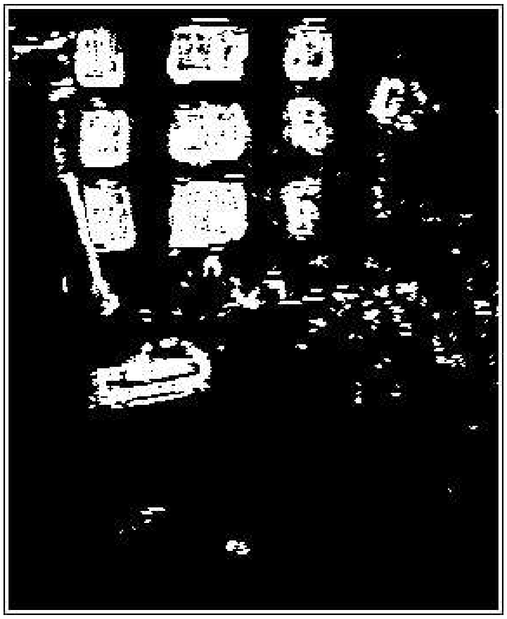

Figure 12: *The resulting Mask, showing where* $d > k$.

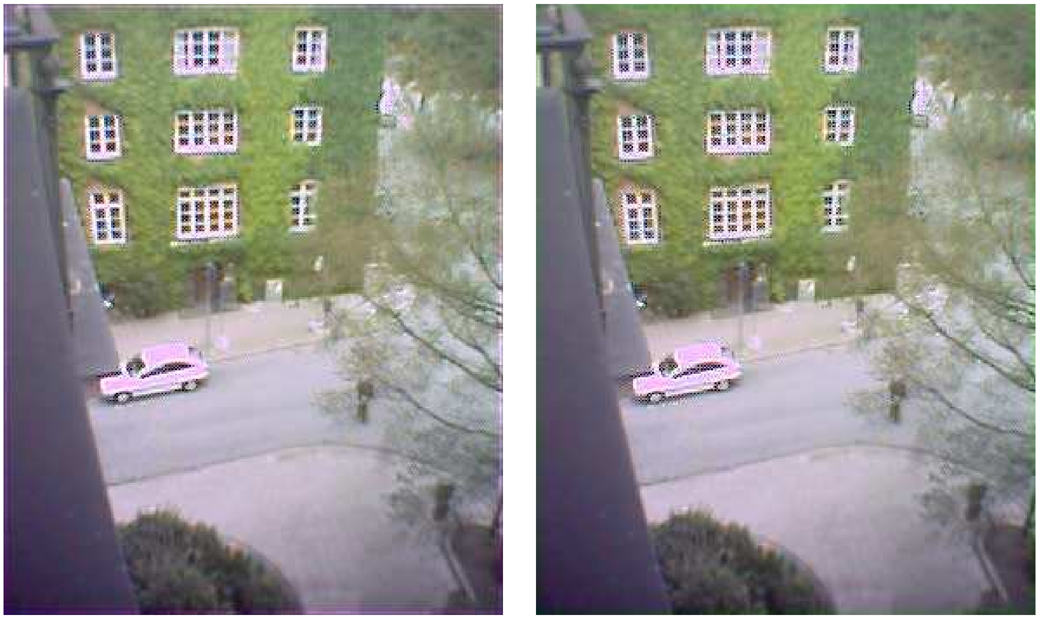

Figure 13: **Left** *Assisted Sharpening with LP filter.* **Right** *Assisted Sharpening with Laplacian filter.*

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