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Document Image Enhancement using Steerable Filters Based Fuzzy Unsharp Masking

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Abstract: Document image analysis is to focus on analyzing the texts, handwritten characters and images in the document. Problem with most of the document image analysis system is the images with low contrast from which it is not possible to produce good results. In this study, a steerable filters based fuzzy unsharp masking algorithmic rule is given to improve the contrast of the document image. In this method, researchers introduce the fuzzy set theory into the unsharp masking scheme. Moreover, the proposed model includes the new methods to replace a high pass filter with manageable filters in unsharp masking scheme. Contrast enhancement is achieved through the output of steerable filters with fuzzy domain. The experimental results clearly show that the proposed methodology not solely improves the image quality, however will get a far better recognition performance.

Key words: Document image enhancement, steerable filters, unsharp masking and fuzzy set theory, Unsharp Masking (UM), contrast

INTRODUCTION

Recognition of document analysis aims to the automatic extraction of information presented on study and initially addressed to human comprehension. The desired output of document analysis and recognition systems is usually in a suitable symbolic representation that can subsequently be processed by computers. The most widely known applications of document analysis and recognition are related to the processing of office documents (such as invoices, bank documents, business letters and checks) and to the automatic mail sorting. With the current availability of inexpensive high-resolution scanning devices, combined with powerful computers, OCR packages can solve simple recognition tasks for most users. Recent research directions are widening the use of the recognition of document techniques, significant examples are the processing of ancient/historical documents in digital libraries, the information extraction from "digital born" documents such as PDF and HTML and the analysis of natural images (acquired with mobile phones and digital cameras) containing textual information.

Several preprocessing methods are proposed and tested by various researchers and also available for document analysis and recognition system such as binarization, image restoration, noise reduction, skew detection, etc. (Marinai *et al*., 2005). In this study, the approach is to enhance the document image using steerable filters. In the literature survey, various methods results are considered and we tend to found (Negishi *et al*., 1999's) several automatic thresholding algorithms in extracting character bodies from the noisy background. In this algorithm, it produces negative result for significantly large pictures and cases wherever the grey levels of the character elements overlap there with of the background. Later, Su *et al*. (1994) morphological approach to extract text strings from regular periodic overlapping text/background images. Chang *et al*. (1995) and Jang and Hong (1999) proposed two binarization algorithms to victimization histogram-based edge detection and thin line modeling. Finally, Don (1995) used the noise attribute options supported a simple noise model to beat the problem that some objects do not type outstanding peaks within the histogram.

An approach for the improvement of faxed documents that's supported assumptions of character regularity is represented by metallic element by Hobby and Ho (1997) during this approach, bitmaps of identical symbols present on high contrast page are clustered and averaged. The averaged symbols are then accustomed enhance the image. This is often a very effective technique for enhancing low resolution scans by combining multiple low-resolution instances of constant symbol to get a better resolution of it. Binarization of historical documents supported adaptive threshold segmentation and varied pre and post-processing steps

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is represented by Gatos *et al.* (2004) during this approach, a background surface is computable and same may be adapted in the image. An iterative approach for segmenting degraded document pictures is represented by Kavallieratou and Stamatatos (2006) there a world thresholding technique is employed to get an initial segmentation. Areas with doubtless incorrect segmentation are detected and a neighborhood thresholding is applied in them. This approach is efficient therein native thresholds are computed slowly at chosen locations. It is also noted that general segmentation techniques provided higher performance on historical documents as compared with document-specific segmentation techniques.

STEERABLE FILTER

Steerable fiters, introduced by Freeman and Adelson (1991) are spatial oriented filters that have received a great interest in image analysis. The basic idea is to generate a rotated filter from a linear combination of a fixed set of basis filters (Simoncelli and Freeman, 1995).

The steerability condition is not restricted to derivative filters and could be expressed for any signal f as:

$$f^{\theta}(x,y)=\sum_{m=1}^{M}k_m(\theta)f^{\theta_m}(x,y) \quad (1)$$

Where:

- $f^{\theta}(x,y)$ = The rotated version of f by an arbitrary angle θ
- $k_m(\theta)$ = The interpolation functions
- $f^{\theta m}(x,y)$ = The basis functions
- M = The number of basic functions required to steer the function f(x, y)

To determine the conditions under which a given function satisfies the steering condition in Eq. 1, let us work in popular coordinates $(r=\sqrt{x^2+y^2}\ \text{and}\ \phi=\arg(x,y))$. The function f could be expressed as Fourier series in polar angle, ϕ:

$$f(r,\phi)=\sum_{n=-N}^{N}a_n(r)e^{jn\phi} \quad (2)$$

where, $j=\sqrt{-1}$ and N is the discrete length of coefficients. It has been demonstrated in the steering condition in Eq. 1 is satisfied for functions expandable in the form of Eq. 2 if and only if the interpolation function $k_m(\theta)$ are solution of:

$$c_n(\theta)=\sum_{m=1}^{M}k_m(\theta)(c_n(\theta))^m \quad (3)$$

Where:

- $c_n(\theta)$ = $e^{jn\theta}$
- n = {0, ..., N}

From Eq. 3, $f^{\theta}(r, \phi)$ is expressed as:

$$f^{\theta}(r,\phi)=\sum_{m=1}^{M}k_m(\theta)g_m(r,\phi) \quad (4)$$

where, $g_m(r, \phi)$ can be any set of functions. It has also been demonstrated that the minimum number M of basic functions required to steer $f(r, \phi)$ is equal to the number of non-zero Fourier coefficients $a_n(r)$.

DESIGNING STEERABLE FILTERS

All functions which are band limited in angular frequency are steerable given enough basis filters. But in practice the most useful functions are those which require a small number of basis filters.

As an example, researchers will design a steerable quadrature pair based on the frequency response of the second derivative of a Gaussian, G_2. A pair of filters is said to be in quadrature if they have the same frequency response but differ in phase by 90 (i.e., are Hilbert transforms of each other (Bracewell, 1978). Such pairs allow for analyzing spectral strength independent of phase and allow for synthesizing filters of a given frequency response with arbitrary phase. They have application in motion, texture, shape and orientation analysis (Bovik *et al.*, 1990). Gaussian derivatives are useful functions for image analysis (Koenderink and van Doorn, 1987) and a steerable quadrature pair of them would be useful for many vision tasks. First, researchers design a steerable basis set for the second derivative of a Gaussian:

$$f(x,y)=G_2^{0^0}=(4x^2-2)e^{-(x^2+y^2)}$$

For interpolation function, $k_j(\theta)$:

$$\begin{pmatrix}1\\ e^{i2\theta}\end{pmatrix}=\begin{pmatrix}1 & 1 & 1\\ e^{i2\theta_1} & e^{i2\theta_2} & e^{i2\theta_3}\end{pmatrix}\begin{pmatrix}k_1(\theta)\\ k_2(\theta)\\ k_3(\theta)\end{pmatrix} \quad (5)$$

Requiring that both the real and imaginary parts of Eq. 5 agree gives a system of three equations. Solving the system using θ_1 = 0°, θ_2 = 60°, θ_3 = 120°, yields:

$$k_j(\theta)=\frac{1}{3}\left[1+2\cos(2(\theta-\theta_j))\right] \quad (6)$$

And researchers have:

$$G_2^{\theta}=k_1(\theta)G_2^{0^\wedge}+k_2(\theta)G_2^{60^\wedge}+k_3(\theta)G_2^{120^\wedge} \quad (7)$$

Researchers can form an approximation to the Hilbert transform of by finding the least squares fit to polynomial times a Gaussian. Researchers found a satisfactory level of approximation (total error power was 1% of total signal power) using a 3rd order, odd parity polynomial which is steerable by four basic functions. Researchers refer to this approximation as H_2. Its steering formula is given with that for several other polynomial orders by Negishi *et al.* (1999).

UNSHARP MASKING TECHNIQUE

The popular Unsharp Masking (UM) technique is a simple and effective method both computationally and conceptually for emphasizing high frequency contents to enhance edges and other details in an image. Its basic idea is that a high-pass filtered and scaled version of an input image is added to itself and the enhanced image y(m, n) is obtained from the input image x(m, n) as:

$$y(m,n) = x(m,n) \pm \lambda z(m,n) \quad (8)$$

Where:

z(m, n) = The output of a linear high pass filter
λ = A positive scaling factor that controls the gray level of the output image

If the center coefficient of the high pass filter operator is positive, the operator sign is plus in Eq. 8. Contrarily, it is subtraction sign. The linear unsharp masking technique is used and works well in many applications. However, the linear high-pass filter is extremely sensitive to noise. In order to reduce the noise sensitivity of the UM technique by Lee and Park (1990) used an order statistic Laplacian operator in the UM. They demonstrated that UMOS filter could amplify much less noise than the conventional UM filter. In addition, different non-linear filters have been proposed to reduce the noise.

Mitra *et al.* (1991) replaced the Laplacian filter with a simple second-order Volterra filter. Mitra *et al.* (1991) introduced a modified version of unsharp masking in which they used a quadratic filter. A Cubic Unsharp Masking (CUM) technique was presented by Ramponi (1998) suppress the effect of noise amplification. Polesel *et al.* (2000) introduced a variation of the basic UM scheme that contain an adaptive filter in the correction path. Still, all previous Unsharp Masking Method suffer from another common drawback they are not effective for low-contrast images.

FUZZY SET THEORY

Fuzzy set theory is a useful mathematical tool for handling ambiguous situations, particularly for the vagueness in human languages and reasoning. It has advanced in a variety of way and applied in many disciplines. The application of the theory can be found for example in artificial intelligence, computer science, control engineering, decision theory, expert systems, logic, management science, operations research, pattern recognition and robotics (Zimmermann, 2001). While many branches of mathematics are classified regarding truth and falsehood, the fuzzy set theory provides a systematic way to study human factors with all its vagueness of perception, subjectivity, attitudes, goals and conceptions.

The fuzzy set theory is an extension of the conventional set theory. By introducing vagueness and linguistics, fuzzy set theory becomes more robust and flexible than the classical dichotomous set theory.

A membership function describes the fuzziness of a fuzzy set. Determining a suitable membership function is a basic task (Lai and Hwang, 1992).

Let the inverse be $X = \{x_1, x_2, ..., x_n\}$. A fuzzy set A on X is set defined by a membership function μ_A representing a mapping, μ_A: $X \rightarrow [0, 1]$ here the value of $\mu_A(x)$ for the fuzzy set A is called membership value or the membership degree of $x \in X$. The membership value represents the degree of x belonging to the fuzzy set A. The membership value of a fuzzy set can be an arbitrary real value between 0 and 1. The closer the value of $\mu_A(x)$ to 1 is the higher the membership degree of the element x in fuzzy set A. If $\mu_A(x) = 1$, the element x completely belongs to the fuzzy set A. If $\mu_A(x) = 0$, the element x does not belong to A at all. According to the shape of a membership function, commonly used membership functions are classified into three classes: downtrend, central limit and uptrend.

Fuzzy membership function: The fuzzy set theory has been successfully applied in image enhancement (Cheng *et al.*, 1999; Hsieh, 1995; Choi and Krishnapuram, 1997; Farbiz *et al.*, 2000; Liu *et al.*, 2004). Image fuzzification is an important and necessary process for fuzzy enhancement. It uses a member function to map all the gray levels of an image into real numbers in [0, 1]. The most commonly used membership function for gray levels is the standard S-function. For example, a standard S-function is used to transform a function image from the intensity domain into the fuzzy domain by Chang *et al.* 1995). Hsieh (1995) had extended the standard S-function by combining S-function and the Z-function. Define a half open fuzzy membership function:

$$\mu_A = \begin{cases} 0 & x<a_1 \\ 0.5 + 0.5\sin\left(\dfrac{\pi(x - a_1 + a_2/2)}{a_2 - a_1}\right) & a_1 \le x \le a_2 \\ 1 - 0.25\left(\dfrac{a_4 - x}{a_4 - a_3}\right)^2 & a_2 \le x \le a_3 \\ 0.5 + 0.25\left(\dfrac{a_4 - x}{a_4 - a_3}\right)^2 & a_3 \le x \le a_4 \end{cases} \quad (9)$$

Where:

x = A variable in the real domain
a_1-a_4 = The parameters which determine the shape of the half open membership function

These parameters can be determined by some statistic values of x.

STEERABLE FILTERS BASED FUZZY UNSHARP MASKING ALGORITHM

Basic idea: While analyzing contents features of document images, it can be found that a document image has its own characters:

- The intensity values of contents (text, lines and images) are lower than background surface
- The gray levels of images present in documents are higher than contents. Furthermore, contents are blurry even some of the items cannot be made out
- Texts, lines are irregular and have various directions and depths

In the document image, contents are very important information and they are just what we need to extract. The UM method uses a high pass filter such as Laplacian filter to obtain the high frequency components and effectively highlight them. But, it is extremely sensitive to noise. Thus, to decrease noise in the method, the high frequency components in original image are obtained by steerable filters at different directions not by a Laplacian filter.

Here, the negative values of the responses of both the filters of Laplacian and steerable are ignored. That the output of the Laplacian filter contains a great amount of noise and part of high frequency components are faded away in the noise. In comparison with the result of the Laplacian filter there is only relatively little noise in the output of steerable filters and the high frequency components are still clear. Thus, using steerable filters to obtain high frequency information is a better choice in the UM Method.

Though the noise can be reduced, the degree of enhancement is far from satisfactory. It is because the degree of enhancement varies with the response of filters. Thus, to a certain extent, researchers can distinguish them and control their degree of enhancement. To increase the degree of enhancement of image, a half open fuzzy membership function is designed for fuzzification of the response of steerable filters. By the fuzzy membership function, the medial response that is the response of steerable filters are mapped into the maximum value and the stronger responses are weakened. In the way, the degree of enhancement of image is increased and the degrees of enhancement are balanced. After the process of fuzzification, the scheme of the unsharp masking is generalized into fuzzy field. The enhancement performed in the fuzzy field can be described as:

$$g(m,n)=\gamma(m,n)-\lambda w(m,n) \quad (10)$$

Where:

g(m, n) = The enhanced image in fuzzy domain
γ(m, n) = The normalized input image
w(m, n) = The fuzzification of the response of steerable filters is the positive scaling factor

The block diagram of steerable filters based fuzzy unsharp masking approach is shown in Fig. 1.

Implementation of the proposed method: Suppose that x(m, n) is the intensity values of the pixel at (m, n) the input image. In order to implement Eq. 10, the value of w(m, n) should be calculated first. The steerable filters based fuzzy unsharp Masking algorithm consists of the following steps:

Step 1: Use steerable filters in Eq. 7 to get the high frequency components of the original image. Researchers chose five synthesized filters $G_2^{\theta_i}$ along θ_i, here $\theta_i = 20°+i\times 40°$, i = 1, 2, ..., 5. The response of every filter is $Z_i = G_2^{\theta_i} \times x$. The final output of steerable filters is $Z(m,n)=\sum_{i=1}^{5} Z_i(m,n)$.

The output of steerable filters Z(m, n) consists of positive and negative values. If Z(m, n) is positive, the pixel at (m, n) in the original image may be is a high frequency component otherwise, the pixel at (m, n) does not belong to high frequency component. In addition, the larger absolute value of Z(m, n) is the higher the probability that the pixel at (m, n) has a high frequency component. Since, researchers are only interested in

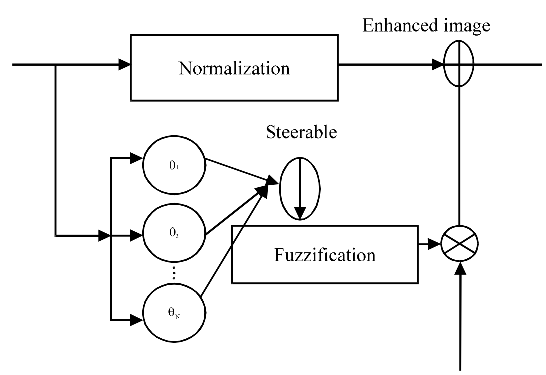


Fig. 1: The block diagram of steerable filters based fuzzy UM

contents of documents and their intensity values are lower than other areas, they modify the result of Z to z to make the images stand out:

$$Z(m, n) = \begin{cases} Z(m,n) & Z(m,n) \\ 0 & \text{otherwise} \end{cases} \tag{11}$$

Step 2 (fuzzification): Using Eq. 9 maps the final output of steerable filters Z(m, n) into fuzzy field andgets W(m, n). The parameters of the membership function directly affect the result of fuzzification. In the algorithm, the parameters depend on the mean and variance of the final output of steerable filters:

$$\begin{cases} a_1 = m - \dfrac{\delta}{2} a_3 = m + \dfrac{5\delta}{2} \\ a_2 = m + \dfrac{3\delta}{2} a_4 = Z_{max} \end{cases} \tag{12}$$

Where:

m and δ = The mean and standard deviation of the final output of steerable filters z, respectively
Z_{max} = The maximum value of z

Step 3 (normalization): Because the output of fuzzification is mapped into [0, 1], researchers normalize the original image by the following function:

$$\gamma = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{13}$$

Where:

x = The gray level of the original document image
x_{min} and x_{max} = The minimum and m aximum gray levels of the document image

If the function γ is considered as a fuzzy membership function, the normalized image can also be seen a fuzzification image.

Step 4: Calculate the values of using Eq. 10 calculates the value and implements the image enhancementin the fuzzy domain.

Step 5 (map into the image filed): The enhanced image in fuzzy field should be mapped to gray levels.

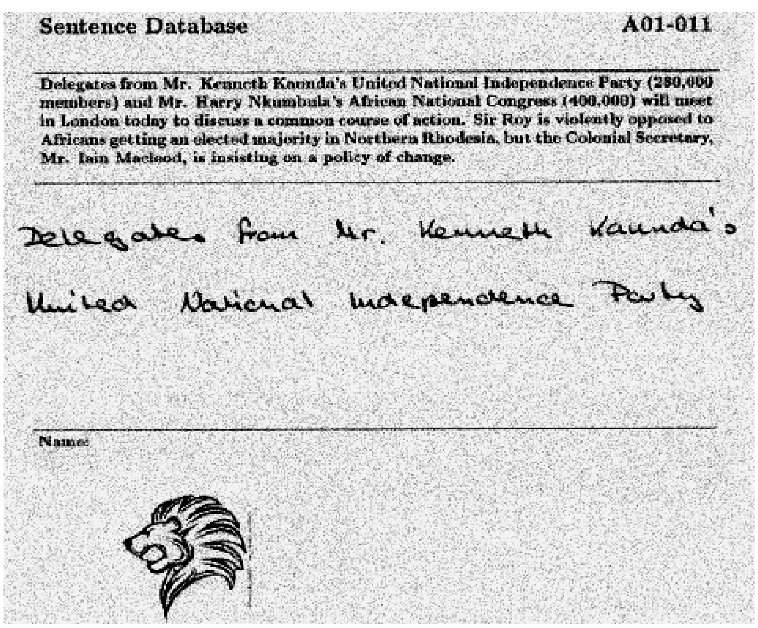
$$y(m,n) = \frac{L(g(m,n) - g_{min})}{g_{max} - g_{min}} \tag{14}$$

Where:

y (m, n) = The enhanced image pixel is gray level
g_{max} and g_{min} = The maximum and minimum values of g(x,y), respectively
L = The maximum gray level of the enhanced image and it means that the dynamic range of the enhanced image is in [0, L]

EXPERIMENTAL RESULTS

For this image enhancement database are collected from the IAM Handwriting Database. This contains forms



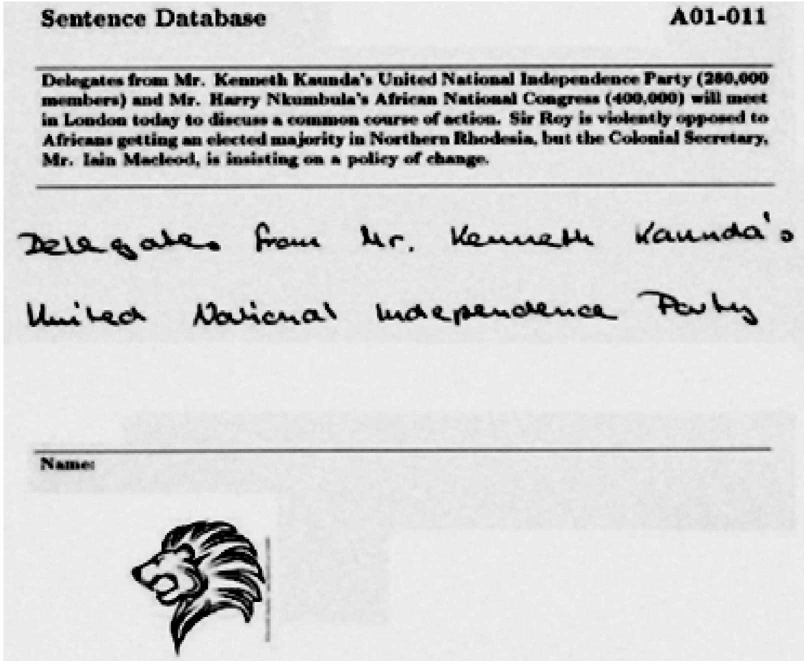
Sentence Database A01-011

Delegates from Mr. Kenneth Kaunda's United National Independence Party (280,000 members) and Mr. Harry Nkumbula's African National Congress (400,000) will meet in London today to discuss a common course of action. Sir Roy is violently opposed to Africans getting an elected majority in Northern Rhodesia, but the Colonial Secretary, Mr. Iain Macleod, is insisting on a policy of change.

Delegates from Mr. Kenneth Kaunda's
United National Independence Party

Name:

Fig. 2: Input image


Sentence Database **A01-011**

Delegates from Mr. Kenneth Kaunda's United National Independence Party (280,000 members) and Mr. Harry Nkumbula's African National Congress (400,000) will meet in London today to discuss a common course of action. Sir Roy is violently opposed to Africans getting an elected majority in Northern Rhodesia, but the Colonial Secretary, Mr. Iain Macleod, is insisting on a policy of change.

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Fig. 3: Enhanced Image using steerable filters

of handwritten and printed English text which can be used to train and test handwritten text recognizers and to perform writer identification and verification experiments. The database contains forms of unconstrained handwritten text which were scanned at a resolution of 300 dpi and saved as PNG images with 256 gray levels.

Figure 2 contains the input image, it is collected from IAM handwritten database. Figure 3 gives or produce the output of enhanced image by using Steerable Filters based Fuzzy Unsharp Masking approach.

CONCLUSION

In this study, researchers have proposed a steerable Filters Based Fuzzy Unsharp Masking Method for document image enhancement by introducing steerable filters and the fuzzy set theory into the unsharp masking scheme. Membership function is designed to highlight the intermediate frequency components of the output of steerable filters so as to enhance the contrast of texts which is significantly propitious for extracting character features. The result images demonstrate that the proposed approach can enhance the contrast of printed and handwritten text in the document image visually in Fig. 2 and 3. In summary, the steerable filters based fuzzy unsharp masking method is simple and effective enhancement approach of the document images for document analysis and recognition.

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