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Morphological Multiscale Stationary Wavelet Transform based Texture Segmentation

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Abstract—Image segmentation is an important step in several computer vision applications. The segmentation of images into homogeneous and meaningful regions is a fundamental technique for image analysis. Textures occupy a vital role in a wide range of computer vision research fields; from microscopic images to images sent down to earth by satellites, from the analysis of multi-spectral scan images to outdoor scenes, all consist of texture. Although several methods have been proposed, less work has been done in developing suitable techniques for segmentation of texture images. After a careful and in-depth survey on wavelet transforms, the present study found that efficient numerical solutions in the signal processing applications can be found using Stationary Wavelet Transform (SWT). SWT is redundant, linear and shift invariant, that's why it gives a better approximation than the DWT. In this paper a novel texture segmentation method based on "SWT and Textural Properties" is proposed. Multi scale SWT with Textural Properties and morphological treatment is used in the present study to detect fine edges from texture images for a fine segmentation.

Index Terms—SWT, texture, segmentation, morphology.

I. INTRODUCTION

One of the first and most important operations in image analysis and computer vision is segmentation. The aim of image segmentation is the domain independent partition of the image into a set of regions, which are visually distinct and uniform with respect to certain properties, such as grey level, texture or color. The problem of segmentation is an important research field and many segmentation methods have been proposed in the literature. Many segmentation methods are based on two basic properties of pixels in relation to their local neighborhood: similarity and discontinuity. Pixel similarity gives rise to region-based methods, whereas pixel discontinuity gives rise to boundary-based methods.

Image segmentation is an important research area in computer vision and hundreds of segmentation algorithms have been proposed in the last 30 years. Boundary based or region-based methods alone often fail to produce accurate segmentation results [1]. In fact, color and texture are fundamental features in defining human visual perception. Hence, complementary information such as brightness, color and texture is taken into consideration [2, 3, 4].

Image segmentation based on texture is to partition an image into homogeneous regions and identify the boundaries which separate regions of different texture. One of the widely used segmentation methods is to apply filters on image and calculate the gradient in texture feature space. Based on the observation that only several distinct filter responses are needed to represent textures, Malik etc. [5, 6] group the filter responses into a small set of prototype response vectors which are called "textons". Thereafter, they developed a texture gradient algorithm using these textons to generate a soft boundary map for image segmentation.

Texture is defined as something consisting of mutually related elements. A texture may be fine, coarse, smooth, or grained depending upon its tone and structure. While tone is based on pixel intensity properties, structure is the spatial relationship between pixels [7]. In case of statistical approach, texture is defined by a set of statistically extracted features represented as vector in multidimensional feature space. The statistical features could be based on first-order, second-order or higher-order statistics of gray level of an image. Texture based methods are best suited for segmentation of medical image, when compared to segmentation of medical image using simple gray level based methods [8-10]. Texture-based medical images include mammograms [11, 12], ultrasonic liver images [13-15], and X-Ray lung images [16, 17]. Edge based image analysis usually implies assumption that the local intensities are uniform in pixel belonging to the same object which is typically not the case in grayscale medical images [18]. Texture-based image analysis is not limited by this assumption. However, it has been proposed that texture can be characterized by relatively small scale structures which are distributed uncertainly relative to the object [19]. It is apparent that these characteristics are typical of variances in medical images.

Texture-based image segmentation is a fundamental task for computer vision. The existing methods for texture based segmentation are model based methods [20-27] and multi-resolution multi-channel methods [28-31].

In order to achieve the objective of designing effective algorithms which could provide the properties pointed out by Haralick [32], the ingredients essential for a textured image segmentation system are:

- Set of texture features having good discriminating power;
- Segmentation algorithm having spatial constraints;
- Estimation of texture features taking the nature of the feature image planes into account. Selection of texture features from a set of existing texture features [33-43] which can provide good discriminating power and are easy to compute to serve the need is very important.

The paper is organized as follows. In section I brief introduction, in section II Texture, section III deals with stationary wavelet transform, section IV deals with Advantages of SWT in image processing applications, in section V proposed methodology, results & discussions are given in section VI and finally conclusions are given in section VII.

II. TEXTURE

Texture plays an important role in many machine vision tasks such as surface inspection, scene classification, and surface orientation and shape determination. For example, surface texture features are used in the inspection of semiconductor wafers, gray-level distribution features of homogeneous textured regions are used in the classification of aerial imagery, and variations in texture patterns due to perspective projection are used to determine three dimensional shapes of objects. Texture is characterized by the spatial distribution of gray levels in a neighborhood. Thus, texture cannot be defined for a point. The resolution at which an image is observed determines the scale at which the texture is perceived. For example, in observing an image of a tiled floor from a large distance we observe the texture formed by the placement of tiles, but the patterns within the tiles are not perceived. When the same scene is observed from a closer distance, so that only a few tiles are within the field of view, we begin to perceive the texture formed by the placement of detailed patterns composing each tile. For our purposes, we can define texture as repeating patterns of local variations in image intensity which are too fine to be distinguished as separate objects at the observed resolution. Thus, a connected set of pixels satisfying a given gray-level property which occurs repeatedly in an image region constitutes a textured region. A simple example is a repeated pattern of dots on a white background. Text printed on white paper such as this page also constitutes texture. Here, each gray-level primitive is formed by the connected set of pixels representing each character. The process of placing the characters on lines and placing lines in turn as elements of the page results in an ordered texture.

Before either segmentation or classification can take place, some homogeneity or similarity criterion must be defined. These criteria are normally specified in terms of a set of feature measures, which each provide a quantitative measure of a certain texture characteristic. These feature measures are alternatively referred to here as texture measures or just simply features. Simple measures of texture may be derived based upon the moments of the gray-level probability distribution function (PDF) of the given image. The k^{th} central moment of the PDF *p(l)* is defined as

$$m_k = \sum_{l=0}^{L-1} (l - \mu_f)^k \, p(l) \qquad (1)$$

Where *l= 0, 1, 2, ……, L-1* are the gray levels in the image f, and μ_f is the mean gray level of the image given by

$$\mu_f = \sum_{l=0}^{L-1} l \, p(l) \qquad (2)$$

The second central moment, which is the variance of the gray levels is given by

$$\sigma_f^2 = m_2 = \sum_{l=0}^{L-1} (l - \mu_f)^2 \, p(l) \qquad (3)$$

The normalized third moment which is known as skewness is given as

$$skewness = \frac{m_3}{m_2^{3/2}} \qquad (4)$$

Skewness indicate the asymmetry of the probability distribution function. Since skewness represent the discrepancies in the pixels of a given image it is considered as the important texture feature for the image segmentation.

III. STATIONARY WAVELET TRANSFORM

The SWT is independently developed by several researchers and under different names, e.g. the un-decimated wavelet transforms, the invariant wavelet transform and the redundant wavelet transform. This algorithm is more famously called by Holdschneider et al., [44] as "algorithme à trous" in French (word trous means holes in English) which refers to inserting zeros in the filters.

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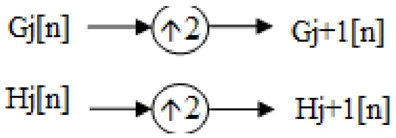
The SWT provides efficient numerical solutions in the signal processing applications. It gives a better approximation than the DWT, since it is redundant, linear and shift invariant. These properties allow SWT to be realized using a recursive algorithm but experiences the drawback of very high redundancy and involved computations. In SWT, the major problem of translation-invariance experienced by DWT is overcome by removing the down samplers and up samplers in the DWT and up sampling the filter coefficients by a factor of $2^{(j-1)}$ in the j^{th} level of the algorithm.

The SWT is an inherently redundant scheme as the output of each level of SWT contains the same number of samples as the input, so for a decomposition of N levels there is a redundancy of N in the wavelet coefficients. Fig.1 details the digital implementation of SWT up to level 3 coefficients. From the diagram we could see that, the filters in each level are up-sampled versions of the previous. Fig. 2 illustrates the SWT decomposition tree and wavelet decomposition tree for 3 levels. In the computation of the SWT of a signal $x(k)$, W_{jk}, and V_{jk} are the detail and the approximation coefficients of the SWT. The filters H_j and G_j are the standard low pass and high pass wavelet filters, respectively. In the first step, the filters H_1 and G_1 are obtained by up sampling the filters using the previous step (i.e. $H_j - 1$ and $G_j - 1$).



(5)

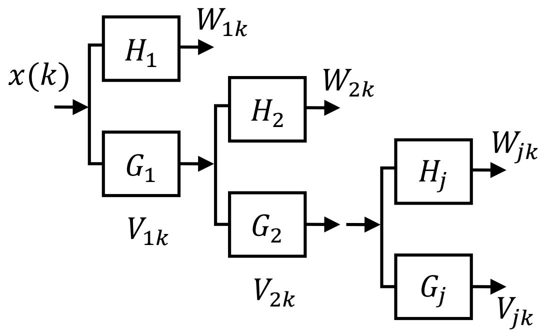


Fig 1. A 3-level SWT digital implementation

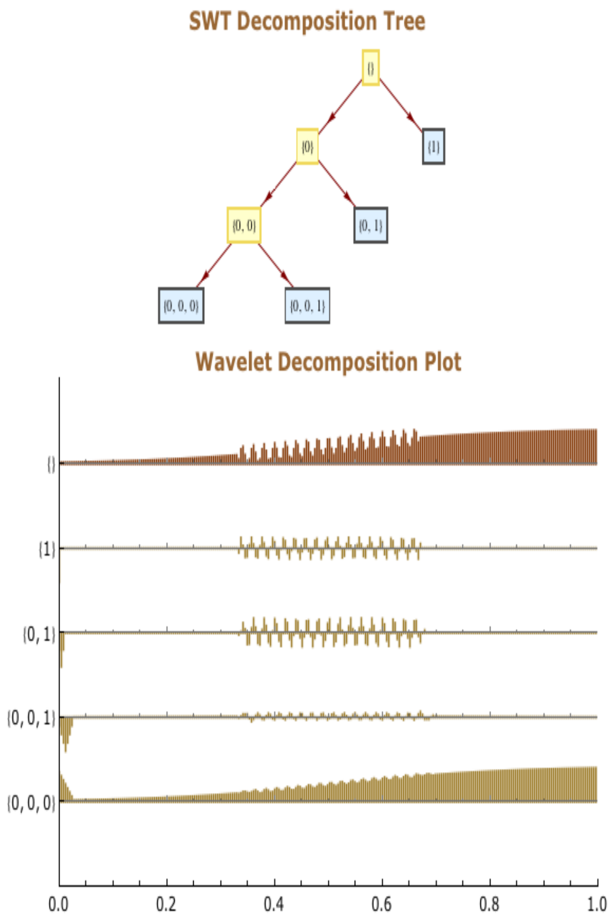


Fig 2. SWT Decomposition tree and wavelet decomposition plot

IV. Advantages of SWT in Image Processing Applications

The major problem of translation shift invariance experienced by DWT is overcome by SWT and it provides efficient numerical solutions in the signal processing applications. Moreover SWT gives a better approximation than the DWT, since it is redundant, linear and shift invariant. These properties allow SWT to be realized using a recursive algorithm but experiences the drawback of very high redundancy and involved computations.

1. SWT has an evident advantage over DWT when the requirement of real time image processing applications are not high, and it can offer more precise flow information.
2. SWT is translation invariant, even if the signal is shifted, the obtained coefficients will not change which happens to be the highly desired property for many image processing applications, edge detection, image fusion and break down point detection.
3. DWT is only suitable for implementing for discrete signals of images whose size is a power of 2 but SWT can be applied to any arbitrary size of images.
4. In few harmonic analyses, energy levels and phase information are required. The advantage of SWT is that it does not require the above information. The time of occurrence and type of disturbances of SWT is calculated directly from the detail coefficients.

V. PROPOSED METHODOLOGY

The proposed method is as given below and it consists of 9 steps. the block diagram for the entire process is given in Fig. 3.

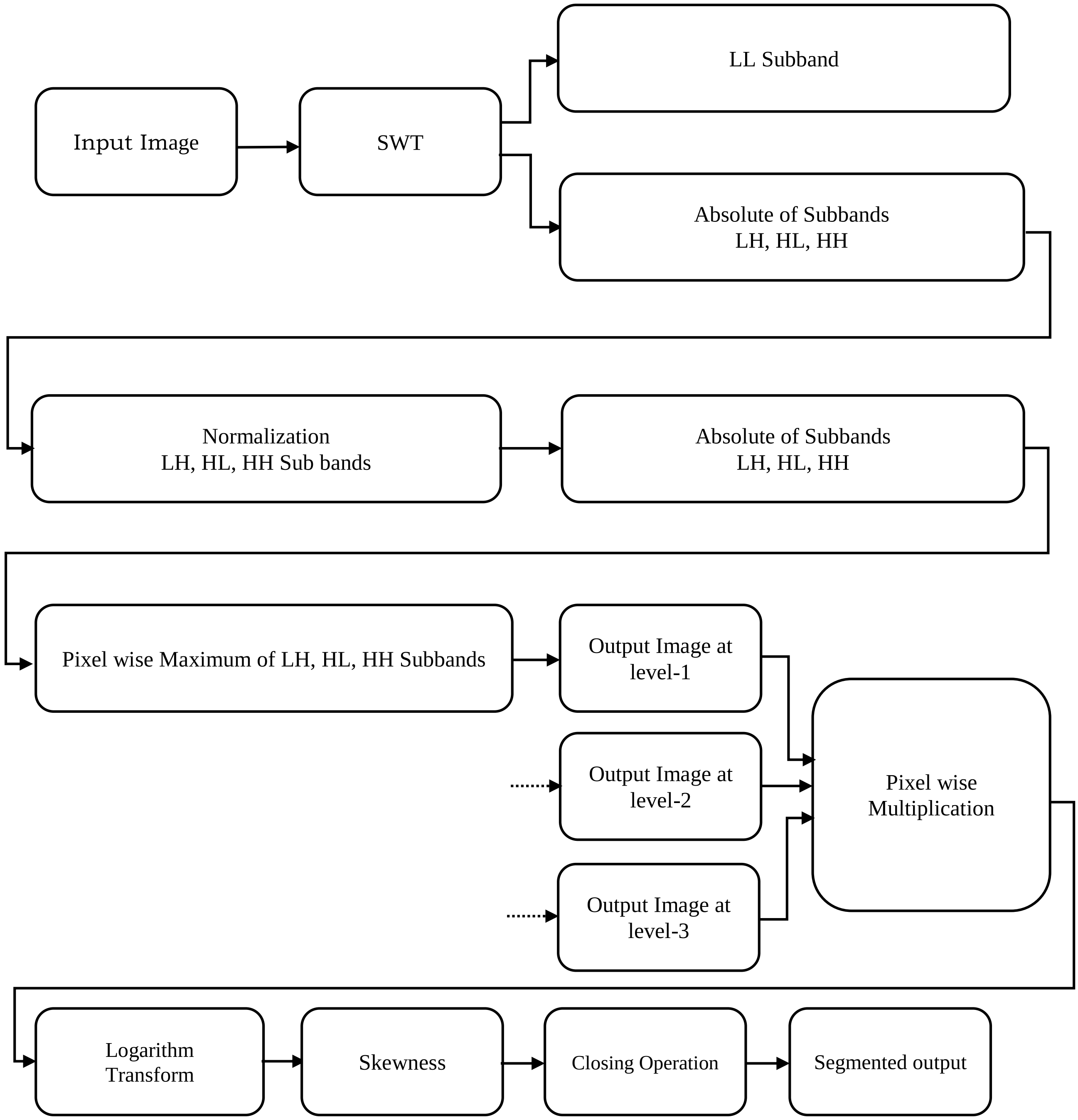


Fig 3. Block diagram of proposed algorithm

Alogorithm Steps

First step: Stationary wavelet transform (SWT) is applied on the input image to obtain the translation invariant property, and also to gain other advantages as specified in section 4.1 In the first level of SWT - LL1, LH1, HL1, HH1 are formed.

Second step: To eliminate complex values absolute value is calculated for horizontal, vertical and diagonal details in step two.

Third step: The output images of step two are normalized to the maximum values of corresponding images.

Fourth step: in step four again absolute values are calculated for the output images of step three and pixel wise maximum is taken for all the images. The obtained image is named as “output image at level-1”.

Fifth step: In the same way on LL1 sub band of step one SWT is applied. By this second level of SWT – LL2, LH2, HL2, HH2 are formed. On this - step two to four are repeated to form “output image at level-2”. The same process is repeated on LL2 and “output image at level-3” is obtained.

Sixth step: pixel wise product is calculated for all the maxims of output image 1, 2 and 3.

Seventh step: logarithmic transform is applied to reduce the noise levels in the output of sixth step.

Eighth step: Skew-ness represents the discrepancies in the pixels of a given image, that’s why it is considered as the important texture feature for the image segmentation. In the present work skewness is calculated in overlapping 5x5 blocks in the eigth step as given in equation 4.

Ninth step: Finally morphological closing operation is applied in order to achieve further noise reduction and to fill small holes.

VI. EXPERIMENT RESULTS AND DISCUSSION

The proposed segmentation scheme based on SWT-TP is tested on bark textures, stone and fabric textures of vistex and brodatz databases.

The output after the pixel wise product of first level and second level of SWT maxima is shown in Fig. 4 (b), 5(b) & 6(b). The output after the product of first level, second and third level of SWT maxima is shown in Fig. 4 (c), 5(c) & 6(c). Fine edges are visible in Fig. 4(c), 5(c) & 6(c) when compared to Fig. 4 (b), 5 (b) & 6(b). The skew-ness image in Fig. 1(d), 2(d) & 3(d) show clearly the discrepancies in the pixels, and thus results a fine segmentation. In order to eliminate tiny holes and for further noise reduction finally morphological closing operation is performed, the output of which is shown in Fig. 4(e), 5(e) & 6(e).

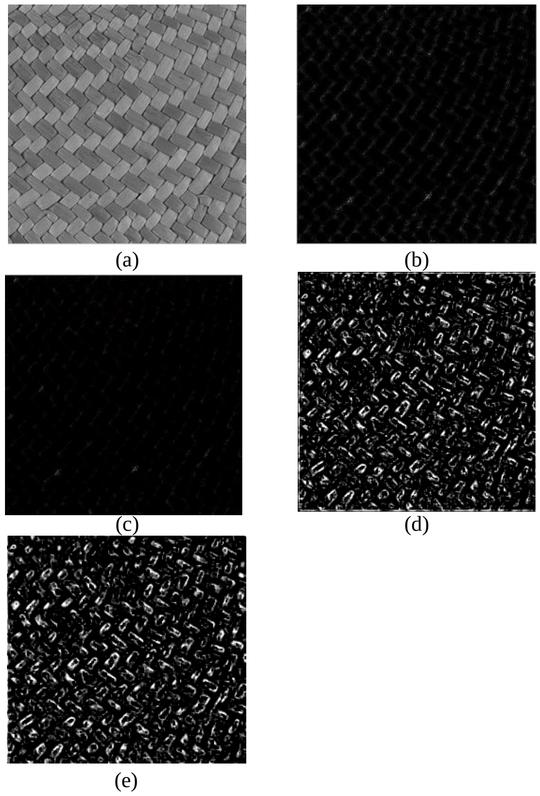


Fig 4. Fabric 0 image segmentation experimental results
(a) Original image (b) Product of two maximas (c) Product of three maximas (d) Skewness (e) Closing

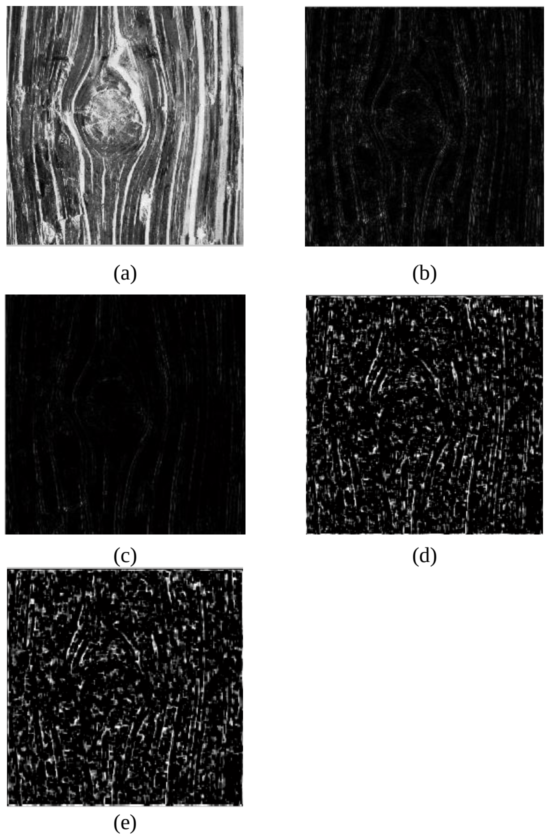


Fig 5. D72 image segmentation experimental results
(a) Original image (b) Product of two maximas (c) Product of three maximas (d) Skewness (e) Closing

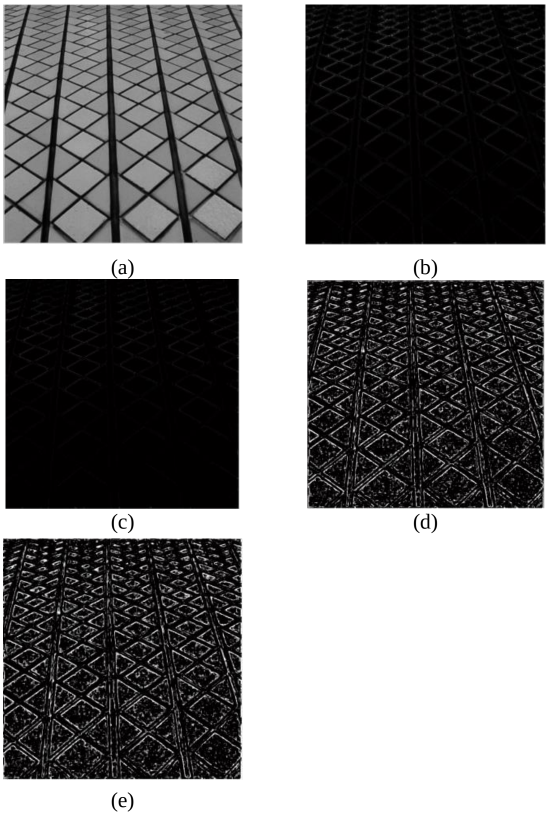


Fig 6. image segmentation experimental results (a) Original image Tile 0 (b) Product of two maximas (c) Product of three maximas (d) Skewness (e) Closing

VII. CONCLUSION

The proposed segmentation algorithm based on SWT and textural properties with morphological treatment obtained the information on the asymmetry of the pixels in the image, thus the algorithm is able to segment the image very effectively. The proposed method is efficient in reducing the noisy effects in the image and is also able to eliminate information loss by the usage of logarithmic transform and SWT respectively. The proposed algorithm does not make use of any edge detection operator for segmentation; therefore the method overcomes the edge detection operator's disadvantage of noise enhancement.

The first consideration of the proposed segmentation scheme based on SWT and textural properties with morphological treatment is its simplicity. The proposed technique is simple, and its computational cost is low. It is an iterative process just requiring the following two operations per iteration: the application of a single iteration of the SWT and the evaluation of the pixel wise maxima. Moreover, no profiteering step is added, and the method is not dependent on the statistics of the input image. Nevertheless, at first sight, the most noticeable effect of the proposed technique is the contrast achieved between edges and background, which is, in fact, the main objective of any edge enhancement algorithm. The adaptation capability of the method it does not require any prior knowledge of the image.

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