High pass filter based on curvelet transform coefficients

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Abstract. High pass filter are widely used in image processing for different purpose, due to that use many researchers provide this field with so many type for those filters with different techniques. This research provide a new approach to design high pass filter by adopting the properties of the curvelet transformation coefficients (fine, coarse and detail). Studying the effect of that coefficient by dropping some of them, then reconstructed the image from the remaining coefficients. The proposed technique applied on different type of images, which hold different amount of frequencies, dropping one level of high frequencies starting from level two up to last level of image decomposition. The result shows that dropping cells at last level will produce fine edges and thicker edges can be got by dropping cells at level 2. The benefits that were appear from the approach that this type of high frequency does not need kernel to reject low pass frequencies but depend upon the image itself. Using different images with different high frequencies support users to get wild field in using edge detection.

Keywords: image processing, signal processing, image transformation

1. Introduction

Image processing filters are mainly used to remove unwanted frequencies. High frequency removal remains low frequencies in the image, in other words, the image is softened, or when low frequencies are removed, high frequencies remain, i.e., enhancement or detection of edges in the image. Mean filter is a simple, easy-to-use and easy-to-implement method for digital images, reducing the amount of intensity difference between one pixel and the next. It is often used to reduce noise in images. The filter medium is usually seen as a twisting filter. Like other convolutions, they are based around the kernel, which represents the shape and size of the site from which samples will be taken when calculating the average [12].

2. Filter Gaussian

Filter Gaussian is a two-dimensional wrap process used to make blurry images and remove details and noise. In this sense, it is similar to the average filter, but uses a different kernel that resembles a bell. It can be represented as in the following equation [11].
\[ G(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{-\frac{x^2}{2\sigma^2}} \]  

(1)

Where: \( \sigma \) is the standard deviation of the distribution. The filter is represented in one dimension as in figure 1.

![Figure 1](image1.png)

**Figure 1.** (1-D) Gaussian distribution with mean 0 and \( \sigma = 1 \)

In the two dimension 2D, the kernel of Gaussian filter shown in figure 2.

![Figure 2](image2.png)

**Figure 2:** The 2D kernel of Gaussian filter.

And in the two dimension 2-D, the equation (2) is:

\[ G(x, y) = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \]  

(2)

Where: \( \sigma \) is the standard deviation of the distribution. The filter is represented in two dimension as in Figure( 3).

![Figure 3](image3.png)

**Figure 3.** (2-D) Gaussian distribution with mean (0,0) and \( \sigma = 1 \)
In the frequency domain, frequency filters process the image in the frequency band after conversion using a transformer such as Fourier transform or wavelet transform where low or high frequencies are obtained by limiting one to the other. If the low frequency is reduced, clear and each conversion produces the appearance strength of the edges based on the strength of that conversion and the methods used in image scanning [2]. The most commonly used application for intermittent waveform conversion consists of repetitive applications of the low pass & high pass respectively in the horizontal and vertical directions of the image. The low-level filter provides smooth approximation of the coefficients, while the high-level filter is used to extract the parameter details at a given resolution [12].

3. Curvelet Transformation

Most digital images are made up of curved lines and edges. The applications of wavelet transformations are becoming more popular in science and engineering, traditional wavelet transformations are good at representing points, ignoring geometric image characteristics and not optimally exploiting the edges. For this reason, the wavelet transformations on which adopted for noise reduction or feature extraction are based have become inefficiently computational with the features of the individual surface. Thus, the unlinked wavelet threshold often leads to oscillations along the edges of the coherent vortices. Consequently, it can lead to an abnormal leakage of energy to neighboring scales producing an industrial energy cascade. Multifocal methods are also deeply associated with biological and computer vision [1]. The researchers in biological vision have mixed between vision and multi-center image processing. To overcome the directional selectivity lost from traditional 2D wavelet transformations (DWT), a multi-spectral geometry analysis (MGA) technique, called the curvelet conversion, has emerged. Curvelet conversions become very efficient in the representation of curves [6][2]. The theoretical concept of curvelet transformations is easy to understand but the challenge is how to achieve separate algorithms for practical applications. To overcome wavelet conversion defects, a new multi-scale transformation was developed by Candés and Donoho in 1999. This conversion is an extension of wavelet transformations, a conversion originally designed to represent edges and others better than wavelet transformations. In wavelet conversions elements have location coefficients and scale, while in curvelet conversion elements have location coefficients, scale and direction [4].

The main drawback of the wavelet transforms lies in the fact that it is unable to represent the discrete edge along the curves. The Curvelet transforms surpass the wavelet transformations in the following cases: first, optimally spacing the objects with edges. The second case is the optimal reconstruction of the image in many problems. The third case is the optimal dispersion of the wave [3]. The Curvelet conversion has a large number of elements in each scale compared to the specified number of directional elements in wavelet conversion and other methods (horizontal, vertical and diagonal). Curvelet is a variation that divides frequency into a kinetic scale in addition to divide them into angles and directions [2].

3.1 Discrete Curvelet Transform [DCT]

Discrete Curvelet Transform is a new representation of the image whose edges are more efficient than the wavelet transform, and the Curvelet transform has useful geometric elements that made it away from the wavelet transform, and the Curvelet transform coefficients of the object can be used as features [5]. The Fourier field is divided into central circles and then divided into wedges. These radial substrates represent the efficiency or structural activity in the frequency domain, thus obtaining the intermittent Curvelet transform. The Curvelet transform shows intrinsic properties including high-contrast properties with sensitivity to the direction [6]. It is possible to calculate the discrete Curvelet transform to different dimensions, measurements and angles. To convert Curvelet, two variables share the digital application: the dimensions of the image and angles at the rough level [7]. The discrete Curvelet transform uses Fourier transform properties in the spectral domain, through which both the image and the Curvelet are given a specific scale and a particular orientation is
converted into the Fourier field. The curve of the Curvelet is performed with the image in the spatial domain and then in the field of Fourier. At the end of the calculation, a set of Curvelet coefficients is obtained by applying the inverse Fourier transform to the spectral output, which contains coefficients in ascending order of the scale and direction [8].

3.2 Fast Discrete Curvelet transform

Fast Discrete Curvelet transform is a fast type transform and this type is much easier, faster and less frequent than the original Curvelet transform, which is based on the transformation of Reglet [9]. It is a multi-dimensional and hierarchical transform of multiple directions and positions in each scale and is applied by Un equispaced Fast Fourier Transform (USFFT). The coefficients are high when the curvelet is closely related to the curve, (A) and (b) are far from alignment with the curve, and the laboratory value is close to zero [10] as shown in Figure 4.

![Figure 4](image)

Figure (4) illustrates the alignment of the curvelet along the curves

The Curvelet coefficients can be illustrated by the discrete curvelet transformations when converting the original image into the frequency domain according to the following retail equation (3):

$$\text{nscales} = \log_2 n - 3, \text{ where } [n,n] = \text{size(image)} \quad \text{ ............ (3)}$$

Get the nscales level number from the equation above. If the size of the image is (512*512), the level of nscales will be 6 after fragmentation. The original image is divided into three sections: coarse, detail and fine. Therefore, low frequency transactions are allocated at the rough level, The deepest level Intermediate frequencies are allocated at the detailed level. High-frequency transactions are allocated at the soft level, which is the external level [3]. The detailed structure of the Curvelet coefficients can be seen in Table (1).

| Levels  | Scales         | Orientations |
|---------|----------------|--------------|
| Coarse  | Cell(1)        | 1            |
| Detail  | Cell(2)        | 32(4x8)      |
|         | Cell(3)        | 32(4x8)      |
|         | Cell(4)        | 64(4x16)     |
|         | Cell(5)        | 64(4x16)     |
| Fine    | Cell(6)        | 1            |

Table (1) show the curvelet coefficients
Curvelet transform was introduced in many different applications in scientific research such as (Image Retrieve, Image enhancement, Improved contrast in images (contrast enhancement), Fabric analysis or texture analysis, Remove noise from images (image denoising), Image compression, Watermarking, Signal processing, Image analysis [4].

4. Proposed Algorithm

In this research an image will Acquire and a preprocess will applied to make it noise free, then truncating some unwanted parts and finally the size should be suitable to be decomposed using curvelet transformation. Curvelet transform decomposition will produce image coefficients depend on the selected scale and levels. Dropping the high frequency coefficients, starting will low level up to the last level, step by step, reconstructing the image from the remaining coefficients at each step. The rebuild images will be given in a table to make the user a chance to select which one is suitable for him.

5. Applied examples and result discussion

Table (2) up to table(6) show clearly the reconstructed images with different scale dropped low frequency (LF) and fine frequencies from scale 2 up to scale 5.

| Table (2) Dropping the low frequency coefficient (LF) |
|-----------------------------------------------------|
| LF | scale-2 | scale -3 |
| ![Image](scale-2.png) | ![Image](scale-3.png) |
| ![Image](scale-4.png) | ![Image](scale-5.png) |
| ![Image](scale-6.png) | ![Image](scale-7.png) |

| Table (3) Dropping the low frequency coefficient in addition to scale 2 of fine frequencies |
|-----------------------------------------------------------------------------------------|
| LF | scale -2 | scale -3 |
| ![Image](scale-2.png) | ![Image](scale-3.png) |
| ![Image](scale-4.png) | ![Image](scale-5.png) |
| ![Image](scale-6.png) | ![Image](scale-7.png) |
Selecting Lena image, which has high level of smoothing, produce edges of different levels to show whom much the proposed techniques can be adopted in field of edge detection. The reconstructed image in each tables, will hold different amount of high frequencies, which can show the effect of each band of the high frequency on the image.

6. Conclusion
The experimental application of the proposed algorithm shows that this technique has a special characteristic that it does not need any kernel equation as the other high filters need transformation equations, in addition to that this technique depended on the image contents. In addition, this technique gives an apportioned to the users to select the proper output (one out of six). The output images have edges seems to be useful to be adopted for image segmentation if the selected output image (which is binary image) multiplied by the original one to add boundary.

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