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A Decimation Free Directional Filter Banks for Medical Image Enhancement

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Abstract: Uniformly illuminated image greatly reduces the stress on the rest of the image processing tasks such as segmentation, object detection and classification etc. However, an image processing system designer has no control of the environment. The images obtained are usually poorly illuminated. The conventional approach to deal with non-uniform illumination of an image is to employ an appropriately scaled homomorphic filter. Direct application of homomorphic filter on an image controls non-uniform illumination but at the cost of blurring weak edges present in an image. In this paper we proposed decomposing an image in its directional components. This restricts non-uniform illumination in one of the directional components and then directional homomorphic filtering can be applied selectively to directional components. Towards the end, modified directional components are added to provide an enhanced and correctly illuminated image.

Key words: Directional filter bank (DFB), linear phase FIR filter, angiogram, homomorphic filtering

INTRODUCTION

Directional filters have been used for processing in the areas of robotics and computer vision, seismology, linear feature detection and enhancement and to some extent in wavelet image compression[1,2].

The directional filter bank, originally introduced as a tree structured filter bank[3]. In spite of their successful directional frequency decomposition, the main draw back of directional filter bank has been that the decomposed sub-band outputs are visually distorted. A new structure for directional filter bank has been proposed that provides visualizable outputs[4].

Homomorphic filtering has been successfully applied in correcting slowly varying illumination of a natural image. However, for the images rich in edges and with abruptly changing illumination pattern homomorphic filtering fails to produce desired results. One example of such images is angiogram image shown in Fig. 1.

Fig. 1: Angiogram image

We propose a hybrid approach combining directional filter bank with homomorphic filtering to enhance images rich in edges and having abruptly changing illumination. The pictorial representation of this hybrid system is shown in Fig. 2.

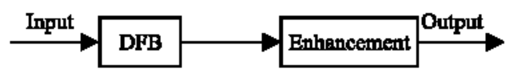

Fig. 2: Block diagram of proposed system

Decimation-free directional filter bank: We will described the design of a decimation-free directional filter bank used as a front end in our enhancement approach. The proposed filter bank provides eight directional components as outputs for a given image. The geometry of these eight components in frequency domain is shown in Fig. 3.

The Proposed filter bank has the following features.

1. No Decimation.
2. Linear Phase FIR Filtering.
3. Visualizable sub bands at any stage without further processing.
4. Tree structured filter banks. A 2^n band Directional filter bank can be implemented by cascading basic components.
5. Single filter prototype is used for the whole DFB.
6. As no decimation property is there, just adding the sub bands at any stage will result in reconstruction.

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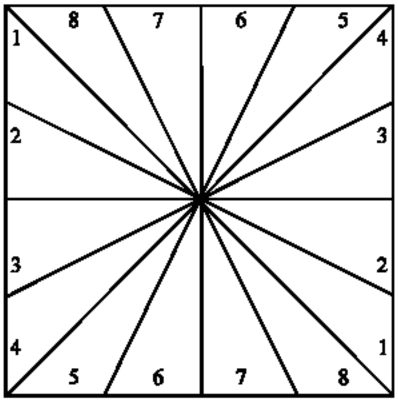


Fig. 3: 8-band frequency partition map

The design of directional filter bank starts by constructing prototype filter that will be used as a basic structure. The basic prototype filter is referred to as hour glass filter shown in Fig. 4.

Fig. 4: $H_0(\omega)$

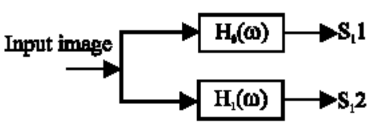


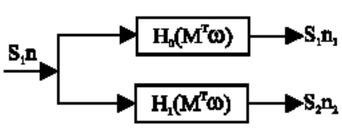
Fig. 5: First stage of DFB

The schematic diagram for the first stage of directional filter bank is shown in Fig. 5.

Here $H_0(\omega)$ is formed by modulating the diamond filter[3,5] any of the horizontal or vertical direction by π. $H_0(\omega)$ is basically an Hour-Glass shaped filter. $H_1(\omega)$ can be formed by modulating $H_0(\omega)$ in both direction by π. Mathematically it can be expressed as

$$H_1(e^{j\omega}) = H_0(e^{j(\omega+\pi)})$$

The output from the first stage is cascaded to the 2nd stage which has the following strucuture



To construct $H_0(M^T\omega)$ from $H_0(\omega)$, we up-sampled $H_0(\omega)$, (derived[6-8]) by M, which has been shown in the following Fig. 6.

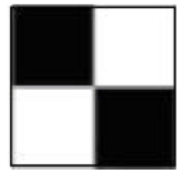


Fig. 6: $H_0(M^T\omega)$

where

$$M = \begin{pmatrix} -1 & 1 \\ 1 & 1 \end{pmatrix}$$

The resulting images from 2nd stage are cascaded into the third block of DFB whose structure is same as 2nd stage except matrix 'M'. Basically M is replaced by four unimodular matrices given below. The purpose of these matrices is to map an image onto a parallelogram shaped region proposed in Chen and Vaidyanathan[5].

$$N_1 = \begin{pmatrix} 1 & 1 \\ 0 & 1 \end{pmatrix} \qquad N_2 = \begin{pmatrix} 1 & -1 \\ 0 & 1 \end{pmatrix}$$
$$N_3 = \begin{pmatrix} 1 & 0 \\ 1 & 1 \end{pmatrix} \qquad N_4 = \begin{pmatrix} 1 & 0 \\ -1 & 1 \end{pmatrix}$$

The structure of four filter produced from $H_0(\omega)$ at third stage have been shown below in Fig. 7.

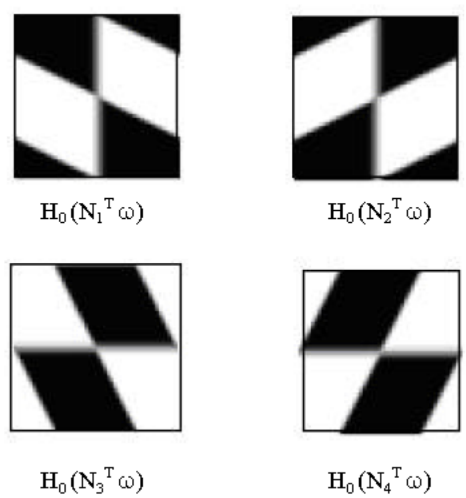
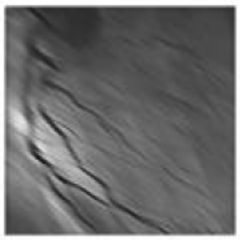


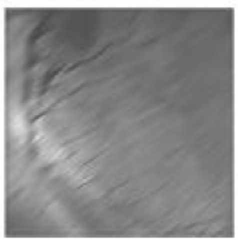
Fig. 7: Four filters of third stage from $H_0(\omega)$

The outputs from the third stage are eight sub band images of same size as input image. Each of the sub band images correspond to different direction as shown in Fig. 3.

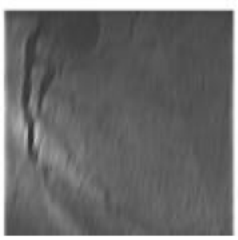
For illustration purposes the angiogram shown in Fig. 1, has been decomposed with proposed filter bank and three out of eight directional components are displayed in Fig. 8. Fig. 8a shows only those vessels of angiogram images going in positive 45 degrees while the Fig. 8c shows vessels with negative 45 degrees and Fig. 8b shows vessels vertically going downward.



(a)



(b)



(c)

Fig. 8: Directional component images

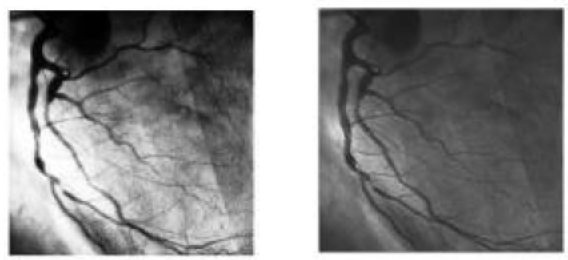
Directional homomorphic filtering: After decomposing an image in eight directional components we need to apply homomorphic filters. Since, the components contains only single direction features, the homomorphic filter needs also to be directional in nature. An isotropic homomorphic filter can be made directly by applying appropriate axis transformation. Directional homomorphic filters are then applied to directional components of an image, as opposed to one isotropic homomorphic filter used with the image in conventional method.

This will add to the flexibility of treating each directional component separately from the rest of image and the treatment will vary from one component image to another providing greater control towards enhancement of an image.

The directional homomorphic filters are shown in Fig. 9. By looking at these filters we see that low as well as high pass characteristics are present in the filter but in a specific direction.

Fig. 9: Directional homomorphic filters

Simulation results: Our proposed scheme has been applied on angiogram images and results are displayed in Fig. 10.



(a) (b)

Fig. 10 a: Histogram equalized image
b: Proposed DFB enhanced image

The original angiogram image suffers from low contrast due to non-uniform illumination and various poorly displayed vessels. From the image processing point of view one can apply histogram equalization for contrast enhancement. However, we found that histogram equalization enhances the non-uniform illumination pattern present in the image and thus distort the original image in the sense of removing small vessels.

In contrast to this we applied our hybrid scheme and get enhanced result. Our result displays vessels which have the embossing effect and illumination has been uniformly distributed across the image.

Tree structured directional filter bank has been proposed based on a single and efficient prototype filter. Further more, directional homomorphic filters are developed and used in enhancement of angiogram images. We attribute the improved enhancement to the directional decomposition of the image that provides flexibility in controlling non-uniform illumination.

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