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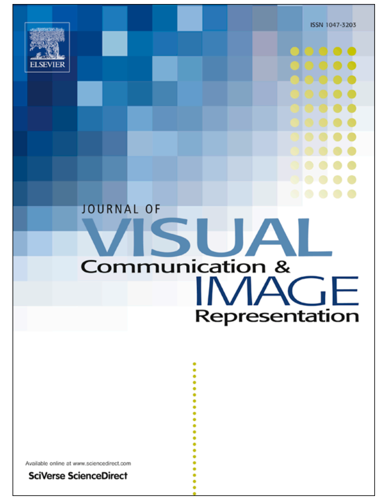

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DESIGN OF LINEAR-PHASE NONSUBSAMPLED NONUNIFORM DIRECTIONAL FILTER BANK WITH ARBITRARY DIRECTIONAL PARTITIONING

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ABSTRACT

In this paper, we propose a design method for linear phase (LP) nonsubsampled nonuniform directional filter bank (NUDFB) with arbitrary number of subbands and arbitrary directional partitioning. The proposed NUDFB is simply designed by windowing the analytical expressions of wedge-shaped filters in space domain. The direction and angular bandwidth of the filters are determined by only two angular parameters. It can extract directional information according to the directional distribution of images, making it efficient in the directional representation of images. In addition, the perfect reconstruction conditions are derived. Numerical experiments on image directional information extraction and image denoising are given to illustrate the performance of our NUDFB. The results show that our NUDFB outperforms various directional decomposition methods while possesses LP property and more flexibility.

Index Terms— Nonsubsampled nonuniform directional filter banks, arbitrary directional partitioning, multiresolution decomposition

1. INTRODUCTION

Directional information is important in many image processing applications [1]. Therefore, as a powerful tool to extract directional information of images, directional filter banks (DFBs) have attracted much attention [1–9]. Most methods on designing DFBs are implemented via a tree-structured construction, resulting in uniform subbands and fixed directional partitioning scheme. Due to the rich textures contained in images, the DFBs with arbitrary number of subbands and flexible direction selectivity are still highly expected.

It should be noticed that the aforementioned DFBs are mostly maximally decimated. However, the decimation is not always necessarily required in many applications, such as image denoising, enhancement, restoration, and texture detection [10]. And thus some redundant directional transforms, such as curvelet [11], nonsubsampled contourlet [10] and shearlet [12], have employed nonsubsampled directional filter banks (NSDFBs). Concretely, the shearlet transform can extract directional information by applying bandpass filters in the frequency domain on pseudo-polar grid [13]. Inspired by this, the NSDFBs were proposed to decompose images in frequency domain based on discrete pseudo-polar transform (PPFT) [14] and 1-D nonsubsampled filter banks (NSFBs), which are capable to design uniform [15] and nonuniform [16] NSDFBs with arbitrary number of subbands. After separating in frequency domain on pseudo-polar grid by 1-D NSFBs, each directional band is then inverted back to space domain. However, in some applications such as denoising, local variants of filters are desired in order to reduce the Gibbs type ringing present when filters of large support sizes are used [13]. Moreover, the individual filters applied in pseudo-polar frequency domain always perform a phase shift on the corresponding directional bands along the angular axis instead of the Cartesian axis, introducing phase distortions to decomposed subbands and impacting on the thresholding decision. This suggests a better performance in using the space domain method for denoising.

In this paper, we propose a novel nonsubsampled NUDFB with not only nonuniform wedge-shaped subbands but also arbitrary directional partitioning. Our approach is implemented in space domain and possesses LP property, making it efficient to process images. The explicit expressions of wedge-shaped filters are derived and small support size filters are obtained by windowing in space domain. Theoretical deduction proves that no matter what window function we choose or what the window size is, perfect reconstruction (PR) is always achieved. Tow experiments show that our NUDFB can offer more flexible directional information extraction strategy and superior image denoising performance to various directional decomposition

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