

PAPER

A New Class of Multichannel Image Processing Filters: Vector Median-Rational Hybrid Filters

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SUMMARY A new class of nonlinear filters called Vector Median Rational Hybrid Filters (VMRHF) for multispectral image processing is introduced and applied to color image filtering problems. These filters are based on Rational Functions (RF). The VMRHF filter is a two-stage filter, which exploits the features of the vector median filter and those of the rational operator. The filter output is a result of vector rational function operating on the output of three sub-functions. Two vector median (VMF) sub-filters and one center weighted vector median filter (CWVMF) are proposed to be used here due to their desirable properties, such as, edge and details preservation and accurate chromaticity estimation. Experimental results show that the new VMRHF outperforms a number of widely known nonlinear filters for multispectral image processing such as the Vector Median filter (VMF) and Distance Directional Filters (DDF) with respect to all criteria used.

Key words: rational functions, vector rational filters, vector median filters, vector median-rational hybrid filters

1. Introduction

Multichannel image processing is investigated in this paper using a vector approach [10]. This has been proved to be more appropriate for vector-valued signals compared to traditional component-wise approaches. The suitability of such a technique is often credited to the inherent correlation that exists between the image channels [10]. In the vector approach, each image element is considered as an m -dimensional vector (m is the number of image channels). Color image pixels are often represented by three-component vectors, $m = 3$, whose characteristics, i.e., magnitude and direction are examined. The vector's direction signifies its chromaticity; while, its magnitude is a measure of its brightness. A number of vector processing filters have been proposed in the literature for the purpose of color image processing [2], [11]. One class of filters considers the distance in the vector space between the image vectors; typical representative of this class is the "vector median filter" (VMF) [1]. A second class of filters, called "vector directional filters" (VDF) [16], operates by considering the vectors' direction. VMFs are derived as maximum likelihood estimators for an exponential distribution [1]; while, VDFs are spherical estimators, when the underlying distribution is a spheri-

cal one [16]. A third class of filters uses rational functions in its input/output relation, and hence the name "vector rational filters" (VRF) [6]. There are several advantage to the use of this function. Similarly to a polynomial function, a rational function is a universal approximator (it can approximate any continuous function arbitrarily well); however, it can achieve a desired level of accuracy with a lower complexity, and possesses better extrapolation capabilities. Moreover, it has been demonstrated that a linear adaptive algorithm can be devised for determining the parameters of this structure [9].

In this paper, a novel nonlinear vector filter class is proposed: the class of vector median-rational hybrid filters (VMRHF). This is an extension of the nonlinear rational type hybrid filters called median-rational hybrid filter's (MRHF) recently introduced for 1-D and 2-D signal processing [7], [8], based on rational filters [9], [15]. The VMRHF is formed by three sub-filters (two vector median filters and one center weighted vector median filter) and one vector rational operation. VMRHF are very useful in color (and generally multichannel) image processing, since they inherit the properties of their ancestors. They constitute very accurate estimators in long- and short-tailed noise distributions and, at the same time, preserve the chromaticity of the color image. Moreover, they act in small window and require few number of operations, resulting in simple and fast filter structures.

This paper is organized as follows. Section 2 briefly reviews rational functions and vector rational function filters. In Sect. 3, we define the vector median-rational hybrid filter (VMRHF) and point out some of its important properties. The proposed filter structures are presented in Sect. 4. Section 5 includes simulation results and discussion of the improvement achieved by the new VMRHF. In order to incorporate perceptual criteria in the comparison, the error is measured in the the uniform $L^*a^*b^*$ color space, where equal color differences result in equal distances [14]. Section 6 concludes the paper.

2. Rational Function and Vector Rational Function Filters

A rational function is the ratio of two polynomials. To be used as a filter, it can be expressed as:

[†]Manuscript received November 19, 1998.

Manuscript revised June 30, 1999.

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