

# Comparison study of nonlinear filters in image processing applications

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**Abstract.** Nonlinear filters are used in many applications, including speech and image processing, owing to their ability to suppress noise and preserve signal features such as edges. This study presents a performance evaluation of nonlinear filters derived from the robust point estimation theory. The first part of the work is a classification of various approaches to nonlinear filtering into three types of estimators according to the process of the filter. The second part is a computer implementation and evaluation of all of the filters discussed. Finally, a summary of experimental results is presented.

*Subject terms:* image processing; nonlinear filters; detail-preserving filters; robust point estimators; location parameters.

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## 1. INTRODUCTION

Linear and nonlinear filters are used extensively in signal processing applications to remove noise. It has been shown by many experimental studies that although linear filters possess good noise attenuation capabilities, they smear the edges and attenuate thin lines present in the original signal because of the linear averaging operation that they perform. On the other hand, nonlinear filtering is a well-known noise filtering and edge-preserving method. This class of filters has become popular in digital speech and image processing and has achieved some interesting results in many image processing applications.

Tukey<sup>1</sup> first used the median filter for nonlinear smoothing of data. This filter became attractive because it is easy to implement and can reduce quite effectively the impulsive noise component. Median filtering is a local filtering technique in which each pixel is replaced by a value obtained through a "median" operation performed within a window. The term window refers to a neighborhood of the pixel, centered at that pixel. As an example, Fig. 1 shows the performance of a median filter with a square window of size  $3 \times 3$  for the removal of impulse noise.

Median filters have been applied to several areas of digital signal processing, including image processing and speech processing.<sup>2,3</sup> One main feature of the median filter is that it eliminates the impulse that has a duration of less than half the window size. Since the degree of smoothing of the median filter can be influenced only by the processing window size, it does not generally allow the user sufficient control over its characteristics. Furthermore, it does not have the averaging operation that is particularly appropriate in reducing additive Gaussian noise components. Several techniques have been introduced in an effort to overcome these limitations. One is to combine linear and nonlinear operations. The combination allows a degree of control over the relative influence of these operations. Bednar and Watt<sup>4</sup> proposed such a new algorithm for applying median filtering. It is called the  $\alpha$ -trimmed mean ( $\alpha$ -TM) filter. Suppose that  $X$  is a finite set of  $N$  numbers. The  $\alpha$ -TM of  $X$  is obtained by sorting  $X$  into rank order, removing

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