Fuzzy Filters for Noise Reduction: the Case of Gaussian Noise

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Abstract—Noise reduction is a well-known problem in image processing. The reduction of noise in an image sometimes is as a goal itself, and sometimes is considered as a pre-processing step. Besides the classical filters for noise reduction, quite a lot of fuzzy inspired filters have been proposed during the past years. However, it is very difficult to judge the quality of this wide variety of filters. For which noise types are they designed? How do they perform for those noise types? How do they perform compared to each other? Can we select filters that clearly outperform the others? Is there a difference between numerical and visual results? In this paper, we answer these questions for images that are corrupted with gaussian noise.

Index Terms—Image processing, noise reduction, fuzzy filters, gaussian noise.

I. INTRODUCTION

Images are very important information carriers. This information can be of a diverse nature, ranging from commercial to industrial or scientific. The wide availability of images and the easy way to generate them has also increased the interest in image processing in general. In this paper and in [17] we focus on the issue of noise reduction.

In practice, images easily get corrupted with noise, e.g. due to the circumstances of recording (e.g. dust on a lense, electronic noise in cameras and sensors, ...), transmission (e.g. electromagnetic interaction with satellite images, transmission over a channel, ...), storage, copying, scanning, etc. Therefore, it is not surprising that different algorithms to deal with that noise have been developed. During the past years, also a lot of fuzzy logic based filters have been introduced. It is now our goal to make a comparative study of the classical and fuzzy logic based noise reduction filters. We have performed such a study in [13], [14], [15] for a limited number of filters. Here, we compare 38 different algorithms on their performance w.r.t. gaussian noise in grayscale images.

The interested reader should know that we have recently made a similar comparative study w.r.t. impulse noise in [17].

II. IMAGES AND NOISE

Grayscale images are mathematically modelled as finite grids of numbers, where the numbers represent gray values. The number of gray values usually is 256 (i.e. the values range between 0 and 255), the number of rows and columns determines the size of the image (e.g. size of $256 \times 256$, $512 \times 512$, ...). A point in the grid is called a pixel (picture element).

As stated before, images easily get corrupted with noise. In this paper we focus on gaussian noise. Gaussian noise is an additive noise type, i.e. a corrupted image can be regarded as the sum of the original image and a noise image (which has the same dimensions as the original image) and of which the pixel values have a gaussian distribution with mean value $\mu$ (usually zero) and variance $\sigma^2$. The higher the value of $\sigma$, the higher the noise level.

It is important to note that images and fuzzy sets can be modelled in the same way. A fuzzy set in a universe $X$ is modelled as a mapping from $X$ into the unit interval $[0,1]$, i.e. every element $x$ of $X$ is associated with a value in $[0,1]$ which is a membership degree of $x$ in the considered fuzzy set. Images are modelled in a similar way: the universe is a finite grid $G$, and the image can be modelled as a mapping from $G$ into the set $\{0,1,\ldots,255\}$. This set can be rescaled by dividing every element by 255, leading to the observation that also an image can be modelled as a mapping from $G$ to $[0,1]$. Consequently, techniques from fuzzy set theory can be used in image processing, and the past years have shown that they can have an added value.

III. FILTERS FOR NOISE REDUCTION

The variety of filters can be divided in three subclasses: (1) classical filters; (2) fuzzy-classical filters, i.e. fuzzy logic based filters that are a modification or extension of classical filters; (3) fuzzy filters, i.e. filters that are purely based on fuzzy logic and have no straightforward connection with classical filters. We will present the studied filters based on this classification. It concerns 38 different algorithms; the fuzzy-classical and fuzzy filters are accompanied by a reference for those readers who want more background information on them.

A. Classical Filters

- **MF**: Median Filter
- **WF**: Weighted Filter
- **AWF**: Adaptive Weighted Filter
- **WIENER**: Wiener Filter
- **GAUS**: Gaussian Filter
- **EMF**: Extended Median Filter
really good images. Consequently, the quest for gaussian noise reduction algorithms is not over yet.

REFERENCES