A Fuzzy Filter for the Removal of Random Impulse Noise in Colour Video

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Abstract—In this paper a new filtering framework for colour image sequences corrupted by random impulse noise is introduced. The proposed method consists of three successive filtering steps in order to find a good trade-off between detail preservation and noise removal. One hard filtering step, that should remove all the noise at once, would namely also remove a considerable amount of details. In the different noise detection steps, we make use of human knowledge represented in the form of fuzzy if-then rules. The detection of noisy pixel components is based on spatial and temporal information as well as on information from the other colour bands. Additionally, only detected pixel components are filtered by blockmatching based on an adaptation of the mean absolute difference (MAD) to noise. The other components remain unchanged. From the experimental results, it can be concluded that the proposed filter outperforms other state-of-the-art impulse noise filters.

I. INTRODUCTION

The performance of many image/video processing algorithms is highly reduced due to the presence of noise. Therefore, a filtering premodule often becomes necessary.

Most video filtering techniques that can be found in literature, are designed for the removal of additive Gaussian noise. Some examples are [1], [2], [3], [4], [5]. Much less filters for videos corrupted with impulse noise exist [6], [7], [8], [9], [10], [11], [12]. However, several techniques for 2D images have been developed, of which the median based rank-order filters ([13], [14], [15], [16], [17], [18], [19], [20], [21], [22], [23]) are the most popular. Further, also some fuzzy alternatives start to appear [24], [25], [26], [27], [28], [29], [30], [31], [32], [33]. One could argue that those 2D filters could also be used to filter video. The frames of the sequence can namely be considered as separate 2D images on which the 2D filters can be performed. Such approach however neglects the temporal correlation between the frames in a video. As a consequence, numerous temporal inconsistencies will arise. So it is preferred to use 3D filtering windows as in [6], [7], [8], [9], [10], [11], [12].

Additionally, in a colour video, there is not only correspondence between successive frames, but also between the different colour bands of each frame. So also a distinction between filters intended for greyscale images and for colour images needs to be made. The use of greyscale techniques on each colour band of the frame separately now neglect the correlation between the different colour bands and will introduce colour artefacts. A solution for this problem, would be to consider each colour pixel as one entity, one vector. Such vector-based techniques usually order the pixels in a predefined 3D filtering window by increasing accumulated distance (Euclidean distance, angular distance,...) or similarity to the other vectors in the window [11], [12], [16], [17], [18], [19], [20], [21], [22], [23], [33]. The vector that has the lowest rank, is then used as output for the filter. In order to avoid the needless filtering of noisefree pixels, the distances are weighted to give more importance to the original pixel and its close neighbours [7], [15], [21] or a switch is used such that only pixels that differ largely from the pixels that have the lowest rank in the ordering, are filtered [11], [12], [16], [17], [22], [33].

However, it is known that vector-based techniques will perform less good for higher noise levels. Indeed, if e.g. all vectors in the filtering window have one noisy component (and most of the components are thus actually noisefree), then no noisefree vector exists to be used as output. So, filtering each of the colour bands separately (such that there are still noisefree components that can be used for the output), while using information from the other colour bands (to take into account the correlation between the different colour bands), would be a better alternative. In literature, only very few such alternatives (e.g. [25], [26], [32]) can be found.

In this paper, we present such a non-vector-based filter for colour image sequences corrupted by random impulse noise. Each of the colourbands is filtered separately in three successive steps. Only pixel components that have been detected as noise in the current step are filtered, the others remain unchanged. The detection of the noisy component is based on fuzzy rules in which information from spatio-temporal neighbours and from the other colour bands is used. The detected pixels in each step are then filtered based on block matching, a technique that is often used in video filters for gaussian noise but that has not yet really found its way to impulse noise filters. The mean absolute difference (MAD) between the block of pixels, that is usually used for this block matching is not reliable anymore due the presence of the impulses. Therefore, we have made it adaptive to the noise.

From the experimental results, it can be seen that the proposed filtering framework outperforms other state-of-the-art impulse noise filter both in terms of the peak-signal-to-noise-ratio (PSNR) as well as visually.

The remainder of this paper is structured as follows: Section II introduces the used notations and gives some preliminaries concerning fuzzy set theory and fuzzy rules. The proposed filtering framework is then discussed in Section III.