A SUBBAND BASED SPATIO-TEMPORAL NOISE REDUCTION TECHNIQUE FOR INTERLACED VIDEO SIGNALS

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Abstract — **The reduction of gaussian noise is still an important task in video systems. The presented scheme consists mainly of a subband based recursive temporal filter adapted to special properties of the human visual system. This filter is supported by a spatial filter with low hardware expense, which consists of an image analysing highpass filter bank and an adaptive lowpass FIR-filter for noise reduction.**

Introduction

TV-signals can be corrupted by noise in different ways, e.g. image aqusition in a camera, transmission over analogue channels and recording with a VCR. All noise sources together may result in a non-tolerable noise level. So a reduction of these distortions is important for a good subjective impression of image quality.

Noise reduction is performed by application of linear or nonlinear operators which uses correlations within and between the images. Because of correlation in temporal and spatial directions noise reduction algorithms exist for up to 3 dimensions [1,2,3].

The presented system is a cascaded spatio-temporal one. It consists of a structure preserving spatial noise reduction which is controlled by a structure analyzer. The output of this system is the input of a motion adaptive temporal lowpass filter which performs a noise reduction in two subbands and makes use of properties of the human visual system [3].

Subband based temporal noise reduction

Temporal noise reduction is usually performed by a temporal lowpass filter [4]. In most cases recursive filters are used to improve the efficiency. To avoid artifacts as motion blur the filter is controlled by a motion detector. The output of a simple first order recursive filter can be written as

$$g(x,y,t) = k \cdot s(x,y,t) + (1-k) \cdot g(x,y,t-T_p) \,. \qquad (1)$$

With such a filter a noise reduction R can be achieved of

$$R[dB] = 10 \cdot \log\left(\frac{2}{k} - 1\right) \cdot \qquad (2)$$

Noise reduction for interlaced video signals using a simple recursive filter as presented above has one disadvantage: If the noise reduction is performed between either two consecutive fields or frames it results in a loss of vertical resolution or in large noisy areas around moving objects.

This trade-off can be solved if a two channel model of the human eye [5,6] is taken into account. An image processing algorithm working in two channels allows to make use of the specific perception characteristics of the respective channels. This was already successfully applied in other areas of image processing [8,9]. This considerations result in a temporal processing scheme which works in two spatial subbands. In the highpass channel a loss of resolution must be avoided which results in a frame based recursion. This is supported by low noise sensitivity of the human eye for high frequency noise. In the lowpass channel unprocessed areas have to be avoided. So a field recursion is optimal. The lowpass channel includes a particular median-based deinterlacing. For structureless non-moving areas it results this yields additional noise reduction.

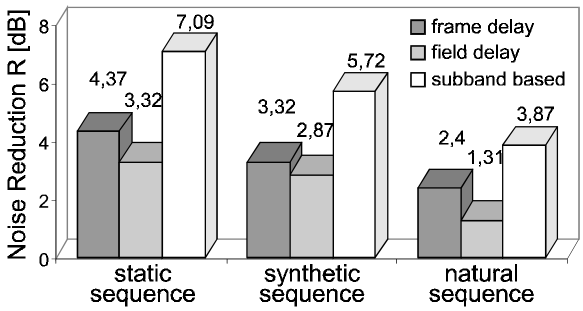

Fig. 1. Noise reduction of the proposed method compared to single band methods with frame- or field-delay (Sequences with PSNR of 30 dB)

Simulation results concerning the signal to noise ratio of this temporal noise reduction in the presence of white gaussian noise compared to other currently used methods with frame- or field-filters are depicted in Figure 1. The proposed system outperforms the other methods in all cases. It has to be mentioned that these values are subjectively unweighted results. Taking into account perception properties of the visual system the perceived quality is much higher.

Spatial noise reduction

The problem of a spatial noise reduction is to eliminate spatially uncorrelated noise from spatially correlated image content. The easiest way to get this is a spatial lowpass filter. For a simple symmetric 3-Tap FIR-filter the noise reduction can be calculated to

$$R[dB] = \frac{\sigma_{in}^2}{\sigma_{out}^2} = 10 \cdot \log\left(\frac{3r^2 - 2r + 1}{2}\right), \qquad (3)$$

where r is the weight of the center coefficient.

To avoid blurring edges and lines the filter has to be content adaptive. This is achieved with an image analyzer which controls the coefficients of the lowpass filter depicted in Figure 2. In the proposed system 8 different coefficient sets are allowed.

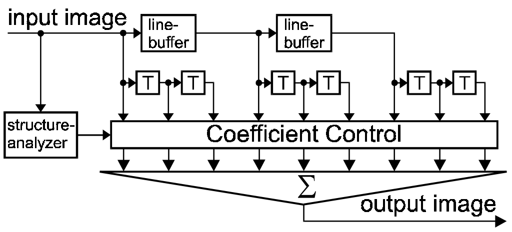

Fig. 2. Block diagramm of the detail preserving spatial noise reduction

Simulations concerning the PSNR result in noise reduction values R of 1 dB up to 2 dB.

Chain of spatial and temporal noise reduction

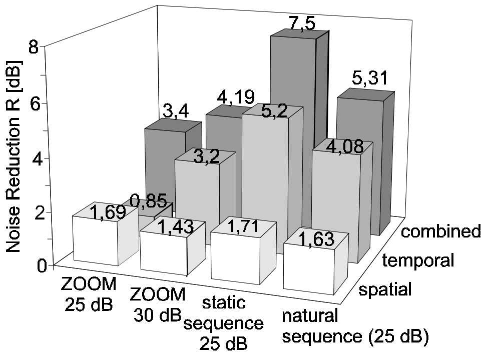

Fig. 3. Comparison of pure spatial, pure temporal and spatio-temporal noise reduction

In a chain of both spatial and temporal noise reduction the spatial filter will increase the accuracy of the motion detector. High reduction values can be expected. Results of simulation confirm this presumption. Figure 3 shows some results for different test sequences indicating that the results of the complete chain may be even higher than the sum of pure spatial and temporal noise reduction. Furthermore critical sequences for motion adaptive noise reduction (e.g. zoom) yield good results processing them by the described combined procedure.

Conclusion

A spatio-temporal noise reduction scheme is presented in this paper. It consists of a detail preserving spatial noise reduction with low hardware expense and a motion adaptive subband based temporal noise reduction which makes use of special properties of the human visual system. The noise reduction results of the complete chain can even be higher than the sum of pure spatial and temporal noise reduction.

References

[1] de Haan, G.; Kwaaitaal-Spassova, T.G..; Larragy, M.; Ojo, O.A: "Memory Integrated Noise Reduction IC for Television", IEEE Tr. On Consumer Electronics, Vol. 42, No. 2, 1996

[2] de Haan, G.; Kwaaitaal-Spassova, T.G..; Ojo, O.A: "Automatic 2-D and 3-D noise filtering for high-quality television receivers", International Workshop on HDTV'94,4-B-2,1994-10

[3] Amer, A.; Schröder, H.: "A New Video Noise Reduction Algorithm Using Spatial Subbands", Int. Conf. On Electronics, Circuits and Systems; ICECS '96; Rhodes

[4] Drewery, J.O.; Storey, R; Tanton, N.E.: "Video Noise Reduction", BBC Research Department Report, 1984/7

[5] Hiwatashi, K.; Yamaguchi, Y.: "Perception of Random Monochrome Video Interference", NHK Tech. Journal, Vol. 10, No. 5, 1959

[6] Yasuda, M.: "A Retina Model and its Spatio-Temporal Information Processing", NHK Tech. Journal, Vol. 23, No. 5, 1971

[7] Glenn, W.E.: "Reducesd Bandwith Requirements for Compatible HDTV Transmission", Proc. 38th Annual Broadcast Engineering Conference, NAB, Las Vegas, pp. 297-305, 1984

[8] Schröder, H.; Botteck, M.: "Temporal Subsampling of spatial Highs Components in Video Apllications", 4th International Workshop on HDTV and Beyond, Torino, 1991

[9] Blume, H.: "Subband Based Upconversion Using Complementary Median Filters", Proc. of the 7th International Workshop on HDTV and Beyond, Torino, 26.-28.10.1994