LOW COMPLEXITY STREAK NOISE REDUCTION FOR MOBILE TV USING LINE SELECTIVE INTERPOLATION OF FIELD INFORMATION

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ABSTRACT

This contribution presents a method for quality enhancement of mobile received analog TV signals using line selective interpolation of field information (LSI-FI). Using combining techniques of neighboring lines one can restaurate mobile received images successfully. Spatial statistical methods are used to detect distorted lines of an image. Distorted lines are interpolated by correctly received neighboring lines. The low complexity of the algorithm makes it possible to enable real-time implementation in a DSP or FPGA.

1. INTRODUCTION

In mobile received analog TV signals, the receivers have to handle strong and short-time path loss introduced by the flat fading channel. These fluctuations of the electric field should be compensated in the demodulator by an Automatic Gain Control (AGC) circuit. Normally, AGC circuits respond very slow and therefore the fluctuations of the electrical field cannot be well-adjusted. The results are image distortions which look like connected and correlated impulse noise samples (see Fig. 1 left). These noise samples are also called streaks. This artifact appears also in analog TV receivers, in case of transmitting TV signals from a mobile TV transmitter to TV receivers (see Fig. 1 right). This kind of artifact is visually very annoying.

Latest mobile analog TV receivers achieve a higher signal to noise ratio and better video quality by using maximum ratio combining or selection combining of different antenna signals. Using these methods, not all fluctuations of the electrical field can be adjusted and streaks are still visible in some received images.

Traditionally, the Median filter [1] has been used for reducing impulse noise. Here, each image sample is filtered and details in undistorted image areas may become blurred. A Signal-Dependent Rank-Ordered-Mean (SD-ROM) filter [2] detects samples with a high probability of corruption. Only these detected samples are then replaced with the Rank-Ordered-Mean value of the surrounding samples. A special kind of the SD-ROM filter for restauration of images corrupted by streaks is introduced in [3]. These two methods are objectively compared in [4] and used as reference to this approach. Other methods, like [5] are due to the iterative behavior and sorting functions relative complex and therefore not used as reference.

Fig. 1. Left: Mobile received image. Right: Mobile transmitted image.

2. COMBINATION OF FIELD INFORMATION

In analog TV signals each frame is composed of two fields. The first field contains the odd lines and the second field the even lines (see Fig. 2). When transmitting one frame, first field one and then the second field is transmitted. In general neighboring lines are correlated to each other. The mean values of neighboring lines are similar. The time gap between neighboring lines in a frame ($T_{field}^{PAL} = 20ms$) is much higher than in a field ($T_{line}^{PAL} = 64\mu s$). During this time period T_{field}^{PAL} between field one and two the mobile channel can vary a lot (see Fig. 3). At the left hand side the corrupted first field and at the right hand side the well transmitted is shown. We assume that the same field information is transmitted at two different times ($\Delta T = T_{field}^{PAL}$). Using these neighboring field information for spatial interpolation, well streak reduction can be achieved. Distorted lines are canceled and interpolated by neighboring correctly received lines. The decision, if one line is correctly received is done by comparing statistical moments of neighboring frame lines.

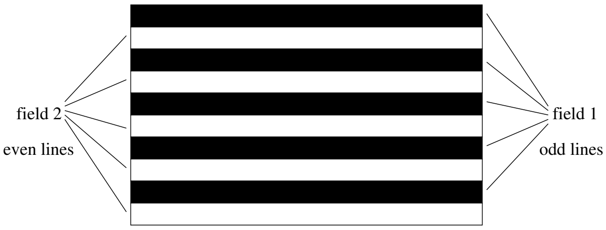


Fig. 2. TV frame.

Fig. 3. Left: Field one of mobile transmitted image. Right: Field two of mobile transmitted image.

2.1. Impulse noise detection

First the receiving conditions are checked by detecting impulse noise in two neighboring lines. In the "noise detection" block in Fig. 4, impulse noise with mean value is detected by comparing the line mean values. If the absolute difference between neighboring odd and even line mean values is above a threshold T_1, than one of the two lines is supposed to be distorted. If not, the two lines remain unchanged. $S(m, n, t)$ represents the received frame with M lines and N columns. m and k are indices for odd and even lines and n for columns.

$$\begin{aligned} \mu(m,t) &= E_{oddlines}\{S(m,n,t)\} \\ &= \frac{1}{N}\sum_{n=1}^{N} S(m,n,t) \quad (1) \\ \mu(k,t) &= E_{evenlines}\{S(k,n,t)\} \\ &= \frac{1}{N}\sum_{n=1}^{N} S(k,n,t) \quad (2) \\ |\mu(m,t)-\mu(k,t)| &> T_1 \quad (3) \end{aligned}$$

The neighboring condition is achieved by

$$m = 1, 3, 5, ..., M-1 \quad \wedge \quad k = m+1. \quad (4)$$

T_1 is self-defined and could be further evaluated. The impulse noise detection is first done for the whole frame before selecting and canceling distorted lines.

2.2. Select and cancel distorted lines

In Fig. 5, the block "select distorted line" selects the likely corrupted line by comparing each line mean value of odd and even lines. We assume that the present frame mean

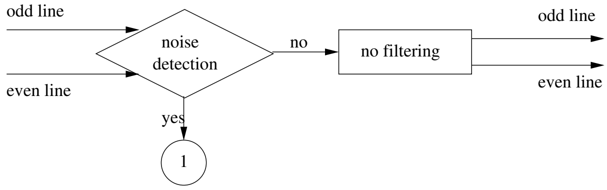


Fig. 4. Impulse noise detection.

value of the original (undistorted) image $I(m, n, t)$ correlates to the prior frame mean value of the output image $Y(m, n, t-1)$. The decision is dependent on the prior output frame mean value (block "mean value").

$$\begin{aligned} \mu_{prior} &= E\{Y(m,n,t-1)\} \\ &= \frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N} Y(m,n,t-1) \quad (5) \\ E\{I(m,n,t)\} &\approx E\{Y(m,n,t-1)\} \\ \mu_{org} &\approx \mu_{prior} \quad (6) \end{aligned}$$

If the original frame mean value μ_{org} is small, impulse noise of maximum amplitude will affect the subjective video quality more than impulse noise of minimum amplitude and vice versa. μ_{org} is compared to a threshold T_2. If μ_{org} is smaller or equal than this threshold

$$\mu_{org} \le T_2, \quad (7)$$

the decision to select the distorted line j is done by the following expression

$$j = \begin{cases} m, & |\mu(m,t)| > |\mu(k,t)| \\ k, & |\mu(m,t)| < |\mu(k,t)| \end{cases} . \quad (8)$$

If the line mean value of an odd line m is greater than the line mean value of an even line k, the odd line m is selected as the distorted line and vice versa. j represents the line which is supposed as impulse noise distorted line, either m or k.

On the other hand, if μ_{org} is greater than this threshold

$$\mu_{org} > T_2, \quad (9)$$

the decision to select the distorted line j is done by this expression

$$j = \begin{cases} m, & |\mu(m,t)| < |\mu(k,t)| \\ k, & |\mu(m,t)| > |\mu(k,t)| \end{cases} . \quad (10)$$

If the line mean value of an odd line m is smaller than the line mean value of an even line k, the odd line m is selected as the distorted line and vice versa. If two neighboring lines are distorted, then one of the distorted lines remain for interpolation. The distorted lines j are canceled by setting all line samples to zero (block "cancel distorted line"). Here two fields with canceled impulse noise distorted lines are created.

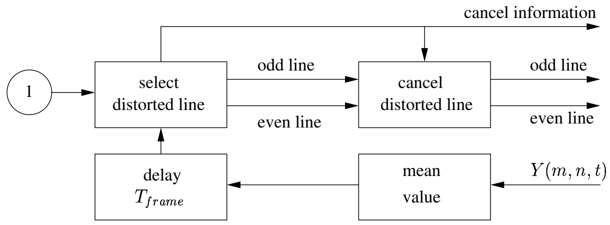


Fig. 5. Select and cancel distorted lines.

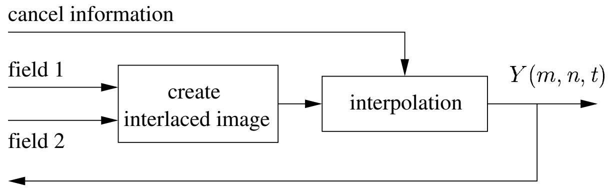


Fig. 6. Interpolation.

2.3. Interpolation

First the two distortion free fields are combined to an interlaced image (see Fig. 6 block "create interlaced image"). Then the canceled lines are linearly interpolated. In section 2.1 only one line of two neighboring lines can be estimated as distorted line. Therefore two different interpolation possibilities are given and shown in Fig. 7a) and 7b). In case a), the canceled lines j are interpolated with

$$Y(j,n,t) = \frac{1}{2}(S(j-1,n,t) + S(j+1,n,t)). \quad (11)$$

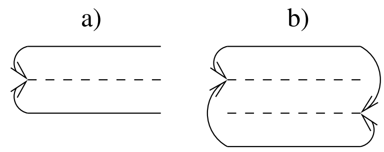
Here only one line between two correctly received lines is canceled. The linear interpolation is done by line $j-1$ and $j+1$. In case b) two lines between two correctly received lines are canceled. The upper canceled line is interpolated by line $j-1$ and $j+2$ with

$$Y(j,n,t) = \frac{2}{3}S(j-1,n,t) + \frac{1}{3}S(j+2,n,t), \quad (12)$$

and the lower canceled line is interpolated by line $j-2$ and $j+1$ with

$$Y(j,n,t) = \frac{1}{3}S(j-2,n,t) + \frac{2}{3}S(j+1,n,t). \quad (13)$$

The impulse noise distorted lines are estimated from the surrounding correctly received lines. The weights are dependent on the distance between distortion free and distorted lines. Due to motion artifacts, only lines from the current frame are used. The interpolation introduces lowpass filtering in vertical direction and details may be blurred. However, this effect is subjectively much less annoying than impulse noise distortions.



	line
without distortion	———
with distortion	- - - -

Fig. 7. Interpolation possibilities.

3. SIMULATION RESULTS

In the following, only subjective quality enhancement is shown. Objective quality measurements like peak signal noise ratio cannot be used, because we have no reference images to the mobile received and transmitted images. Due to limited space only parts of images are shown (full images can be seen on [6]).

In Fig. 8 on the left hand side, a mobile analog received image can be seen. Image lines contain many connected impulse noise samples. These impulse noise samples looks like horizontal streaks. Horizontal streaks can be reduced by using a 5×1 filter mask [3]. The simulation results for the Median 5×1 can be seen in Fig. 8 on the right hand side and for the SD-ROM 5×1 filter in Fig. 9 on the left hand side. Median and SD-ROM filter are applied to interlaced frames. Here, in both results can be seen on the left and right image areas, that these algorithms work well for sporadically impulse noise. If there are in one field vertically connected impulse noise samples, Median and SD-ROM filter can not reduce the impulse noise. This effect can be seen in the middle image area in both results. In Fig. 9 on the right hand side, the result of the LSI-FI can be seen. This approach can restore the distorted images quite well, also if there are in one field vertically connected impulse noise samples.

In Fig. 10 on the left hand side a stationary received image can be seen, which was send by a mobile analog TV transmitter. In Fig. 10 on the right hand side the result for the Median 5×1 and in Fig. 11 on the left hand side the result for the SD-ROM 5×1 filter can be seen. In the upper image area, both reduces sporadically impulse noise. In the bottom image area are in one field vertically connected impulse noise samples and these two approaches can not reduce the impulse noise. In Fig. 11 on the right hand side, the result of the LSI-FI can be seen. This approach can restore the whole transmitted image very well.

Both, Median 5×1 and SD-ROM 5×1 filter have to sort image samples. This leads to long computing time. In Table 1 the computing times relative to Median 5×1 filter are shown. The simulations have been done in Matlab. The SD-ROM has compared to the Median filter additionally an

Fig. 8. Left: Mobile received image. Right: Result with Median 5×1.

Fig. 9. Left: Result with SD-ROM 5×1. Right: Result with proposed LSI-FI approach.

Method	Relative computing time
Median 5×1	1.0
SD-ROM 5×1	1.16
LSI-FI	0.05

Table 1. Computing time relative to Median 5×1 filter.

impulse noise detection function, which needs further computing time. Therefore the SD-ROM performs 1.16 times slower than the Median filter. The LSI-LI algorithm contains no sorting function and the impulse noise is estimated for whole lines instead for each image sample (SD-ROM). The saving in computing time is approximately 20 in contrary to the Median filter.

4. CONCLUSION

We presented a method for streak noise reduction of mobile received and transmitted TV signals. In contrary to Median and SD-ROM filtering, this approach restores the impulse noise distorted lines very well. Another advantage is the low computing time in contrast to the other two approaches. This leads to a possible real-time implementation on a DSP or FPGA.

In our complete system, the LSI-FI approach is used in combination with other noise reduction, intensity flicker, ghost cancel and deinterlacing methods for quality enhancement of mobile received analog TV signals.

Fig. 10. Left: Mobile transmitted image. Right: Result with Median 5×1.

Fig. 11. Left: Result with SD-ROM 5×1. Right: Result with proposed LSI-FI approach.

5. REFERENCES

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