DETECTION AND RECONSTRUCTION OF MISSING DATA IN DAMAGED IMAGE SEQUENCES

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SUMMARY

Our paper presents several median based models of filters designated for solution of the problem mentioned in head-line.

In the motion picture industry, both, "dirt and sparkle" often appear. These are flashes, i.e. more than one pixel, of totally different brightness, unrelated to the surrounding area of the frame, and also unrelated to adjacent frames. To restore such image sequences, it is possible to use median based multilevel filters, which yield to quite good results and are computationally modest. To avoid useless affect the other - uncorrupted - pixels, these filters have to cooperate with operation of missing data detection, which is also briefly described in this submission. The results are declared by representative frames as well as by numeric error criteria.

Keywords: *degraded image sequence, multilevel median filters, missing image data detection*

1. INDRODUCTION

The problem of missing data in image sequences occurs regularly in archived motion picture film. The missing data regions manifest as blotches of random intensity, called "dirt and sparkle" in the motion picture industry.

This problem can be solved by a global filtering strategy, but this approach affects all pixels, i.e. also these ones that were not damaged. So the result after filtration must not be satisfactory - the blotches may be eliminated, but the structure of frames may be smoothed and the details lost. A more effective solution is to find damaged areas in image sequence before filtering and subsequently renovate just these ones. For this purpose, detector of blotches was proposed. The detector decides to filtrate or not upon of amount of discontinuity (considering also previous and next frame), which the actual pixel under the consideration shows. If discontinuity overhangs a predetermined value (threshold) it is violent that there is a damaged area and it must be repaired. Otherwise, the pixel is not touched, because this is probably its original value.

In this paper, there are considered just the standard dynamic image sequences in gray scale. They differ one from another on texture and amount of details in the frames and also on the "value" of motion.

For simplicity, the blotches were considered to be only of black and white colors. So, the mentioned dynamic image sequences were artificially contaminated by groups of black or white pixels for the sake of simulating defects in archived film.

The basic method, elected for reparation, was median filtration. This order statistic method is very good for impulse suppression. Each member pixels of the blotch in image sequence can be also considered as an impulse in compare with these ones from previous and next frames. That is why, it was expected, 3-D (3-dimensional) median filter can also take off blotches from image sequence. If 3-D filter window is not too large, its influence over the move in the scene is not remarkable.

The other methods with similar object, i.e. detection and interpolation of missing data in dynamic image sequences, described e.g. in [3, 4] are much more complex in fundamentals and computation. They consider motion of objects in the scene, and use Markov random fields (MRF) model or 3-D autoregressive (AR) model of image for detection and interpolation of blotches. In our work, we have decided to employ more simple approach. The results of experiments with standard image sequences seem restful.

2. DESCRIPTION AND MODEL OF DIGITAL IMAGE SEQUENCE

For this purpose, there are considered image sequences (IS) in gray scale, so called black-and-white (BW) image sequences and there were used the standard BW sequences Trevor, Susie, Salesman and People (fig.1). They differ one from another by complexity of frame structure, amount of details, and by the rate of motion in the scene. In digital area, a dynamic IS, i.e. a frame sequence presents a chain of n matrices of M by N dimension. Each of elements of the frame (picture elements or pixels), is represented by the level of gray or of brightness. This is, in bi-nary area, for example, by 8-bit word (256 levels of the gray).

Fig.1 The representative samples from sequences named Susie, Trevor, Salesman and People

3. THE MODEL OF BLOTCH GENERATOR

The blotches, which often degrade archive films have an irregular border, random position, a surface of several (e.g. 10 or more) pixels, brightness near the maximum or minimum and their amount is also random. In this work, for the purpose of artificial degradation of IS, a program in C-language was employed. In each original frame, several groups of pixels were changed by group of black or by group of white pixels.

The enter data of generator contain a rate of degradation (in %), which relates with a number and size of spots per frame. An election of position of spots, as well as their shape and color (white or black) are random. In the fig.2, there is presented, e.g. 22nd frame of People sequence, which is damaged by black and white spots. These damaged places amount 1% of the total count of frame pixels.

Fig.2 Illustration of damaged frame of People sequence

4. MULTILEVEL MEDIAN FILTERS

A median operation poses a support of multilevel filters, which were in [1, 2] proposed for impulsive noise suppression. For the purpose of damaged image sequence data interpolation, the multilevel filters were tested with many different 3-D masks [5]. There was searched an optimal combination of one from many 3-D filter windows in accordance with one from some multilevel methods. There were proofed choices of median from 3-D filter windows (spatiotemporal filters), and also the choice of 2nd stage median from spatial medians and lonely pixels from adjacent frames (as it can be seen in fig.4). The goal was to eliminate the blotches well, but on the other hand - to protect the structure details and the moving in sequence. The best results were achieved with temporal and MMF filters depicted in figures 3 and 4.

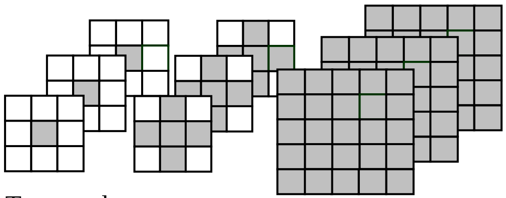


Fig.3 The most successful filter masks for 1-level filters

In the case of each filter structure, the filter window slides down the pixel by pixel in the damaged frame, and after that, frame by frame. However it skips the border pixels, as well as the introductory and the final frames, because of border effect.

Temporal filter (fig.3) is one level filter, which per-forms common median operation with only 3 pixels:

$$y_{jik} = med[x_{j,i,k-1,} x_{j,i,k}, x_{j,i,k+1}] \quad (1)$$

where the symbols y, x denote the pixel of new or damaged frame respectively, j,i,k, are indexes of column, row, or of sequence frame respectively.

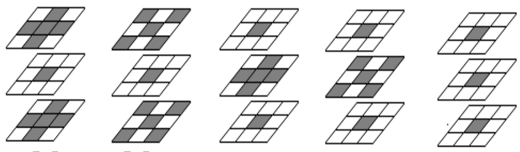
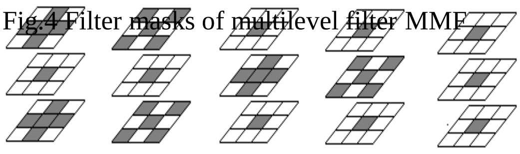


Fig.4 Filter masks of multilevel filter MMF



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l=1,2,3,4,5, and then performs the operations as follow:

$$z_{jik\max} = max[z_l],\ z_{jik\min} = min[z_l],$$
$$y_{jik} = med[z_{jik\max}, z_{jik\min}, x_{jik}] \quad (2)$$

The employing of temporal and MMF filters described above yields to the best results in comparison with many others (one- or multilevel filters, with various filter masks) by visual means and in numeric error parameters, too. However, the frames after filtration have stayed blurred, as one can see in representative frame in fig.5 - at left. Indeed, this is the basic property of median filters, a smoothing of details in image, hence it appeared necessary to find damaged places in frames and to treat only them.

5. FILTERS WITH DETECTOR OF BLOTCHES

There are several methods for detection of missing data, e.g. the methods by employing of MRF model or AR model [3], etc. In this work a threshold impulse detector similar as in [3] or [6] was adapted and applied. Its principle can be simply described like this:

IF

$$\left|x_{jik} - x_{jik-1}\right| > e_t \text{ AND } \left|x_{jik} - x_{jik+1}\right| > e_t \quad (3)$$

THEN filter, ELSE let untouched.

In equation (3), the symbol e_t represents a threshold value. The principle of threshold detection is based on mathematical comparison of brightness value of actual pixel x_{jik} with brightness of pixels at the same position in previous and next frame. When the found difference exceeds predetermined threshold, it is very probable, that it deals with a spot and this one must be filtered. In opposite case, the pixel under consideration is left untouched.

The threshold value relates with statistical characteristics of sequence frames. Upon the experiments, in joint with temporal filter and with minimum of MAE (mean absolute error) and MSE (mean square error), there was found its quasi-optimal value for each type of sequence. Thus, it was fixed to value from 30 to 70 for the corresponding IS.

The employing of detector before filtering has led to markedly better results, as one can see below.

6. THE NUMERIC ERROR CRITERIA

To take measure of the filter efficiency objectively, the criteria as the mean absolute error (MAE), the mean square error (MSE), and δ_{MAE} were utilized. MAE and MSE express the rate of frame detail smoothing and degradation after filtration, in comparison with original frame sequence. An absolute covariance error δ_{MAE} was established for evaluation of motion destroying in IS. In this continuity, these statistic parameters are defined by relations (4) to (7)

$$MAE = \frac{1}{(n-6)(M-30)(N-30)} \sum_{k=4}^{n-4}\sum_{j=16}^{M-30}\sum_{i=16}^{N-30}\left|o_{jik} - y_{jik}\right| \quad (4)$$

$$MSE = \frac{1}{(n-6)(M-30)(N-30)} \sum_{k=4}^{n-4}\sum_{j=16}^{M-30}\sum_{i=16}^{N-30}\left(o_{jik} - y_{jik}\right)^2 \quad (5)$$

$$\delta_{MAE} = \frac{1}{n-6}\sum_{k=4}^{n-4}\left|\rho_k^o - \rho_k^y\right| \quad (6)$$

$$\rho_k^o = \frac{1}{(M-30)(N-30)} \left|\frac{\sum_{j=16}^{M-16}\sum_{i=16}^{N-16} o_{jik}\, o_{jik-1} - E_k^o E_{k-1}^o}{\sigma_k^o \sigma_{k-1}^o}\right|, \quad (7)$$

and ρ_k^y, the like.

The understanding of some equation symbols is already known from the text above, and the understanding of the others – o_{jik} denotes a pixel of frame of original IS, *o*, *y* in indexes are utilized for identification of original or filtered sequence parameter respectively. In relations for δ_{MAE}, ρ, E and σ are the symbols for the corresponding whole frame matrix covariance (7), frame mean value (8) and standard deviation (9) respectively. The each 15 border pixels and each 3 introductory and final frames are left out.

$$E_k^o = \frac{1}{(M-30)(N-30)} \sum_{j=16}^{M-16}\sum_{i=16}^{N-16} o_{jik} \quad (8)$$

$$\sigma_k^o = \sqrt{\frac{1}{(M-30)(N-30)} \sum_{j=16}^{M-16}\sum_{i=16}^{N-16}\left(o_{jik} - E_k^o\right)^2} \quad (9)$$

7. EXPERIMENTS AND RESULTS

The median based methods introduced above were applied by means of C-program language for all four standard IS. At first, they were tested by many different 3-D masks, without blotch detection. Next, for each IS, its own threshold was found, and then, the same filters were applied in collaboration with threshold detector. The new results have shown an expressive improvement of all numeric and visual criteria. The structure details and the moving in sequences were effected very little, and visually inconsiderable. In some frame of IS there have stayed very small blotches, because of the presence of damaged areas at the same coordinates in adjacent frames of defective film copy. According to the

Fig.5 The illustrative People sequence frame after filtering with the best structure without blotch detector (MMF – the frame left) and with det. respectively (Cube5x5)

results of interpolation after detection, now, another filter windows (cross and cube5x5, see fig.3) were shown as the best. The effect of temporal filter was again quite nice, but MMF structure failed. For the illustration, in the figure 5, the difference between effects of MMF and Cube5x5 filters can be seen.

The table under the text, documents inscribed facts for Trevor, People and Susie sequences respectively. There, the bold digits suggest the most effectual filter structure for the corresponding sequence.

8. CONCLUSION

Threshold detection of missing data was realized in cooperation with 1-level and multilevel median filters in order to the best interpolation of the missing data of the dynamic image sequences. For this purpose, the standard sequences were artificially damaged. The results of experiments allow us to consider about usage of these methods in restoration of real damaged archive film copies, too. Their advantage, is simplicity in principle and in computation, in opposite to e.g. AR and MRF methods or methods described in [7].

Table 1 The values of error criteria of the best filter structures with and without detection of blotches

		Sequence (e_t –detection threshold)								
		Trevor (30)			**People (70)**			**Susie (55)**		
		MAE	**MSE**	**δ_{MAE}**	**MAE**	**MSE**	**δ_{MAE}**	**MAE**	**MSE**	**δ_{MAE}**
Filter type	**MMF**	0,801	6,8	**0,00266**	3,507	69,3	**0,06920**	1,289	18,6	0,01250
	Temporal	**1,113**	**8,5**	0,00254	**4,214**	**86,5**	0,06856	**1,607**	**22,0**	**0,01267**
	Cube5x5	**4,737**	**62,0**	**0,00626**	**8,232**	**162,4**	**0,09594**	**4,345**	**55,0**	**0,01908**
	Cross	**2,270**	**16,6**	**0,00452**	**5,817**	**96,0**	**0,08345**	**2,902**	**30,7**	**0,01628**
	MMF with det.	**0,067**	**3,53**	**0,00119**	**0,329**	**20,50**	**0,00368**	**0,132**	**8,62**	**0,00388**
	Temporal with det.	0,061	**3,65**	**0,00127**	**0,335**	**21,44**	**0,00364**	**0,133**	**9,14**	**0,00393**
	Cube5x5 with det.	**0,101**	**4,67**	**0,00120**	0,302	17,84	0,00322	0,120	6,31	0,00356
	Cross with det.	**0,071**	3,35	0,00110	**0,310**	**19,22**	**0,00351**	**0,123**	**7,75**	**0,00380**

REFERENCES

[1] G. R. Arce, "Multistage order statistic filters for image sequence processing", IEEE Trans. on Signal Processing, Vol.39, No.5, May 1991, pp.1146-1163.

[2] R. Lukáč, "Impulse Detectors for Noised Sequences", Radioengineering, Vol.10, No.2, July 2001, pp.24-31.

[3] A. C. Kokaram, R. D. Morris, W. J. Fitzerald, P. J. W. Rayner, "Detection of Missing Data in Image Sequences", IEEE Trans. on Image Processing, Vol.4, No.11, Nov.1995, pp.1496-1508.

[4] A. C. Kokaram, R. D. Morris, W. J. Fitzerald, P. J. W. Rayner, "Interpolation of Missing Data in Image Sequences", IEEE Trans. on Image Processing, Vol.4, No.11, Nov.1995, pp.1509-1519.

[5] M. Hrešo, "Restoration of damaged black-and-white image sequences", Diploma work, Techn.University, Košice, 2001.

[6] R. Lukáč, "Multidimensional digital image filtration by means of permutation theory, LUM filters and impulse detectors", minima work, Techn.University, Košice, 1999.

[7] R. Lukáč, "Processing of Noised Dynamic Image Sequences: Adaptive Boolean Smoother Based on Permutation Theory and Optimized by Genetic Algorithm", Proc. of 6th International Conference of the Fund of Jozef Murgas for Telecommunications joined with competition in Bratislava, Slovakia, June 13-14, 2000, pp.49-53.

BIOGRAPHY:

Stanislav MARCHEVSKÝ received the M.Sc. degree in electrical engineering at the Faculty of Electrical Engineering, Czech Technical University in Prague, in 1976 and Ph.D. degree in radioelectronics at the Technical University of Košice in 1985. From 2001 he is the full professor at the FEI TU in Košice. His research interest includes multimedia communication.

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