THE FAST SEARCH MOTION ESTIMATION ALGORITHMS AND THEIR ERRORS

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ABSTRACT

This paper presents the analysis of errors produced by block matching motion estimation methods with lower computational cost (fast search algorithms). We try to find an answer on the question what measure can be used to determine correctness of searched motion vectors and which motion vectors are founded as fault (corrupted by noise). We consider the vector fields obtained by using of full search algorithm (FSA) as lossless data. We take the vectors of movement obtained by using 2D logarithmic (2D log) search procedure as data corrupted by noise. The results of analysis can help optimize post processing of motion vectors in endeavoring to reduce computational cost or regularize vector fields.

Keywords*: *motion estimation, block matching, motion vector

1. INTRODUCTION

The purpose of the motion estimation (ME) and compensation is reduction of redundancy caused by interframe correlation of movement objects [1-6]. However, the estimation and coding of movement vectors should be appropriated to computational costs and bit rates at the perspective high compression systems. That's way is very important relationship between accuracy of movement estimation and simplicity of the description vector fields. Better motion estimation means higher space decorrelation of prediction errors in time area.

The most popular approach is to reduce the number of search locations by using the assumption of unimodal error surface in which the matching error decreases monotonically when the searching location approaches to the global optimum. However, this assumption is not usually satisfied, thus resulting in local optimal solution. Instead of limiting the number of search locations, another interesting tech-nique aims at reducing computation of block matching with pixel subsampling, successive elimination algorithm (SEA).

The above two techniques achieves computation reduction with or without loss of search performance.

This paper is concentrated on analyze one of often mentioned method of ME with reduced searching steps - 2Dlog method. The 2Dlog method is analyzed from point of view of estimation and localization of potentially possible errors of motion vectors in the searching procedure.

2. THE REASONS OF ERRORS

The essential condition of the correct displacement vector finding (for ME methods with reduced searching steps) is flatness of matching criteria. It means that function of matching criteria monotonically increases as we move away from direction of minimum matching criteria in each of the four quadrants [7].

The example of founded motion vectors (MV's) from the image sequence "Railway station" is in fig. 1. The black arrows are MV's founded by 2Dlog method for subblock size BS = 16x16 pel and proposed maximum displacement d_m = 13 pel in all directions. The white arrows are MV's founded by full search (FS) method with the same searching parameters and can be seen for the subblocks in which vectors are different from 2Dlog MV's. A darker rectangle in fig. 1 highlights one of subblocks with mismatch vector (2Dlog-black, FS-white).

Fig. 1 The frame from the image sequence "Railway station" with motion vectors founded by FS method (white) and 2Dlog method (black)

All computed values by FS method of matching criteria (MAD - Mean Absolute Difference) of highlighted subblock in fig. 1 are plotted in fig. 2. The number of these values is $(2d_m + 1)$x$(2d_m + 1)$, i.e. 27x27 values. It can bee seen that values of matching criteria do not increase monotony. The position of global matching criterion (MAD) minimum corresponds with actual MV. The values of criterion MAD are represented as gray levels in fig. 2b. The white point in very dark area indicates the position of minimum. The white arrow is searched MV by FS method. The positions of searching

2Dlog procedure are signed as the black dashed arrows. The black arrow drawn by solid line represents final MV searched by 2Dlog method for highlighted subblock. From proposed figures can be seen the mismatched 2Dlog MV due to convergence of searching process to local minimum not to global minimum.

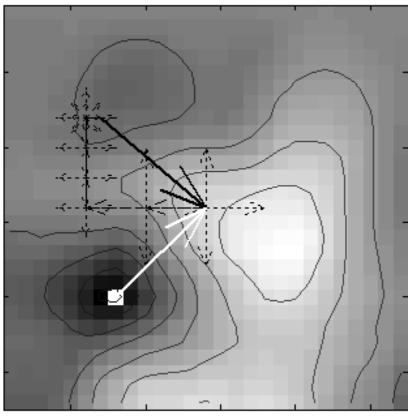


Fig. 2 Values of MAD shown as gray levels and 2Dlog search procedure (black dashed vectors)

The other reason of the possible MV error is interframe noise in the picture (caused by quality of image sensor, reflection and illumination of scene, etc.). The next reason of error can be fact that only a part of subblock is submitted to displacement and remaining part is the static background.

The examination of searched MV's and acceptation of error reasons generated by fast search algorithms indicate their impulse nature [8] (the values of impulse noise are not only extreme - "salt and pepper" but are from overall range). The error function *ef* of vector components (with respect to impulse model (1) of errors

$$y = (1 - ef).s + ef.n,$$
$$ef = \begin{cases} 1, \; probability \; P_{ef} \\ 0, \; other \end{cases}, \tag{1}$$

where *s* is signal, *n* is noise), can be evaluated in form:

$$ef\,(i,j) = \begin{cases} 1, \text{ if } \left[\mathbf{U}_{FS}(i,j) \neq \mathbf{U}_{2Dl}(i,j)\right] \cup \\ \quad \cup \left[\mathbf{V}_{FS}(i,j) \neq \mathbf{V}_{2Dl}(i,j)\right] \\ 0, \text{ other,} \end{cases} \tag{2}$$

where symbol $\cup$ represents the operator OR, $\mathbf{U}_{FS}$ and $\mathbf{U}_{2Dl}$ are matrices of horizontal MV components founded by FS or 2Dlog method respectively and $\mathbf{V}_{FS}$, $\mathbf{V}_{2Dl}$ are matrices of vertical MV components.

3. ESTIMATION OF THE ERROR FUNCTION

The detection of distortion pulses is important task in noise diagnostics. If the signals without and with distortion are known then the values of noise pulses can be detected by their comparison (very unpractical or impossible). The other and more practical solution is using of impulse detectors [9].

The quantity *ef*(*i, j*) defined in (2) is binary function in reality. The value "1" of *ef*(*i, j*) indicates the position (*i,j*) in which at least one of MV components founded by 2Dlog methods differs from equivalent MV components founded by FS method. The founded MV is so treated as value of impulse noise.

In fig. 4 are shown values of *ef*(*i, j*) (white sign "1", black "0") for frames of image sequence "Football" (fig. 3). The error function *ef*(*i, j*) (fig. 4) is determined by (2) for 2Dlog method when MV's of FS method were accepted as lossless signal. The parameters for both methods were *BS* = 8x8 pel and d_m = 10 pel.

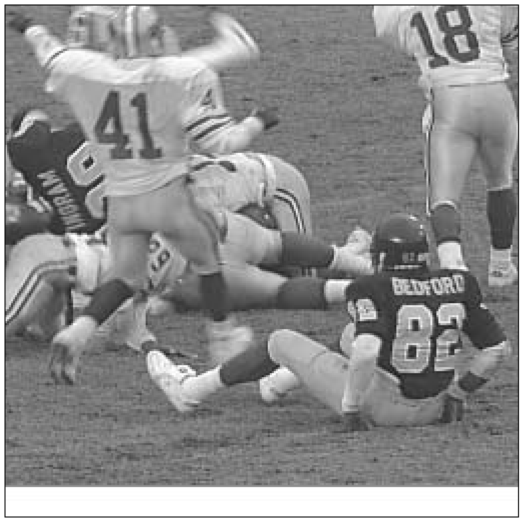


Fig. 3 The frame of sequence "Football"

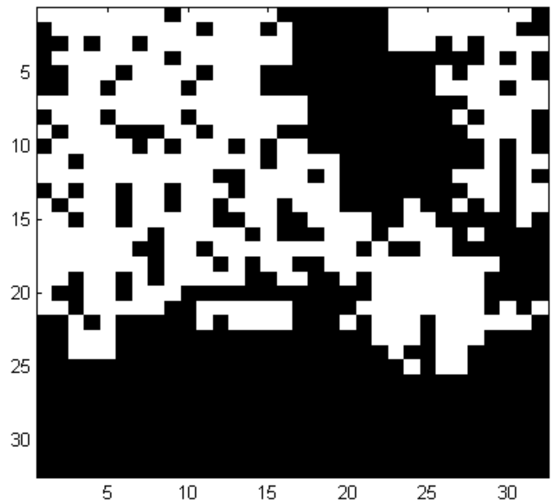


Fig. 4 Error function *ef*(*i, j*) for frames of sequence "Football" (white⇔"1", black⇔"0")

The proposed finding procedure of values *ef*(*i, j*) is unpractical due to necessity of knowing of FS MV's (high computational cost).

The matching criteria value MAD_B can be useful measure of fruitfulness finding of MV $\vec{V}_B$ with components (u_B, v_B) for subblock $B(i, j)$ in the position (i, j). The MAD_B is expressed as:

$$MAD_B(i,j,u_B,v_B) = \frac{1}{M.N}\sum_{m=1}^{M}\sum_{n=1}^{N}\left|X_k(m,n) - X_{k-1}(m+u_B, n+v_B)\right| \quad (3)$$

where M, N are dimensions of subblock in the position (i, j), $X_k(m,n)$ are values of picture elements of frame k and $X_{k-1}(m+u_B,n+v_B)$ are picture elements of frame k-1 with displacement (u_B, v_B) from searching area (SA). The value MAD_B doesn't need be minimal if the fast search procedure is used. In this case the estimated vector $\vec{V}_B$ is probably mistaken i.e. corrupted by noise.

In the fig. 5 values of $MAD_B(i, j, u_B, v_B)$ are shown as gray levels (from 0 to 256) for all positions of subblocks (i, j) of image sequence "Football". The motion vectors (u_B, v_B) were found by 2Dlog method with parameters as in fig. 4. The range of $MAD_B(i, j, u_B, v_B)$ values was markedly lover then 256 but for better readability was scaled to this range.

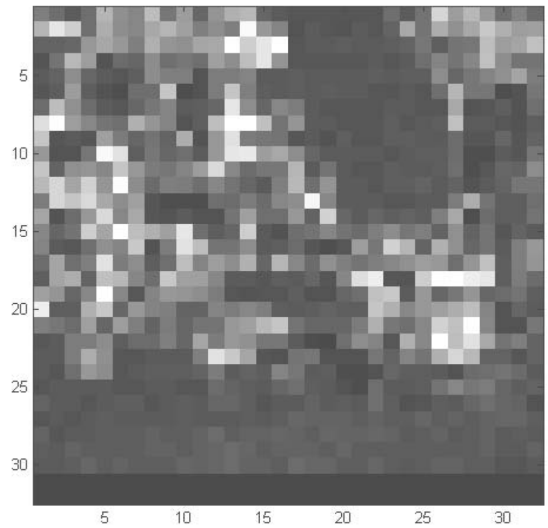


Fig. 5 The values of function $MAD_B(i, j, u_B, v_B)$ normalized to 256 levels (lighter-higher value, darker-lower value)

If the values of $MAD_B(i, j, u_B, v_B)$ are taken as measure of finding vector fruitfulness it is possible to estimate the binary error function $ef_E(i, j)$ by setting suitable threshold T_2 in the positions of subblocks (i, j). The function $ef_E(i, j)$ is comparable with $ef(i, j)$. However, for investigation of $ef_E(i,j)$ there is no need to find out of MV's by FS method. The quantity of $ef_E(i, j)$ can be evaluated as:

$$ef_E(i,j,u_B,v_B) = \begin{cases} 1, \text{if } MAD_B(i,j,u_B,v_B) > T_2 \\ 0, \text{if } MAD_B(i,j,u_B,v_B) \le T_2 \end{cases} . \quad (4)$$

4. ESTIMATED ERROR FUNCTION AND HER CORRECTNESS

In fig. 6 the values of function $ef_E(i, j, u_B, v_B)$ with threshold T_2=8 are shown as binary picture (white sign value "1" , black "0") of image sequence "Football" for 2Dlog method with parameters BS = 8x8 pel and d_m = 10 pel. The noticeable similarity between function $ef_E(i, j, u_B, v_B)$ (fig. 6) and function $ef(i, j, u_B, v_B)$ (fig. 4) can be registered.

A two dimensional correlation coefficient r_2 was used to quantitative evaluation of their similarity. The two dimensional correlation coefficient r_2 is defined as:

$$r_2 = \frac{\sum_i\sum_j\left[ef(i,j) - \overline{ef}\right]\left[ef_E(i,j) - \overline{ef_E}\right]}{\sqrt{\left\{\sum_i\sum_j\left[ef(i,j) - \overline{ef}\right]^2\right\}\left\{\sum_i\sum_j\left[ef_E(i,j) - \overline{ef_E}\right]^2\right\}}} \quad (5)$$

where $\overline{ef_E}$, and $\overline{ef}$ represent mean values.

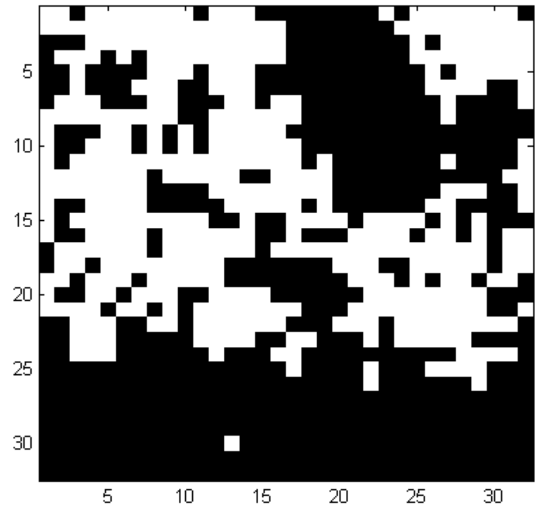
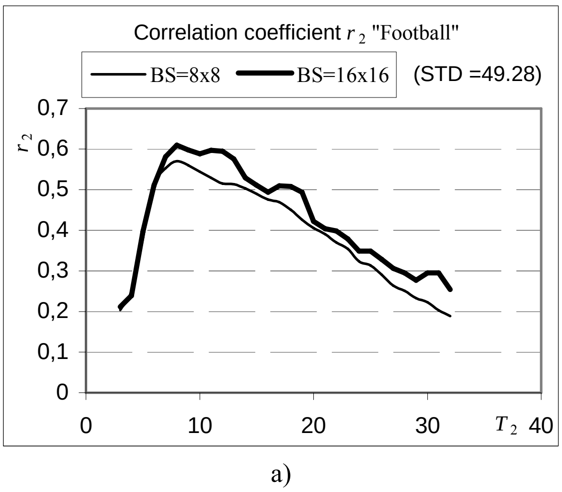
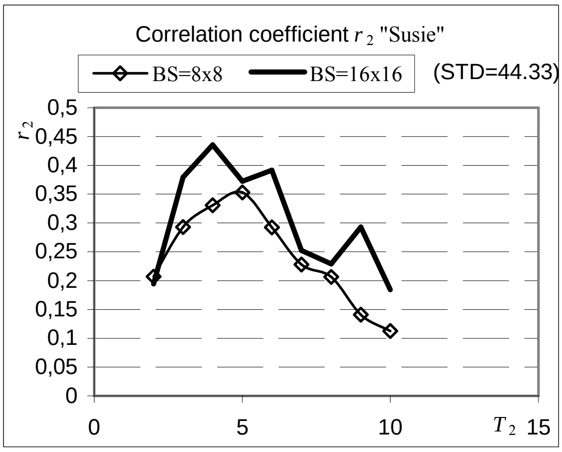


Fig. 6 Estimated error function $ef_E(i, j, u_B, v_B)$ for frames of sequence "Football" (white⇔"1", black⇔"0")

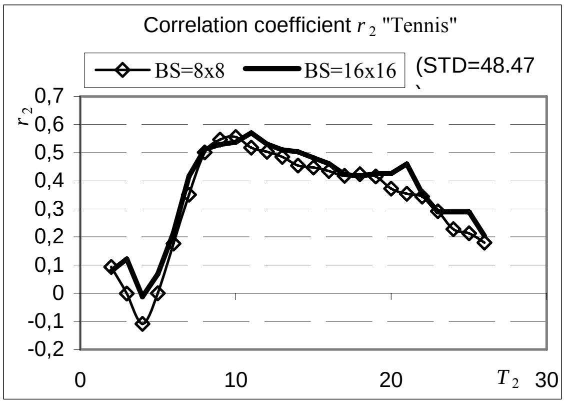
The charts in fig. 7 represents relations between r_2 (5) and value of threshold T_2 for frames of image sequence "Football", "Susie" and "Tennis" (well known sequences of ITU standard) with the same parameters as above.



a)



b)



c)

Fig. 7 Charts of dependency of correlation coefficient r_2 versus value of threshold T_2 for different sequences: a) “Football“, $d_m = 10$, b) “Susie”, $d_m = 4$, c) “Tennis” $d_m = 8$

5. CONCLUSSION

The proposed results follow on deduction that r_2 is dependent on threshold T_2. The nature of dependency is equivalent for different values of subblock size. The significance r_2 rapidly increases after overcoming same value of threshold and when T_2 is further increased the r_2 moderate decreases. The magnitudes of r_2 differ for different image sequences (nature of image and motion activity). The function $ef_E(i, j)$ shows good match with theoretical function $ef(i, j)$ if T_2 is optimized. In our experiments we have notice for image sequence with higher value of frame standard deviation (STD) a higher value T_2 as optimal threshold. The facts mentioned above enables an implementation of modifications not only for 2Dlog methods but for other fast search motion estimation algorithms and so increasing of their affectivity.

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