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A New Block-Matching Algorithm Based on an Adaptive Search Area Adjustment Using Spatio-Temporal Correlation

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Abstract A new block-matching algorithm based on an adaptive adjustment of search area using spatio-temopral correlation is presented to reduce the computational complexity of the full-search algorithm without significant degradation of video quality. It is shown that the proposed method has good video quality in terms of mean square error and has less complexity than previous works by simulation using various test video sequences.

I. INTRODUCTION

For real-time video coding applications, a new method to cut down the computation of the full-search block-matching algorithm(BMA) is necessary. There are two strategies to implement the BMA in real-time fashion. One is VLSI implementation of the BMA, which is costly in lightweight video coding applications. The other is the development of fast search methods to get motion vectors(MVs). In this paper, we present a new BMA to reduce the computational complexity by using adaptive adjustment of the search area based spatio-temporal correlation, especially for low bit rate video coding.

The fast BMA using the search area adjustment methods have been investigated in [1, 2, 3]. The adaptive BMA(ABMA) adjusts the search window depending on the displaced block differences(DBDs) between a current block and candidate blocks pointed to by the MV of its neighborhood blocks[1]. The large search window is used for the block having a large DBD and the small search area is allocated to the block having a small DBD, respectively. This method was simple, but ignored the facts that low bit rate video sequences have center-biased motion distribution and the correlation between DBD and MV magnitude is not significant.

The method, called dynamic adjustment of the search window with fixed/variable size of blocks(DASWF/V)[2,3] are presented to adjust the search window using block similarity with fixed and variable size of block. These methods have some problems to be implemented on real-time video codec. The DASWF/V used the spatial correlation but have huge overhead for preprocessing to get block similarity and block segmentation. To remedy the problems of the previous works, we present a new BMA using spatio-temporal correlation that is derived from the characteristics of low bit rate video sequences. In section II, we describe the proposed algorithm based on spatio-temporal correlation, and give simulation results with several test video sequences for low bit-rate video coding in section III.

II. BMA USING SPATIO-TEMPORAL CORRELATION

The proposed search area adjustment scheme is performed as follows to adjust the size of search window of the BMA. First, the current frame is divided into fixed size of blocks. Each block is classified into one of four types : background block, active moving block, and changing block from background to active region or vice versa. The classification is done depending on the block type of the block in the previous frame. In low bit-rate video sequences, moving objects occupy only small part of the frame, so the temporal correlation between corresponding blocks in successive frames is very high. Thus the block type of the current block is closely dependent on the type of the corresponding block in the previous frame. Therefore, we set the block type of the current block to that of the block at the same position in the previous frame. For each block type, the size of search area is set as w for active block and changing block from background to active region, $w/4$ for background block, and $w/2$ for changing block from active region to background, respectively, where w is an initial maximum displacement of MVs. For first frame of video sequence, exhaustive search within search area w is performed to get block classification information of each block. The following frames use the block classifications of the previous frame. The search area for each block is refined using spatial correlation. Because some objects in a frame span the several blocks, the adjacent blocks positioned within the same object have similar motion structure. To use the spatial correlation between neighborhood blocks, we use the motion correlation of spatially neighboring blocks to determine the new search origin and adjust the search range according to the different motion content of the block. The size of search area for each block type is refined depending on the displaced block difference at new search origin. The new search origin is determined with MVs of the adjacent blocks in the left, upper-left, and upper directions together with zero displaced to predict a MV of a current block; then, the vector that has minimum displaced block difference is selected as a predicted MV. The size of search area set in proposition to the displaced block difference at new search origin.

After the size of search area for each block is determined, the BMA is performed within the search window in a fashion of logarithmic search window reduction. At first, the BMA is performed within the determined search area using full search. If the best-matched candidate block is positioned within search area, the motion estimation is stopped. Otherwise(MV points to the boundary of search area), the FSBMA is performed with a new search origin pointed to by the MV at first stage within

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a new search area that is half the size of the first search area. This procedure continues until the MV does not point to the boundary of search area. When the motion estimation process continues and the size of search area becomes 1, the next search area is set to 1 and the motion estimation is performed continuously until the MV points new search origin. This process can reduce the quality degradation caused by misclassification of block types. The block classification information is updated depending on the MV result of each block.

For example, Figure 1 shows the procedures to find the MV for a $N \times N$ block. In first step, the MV points to the boundary of first search area $2w+N$, therefore, the motion estimation goes on within second search area $w+N$. The motion estimation process stops in the second search area because the second MV points to the position within the search area. Final MV is a vector sum of the first and second MVs.

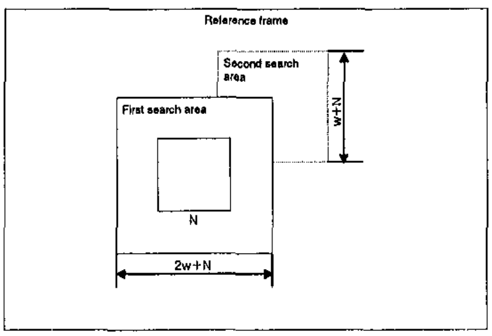

Figure 1 : Procedure of motion estimation with the determined search area

III. SIMULATION RESULTS

Four QCIF(quarter common immediate format : 176x144) video sequences, called *Miss America*, *Carphone*, *Foreman*, and *Claire*, are used to evaluate the proposed search area adjustment scheme with block size of 16 by 16. The initial motion displacement is set to ±16. The mean absolute error(MAE) is used as matching criterion for BMA. The average performances are summarized in Table 1 in terms of the mean square error(MSE) per pixel and the number of matching points(NSP) per block. The NSP is the number of candidate blocks, which are compared with the current block to obtain the best-matching block. In general, the NSP per block is $(2w+1)^2$, where w is initial displacement. But the blocks at the frame boundaries have a smaller NSP than others. Therefore, the NSP is calculated by counting the number of blocks that are actually compared. The performance of the proposed search area adjustment method is compared with those of FSBMA, ABMA, and DASWF.

The proposed scheme has better MSE performance than ABMA with similar or less complexity. It has also similar MSE performance compared with the FSBMA and DASWF but only requires much less NSP. The MSE performance gain is not quite good in simulation with test sequences that have slow motion fields. But the NSP reduction is noticeable. Comparing with the FSBMA, ABMA, and DASWF only 25%, 50%, and 87% of NSP are required, respectively. With video sequences which have moderate motion fields such as *Carphone* and *Foreman*, the large MSE gain is obtained with less NSP in comparison with ABMA By simulation results, the proposed method for search area adjustment is compatible with the FSBMA but requires only a half or less computation complexities, especially in the applications of low bit-rate video transmission.

IV. CONCLUSION

A new method for reducing the search area using spatio-temporal information is described for low bit-rate video coding. The algorithm is very simple and efficient in terms of MSE performance and computational complexity. The method can be easily adapted to fast search algorithms which are developed so far such as the three-step search, 2-D logarithmic search, parallel hierarchical 1-D search, etc. to reduce computational complexity quite more.

Table 1 : Average MSE and computational complexity of each search area adjustment method

BMA method	Test video sequences							
	Miss America		Carphone		Foreman		Claire	
	MSE	Complexity	MSE	Complexity	MSE	Complexity	MSE	Complexity
FSBMA	6.96	886	66.10	886	94.92	886	9.17	886
ABMA	7.29	415	70.06	496	100.03	467	9.44	477
DASWF	7.02	376	67.24	498	96.44	459	9.23	416
Proposed	7.15	225	67.25	334	95.79	340	9.25	92

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