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A Motion-characteristics-based Unsymmetrical-cross Multi-hexagon-grid Search Algorithm for Fast Motion Estimation

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Abstract: H.264/AVC encoder achieved excellent encoding performance of at the cost of increased computational complexity and falling encoding speed. In order to overcome poor real-time encoding performance of video encoding, aiming at computing redundancy, based on the integration of visual selective attention mechanism and low complexity encoding of information analysis, making use of the macro-block's motion characteristics, a low-complexity motion estimation scheme is implemented in this study. The simulation results show that the approach encoding effectively resolves the conflict between coding accuracy and speed, achieve reduction of 23.11% motion estimation encoding time on average compared with UMHexagonS algorithm, which effectively maintains good video quality and overall improves the encoding performance of H.264/AVC video encoder.

Key words: Video encoder, motion estimation, UMHexagonS, macro-block

INTRODUCTION

H.264/AVC (Shen *et al*., 2013) is the most recent and promising international video coding standard developed by the ITU-T Video Coding Experts Group in conjunction with the ISO/IEC Moving Picture Experts Group. The new standard H.264/AVC aims at high-quality coding of video content at very low bit-rates and is designed for application in the areas such as broadcast, video-on-demand or multimedia streaming, multimedia messaging etc. over ISDN, DSL, Ethernet, LAN, wireless and mobile networks. Some new features and capabilities of the H.264 standard such as variable block size (7 types), quarter-sample-accuracy and multiple reference frames enable enhanced coding efficiency, compared with advanced standards, up to 50% of bit-rate reduction can be achieved but at the same time increase the complexity and computation load of motion estimation greatly in H.264/AVC encoder.

Motion Estimation (ME) is the basic bandwidth compression method adopted in the video coding standards, while it is the most time consuming module. The Block Matching Algorithm (BMA) is the most implemented one in real time for ME. BMA for ME is the mainstream algorithm for video compression, which has been adopted by many standards such as MPEG-1/2/4, H.263, H.264, etc. The key problem for BMA is to find the best matched motion vector in their reference frames for every macro-block.

FS algorithm is well-known and widely used because it is simple and accurate. It exhaustively tests all the candidate points within a pre-defined searching area in a reference frame to get the best matched motion vector, the calculation is huge. Especially for H.264/AVC, it adopts some effective features mentioned above to improve the compression quality. So FS have to calculate all the search points in the search window for all the variable 7 types block sizes (16×16, 16×8, 8×16, 8×8, 8×4, 4×8, 4×4) and reference frames.

To reduce the calculation burden of FS block motion estimation, in the past years, many fast motion estimation algorithms were presented. They can be classified in two categories. One type is to reduce the search points, such as three step search algorithm, four step search algorithm, diamond search algorithm, hexagon-base algorithm etc. These fixed pattern search algorithms can reduce the search points largely and get a good image quality. But when the actual motion does not match the pattern well, the image quality will decrease. The other type of algorithm is to reduce the calculation for every search candidate. It uses sub-sampling method and partial calculation. Sub-sampling method is efficient but not accurate, while the partial calculation is accurate but not enough efficient.

Recently several fast ME algorithms were proposed for H.264. They combine many methods together and

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achieve both fast speed and good image quality. Especially, UMHexagonS (Pan and Kwong, 2013) (Unsymmetrical-cross Multi-Hexagon-gird Search) algorithm has been adapted by H.264 reference software, claiming that nearly 90% computations can be saved on average compared with the fast FS algorithm in JVT reference software with a fairly good PSNR performance. However, based on many experiments results analysis, we find that the UMHexagonS algorithm is also complicated, speed-up of it is not very outstanding and it can be speed-up further.

In recent years, a lot of advanced motion estimation search algorithms have been proposed. Song and Akoglu (2013) raised variable block size motion estimation architecture and optimized in hardware. Park (2013) developed a search strategy based on multiple reference frames. Choi and Jeong (2013) proposed a constrained two-bit transform for low complexity motion estimation. Kim *et al*. (2013) proposed a novel motion estimation algorithm based on spectral image analysis and statistical object. Chen *et al*. (2012) firstly defined the clustering feature of MVs and reduction the motion estimation time successfully. The above novel motion estimation algorithms not only make full use of the advantages of the H.264/AVC but also combine the statistics with the scheme.

In this study, we proposed a novel motion estimation search algorithm. It makes use of MV distribution characteristics to decrease the search range and designs new search patterns based on motion features and achieves selecting search areas self-adaptively. The proposed algorithm enhances performance of UMHexagonS algorithm remarkably on the condition that the algorithm maintains a low bit rate and high video quality.

The remainder of this study is organized as follows. In section 2, some related works about the principle of motion estimation, UMHexagonS algorithm is introduced. Section 3 analyses the MV distribution characteristics and describes the method of search strategy with new search patterns. Experimental results are given to verify the effectiveness of the proposed algorithm in section 4. Section 5 gives the conclusions.

PRINCIPLE OF UMHEXAGONS ALGORITHM

UMHexagonS algorithm has been accepted for integer-pixel block motion estimation by H.264 reference software. It can actually reduce the computational load for ME by reducing the number of candidate blocks within a search window. To achieve the high coding efficiency and avoid the local-minimum problem, it is widely conducted

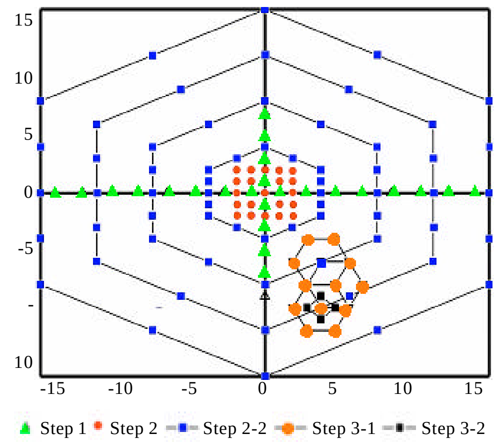

Fig. 1: Flow chart and the search pattern of UMHexagonS

into two parts: The first is initial search center prediction and the second is use the hybrid of integer pixel search.

Initial search center prediction: Generally speaking, spatial and temporal predictions are the main mechanisms for ME to find the Motion Vectors (MV) of the current block. These mechanisms generate four types of prediction means (Lin *et al*., 2009): Median prediction, Up-Layer Prediction, Corresponding block Prediction, Neighboring Ref-frame Prediction. UMHexagonS uses these prediction means to predict the initial search center with high veracity.

Search strategies of UMHexagonS algorithm: UMHexagonS can predict the motion vector accurately. There are three main steps in its search algorithm:

Step 1: Search begins with the unsymmetrical cross search. Taking a search range of 16 the defined search window is shown with the search points in Fig. 1 (step1)

Step 2: Best match of step1 gives the center point for the step2 search which is the 5×5 full search with the search points are shown in Fig.1 (step2-1) and the uneven multi-hexagon-grid search. The search points for this search are shown in Fig.1 (step2-2)

Step 3: Last search process uses extended hexagon-based search, composed of symmetrical-hexagon-grid search shown in Fig. 1 (step3-1) and a small diamond search shown in Fig. 1 (step3-2) until the center of the search pattern is the best candidate point

To find the optimum MV in these steps, UMHexagonS algorithm uses the hierarchical and hybrid motion search strategies. Obviously, the hybrid strategies exploit the irregularity of search patterns to find the best MV. The irregularity pattern search still causes a heavy computation overhead and limits the performance of ME speed.

PROPOSED ALGORITHM

In order to overcome the time-consuming ME, reduce the search points and the computational complexity in H.264/AVC, a fast ME algorithm for variable block sizes by classifying motion activity of macro-block based on the UMHexagonS algorithm is proposed in this study. The proposed method is composed of two parts.

Prediction of motion vector: Motion prediction is an important part in the ME. If get a good MV predictor, it means the search center is much nearer the best MV. It will need to calculate and compare less search points and have higher possibility to get the optimal MV. So we utilize four kinds of MV predictors, which are median MV predictor, up-layer MV predictor, corresponding block MV predictor and neighboring ref-frame MV predictor.

Median MV predictor is exploited the spatial relationship of neighbor macro-blocks. It is easy to find that neighbor macro-blocks have similar MV. So we can use the median value of the adjacent blocks on the left block (block A), top block (block B) and top-right (block C) of the current block (block E) shown in Fig. 2 to predict the MV of the current block. The equation of the median predictor is described in Eq. 1:

$$\text{Median\_preditro} = \text{median}\,[MV_A, MV_B, MV_C] \quad (1)$$

Up-layer MV predictor shown in Fig. 3 is to utilize in the variable block sized ME. In H.264, test all the 7 types

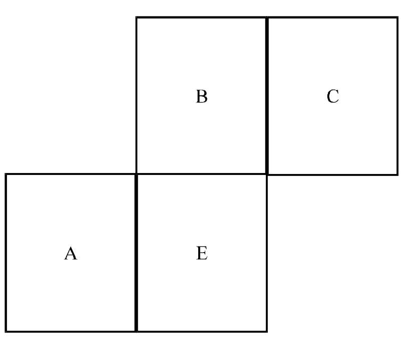

Fig. 2: Median MV predictor

of the current macro-block, choose the partition with lowest cost. Test big partition first and then turn to smaller ones gradually. The MV search of big partition is a guide for the small partition. It shows the trend of the movement of the macro-block. So the 16×16 macro-block's MV can be referenced by 16×8 or 8×16 macro-block, etc. The equation of up-layer motion vector predictor is described in Eq. 2:

$$\text{Up\_layer\_predictor} = \text{up\_layer}\,[MV] \quad (2)$$

The moving track of a moving object is continuous in the major portion of the video sequence. Corresponding block MV predictor utilizes this characteristic to calculate the MV of the corresponding block in the last frame which is used as one MV candidate. The equation of corresponding block motion vector predictor is described in Eq. 3:

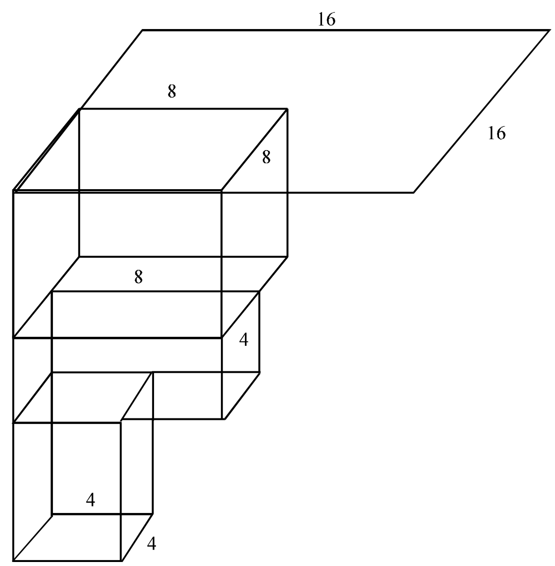

Fig. 3: Up-layer MV predictor

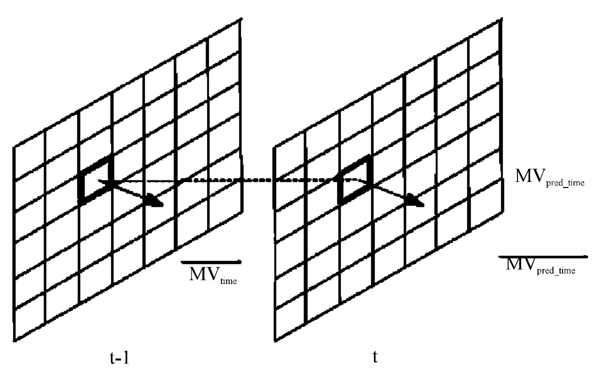

Fig. 4: Corresponding block motion vector predictor

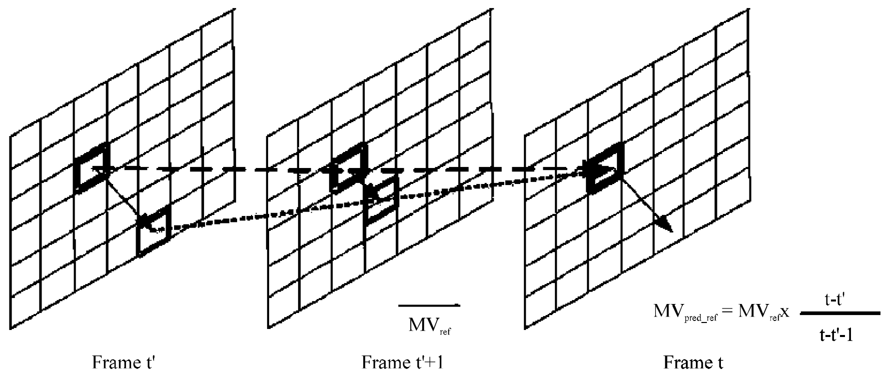

Fig. 5: Reference frame motion vector predictor

$$CP\_predictor = lastframe\_MV \quad (3)$$

Reference frame MV prediction is to utilize the temporal relation ship of the same macro-blocks in neighbor frames. The temporal neighbor of reference frame has the similar MV. So we can use this similarity to do MV prediction. The current block's MV in reference frame t' can be predicted by scaling the current block's MV in the reference frame t'+1, Eq. 4 and Fig. 5 shows the approach:

$$NR\_predictor = MV_{NR} \times \frac{t-t'}{t-t'-1} \quad (4)$$

Flexible search criterion: After the initial search center having been predicted high accurately, adaptive search pattern will be selected according to the motion activity of the macro-block based on the original search pattern of UMHexagonS algorithm. This part includes three main techniques.

Modify the search pattern: For original search pattern of UMHexagonS algorithm in the step2-2, it can be find that the uneven multi-hexagon-grid search adopts hexagon-grid search pattern with 16 points all the time. Assume that 16 points of the outmost layer can satisfy the search demand, it will be redundant for the benmost layer still adopts 16 points in the search criterion. So in the proposed algorithm, we modified the original uneven multi layers-hexagon-grid search pattern shown in Fig. 6. In step2-2, the search points of each layer will increase with the extent of the search radius. From inside to outside layer, the search points are 8, 8, 12 and 16, respectively. The modified search pattern can maintain the search precision and reduce the unnecessary search points to enhance the efficiency of the ME.

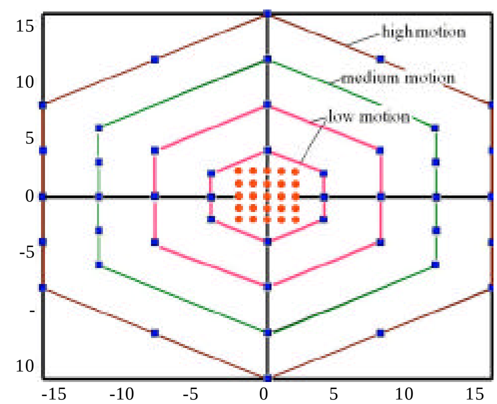

Fig. 6: Modified search pattern for step2-2

Search layer changed according to motion activity: According to the RD (Rate-Distortion) cost (Tang and Nasiopoulos, 2010) of MVs in adjacent blocks, the motion search pattern is classified to three categories: Low, medium and high motion activity. The categories determine the search pattern respectively shown in Fig. 6. The detail search strategy is as following.

- **In case of low motion activity:** The uneven 2 layers-hexagon-grid search pattern is used because it is expected that the optimal current MV would be near the origin
- **In case of medium motion activity:** The uneven 3 layers-hexagon-grid search pattern is performed
- **In the case of high motion activity:** It is easily expected that the optimal motion vector would be far from the initial search center, so the uneven 4 layers-hexagon-grid search pattern is selected for search pattern

The motion activity of the current macro-block is defined as follows:

Table 1: Compared simulation results of the proposed algorithm with FS and UMHexagonS algorithm

Compared algorithm	Full search algorithm			UMHexagonS algorithm			Proposed algorithm		
Simulation results	ME-time (sec)	Bite-rate (kbps)	PSNR-Y (dB)	ME-time (sec)	Bite-rate (kbps)	PSNR-Y (dB)	ME-time (sec)	Bite-rate (kbps)	PSNR-Y (dB)
Coastguard	131.989	244.85	34.01	32.678	245.66	34.01	26.648	245.16	34.02
Forman	128.340	132.62	36.44	24.251	131.50	36.43	20.198	131.87	36.43
Akiyo	128.581	29.47	38.25	10.397	29.53	38.28	9.001	29.45	38.28
Miss America	132.322	32.39	40.15	11.099	32.16	40.13	9.097	32.48	40.13
Mother and daughter	131.103	46.99	37.44	14.472	46.88	37.40	12.084	47.11	37.43
Mobile	128.202	422.85	33.34	27.861	420.01	33.34	23.369	421.83	33.34
Performance comparison with FS, UMHexagonS algorithms on average	ME-time Δ(%)	Bite-rate Δ(%)	PSNR-Y Δ(dB)	ME-time Δ(%)	Bite-rate Δ(%)	PSNR-Y Δ(dB)			
	-87%	-	-	-17%	-	+0.007			

Annotations: ME-time: Motion Estimation time, -: Almost the same level "-" Means reduce "+" Means increase

$$
\begin{aligned}
&\text{motion activity} = \text{low}; \quad \text{minRDcost} < (1+\varepsilon)\times \text{predminRDcost}\\
&\text{motion activity} = \text{medium}; \ (1+\varepsilon)\times \text{predminRDcost} < \text{minRDcost}\\
&\qquad\qquad < (1+\delta)\times \text{predminRDcost}\\
&\text{motion activity} = \text{high}; \quad \text{minRDcost} > (1+\delta)\times \text{predminRDcost}
\end{aligned} \tag{5}
$$

Here, minRDcost is the minimum RD cost of the current MV, predminRDcost expresses the minimum RD cost of the prediction MV. ε and δ are the adjustable coefficient (Sullivan and Wiegend, 1998):

$$\varepsilon = \frac{\text{Bsize[blocktype]}}{\text{predminRDcost}^2} - \alpha_{\text{Radii1}}[\text{blocktype}]$$

$$\delta = \frac{\text{Bsize[blocktype]}}{\text{predminRDcost}^2} - \alpha_{\text{Radii2}}[\text{blocktype}]$$

$$\alpha_{\text{Radii1}}[\text{blocktype}] = [-0.23, -023, -0.23, -0.25, -0.27, -0.27, -0.28]$$

$$\alpha_{\text{Radii2}}[\text{blocktype}] = [-2.39, -2.40, -2.40, -2.41, -2.45, -2.45, -2.48]$$

Selected 5×5 full search technique: In the original UMHexagonS, after doing initial search center prediction, it is expected that the optimal MV would be close to the origin search center, so it do 5×5 full search primarily in step2-1.

But according to the analysis above, if the motion activity is higher, the optimal motion vector is not near the origin search center, the 25 search points are unnecessary and time-consuming. So in the proposed algorithm, only when the motion activity belongs to the low motion, 5×5 full search (Fig. 6) will selected.

EXPERIMENTAL RESULTS AND COMPARISON

The proposed algorithm is integrated with JM 12.2 of the H.264 software for verification with 6 video sequences consisted of different degrees and types of motion content in QCIF format, those are fast motion sequence Coastguard, middle-speed motion sequence Forman, slow motion sequence Miss America and Akiyo, with a lot of detail and scene horizontal motion sequence Mobile. The simulation experiment parameter setting is as follows. Each test sequence contains 100 frames, IPPP structure. The quantization parameter QP is fixed at 28, B frame option is turn off, 5 reference frames, search range is 16 pixels, use Hadamard transform and CAVLC entropy coding.

Compare the performance of the proposed algorithm with that of FS and UMHexagonS. The simulation results show that the proposed algorithm consistently produces good performance of motion estimation time. Compared with UMHexagonS, it has saved nearly 20% ME time, the PSNR is compatible to that of FS, while maintaining the same coding efficiency level.

Table 1 shows the compared simulation results of ME time, Bit-rate and PSNR.

CONCLUSION

In this study, we proposed a fast motion estimation algorithm based on UMHexagonS algorithm for H.264 encoder, which matches different motion contents of video sequence for macro-block. It can not only find the initial search center accurately but also modified the search pattern of UMHexagonS algorithm and reduce the search points further to enhance the ME efficiency. Simulation experimental results indicate that, the proposed algorithm achieves the significant calculation burden reduction with almost the same level in PSNR performance compared with that of FS and UMHexagonS algorithms. The proposed method is a very efficient and robust ME algorithm for real-time video coding applications. The fast speed-up performance and unnoticeable quality losses make the proposed search criterion outperform the famous ME algorithm UMHexagonS.

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REFERENCES

Choi, C. and J. Jeong, 2013. Constrained two-bit transform for low complexity motion estimation. Proceedings of the IEEE International Conference on Consumer Electronics, January 11-14, 2013, Las Vegas, NV., pp: 350-351.

Chen, K., Z. Zhong and W. Wei, 2012. Clustering based search algorithm for motion estimation. Proceedings of the IEEE International Conference on Multimedia and Expo, July 9-13, 2012, Melbourne, VIC., pp: 622-627.

Sullivan, J.G. and T. Wiegend, 1998. Joint video team, rate-distortion optimization for video compression. IEEE Sig. Process. Mag., 11: 74-90.

Kim, S.G., T.G. Ahn and S.H. Park, 2013. Motion estimation algorithm for periodic pattern objects based on spectral image analysis. Proceedings of the IEEE International Conference on Consumer Electronics, January 11-14, 2013, Las Vegas, NV., pp: 310-311.

Lin, C.C., Y. Lin, H.J. Hsieh, 2009. Multi-direction search algorithm for block motion estimation in H.264/AVC. IET Image Process., 3: 88-99.

Park, C.S., 2013. A general search strategy for multiple reference frame motion estimation. Proceedings of the IEEE International Conference on Consumer Electronics, January 11-14, 2013, Las Vegas, NV., pp: 326-327.

Tang, Q. and P. Nasiopoulos, 2010. Efficient motion re-estimation with rate-distortion optimization for MPEG-2 to H.264/AVC transcoding. Proceedings of the IEEE Transactions on Circuits and Systems for Video Technology, Volume 20, February 2010, IEEE Circuits and Systems Society, pp: 262-274.

Song, Y. and A. Akoglu, 2013. An adaptive motion estimation architecture for H.264/AVC. J. Signal Process. Syst., 73: 161-179.

Shen, T., Y. Lu, Z. Wen, L. Zou, Y. Chen and J. Wen, 2013. Ultra fast H.264/AVC to HEVC transcoder. Proceedings of the Data Compression Conference, March 20-22, 2013, Snowbird, UT., pp: 241-250.

Pan, Z. and S. Kwong, 2013. A direction-based unsymmetrical-cross multi-hexagon-grid search algorithm for H.264/AVC motion estimation. J. Signal Process. Syst. Signal Image Video Technol., 73: 59-72.