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Application of inter-frame motion compensation compression coding based on modified block-matching MC fast searching algorithm

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ABSTRACT

This paper anal sized obtained MC fast searching algorithm and proposed a modified block matching MC fast algorithm. This method carried out the search in the combination of Square Search method and current Hexagon-based Search method, considering completely various video sequence chrematistics, and proved that the search points for the improved algorithm reduced in some extent by Simulation experiment, which provided theoretic basis for improving the compensation function effectively.

KEYWORDS

Block matching;
MC fast searching;
The correlation of motion vectors;
Signal-noise ratio.

INTRODUCTION

Multimedia Technology is a computer-used technology by which multiplied media information is processed integrated, which included text, figure and image, animation, audio frequency and video etc. however, the media data amount becomes larger after digitization, so how to store, convey and process these digits become a basically problem which must be solved for the Multimedia Technology developing. As for solving the problem, it is not economical and realistic to just employ some hardware conditions such as enlarging the storage capacity, adding transmission rate, improving processing speed and so on, therefore, the technology of increasing data size becomes a main focus. "Along with it come the multimedia data compression technology, which is a effective means for solving problem of large data amount. Digital technology is applied widely in computer field, so television, broadcast, video, and communication technology are transformed from traditional constant signals and the way of mimetic signals to discrete signal and the way of digitization. Among the various media, the Transmission and storage draw much attention. Video data is a kind of no formatted streamed data, which is along with video data transmission. Video data has the characteristic of great capacity, which is tens of thousands of times as great as the capacity of text data, also more than four but less than eight times as great as that of video data. To deal with the application of some problems in different occasions, such as data video broadcast(DVB), data video disc(DVD), digital Video Camera, Tele-teaching, on-line broadcasting and video meeting, ISO (International Organization for Standardization) and some great international companies formulated different kinds of video coding standards. MPEG-4 is one of the important and bowlful standards on multimedia data contraction coding. By studying coding and compressive principle, it can be seen that the key of the compressive object is Motion Compensation algorithm whose advantages and dis-

advantages influence the compression quality of multimedia dada directly.

Many people made efforts for the research on multimedia compression technology, whose result has been well-applied, and provided great theoretical basis. this paper anal sized obtained MC fast searching algorithm and proposed a modified block matching MC fast algorithm. This method carried out the search in the combination of Square Search method and current Hexagon-based Search method, considering completely various video sequence chrematistics, and proved that the search points for the improved algorithm reduced in some extent by Simulation experiment, which provided theoretic basis for improving the compensation function effectively.

MC FUNDAMENTAL PRINCIPLE AND BLOCK MATCHING ALGORITHM

MC fundamental principle

In most cases, just few parts of moving images are in moving state, there is little difference in content between two adjacent frame images in the same scene, that is, many contents of neighboring frames are repetitive. it can explain that frames in neighboring images are relevant. Some opinions in Information Theory by Claude Elwood Shannon also can explain that there exists data redundancy in moving images, actually time redundancy, which exists largely in video images.

If interface predictive coding can clearly remove redundancy in time domain, the compensation ratio can be raised during compensating. if the Pixel value in the same former frame space site is used as predictive value of current frame, this prediction towards the stationary background in image is effective., but as for the motoring part, this simple inter-frame prediction

Without considering object motion is not good. If the method exists

When the pixel value of current frame is predicted, which is moved from the position of former frame. Suppose that the pixel value is used as predictive one, the accuracy of the prediction will be improved greatly, the method of which is Motion Compensation technology. Motion Compensation is the key technology to reduce time redundancy, which can ensure which position of former frame the pixel of current frame comes from, and can obtain their own motion vector of relative displacement. afar obtaining the vector, its difference value block can be worked out by motion compensation. As the tive pixel gray value in difference block become smaller, even zero, Motion Compensation has higher accuracy. Meanwhile, the difference block is through DCT transformation, quantization and entropy coding, afterwards, bits figures of the compensation code stream become fewer, thus, the aim of compensating image data is achieved, and its compensating space is great relatively.

MC based on block matching

MC, as the key of inter-frame motion compensation technology, drew much attention. As to the research for this technology, different kinds of research plan arised, mainly including Optical flow equation method, Bayesian estimation method, pixel recursive method and block matching method. The block matching method has the characteristic of low computational complexity, less computation and strong real-time, so it becomes the mainstream, and international standard on video compression also adopts the block matching method as the MC solution.

The MC fundamental idea based on block matching method is that current frames are divided into unoverlapping sub blocks of same size, each current block lies in the area of reference frame, and search the nearest block according to a certain searching criteria, which is defined as matching block or predicting block. The Displacement coordinate between Matching block and current block is called motion vector, and the pixel difference value between them is called difference value block, thus, every block of current frames can be indicated by a difference block and a motion vector, and the codes of current frame are transformed as quantization codes towards every difference block and every motion vector. Therefore, the actual transferred data didn't compress pixel data, but transfer motion vector and residual block, when the value of Obvious difference block and motion vector is smaller, the compression has more advantage so that the bits numbers of actual transmission decrease greatly. So the main purpose of MC is making the value of the residual block and motion vector between matching-block and current block smaller, thus, the corresponding displace-

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ment of the minimum matching-error reference block is the wanted motion vector.

Before conducting MC, the sub-block's shape, size, Search window size, search seven point s, search strategy and matching norms should be confirmed.

Block matching criterion function

The MC basic idea is to divide every frame of image sequence into lots of unoverlaped macro-blocks, and it believes that the displacement amount of all the pixels in macro-blocks is identical, then to find out the similar block with current block and the matching block within the given search range from every block in current frame to the one in previous frame according to certain matching norms. The motion displacement result can be worked out by relative position of matching block and current block, so, the obtained motion displacement is the motion vector (MV) of current block. The situation before and after the movement is as shown in Figure1:

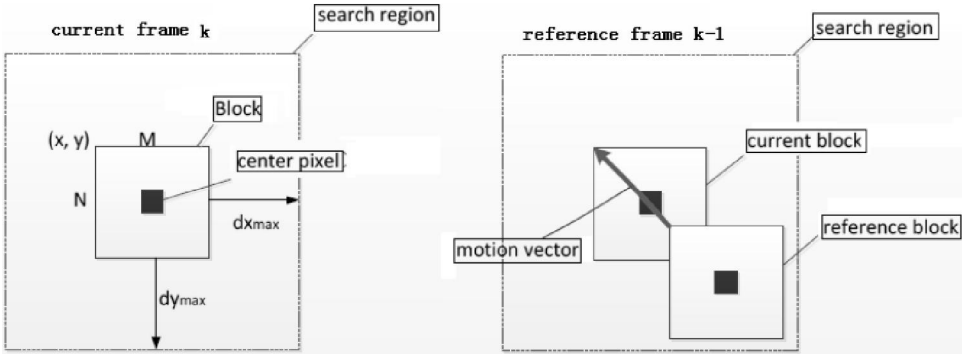

Figure 1 : The diagram for relative movement of current block and matching block

Suppose Formula 1 is treated as target function and its minimum value is shown and the minimum value of $MSE(i_0, j_0)$ exists when considering (i_0, j_0), then, (i_0, j_0) can be defined as the optional motion vector. compared Formula 1,2,3, the accuracy of MSE is higher, but its complexity degree is greater. The minimum value of MAD and MSE is equivalent, which reduced power operation, simplify the operation, but the operation amount of SAD norm is the least and the computation becomes simpler. Though it is related to solve absolute value using signed magnitude arithmetic, the properties is very close to MSE. At present, SAD is usually used as block matching norm in MC algorithm, its corresponding motion vector is defined in formula 4 below:

Definition: the size of macro block is M×N, $f_k(m,n)$ represents the pixel value of position coordinates in current frame, which is (m,n). $f_{k-1}(m+i,n+j)$ represents the pixel value of the neighboring previous frame in this frame, in which the position coordinates is $(m+i,n+j)$, and (i,j) indicates the relative displacement of this matching block and current macro block. Thus the expressions of mean absolute difference (MAD) function, sum of absolute difference(SAD) and minimum mean square error(MSE) are as shown in Formula 1,Formula 2,and Formula3:

$$\mathbf{MAD(i,j)=\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}\left|f_k(m,n)-f_{k-1}(m+i,n+j)\right|} \quad (1)$$

$$\mathbf{SAD(i,j)=\sum_{m=1}^{M}\sum_{n=1}^{N}\left|f_k(m,n)-f_{k-1}(m+i,n+j)\right|} \quad (2)$$

$$\mathbf{MAD(i,j)=\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}\left|f_k(m,n)-f_{k-1}(m+i,n+j)\right|^2} \quad (3)$$

$$\mathbf{MV=(i,j)}\Big|_{\min SAD(i,j)} \quad (4)$$

MC FAST SEARCH ALGORITHM

The purpose of movement searching is to find the optimal matching point. During the course of searching, different beginning prediction methods and block matching norms are adopted to quicken the searching or improve the precision. Whether the searching strategy is proper or not has great impact on the accuracy and speed of motion estimation. The following will introduce new Three Step Search (TSS) algorithm, Four step Search (FSS) algorithm, Diamond Search (DS) algorithm so as to explore the improved programmed

of MC fast search algorithm

New Three Step Search(NTSS) algorithm

STEP1: Establish a starting point as the center, including the largest search window, and then as is shown in Figure 2, through calculation, eight step size is equal to the average point in the maximum search range, or slightly greater than it, and the matching error of eight adjacent point and the starting point is also shown as follows;

① When the minimum point of matching error is the starting one, the starting point acts as the search result, and searching will end;

② When the minimum matching error point is the neighboring point around the starting point and this point acts as the center, find the three Black spots in Figure 3, or the matching error of five black spots in Figure 4, then, minimum point of the matching error is the final search result

③ When not meeting the condition ① and ②, go to STEP2;

STEP2: if the minimum point of matching error in

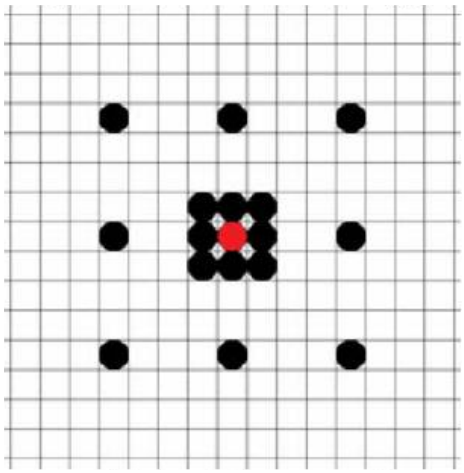

Figure 2 : Position diagram in which eight-steps is equal to the general point of maximum search range

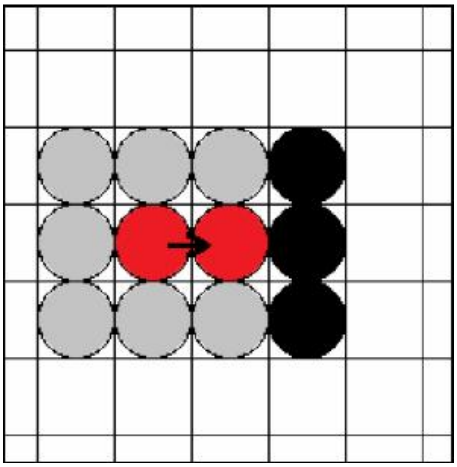

Figure 3 : Position diagram of three black spots

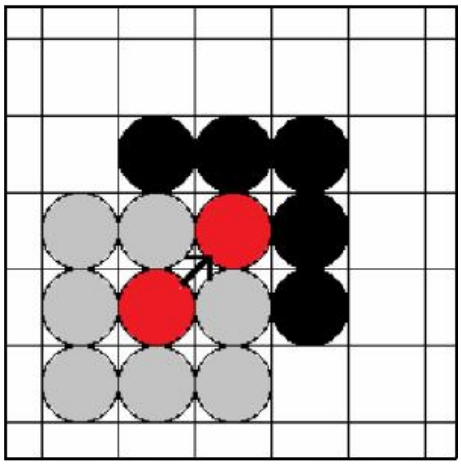

Figure 4 : Position diagram of five black spots

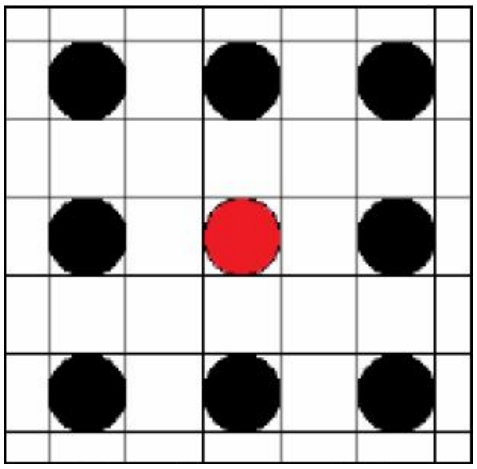

Figure 5 : Position diagram of nine black spots

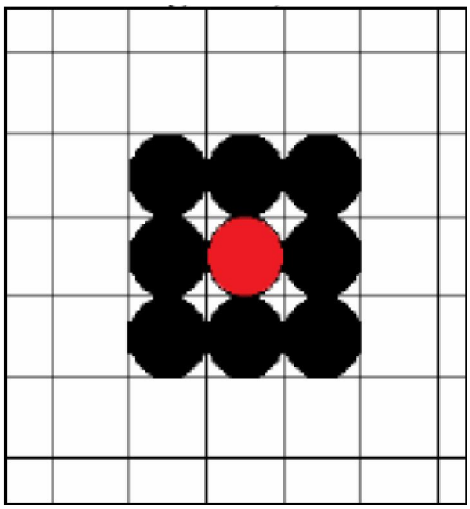

Figure 6 : Position diagram of the minimum matching error point

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STEP1 acts as the center, and the step size is half of the original steps, calculation result of matching error of nine points is as shown in Figure 5;

STEP3:Repeat STEP2 until the step size is number one, and find out the minimum matching error point from Figure 6, which is exactly the search result.

Figure 7shows three examples of three new steps route

Four steps MC fast searching algorithm

STEP1: for The maximum search range 7, establish a 5 × 5 window based on starting point as the center, and calculate the matching error of nine points is shown in Figure 8. If the minimum matching error point is the center, it will jump to the STEP4, otherwise, jump to STEP2;

STEP2:considering the minimum matching error point as the new window center, create 5 * 5 window;

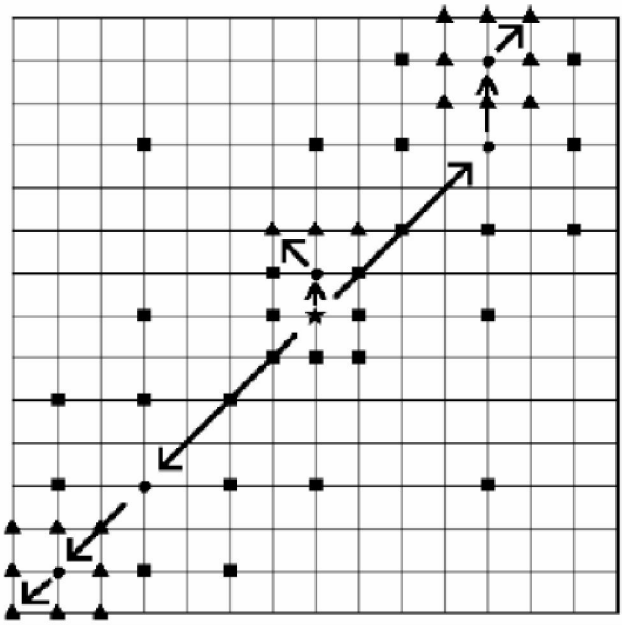

Figure 7 : Three new steps route diagram

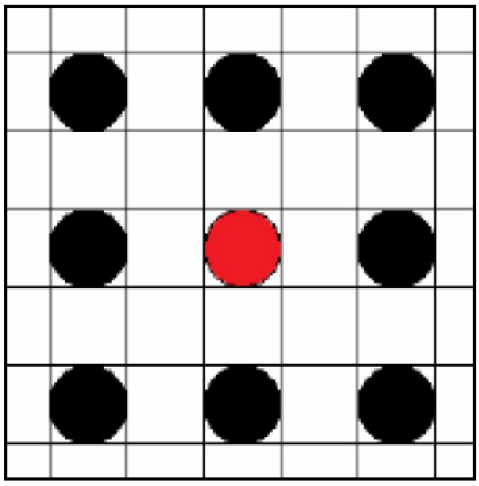

Figure 8 : Relative position diagram of nine points

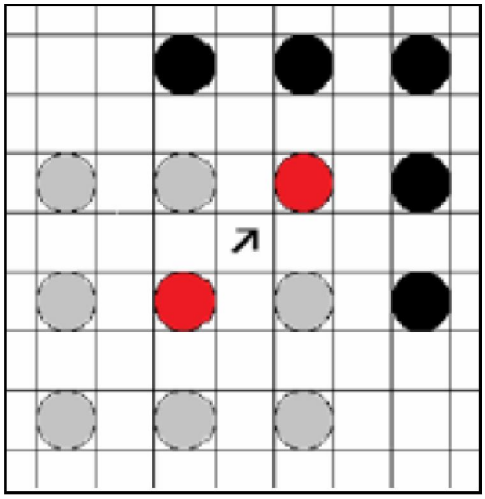

Figure 9 : Position diagram for five black spots

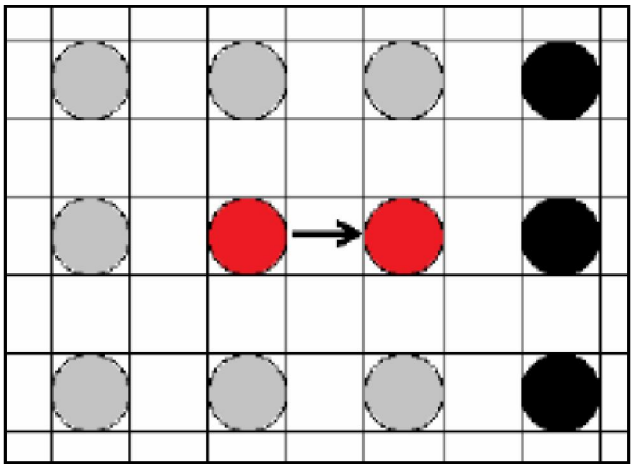

Figure 10 : Position diagram for three black spots

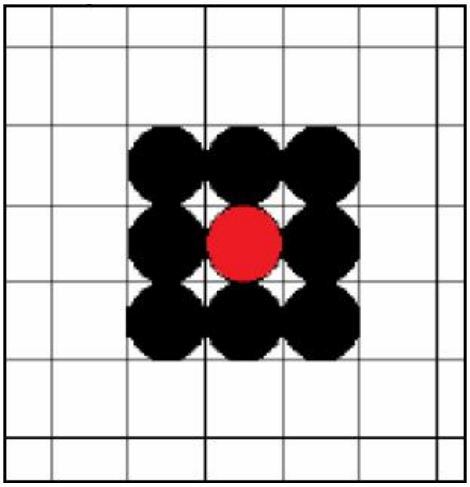

Figure 11 : Position diagram for the minimum matching error point

① When the minimum matching error points found before are the four angles, calculation of matching error of five black is as shown in Figure 9, then find the minimum matching error point;

② When the minimum matching error point found before is the center, calculation of matching error of three black is as shown in Figure 10

When the matching errors of these points are larger than the center point, jump to STEP4, otherwise, jump to STEP3;

STEP3: As is the same in the Operation method of STEP2, but eventually it will jump to the STEP4;

STEP4: search window reduced to 3 × 3, find the minimum matching error points from nine points in Figure 11, the point at which is the search result

Figure 12 show two example of four steps route

Diamond MC fast search algorithm

STEP1:for The maximum search range 7, establish a 5 × 5 window based on the starting point as the center, and calculate the matching error of nine points is shown in Figure 13. If the minimum matching error point is the center, it will jump to the STEP3, otherwise, jump to STEP2;

STEP2:considering the minimum matching error point as the new window center, create 5 * 5 window;

① When the minimum matching error points found before are the four angles, calculation of matching error of five black is as shown in Figure 14, then find the minimum matching error point;

② When the minimum matching error point found before is the center, calculation of matching error of three black is as shown in Figure 15

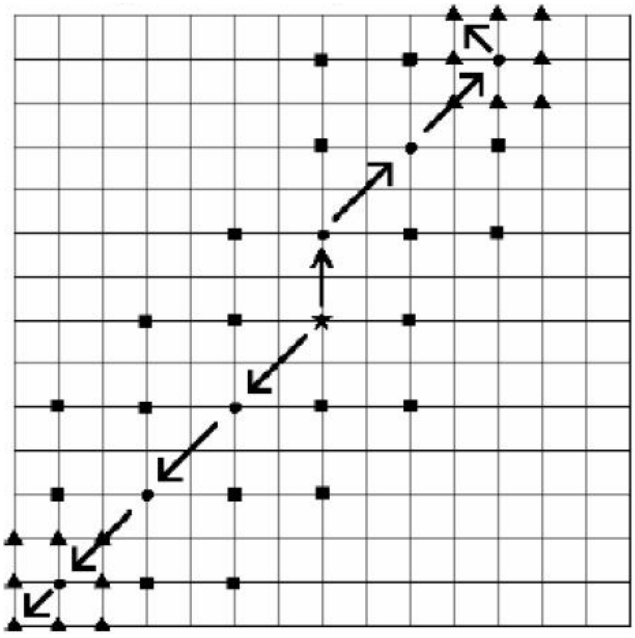

Figure 12 : Two route diagrams for four steps

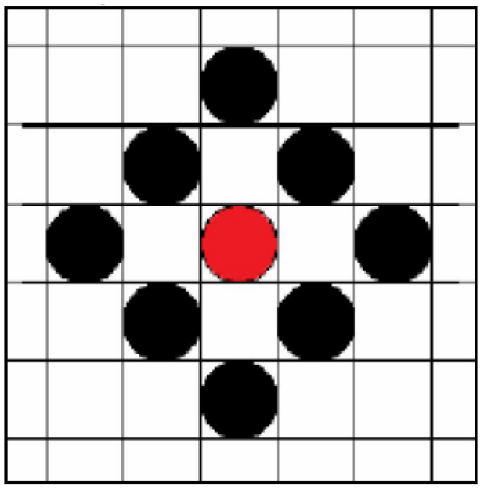

Figure 13 : Relative position diagram of nine points

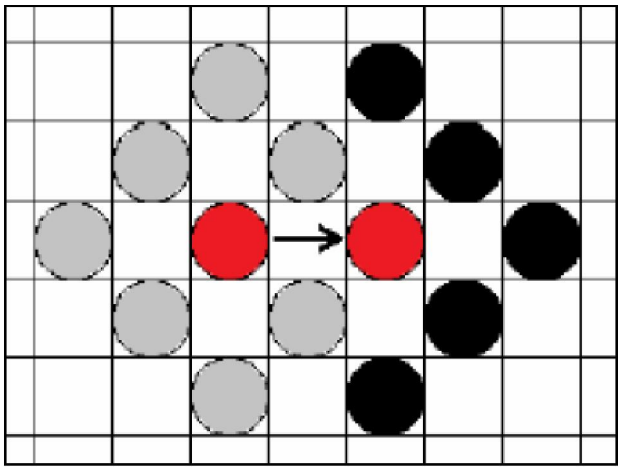

Figure 14 : Position diagram of three points

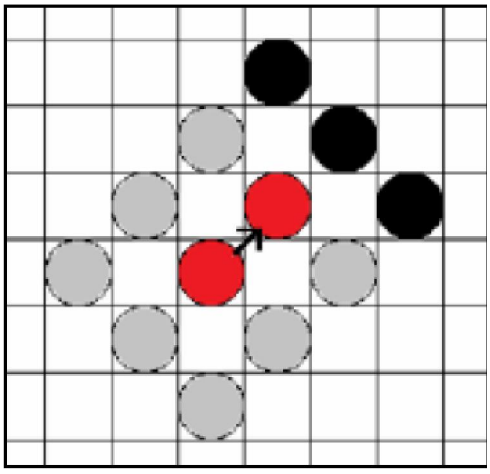

Figure 15 : Position diagram of five points

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③ When not meeting the condition ① and ②, go to STEP2;

STEP3:search window reduced to 3 × 3, find the minimum matching error points from nine points in Figure 16, the point at which is the search result

Figure 17show the example of two diamond algorithm routes

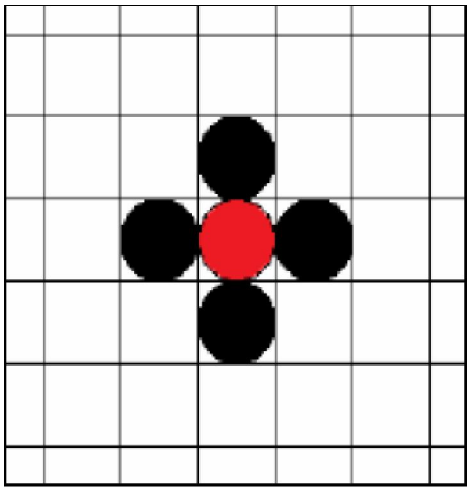

Figure 16 : Position diagram for the minimum matching error point

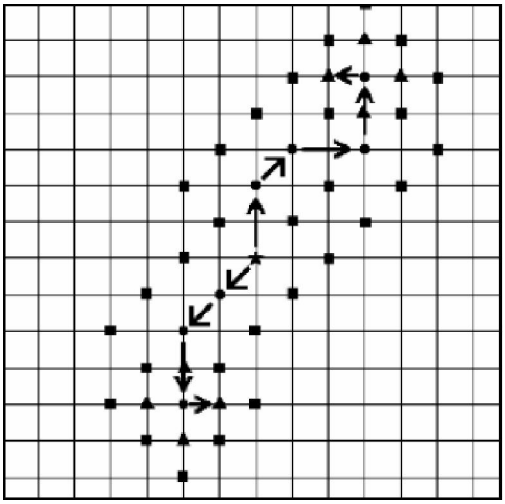

Figure 17 : Two route diagrams for diamond algorithm

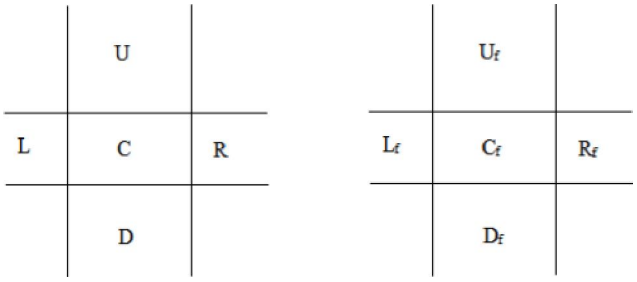

Figure 18 : The domain correlation characteristic of motion vector

MODIFIED BLOCK-MATCHING MC ALGORITHM ANALYSIS

Motion vector relativity analysis

In video sequence, there is higher relativity between neighboring interfaces. When frame rate is higher, the relativity becomes more obvious. Video object possesses the continuous movement characteristic, so there exists the relativity towards time and space when the macro block motion vector of video sequence movement characteristic is described. Especially, between neighboring block, motion vector usually has higher relativity. For example, Figure 8 showed time-space domain correlation characteristic of motion vector. suppose C is the block of the current code, L, U, R, D are respectively the left neighboring block, the above one, the right one and the below one, while C_f, L_f, U_f, R_f, D_f is the correspondent block in the previous frame.

Suppose the motion vector of L,U,C_f,U_f,R_f,D_f is respectively V_1-V_5, and as for V_3, each motion vector meets formula (5), the motion correlation among the blocks is believed to be higher. If the motion vector is zero, it is indicated that the domain alteration is placid. Then, there is no need to perform the following motion estimation, thus, the calculation time of encoder is saved, otherwise, the motion correlation among the blocks close to block C will be believed to be lower, which shows the change in the area is stronger.

$$|V_i - V_3| \le Th0 \quad (5)$$

In Formula 5, $Th0$ indicates the threshold value, it is important to choose the threshold value, if it is chosen too small, the advantage of this algorithm can not be shown, on the contrary, some still block may be judged as zero vector block so that the image quality

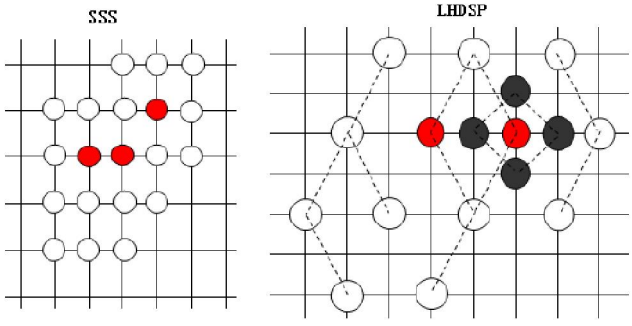

Figure 19 : The position diagram of two Pattern points

after motion compensation will be reduced. Many experiment proved that when $Th0 = 512$, about 40% of the macroblocks are judged as zero motion vectors, which can escape motion estimation and its image quality didn't debase subjectively, also, in the occasion that image movement is not clear, the threshold value is very proper.

For the region where the movement is sharp, generally, use the small partition mode, such as 8×4, 4×8 and 4×4, but for moving-slowly area, use the large partition mode, such as 16 x 16, 16 x 8, 8 x 16 and 8 x 8. So, so, according to the motion correlation height, the size of motion estimation compensation block. can be determined

The determination of the initial search point and elimination standard

Usually between adjacent blocks motion vectors exists high correlation, so the initial motion vector of the current block can be predicted in accordance with the motion vector of current and adjacent block, the motion vector of the current block on the left side, the top side, and the upper right can be chosen to make predictions, according to the median of three vectors as predictive vector, from which the initial search point. can be determined

According to the principle of mathematical absolute value, formula (6) and (7) can be carried out as follows;

$$\mathbf{f_k(m,n) - f_{k-1}(m+i,n+j) \le \left|f_k(m,n) - f_{k-1}(m+i,n+j)\right|} \quad \mathbf{(6)}$$

$$\mathbf{f_{k-1}(m,n) - f_k(m+i,n+j) \le \left|f_k(m,n) - f_{k-1}(m+i,n+j)\right|} \quad \mathbf{(7)}$$

find the cumulative sum for two ends of the type (6) and (7) respectively, formula (8) and (9) is available as follows:

$$\mathbf{\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f_k(m,n) - \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f_{k-1}(m,n) \le SAD(i,j)} \quad \mathbf{(8)}$$

$$\mathbf{\sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f_{k-1}(m,n) - \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f_k(m,n) \le SAD(i,j)} \quad \mathbf{(9)}$$

If parameter C represents the sum of all pixel values in the current block,then, expression C is as shown in formula (10)

$$\mathbf{C = \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f_k(m,n)} \quad \mathbf{(10)}$$

If parameter R represents the sum of all pixel values in the reference block, then, expression R is as shown in formula (11)

$$\mathbf{R(i,j) = \sum_{m=0}^{M-1}\sum_{n=0}^{N-1} f_{k-1}(m+i,n+j)} \quad \mathbf{(11)}$$

During the actual search process, only when the absolute difference sum $SAD(i, j)$ of the current block and the reference block is less than the gained absolute difference sum $SAD(x, y)$, reference block matching calculation is required. If the absolute difference corresponding with the motion vector (x, y) is the current minimum value, then when calculating the absolute difference sum of the next search point for the block, formula (12) should be meet as follows:

$$\mathbf{SAD(i,j) \le SAD(x,y)} \quad \mathbf{(12)}$$

when calculation of the absolute difference sum of the next search point for the block can not meet formula (12), stop calculating. Thus, duo to (8), (9), (10), (11), (12), formula(13) can be drawn as follows:

$$\mathbf{C - SAD(x,y) \le SAD(i,j) \le C + SAD(x,y)} \quad \mathbf{(13)}$$

From the formula (13), it can be known that the matching calculation is required when $R(i, j)$ is greater than or equal to all the pixel value of the current block and the difference of the minimum SAD value, or, is less than or equal to all pixel value of the current block and sum of the minimum SAD value. so judging by the criterion condition, the match block without being calculated can be removed, the amount of calculation can be cut down, and the search speed Can be improved relatively.

Hexagon-based algorithm and the improved fast search algorithm

Hexagon-based search algorithm is a improved algorithm of diamond algorithm, the algorithm steps are shown as follows

STEP1: determine the starting point of the search, and the point as the search center;

STEP2: Perform hexagon search around the cen-

tral point, calculate SAD of the various points, when the minimum value acts as the center point, then jump to the STEP3, otherwise, move the center point to the minimum value point, repeat this step, when knowing the minimum value appear in the halfway point, then jump to the STEP3;

STEP3: Adopt a large diamond search algorithm, calculate SAD of the various points the, among it, corresponding point for the minimum SAD value is the optimal matching point.

Two different search ranges are adopted in hexagon algorithm, and always first pass through the search range and then turn to the small search range. But in real video sequences, most of the background did not move, so the algorithm leads to great calculating redundancy for block motion estimation whose the motion vector is almost zero, reduces the search speed;

The fixed step size is used in all the reference images, so the image of sharp movement and that of changing-slowly can not be met simultaneously. So, based on this, this paper presents an improved fast search algorithm.

According to the different motion correlation of predictive motion vector and its adjacent ones, adopt two templates, which are Square Search Pattern and Large Hexagon Diamond Search Pattern, as is shown in Figure 19

Square search template is expressed as SSS in Figure 19, the initial search point as the center, which forms components with the eight adjacent surrounding points, if the minimum value point is the center, stop searching, then the center point is the final motion vector. If the minimum point is on the edge, the minimum value point considered as the center, do the next search computation with its surrounding the eight points adjacent to it, until the minimum value becomes center point. If the motion correlation between adjacent blocks is relatively high, and the predicted motion vector value is zero or close to zero, then, use SSS search template. Large hexagon search template in Figure 19 is shown as LHDSP, if the motion correlation between adjacent blocks is relatively low, the LHDSP search template is used.

Improved search algorithm steps are shown as follows:

STEP1: determine the predicted motion vector of current block and the initial search point, and judge the movement correlation among adjacent blocks;

STEP2: if the correlation between adjacent blocks motion is high, the predicted motion vector value is very small or zero, then jump to the STEP5, otherwise, jump to STEP3;

STEP3: LHDSP template is used to do searching, compute SAD value of the seven points, meanwhile, make condition judgment using the exclusion criteria, when the minimum value point acts as the center, then, jump to the STEP4, or repeat STEP3, until the center point of the minimum value point appears, then jump to the STEP4;

STEP4: A small diamond is made of four points which are respectively the upper, the lower, the left, the right around center point, by which SAD values of five points are calculated, and make condition judgment using the exclusion criteria. The smallest point of SAD value is the final motion vector;

STEP5:Employ SSS template to search, commutate SAD values of nine points, meanwhile. make condition judgment using the exclusion criteria. If the minimum value point acts as the center point, the motion vector of the corresponding point is the final motion vector. If the minimum value point is the edge points, repeat STEP5, until the minimum point appears.

Comparison of algorithm evaluation and results

Evaluation standard of an MC algorithm is to find out the matching effect and the time complexity of searching. Matching effects can be obtained by subjectively assessing quality of reconstructed image, quantitative standards of evaluation of image quality can be measured by the average peak signal noise ratio PSNR of image or average MSE, whose calculation formulas are as shown in formula (14) and (15).

$$\mathbf{PSNR = 10\lg\left(\frac{x_{max}^2}{MSE}\right)} \quad \mathbf{(14)}$$

$$\mathbf{MSE = \frac{1}{N^2}\sum_{i=1}^{N^2}(x_i - \bar{x}_i)^2} \quad \mathbf{(15)}$$

In formula (14) and (15), $x_i, \bar{x}_i$ indicates respectively the original image, and corresponding pixel value, x_{max} is the pixel maximum gray value in the original

image, for $x_{max} = 225$ by 8 bit quantization, N^2 represents the total pixel of N * in N images.

Data comparisons are as shown in Table 1 for New three step search (NTSS), four step search (FTS), diamond search (DS)algorithm, hexagon-based search (HS) and modified algorithm in terms of time-consumption and quality.

From data comparisons in TABLE 1, it can be seen that modified algorithm has an advandage over the other five algorithms in terms of time-consumption and quality

TABLE 1 : Data comparison

search algorithm	Consumed time(second)	signal noise ratio
New three step search (NTSS)	0.900035	37.2834
four step search(FTS)	0.948070	37.4156
diamond search (DS)	0.923841	37.2633
hexagon-based search(HS)	0.924044	37.2702
modified algorithm	0.889560	37.6843

CONCLUSION

Inter frame motion compensation technology is an important part in international video coding standard framework, the compensation technology is an important method to eliminate the time redundancy, and inter frame motion compensation coding is generally divided into three parts, the first one is to estimate the displacement value of moving object in the adjacent frames, the second is to do interface prediction coding by obtained motion estimation, the third one is to predict the motion vector and error coding. The first part is mainly about value motion object estimated in the adjacent frames, which is called the motion estimation (Motion Compensation, MC), this part is the key part of the implementation of inter frame motion coding, MC algorithm directly affects the efficiency and quality of video coding. Tests show that the consumed time by MC is about half of the whole compression time when encoding video sequences, and the Compensation accuracy also affects the video quality of the encoding.

Research shows that the improved algorithm has obvious advantage in the comparison of the data. The idea on Improved algorithm is performed in combination of two kinds of templates, which is conducted under the analysis of the proper motion correlation, and provides example demonstration for the combination of several kinds of algorithms and classification and process of actual situation

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