A MOTION ESTIMATION ALGORITHM BASED ON MARKOV CHAIN MODEL

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ABSTRACT

In this paper, we present a new fast Motion Estimation (ME) algorithm based on Markov Chain Model (MEMCM). Spatial-temporal correlation of video sequence and Markov Chain Model are used in the algorithm, which considers the continuity of video. Experimental simulation shows that the proposed algorithm has better performance in both speed-up and PSNR than PMVFAST.

Index Terms—Motion Estimation, PMVFAST, Spatial-temporal Correlation

1. INTRODUCTION

Recently, with the development of the MV predicting ME algorithm, especially with the emergence of MVFAST [1] and PMVFAST [2] algorithms, the speed of ME algorithms has been greatly improved with reconstructed quality. Based on the idea of 'stop if good enough' proposed by MVFAST, several MV predicting ME methods have been proposed, such as the A-TDB [3], AME [4], E-PMVFAST [5], and M-DAS [6]. Considering the ability of adapting video sequences with different motion activity, computational complexity, average searching points (speed up), and reconstructed video quality, these algorithms can achieve or exceed PMVFAST in some aspects. However, the usage of the spatial-temporal correlation and image features is not good enough.

In order to use the spatial-temporal correlation of video sequence more deeply, we propose a new fast ME algorithm based on Markov Chain Model (MEMCM) in this paper. The rest of this paper is organized as follows. In section two, we introduce the MVFAST and PMVFAST algorithms briefly. In section three, we describe the high performance ME algorithm proposed in this paper MEMCM in detail. In section four, the experiment results are given. Finally, in section five, the conclusion of this method is given.

2. MVFAST & PMVFAST

MVFAST algorithm adopted early elimination of search and

prediction of the starting point for search as well as adaptive big-small diamond search patterns to improve the performance of ME algorithm. In PMVFAST, for increasing the speed-up and the reconstructed video quality equally, adaptive threshold for judging if it can stop searching was adopted.

2.1. Early elimination of search

In MVFAST, before doing local search by small or big diamond search pattern, a step called early elimination of search was used to detect if the current MB (CMB) is still or quasi-still. If it is a still or quasi-still MB, we could terminate the search immediately. In MVFAST the threshhold (T) is 512.

In PMVFAST, the first predicted MV such as (0, 0) in MVFAST is the median of three MVs spatially adjacent to current MB (top, top-right and left), called PMV. If PMV is equal to the MV of MB at the same spatial position of current MB in reference frame (called REFMV) and the SAD value at PMV is less than that of REFMV, stop searching. In addition, if the PMV does not satisfy stop criteria, a set of MVs composed of (0, 0), MV of left (MVL), top(MVT) and top-right(MVTR) spatially adjacent to the CMB and REFMV are tested and search is stopped if the best MV in the MV set is equal to REFMV and the corresponding SAD value is less than the REFMVs'. To sum up, before local search, a set of MVs were tested to decide whether to stop or not. These MVs set (PRESET) conclude PMV, MVL, MVT, MVTR, (0, 0) and REFMV.

2.2. Prediction of the Starting Point for Search

If all the MVs in the PRESET do not satisfy the stop conditions, we must firstly decide the starting point of the local search. A method is used according to motion activity. If the motion activity is low or medium, the starting point is origin. Otherwise, the MV in the PRESET which yields the minimum SAD value is chosen as the starting point.

2.3. Searching Strategy

A local search is performed around the starting point to find the global optimal MV of the current MB. Small or big diamond pattern is employed for the local search. If the

motion activity of current MB is low or high, small diamond pattern is chosen to perform local search. Otherwise, big diamond pattern is chosen. The detail steps of MVFAST and PMVFAST can be found in [2].

3. MARKOV CHAIN MODEL BASED MOTION ESTIMATION ALGORITHM

As mentioned above, only (0, 0) is tested in MVFAST to decide whether or not to stop searching. In order to increase the ratio of early elimination of search, in PMVFAST, some other MVs are also tested. However, there exists a problem that all the highly possible MVs were all tested every time. The conclusion is that these two algorithms do not take full advantages of spatial-temporal correlation of the video sequence, especially the temporal continuous motion information. To address this issue, a new motion estimation algorithm (MEMCM) has been proposed. The main idea of this algorithm is to use the Markov chain model to predict the test point at early elimination step.

3.1. MEMCM

The existing predicted ME algorithms are mainly based on the zero-centered bias characteristics of motion vectors [7]. Through the statistical analysis of various video sequences, the result shows that motion vectors are mainly scattered in the region of two pixels around zero, especially video sequence with low-motion content case. Figure 1 shows two continuous motion vector fields (MVF) of foreman sequence.
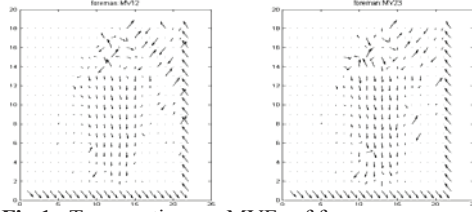

Fig.1. Two continuous MVFs of foreman sequence

Method based on this characteristic usually tests zero vector before local search firstly to speeds up the search. Is origin the best candidate? If subtraction operation is applied between the two MVFs in Figure 1, we will get the motion vector different fields (MVDF) as shown in figure 2.
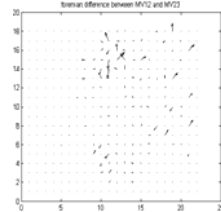

Fig.2. MVDF of two continuous foreman sequence

It is noticed that there are more zero points in MVDF than MVF. Obviously, in addition to the zero vector MBs, if the successive two MB's MV are of the same value, the two MBs are (referred as) 'relatively still' MB. It means that if

we choose the MV of REFMB as the first tested MV, the method will be more effective and video sequence, especially the low-activity video with low-motion content, has very strong temporal correlation.

For using the spatial-temporal correlation more effectively, Markov chain model to predict the test point was used in the improved ME algorithm. PRESET in PMVFAST algorithm contains PMV, MVL, MVT, MVTR, (0, 0) and REFMV. All the six MVs were group in a predicting motion vector set (PMVSET).

$$\Omega = \{(mvx_i, mvy_i) \mid i = 1,2,3,4,5,6\} \qquad (1)$$

Then they were set to six different states. The criteria to determine the current state is

$$(mvx_{pre}, mvy_{pre}) = \arg\min_{i=1\sim6}(SAD(mvx_i, mvy_i)) \qquad (2)$$

Where mvx_{pre}, mvy_{pre} denote the horizontal and vertical component of the predicted MVs respectively.

Considering the strong correlation among PMV, MVL, MVT, MVTR and simplifying the model, we choose (0,0), REFMV as well as PMV to compose a state space as below

$$S_M = \{S_1, S_2, S_3\} \qquad (3)$$

Where S_M is the state space S_1, S_2, S_3, denote REFMV predicting mode (temporal mode), origin mode as well as PMV predicting mode (spatial mode) respectively.

The simplified PMVSET is

$$\Omega = \{(mvx_i, mvy_i) \mid i = 1,2,3\} \qquad (4)$$

where $(mvx_i, mvy_i) \mid i = 1,2,3$ denote REFMV, (0,0) and PMV. Now, the issue of determining the state of the Markov chain model which is for describing the process of predicting tested MV can be expressed as below

$$S_j : (mvx_j, mvy_j) = \arg\min_{i=1,2,3}(SAD(mvx_i, mvy_i)) \qquad (5)$$

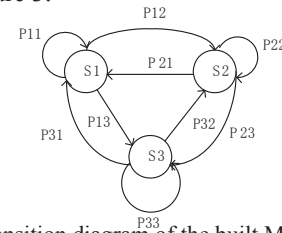Where $j = 1, 2, 3$. State-transition diagram of the model is shown in figure 3.

Fig.3. State-transition diagram of the built Markov chain model

Firstly, let f_n is the predicting mode of MB located at a given position (x, y) in the nth frame of video sequence, then all the predicting modes $\{f_n : n \geq 0\}$ of continuous MBs at the same location form a Markov chain. That is, with $\forall n \geq 0$ and any states $\{i, j, i_0, \cdots, i_{n-1}; i, j, i_0, \cdots, i_{n-1} \in S_M\}$, these is

$$p(f_{n+1} = j \mid f_n = i, f_{n-1} = i_{n-1}, \cdots, f_0 = i_0) = p(f_{n+1} = j \mid f_n = i) \quad (6)$$

And then we can define the state transition probability

$$(7)$$

1175

$$p_{ij}(n,m) = p(f_m = j \mid f_n = i) \; m \geq n$$

And the one-step transition probability

$$p_{ij}(n,n+1) = p(f_{n+1} = j \mid f_n = i) \qquad (8)$$

According to the relationship of values among tne transition probability, the order of initial predicting mode can be decided. For the continuity of video sequences and the consistency of the motion objects, it is assumed that, if MB of a given position is at state i currently, then the probability while the MB at the same position of the next frame is in state j is P_{ij}. So that the states of continuous MBs form a Markov Chain.

3.2. Algorithm Steps

Step1: Initialize the corresponding parameters(Found、 PredEq 、Distance、T1、T2) according to PMVFAST. Let Found=0, PredEq=0. According to the location of current MB, we can obtain the PMV and the MV of REFMB for test preparation. If MVL=MVT=MVTR, let PredEq=1.

Step2: Get the value of Distance by formula
$Dis \tan ce = |PMV_x| + |PMV_y|$ If PredEq=1 and the predicted MV is equal to MV of REFMB, let Found=2.

Step3: If Distance>0 or T2<1536 or PredEq = 1, choose the small diamond pattern for next search process.

Step4: According to the relationship among the transition probabilities, compute the SADs of REFMV, (0, 0) and PMV in order. If any of them satisfies the early elimination conditions, then stop searching immediately and assign the current predicting mode, go to step 8. If none of them satisfies the conditions, go to step 5.

Step5: Compute SADs of the MVL, MVT and MVTR in turn, if any of them satisfies the early elimination conditions, stop searching immediately and assign spatial mode to the current predicting mode, go to step 8. Otherwise, get the minimum SAD as MinSAD and then go to step 6.

Step6: Get the minimum SAD among SAD of PMV, SAD of REFMV and the MinSAD as MSAD. If the corresponding MV is equal to REFMV and MSAD are less than the SAD of REFMV, stop searching and go to step 8. Otherwise assign the current predicting mode and go to step 7.

Step7: Search with line-small diamond or big diamond pattern.(what is the meaning of "search with line") If Found=2, perform one step diamond search, go to step 8 and assign the current predicting mode.

Step 8: Assign the point with the finial minimum SAD to the MV of current MB.

4. EXPERIMENT RESULTS

In order to evaluate the performance of the proposed MEMCM algorithm, MVFAST, PMVFAST and MEMCM with test sequences with different motion activity such as foreman.qcif, highway.qcif, bus.qcif, and mobil.qucif individually. And we have gotten data of speed-up (average searching points) against full search (FS) algorithm and data of average PSNR. The speed-up data are shown in table 1. The average PSNR is shown in table 2.

The corresponding curves (the left one is Speed Up Curve and the right one is PSNR) of different tested sequences (foreman ~ mobile) are shown in figure 4 in the last page.

Tab.1. Performance of speed up against FS (%)

Algorithm	foreman	highway	bus	mobile
MVFAST	50.56	120.16	9.81	43.16
PMVFAST	92.73	133.16	37.95	82.86
MEMCM	100.63	152.57	48.04	111.98

Tab.2. Performance of average PSNR of different algorithm (dB)

Algorithm	foreman	highway	bus	mobile
FS	33.23	34.92	24.10	26.31
MVFAST	32.42	34.68	22.06	26.28
PMVFAST	33.17	34.90	24.08	26.25
MEMCM	33.12	34.72	24.21	26.20

5. CONCLUSIONS

By analyzing MVFAST and PMVFAST algorithms and making full use of the spatial-temporal correlation, an efficient ME algorithm-MEMCM has been proposed. Experimental results show that this algorithm is about 21.2% faster than PMVFAST in average with almost the same reconstructed image quality.

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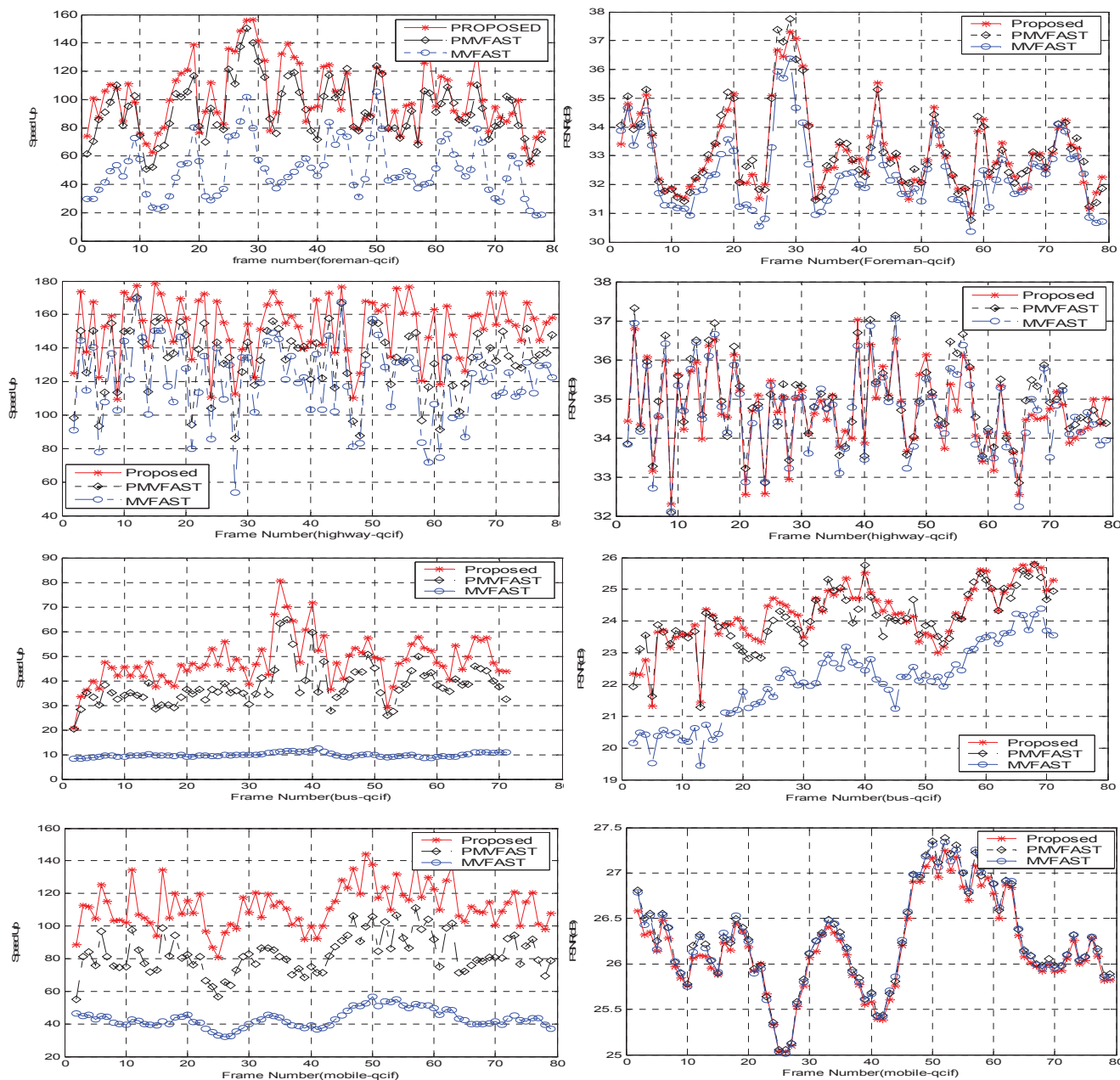
Fig.4. The corresponding curves of the tested sequences