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Fractal Coding based Optimization Algorithm for Interframe Prediction of High-definition Video

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Abstract. A fractal coding based interframe prediction algorithm is proposed, to hugely reduce the calculation amount of interframe prediction and raise the coding velocity. The complexity of interframe prediction algorithm is the motion search. The interframe prediction in HEVC needs to find out the best matched block for each image block of each division mode of the current frame in the reference frame. The defining of the reference frame is also very complex, especially for the frame of bidirectional prediction, its reference frame needs to be defined on two directions, and then the best matched image block for the current image block in the reference frame is to be further defined. To cope this high complexity of interframe prediction, we make some improvements on the part of motion search for the interframe prediction by introducing the fractal idea to match the image block to realize more rapid matching of image block. The experimental result shows that the coding efficiency of fractal coding-based interframe prediction algorithm averagely improves by 7.86%, the peak SNR averagely reduces 0.164 dB and the coding time averagely reduces by 22.37%. The proposed algorithm can significantly raise the coding velocity and cut the coding time hardly with any influence on the coding quality.

Introduction

The fractal image coding is to look for an iteration function system (IFS) for the original image before using IFS to express the original image [1-4]. The fractal image coding does not only produce a good result in compression of static image, but also can deliver a very satisfactory effect in coding of image sequence, and its performance outperforms the coding transformation in the case of very low code rate [5]. The interframe prediction refers to the prediction over the pixel of the current block by dint of the pixels of the previous already coded image or the already coded image blocks in the current image, to remove the time redundancy of the video [6-8]. The paper introduces the fractal ideal to match the image block and optimize the interframe prediction, thereby improving the coding efficiency of HEVC [9,10].

Fractal Image Coding Algorithm

The fractal image coding algorithm is based on the segmenting of image, with basic steps as shown below:

1) Segment the image: Segment the original image into image blocks that do not overlap with each other (called R blocks), with size generally being 4×4, 8×8 and 16×16, etc. Then segment the original image into image blocks that can overlap with each other (called D blocks), with size being generally 8×8, 16×16, 32×32, etc. Shrink the D blocks to make them become $\hat{D}$ blocks with the same size as R blocks, express these $\hat{D}$ blocks as $\Omega=\{\hat{D}_j=S(D_j),\ j=1,2,...,N_d\}$.

2) Equidistant transformation: Some equidistance transformations can be made for $\hat{D}$ blocks to make $\hat{D}$ blocks more approximate R blocks [1].

3) Error measurement: Measure the error MSE for matching $\hat{D}$ blocks and R blocks, then the PSNR $(\textit{Peak signal to noise ratio})$ measuring the quality of coded image can be calculated according to MSE [11,12].

$$PSNR = 10\lg\left(\frac{255^2}{MSE(\mu_{org}, \hat{\mu}_{org})}\right) \text{(dB)} \quad (1)$$

4) Fractal coding: Look for a $\hat{D}$ block $D_{m(i)}$ from Ω via a certain search mode, to make the error between $D_{m(i)}$ and R block the smallest after adjusting $D_{m(i)}$ with contrast factor s_i and luminance factor o_i [13], i.e. to make the error $MSE(R_i, \hat{D}_{m(i)})$ between $\hat{D}_{m(i)} = s \cdot D_{m(i)} + o$ and R block the smallest. Here a constraint optimization problem needs to be calculated [14,15]:

$$\min_j\{\min_{s,o\in R,|s|<1} \| R_i - (s\cdot D_j + o) \|^2\} \quad (2)$$

The calculation formula of error $MSE(R_i, \hat{D}_{m(i)})$ is:

$$MSE(R_i, \hat{D}_{m(i)}) = \frac{1}{B^2}\min_j\left\{\min_{s,o\in R,|s|<1} \| R_i - (s \cdot D_j + o) \|^2\right\} \quad (3)$$

Set the solution of constraint optimization problem as $\{m(i), s_i, o_i\}$, then the pixel of R block can be predicted via Eq. 4:

$$R_i \approx s_i \cdot D_{m(i)} + o_i \quad (4)$$

Then $\{m(i), s_i, o_i\}$ is the part of R block that needs coding.

Fractal-based interframe prediction algorithm

The interframe prediction coding of fractal high efficiency video coding system designed in this paper is to search the already coded reference frames for the best matched D block for current coding R block, then to record the position deviation between the current coding block and the best matched block, i.e. the motion vector and parameters s, o of fractal iterative function system, as shown in Fig.1. The searching of matched block is the most key and time-consuming step [16-18]. Between the neighboring coding blocks exists a certain correlation, and their motion vectors also mutually have certain dependence. The coding code rate and coding efficiency can be raised if we predict the current MV according to the blocks neighboring the current to-be-coded blocks in terms of time domain and space domain and take the predicted MV as the origin of the searching for the matched blocks for the current block to improve the block matching searching precision in a manner and only transmit the D-value between the motion vector and the real motion vector in code stream transmission.

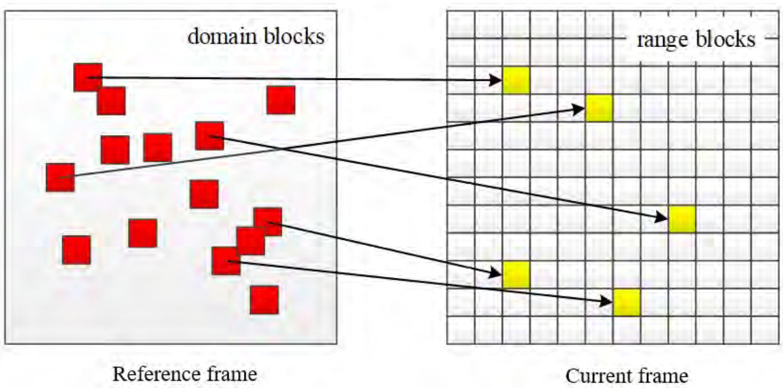

Figure 1. Schematic diagram for matching of interframe prediction coding blocks

In the image block matching of motion searching, the matching principle adopts the sum $SAD_{s,o}$ of absolute error between fractal factor s and o:

$$SAD_{s,o} = \sum_{i=1}^{n} | \mathrm{r}_i - (\mathrm{s} \bullet \mathrm{d}_i + \mathrm{o}) | \quad (5)$$

Where, r_i is the pixel of R block, d_i the pixel of matched block *D* block of *R* block in the reference frame, n is the quantity of pixels in current *R* block, s and o respectively represent the contrast factor and the luminance factor. The calculation of s and o is as follows:

Take the square of Eq. 5 and derive the partial derivative with respect to s, to obtain:

$$\frac{\partial SAD_{s,o}^2}{\partial s} = \sum_{i=1}^{n} 2(s \cdot d_i + o - r_i) \cdot d_i \quad (6)$$

The calculation formulae of s and o can be derived from mathematical transformation:

$$\begin{cases} s = \dfrac{n\sum_{i=0}^{n} r_i d_i - \sum_{i=0}^{n} r_i \sum_{i=0}^{n} d_i}{n\sum_{i=0}^{n} d_i^2 - (\sum_{i=0}^{n} d_i)^2} \\ o = \dfrac{1}{n}\left(\sum_{i=0}^{n} r_i - s\sum_{i=0}^{n} d_i \right) \end{cases} \quad (7)$$

The steps of implementation for the fractal-based interframe prediction algorithm are as follows:

Step 1: For one interframe prediction PU, obtain several MVs [19] via the AMVP technology, calculate the rate-distortion cost when each MV is predicting [20,21], select the point corresponding to the MV with the smallest rate-distortion cost as the origin of search, shift to step 2.

Step 2: Search with starting step of 1 in the search scope, and increase the step by power of integer of 2 in each search, calculate the fractal factor and matching error of each matching, find out the search point corresponding to the block with the smallest matching error, shift to step 3.

Step 3: If the search step corresponding to the search point is 1, make two-point search around this search point, calculate the fractal factor and matching error, avoid missing of the optimal point, shift to step 4. If the search step corresponding to the search point is not 1, shift to step 4 directly.

Step 4: If the search step corresponding to the search point is greater than our pre-set threshold [22-25], make full search around this search point, calculate the fractal factor and matching error, avoid missing of the point around the optimal point, shift to step 5. If the search step corresponding to the search point is smaller than our pre-set threshold, shift to step 5 directly.

Step 5: If the MV searched out this time and the MV searched out last time end simultaneously, this MV is just the MV of current interframe PU, or shift to step 2 for the new search and matching with the optimal point searched out this time as the new search origin.

Experimental result

The proposed algorithm is implemented on HEVC standard software HM15.0 on computer with @3.4GHz Intel Core i7-3770 and memory of 8G. The coding quality is evaluated by BD-Rate BD-PSNR and coding efficiency by coding time.

Table 1 compares the result obtained by using the proposed algorithm to code the 30 frames for 16 test video sequences of 4 classes using configuration of encoder_lowdelay_main with the coding result obtained by HM15.0. As the proposal [26] stipulates that the video sequence of class A is not applicable to the test on this configuration, we only provide the coding result for the video sequences of class B ~class E.

It is observed that compared with HM15.0, the BD-PSNR of the proposed algorithm averagely reduces 0.161dB, BD-Rate averagely increases 7.86%, and time averagely saves by 22.37%. The proposed algorithm realizes high coding efficiency and raises the coding velocity with fine lowering of coding quality.

Table 1 Result of encoder_lowdelay_main experiment for the proposed algorithm

Video sequence		BD-PSNR (dB)	BD-Rate (%)	Time Saving (%)
Class B	Kimono	-0.091	6.62	20.95
	ParkScene	-0.101	6.94	23.80
	Cactus	-0.182	8.48	22.67
	BasketballDrive	-0.184	9.21	21.56
	BQTerrace	-0.205	8.66	22.82
Class C	BasketballDrill	-0.116	7.55	21.86
	BQMall	-0.158	7.63	21.49
	PartyScene	-0.192	6.97	22.53
	RaceHorses	-0.157	8.04	23.69
Class D	BasketballPass	-0.237	8.84	19.53
	BQSquare	-0.226	8.06	20.80
	BlowingBubbles	-0.184	7.39	19.98
	Racehorses	-0.207	8.41	21.76
Class E	FourPeople	-0.117	7.82	24.57
	Johnny	-0.159	7.50	24.38
	KristenAndSara	-0.121	7.61	25.60
Average		-0.164	7.86	22.37

Summary

The fractal coding-based interframe algorithm proposed in this paper hugely reduces the calculation amount of interframe prediction and raises the coding velocity. The fractal idea is introduced in the coding process to more rapidly define the matched block. The experiment result shows that the proposed algorithm can significantly raise the coding velocity and cut the coding time hardly with any influence on the coding quality.

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