Int. J. Electron. Commun. (AEÜ) 68 (2014) 795–805

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

journal homepage: www.elsevier.com/locate/aeue

An automatic region-based video sequence codec based on fractal compression

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ARTICLE INFO

Article history:
Received 10 November 2012
Accepted 11 March 2014

Keywords:
Fractal video coding
Pre-searching limitation condition
Deblocking loop filter
Sub-pixel block matching
Automatic region-based coding

ABSTRACT

In order to improve the performance of fractal video coding, we explore a novel fractal video sequences codec with automatic region-based functionality. To increase the quality of decoding image, intra frame coding, deblocking loop filter and sub-pixel block matching are applied to the codec. An efficient searching algorithm is used to increase the compression ratio and encoding speed. Automatic region-based fractal video sequences coding reduces coding stream greatly. Experimental results indicate that the proposed algorithm is more robust, and provides much less encoding time and bitrate while maintaining the quality of decompression image than the conventional CPM/NCIM method and other related references. We compare the proposed algorithm with three algorithms in Refs. [24–26], and the results of all these four algorithms are compared with H.264. The bitrate of the proposed algorithm is decreased by 0.11% and the other algorithms are increased by 4.29%, 6.85% and 11.62%, respectively. The average PSNR degradations of the four algorithms are 0.71 dB, 0.48 dB, 0.48 dB and 0.75 dB. So the bitrate of the proposed algorithm is decreased and the other algorithms are increased. At the meantime the compression time is reduced greatly, about 79.19% on average. The results indicate that, on average, the proposed automatic region-based fractal video sequences coding system can save compression time 48.97% and bitrate 52.02% with some image quality degradation in comparison with H.264, since they are all above 32 dB and the human eyes are insensitive to the differences.

1. Introduction

Fractal coding is thought to be one of the three most prominent codec methods. It was first proposed by Barnsley, and was successfully applied to image coding [1]. In recent years, fractal coding receives wide academic attention with its innovative idea, high compression ratio, high decoding speed, independent resolution, etc. [2–5]. Currently, the research is not limited to image compression applications [5]. It also extensively penetrates in other image processing applications, such as image retrieval [6], image noise elimination [7,8] and digital watermarking [9,10].

The idea of fractal image compression is based on the Iteration Function System (IFS). The governing theorems are the Contractive Mapping Fixed-Point Theorem and Collage Theorem. That is, we will find a map that takes an input image and yields an output image. Jacquin made use of local Iterated Function System to segment the image. He took the local affine transformation instead of global affine transformation, greatly promoting the fractal application in image coding. But the image segmentation of this method requires human–computer interaction and cannot realize automation. With the drawback that fractal encoding is complex and time-consuming, many researchers work on it [11–14].

There are two major approaches of fractal video sequence coding. The first one uses an extension of the still-image scheme to three-dimensional blocks of video. Although the data compression is impressive, but the picture quality is poor and severe blocking artifacts are presented. The second one is a combination of intra-frame and motion-compensated inter-frame fractal coding. The famous hybrid circular prediction mapping and non-contractive inter-frame mapping (CPM/NCIM) [15] combines fractal video coding with the well-known motion estimation and compensation (ME/MC) algorithm. ME/MC exploits the high temporal correlations between adjacent frames. The hybrid structure codec based on CPM and NCIM is shown in Fig. 1. The main difference between CPM and NCIM is that CPM should be contractive for the iterative decoding

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http://dx.doi.org/10.1016/j.aeue.2014.03.003
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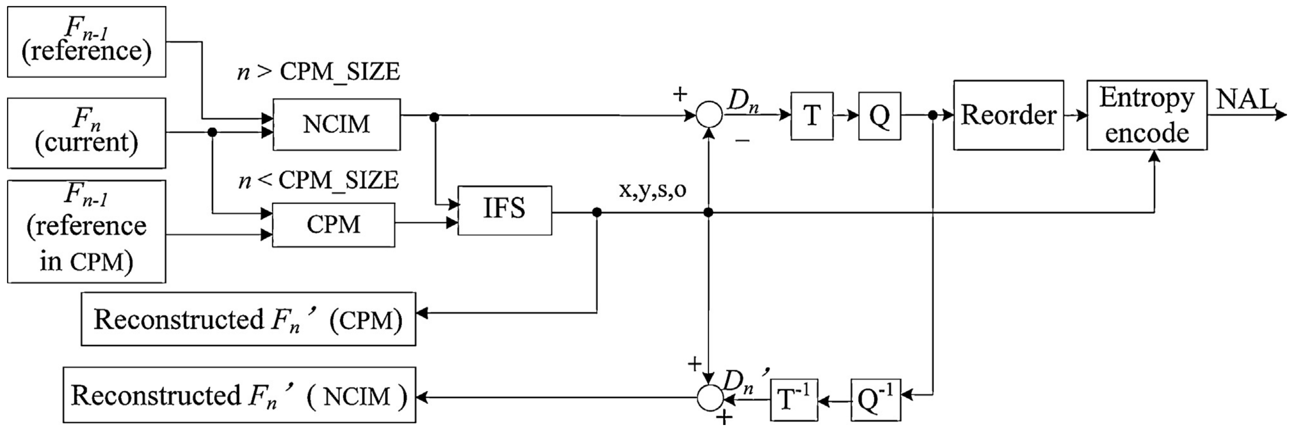

Fig. 1. Hybrid structure of CPM and NCIM.

process to converge, while NCIM needs not be contractive. Since the decoding of the NCIM depends on the already decoded frames and is non-iterative. As shown in Fig. 1, the first frame is coded with the CPM. And the reference frame must be the CPM frame. The CPM frames are decoded by 6 iterations. The NCIM frames are coded with the former reference frame. Both inter/intra coding and three-dimensional fractal block coding techniques are resolution-independent in the spatial domain. NAL represents the bitstream that forms the representation of coded pictures and the associated data forming the coded video sequence.

Considerable researchers study video sequence compression using fractal coding method [16–21], for instance, the intercube correlation search method [19]. The hybrid volume coder with neighborhood vector quantization for video and volume data is useful for removing both intra-frame and inter-frame coherences. It makes low coding complexity. However, it is difficult to establish the neighborhood codebook. A hybrid volume coder was later proposed by Wang [20]. The hybrid method employs the inter-cube correlation search algorithm. It considers four domain cubes mapped by previous neighboring range cubes as the good candidates for the input range cube. It can reduce the encoding time and bitrate. Unfortunately, this method suffers from convergence problems during the decoding stage. A hybrid compression algorithm [16,18] merges the advantages of a cube-based fractal compression method and a frame-based fractal compression method. The adaptive partition and the hybrid compression algorithm exhibit relatively high compression ratio for the sequence of motion images from a videoconference. But it is much time consuming. Lima described a low bit-rate 3D searchless fractal video encoder to perform fast compression with high visual fidelity. And it only has low bitrate in the high motion video sequences [21].

The present authors propose an improved fractal video sequences codec with automatic region-based functionality. It can improve the decompression video quality and make the codec more flexible and functional. The block diagram of the proposed fractal video sequence codec is shown in Fig. 2. The object-based video coding allows manipulation of image objects without complete decoding the stream. It permits new functionalities at the receiver, such as advanced object-based query, selective region transmission. Also, for a given bitrate, region-based coding often achieves better image quality than standard coding. In such a scheme, a prior segmentation map (alpha plane) of the image, which segments the image into objects, is known in advance [22,23]. And it has been considered as a very promising alternative to the block-based approach. During the motion estimation (ME), pre-searching limitation condition is used to simplify the block matching. A new asymmetrical hexagon searching algorithm is employed to find the accurate matching block quickly. Moreover, the deblocking loop filter is added to make a more faithful reproduction of the original frame than a blocky and unfiltered image.

The contents are organized as follows: the proposed novel methods of automatic region-based fractal video sequence coding are presented in Section 2. In Section 3, the experimental results are presented. And finally the conclusions are outlined in Section 4.

2. The proposed novel automatic redion-based fractal video coding scheme

Although considerable researches in fractal video coding focus on its compression capabilities, there is still a lot of space for further improvements. In the paper, we improve the conventional CPM/NCIM method, seek to obtain the best domain–range block matching with the minimal amount of fractal code and use an efficient searching algorithm to improve the poor image quality and the encoding time. Automatic region-based coding is also applied to further raise the compression efficiency.

2.1. Basic works

2.1.1. Intra frame coding

Generally, in the basic fractal video codec, intra frame (I frame) coding uses CPM as shown in Fig. 1. Our algorithm employs the coding method based on the Discrete Cosine Transform (DCT), which converts the I frame data into frequency domain to encode as shown in Fig. 2. I frame is firstly partitioned into blocks. In order to obtain high quality decoded video sequences, the size of blocks used in fractal video coding is adaptive from 16×16 to 8×8. DCT transformation and the quantization of the DCT coefficients with a given quantization step are then applied. At last Huffman coding of DCT coefficients is done to each block. The usefulness of the DCT becomes clear when the block is reconstructed from a subset of the coefficients. And the reconstructed block is a reasonably close match to the original and has a high vision quality.

2.1.2. Deblocking loop filter

To avoid blocking artifacts, a deblocking filter is employed in the loop as shown in Fig. 2. The loop filter is applied after the inverse transform in the codec (before reconstructing and storing the macroblock for future predictions). Heavy and long distance smoothing is imposed to suppress the visually severe blocking and guarantee the perceptual quality of reconstructed video.

Fig. 3 shows four pixels on either side of a vertical or horizontal boundary in adjacent blocks P and Q (P_3, P_2, P_1, P_0 and Q_3, Q_2, Q_1, Q_0). It is important to distinguish between the true boundary and