Wavelet transform based video compression algorithm and its application in video transmission

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Received 6 October 2013, www.cmnt.lv

Abstract

This paper proposes a novel wavelet transform based video compression algorithm, and then we apply it in the video transmission. Firstly, we introduce a general video coding framework and Basic coding process in the video compression. Secondly, we design an improved wavelet transform in the video compression problem. The proposed modified wavelet transform is executed by a threshold or a bound, which can guarantee the pathway to discover a direction to satisfy the maximum zero engries. Afterwards, we define the path vectors with point subsets of a finite grid to modify the standard wavelet transform. Thirdly, we illustrate how to exploit the proposed wavelet transform based video compression algorithm and a FPGA chip in a video transmission system. Finally, we test the performance of our algorithm using the VIRAT Video Dataset. Compared with Wavelet-SPIHT and JPEG 2000, the conclusions can be drawn that the proposed can effectively compress videos and greatly promote the performance of video transmission as well.

Keywords: Wavelet transform, Video compression, Video transmission, Filter coefficient, Path vectors

1 Introduction

With the rapid development of computer technology and information, users can easily share information with each other. Particularly, the proportion of different video frequency on the Web has become more and more important [1, 2]. However, as the big capability of video frequency greatly influence the video communication speed on the Web. Therefore, the compression of video frequency is of great importance in video information processing [3]. Hence, the final purpose of image and video compression is to obtain higher quality image and video to satisfy the bandwidth of multimedia information system, that is, we aim to compress the video in the Internet as low as possible.

On the other hand, wavelet theory is developed rapidly in recent years, and the research fields of wavelet theory are expanded fast as well [4]. Wavelet theory has been successfully utilized in many fields, such as still-image compression, the JPEG2000 (standard of image compression). In this paper we focus on the problem of video compression based on the wavelet transform technology. Video frequency compression highly relies on wavelet image compressions and increasing of signals dimension [5, 6].

In recent years, video compression has been one of the most hot problems of compression coding, and this technology is very important to HDTV, DVD, Video conference, and so on. To avoid the mistakes of international standards, several embedded wavelet coefficients coding models are designed [7, 8]. As wavelet has the characteristics of multi-resolution, time/frequency localization and lower time complexity, it is suitable to be used in video coding [9].

Furthermore, in china, the application of digital TV and stream media have great opportunities to great development, particularly, the multimedia communication has attracted more and more attentions [10, 11]. As huge market, the researchers concentrate on communication of multimedia information through the Web [12]. Moreover, the compressed video communication refers to the most important part in the fields of multimedia communication [13].

The main innovation of this paper lies in that we utilize the wavelet transform in video compression. Wavelet transform has been widely used in many applications, such as SAR complex image data compression [14], Short term load forecasting [15], license plate location [16], Raman optical fiber distributed temperature sensor [17], identifying fault zone in a series compensated transmission [18], medical image resolution enhancement [19], cardiac sound signals classification [20], Damping ratio identification [21], logo watermarking scheme [22], Multi-attribute Seismic Analysis [23], high-performance hardware architectures design [24].

2 Basic knowledge for the video compression problem

Video coding is a basic work for video compression, and this technology mainly includes three key modules, such as shape, motion, and texture. A general video coding framework is illustrated in Figure 1.

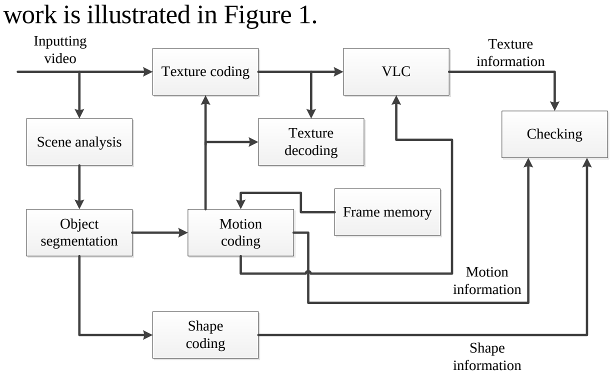

FIGURE 1 A general video coding framework

Particularly, the process of basic coding in the video compression is described in Figure 2.

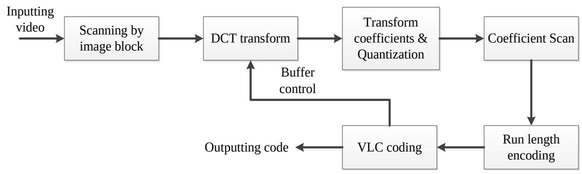

FIGURE 2 Basic coding process in the video compression

Based on the above basic knowledge, the video compression algorithm is presented in the following section.

3 The proposed video compression algorithm and its application

In this paper, we utilized a modified wavelet transform to implement the video compression process. Our proposed wavelet transform operates via setting a threshold or a bound Θ_1, which can let the pathway to seek a direction to satisfy the maximum zero engries. The threshold criterion is satisfied the following equation:

$$\left| f_k^L\left(p_k^L(i)\right) - f_k^L\left(2\cdot p_k^L(i-1)\right)\right| \le \Theta_1 . \quad (1)$$

The condition in Eq. 1 is not dependent from the minimum difference. Afterwards, the next available minimum index to seek $p_k^L(i+1)$ is chosen when the following condition is satisfied:

$$\left| f_k^L\left(p_k^L(i)\right) - f_k^L\left(p_k^L(i)+q^{ch}(b)\right)\right| \le \Theta_1 . \quad (2)$$

Next, we suppose that $\varphi \in C^\beta, \beta \ge \alpha$ means a one dimensional scaling function, φ is a smooth scaling function with compact support. Furthermore, functions ψ and ψ refer to a pair of compactly supported wavelet functions. Functions φ and ψ are defined by Eq.3 and Eq.4 respectively.

$$\varphi_{j,k}(t) = 2^{\frac{j}{2}} \cdot \varphi\left(2^j \cdot t - k\right), \quad (3)$$

$$\psi_{j,k}(t) = 2^{\frac{j}{2}} \cdot \psi\left(2^j \cdot t - k\right). \quad (4)$$

Moreover functions φ, φ, ψ and ψ should meet the following refinement equations:

$$\varphi(x) = \sqrt{2}\cdot\sum_n h_n \cdot \varphi(2x-n), \quad (5)$$

$$\varphi(x) = \sqrt{2}\cdot\sum_n h_n \cdot \varphi(2x-n), \quad (6)$$

$$\psi(x) = \sqrt{2}\cdot\sum_n q_n \cdot \varphi(2x-n), \quad (7)$$

$$\psi(x) = \sqrt{2}\cdot\sum_n q_n \cdot \varphi(2x-n), \quad (8)$$

where h_n, h_n, q_n, q_n are filter coefficients. For a specific univariate function $f^j, j \in Z$ and f is belonged to $L^2(R)$. Then function f is defined as follows.

$$f = \sum_{j,k\in Z} \left\langle f, \psi_{j,k} \right\rangle \psi_{j,k} . \quad (9)$$

We modify the standard wavelet transform mainly by defining path vectors with point subsets of a finite grid G. For each point $y = (y_1, y_2) \in G$, its neighborhood node is defined in Eq. 10.

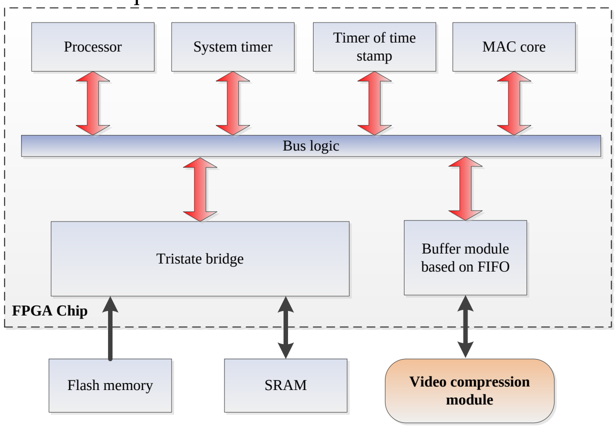

FIGURE 3 Video transmission system

$$N(y) = \left\{ x = (x_1, x_2) \in G \setminus \{y\} \right\}, \quad (10)$$

where the condition $\|x-y\|_2 \le 2^{-J+0.5}$ and $\|x-y\|_2^2 \le (x_1-y_1)^2 + (x_2-y_2)^2$ are satisfied.

Based on the above video compression algorithm, an effective video transmission system can be design and the video compression module is the key part of it, and the video transmission function is implemented on a FPGA chip (shown in Figure 3).

It can be seen that the video compression module greatly affect the performance of the video transmission. In the next section, we will conduct experiments to testify the proposed video compression algorithm.

4 Experiment

4.1 EVALUATION CRITERIA

1) CR refers to the ratio between the size of the original video sequence and the video sequence after compressing.

$$CR = \frac{Size\ of\ the\ orginal\ image}{Size\ of\ the\ compressed\ image} . \quad (11)$$

2) BPP represents the relationship between bits and pixel.

$$BPP = \frac{Size\ of\ the\ compressed\ image}{Number\ of\ pixels\ in\ the\ image} . \quad (12)$$

3) $RMSE$ means the root mean square error, which can evaluate the improvement in image quality. Particularly, it is very meaningful to evaluate image quality when comparing the same compression approach at different level of bit rates.

$$RMSE = \sqrt{\frac{\sum_{k=1}^{nf}\sum_{x=1}^{M}\sum_{y=1}^{N}\left(f(x,y,k) - f'(x,y,k)\right)^2}{M\cdot N\cdot nf}} . \quad (13)$$

4) $PSNR$ denotes the peak signal noise ratio, which is widely used as a criteria to evaluate the quality of reconstruction of lossy image compression code. Moreover, the higher value of $PSNR$ expresses the higher reconstruction quality.

$$PSNR = 10 \cdot \log_{10} \frac{MAX^2}{MSE}, \quad (14)$$

where MAX refers to the max possible value of the pixel.

4.2 PERFORMANCE EVALUATION

We choose a video dataset – "VIRAT Video Dataset" [25] to make performance of the proposed algorithm. The VIRAT Video Dataset is constructed to be realistic, natural and challenging for video surveillance domains according to the resolution, background clutter, diversity in scenes, and human activity/event classes than the former action recognition datasets. Particularly, in this dataset, there are twelve kinds of videos, including: V1: Person loading an Object to a Vehicle, V2: Person Unloading an Object from a Vehicle, V3: Person Opening a Vehicle Trunk, V4: Person Closing a Vehicle Trunk, V5: Person getting into a Vehicle, V6: Person getting out of a Vehicle, V7: Person gesturing, V8: Person digging, V9: Person Carrying an Object, V10: Person running, V11: Person entering a facility, V12: Person exiting a facility.

TABLE 1 Performance evaluation for the VIRAT Video Dataset

Video types	Size of the sequence	CR	BPP	RMSE	PSNR
V1	512×512×45	18.378	0.457	1.196	45.957
V2	512×512×47	20.081	0.380	1.208	47.012
V3	512×512×53	22.192	0.358	1.129	45.932
V4	512×512×42	22.886	0.406	1.117	46.873
V5	512×512×46	20.855	0.383	1.202	47.081
V6	512×512×52	20.158	0.485	1.133	46.535
V7	512×512×47	21.581	0.349	1.229	46.767
V8	512×512×51	19.572	0.361	1.124	45.191
V9	512×512×57	20.869	0.366	1.135	45.974
V10	512×512×43	22.016	0.488	1.150	45.045
V11	512×512×49	22.337	0.442	1.128	45.150
V12	512×512×43	18.581	0.402	1.298	47.623

Next, we will compare the proposed algorithm with other common video compression methods using CR and PSNR, such as Wavelet-SPIHT [26], and JPEG 2000 [27].

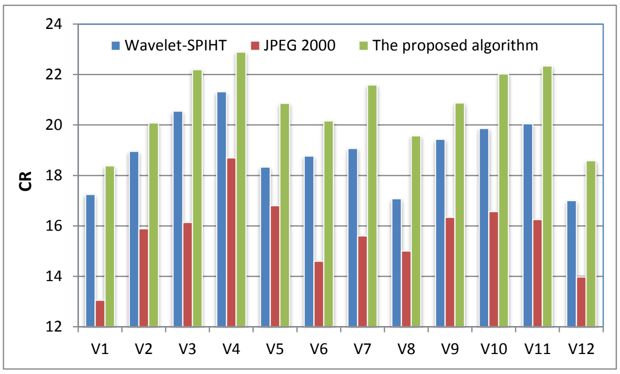

FIGURE 4 Performance comparison using CR

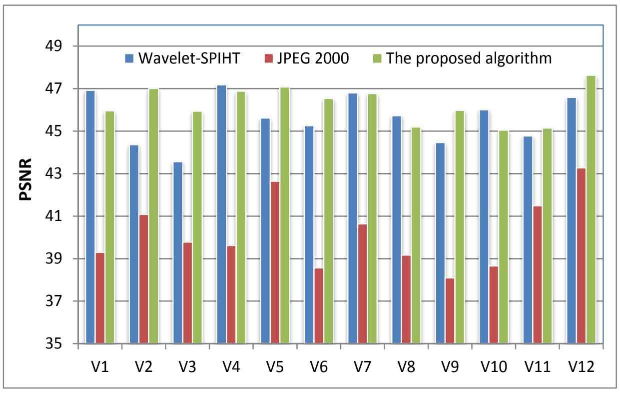

FIGURE 5 Performance comparison using PSNR

Integrating all the experimental results together, in it can be seen that the proposed algorithm has the ability to effectively compress videos, and performs better than Wavelet-SPIHT, and JPEG 2000.

5 Conclusions

In this paper, we present a wavelet transform based video compression algorithm, and then exploit it in the video transmission system. We modify the standard wavelet transform using a threshold or a bound, which can guarantee the pathway to find a direction to satisfy the maximum zero engries. Then, the path vectors are defined with point subsets of a finite grid to improve the standard wavelet transform. Afterwards, we describe how to use the proposed wavelet transform algorithm in video transmission. In the end, a series of experiments demonstrate the effectiveness of our algorithm.

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