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Four dimensional matrix discrete cosine transformation-based remote education video compression technical research

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ABSTRACT

Remote education seriously is a kind of newly-developed teaching technique, the technique development can provide stronger impetus for education development, and in the technique implementation process, it faces slow video transmission and big material consumption in documents saving such problems, if it can look for a kind of effective algorithm targeted video compression coding, then it can alleviate the problem to some extent. The paper researches on video image sequence features, uses four dimensional matrix discrete cosine transformation algorithm to make compression code on video image files, in the research process, the paper firstly states four dimensional matrix definition and computing ways, and then discusses four dimensional matrix cosine transformation mathematical algorithm and video coding process involved compression algorithm, and finally uses paper stated video code compression algorithm to get evaluation table data in DSP. Data shows that four dimensional matrix discrete cosine transformation-based video compression code algorithm has obvious superiorities by comparing with other algorithms, which provides theoretical algorithm for video coding and provides technical support for remote education lots of implementation.

Key words: four dimensional matrix, cosine transformation, coding and decoding, DSP simulation data

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INTRODUCTION

Modern remote education relies on satellite digital transmission and computer network, adopts multiple kinds of media resources and ways combinative formed system Xinhua educational form that adapts to students' individual learning, ministry of education has already taken modern remote education development as twenty-first century lifelong learning system construction way, and regarded it as strategic measure to conduct education on the condition that Chinese education sources are deficient so as to strengthen construction, remote education attracts educational circle widespread attentions with its broad participants, low input, without limiting of faculty and school dormitory and other school infrastructure conditions, easily organizing high level teaching, and teaching quality is relative easier to ensure and other features[1].With Internet development, network remote education has already penetrated into all fields, which provided lots of convenient learning conditions for learners, in order to let network remote education better serve to people, the paper researches on remote education video compression coding and decoding, in the hope of making contributions to remote education video transmission speed improvement and storage consumption reduction.

Video document compression algorithm merits evaluation basically has two criterions, one is compression ratio, the other is peak signal to noise ratio, with digital video document development, its compression coding algorithm has gone ahead with constant development and developed towards faster, smaller occupied space orientations, the paper makes research on remote education video document compression coding and decoding process, applies four dimensional matrix discrete cosine positive transformation and example change algorithm to handle with it, in the hope of exploring more convenient compression coding method.

For remote education and video compression research, lots of people have made efforts, just their efforts that let remote education to get more rapidly development, and let video compression algorithm to be fit for network transmission and convenient filing. Regarding remote education research, there were: Ji Chang-Qing from Dalian University in "Mobile and Computation-based remote education mode research", he deeply discussed mobile learning and cloud services essence and their main application, and then combined with present remote school teaching practical status, proposed to introduce mobile computing, cloud computing and other next generation network techniques into remote education teaching resources construction, established mobile cloud computing new teaching mode, and positively discussed mobile learning studies on remote teaching staff, fusion, network pattern and other aspects[2];Lu He-Yan from network education institute of South China Normal University in "Remote education video conference applied cases research", he analyzed video conference system applied effects differences between academic education and Non-academic education training, put forward suggestion that video conference system adopted "classroom model" in application and introduction period[3].For video compression researches, there were: Chen Shuang-Wen from College of information engineering, Communication University of China in "Distributed video coding", he introduced distributed video coding theoretical basis and its application method, briefly introduced present distributed video coding field researching directions and research achievements[4];Xu Wei and others from Jiangsu autoimmunization institute, China shipbuilding Industry Corporation in "Wavelet transform application in radar video compression", for engineering application radar video big data amount, difficult to timely transfer such problems, they analyzed radar video data information redundancy and signal correlation as other features, put forward a kind of wavelet transform-based radar video data compression algorithm, and used the algorithm to compress and uncompress handle with actual collected one type radar video data, result showed the algorithm had higher compression ratio and better signal restoration quality, which had certain use values [5];Zhao Zhi-Jie majored in communication and information system of Jilin University in his master's thesis "Multi-way matrix video compression algorithm parallel DSP system research implementation", he analyzed video image processing importance, and made brief discussion on current image coding technology, on the basis of fully researching on image coding technology merits, combined with video image itself features, put forward multi-way matrix theory concept, and specific given three dimensional matrix theory and four dimensional matrix theory correlation definitions and properties, and on the basis of researched discrete cosine transformation, provided three dimensional matrix discrete cosine transformation and four dimensional matrix discrete cosine transformation definition, while regard that as core algorithm to process with video images, by simulation on DSP system, got relative credible experiment results[6]; Deng Shi-Yang from Taiyuan University of Science and Technology in "Residua distributed video compression sensing", by integrating DVC and CS respective features to construct coding simple video coding frame, and adopted residua technique to improve system functions, finally put forward a kind of residua distributed video compression sensing algorithm, made traditional intra-frame coding and decoding on key frame, and for non-key frame, the coding end adopted a kind of residua united sparse model-based random observation, decoding end utilized side information and improved gradient projection reconstruction algorithm to optimize and reconstruct, experiment result showed RDCVS algorithm improved 2-3dB on recovery quality than reference scheme[7];

The paper on the basis of previous research, studies on remote education video compression coding and decoding process, applies four dimensional matrix discrete cosine positive transformation and inverse transformation algorithms to make DSP system simulation, by comparing simulation results with other algorithms, it gets the paper research methods' superiorities.

2. Four dimensional matrix theoretical basis

2.1 Four dimensional matrix definition

Definition 1. $I \times J \times K \times L$ pieces of real number a_{ijkl} compose I pieces of horizontal lines, J pieces of vertical columns, K pieces of vertical sequences and L pieces of deep hypercube form data ranking, the data ranking is called $I \times J \times K \times L$ order four dimensional matrix, as formula (1)show:

$$A_{I\times J\times K\times L} = \left[a_{i\times j\times k\times l}\right]_{I\times J\times K\times L}, \left(1\le i\le I, 1\le j\le J, 1\le k\le K, 1\le l\le L\right) \tag{1}$$

In formula(1), a_{ijkl} represents four dimensional matrix $A_{I\times J\times K\times L}$ element.

Definition 2. Any four dimensional matrix $A_{I\times J\times K\times L}$ can use some horizontal lines, vertical lines, ordinates and depth lines to classify into small size four dimensional matrix, and the small four dimensional matrix after classification is called that $A_{U\times V\times W\times S}$ is four dimensional matrix $A_{I\times J\times K\times L}$ sub matrix, from which :$U < I, V < J, W < K, S < L$.

2.2 Four dimensional matrix operational criterion

If two four dimensional matrixes of the same order: $A_{I\times J\times K\times L} = \lfloor a_{i\times j\times k\times l} \rfloor_{I\times J\times K\times L}$ and $B_{I\times J\times K\times L} = \lfloor b_{i\times j\times k\times l} \rfloor_{I\times J\times K\times L}$ corresponding elements are all the same, then call two four dimensional matrixes are equal.

If two four dimensional matrixes of the same order: $A_{I\times J\times K\times L} = \lfloor a_{i\times j\times k\times l} \rfloor_{I\times J\times K\times L}$ and $B_{I\times J\times K\times L} = \lfloor b_{i\times j\times k\times l} \rfloor_{I\times J\times K\times L}$ sum is : $C_{I\times J\times K\times L} = \lfloor c_{i\times j\times k\times l} \rfloor_{I\times J\times K\times L}$, then same order matrixes corresponding elements have formula (2) showed relations:

$$C_{I\times J\times K\times L} = \lfloor c_{ijkl} \rfloor_{I\times J\times K\times L} = \lfloor a_{ijkl} + b_{ijkl} \rfloor_{I\times J\times K\times L} \tag{2}$$

In formula(2)showed four dimensional matrix addition meets associative law and commutative law.

Multiplication of two four dimensional matrixes of same order have six kinds that are respectively line-column multiplication, line-ordinate multiplication, line-height multiplication, column-ordinate multiplication, column-height multiplication and ordinate-height multiplication, two same order matrixes $A_{I_1\times J_1\times K_1\times L_1} = \lfloor a_{ijkl} \rfloor_{I\times J\times K\times L}, B_{I_2\times J_2\times K_2\times L_2} = \lfloor b_{ijkl} \rfloor_{I\times J\times K\times L}$ product expression is as formula (3)show:

$$\left(A_{I_1\times J_1\times K_1\times L_1} \cdot B_{I_2\times J_2\times K_2\times L_2}\right) = \lfloor C_{ijkl} \rfloor_{I_3\times J_3\times K_3\times L_3} \tag{3}$$

As formula (3) show, line-column multiplication conditions are as formula (4)show:

$$\begin{cases} c_{ijkl} = \sum_{e=1}^{j} a_{iekl} \cdot b_{ejkl}, (i = 1,2,\cdots,I_3;\ j = 1,2,\cdots,J_3; k = 1,2,\cdots,K_3; l = 1,2,\cdots,L_3) \\ K_3 = K_2 = K_1, L_3 = L_2 = L_1, I_2 = J_1, I_3 = I_1, J_3 = J_2 \end{cases} \tag{4}$$

Conditions that line-ordinate multiplication should meet is as formula (5)show:

$$\begin{cases} c_{ijkl} = \sum_{e=1}^{k} a_{ijel} \cdot b_{ejkl}, (i = 1,2,\cdots,I_3;\ j = 1,2,\cdots,J_3; k = 1,2,\cdots,K_3; l = 1,2,\cdots,L_3) \\ J_3 = J_2 = J_1, L_3 = L_2 = L_1, I_2 = K_1, I_3 = I_1, K_3 = K_2 \end{cases} \tag{5}$$

Conditions that line-height multiplication is as formula(6)show:

$$\begin{cases} c_{ijkl} = \sum_{e=1}^{l} a_{ijke} \cdot b_{ejkl}, (i = 1,2,\cdots,I_3;\ j = 1,2,\cdots,J_3; k = 1,2,\cdots,K_3; l = 1,2,\cdots,L_3) \\ J_3 = J_2 = J_1, K_3 = K_2 = K_1, I_2 = L_1, L_3 = L_2, I_3 = I_1 \end{cases} \tag{6}$$

Conditions that column-ordinate multiplication is as formula(7)show:

$$\begin{cases} c_{ijkl} = \sum_{e=1}^{k} a_{ijel} \cdot b_{iekl}, (i = 1,2,\cdots,I_3;\ j = 1,2,\cdots,J_3; k = 1,2,\cdots,K_3; l = 1,2,\cdots,L_3) \\ I_3 = I_2 = I_1, L_3 = L_2 = L_1, J_2 = K_1, J_3 = J_1, K_3 = K_2 \end{cases} \tag{7}$$

Conditions that column-height multiplication is as formula(8)show:

$$\begin{cases} c_{ijkl} = \sum_{e=1}^{l} a_{ikke} \cdot b_{iekl}, (i = 1,2,\cdots,I_3;\ j = 1,2,\cdots,J_3; k = 1,2,\cdots,K_3; l = 1,2,\cdots,L_3) \\ I_3 = I_2 = I_1, K_3 = K_2 = K_1, J_2 = L_1, J_3 = J_1, L_3 = L_2 \end{cases} \tag{8}$$

Conditions that ordinate-height multiplication is as formula(9)show:

$$\begin{cases} c_{ijkl} = \sum_{e=1}^{l} a_{ijke} \cdot b_{ijel}, (i = 1,2,\cdots,I_3;\ j = 1,2,\cdots,J_3; k = 1,2,\cdots,K_3; l = 1,2,\cdots,L_3) \\ I_3 = I_2 = I_1, J_3 = J_2 = J_1, K_2 = L_1, K_3 = K_1, L_3 = L_2 \end{cases} \quad (9)$$

Four dimensional matrix $A_{I\times J\times K\times L}$ transposition computing has six types that are respectively line-column transposition that is interchanging I, J, line-ordinate transposition that is interchanging I, K, line-depth transposition that is interchanging I, L, column-ordinate transposition that is interchanging J, K, column-depth transposition that is interchanging J, L, ordinate-depth transposition that is interchanging L, K.

3. Four dimensional matrix discrete cosine transformation-based vide coding

Discrete cosine transformation was proposed by N.Ahmed and others as earliest, it was widely used in image compression coding field, from which international standard JPEG、MPEG coding also adopted two dimensional discrete cosine transformation technique, in image documents, it included lots of low frequency information, while discrete cosine transformation had approximately optimal decorrelation functions on signals with Gauss-markov-1 statistical features. In order to better represent video image correlations in airspace, time domain as well as R、G、B three frames, promoted three dimensional discrete cosine transformation to four dimensional matrix, it could get better effects. In the following, it makes theoretical statements on one dimensional cosine discrete transformation, four dimensional cosine discrete transformations, in the hope of provide more reasonable and better theoretical basis for video coding.

3.1 One dimensional cosine discrete transformation

If one dimensional discrete sequence $f(x)$, from which $x = 0,1,2,\cdots,N-1$, take $-\frac{1}{2}$ as break, it can form into $-N \to -1$ sequence and combine with original sequence into $2N$ even function sequence, then transform kernel is as formula (10)show:

$$\exp\left[-j\frac{2\pi\left(x+\frac{1}{2}\right)u}{2N}\right] = \exp\left[-\frac{j\pi(2x+1)u}{2N}\right] \quad (10)$$

Then discrete variable turns into $-N, -N+1, \cdots, -1, 0, 1, \cdots, N-1$, according to Fourier transformation attributes, imaginary number as zero don't need to calculate, formula(10) only leaves $\cos\left[\frac{\pi(2x+1)u}{2N}\right]$, therefore cosine positive transformation is as formula (11)show:

$$F(u) = c(u)\sqrt{\frac{2}{N}}\sum_{x=0}^{N-1} f(x)\cos\left[\frac{\pi(2x+1)u}{2N}\right] \quad (11)$$

In formula(11), $c(u)$ range is when $u = 0$, $c(u) = \frac{\sqrt{2}}{2}$, when $u = 1,2,\cdots,N-1$, $c(u) = 1$, formula (11)corresponding inverse transformation is as formula (12)show:

$$f(x) = \sqrt{\frac{2}{N}}\sum_{x=0}^{N-1} c(u)F(u)\cos\left[\frac{\pi(2x+1)u}{2N}\right] \quad (12)$$

3.2 Four dimensional cosine discrete transformation

Four dimensional discrete cosine transformation is as formula (13)show:

$$[c_{uvws}]_L = \begin{cases} \sqrt{\frac{2}{N}}\cos\frac{i\pi(2j+1)}{2N} & i \neq 0 \\ \frac{1}{\sqrt{N}} & i = 0 \end{cases} \tag{13}$$

In formula(13), when $L=1$, it has $i=u, j=v$; when $L=2$, it has $i=u, j=w$; when $L=3$, it has $i=u, j=s$; when $L=4$, it has $i=v, j=w$; when $L=5$, it has $i=v, j=s$; when $L=6$, it has $i=w, j=s$; if set A and B to be four dimensional matrix, then four dimensional matrix discrete cosine transformation is as formula (14)show:

$$\begin{aligned} B &= \left(C_6\left(C_1 A C_1^{T1}\right)_1 C_6^{T6}\right)_6 = \left(C_1\left(C_6 A C_6^{T6}\right)_6 C_1^{T1}\right)_1 \\ &= \left(C_5\left(C_2 A C_2^{T2}\right)_2 C_5^{T5}\right)_5 = \left(C_2\left(C_5 A C_5^{T5}\right)_5 C_2^{T2}\right)_2 \\ &= \left(C_3\left(C_4 A C_4^{T4}\right)_4 C_3^{T3}\right)_3 = \left(C_4\left(C_3 A C_3^{T3}\right)_3 C_4^{T4}\right)_4 \end{aligned} \tag{14}$$

Correspond to formula (15) four dimensional matrix discrete cosine inverse transformation is as formula (15)show :

$$\begin{aligned} A &= \left(C_6^{T6}\left(C_1^{T1} A C_1\right)_1 C_6\right)_6 = \left(C_1^{T1}\left(C_6^{T6} A C_6\right)_6 C_1\right)_1 \\ &= \left(C_5^{T5}\left(C_2^{T2} A C_2\right)_2 C_5\right)_5 = \left(C_2^{T2}\left(C_5^{T5} A C_5\right)_5 C_2\right)_2 \\ &= \left(C_3^{T3}\left(C_4^{T4} A C_4\right)_4 C_3\right)_3 = \left(C_4^{T4}\left(C_3^{T3} A C_3\right)_3 C_4\right)_4 \end{aligned} \tag{15}$$

3.3 Video image four dimensional sub matrix segmentation and video coding system

A color image normally is composed of same size R、G、B gray level images, and video image constitutes are multiple continuous static color images, so it can use four dimensional matrix model to express video image, four dimensional matrix discrete cosine transformation-based video compression algorithm can do without adopting motion compensation techniques among intra-frame coding.

During utilizing two dimensions to express image space location, color image three color components can be used as one dimension, and another dimension is used to express time coordinate axis, then express video image relations among airspace, time domain and each color components as a unified mathematical model, the method makes full use of video image airspace, time domain and color components correlations. And four dimensional matrix discrete cosine change-based video coding needs firstly to make four dimensional submatrix segmentation on image sequence, in segmentation process, considering computing complexity, blocking effects and system time delay and other factors, it can adopt $4\times4\times3\times3$ submatrix segmentation scheme, take 3 frames as one group and regard every group 3 frames as a four dimensional image matrix, while to every frame image, take 4×4 block, let it to form into several $4\times4\times3\times3$ video submatrixes, and then separately carry out four dimensional matrix discrete cosine transformation on every submatrix.

Apply four dimensional matrix models to express video images, segment image sequence into thought video submatrix, system is fully symmetric in coding end and decoding end, due to it doesn't involve motion estimation and motion compensation, let computing complexity to be slightly reduced, structure is also relative easy to implement, four dimensional matrix discrete cosine transformation video decoding system chart is as Figure 1 show.

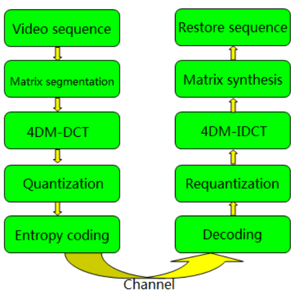

Figure 1: Video decoding and coding system chart

As Figure 1 show, firstly group continuous video sequences, let them to fulfill video sequence four dimensional matrix model expression, then make four dimensional matrix discrete cosine transformation on every

$4\times4\times3\times3$ four dimensional submatrix, obtained four dimensional coefficient matrix implements effective decorrelation on airspace, time domain and color space in 4DM-DCT transformation link, due to 4DM-DCT coefficient correlation is lower and causes most of energy concentrating on fewer low frequency coefficient, most of coefficient is zero or gets closer to zero, especially for each color component transformation coefficient, they are almost zero, the features provide higher possibility to get high compression ratio. Quantization link effect is on the premise of ensuring certain images qualities, removing such information that has smaller effects on visual effects, so quantization link is also introducing method of errors, quantization in the paper is vector quantization. After fulfilling vector quantization on transformation coefficient, it needs to make run coding and entropy coding on quantization coefficient, use run coding to let quantization coefficient distribution to be more regular, in order to further arrive at the purpose of compressing data, make entropy coding on run coding codon, the paper adopts Huffman coding .Decoding process is reverse process of coding.

4. Simulation data analysis

4.1 Data evaluation criterion

Apply the paper stated four dimensional matrix discrete cosine transformation-based video compression algorithm, implement coding experiment in DSP simulation system, for experiment data evaluation quantities, it has compression ratio and peak signal to noise ratio, compression ratio formula is as formula (16) show:

$$C_r = \frac{preByte}{pasByte} \tag{16}$$

In formula(16), C_r represents compression ratio, $preByte$ represents original image bit number, $pasByte$ represents bit number after compressing and coding .Objective quality evaluation standard peak signal to noise ratio computational formula is as formula (17)show:

$$\mathrm{PSNR}(\mathrm{dB}) = 10\mathrm{Lg}\left(\frac{255^2}{\sigma_e^2}\right) \tag{17}$$

In formula(17), PSNR represents peak signal to noise ratio, σ_e^2 represents original image sequence pixel value and reconstruction image pixel value differences' mean square error.

4.2 Evaluation standard data comparing

Table 1: Different compression methods' evaluation standard data comparison table

Experiment image sequence	Compression method	Compression ratio	Average signal to noise ratio
Image sequence 1	3DM-DCT	64	40.95
		256	35.70
	MC/2D-DCT	287	35.50
Image sequence2	3DM-DCT	64	38.19
		256	34.35
	MC/2D-DCT	139	32.60
Image sequence1	4DM-DCT	72	39.44
		288	36.75
	MC/2D-DCT	287	35.50
Image sequence3	4DM-DCT	72	33.20
		288	32.77
	MC/2D-DCT	168	33.30

Table 2: Coding and decoding process time-consuming comparison table

Compression process	Decoding each link	Running time coordinate	Total time-consuming
3D-DCT coding process	Submatrix segmentation and cosine positive transformation	4.02ms	4.58ms
	Vector quantization and entropy coding	4.58ms	
3DM-IDCT decoding process	Decoding and inverse quantization	3.13ms	4.19ms
	Cosine inverse transformation and submatrix synthesis	4.19ms	
4DM-DCT coding process	Submatrix segmentation and cosine forward transformation	2.67ms	2.67ms
	Vector quantization and entropy coding	1.52ms	
4DM-IDCT decoding process	Decoding and inverse quantization	1.00ms	2.72ms
	Cosine inverse transformation and submatrix synthesis	2.72ms	

Data in Table 1 and Table 2 shows that under high compression ratio four dimensional matrix discrete cosine transformation-based video coding has higher average signal to noise ratio, time-consuming is obvious fewer than that of video coding based on three dimensional matrix discrete cosine transformation.

CONCLUSION

1)By theoretical statement and simulation data indication, four dimensional matrix discrete cosine transformation-based video compression algorithm is obvious superior to three dimensional transformation compression algorithm in the aspect of performance and computing;
2) In order to implement remote video education easily transmission demand, four dimensional matrix discrete cosine transformation-based video compression algorithms can provide more convenient theoretical basis for the demand;
3)The paper puts emphasis on researching four dimensional matrix computing method and vide coding and decoding system constitutes, by stated mathematical algorithm, it simulates on DSP, and gets evaluation standard data, indicates by data that four dimensional matrix discrete cosine transformation possessed superiorities in video compression.

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