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The study based on four-dimensional matrix DCT distance education video compression technology

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ABSTRACT

In the gorgeous era, the role of video in the human life growing. However, the high-definition picture quality caused the difficulty in storage. In order to save more resources and maintain the quality of image, this article found out the method to solve the problem of remote compression through combining the four-dimensional matrix discrete cosine transform with statistical quantification firstly, then validated its effect in practical application according to the specific examples. The results shows that the compression through combining the integer transform with quantization achieved the desired effect.

KEYWORDS

Discrete cosine transform; Four-dimensional matrix; Discrete integer transform; Video compression; Distance education.

INTRODUCTION

Nowadays, in the advanced information era, Video is particularly important in human life., the video is essential whether concerning about national affairs or relax in their leisure time. However, the video production process is known by very few people, because it is a very complicated process. The entire process including the signal capture, recording and processing followed by storage, transmission and finally to reproduce the images for everyone to see. Today's video is no longer the past era of 'black and white'. With the rapid advancement of technology, the recording and the handle ability of video also continue to strengthen. Therefore, the resolution of the video is also at an alarming rate, also increased the amount of information stored, which led to the demand for video storage space is also growing. But the computer's storage space is limited, and the video which is too big in the video transmission is also very troublesome. So the compression of video become an inevitable trend. Video compression technology is also very important. Today there are many compression software, but most of the principles are the same. Today the most widely used method of compressed video technology is discrete cosine law. This article will analyze and study for four-dimensional matrix discrete cosine change of distance education video compression technology.

ESTABLISHMENT AND SOLUTION OF THE MODEL

The concept of four-dimensional discrete cosine transform matrix

Similar to the discrete Fourier transform, we could see the shadow of the Fourier transform from the discrete cosine transform. But its difference from Fourier transform is that discrete cosine transform is only applicable to real numbers, and its length is only half of a discrete Fourier transform. The commonly used discrete cosine transform can be divided into two categories. I.e., Inverse discrete cosine transform and inverse discrete cosine transform. And an inverse discrete cosine transform is often used in video compression or encoding process.

The definition of four-dimensional discrete cosine transform matrix

Now define a four-dimensional matrix A , is a data matrix $I \times J \times K \times L$, formula is as follows:

$$A_{I\times J\times K\times L} = \left[a_{ijkl} \right]_{I\times J\times K\times L}$$

Among them, a_{ijkl} is an element for the matrix $A_{I\times J\times K\times L}$. For the solution of four-dimensional discrete cosine transform, now set

$$[C_{wws}]L = \begin{cases} \sqrt{\dfrac{2}{N}} \cos \dfrac{i\pi(2i+1)}{2N}, i \neq 0 \\ \dfrac{1}{\sqrt{N}}, i = 0 \end{cases}$$

When $L=1$, $i=u$, $j=v$;
When $L=2$, $i=u$, $j=w$;
when $L=3$, $i=u$, $j=s$;
when $L=4$, $i=v$, $j=w$;
when $L=5$, $i=v$, $j=s$
when $L=6$, $i=w$, $j=s$;
If A and S are four-dimensional matrix, then the discrete cosine transform of S is:

$$
\begin{aligned}
S &= (C_6(C_1 A C_1^{T\mathrm{I}})_{\mathrm{I}} C_6^{T\mathrm{VI}})_{\mathrm{VI}} \\
&= (C_1(C_6 A C_6^{T\mathrm{VI}})_{\mathrm{VI}} C_1^{T\mathrm{I}})_{\mathrm{I}} \\
&= (C_5(C_2 A C_2^{T\mathrm{II}})_{\mathrm{II}} C_5^{T\mathrm{V}})_{\mathrm{V}} \\
&= (C_2(C_5 A C_2^{T\mathrm{V}})_{\mathrm{V}} C_2^{T\mathrm{II}})_{\mathrm{II}} \\
&= (C_3(C_4 A C_4^{T\mathrm{IV}})_{\mathrm{IV}} C_3^{T\mathrm{III}})_{\mathrm{III}} \\
&= (C_4(C_3 A C_3^{T\mathrm{III}})_{\mathrm{III}} C_4^{T\mathrm{IV}})_{\mathrm{IV}}
\end{aligned}
$$

then the discrete cosine transform of A is:

$$
\begin{aligned}
A &= (C_6^{T\mathrm{VI}}(C_1^{T\mathrm{I}} B C_1)_{\mathrm{I}} C_6)_{\mathrm{VI}} \\
&= (C_1^{T\mathrm{I}} (C_6^{T\mathrm{VI}} B C_6)_{\mathrm{VI}} C_1)_{\mathrm{I}} \\
&= (C_5^{T\mathrm{V}} (C_2^{T\mathrm{II}} B C_2)_{\mathrm{II}} C_5)_{\mathrm{V}} \\
&= (C_2^{T\mathrm{II}} (C_2^{T\mathrm{V}} A C_5)_{\mathrm{V}} C_2)_{\mathrm{II}} \\
&= (C_3^{T\mathrm{III}} (C_4^{T\mathrm{IV}} A C_4)_{\mathrm{IV}} C_3)_{\mathrm{III}} \\
&= (C_4^{T\mathrm{IV}} (C_3^{T\mathrm{III}} A C_3)_{\mathrm{III}} C_4)_{\mathrm{IV}}
\end{aligned}
$$

The matrix A and the digital in matrix represent the difference of the type that they transpose.

In the encoding and compression processing of a color video, each pixel of the video can be converted into one of the elements in four-dimensional matrix. Therefore, the pixel values of the video can be expressed as $f(x, y, z, t)$, Where x、y、z are three-dimensional coordinate components, I.e., horizontal, vertical, and the vertical component, t represents the time. Therefore, the video formula can be written as:

$$\{ f(x, y, z, t)\ x = 0,1,...,M-1;\ Y = 0,1,...,N-1;\ Z = 0,1,...,L-1;\ T = 0,1,...,H-1 \}$$

It is represented as a discrete linear transformation equation, as the following equation:

$$F(u, v, w, s) = \sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\sum_{z=0}^{L-1}\sum_{t=0}^{H-1} f(x, y, z, t)\, p(u, v, w, s, x, y, z, t)$$

In the above formula $F(u, v, w, s)$ is called a transform coefficient of $f(x, y, z, t)$, and the transform nuclear is as follows:

$$p(u, v, w, s, x, y, z, t),$$

$$u = 0,1,...,M-1;\ v = 0,1,...,N-1;\ w = 0,1,...,L-1;\ s = 0,1,...,H-1$$

Similarly, the inverse transform of the matrix can be expressed as:

$$F(x, y, z, t) = \sum_{u=0}^{M-1}\sum_{v=0}^{N-1}\sum_{w=0}^{L-1}\sum_{s=0}^{H-1} F(u, v, w, s)\, q(u, v, w, s, x, y, z, t)$$

Then:

$$q(u, v, w, s, x, y, z, t),$$
$$x = 0,1,...,M-1;\ y = 0,1,...,N-1;\ z = 0,1,...,L-1;\ t = 0,1,...,H-1$$

is the inverse transform core.

Now regard $f(x,y,z,t)$ as a element of four-dimensional matrix, and treat it as a special case of linear transformation, it's discrete cosine transform can be expressed as:

$$F(u,v,w,s)=\sqrt{\frac{2^4}{MNLH}}c(u)c(v)c(w)c(s)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\sum_{z=0}^{L-1}\sum_{t=0}^{H-1}$$

$$f(x,y,z,t)\cos\left[\frac{(2x+1)\pi u}{2M}\right]\cos\left[\frac{(2y+1)\pi v}{2N}\right]\cos\left[\frac{(2z+1)\pi w}{2L}\right]\cos\left[\frac{(2t+1)\pi s}{2H}\right]$$

Among them, $u=0,1,...,M-1;\ v=0,1,...,N-1;\ w=0,1,...,L-1;\ s=0,1,...,H-1$ 。

Its inverse discrete cosine transform can be represented as:

$$f(x,y,z,t)=\sqrt{\frac{2^4}{MNLH}}\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}\sum_{z=0}^{L-1}\sum_{t=0}^{H-1}F(u,v,w,s)c(u)\cdot$$

$$c(v)c(w)c(s)\cos\left[\frac{(2x+1)\pi u}{2M}\right]\cos\left[\frac{(2y+1)\pi v}{2N}\right]\cos\left[\frac{(2z+1)\pi w}{2L}\right]\cos\left[\frac{(2t+1)\pi s}{2H}\right]$$

Among them, $x=0,1,...,M-1;\ y=0,1,...,N-1;\ z=0,1,...,L-1;\ t=0,1,...,H-1,$

$$c(u)=\begin{cases}\frac{1}{\sqrt{2}}, & u=0\\ 1, & others\end{cases};\quad c(v)=\begin{cases}\frac{1}{\sqrt{2}}, & v=0\\ 1, & others\end{cases};$$

$$c(w)=\begin{cases}\frac{1}{\sqrt{2}}, & w=0\\ 1, & others\end{cases};\quad c(s)=\begin{cases}\frac{1}{\sqrt{2}}, & s=0\\ 1, & others\end{cases}\text{。}$$

The realization of the four dimensional discrete cosine transform for Video compression

In this article, the video is divided into multiple child on R, G, B component and time t according to four-dimensional matrix model, then transform and coding the four dimensional discrete cosine. See Figure 1for specific process.

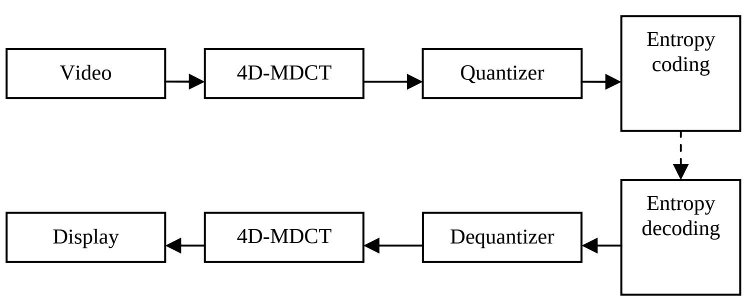

Figure 1 : Four-dimensional discrete cosine transform video encoding process

Take the transform of a as an example, when $x \in Z$, if $a,b \in Z$, then can be introduced $y \in Z$. when $b \in Z$, $a=\pm 1\ or\ \pm i$, can get the conclusion that $y=ax+b$ is completely reversible. then the factors a and b are integers. when $b \notin Z$, by integer to ensure that the results of a computation as an integer. At the same time also ensure $y=ax+b$ transformation reversible. A transformation matrix is described below:

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_n \end{bmatrix} = \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 0 & 1 & \dots & \vdots \\ \vdots & 0 & \ddots & a_{\dots n} \\ 0 & \dots & 0 & 1 \end{bmatrix} \times \begin{bmatrix} x_1 \\ x_2 \\ \vdots \\ x_n \end{bmatrix}$$

Set A in the above formula as the basic matrix, then can get:

$$y_i = x_i + \left| \sum_{n=j+1}^{N} a_{jn} x_n \right|, j = 1, 2, ..., N$$

It's inverse transformation expressed as :

$$x_j = y_j - \left| \sum_{n=j+1}^{N} a_{jn} x_n \right|$$

$$j = N, N-1, ..., 1$$

Thus, if A can be decomposed into an upper triangular matrix, the transformation of $y = Ax$ can be carried out inverse transform.

Now set $u = v = w = s = N$, if w、s known, then the orthogonal transform nuclear can be regarded as a matrix of $N \times N$, then

$$c_{ij} = \begin{bmatrix} \frac{1}{\sqrt{N}} & \frac{1}{\sqrt{N}} & \cdots & \frac{1}{\sqrt{N}} \\ \frac{\sqrt{2}}{\sqrt{N}} \cos\frac{\pi}{2N} & \frac{\sqrt{2}}{\sqrt{N}} \cos\frac{3\pi}{2N} & \cdots & \frac{\sqrt{2}}{\sqrt{N}} \cos\frac{(2n-1)\pi}{2N} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{\sqrt{2}}{\sqrt{N}} \cos\frac{(N-1)\pi}{2N} & \frac{\sqrt{2}}{\sqrt{N}} \cos\frac{3(N-1)\pi}{2N} & \cdots & \frac{\sqrt{2}}{\sqrt{N}} \cos\frac{(N-1)(2N-1)\pi}{2N} \end{bmatrix}$$

The C_6 above is in contrast, by the nature of the 4 d – MDCT, 4D-MDCT are orthogonal transformation, Therefore, when a determinant of A is $|A| = \pm 1$, can prove that a matrix can be decomposed into reversible triangular fundamental matrix, that is:

$$A = PLUS_0$$

Wherein P represents a permutation matrix, upper and lower triangular matrix with L and U respectively, and S_0 can be expressed as:

$$S_0 = I + e_n s_o = I + e_n (s_1, s_2, ..., s_{n-1}, 0)$$

e_n indicates a vector in column N of S_0, s_n is a vector element in the zero column.

Each element of orthogonal transform nuclear can be carried out ina triangular decomposition by $PLUS_0$, then composit each of the elemental of 4D-MDCT into a nuclear matrix, So 4D-MDCT transform can be achieved.

In this paper, take the four dimensional discrete cosine transform for example, that $S = (C_6(C_1 A C_1^{T\text{I}})_{\text{I}} C_6^{T\text{VI}})_{\text{VI}}$ prove its overall nuclear matrix transformation. Seen from above, nuclear transformation matrices C_1、C_6、C_1^T and C_6^t all belong orthogonal matrix, Therefore, they can be broken down into the triangle decomposition.

If T_i is the nuclear transformation factorization of C_i, its expression is as follows:

$$T_i = P_i L_i U_i S_{0i}$$

Then the four-dimensional discrete cosine integral transform expression is:

$$B = \overbrace{\overbrace{\overbrace{\|\,|T_6|\overbrace{T_1 A}^{frist}|T_1^{T1}}^{second}|I|}^{third}T_6^{TVI}|\mathrm{VI}}^{fourth}$$

In the above formula, $frist$、$second$、$third$、$fourth$ indicates the order abcd transformation. Similarly, the opposite order of the inverse transformation. can be reverse with the procedure above.

Experimental validation of the four-dimensional discrete cosine transform matrix

Now make a four dimensional discrete cosine transform on an image of a color video which sequence is $Miss\ \ America$ and $Suzie$, and compress it. The processing sequence is as follows:

Firstly, divide the sequence RGB into a four-dimensional matrix of $3\times3\times3\times3$, and make a four dimensional discrete cosine transform on it, then obtain the four-dimensional matrix transformation. Secondly, encode the quantified using statistical methods to the resultant transformation matrix, then take the code number in integer values. Thirdly, compare the results with the floating-point matrix obtained by dimensional discrete cosine transform. The evaluation standard of image is $PSNR$, the expression is as follows:

$$PSNR = 10\log\frac{255\times255}{MSE}dB$$

The comparative results as shown in TABLE 1.

The TABLE 1 above indicates that when ratios of two image is108、92.6、81 in the original image data is image data and the modification data of each frame. Figure 2 and Figure 3 are the comparison chart of two images.

Figure 2 : The original image and contrast figure after repair of Miss America

Figure 3 : comparison chart of Suzie before and after change

TABLE 1 : The comparison on 4D-MDCT of integer and floating-point

Video sequences	CR	Frame	floating-point 4D-MDCT				integer 4D-MDCT			
			PSNR (R)	PSNR (G)	PSNR (B)	$\overline{\text{PSNR}}$	PSNR (R)	PSNR (G)	PSNR (B)	$\overline{\text{PSNR}}$
MISS America	108	12	29.616	32.945	31.337	31.332	31.530	33.818	32.450	32.600
		13	29.656	33.084	31.345	31.365	31.530	33.818	32.450	32.600
		14	29.601	33.093	31.345	31.530	31.530	33.818	32.450	32.600
	92.6	12	31.201	34.258	34.354	32.411	32.567	33.588	33.710	34.110
		13	31.195	34.467	32.598	32.754	32.948	35.830	33.710	34.144
		14	31.031	34.488	32.300	32.600	32.948	35.830	33.710	34.144
	81	12	32.885	36.358	33.915	34.384	35.122	37.716	35.344	36.061
		13	32.968	36.445	33.929	34.456	35.122	37.716	35.344	36.061
		14	32.654	36.480	33.625	34.248	35.122	37.716	35.344	36.061
Suzie	108	12	28.983	30.262	29.434	29.561	30.806	31.411	31.142	31.118
		13	29.287	30.585	29.775	29.881	30.970	31.600	31.319	31.297
		14	28.804	29.944	29.364	29.365	30.651	31.227	31.053	30.976
	92.6	12	30.192	31.594	30.639	30.809	32.111	32.817	32.569	32.499
		13	30.730	32.011	31.127	31.290	32.334	33.218	32.817	32.790
		14	30.253	31.281	30.643	30.720	32.108	32.688	32.566	32.454
	81	12	31.722	33.056	31.942	32.248	33.818	34.515	34.152	34.162
		13	32.181	33.449	32.365	32.663	34.152	34.910	34.515	34.526
		14	31.618	32.666	31.828	32.035	33.815	34.327	34.149	34.097

CONCLUSION

This article found out the method to solve the problem of remote compression through combining the four-dimensional matrix discrete cosine transform with statistical quantification firstly, then validated its effect in practical application according to the specific examples. The results shows that the compression through combining the integer transform with quantization achieved the desired effect.

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