論文
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비디오 코딩 기술을 이용한 컴퓨터 형성 홀로그램 압축
Computer generated hologram compression using video coding techniques

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요약

본 논문에서는 디지털 홀로그램의 효과적인 코딩 방법으로써 비디오 영상에서 사용되는 표준 압축 방식을 사용하였다. 먼저, 컴퓨터 형성 홀로그램(CGH)으로부터 생성된 격자패턴을 비디오 데이터로 변환한 다음 이를 부호화 하였다. 또한, 변환을 위한 전처리, 물체 영상의 전체적인 정보에 대한 국부적인 영역분할, 부호화를 위한 주파수 변환, 격자패턴의 비디오 스트림을 위한 스캐닝, 계수 값의 분류, 복합적인 비디오 부호화 등을 제안하였다. 제안된 복합 압축 알고리듬은 기존의 방법에 비해 뛰어난 압축율과 재생력을 얻을 수 있었다.

ABSTRACT

In this paper, we propose an efficient coding method of digital hologram using standard compression tools for video images. At first, we convert fringe patterns into video data using a principle of CGH(Computer Generated Hologram), and then encode it. In this research, we propose a compression algorithm is made up of various method such as pre-processing for transform, local segmentation with global information of object image, frequency transform for coding, scanning to make fringe to video stream, classification of coefficients, and hybrid video coding. The proposed algorithm illustrated that it have better properties for reconstruction and compression rate than the previous methods..

Keywords: Computer generated hologram, video coding techniques, pre-processing, segmentation,

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본 논문은 정보통신부 대학 IT연구센터 육성지원 사업의 연구 결과 및 2004년도 광운대학교 교내 연구비에 의해 연구되었습니다.

1.Introduction

Since the holography is first proposed by Garbor in 1948, many researchers have been concerned about it for characteristic that can record whole information of 3D(3 Dimension) object. The previous method for holography reconstructed 3D object using the printed film after recording 3D information on the hologram film. Therefore, the application of holography is so restricted. After 1966, many researchers have investigated the production of hologram by computer which is newly approached method for overcoming these limitations. Although the researches for digital holography on many international research institutions recently have been in progress, most of researches have restriction such as acquisition of the optical hologram image and techniques to reconstruct it efficiently. Yoshikawa proposed a method to reduce hologram data by a still image compression technique like JPEG. Since fringe pattern doesn't have the properties similar with the general 2D image, his early method has low compression efficiency[2][3]. To solve these problems, he divided the fringe pattern into the several segments and transformed these with 1D DCT(Discrete Cosine Transform). After frequency transform, DCT coefficient was encoded with moving picture compression technique such as MPEG-1[4]. Thomas was also proposed a coding scheme to compress digital hologram using LZ77, LZW, and Huffman coding techniques that are lossless data compression tools[5].

In this paper, we propose a hybrid coding algorithm which first segments a fringe pattern into the blocks including the entire information of the object image, and then transforms the segment with 2D DCT. The transformed data is rearranged to video stream by post-processing step, scanning. Finally the video sequence is compressed using the international standard image/video compression technique such as JPEG2000, MPEG-2, MPEG-4, and H.264/AVC, and other coding tools.

2. Proposed digital hologram coding

2.1.Coding summary

An algorithm proposed by Yoshikawa[4] for lossy compression is known as the most developed method, but it has limitation for compression efficiency because it didn't consider the intermediate type of the processed data. So, we analyze the properties of the video coding technique, which accepted for the international standard and characteristics of the data generated in coding steps, and then propose a hybrid coding scheme for hologram compression, which has better performance than previous researches. We also use (5,3) filter of JPEG2000 for lossless compression. However we don't include lossless compression techniques suck as JBIG and LZW. In previous research, it is proved that these lossless compression methods are not suitable for coding of digital hologram[5].

2.2.Coding system

Fig.1 shows the whole flow for coding digital hologram. The coding process of digital hologram consists of pre-processing, segmentation, transform, post-processing, and compression. Fringe pattern is divided intoseveral blocks for 2D DCT. The DCT coefficients are rearranged into a video stream by post-processing which is scanning. Therefore, we can apply it to compression system for moving picture. Fig. 2 shows the graphical coding process for an object that has depth information. We will explain the process in detail in next sections.

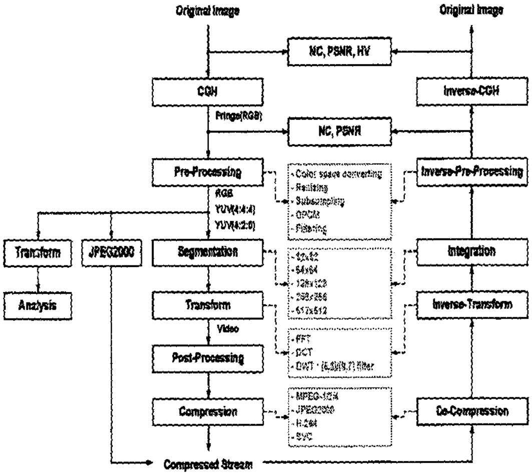


Fig. 1. Proposed process of digital hologram coding.

2.2.Pre-processing

Fringe from original image has color components. For coding color components, original image must be divided into R, G, B components or Y, U, V components. Fig. 3 shows a process dealing with color components. The divided components (RGB or YUV) are coded as independent channels.

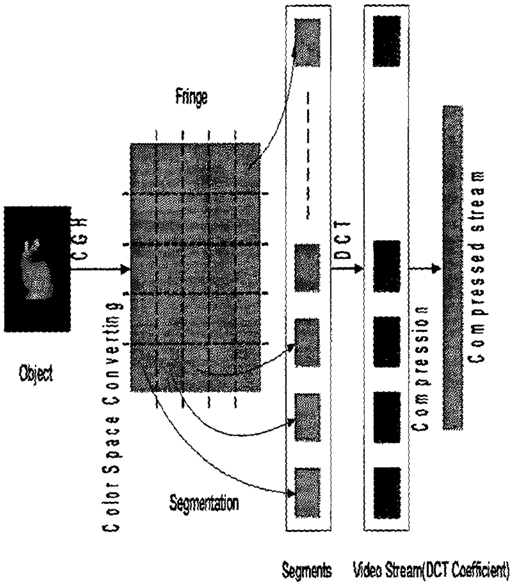


Fig. 2. Graphical procedure of digital hologram compression.

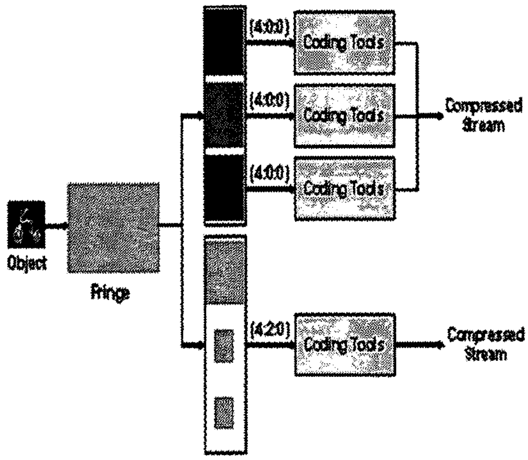


Fig. 3. Pre-processing of fringe image for coding.

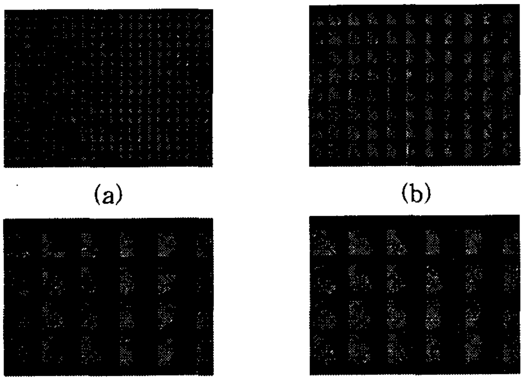


Fig. 4. Frequency transform result of fringe (a) 64×64 (b) 128×128 (c) 256×256 (d) 512×512.

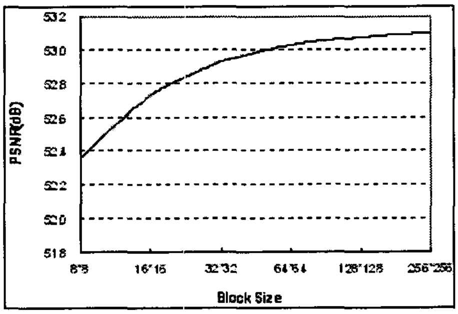
2.3.Segmentationandfrequencytransform

2.3.1. Segmentation and frequency transform

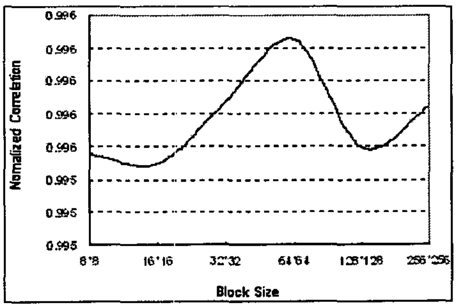
Fig. 4 shows the frequency transform results of divided segments that have the size from 16×16 to 512×512. 2D DCT selected by generation principle of CGH is used for transforming from fringe pattern to DCT coefficient of it. If the coefficient produced by transform process is treated like a 2D image, the shape similar with the original object appears in the segments. In other words, we can treat fringe patterns into video stream like Fig. 4 because the local characteristic of divided fringe patterns is the same as temporal variation. In addition, the differences between fringe patterns are not so much because the patterns are similar to each other. Therefore, it can be treated into temporal redundancy and compressed efficiently in the coding system for moving picture.

2.3.2. Feature of fringe by segmentation

Fig. 5 (a) and (b) show PSNR(Peak Signal to Noise Ratio) of reconstructed fringe andNC(Normalized Correlation) of reconstructed object image in case of applying only DCT transform and inverse transform. In Fig. 5 (a), PSNR increases as the block size increases, but NC(Normalized Correlation) is not related to it in Fig. 5 (b).



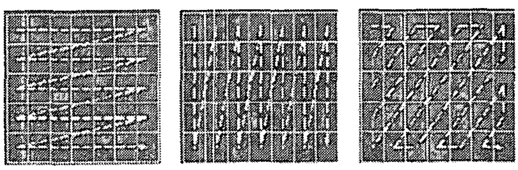
(a)



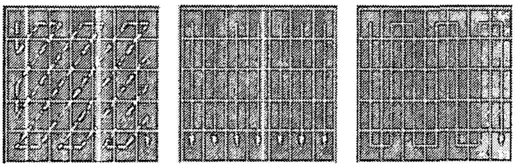
(b)

Fig. 5. Simulation result of object by segmentation and DCT (a) PSNR (b) NC.

2.4.Videosequenceformation



(a) (b) (c)



(d) (e) (f)

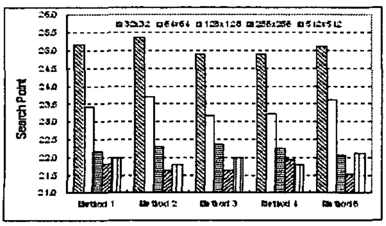
Fig. 6. Scanning of segmented fringe image.

2.4.1. Scan method

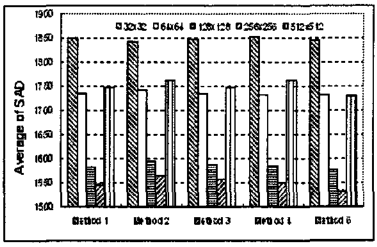
If divided fringes are treated independently by DCT, DCT coefficients are similar to video stream. Therefore, divided fringes haveto be scanned for temporal ordering. Fig. 6 shows the possible scan methods. After 2D DCT, the choice of scan method is related with temporal characteristic and efficiency.

2.4.2. Efficiency analysis to ME/MC

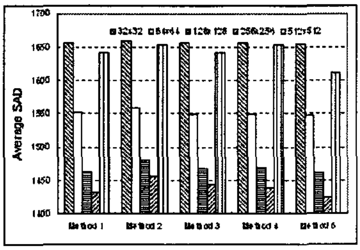
We analyzed the cost and performance for various scanning methods in Fig. 6 after application of DS (Diamond Searching) based ME/MC(Motion Estimation/ Compensation). Searching point is computational result to find motion, and SAD(Sum of Absolute Difference) value is error value in ME/MC process. Fig. 7 (a), (b) and (c) show results of search point and SAD according to scanning in Fig. 6. Fig. 6 (f) is the best for cost and performance.



(a)



(b)



(c)

Fig. 7. Comparison of (a) search point in DS (b) SAD in DS (c) SAD in FS (per macro block)

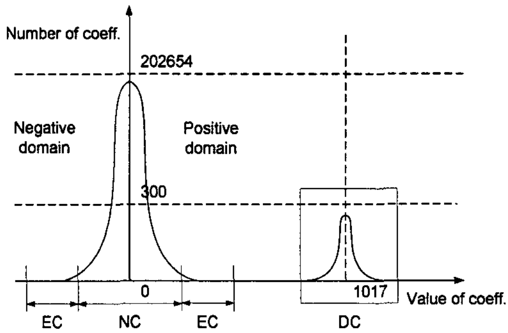


Fig. 8. Classification of DCT coefficient.

2.5.Hybridcodingusingvideocodingmethod

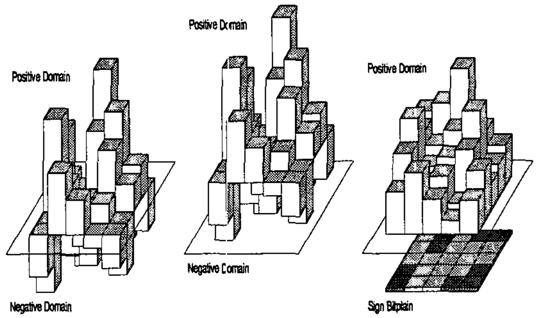
2.5.1. Compression and reconstruction algorithm

After 2D DCT, the DC and several AC coefficients that have value over 255 are treated into EC(Exceptional Coefficient) shown as Fig. 8. EC is compressed by

DPCM and entropy coding. The reason of this process is that occurrence of EC has low probability but EC has high influence to entire image because of its large size of value. Therefore, it is essential to process exceptionally these coefficients. The general values that have a value from +255 to -256 value are classified into NC(Normal Coefficient). NC have the negative value. However the negative values are not suitable for input of general compression tools like MPEG. In Yoshikawa's previous research[4], this nagativeness was not considered. To solve this problem we change negative value of DCT coefficients into positive value by introducing a sign bitplane. Fig 9 (c) is our proposal; the negative values of fig. 9 (a) are changed into positive values, and then the positions of negative value are marked on the sign bitplane. Therefore we can do the compression process for only positive coefficients. The sign bitplane is compressed by binary -based lossless encoder because the sign bitplane is important information. Fig. 10 shows the global hybrid coding algorithm that was explained previously.

2.5.2. Processing of exception coefficient

The number of EC is under 0.1% ratio in whole coefficients. Although EC is deal with exceptional process, it slightly affects compression ratio. But their effect for entire image quality is so huge because they have high value. So, we use lossless compression technique for EC.



(a) (b) (c)

Fig. 9. Rearrangement of DCT coefficient (a) original coefficient (b) level shift (c) proposed method

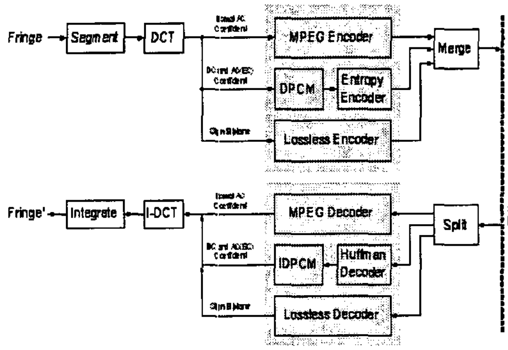


Fig. 10. Proposed hybrid coding algorithm for digital hologram compression

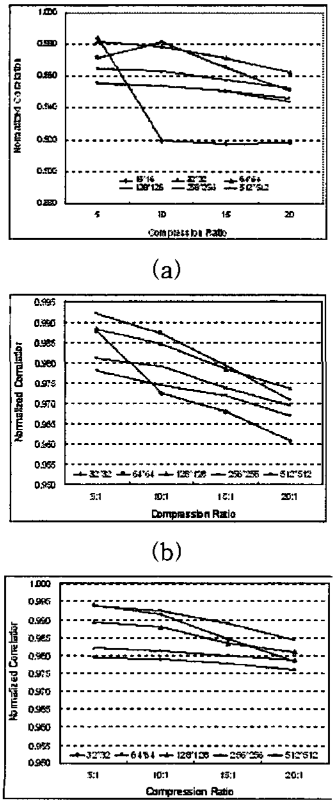
2.6.Coding using still image compression

We analyze the effect of hologram compression. The analysis process is that the fringe patterns generated from CGH are compressed and reconstructed by JPEG2000, and then it is converted into original object.

3.experiments and results

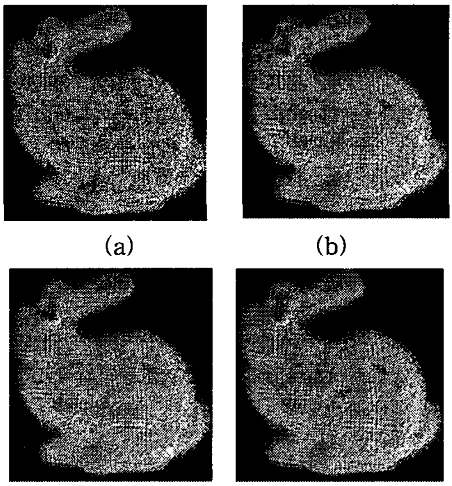
3.1.Compression result using video coding

We use MPEG-2, MPEG-4, and H.264/AVC for video coding. The used image is 200×200 pixel size images and 1024×1024 fringes. The segmentation sizes are from 16×16 to 512×512. Experimental results are shown in Fig 11 and Fig.12. The segmentation size of 64×64 gives the best quality on the reconstructed images. H.264/AVC also shows the best compression rates in Fig. 10. (c). NC of reconstructed image keeps more than 0.95 in 20:1 compression rates. Therefore, compression of fringe is possible to higher compression rates. Comparing with previous work[4][5], the proposed algorithm has better performance over about two time.



(a) (b) (c)

Fig. 11. NC of reconstruction image (a) MPEG-2 (b) MPEG-4 (c) AVC.



(a) (b) (c) (d)

Fig. 12. Reconstruction result of object image (a) original (b) MPEG-2 (c) MPEG-4 (d) AVC(CR 20:1, 64×64 segment).

3.2. Compression result using still image coding

We use JPEG2000 still image compression standard for compression of fringe. The effect of still image compression technique analyze in the coding of hologram. The coding result using R-component image shows the best quality on the reconstructed images. The object image is reconstructed in 10:1 compression rates. In the case of lossless, it showed an average 1.3:1 compression rates.

4.conclusions

This paper proposed a novel algorithm to compress holographic image by hybrid technique of the international image/video compression standard. To compress fringe pattern generated by CGH, we proposed the pre-processing step to color format transform, efficient fringe segment, 2D-DCT, efficiency scan method for generation video stream, classification of DCT coefficient, and hybrid coding method. We expect that the proposed algorithm becomes a solution and a guideline for hologram compression and next researches.

Reference

[1] P. Hariharan, *Basics of Holography*, Cambridge University Press, May 2002.

[2] K. Sasaki, E. Tanji and H. Yoshikawa, "Data compression for holographic 3D image," The journal of the Institute of Television Engineers of Japan, Vol. 48, No. 10, pp. 1238-1244, Oct. 1994.

[3] H. Yoshikawa, "Digital holographic signal processing," Proc. TAO First International Symposium on Three Dimensional Image Communication Technologies, pp. S-4-2, Dec. 1993.

[4] H. Yoshikawa and J. tamai, "Holographic image compression by motion picture coding," editor, SPIE Proc. vol 2652 Practical Holography, pp. 2652-01, Jan, 1996.

[5] T. J. Naughton, Y. Frauel, B. Javidi and E. Tajahuerce, "Compression of digital holograms for three-dimensional object recognition," SPIE Proc. Vol 4471, pp. 280-289. 2001.

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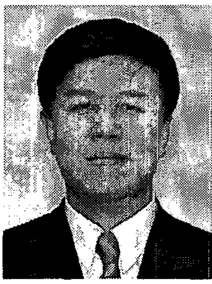

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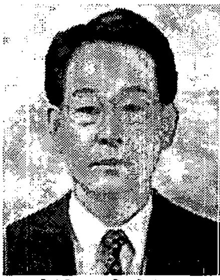

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