Quality Analysis of Light-Waves Considering Transmission Errors of Various Images for Wireless Transmission System of CGHs

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ABSTRACT

In this paper, a wireless transmission system model for computer-generated holograms is constructed, and quality of light-waves considering transmission errors of CGH are analyzed by using computer simulations. SNRs (Signal to noise ratio) of light-waves reconstructed from transmitted CGHs having some transmission errors were measured and evaluated.

1 INTRODUCTION

Holography is a three-dimensional technology, where provides us natural three-dimensional objects. CGH (Computer-generated hologram) is generated by using computer simulations based on the holographic phenomena such as reflection, diffraction, propagation, interference of light-waves [1] in optical holography. CGH can also satisfy the physiological conditions of human eyes as same as the holography, so that natural and virtual objects can be reconstructed.

A lot of researches about calculation algorithms and displaying optical systems for CGH have been reported; however, a few studies have been reported to transmit CGH data [2, 3]. As related works of transmission system of CGH data, wireless transmissions of CGH under simply and limited wireless channels were reported [2, 3]. Transmission of CGH over noisy channels was assumed in [2], so that pseudo-transmission errors, such as a white noise, was simply adding a CGH as a received CGH data. In [3], the transmission error was not considered through transmitting and receiving CGH data, and compressing data size was only focused for supposing transmission although there was a trade-off relationship between the transmitting speed and transmission error ratio.

As previous works, we evaluated quality of optically reconstructed images from CGH with some transmission errors [4, 5]. In these works, quality of light-waves was analyzed about optical reconstructed images in [4] and computational reconstructed images in [5]; however, the difference of light-waves from various images are not enough to be analyzed.

In this paper, a system model for wireless transmission of CGH data was constructed, and light-wave from the transmitted CGH with various images were analyzed by using computer simulations in the proposed wireless transmission system. The light-waves were simulated by using transmitted CGH data with some transmission errors, and influence of the transmission errors was evaluated by the objective evaluation method as SNR (Signal to Noise Ratio).

2 WIRELESS TRANSMISSION OF CGH

A system model for wireless transmission of CGH was constructed, where includes computational calculation, wireless transmission, and computational reconstruction of CGH.

2.1 System Model

Figure 1 shows block diagram of the proposed system model for CGH transmission. CGH data is calculated as light-wave propagation and interference from a virtual object; then, the CGH data is transmitted to a receiver from a transmitter through a wireless channel. After receiving the CGH data, an image is computationally reconstructed by using the transmitted CGH data with some transmission errors.

2.2 Calculation of CGH Data

Light-wave is defined as a complex amplitude. We discuss a process for calculating CGH data by referring to the basic coordinate system shown in Figure 2.

CGH data is calculated for light-wave propagating

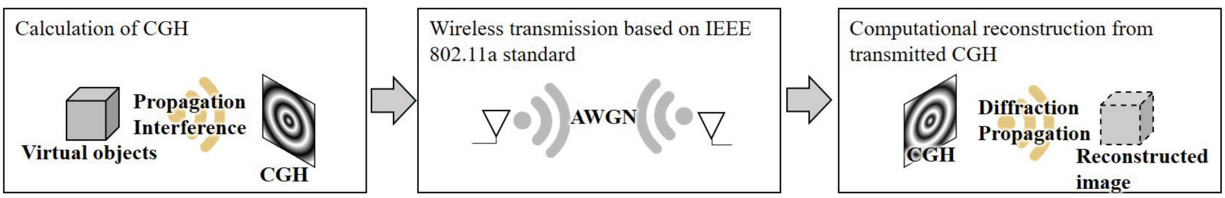


Figure 1. System model for wireless transmission of CGH

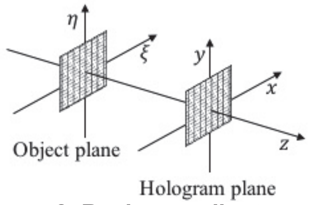


Figure 2. Basic coordinate system

between the object and hologram planes. Complex amplitude on the object plane, $g(\xi,\eta)$, is initialized by

$$g(\xi,\eta) = A(\xi,\eta)\exp[-j\phi(\xi,\eta)] \quad ,$$

where ξ and η are the coordinate axis on the object plane, j denotes an imaginary number, $A(\xi,\eta)$ and $\phi(\xi,\eta)$ denote the amplitude and phase distributions for initializing as an aperture.

The complex amplitude on the hologram plane, $u(x,y)$, is calculated as the propagation from the object plane to the hologram plane. The propagation is calculated with FFT (Fast Fourier Transform) and IFFT (Inverse FFT) based on the angular spectrum algorithm [6].

By adding a reference light into the light-wave on the hologram plane, complex amplitude of interference is calculated as

$$h(x,y) = |u(x,y) + r(x,y)|^2 \quad ,$$

where $h(x,y)$ denotes interference of light-wave, and $r(x,y)$ denotes the reference light. CGH data is generated by normalizing and quantizing $h(x,y)$.

2.3 Wireless Transmission

In wireless transmission, calculated CGH data mentioned in the above subsection is transmitted to a receiver from a transmitter with wireless transmission by using the wireless transmission simulator. The CGH data is influenced by the channel conditions, and there are some transmission errors according to the channel model. In this paper, we assumed the simply channel model as AWGN (Additive White Gaussian Noise) channel.

The calculated CGH data, $h(x,y)$, is transmitted to the receiver; then, the transmitted CGH data, $h'(x,y)$, is calculated. According to the quality of the wireless channel, the transmitted CGH data has some bit errors. The error ratio caused by the wireless transmission is represented as BER (Bit Error Ratio).

2.4 Computational Reconstruction

After receiving CGH data, an image is computationally reconstructed by using the computer simulation. As same as the procedure of propagation, light-waves from CGH data are calculated as diffraction and propagation by using the angular spectrum algorithm.

The complex amplitude of light-waves in a three-dimensional spatial domain is defined as $f(m,n;z)$ in this paper. m and n are the horizontal and vertical coordinate axis, z denotes a distance from the hologram plane whose distance is $z = 0$.

Table 1. Parameters of CGH calculation

Parameters	Values
Number of pixels	256 x 256 pixels
Size of pixel pitch	1.0 x 10. μm
Size	0.256 x 0.256 mm
Propagation distance	0.5 ~ 10.0 mm
Wavelength	625 nm

Table 2. Parameters in wireless transmission

Parameters	Values
Standard	IEEE 802.11a
Modulation Scheme	OFDM (64QAM)
Number of sub-carriers	52 (64 FFT points)
OFDM symbol length	4.0 μs
Convolutional code	3/4
Channel model	AWGN

3 COMPUTER SIMULATIONS

In order to evaluate a quality of light-waves from CGHs generated by using various images, SNRs were measured by computer simulations.

3.1 Setup

The CGH data was calculated by using images as SIDBA (Standard Image Database). Parameters in CGH calculation are listed in Table 1, and parameters in wireless transmission are listed in Table 2. These parameters in wireless transmission are based on IEEE 802.11a standard.

Measured SNRs of light-waves defined in the reference [7] was calculated as

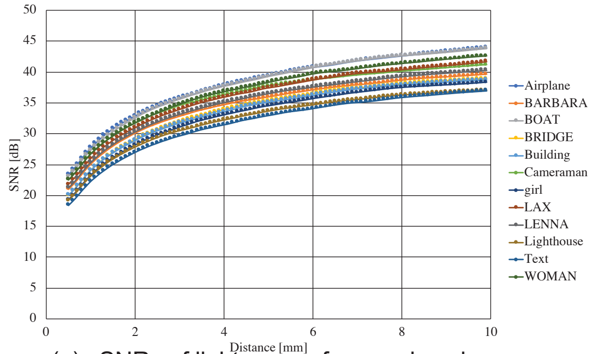
$$SNR_z = \frac{\sum_{m=1}^{M}\sum_{n=1}^{N}|f(m,n;z)|^2}{\sum_{m=1}^{M}\sum_{n=1}^{N}|f(m,n;z) - \alpha f_0(m,n;z)|^2} \quad ,$$

where

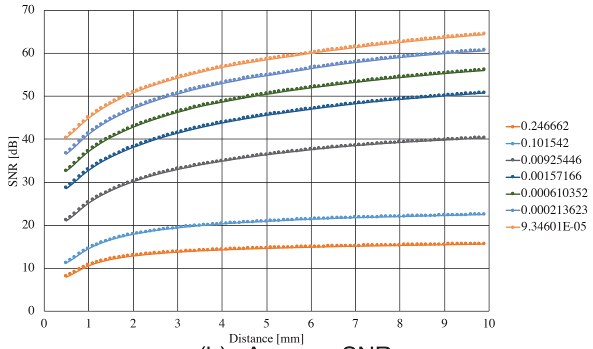
$$\alpha = \frac{\sum_{m=1}^{M}\sum_{n=1}^{N} f(m,n;z) f_0^*(m,n;z)}{\sum_{m=1}^{M}\sum_{n=1}^{N}|f_0(m,n;z)|^2} \quad .$$

Here, z denotes a distance from CGH, SNR_z denotes a SNR between light-waves $f(m,n;z)$ and $f_0(m,n;z)$. These light-waves were calculated at the distance z in three-dimensional domain, and $f(m,n;z)$ denotes the light-waves from CGH with some transmission errors, and $f_0(m,n;z)$ denotes the light-waves without any transmission errors (an ideal condition). By using various images, SNRs of light-waves were measured at various distances.

In order to compare the difference according to generated CGHs, CGH data is calculated by using various images.



(a) SNRs of light-waves from various images



(b) Average SNR

Figure 3. Propagation distance versus SNR

3.2 Propagation Distance versus SNR

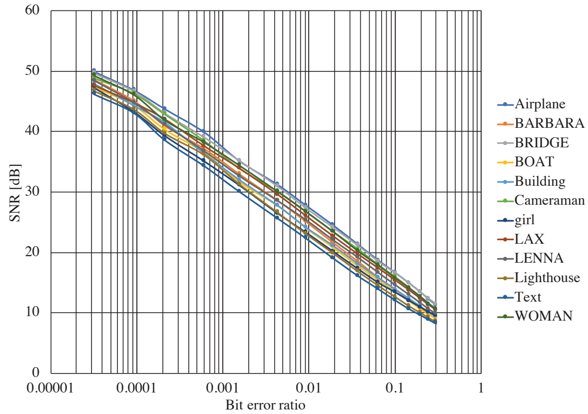
Figure 3 shows the results of computer simulation about propagation distance from CGHs versus SNRs of light-waves. (a) denotes the results with each image, SNRs of light-waves from CGH with each image are plotted when BER was about 0.0093. (b) denotes the results of averaged SNRs from each image when BER were about 0.25, 0.10, 0.0093, 0.0016, 0.00061, 0.00021 and 9.3×10^{-5}.

Compared with SNRs in (a), it was confirmed that quality of light-waves has the almost same tendency according not to images. Compared with SNRs in (b), it was confirmed that quality of light-waves is improved according as propagation distance is increased.

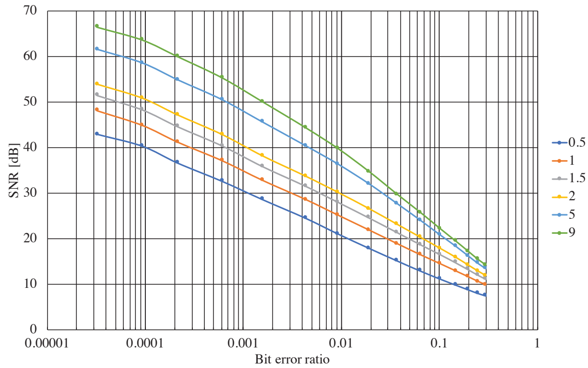
3.3 BER versus SNR

Figure 4 shows the results of computer simulation about BER versus SNRs of light-waves. (a) denotes the results with each image, SNRs of light-waves from CGH with each image are plotted when propagation distance was 1.0 mm. (b) denotes the results of averaged SNRs from each image when propagation distances were 0.5, 1.0, 1.5, 2.0, 5.0, 9.0 mm.

Compared with SNRs in (a), as same as the results of Figure 3, it was confirmed that quality of light-waves has the almost same tendency according not to images. Compared with SNRs in (b), it was confirmed that quality of light-wave is degraded according as BER is increased,



(a) SNRs of light-waves from various images



(b) Average SNR

Figure 4. BER versus SNR

and SNRs of light-waves almost exceed 30 dB when BER is lower than 0.1% (0.001).

4 CONCLUSIONS

In this paper, wireless transmission system model of CGH considering transmission errors were proposed. Calculated CGH data was transmitted based on IEEE 802.11a standard system, and received CGH data with some transmission errors were generated according to the quality of wireless channel. In computer simulations, SNRs of light-waves reconstructed from received CGH with some transmission errors were measured by using various images. As the results of computer simulations, quality of light-waves caused by the transmission errors were analyzed, and it was confirmed that SNRs of light-waves almost exceed 30 dB when BER is lower than 0.1%.

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