체적 홀로그래픽 메모리에서의 효율적인 인터리빙 기법

Efficient Interleaving Scheme of Volume Holographic Memory

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In volume holographic memory (VHM), two-dimensional data array (i.e. data page) is used for the recording and the retrieving process with the aid of spatial light modulator (SLM) and CCD camera. Due to this two-dimensional parallel data processing, burst errors in this system also have two-dimensional characteristics in a data page domain. In this paper, we present a channel model of the burst noise and burst error for the VHM system using disk type recording media. We consider dust particles in the indoor space stacked on the disk as a main source of the burst noise. Based on this model, an efficient interleaving scheme which is based on two-dimensional lattice in a data page is proposed and compared to the formerly proposed one[1] in view of interleaving efficiency (i.e. error correction capability of the system). We note that the main differences in the structure and the performance stem from the different metric used to measure the size of the burst error.

Fig. 1 shows a simple 4*f* optical system of VHM for modelling burst noise. Each data bit information of a data page is corresponded to and modulated by each pixel of the SLM. The whole modulated information is recorded to the volume recording medium holographically with a reference beam (not shown here). In general, the recording medium is located at the Fourier plane or Fresnel plane and the recorded data are retrieved to the CCD camera by illuminating reference beam. Because of the finite size of the SLM pixels and the coherence of the laser beam, each pixel of data bit produces some diffraction in the shape of two-dimensional *sinc* function during the propagation to the first Fourier transforming lens. Then each data bit is tilted by the lens with different wave vector directing to the focal point in a form of plane wave. We can define the diffraction size for each pixel plane wave as following

$$\triangle x = \lambda f / w_x \tag{1}$$

where $\triangle x$ is the x-directional distance between the first two nulls of *sinc* diffraction, λ the wavelength of laser beam, f the focal length of the lens, and w_x the pixel pitch. Then the size of the effective burst noise source on the boundary of the disk can be described as

$$\sigma_{eff} = \alpha\sigma \tag{2}$$

where σ is a physical transverse size of the noise source and α a factor for the effective size correction depending on the iris size, the burst noise source scattering properties and the detection method in the retrieving procedure. When this effective burst noise source size grows comparable to the diffraction size of the pixel plane wave, a burst noise occur in the output plane. The size of the burst noise is related to the convolution of the diffraction pattern of each pixel plane wave with the effective burst noise size (Fig. 2).

Interleaving is a permutation of symbols of error-correction code words. Each error-correction code word is composed of several symbols with enough redundancy, where a symbol is a unit of error-correction. These symbols are also composed of one or several data bits in each. The redundant symbols of error-correction code contain information to keep the original data from several unwanted errors. If we increase the code word length and therefore reduce the number of code words in a data page, the redundant symbol per each code word can be increased and this enhances the error-correction capability of the overall system. Efficient interleaving scheme aims at minimizing the number of error-correction code word in a data page with optimal two-dimensional symbol dispersing in relation with the burst noise characteristics.

Fig. 3 explains several concepts for the description of burst errors and the interleaving. Here, we assume a symbol is composed of square integer number of bits in a square shape. If a burst noise occurs through the former modelling process, we can distinguish cluster of error bits considering the one/zero binary detection method of the system like the grayed area in Fig. 3 (a). We call them a burst erasure. Then, we can also distinguish the cluster of symbols embracing the burst erasure as the bold lined area. This is the burst error of symbols we should deal with. In Fig. 3 (b), the longest length across the burst erasure in units of symbols can be obtained and let it be called a symbolic radius. In combination of the statistics of burst noise sources with the former optical model and the detection method, it is proper to decide the maximum length of the symbolic radius in the system. Then, we can construct the two-dimensional interleaving as Fig. 4 (a). With the maximum symbolic radius, we can draw a quasi circular region in contact with a symbol of an error-correction code word as an origin. Then, another symbol of the same code word should be positioned at a location outside of that region and nearest to the origin symbol. For the third other symbol, the above procedure should be repeated. Filling the inner quasi circular region with symbols from different code words keeping relative position order and repeating this procedure in the whole data page, we can construct the efficient interleaving structure as Fig. 4 (b). We can see the structure forms a two-dimensional tilted hexagonal lattice.

In comparison with the formerly proposed interleaving method, we can obtain about 13% error-correction code word number reduction as the maximum symbolic radius grows large(~10). Only when the burst noise sources have the maximum symbolic radius always in the horizontal or vertical direction in a data page, it can be seen that the former one has better performance.

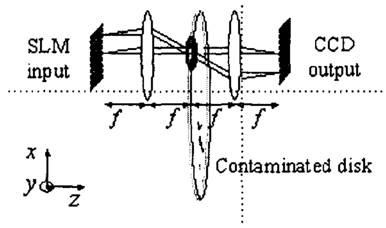


Fig. 1 Optical system of VHM

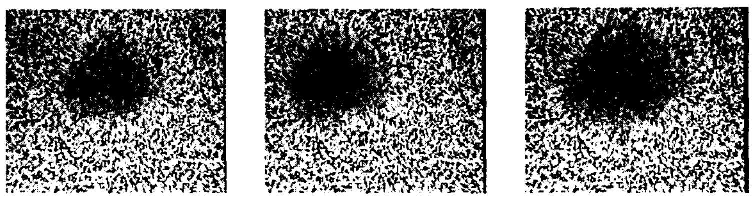
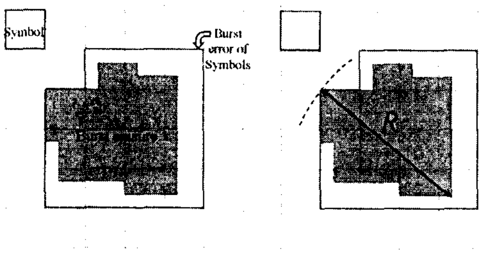


Fig. 2 (a) Burst noise due to inky spot at the Fresnel plane (b) horizontal translation effect of burst noise (c) longitudinal translation effect



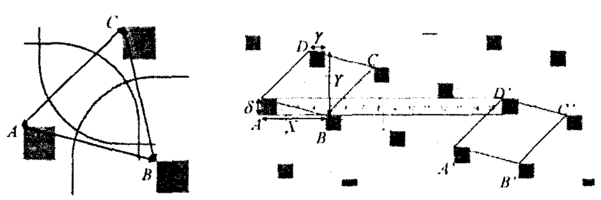


Fig. 3. (a) Symbol and burst erasure (b) symbolic radius. Fig. 4. (a) Lattice construction (b) tilted hexagonal lattice

Reference

1. M. Blaum *et al.*, "Interleaving schemes for multidimensional cluster errors", IEEE Trans. Inform. Theory, 44, 730 (1998).