Chapter 8

Future Directions

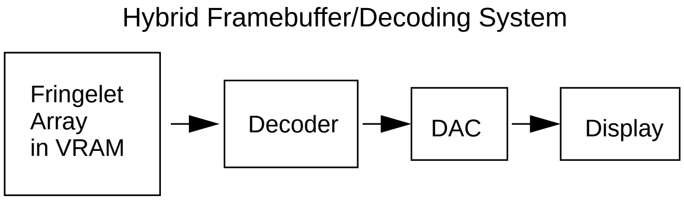
This chapter describes some future research directions based on diffraction-specific fringe computation.

8.1 Specialized Fringelet Decoding

Fringelet decoding is so simple that it can be implemented in a number of ways. The following are three different suggested implementations of fringelet decoding: (1) in special digital hardware, (2) in RF analog processing, and (3) optically in the display.

8.1.1 Digital Fringelet Decoding

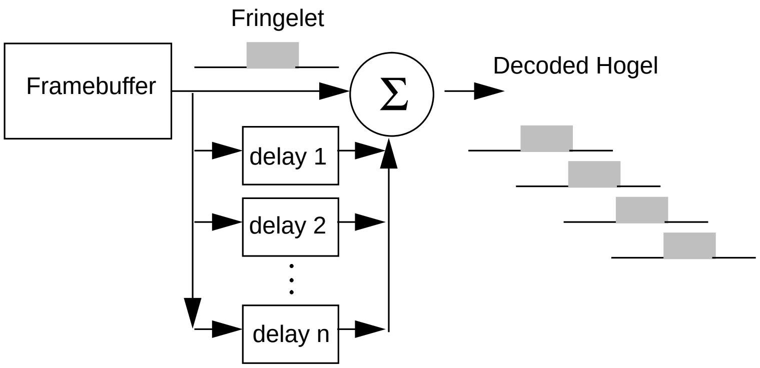
Digital signal processing (DSP) technology can be used to implement fringelet decoding. As shown in the figure below, a hybrid output card that stores fringelets rather than fringes could perform the decoding on the way to the digital-to-analog converter (DAC) as each hololine is needed.



The primary advantage of such an approach is that the bandwidth going into the framebuffer card is on 1/CR the full fringe bandwidth, where CR is the compression ratio. Such a framebuffer card stores fringelets and decodes them into fringes only when necessary. This “fringebuffer” approach allows CR times the storage using the same amount of VRAM. For example, in a standard framebuffer, 2 MB of VRAM can hold a fully computed 2-MB fringe. In a fringebuffer, using CR=18, the same VRAM can hold 2 MB of fringelets that represent a 36-MB fringe pattern. The main disadvantage of such a fringebuffer is that is must be specially designed and constructed. Also, the requirements on this fast digital hardware support for a holovideo display are not conceptually alleviated. This fringebuffer still must ultimately generate the full (36-MB) fringe signal at video frame rates.

8.1.2 Analog Electronic Fringelet Decoding

An analog RF electronic decoding method is similar to the digital implementation described above, but the decoding is done to the analog signal coming out of the framebuffer DAC. A fringelet is read out, followed by sufficient blanking to allow for decoding into a hogel before the next fringelet comes along. Decoding is performed with a series of delays and a combiner.



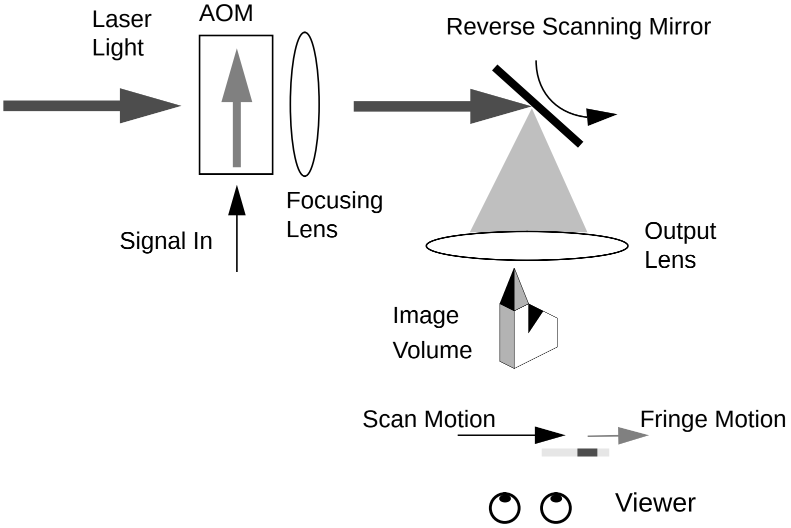
This approach has similar advantages to the digital fringelet decoding implementation. In this case, however, a standard framebuffer reads out the fringelets to the analog decoder. The requirements on the fast digital hardware support for the holovideo display are reduced by a factor of CR. Fringelet decoding occurs in real time. As in the fringebuffer case, 2 MB of VRAM provide fringelets for a 36-MB fringe pattern for a CR=18. The disadvantage of this approach lies in its analog design: it is subject to noise, drift, and nonlinearities.

8.1.3 Optical Fringelet Decoding

A fringelet is shift invariant within the hogel region. An optical fringelet decoding scheme exploits the shift-invariant nature of a fringelet. This shifting can be accomplished temporally. Although an HOE can be used to optically replicate light diffracted from a single fringelet, but it is simpler to perform the replication temporally.

Specifically, fringelets are fed into the AOM of a scophony-type display[57] with mismatched horizontal scanning. Mismatching the horizontal scanning system causes the image of a fringelet to be swept across the hogel region. If each fringelet is read out padded by sufficient blanking, the viewer sees a decoded version of the fringelet. The best way to produce this sweeping effect is to reverse the direction of the horizontal scanner. For example, if the scanner is set to match exactly the motion of the acoustic signal within the AOM, reversing scanner sweeps the signal across twice its width in the opposite direction.

Reverse-Scan Time-Multiplexed AOM Geometry



Typical numbers are as follows: hogels are 4K samples wide, with fringelets of 512 samples. (Compression ratio is therefore 8.) Using this method of optical fringelet decoding in a viewer-plane geometry, the current 36-MB MIT display can produce an image that is 8 times larger (in a combined image-volume and view-angle sense) without requiring additional bandwidth. In general, optical replication works best for viewer-plane geometry since hogel widths can be larger.

This approach has many advantages. Conventional framebuffers can be used since blanking is not only tolerated but is indeed required. Also, the engineering trade-offs[60] used in designing the scophony-geometry holovideo display are relaxed: the horizontal scanning system needs only to scan at the appropriate data rate. Its scanning rate no longer needs to be geometrically matched to exactly compensate for the motion of the acoustic signal within the AOM. This advantage manifests itself in many possible ways. For example, the horizontal scanners can be slower, and larger displays can be built. As another example, other high-bandwidth SLMs, particularly a deformable mirror device (DMD) can be used to modulate the light in a fringelet display. Finally, the saving provided in this “fringelet display” allows for a full-parallax display to be built with only an order of magnitude increase in required bandwidth. The application of holographic encoding to full-parallax holovideo is discussed in the following section.

To summarize the three specialized fringelet decoding schemes, the analog electronic and optical approaches make use of blanking and therefore can utilize conventional framebuffer systems. In these two cases, a framebuffer system is no longer required to store and read out an entire decoded fringe pattern. Instead, multiple channels can be represented on a single framebuffer card, adding to the speed and further reducing communication bottlenecks. In addition, optical fringelet decoding allows the construction of a “fringelet display” that alleviates the burden on the digital and the analog support electronics. The optical decoding approach is best done in a viewer-plane geometry due to a reduction in the achievable image resolution that would result in other geometries.

8.2 Extension to Full Parallax Holovideo

Diffraction-specific fringe computation and the holographic encoding schemes born of it are applicable to full parallax holographic imaging. Although this thesis focused on horizontal-parallax-only (HPO) holovideo, full parallax can be implemented by treating the vertical dimension in the same way as the horizontal dimension. Diffraction is not only linear, but it is separable into the two lateral dimensions. (See Appendix B.) A full-parallax diffraction-specific approach is outlined in this section. The application of hogel-vector and fringelet encoding decreases required bandwidth and computation time by the roughly the square of the reductions found in the HPO case.

A full-parallax fringe pattern has a vertical sampling pitch that is the same order of magnitude as the horizontal sampling pitch. In general, the fringe pattern is sampled with different pitches in each dimension. Hogels take the form of rectangles rather than line segments; each hogel has a height as well as a width. The vertical size of the hogel is roughly the same as the hololine spacing in the HPO case. The vertical spectrum of the hogel is sampled and treated separately from the horizontal hogel spectrum. Each hogel is encoded as two vectors: one for the horizontal spectra and one for the vertical. A set of rectangular basis fringes must be precomputed, with one set for the horizontal spectra and one set for the vertical spectrum. Decoding precedes as in the HPO case, the difference being that both the horizontal and vertical components of the hogel vector are used.

For full-parallax hogel-vector encoding, bandwidth compression is achieved independently in the vertical and horizontal dimensions. The spectrum of each rectangular hogel is subsampled (by generally independent amounts) in each of the two dimensions. If each full-parallax hogel has a height of N_h^V =256 samples and is encoded with a compression ratio of CR^V=16, then the addition of vertical parallax increases the computational task of hogel-vector decoding by a factor of N_h^V/CR^V=16. For comparison, traditional interference-based computation would require roughly 256 times the computation in such a case. Hogel-vector encoding decreases information content and computation time by N_h^H/CR^H in the horizontal dimension and by N_h^V/CR^V in the vertical dimension. The total compression ratio achievable for a full-parallax fringe pattern is $N_h^H/CR^H \times N_h^V/CR^V$. For typical values, this total compression ratio would be about 256. The implications are propitious: a typical full-parallax fringe computed using hogel-vector encoding can be computed in the same time as a full-parallax fringe computed using traditional interference-based methods. The number of samples in the full-parallax hogel-vector array would be roughly equal to the number of sample in an HPO fringe computed using traditional methods.

Fringelet encoding promises the same improvements outlined for hogel-vector encoding. However, the decoding scheme must be considered carefully. A full-parallax fringelet is rectangular, with dimensions $N_h^H/CR^H \times N_h^V/CR^V$. The indirection table (used for the implementation of HPO fringelet decoding) must map each 2-D hogel sample location to one of the 2-D fringelet samples. The indirection table is generated using a separate set of truncation-translation statistics in the vertical dimension. This full-parallax indirection table represents aperiodic replications in both the horizontal and vertical dimensions.

In summary, the holographic encoding schemes developed from diffraction-specific computation allow for the generation of full-parallax fringe with just over an order of magnitude increase in required bandwidth and computation time. The application of these holographic encoding schemes may for the first time make possible a full-parallax holovideo display.