A Large Scale Interactive Holographic Display

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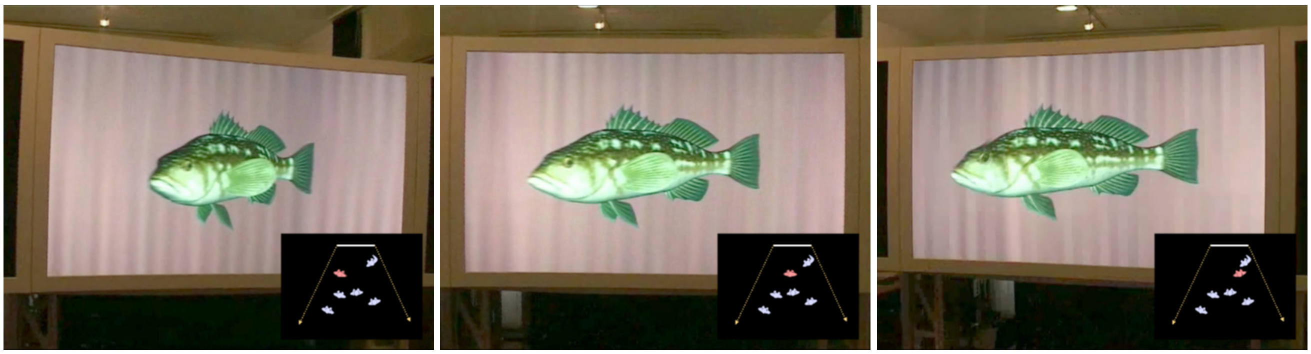

Figure 1: **Holographic display example.** The images that were taken from different positions in front of the display.

Abstract

Our work focuses on the development of interactive multi-user holographic displays that allow freely moving naked eye participants to share a three dimensional scene with fully continuous, observer independent, parallax. Our approach is based on a scalable design that exploits a specially arranged array of projectors and a holographic screen. The feasibility of such an approach has already been demonstrated with a working hardware and software 7.4M pixel prototype driven at 10-15Hz by two DVI streams. In this short contribution, we illustrate our progress, presenting a 50M pixel display prototype driven by a dedicated cluster hosting multiple consumer level graphic cards.

CR Categories: B.4.2 [Input/Output and Data Communications]: Input/Output Devices—Image display

Keywords: holographic displays, 3D displays

1 Short overview

We present a large scale interactive multi-user holographic display that allows freely moving naked eye participants to share a three dimensional scene with fully continuous, observer independent, parallax. The display is an instance of a scalable holographic system design based on a specially arranged array of projectors and a holographic screen. The feasibility of such an approach has already been demonstrated with a working hardware and software 7.4M pixel prototype driven at 10-15Hz by two DVI streams[1]. In this short contribution we illustrate our progress, presenting a large scale holographic display prototype with 50M pixel overall resolution. The display is driven by a dedicated cluster hosting multiple consumer level graphic cards.

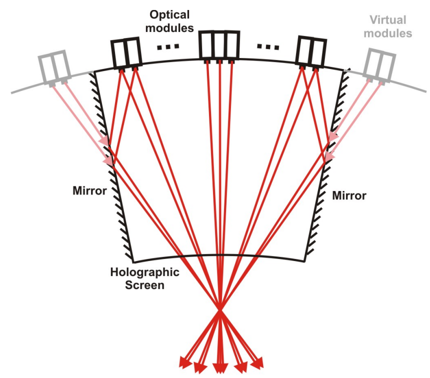

Figure 2: Schematic diagram. A large number of light beams can create a spatial point.

Display concept. Our 50Mpixel display prototype uses a specially arranged array of 64 XGA commodity projectors and a holographic screen with a diagonal of 1.8m. The projection modules project their specific image onto the holographic screen to build up the 3D scene. The applied distributed image organization makes it fundamentally different from other known multi-view solutions. The module views are not associated with specific view directions. Instead, the light beams to be emitted by the projection modules, i.e., the module images that are generated by the projectors, are determined by geometry. Each module emits light beams toward a subset of the points of the holographic screen. At the same time, each point of the holographic screen is hit by more light beams arriving from different modules. The light beams propagate to address fixed spatial positions that are independent from the viewer's position. Many modules contribute to each view of the 3D image, thus no sharp boundary occurs between views, and the display offers continuous and smooth change at different image areas, result-

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Figure 3: **Holographic display example.** Images that were taken from different positions in front of the display. Objects appear at fixed physical positions.

ing in a truly 3D experience with continuous horizontal parallax. Multiple projectors illuminate each pixel on the screen, and the optical modules can be seen under different angles by looking from the pixel's point of view. The holographic screen transforms the incident light beams into an asymmetrical pyramidal form. The cut of this light distribution is a long rectangle, where the vertical size of the rectangle is the vertical field of view, while the horizontal size corresponds to the neighboring emitting directions. This configuration corresponds to the horizontal-only-parallax capability of the current prototype display. The principles on which the display is based would make it possible to provide vertical parallax. Doing so, would require, however, another order of magnitude increase in data size, rendering times, and system complexity, for little gain in the visual performance in standard settings. The horizontal light diffusion characteristic of the screen is the critical parameter influencing the angular resolution of the system, which is very precisely set in accordance with the system geometry. In that sense, it acts as a special asymmetrical diffuser. However, with standard diffusers and lenticulars it would be difficult, if not impossible, to produce the shape of the required angular characteristics. The screen is a holographically recorded, randomized surface relief structure that enables high transmission efficiency and controlled angular distribution profile. These fully randomized (nonperiodic) structures are non-wavelength dependent and eliminate moiré, without chromatic effects. The precise surface relief structures provide controlled angular light divergence. The angular light distribution profile introduced by the holographic screen, with a wide plateau and steep Gaussian slopes precisely overlapped in a narrow region, results in a highly selective, low scatter hat-shaped diffuse characteristics. The result is a homogeneous light distribution and continuous 3D view with no visible crosstalk within the field of depth determined by the angular resolution (see figure 2).

Driving the display. The display is driven in parallel by 64 DVI streams, one for each XGA projector. These streams are generated by an array of 16 PCs, connected to the display through four DVI connections each. Each PC runs a server that controls a graphics frame buffer. The server is responsible for generating images associated to a fixed subset of the display rendering modules. In the 50M pixels prototype, each PC generates 4 XGA images using two double head NVIDIA boards controlling a 4096x768 frame buffer. In order to support legacy graphics programs and to simplify the development of new holographic applications, we have implemented an OpenGL compatible front-end. The front-end runs on a client PC and looks to applications like an ordinary OpenGL library which, in addition to executing local OpenGL commands, also transparently broadcasts the graphics command stream to the dedicated cluster driving the holographic display. The client PC is connected to the cluster through dual Gbit ethernet links. The back-end servers listen to the network and decode the stream of multicast graphics commands coming from the client. Once decoded the commands are interpreted and sent to the local graphics renderer. The interpretation of the graphics commands involves modifying the way they are generated according to parameters available from the local configuration service, in order to transform the original central view into the view associated with each of the associated optical modules. For each of the optical module views, the graphics commands of the current frame are re-executed, with the following modifications: the original perspective matrix is replaced with a matrix that matches the module's specific position and viewing frustum; a geometrical calibration is performed, to correct nonlinearities in the display/optical geometry; a light calibration is performed to correct the intensity and contrast differences response of the optical modules; an angular resolution correction is performed for depth dependent anti-aliasing. The parameters required for each of these transformations are defined at configuration time.

Implementation and results. We have implemented a prototype hardware and software system based on the design discussed in this paper. The developed large scale prototype display is already capable of visualizing 50M pixels by composing optical module images generated by 64 XGA commodity projectors. The display provides continuous horizontal parallax with a approximately 45 degrees horizontal field-of-view. The luminance is over 5000 lumen (10000 lumen in high brightness mode) and allows the display to work under almost any kind of ambient lighting conditions.

The rendering library's front-end runs on either Linux or Windows operating systems, and currently implements most features of OpenGL 1.1. The library back-end, which drives the optical modules, is currently running on an array of 16 Linux PCs.

It is obviously impossible to fully convey the impression provided by the display on paper or video. As a simple illustration of the display capabilities, figure 3 presents photographs that were taken from different points of view in front of the large scale display. An accompanying video shows sequences of scenes recorded live using a moving camera.

Conclusions and future work. Our display allows freely moving naked eye participants to share a three dimensional scene with fully continuous, observer independent, parallax. The image quality of our prototype is comparable to nowadays projector-based Geowall displays, with the additional advantages of not requiring users to wear any kind of viewing device. The display looks like an ideal solution for high end multi-user applications. We are currently working on exploiting it for large scale model visualization.

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References

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