A “LOOK DOWN” SHIP BRIDGE SIMULATOR FOR DOCKING TRAINING EXERCISES

by

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Abstract

In the spring of 2005, Display Solutions, Inc designed and installed the visual system for a full mission ship bridge simulator for the Maritime Pilots Institute (MPI) in Covington, LA (Figure 1). This paper describes the technical aspects of the simulation visual system as well as some of the technical challenges that had to be overcome. The requirements for the visual display system required a much larger vertical field of view than is normal for ship bridge simulators. The system also had to provide a large horizontal field of view. To satisfy these demanding requirements a dome display system with 14 commercial projectors and geometry / edge blending system was provided. The bridge simulator has been operating and in use for training for approximately 12 months.

Figure 1 Maritime Pilots Institute, Covington, LA

Introduction

The MPI “Look Down” Full Mission Ship Bridge Simulator was designed and constructed and installed under the management of Mr. George Burkley of Locus, LLC during the end of 2004 and the beginning of 2005. Display Solutions was tasked to provide the visual display system. Buffalo Computer Graphics provided the simulator hardware, other than the display system and Computer Sciences Corporation, Advanced Marine Center provided the ship simulation and visual image generation software and databases. The primary requirement for the MPI bridge simulator is to support the training of pilots. This requires the simulation of key pilot ship handling tasks that cover the conduct of a range of close in maneuvers including docking / undocking at piers, buoys, bridge transits, anchoring, working with tugs and lines and lightering operations alongside other ships.

The pilot's primary input for these close in operations is visual cues. In order to accomplish these tasks, the pilot needs to be able to walk up to the ships bridge windows or bridge wings and "look down" to see the relative position of the ship's deck and hull, the dock area, tugs, lines, bridge piers, buoys, and or other ships.

Typical ships bridge simulators are configured on a stationary or motion platform with a ship bridge mockup and the visual image projected on a cylindrical or conical shaped screen surrounding the bridge mockup. The projected visual image typically covers between 240 to 360 degrees horizontal field of view (HFOV) and 20 to 45 degrees vertical field of view (VFOV). A vertical field of view between 23 and 26 degrees is most common. Technical constraints such as projector throw distances, distortions due to projection angles and reasonable physical dimensions of the bridge mockup usually dictate that the cylindrical/conical projection screens be 20' to 30' in diameter. As a result, there is typically at least 8'-10' of floor space between the perimeter of the bridge mockup and the bottom of the screen. A viewer standing at the ship's bridge "window" or bridge wing and looking down sees unlit dead floor space between the bridge and the screen (commonly referred to as the "black hole").

In order to meet the stated MPI training objectives, Mr. Burkley developed the concept of a ship bridge simulator with a visual display system providing a vertical field of view of about 30 degrees up and 60 degrees down and a horizontal field of view of about 300 degrees. Display Solutions was tasked with developing and installing a visual display system that would satisfy these very demanding requirements.

The only way of accomplishing this requirement is to use a spherical dome shaped screen, similar to that used in flight simulators. While such domes are common in flight simulators, the small size of the "simulated cockpit" allows for reasonable line of sight access between the projectors and the dome surface. The projectors in a flight simulation dome can be located out of sight above and below the cockpit or, in some instances, outside the dome surface and projected thru a lens hole opening in the screen at a point where it is not in visible to the viewers eye-point.

In the case of the ship bridge simulator, the size of the bridge mockup is such that it occupies much of the space inside the dome. This puts a significant constraint on where the video projectors can be located. At the available projector mounting locations, the lines of sight to the interior dome screen surface create very steep angles of incidence for the projected images. Covering the required area of the screen with a projected image of reasonable image quality is a major challenge.

TECHNICAL OVERVIEW

Physical Description

The MPI Bridge Simulator consists of a generic bridge mockup with the controls and displays found on the ocean going ships that transit the Mississippi River between the

Gulf of Mexico and Baton Rouge LA. The bridge mockup is a 14 ft diameter octagon with a 7 ft ceiling. There are bridge "windows" facing outward with approximately 300 degrees horizontal field of view from the pilot eye-point. The bridge house originally had glass windows installed, but these were later removed to reduce glare and improve image visibility from inside the bridge house.

The entire bridge mockup is mounted on eight 7 ft high steel posts anchored into the concrete floor. Access to the bridge is via a "runway" from the bridge mockup to the second floor of the facility where the Instructor Station is also located. Pictures of the bridge house at various points during the assembly and installation are shown in Figures 2 - 3. The bridge house was designed and installed by Industrial Object Design.

Figure 2 Bridge Mockup Support Posts

Figure 3 Bridge Mockup Structure Mounted on the Support Posts

The dome screen is 22 feet high and 28 feet in diameter and was designed by Mr. David Carambat of Industrial Object Design, Covington, Louisiana. The screen is comprised of 42 spherical sections (Fig 4). The panel sections are hand-laid, solid polyester fiberglass, made in a limited-production mold. The section mold was computer machined from a block of solid foam, finished with a sprayed-hardener, and mounted in a commercial mold frame. The mold utilized a wax-less mold release system to make finishing the pulled-panels easier.

Figure 4 Dome Screen Mold

The assembly of the dome was a two-part process. First the upper dome sections were assembled on the floor around the bridge structure and a structural compression ring of metal-strapped wood was fabricated around the upper ring of the dome. (Figure 5) These sections are bonded together with 3M 5200 marine adhesive and stainless bolts.

Figure 5 Assembly of the Upper Part of the Dome Screen

This upper-dome section was hoisted aloft to the ceiling through the use of six hand-crank hoists and a wire suspension system. Conscious weight control in the materials kept the upper dome total weight at approximately 800lbs assembled, and the lower dome weight at 1500lbs. Once hoisted into place, wood columns were placed underneath the upper dome to straighten the dome shape and relieve the suspended load. (Figure 6)

Figure 6 Upper Dome Section During Installation

The interior seams were caulked, taped and floated with common construction materials. The interior paint is Glidden's "Luminous White" latex interior, which provided a better picture in our tests than custom screen paint. (Figure 7)

Figure 7 Caulking and Painting the Dome Screen.

The lower sections were installed one by one to complete the lower dome. The completed dome is shown in Figure 8.

Figure 8 Completed Dome Screen

Visual System Description

The initial physical layout of the projectors and screen was done using the CompactDesigner Software from 3-d Perception Company in Asker, Norway. 3-d Perception is a leading provider of video post processors for warping video signals to compensate for the optical distortions created by projecting flat format video images onto curved screen surfaces.

CompactDesigner is a low level CAD program that allows the basic theater design to be done in three-dimensional format. With the correct projector and lens modeled in the SW, various layout configurations can be developed and evaluated for feasibility and performance. Figure 9 shows the resulting layout of the projectors and the screen coverage as displayed in CompactDesigner.

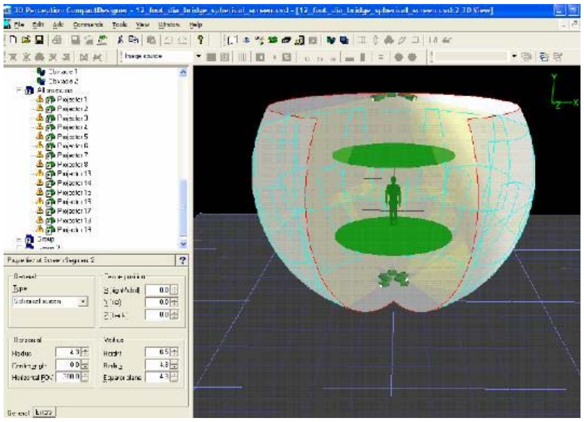

Figure 9   Projector Layout and Screen Coverage

As a result of the CAD design phase of the project, we determined that a total of 14 projectors would be required to illuminate approximately 300 degrees horizontal by 90+ degrees vertical on the screen. The 14 projectors are grouped as a 2 x 7 matrix. Seven projectors are located above the bridge roof, shooting downward and the other seven are located at the base of the bridge house mounting posts (see Figs 10 & 11). As can be seen in the pictures, the mounting location of the lower seven projectors was quite constrained. The projectors had to be “staggered” in order to achieve as much throw distance as possible.

Figure 10 Arrangement of the Lower Projectors

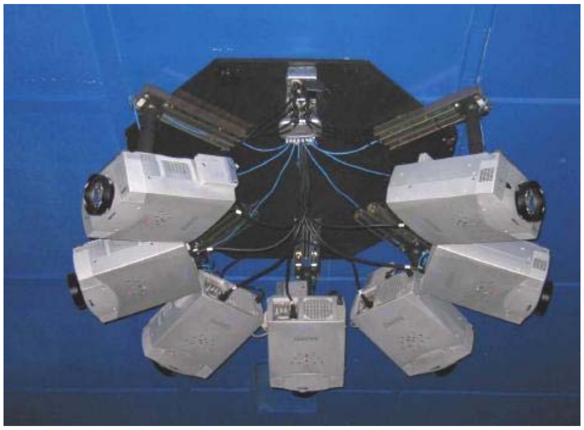

Figure 11 Arrangement of the Upper Projectors

The projectors chosen are the Sanyo PLC-XP46 LCD projectors. The XP46's are LCD projectors with 4100 lumens light output at XGA (1024 x 768) native resolution. The key features of the XP46 that were critical to the success of the project were the availability of optional wide-angle projection lenses, electronic vertical lens shift and a LAN control interface. A 0.8:1 throw ratio lens was chosen to maximize the screen coverage from the available projector locations.

The bottom projectors had to be positioned as low as possible to the floor in order to avoid image "shadowing" from the bottom of the bridge mockup structure. As a result, the projectors had to project at a fairly steep angle to the screen perpendicular. This was compounded by the fact that the screen was curved in the vertical axis. This position and angle of projection placed severe requirements on the depth of focus of the projection lens. It also created significant keystone distortion in the projected image. Wide-angle lenses typically have a reduced depth of focus performance. Initial testing done on the XP46 with the 0.8:1 lens showed it to have nearly +/- 15' of "acceptable" focus depth. The lens shift feature on the projector was used to minimize the keystone distortion as well as the depth of focus requirements. These features were critical to the feasibility of the display.

The upper level projectors were mounted from plywood platform base 7 ft above the roof of the bridge. (Figure 12) Space was available so that it was not necessary to stagger the projectors. However, the angle of projection to the screen again required taking full advantage of the vertical lens shift feature on the projector. The projectors were positioned for maximum vertical screen coverage to minimize the requirements on the more confined lower set of projectors.

Figure 12 Upper Projectors Installed above the Bridge Mockup

When all of the projectors were mounted and positioned for maximum screen coverage and maximum image overlap, the process of creating an undistorted, blended composite image began. The horizontal field of view of each projector (channel) is about 45 degrees although the projectors can cover a larger area. The vertical field of view of the upper projectors is about 55 degrees (30 degrees up to 25 degrees down). The vertical field of view of the lower projectors is about 45 degrees. Allowing for overlap, the total vertical field of view is 90 degrees (30 degrees up to 60 degrees down).

The 3-d Perception video warper post processor, the CompactUTM, was used for the image manipulation functions. The CompactUTM provides a complete package of image manipulation tools. The primary function of the processor is to re-map the input video signal from the image generator to correct for the geometric distortions caused by projecting onto the spherical surface.

For simple curved surfaces such as large radius cylinders with less than 5 channels, the geometric corrections can easily be made manually because the warping processor responds in real time while looking at the actual projected images. For more complex configurations such as a dome screen with 14 projected image channels, a manual correction is extremely time consuming and results in marginal overall geometric accuracy.

In this case, the CAD layout developed for the original feasibility study was updated in detail to match the physical configuration as closely as possible. Exact projector locations, angles and lens shift settings were input to the CAD model. The IG field of view and overlap settings were also input to the model. The resulting CAD model can then be used by the CompactControl SW to automatically generate detailed geometry correction parameters.

After downloading the auto-generated correction map to the warping processors, the resultant image is approximately 90% correct. Final detailed geometry adjustments can then be made manually. To facilitate the geometry adjustments, Computer Science Corporation created a multi-axis grid pattern that was projected on the screen by the IG computers. This calibration sphere is shown in Figure 13. The resulting calibration grid projected on the screen in shown in Figure 14. In this case most of the geometry correction controls were pushed to their limits to achieve the required geometry corrections.

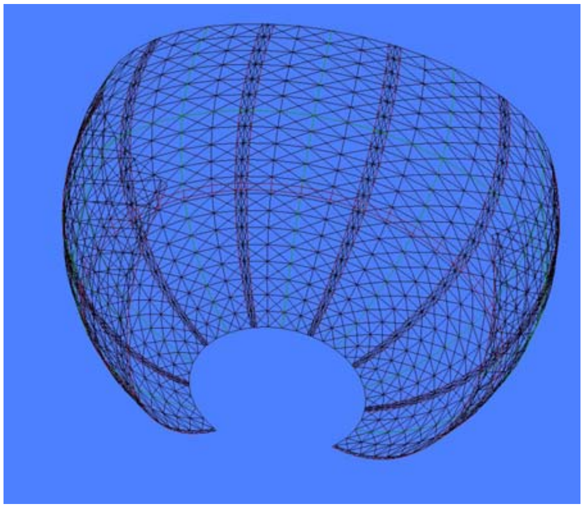

Figure 13 Calibration Sphere Geometry Model

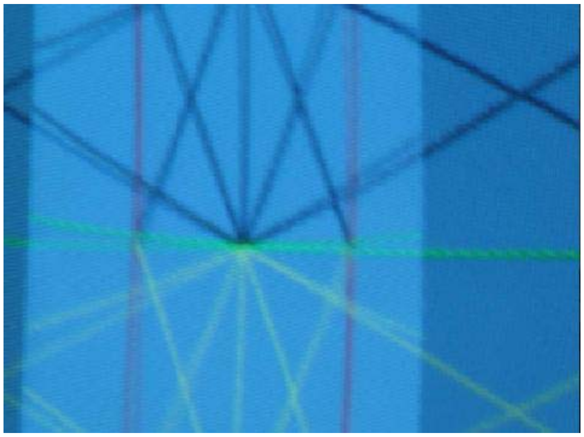

Figure 14 Geometry Correction Grid Projected on the Screen

After the image geometry corrections were completed, the next step was to normalize the 14 independent projected images for color match. Matching channels for color and brightness can be the most daunting part of the alignment process. The CompactUTM/CompactControl SW has all the handles needed to achieve this match. In addition to brightness and contrast controls, the tool set includes individual red, green and blue offset (brightness), gain and gamma (signal linearity) controls. Additional optional features include spatial gain control for hot spot compensation and automatic color matching via a color spot photometer interface to the CompactControl SW.

When the 14 individual images are matched as closely as possible, the CompactControl SW can be used to "blend" the images in the overlap region. In the case of the MPI dome, blending in both the horizontal and vertical planes was required. Figure 15 shows the image projected on the screen prior to the setup of the blend zone parameters.

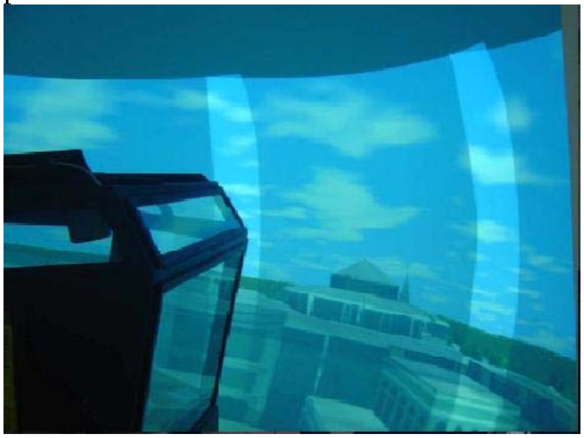

Figure 15 Projected Image Prior to the Adjustment of the Blend Zone Parameters

The final complete set of set-up parameters were then downloaded into the firmware in the warping processors.

Representative pictures of the resultant visual display are shown below.

Figure 16 The 14 Individual IG Channel Images as shown at the Instructor Station

Figure 17 Bridge Mockup and Projected Visual Image

Figure 18 Bridge Console and Projected Visual Image

Fig 19 View from simulator entrance walkway showing image wrapping under wheelhouse window. Note image curve due to off-center parallax. Image is optically correct from conning location.

Figs 20 & 21 Out and down from the conning location

SUMMARY

The visual system installation for the MPI Full Mission Bridge Simulator was successful, but it pushed the technology to the limits of what is feasible with COTS equipment. An important aspect of the success can be attributed to the interaction between the dome/bridge designer and Display Solutions in the early stages of development. CAD files were exchanged several times and the bridge design was modified to provide good “line of sight” between the projectors and screen. There are actually several places where there is some shadowing of the bridge structure in the image plane. The flexibility built into the CompactUTM software allowed us to actually conform the edge blend zones around these “shadows” rendering them invisible in the final image.

Budgetary constraints for the project dictated the use of XGA resolution LCD projectors. While the projectors used resulted in good image quality, future simulators are recommended to use higher resolution (SXGA+ or higher) projectors with higher contrast ratios and adjustable iris in the optics path for improved night simulation. The newer single chip DLP projectors are ideal for such application.

Newer versions of the geometry warping SW also offer the option of automated color balance setup for improved color uniformity and edge blending. This feature is available as an upgrade option from Display Solutions.

ACKNOWLEDGEMENTS

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