

Large-Scale Immersive Theaters

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Entertainment technologies strive to deliver memorable, compelling experiences to large populations. Cinema represents an efficient, reproducible medium for the delivery of such experiences. Historic improvements in cinema technologies have centered on making the image larger, brighter, or higher in resolution. Higher brightness and resolution provides a more realistic image, while a larger image provides a greater visual impact or sense of presence. More recent improvements in cinema technologies center on digital cinema, the use of digital graphics projectors to replace the century-old film-based technologies.

The “Holy Grail” of visual display is to deliver an eye-limited resolution image with a wide instantaneous field-of-view such that the entire retina is excited to its full capacity. Video-based systems that strive in this direction include the CAVE® [Cruz-Neira 93], head-mounted displays [Kaiser 95], and various wrap-around video projection systems such as the Reality Center [Traill 97]. Such systems typically accommodate a single user or small collaborative group. Historic large-scale immersive environments include painted panoramas [Gernsheim 68], multi-projector systems such as Circlevision and Cinerama [Hart 00], and more recently, large format film theaters including omni theaters using hemispheric projection screens [Shaw 83] and dome-based training simulators [Fisher 87].

From these roots, a new generation of visual displays have emerged in the last 7 years that are large-scale video-based “digital dome” immersive theaters [Lantz 96]. These are digital graphics environments that provide a visually (and aurally) immersive display accommodating tens to hundreds of people. Such systems are first appearing within planetaria and other special venue domed screen attractions. Indeed, the 2,700 planetaria worldwide, totaling an annual attendance of nearly 90 million visitors, represent a substantial market for this emerging medium [Loch Ness 02]. Unlike film theaters, these modern video-based environments allow visitors to “plug in” to digital information space, including live telepresence events, realtime computer simulations and games, and the latest happenings in the global digital village.



Digital Dome Theater

the projection of eye-limited resolution onto a hemispheric screen demands over 200 million pixels – two orders of magnitude greater than the new 1080i high-definition television standard. This is far beyond current display system performance. However, acceptable display quality is achievable with as few as 3 million pixels under certain circumstances, and large-scale systems exceeding 9 million pixels are readily available. Interestingly, the immersive imagery provides a strong sense of presence even without 3D stereoscopic effects.

To date 55 digital dome theaters have either opened their doors or soon will, mostly as planetaria (Table 1). As the number of theaters grows, so will the demand for quality show programming and events. While large-format cinematography can provide some material for these facilities, 2D and 3D computer graphics rendering and compositing techniques makes up the vast majority of programming material to date. This course is intended as a primer for animators and other computer graphics professionals wanting to enter this emerging field.

Technical Challenges. The demand for simultaneous high-resolution and ultra-wide field-of-view provides a formidable challenge for even the most advanced graphics generation and display systems. For instance,

Table 1 – Sampling of Digital Dome Theaters Planned or Now Open*

Facility Name	Location	Vendor	Opening Year	Display System
LodeStar Planetarium	Albuquerque, NM	SkySkán	2000	SkyVision
Bibliotheca Alexandria	Alexandria, Egypt	Spitz	2001	Esky 200
Don Harrington Discovery Center	Amarillo, Texas	Evans & Sutherland	2003	D3
Eugenides Planetarium and Science Center	Athens, Greece	SkySkán	2003	SkyVisionHD
Louisiana Arts & Science Center	Baton Rouge, LA	SkySkán	2002	SkyVision
Louisiana Arts and Science Museum	Baton Rouge, LA	Minolta	2003	MediaGlobe
Beijing Children's Museum	Beijing, China	Trimension/SGI	2003	Fulldome
Samford University	Birmingham, AL	Spitz	2001	Esky 200
Orange Imaginarium	Bristol, UK	Spitz	2000	Esky 200
Queen Mary Cruise Liner	Caribbean	SkySkán	2004	SkyVisionHD/ DigitalSky
Clay Center for the Arts & Sciences	Charleston, WV	Spitz	2002	Esky 200
Adler Planetarium	Chicago, Illinois	Evans & Sutherland	1999	StarRider (now Digister 3)
Nathan and Fannye Shafran Planetarium Cleveland Museum of Natural History	Cleveland, OH	SkySkán	2003	SkyVision
Denver Museum of Nature and Science	Denver, CO	SGI/Zeiss/ Schneider	2003	Custom full dome
Detroit Science Center	Detroit, Michigan	SkySkán	2002	SkyVision
Volkswagen Gläserne Manufaktur	Dresden, Germany	Spitz/BRC	2001	Custom full dome
Fujigawa, Japan	Fujigawa, Japan	Goto Optical	2000	Virtuarium
Schiele Museum	Gastonia, NC	Spitz	2002	Esky 200
Glasgow Science Centre	Glasgow, UK	Spitz	2001	Esky 200
Glendale Community College	Glendale, CA	SkySkán	2002	SkyVisionHD
Challenger Learning Ctr. of Northwest Indiana	Hammond, IN	Minolta	2003	MediaGlobe
Burke Baker Planetarium	Houston, Texas	SkySkán	1999	SkyVision
Science City at Union Station	Kansas City, Missouri	Spitz	2000	Esky 200
National Fusion Research Institute	Kyoto Prefecture, Japan	Goto Optical	2001	Virtuarium
National Space Centre	Leicester, UK	Spitz	2001	Esky 200
Rauch Planetarium	Louisville, KY	Spitz	2001	Esky 200

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Longines Zeiss Planetarium - Museum of Transport and Comm.	Lucerne, Switzerland	SkySkán	2001	SkyVision
St. Charles Parish Library	Luling, LA	Minolta	2003	MediaGlobe
Matsue, Japan	Matsue, Japan	Goto Optical	2000	Virtuarium
Centro Cultural Olimpo	Merida, Yucatan	Evans & Sutherland	2003	Digistar 3 SP
Papote Museo del Nino	Mexico City, Mexico	Spitz	2003	ElectricSkyHD
Galilee Planetarium	Montpellier, France	Evans & Sutherland	2001	SkyVision
Minamimakimura Village Local Culture Exchange Center	Nagano, Japan	Goto Optical	1997	Virtuarium
Hayden Planetarium	New York, NY	Trimension/SGI	2000	Full dome
Pensacola Christian College	Pensacola, FL	SkySkán	2002	SkyVision HD
Franklin Institute	Philadelphia, PA	Spitz	2002	ESky Partial Dome
OMSI	Portland, Oregon	SkySkán	2003	SkyVision HD
Science Center of Pinellas County	St. Petersburg, FL	Minolta	2003	MediaGlobe
Parque Isla Magica	Seville, Spain	SkySkán	2001	SkyVision
Unknown	Shenzhen, China	Evans & Sutherland	2001	StarRider
St Etienne Planetarium	St Etienne, France	Barco/RSA	2003	Fulldome
Challenger Learning Center	Tallahassee, FL	SkySkán	2003	SkyVision HD
Thessaloniki Museum	Thessaloniki, Greece	Barco/RSA	2003	Fulldome
Science and Technology Center	Tokyo, Japan	Evans & Sutherland	2002	StarRider
Junior Museum	Troy, NY	SkySkán	2003	SkyVision HD
Valladolid Planetarium	Valladolid, Spain	Barco/RSA	2003	Fulldome
Einstein Planetarium	Washington, DC	SkySkán	2002	SkyVisionHD
Northern Lights Centre	Watson Lake, Yukon	Spitz	1997	ESky 200
Exploration Place	Wichita, Kansas	Evans & Sutherland	2000	StarRider (now Digistar 3)

* This list is preliminary and contains the best information to date. Spitz makes no claims as to its completeness and accuracy. Trademarks are the property of their respective owners.

High-resolution systems utilize multiple edge-blended graphics projectors to achieve a single wide field image. These projectors must focus over a region of the spherical screen, and the image must overlap adjacent projectors for seamless blending. The projectors must have precise geometric positioning to allow accurate image overlay in the edge-blend regions. And all projectors must be similarly color corrected to provide a true seamless effect. Current systems meet these difficult requirements with varying degrees of success using off-the-shelf projectors intended for flat-screen projection. Single-lens hemispheric projection systems were introduced in 2002 that are simpler, more affordable, and more accessible than multiprojector systems. The highest performance system available to date delivers QXGA resolution from

a single projector [Spitz 03]. Smaller systems with SXGA resolution promise to dominate the educational market.

Computer graphics for spherical projection must be rendered onto a view sphere as opposed to the current view plane paradigm. Alternately, multiple flat plane renders can be stitched using 2D image-processing algorithms to form a complete view sphere. The resulting spherical images are brought together in post-production with live-action, titles, stock footage and other composited elements to build a complete edited program. The resulting spherical master frames must be split out into individual channels, spherically warped, properly masked for edge blending and stored on separate digital data recorder channels for synchronous playback.

Alternately, realtime computer graphics can provide multiple simultaneous rendering pipelines for full hemispheric display of high-resolution images to provide an immersive, fully interactive group experience. Show producers for such systems are challenged to effectively involve the audience in meaningful interaction [Chiwy 00], and must also pioneer new storytelling and show production techniques.

Artistic Challenges. Given an immersive audio/visual delivery system and the requisite production tools, the next challenge is to make good use of the medium. We are bombarded by cinema and television every day. It visually communicates with us through a language that has evolved over the past century. It's a language that many of us have been conditioned to receive and understand since birth. The language developed and is continuing to develop through the tireless efforts of hundreds of thousands of filmmakers and videographers striving to learn how to best exploit the frame for the purpose of telling the story that they want to tell.

The underlying technologies that power immersive theater are outgrowths of the same technology that power television and cinema. The artist's goal of communicating a story to the viewer has not changed. What has changed is that the frame has been taken away. The frame has always been part of the cinematographer's language. It has been used as a device to direct the viewer's attention, define a space, convey emotion, or even obscure something from the viewer's gaze [Shedd 97]. Now that the frame is gone, how do we do these things? Artists have to learn to adapt the language to this new medium. When we give up the frame, we gain the power to truly immerse our audience in the story space. The audience is no longer an outside observer viewing the action through a "window on the world". Now we can push the viewer right up to and through that window so that they can experience what they might actually experience if they were a passive, or in the case of real-time theaters, an active participant in the story.

Because immersive experiences fill the retina, such images excite the opto-vestibular response caused by optic flow across the retina [Lappe 99]. This can lead to an exciting experience or cybersickness, depending upon the person and the production. Immersing someone in a rapidly changing space can disorient him or her. As artists and storytellers, we have to develop an understanding of the power that we wield. New storytelling paradigms have to be invented to deal with the wide field of view, frameless images.

Conclusions. With large-scale immersive theaters we are seeing the birth of a new medium. Because the medium is spherical, it has an aesthetic lure that is difficult to describe. Because the medium is video graphics, it is less expensive and more accessible than film and thus more open to independent producers. Because the medium is digital, it is open to rapid or real-time display of electronic information. And because the medium is immersive, it touches us on a deeper level, both psychologically and physiologically. As we learn to fully utilize this powerful medium, as the related display and production technologies mature, and as our ability to rapidly generate increasingly complex images grows, we expect to see growing interest in this format and eventually, widespread use of immersive displays in education, leisure and home entertainment.

References

[Chiwy 00] Phillippe Chiwy, "VR in Immersive and Interactive Theatres: The Bridge between Movie and Video-Game Experiences," *TiLE 2000 Proceedings*, pp. 145-148, 2000

[Cruz-Neira 93] Carolina Cruz-Neira, Daniel J. Sandin, and Thomas A. DeFanti, "Surround-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE," *Computer Graphics, Annual Conference Proceedings Series*, 1993

[Fisher 87] Robert A. Fisher, "A Full Field of View Dome Visual Display for Tactical Combat Training," *Image IV Conference Proceedings*, June 1987

[Hart 00] Martin Hart, Curator, *American Widescreen Museum*
<http://www.widescreenmuseum.com/widescreen/intro.htm>

[Kaiser 95] Kaiser Electro-Optics, Inc. "Full Immersion Head Mounted Display," *Product Information*, Carlsbad, CA (1995)

[Lantz 96] Ed Lantz, "Spatially Immersive Displays for Group Information Visualization," Workshop on New Paradigms in Information Visualization and Manipulation (NPIV'96), in conjunction with CIKM 96, pp. 37-40, October 1996.

[Lantz 97] Ed Lantz, "Future Directions in Visual Display Systems," *Computer Graphics*, 31(2), pp. 38-45, 1997

[Lappe 99] M. Lappe, F. Bremmer & A. V. van den Berg, "Perception of self-motion from visual flow," *Trends in Cognitive Sciences*, Vol. 3, pp. 328-336, 1999

[Loch Ness 02] *The LNP Planetarium Compendium*, 2002-2003 Edition, Loch Ness Productions, p. vi, 2002

[Shaw 83] William C. Shaw and J. Douglas Creighton, "Imax® and Omnimax® Theatre Design," *SMPTE Journal*, March 1983

[Spitz 03] ElectricSky II product brochure, Spitz, Inc., 2003 <http://www.spitzinc.com>

[Shedd 97] Ben Shedd, "*Exploding The Frame*,"
<http://www.cs.princeton.edu/~benshedd/ExplodingtheFrame.htm>

[Traill 97] D.M. Traill, J.M. Bowskill and P.J. Lawrence, "Interactive Collaborative Media Environments," *BT Technology Journal*, Vol. 14, No. 4, October 1997