Using the GPU to Create a Seamless Display from Multiple Projectors

Steve Nash, Nvidia
Paul Green, Scalable Displays
Agenda

- The Problem -- what do we mean by seamless?
- The way it’s been done up until now
- Our solution
- Scalable Display’s implementation
The Problem

- Increases in pixel density and total pixels have not kept pace with increases in CPU and GPU power
- Different solutions for adding more pixels
  - LCDs: obtrusive bezels in the way
  - Nearly bezel-less
Projectors: overlap the edges to hide the seam
The Problem (cont’d)

- Projectors: optics (and screens) are never perfect
Just creating the overlap makes a hot spot since the overlap region gets twice the light.
The Problem (cont’d)

- Projectors: how to project on domes and curved screens?
Working with Multiple Projectors

Current Nvidia SLI Mosaic product lets you specify overlap

To be truly seamless, need to account for geometry and brightness differences between projectors
Warp & Blend

- Warp = Geometry Corrections
- Blend = Intensity adjustments

Can do one or the other, or both
The way it’s been done up until now

- Hardware appliance for warp and intensity adjustment
  - Expensive
  - Extra performance delay tax on the display pipeline
  - Additional complexity

- Software warp and intensity adjustment
  - Applications need to be written to manage
  - There has not been an easy way to implement this for any application, until now…
NVIDIA’s Solution

- We can do this on the GPU!
  - GPUs are fast, and are already have the pixel information
  - Perform the transformation in the display pipeline before the pixels get scanned out
  - By doing this on the GPU, we have more flexibility: high quality filtering, integration with SLI Mosaic, etc.
NVIDIA’s Solution

- Works on Quadro 5000, 6000, and Quadro Plex 7000
- Use it with G-sync to get synchronization between displays
How’s it Done: Work Flow

1. Take picture of calibration pattern
2. Create warping mesh based on picture of calibration pattern relative to true image
3. Typical Warping Mesh contains 1-10K vertices
How’s it Done: NVAPI

- NVAPI is Nvidia’s programmatic interface to configure and control the GPUs. [http://developer.nvidia.com/nvapi](http://developer.nvidia.com/nvapi)
- New interfaces are added in the 275+ NDA version to allow warping and intensity adjustment before the final scanout.
- Currently works with single screen, multiple screen capability coming with R285 driver (mid September)
How’s it Done: Warping

1. Initialize NVAPI
2. Get GPU Handle
3. Get Display ID
4. Define Warping Mesh
   1. Use `NvAPI_GPU_GetScanoutConfiguration()` to get current desktop
   2. Each vertex has:
      1. x,y: 2D Vertex coordinates
      2. u,v: 2D Texture coordinates
      3. r,q: perspective correction

5. Call `NvAPI_GPU_SetScanoutWarping`:

   ```c
   NvU32 displayId,
   NV_SCANOUT_WARPING_DATA* scanoutWarpingData,
   int* piMaxNumVertices,
   int* pbSticky);
   ```
How’s it done: Intensity Adjustment

1. Initialize NVAPI
2. Get GPU Handle
3. Get Display ID
4. Define Intensity Map: GL_RGB value for each pixel
5. Call `NvAPI_GPU_SetScanoutIntensity`
   ```c
   NvU32 displayId,
   NV_SCANOUT_INTENSITY_DATA* scanoutIntensityData,
   int *pbSticky);
   ```
Scalable Display Technologies
Scalable Display Technologies

- Leading provider of auto-calibration software for seamless multiple-projectors displays
- Founded in 2004, based on Ph.D. work of Rajeev Surati at MIT
- Over 100 Customers
  - Command and Control
  - Business Collaboration
  - Visualization
  - Simulation and Training
  - Pro A/V
- Projector OEMs: 70,000+ licenses
Core Auto-Calibration Technology (IP)

- Camera feedback to automatically warp and blend many projectors into one seamless display
- Patented by MIT and licensed exclusively to Scalable
Benefits of NVIDIA W&B API

- **Scalable Display Manager** (mil-sim, cmd&ctrl)
  - No longer need SDK integration
  - No need for warping box hardware ($$$)
  - Application Independence
  - Quadro support for Gen-lock

Fewer requirements, barriers and restrictions means **broader market and stronger growth**
Benefits of NVIDIA W&B API

- **Scalable Desktop** (warped Win7 Desktop)
  - Full integration with Windows (login screen, ctrl+alt+del)
  - Eliminates mouse pointer issues
  - Performance benefit
  - Expands potential outputs up to 24

100% integrated Windows solution
Case Studies

- 100 MPixel Space Command and Control
- Navy Combat System Display
- 20 MPixel Touch Display Wall
- 48 MPixel F-16 Simulator
- Commercial Collaboration Systems
  - Fortune 100 Collaboration room
  - Oil and Gas viz room
  - Classroom Info wall and whiteboard
AFRL - 100 MPixel Space Command System

- 25 Computers with Quadro cards running 50 projectors
- Custom SDK integration that can run a single application
- Application independence with NVIDIA W&B API
Navy Combat System Display

• Aegis Combat System Display
• Delivered 22 Cruisers, 62 Destroyers to follow
• US, Japan, Spain, Norway, Korea, Australia
• Required Gen-Lock and SDK integration
MIT Lincoln Labs - 20 MPixel touch wall

- 12 Projector system using dual Quadroplexes
- Will be first install to use NVIDIA W&B API
- Prototype Design for Virtual Shopping Aisle System
“Low cost” simulator ($500K)
- Immersive Display Solutions (IDSI)
Application independence is essential to make “turn key”
No warping box hardware keeps costs down
Multi-Quadroplex system
- SLI Mosaic
- Gen-Lock
Commercial Collaboration Systems – Edge Blending Goes Mainstream

Present Big Ideas in a Big Way
Summary

- SDT is leader in auto-calibration
- NVIDIA Warp and Blend API makes our technology application independent
- Fewer requirements, barriers and restrictions means broader market
- Full windows integration
- Loads and loads of examples enabled or enhanced by new NVIDIA W&B API
Further Information

- QuadroSVS@nvidia.com
- sales@scalabledisplay.com
Thanks!