SEE THE BIG PICTURE: HOW TO BUILD LARGE DISPLAY WALLS USING NVIDIA DESIGNWORKS™ APIS/TOOLS

Doug Traill (QuadroSVS@nvidia.com)
FROM SD TO 8K - EXPONENTIAL PIXEL GROWTH

Image Courtesy: Rose Adler, Leighana Ginther, Jackie Osterday
4K VERSUS HD
Perceptual Performance of GPU based warp & anti-aliasing

Stim Level: 3.5
Pixel Pitch: .5 arcmin/pixel

Stim Level: 3.5
Pixel Pitch: 1.78 arcmin/pixel

Images courtesy of USAF - School of Aerospace Medicine
4K VERSUS HD
Perceptual Performance of GPU based warp & anti-aliasing

Stim Level: 3.0
Pixel Pitch: .5 arcmin/pixel

Stim Level: 3.0
Pixel Pitch: 1.78 arcmin/pixel

Images courtesy of USAF - School of Aerospace Medicine
### DRIVING ULTRA HIGH RES DISPLAYS

#### MAX SINGLE CABLE BANDWIDTHS/RESOLUTIONS

<table>
<thead>
<tr>
<th>Connector</th>
<th>Version</th>
<th>Max pixel clock</th>
<th>Color depth</th>
<th>Max resolution for single cable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display Port</td>
<td>1.4**</td>
<td>~</td>
<td>12bpc</td>
<td>Up to 4K (UHD)@120Hz (DSC) 8K@60Hz (DSC)</td>
</tr>
<tr>
<td></td>
<td>1.3</td>
<td>~</td>
<td>12bpc</td>
<td>Up to 5K by 3k @ 60Hz Up to 8K @30Hz</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>~592 MHz</td>
<td>12bpc</td>
<td>Up to 4K @ 60Hz</td>
</tr>
<tr>
<td></td>
<td>1.1a</td>
<td>~330 MHz</td>
<td>10bpc</td>
<td>Up to 4k @ 30Hz</td>
</tr>
<tr>
<td>HDMI</td>
<td>2.0*</td>
<td>~600 MHz</td>
<td>12bpc</td>
<td>Up to 4K @ 60Hz</td>
</tr>
<tr>
<td></td>
<td>2.0</td>
<td>~330 MHz</td>
<td>6bpc (YUV 4:2:0)</td>
<td>Up to 4K @ 60Hz</td>
</tr>
<tr>
<td></td>
<td>1.4b</td>
<td>~330 MHz</td>
<td>10bpc</td>
<td>Up to 4k @ 30Hz</td>
</tr>
<tr>
<td></td>
<td>1.0 to 1.3</td>
<td>~330 MHz</td>
<td>10bpc</td>
<td>Does not support 4K</td>
</tr>
<tr>
<td>DVI</td>
<td>Dual Link</td>
<td>330 MHz</td>
<td>8bpc</td>
<td>Up to 4K @ 30Hz</td>
</tr>
<tr>
<td></td>
<td>Single link</td>
<td>165 MHz</td>
<td>8bpc</td>
<td>Does not support 4K</td>
</tr>
</tbody>
</table>

Color: Windows Desktop 8bit, OpenGL Apps - 10/12bit, DirectX??

**NOTE:** Displays, extenders, switches may not implement full speed connections

*High bandwidth HDMI2.0 supported on M6000 using DVI to HDMI adaptor

** DP1.4 support added to Pascal GPUs -
LARGE SCALE VISUALIZATION
See the big Picture

Clockwise from upper left images courtesy of Vislogix, Prysm, Inc., Visbox, Christie Digital, IMMERSIVE DESIGN STUDIOS, Elbit Systems.
Interactive Displays, Conference Rooms

Digital Signage

Video and basic 3D content
Low profile for SFF systems

Performance 3D content
Single slot FF with Sync support

Ultimate performance & Interactivity
Dual slot FF with Sync support

Demanding 3D content & Interactivity
Dual slot FF with Sync support

Video and basic 3D content
Single slot FF with 8 display outputs

Video and basic 3D content
Low profile for SFF systems

NVS 810

Quadro K1200

Quadro M4000

Quadro M5000

Quadro M6000-12GB
Quadro M6000-24GB

Quadro Sync Support - 4 GPUs

2-way SLI support

Product Design Reviews

Specialty Applications
MULTI-GPU MOSAIC WITH SYNC
Sync requires a physical connection between GPUs

Two-way SLI (requires bridge)
- 2 Quadro cards (8 displays)
- Certified OEM workstations
  - Dell/HP/Lenovo
- SLI Motherboards
  - New - R361/R364 driver
  - Quadro now supported in GTX cert motherboards.

Quadro Sync
- 2 to 4 Quadro cards (16 displays)
- Any motherboard or expansion chassis
- Support for external Sync sources.
  - House Sync
  - Sync from another Quadro Sync card.

Note: Same performance level
# Display Management Technologies

## MOSAIC

![MOSAIC Image]

## WARP & BLEND

![WARP & BLEND Images]

## DISPLAY MANAGEMENT APIs

- Monitoring + Setup tools
- NVAPI
- NVWMI

## SYNC

![SYNC Image]

[developer.nvidia.com/designworks]
MOSAIC - SETUP & CONFIGURATION
MOSAIC - WHY IS IT NEEDED?
- Windows on its own  - Independent Desktops
WINDOWS ON ITS OWN

- Independent Desktops
WITH MOSAIC
- One large Desktop
# MOSAIC GRIDS

<table>
<thead>
<tr>
<th>rows</th>
<th>columns</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>9</td>
</tr>
</tbody>
</table>

- Rows x columns <= 16
- Max Horizontal or vertical Pixels <= 16384
- Enumeration of the Grid always starts top left and goes left to right
BEZEL AND OVERLAP CORRECTION

Bezel Correction
Will make the image look continuous as we render ur

Overlap Correction
For projectors it maintains the aspect ratio of the display.
### Understading Topologies

<table>
<thead>
<tr>
<th>Row</th>
<th>Column</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>13</td>
<td>14</td>
</tr>
</tbody>
</table>

#### Bezel Correction
- **Will increase overall pixel size**
- i.e., each display is 1920x1080
- Bezel per column is 100
- Total horizontal width:
  \[ 1920 \times 4 + 100 \times 3 = 7980 \]

#### Overlap Correction
- **Will decrease overall pixel size**
- i.e., each display is 1920x1080
- Overlap per column is 100
- Total horizontal width:
  \[ 1920 \times 4 - 100 \times 3 = 7380 \]
ANATOMY OF A SYSTEM

- stereo sync bracket
- Quadro Sync card

- CPU0 PCIe 1
- CPU0 PCIe 2
- CPU1 PCIe 2
- CPU1 PCIe 1
- GPU-0
- GPU-1
- GPU-2
- GPU-3
- con0
- con1
- con2
- con3
REAR PANEL - 4 M6000S

- VESA Stereo Bracket
- GPU 0
- GPU 1
- GPU 2
- GPU 3
- Quadro Sync

VESA stereo - only one per system required
Doesn’t require PCIe slot - just a blank

Connect to all 4 GPUs.
At boot-up LEDs will be amber showing GPU connected
PORT NUMBERING

VESA Stereo Bracket

GPU 0

GPU 1

GPU 3

GPU 2

Quadro Sync

i.e. only E is attached
E = 0,0

A + E are attached
A = 1,0
E = 1,1

A + B + C + D are attached
A = 3,0
B = 3,1
C = 3,2
D = 3,3
configureMosaic-x64.exe set rows=3 cols=3
configureMosaic-x64.exe set rows=3 cols=3 out=0,0 out=0,1 out=0,2 out=1,0 out=1,1 out=1,2 out=2,0 out=2,1 out=2,2
MOSAIC WITH SYNC

MOSAIC with Sync = Premium MOSAIC = SLI MOSAIC

Setup MOSAIC Menu

- Roll over icon under “Sync capability”
- Indicates whether card can be sync’d
  - Multi-GPU Sync “Quadro Sync” - multi-GPU sync via Quadro Sync card
  - Multi-GPU Sync “SLI Bridge” - 2-way GPU sync via SLI bridge
  - Single GPU Sync - outputs on single card can be framelocked.
LINUX

Single GPU (4 outputs) - MetaModes only

Section "Screen"
  Identifier     "Screen0"
  Device         "Device0"
  Monitor        "Monitor0"
  DefaultDepth  24
  Option        "MetaModes" "1920x1080 +0+0, 1920x1080 +1920+0, 1920x1080 +0+1080, 1920x1080 +1920+1080"
  Option        "nvidiaXineramaInfo" "FALSE"
  SubSection "Display"
    Depth  24
EndSubSection
EndSection
LINUX

2 GPUs example - Use BaseMOSAIC (No SLI or QUADRO SYNC)

Section "Screen"
  Identifier "Screen0"
  Device "Device0"
  Monitor "Monitor0"
  DefaultDepth 24
  Option "BaseMosaic" "TRUE"
  Option "MetaModes" "GPU-0.DFP-0: 1920x1080 +0+0, GPU-0.DFP-1: 1920x1080 +1950+0, GPU-1.DFP-0: 1920x1080 +0+1100, GPU-1.DFP-1: 1920x1080 +1950+1100"
  Option "nvidiaXineramaInfo" "FALSE"
  SubSection "Display"
    Depth 24
  EndSubSection
EndSection
LINUX

2 GPUS with Quadro Sync or SLI connector - Use “SLI” “MOSIAC”

Section "Screen"
  Identifier     "Screen0"
  Device         "Device0"
  Monitor        "Monitor0"
  DefaultDepth  24
  Option         "SLI" "MOSAIC"
  Option         "MetaModes" "GPU-0.DFP-0: 1920x1080 +0+0, GPU-0.DFP-1: 1920x1080 +1820+0, GPU-1.DFP-0: 1920x1080 +0+1000, GPU-1.DFP-1: 1920x1080 +1820+1000"
  Option         "nvidiaXineramaInfo" "FALSE"
  SubSection     "Display"
    Depth       24
  EndSubSection
EndSection

NVS810 - Use this mode
LINUX TIPS

Window Manager (GNOME, Unity, KDE etc) may over-ride MOSAIC settings.

1x3 MOSAIC - but three separate Desktops
MOSAIC is running - i.e. Windows should open full screen

1x3 MOSAIC - Single Desktop
LINUX TIPS
MOSAIC with Quadro Sync

Set SLI MOSAIC in xorg.conf

After restarting X - Enable Framelock (Not automatic)
CLIP MOSAIC
Load balance Pixel fill rate on multi-GPU MOSAIC

Benefits

• Divides pixel fill between GPUs - improves perf on large res displays

Requirements

• Full screen OGL or DirectX app

• Supported on Windows + Linux
  • Windows - command-line utility - send email to QuadroSVS@nvidia.com
  • Linux - environment variable. `__GL_MOSAIC_CLIP_TO_SUBDEV=1`
SMART CLONE
Single GPU MOSAIC only

- Pan and Scan
  - Clones the area around mouse
- Select area to clone
  - Yellow box shows clone are
- Scaled clone
MOSAIC +1
Across multiple GPUs

- Windows
  - GRID spans multiple GPUs
    - Spare ports on GPU cannot be used for additional displays
    - Add a Quadro K620
    - New display is like a new grid
- Linux
  - Not officially supported
    - Use Option “MOSAICplusOne”
MEMORY PRE-ALLOCATION

Force Stereo shuttering

Memory Allocation Policy

Moderate Pre-allocation

Set Stereo to enable

VESA stereo (3-pin) port will now be active - even if no stereo app is running.

- AERO desktop will always be disabled
- 3D Vision Pro hub will be always enabled.

Windows 7 only - not supported on Win8.1/Win10
MEMORY PRE-ALLOCATION

Mode Set Reduction

“mode-sets” (SCREEN FLASH) reduction during setup for:

“Swap Groups”

“tear free” mode - i.e. Video Edit Profile

Memory Allocation Policy

Aggressive Pre-allocation

Note:

force stereo will also be enabled

AERO is disabled

Doesn’t affect MOSAIC setup - i.e. Still screen flash

Windows 7 only - not supported on Win8.1/Win10
JVC 4K/8K E-SHIFT PROJECTOR
Native support in NVIDIA Windows driver (Linux support planned)

- **8k Projector**
  - Similar to active stereo - scans alternate odd/even frames (1200x2400)
  - Automatically detected by driver
    - EDID is seen at 2400x4800 resolution per input (project has 4 inputs)
    - VESA stereo (3pin) port is used to identify odd/even frame.

- **4k Projector**
  - Similar to passive stereo - separate odd/even frames
  - Enabled using configuremosaic tool.

configuremosaic set rows=1 cols=1 pixelshift out=0,0,tl out=0,1,br res=1920,1080,60
WARP + INTENSITY ADJUSTMENTS
PROJECTION BLENDING

Warp + Blend Engine

3rd party software available from

![VIOSO](#)

![play-out.com](#)

![CHRISTIE](#)

![coolux](#)

![IMMERSAVIEW](#)

API for geometry and intensity adjustments for seamless projection environments

Image courtesy of Joachim Tesch
- Max Planck Institute for Biological Cybernetics
WARP NOT JUST FOR PROJECTORS

NVS810 - 8 outputs on 1 card
WARP 2.0

New filtering methods
NvAPI_GPU_SetScanoutCompositionParameter

Selectable via NVAPI

- Bilinear
- BI-CUBIC Triangular
- BI-CUBIC Bell Shaped
- BI-CUBIC Bspline
- BI-CUBIC - Adaptive Triangular
- BI-CUBIC - Adaptive Bell Shaped
- BI-CUBIC Adaptive Bspline
IMPLEMENTING WARP
Links to past talks/info

Windows

• S5143 - Architectural Display Walls Using NVAPI - Doug Traill, GTC 2015
• S2322 - Warping & Blending for Multi-Display Systems - Shalini Venkataraman GTC 2012
• Sample code - DesignWorks developer pages

Linux

• Sample code - nv-control-warpblend. Shipped with driver. Tar ball can be downloaded here: ftp://download.nvidia.com/XFree86/nvidia-settings/
• Go to samples directory.
LCD TILE WALLS
MOSAIC + WARP
Solves issues with sync on LCD panels

Tearing between each row

- Appears with fast moving video or interactive content
- Display wall is framelocked - but response time of LCD panels results in this optical effect
LET’S TAKE A CLOSER LOOK

What’s happening

• Progressive scan-out from line 0 to line 1080
• Each lower row appears to be rendering ahead
• Columns within a row appear to be sync’d
SOLVING THIS PROBLEM

Use WARP API + rotated row

• Progressive scan-out from line 0 to line 1080
• Rotate every other row
  • Line 1080 -> Line 1080
  • Line 0 -> Line 0
• WARP API
  • Rotate Desktop image so looks correct to the viewer
DISPLAY MANAGEMENT APIS
**NVWMI TOOLKIT & NVAPI**

Remote management and NVIDIA control panel APIs manage complexity

### NVWMI remote management API
- Monitor and manage NVIDIA graphics from anywhere
- Do everything the control panel can do and more
- Plugs into Microsoft’s WMI
- Perfmon support
- Scriptable | wmic | powershell | C# support

### NVAPI for the NVIDIA control panel
- Custom resolutions
- EDID management
- Warp + Blend API (Quadro only)
- MOSAIC API
- Reskinning the NVIDIA control panel (build your own)

Image courtesy of Immersive Design Studio
## NVAPI FUNCTIONS

Selection of different features

<table>
<thead>
<tr>
<th>Custom Resolutions</th>
<th>MOSAIC</th>
<th>Sync Management</th>
<th>EDID Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>GFT, DMT, CVT, CVT-RB, Manual timing</td>
<td>Seamless desktop across multiple GPUs</td>
<td>Genlock/TTL sync, framelock (internal sync)</td>
<td>Capture and read EDID from file</td>
</tr>
<tr>
<td>EDID Management</td>
<td>WARP + Intensity API</td>
<td>Driver Profiles</td>
<td>Driver Settings</td>
</tr>
<tr>
<td>Capture and read EDID from file</td>
<td>Edge-blending, projection mapping on Windows or Linux</td>
<td>Global and nView profile management</td>
<td>Manage 3D settings selection</td>
</tr>
<tr>
<td>Display Setup</td>
<td>GPU Direct for Video</td>
<td>Color Management</td>
<td>GPU Utilization</td>
</tr>
<tr>
<td>Clone mode, display position</td>
<td>Picture-in-picture support</td>
<td>Color space conversion via NVAPI SDK</td>
<td>GPU utilization, memory etc.</td>
</tr>
</tbody>
</table>
Public & NDA Version

Public - developer.nvidia.com

Most functions available - MOSAIC, WARP etc. NO Custom Resolution.

NDA - registered developer with NDA. NVIDIA provides access to partner network for download

All functions available - including custom resolution

More SDK examples

Structure versions

Each structure in NVAPI contains a version field that must be set.

NV_XXX.version = NV_XXX_VER;

displayIds - unique identifier for each display attached. Includes GPU info.
NVWMI
Plug into Windows Management Infrastructure

Accessible using:

- WMIC - command line
- Powershell
- C#
- developer.nvidia.com/nvwm
- SDK samples
- White paper

Installed with the driver - C:\Program Files\NVIDIA Corporation\NVIDIA WMI Provider
MOSAIC SETUP

NVWMI - adds remote setup support

• Class - DisplayManager

• Function - createDisplayGrids

• Input parameters - string containing grid information i.e.
  
  “rows=2;cols=2;stereo=0;layout=1.1 1.2 1.3 1.4;mode=1920 1200 32 60”

• Layout - numbering starts at “1”. Different than control panel

C# code snippet

```csharp
ObjectGetOptions Options = new ObjectGetOptions();
ManagementPath Path = new ManagementPath("DisplayManager");
ManagementClass ClassInstance = new ManagementClass(Scope, Path, Options);
ManagementBaseObject inParams = ClassInstance.GetMethodParameters("createDisplayGrids");

string[] grid_input_params = { "rows=1;cols=2" };
inParams["grids"] = grid_input_params;

ManagementBaseObject outParams = ClassInstance.InvokeMethod("createDisplayGrids", inParams, null);
```
PERFORMANCE MONITOR

Performance Counters
• monitor utilization
• Temperature/power

Event monitor
• Quadro Sync events
  • Changes in sync status reported without polling.
WHY IS SYNC IS IMPORTANT?

Bezel’s hide sync issues!!!
• **Vertical Sync** is the pulse that indicates the start of the display refresh.
• To avoid *tearing* on a single screen the application swap buffers are synced to *vertical sync*.
• Although all three displays may have the same refresh rate - *vertical sync* start may be different.
• This can result in *tearing* between displays.
FRAMELOCK/GENLOCK

- **Framelock/Genlock** provides a common sync signal between graphics cards to insure the vertical sync pulse starts at a common start.
- This is commonly referred to as **Frame Synchronization**
- **Framelock** - Synchronization is generated from a master node. All other nodes would be sync to this.
- **Genlock** - synchronization is from an external sync generator (house sync). Each node attached to the genlock signal is synced from that signal.
- **Framelock & Genlock** can be mixed in the cluster. With the master node being synchronized from the genlock pulse.
SWAPBUFFERS

**GPU**
- Draw (1)
- Draw (2)
- Draw (3)
- Draw (4)

**Display**
- Scan
- Scan (1)
- Scan (2)
- Scan (3)
- Scan (4)

Time (in ms):
- 0
- 16
- 32
- 48
- 64
- 80

- Front
- Back
- Swap
SWAPBUFFERS

Time (ms)

0  16  32  48  64

GPU

Front

Swap

Draw (1)

Draw (2)

Swap

Draw (3)

Display

Scan

Swap

Scan (1)

Swap

Scan (2)

Swap

Scan (3)
Each node is now rendering a scene with different complexity i.e. from least to highest we get:
1. node 3 ~ 16ms = 60fps
2. node 4 ~ 36ms = 30fps
3. node 2 ~ 53ms = 15fps
4. node 1 ~ 99ms = 10fps

• With each node running at a different rate the user would perceive tearing on the screen.
• We need a mechanism to ensure that each node will swap at the same time.
SWAPBUFFERS IN A CLUSTER

Each node is now rendering a scene with different complexity i.e from least to highest we get:
1. node 3  ~  16ms = 60fps
2. node 4  ~  36ms = 30fps
3. node 2  ~  53ms = 15fps
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- With each node running at a different rate the user would perceive tearing on the screen.
- We need a mechanism to ensure that each node will swap at the same time.
SWAP GROUP AND SWAP BARRIER

NVIDIA Extensions to OpenGL /DirectX (via NVAPI)

- Swap Group - provides synchronization multiple GPUs in a single host
- Swap Barrier - provides synchronization of GPUs across multiple nodes.
- Use RJ45 (framelock) connection on Quadro Sync - so faster than sync over a network

With Swap Barrier each node will wait until all nodes have completed their render
1. node 3  ~  16ms = 10fps
2. node 4  ~  36ms = 10fps
3. node 2  ~  53ms = 10fps
4. node 1  ~  99ms = 10fps
QUADRO SYNC Firmware
Version 0x57

Fixes

• Issues with 50Hz house sync signals
• Start delay and Sync offset functions
• Mosaic as part of cluster - each node is running MOSAIC locally.
• General stability related to Maxwell generation of GPUs.

If your system isn’t broken - don’t fix it.
i.e. please only upgrade if one of the issues above applies to you
BUILDING CLUSTER AWARE SOFTWARE
CLUSTER SOFTWARE
3rd party/Open Source

Toolkits
- getReal3D
- CAVELib
- unity
- worldviz
- OpenSceneGraph

Middle Ware
- Conduit
- Equalizer
THANK YOU

Questions - dtraill@nvidia.com or QuadroSVS@nvidia.com

twitter @dougtraill