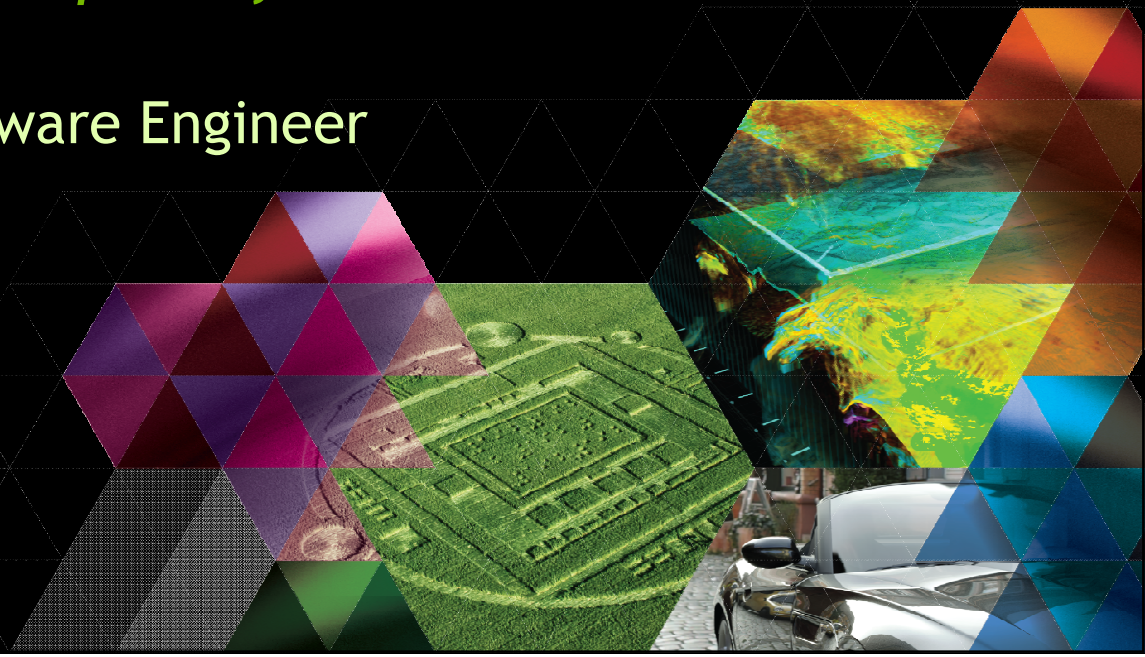
GPU TECHNOLOGY CONFERENCE

NVIDIA

NVIDIA Path Rendering

Accelerating Vector Graphics for the Mobile Web

Mark Kilgard
Principal Graphics Software Engineer
NVIDIA Corporation



About Me

- Principal System Software Engineer
  - OpenGL driver and API evolution
  - Cg ("C for graphics") shading language
  - GPU-accelerated path rendering
- OpenGL Utility Toolkit (GLUT) implementer
- Author of *OpenGL for the X Window System*
- Co-author of *Cg Tutorial*
- Now working on NVIDIA's web browser team

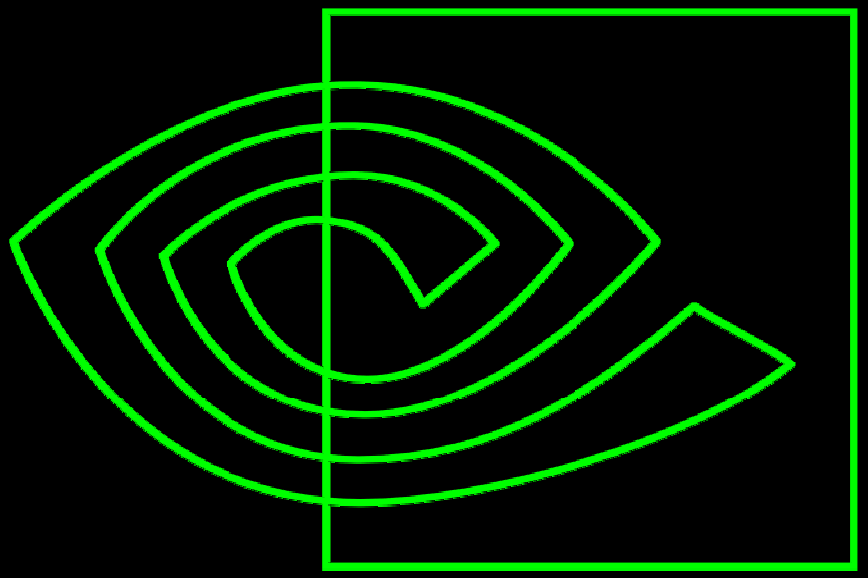
What is Path Rendering?

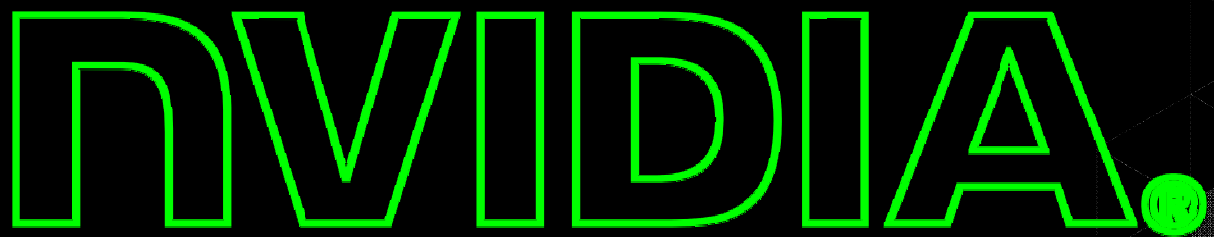
- A rendering approach
  - Resolution-independent two-dimensional (2D) graphics
  - Occlusion & transparency depend on rendering order
    - So called “Painter’s Algorithm”
  - Basic primitive is a path to be filled or stroked
    - Path is a sequence of path commands
    - Commands are
      - **moveto, lineto, curveto, arcto, closepath**, etc.
- Common rendering model to many 2D graphics standards & APIs

What is a path?

- **Intuition:**
  an “outline”

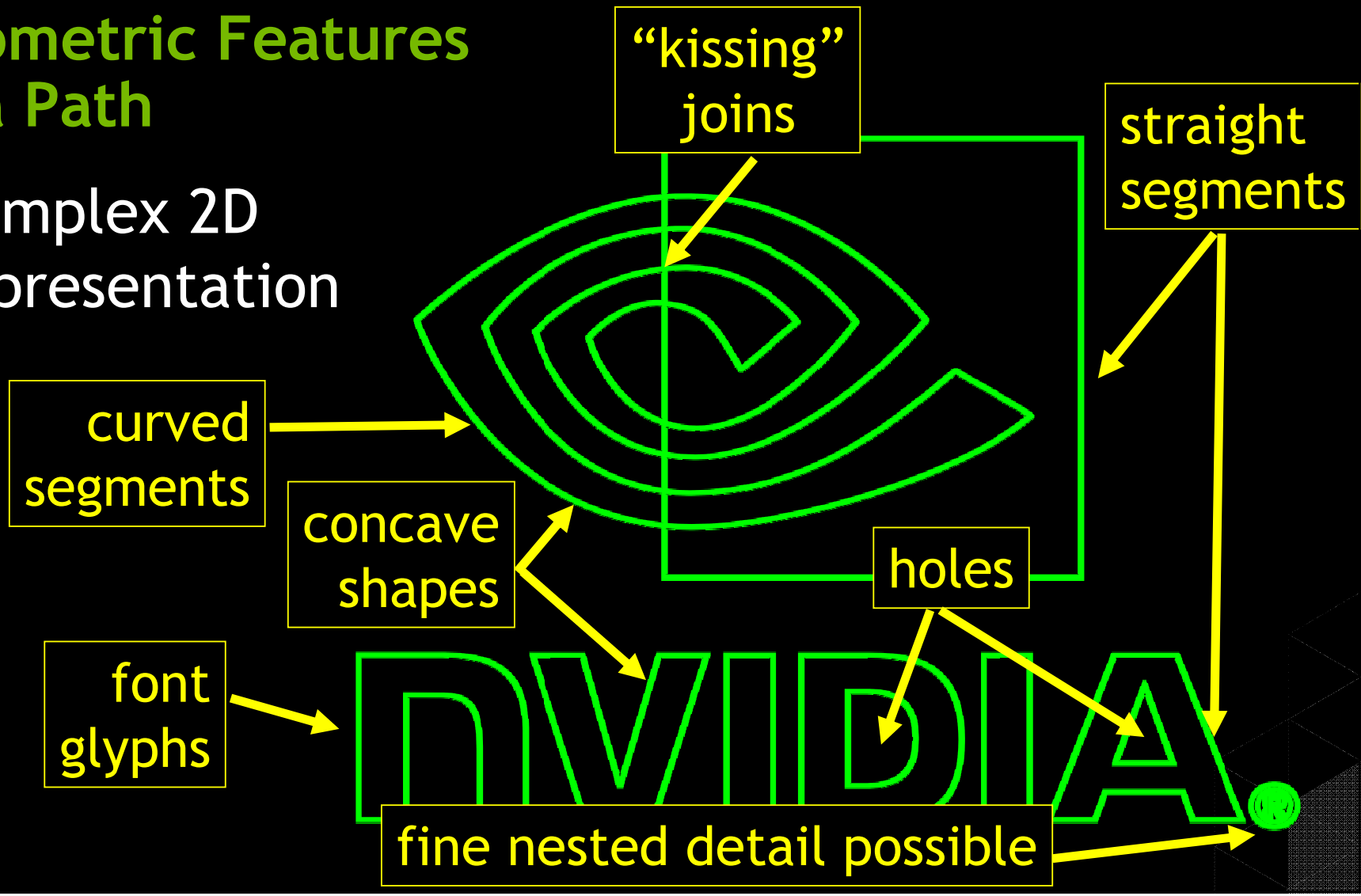
- Well-known to
  2D artists





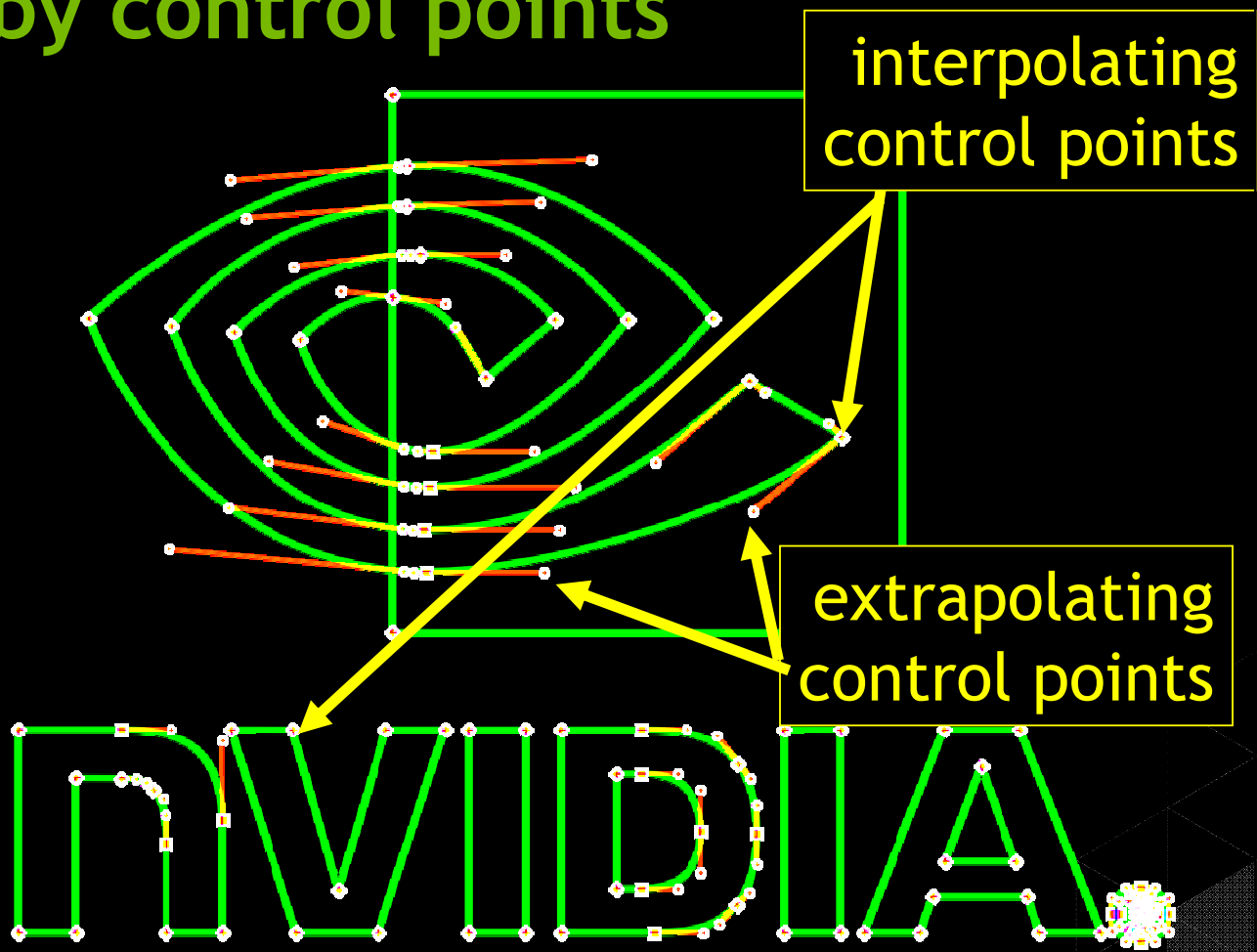
Geometric Features of a Path

- Complex 2D representation



Path defined by control points

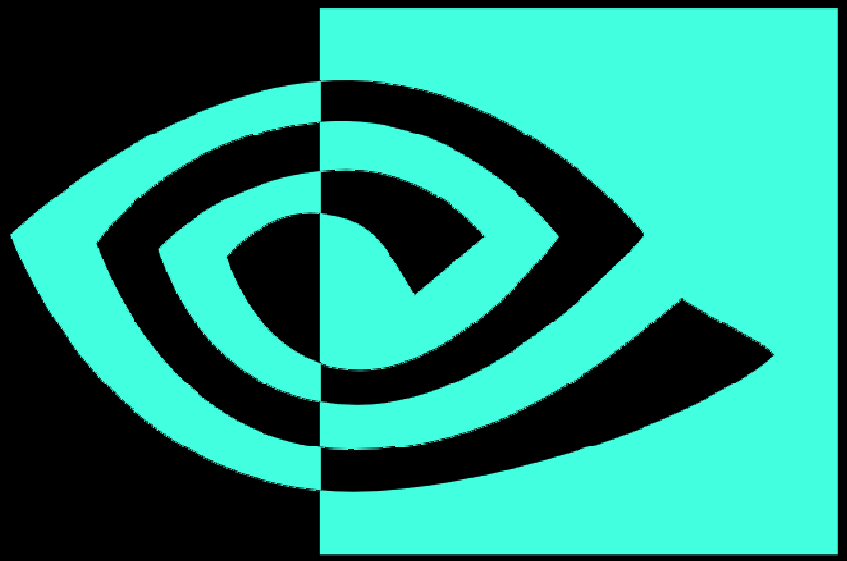
- 2D points define outline
  - Bezier segments define curves



Paths can be Filled

- **Intuition:**
  "Color between the lines"

- Fill rules
  - Non-zero
    - Overlaps allowed
  - Even-odd

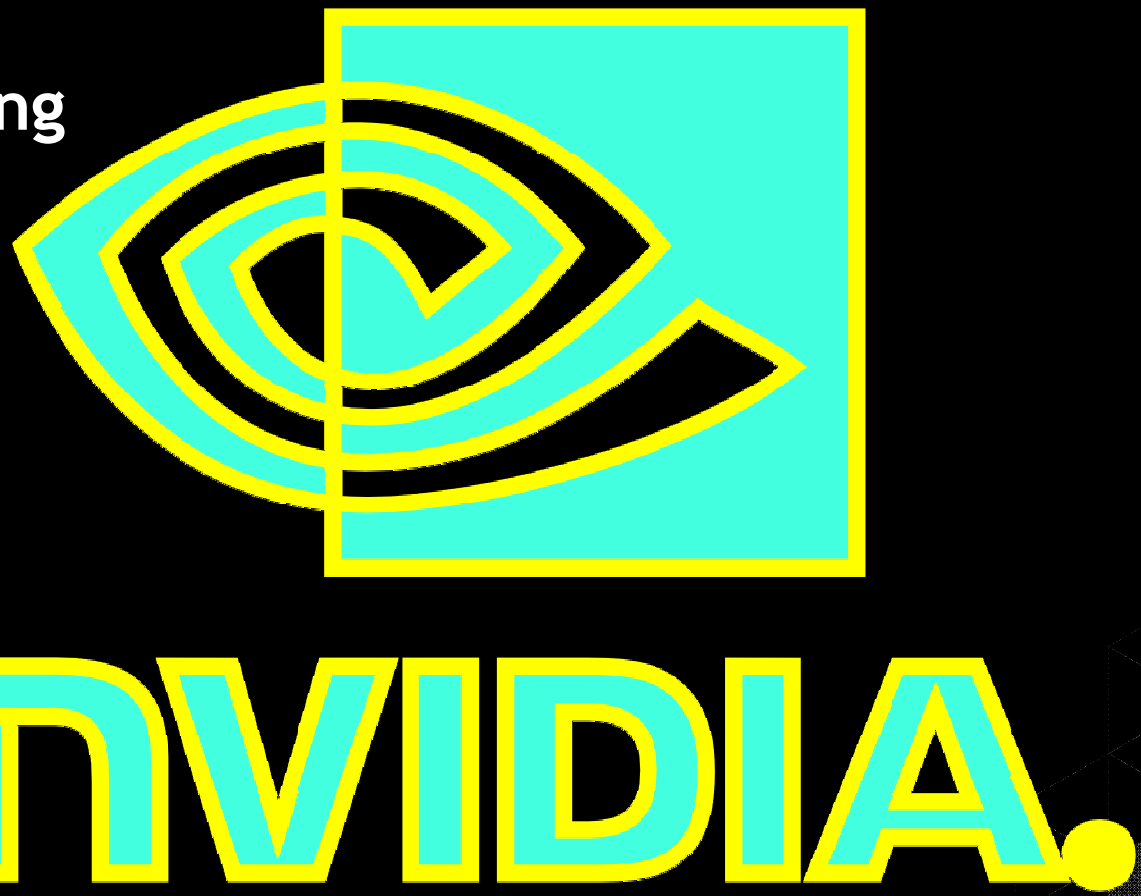


Or Stroked

- **Intuition:** "Trace the outline with a pen"

Or Both

- **Filling, then Stroking** helps “highlight” an object



Embellishments

- Gradients & other shading can be applied
- The stroking can be “dashed”
- Stroking can vary
  - stroke width
  - end-caps
  - dash-caps
  - join-styles
  - mitering

Path are the Basic Primitive of a Rich Set of 2D Graphics Operations

Geometry

- Bezier curves
- Fill & stroke
- Dash
- Cap
- Miter

Paint

- Color
- Image
- Pattern
- Gradient
- Shade!

Composite

- Transparency
- Blend modes
- Mask
- Filter
- Post-process

Path Rendering Standards

Document Printing and Exchange

Open XML Paper (XPS)

Resolution-Independent Fonts

OpenType

TrueType

Immersive Web Experience

Flash

Scalable Vector Graphics

Maps

2D Graphics Programming Interfaces

Java 2D API

QtGui API

Mac OS X 2D API

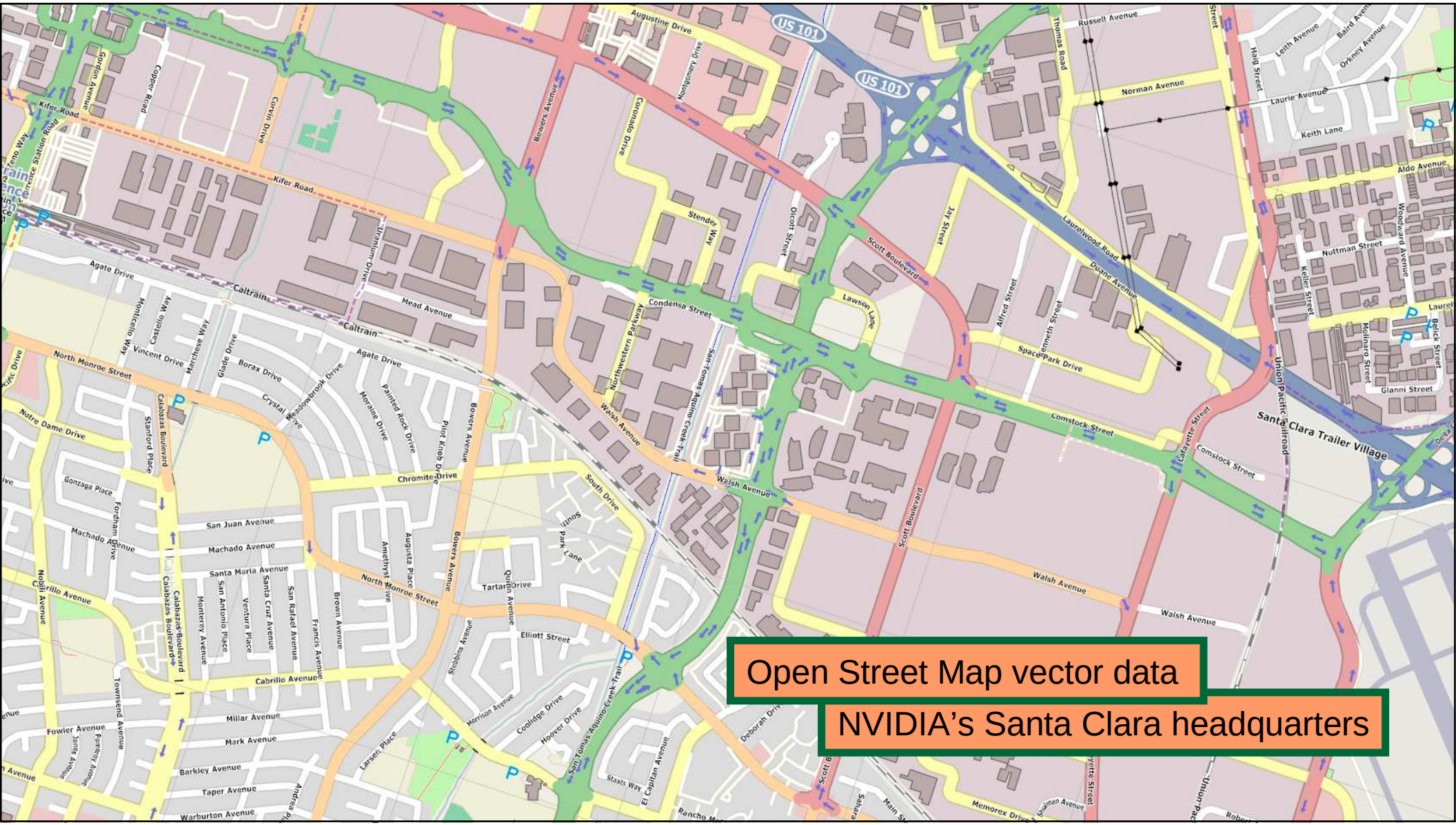
Office Productivity Applications

Adobe Illustrator

Inkscape Open Source

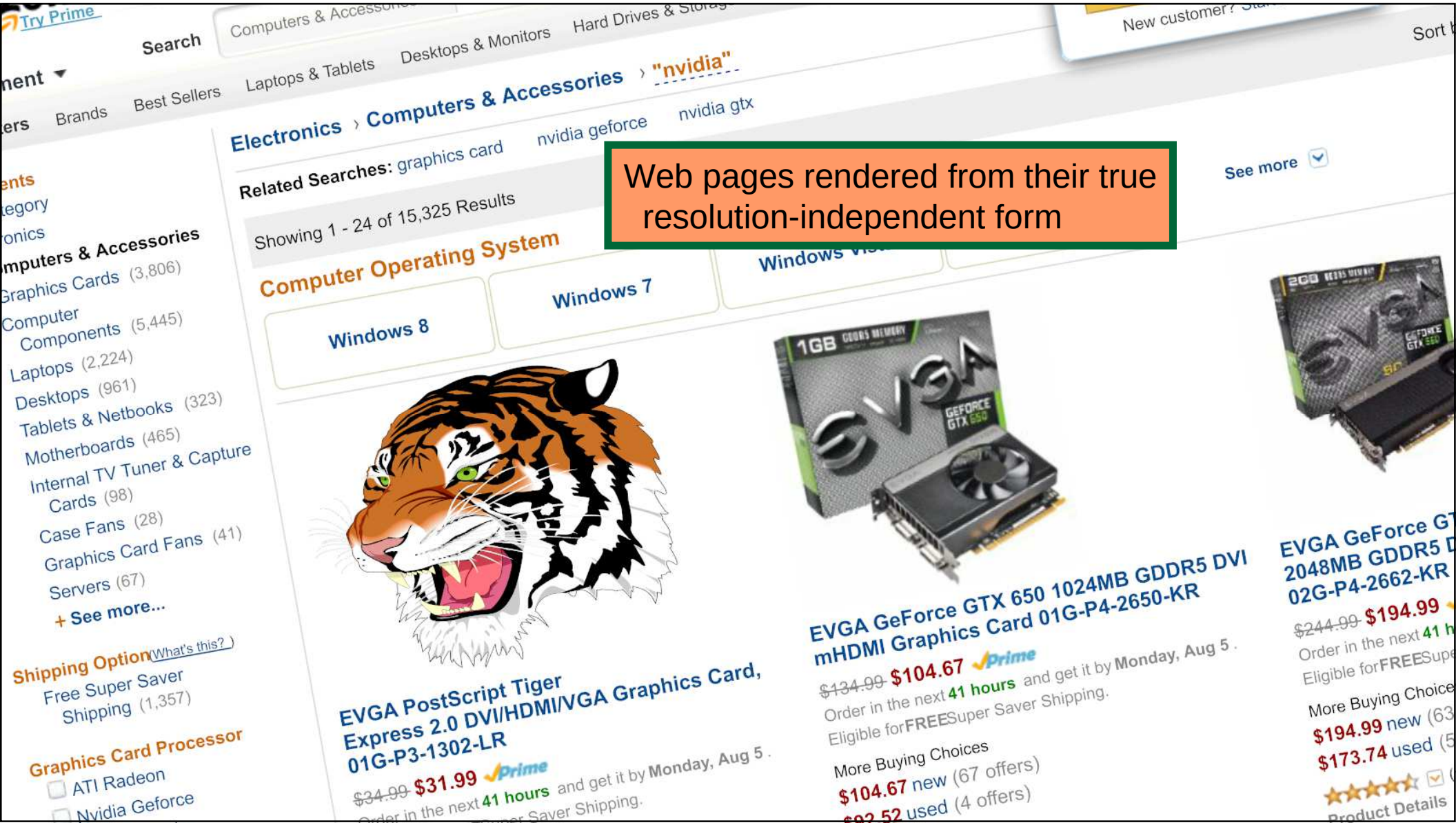
Some Examples of Complex Path Rendering Content

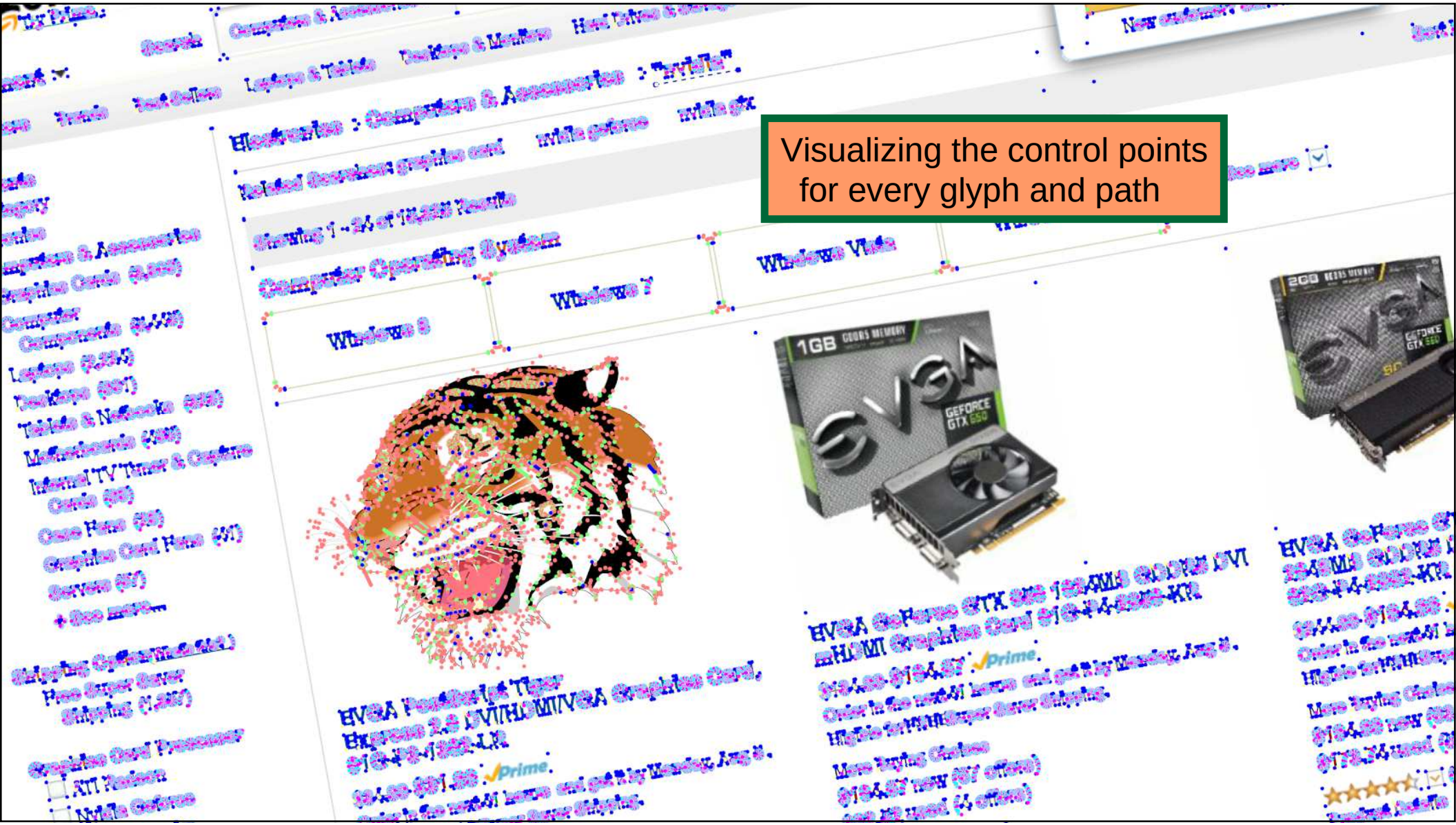
Varied applications


Open Street Map vector data
NVIDIA’s Santa Clara headquarters


Super-intricate Adobe Illustrator artwork
TAD CARPENTER
Adobe Illustrator CS6
Each dot in the zoom above is a path's control point

Web pages rendered from their true resolution-independent form




Visualizing the control points
for every glyph and path


Zoom in and see the detail
And control points
EVGA PostScript Tiger
Express 2.0 DVI/HDMI/VGA Graphics Card,
01G-P3-1302-LR
$31.99
Prime
get it by Monday, Aug 5

Why is NVIDIA Interested in GPU-accelerated Path Rendering?

- Increasing screen resolutions

- Increasing screen densities

- Immersive 2D web content

- Multi-touch

- Power wall
  More functionality with less latency…

…with less power

GPU TECHNOLOGY CONFERENCE

GTC Home > Attendees > Summits

WHY ATTEND?
SESSIONS/ACTIVITIES
SUMMITS
NVSCENE
REGISTRATION/PRICING
TRAVEL

EMAIL SUBSCRIPTION
Subscribe Now

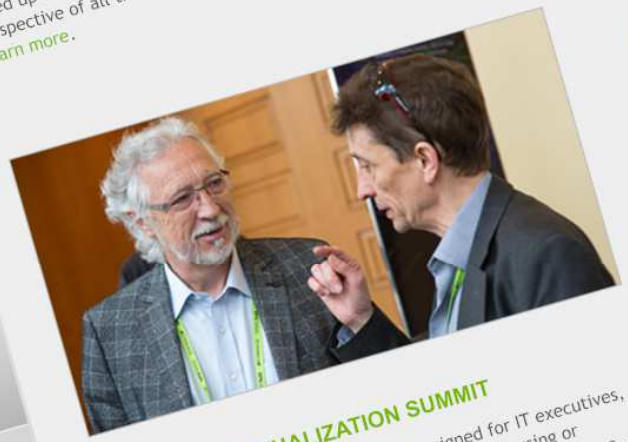
SOCIAL MEDIA

MOBILE APPS

Summits

DIGITAL MANUFACTURING SUMMIT

The Digital Manufacturing Summit is designed for **designers and engineering workgroup managers** virtually prototyping products using the latest 3D design, visualization, and simulation tools to speed up their workflow. Attend this summit to discover a broad perspective of all the latest design techniques and tools available. Learn more.

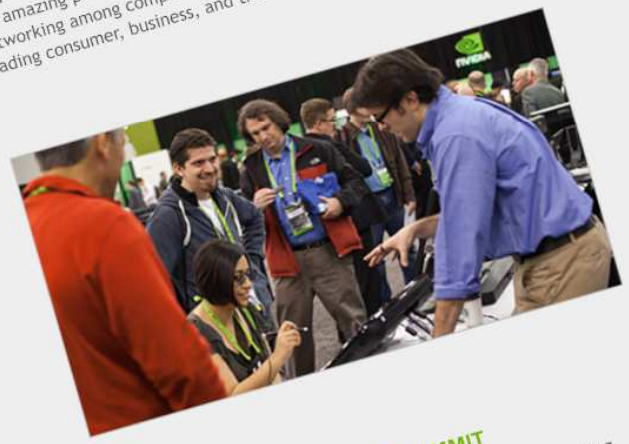


GRAPHICS VIRTUALIZATION SUMMIT

The Graphics Virtualization Summit is designed for IT executives, and system and infrastructure managers currently using or considering implementation of applications or virtual desktops, and ecosystem partners offering public, private or hybrid cloud-based services with GPU acceleration. Attend this summit to join cloud and virtualization leaders to learn how technology advancements now allowing engineers and designers to get the full interactive of a traditional desktop in a virtualized environment - riety of OS platforms, tablets, and thin clients.

EMERGING COMPANIES SUMMIT

The Emerging Companies Summit is designed for **startups and investors** interested in promoting and discovering promising companies developing disruptive technologies revolutionizing the computer industry. Attend this summit to watch CEO presentations, see amazing product demos, and have valuable opportunities for networking among companies, investors, key decision makers, and leading consumer, business, and trade press. Learn more.



MEDIA & ENTERTAINMENT SUMMIT

The Media and Entertainment Summit is designed for **leading producers, visual effects artists, post-production professionals, broadcasters, and software developers** from around the world. Attend this summit for a unique chance to discover best practices, network with peers, build business relationships, and advance the state of GPU acceleration across the industry. Learn more.

Complete Web Pages Rendered via OpenGL

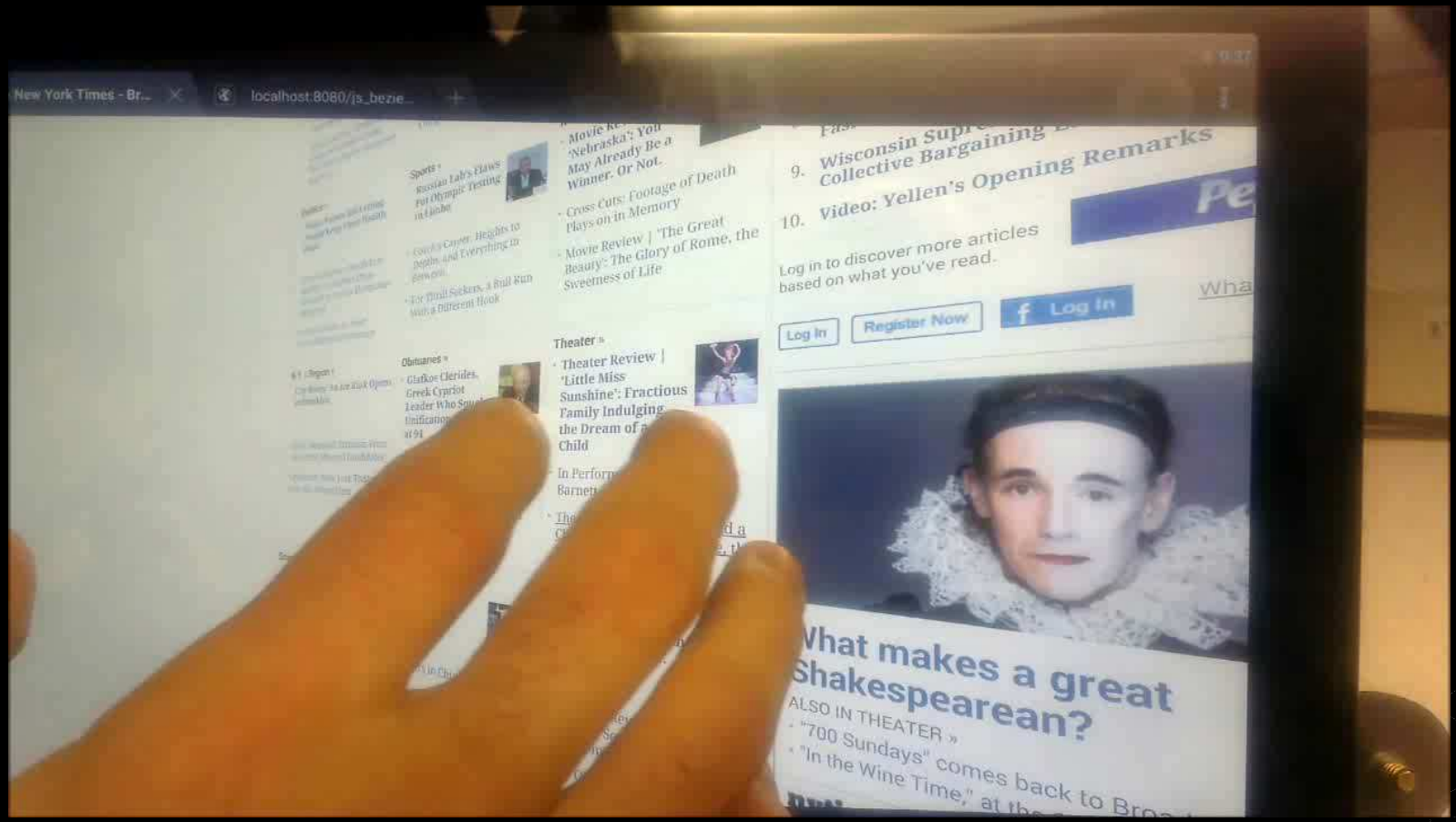
without Pre-rendered Glyph Bitmaps and all on GPU

http://www.gputechconf.com/page/summits.html


No tricks
Every glyph is rendered from its outline; no render-to-texture
Not just zoomed & rotated, also perspective
Magnify & minify with no transitional pixelization or tile popping artifacts
WHY ATTEND?
SESSIONS/ACTIVITIES
SUMMITS
NVSCENE
REGISTRATION/PRICING
TRAVEL
EMAIL SUBSCRIPTION
Subscribe Now
SOCIAL MEDIA
MOBILE APPS
MARCH 24-27, 2014 | SAN JOS
ATTENDEES
PRESENTERS
Summits
DIGITAL MANUFACTURING SUMMIT
GRAPHICS VIRTUALIZATION SUMMIT
RESOURCES
REGISTRATION LOGIN
CONTACT GTC
EMERGING COMPANIES SUMMIT
MOBILE SUMMIT
MEDIA & ENTERTAINMENT SUMMIT

Android Path Rendering Demo

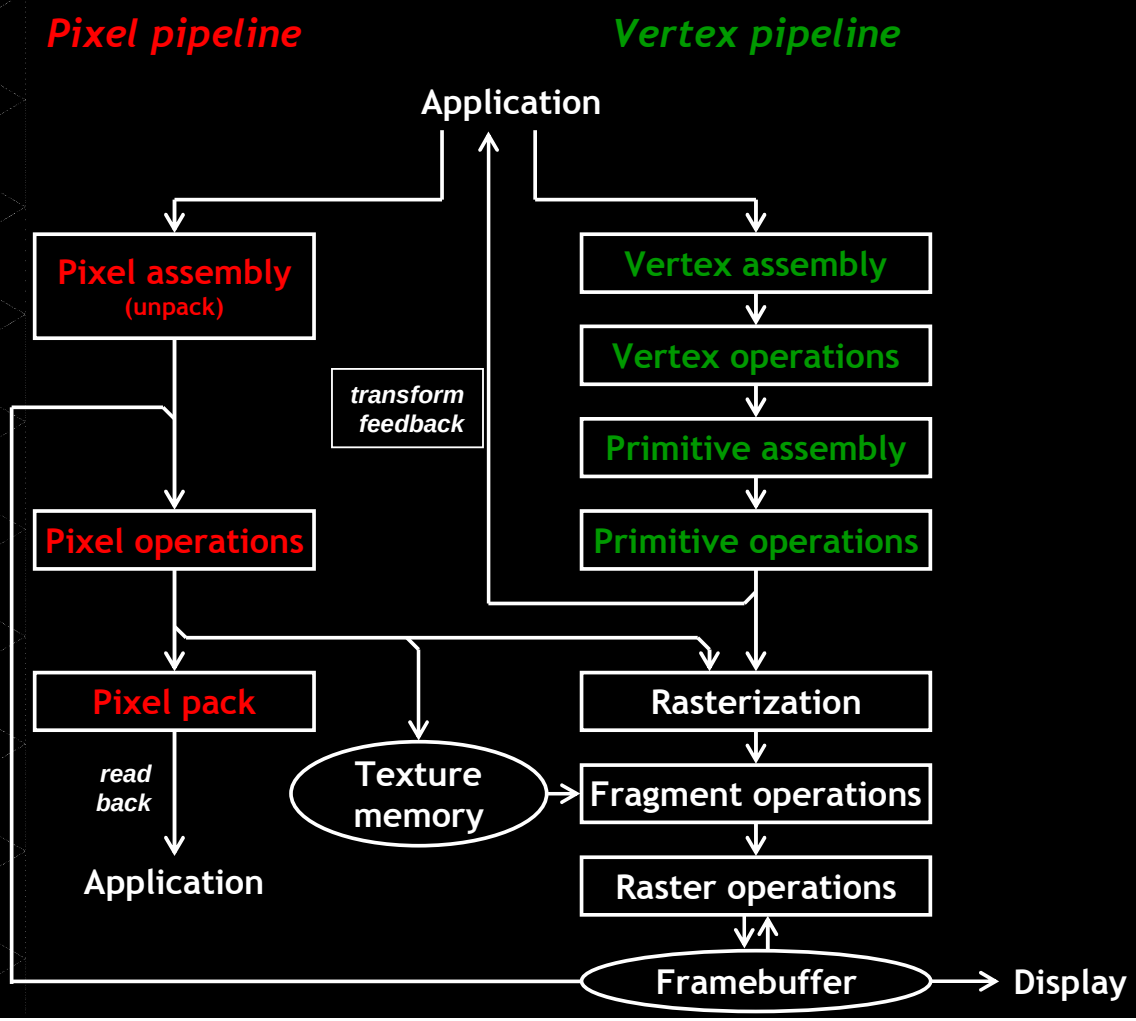
Mobile Web Browser
Rendering with NV_path_rendering



NVIDIA's Approach to Path Rendering

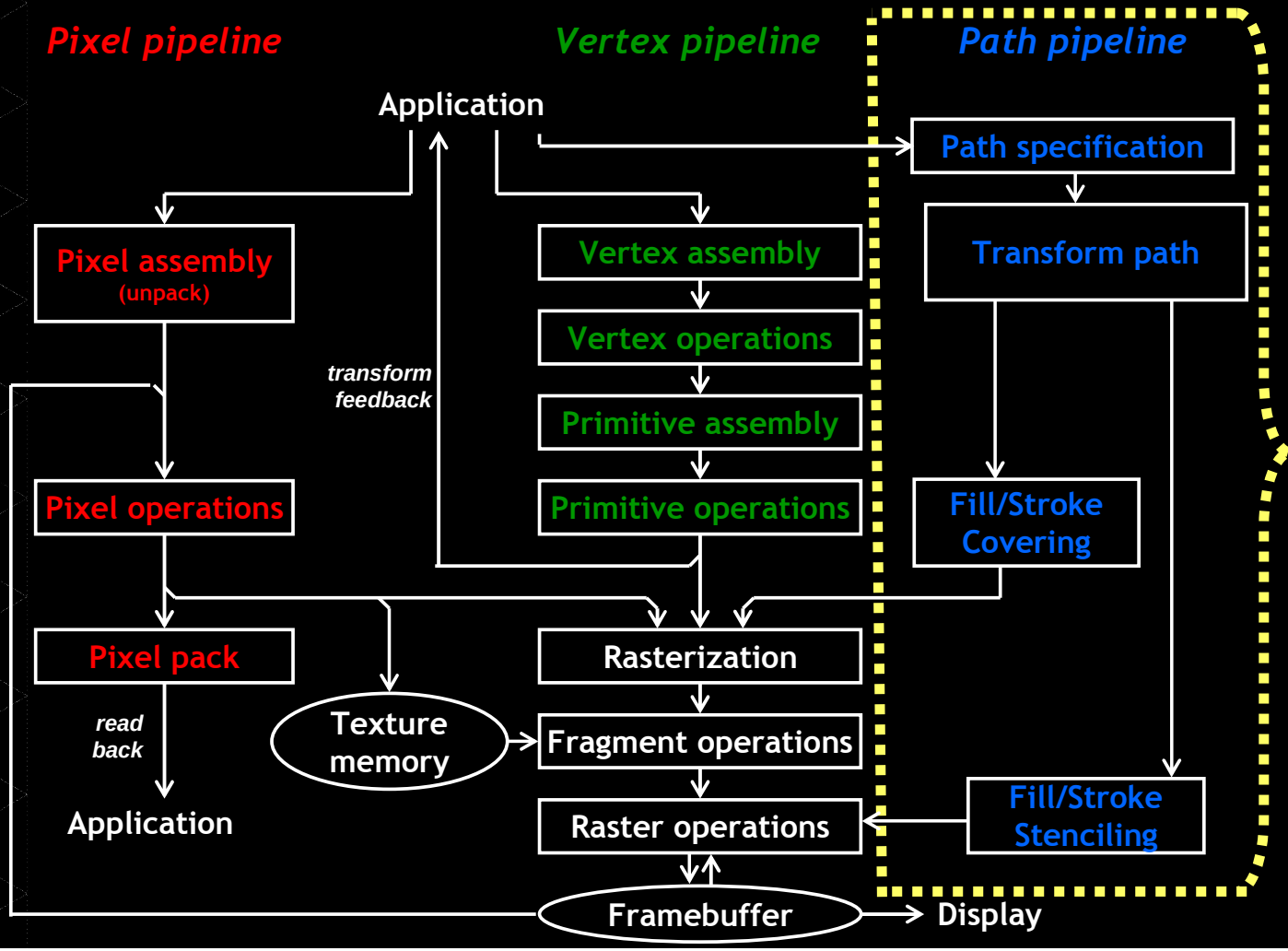
- OpenGL extension to GPU-accelerate path rendering
- Uses "stencil, then cover" (StC) approach
  - Create a path object
  - Step 1: "Stencil" the path object into the stencil buffer
    - GPU provides fast stenciling of filled or stroked paths
  - Step 2: "Cover" the path object and stencil test against its coverage stenciled by the prior step
    - Application can configure arbitrary shading during the step
- Supports union of functionality from all major path rendering standards
  - Includes all stroking embellishments
  - Includes first-class text and font support
  - Allows functionality to mix with traditional 3D and programmable shading

Conventional OpenGL Pipeline



- Great for 3D geometry
  - Triangles!
  - Depth buffering
  - Shading
- Also good for pixels and textures
  - Texturing
  - Off-screen rendering
  - Multisampling
  - First-class sRGB
- No support for path rendering ☹

OpenGL Pipeline + NV_path_rendering



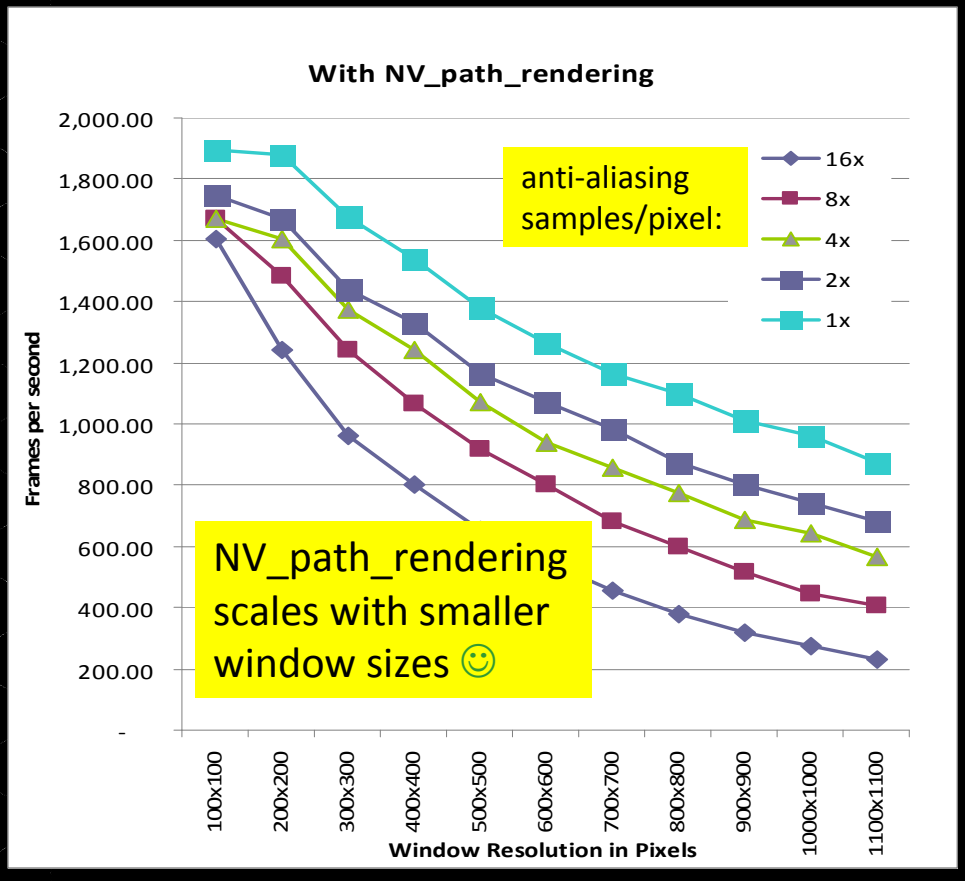
NV_path_rendering adds new pipeline specifically for path rendering

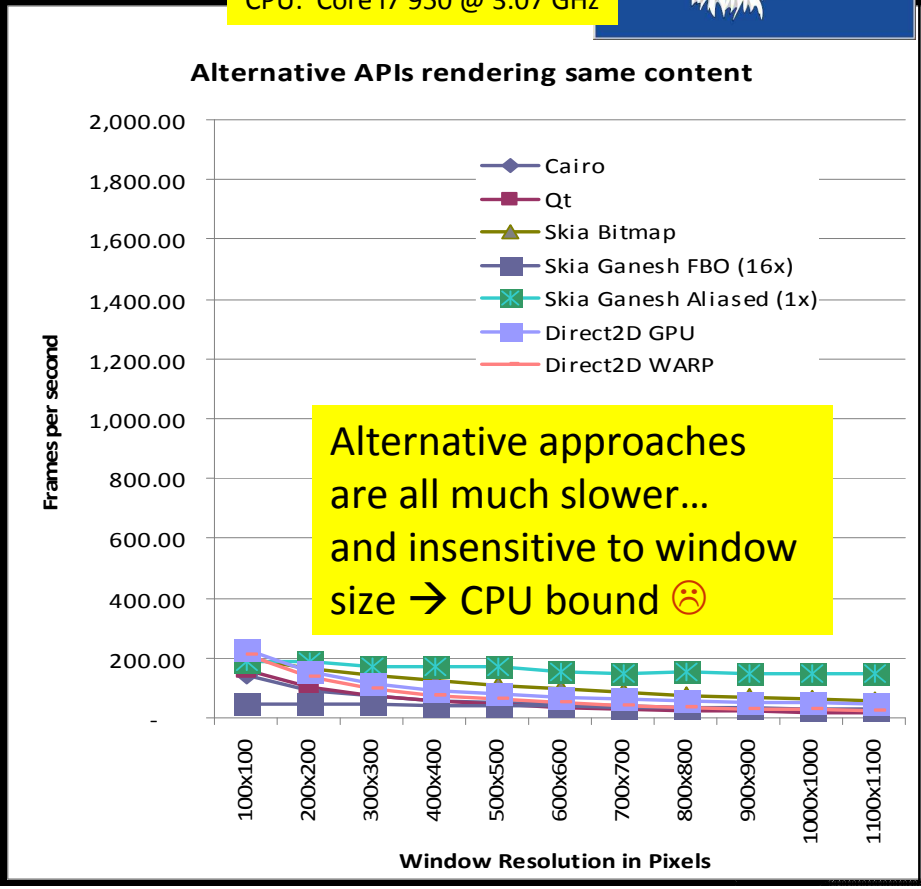
First class! ☺

Designed with path rendering standards and features in mind

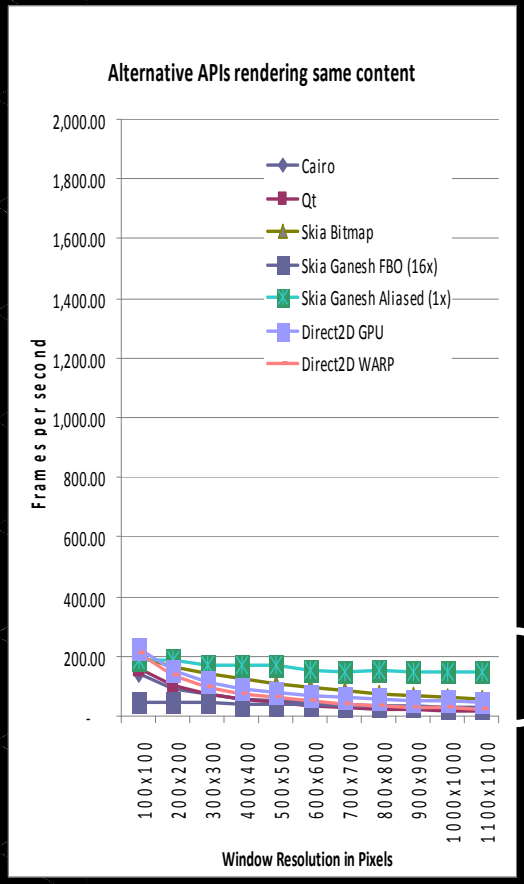
Way Faster than Alternatives

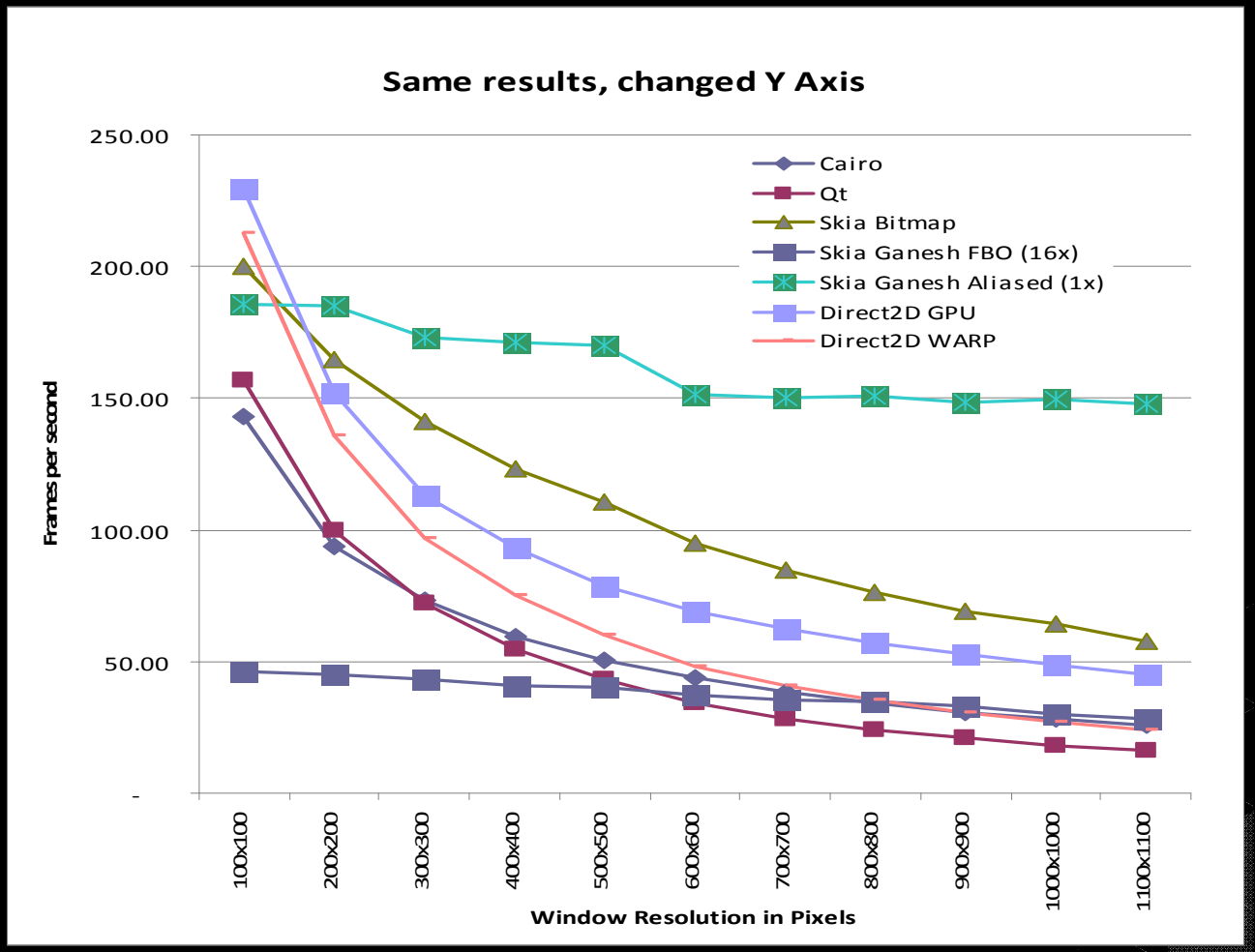
Configuration
GPU: GeForce 480 GTX
CPU: Core i7 950 @ 3.07 GHz





Details on (all much slower) alternatives





Why a first-class OpenGL extension?

- Many have tried to layer path rendering atop a 3D API
  - Microsoft's Direct2D atop Direct3D
  - Google's Skia atop OpenGL ES
  - Various efforts by Cairo, Adobe, and OpenVG layers
- Recurrent challenge
  - Real-world path rendering content = lots of tiny paths
  - Frequent 3D API state changes or CPU work in layered algorithms → CPU bound performance ☹
    - Other approaches wind up simply "GPU-assisted", not GPU-accelerated
- With an OpenGL extension, the driver overhead can be mitigated
  - Result is NV_path_rendering is truly GPU-accelerated ☺

NV_path_rendering vs. "Layered" OpenGL Implementation

Conclusion

- *Layered implementations very CPU bound;*
- *NV_path_rendering is actually GPU bound*

GeForce 570 GTX on *fast* Core i7

other alternatives even more CPU bound ☹

Evaluating Power Efficiency & Interactivity

- System performance expectations

GPU power efficiency	>	CPU power efficiency

GPU performance	>	CPU performance

- Rule of Thumb

"Faster you can efficiently get the frame done, sooner you can idle the power usage!"

- Metrics of interest
  - *energy / frame, in Millijoules* ← *efficiency*
  - *frames / second, in Hertz* ← *interactivity*

Latency & Power-efficiency Measurements

- Skia CPU
  - **81** milliseconds, 12.3 fps
  - 1 unit of energy to draw a frame
- Native NV_path_rendering
  - **22.2** milliseconds, 45 fps
  - 0.44 units of energy to draw a frame
- **56%** less energy per frame at **3.6x** interactivity!

Fine print

- All glyphs rendered from paths
- Continuous rendering, for reliable power measurements
- Using NVPR Demo for apples-to-apples rendering
- Tegra K1 device running Android
- Dual core OpenGL driver used
- Preliminary data, still improving GPU results ☺
- Comparing power at disparate frame rates is tricky

scene: New York Times web page capture

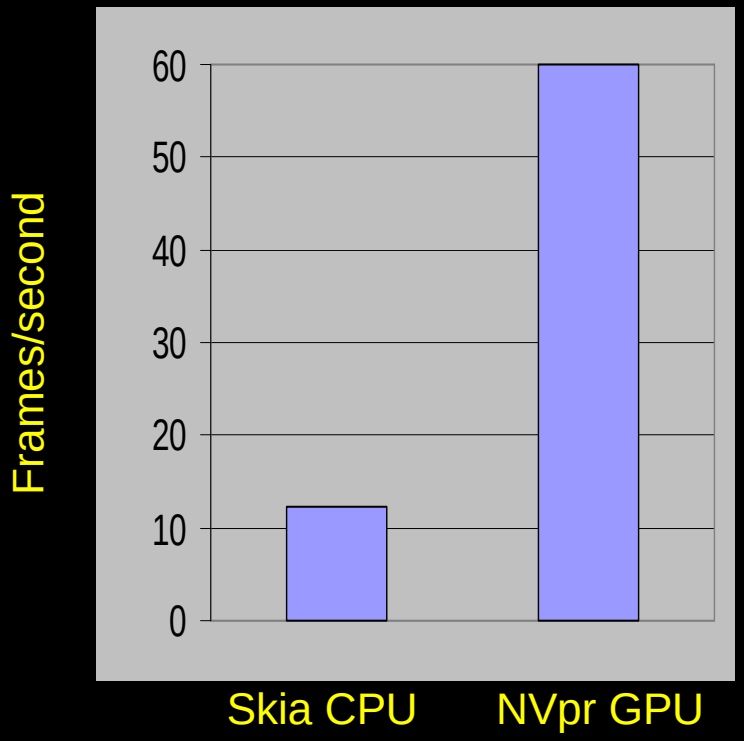
Wow, 56% less energy/frame

at 3.6x the interactivity!

Consequence of GPU-accelerated algorithms for path rendering

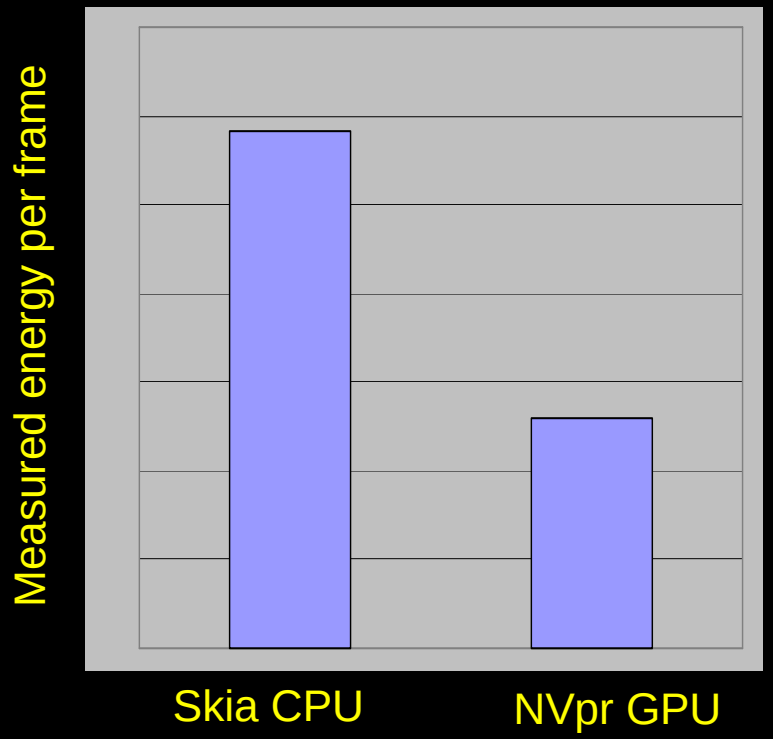
GPU Path Rendering: More Interactive for Less Power

Interactivity



bigger is better

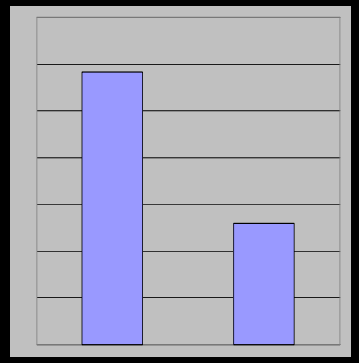
Energy Efficiency



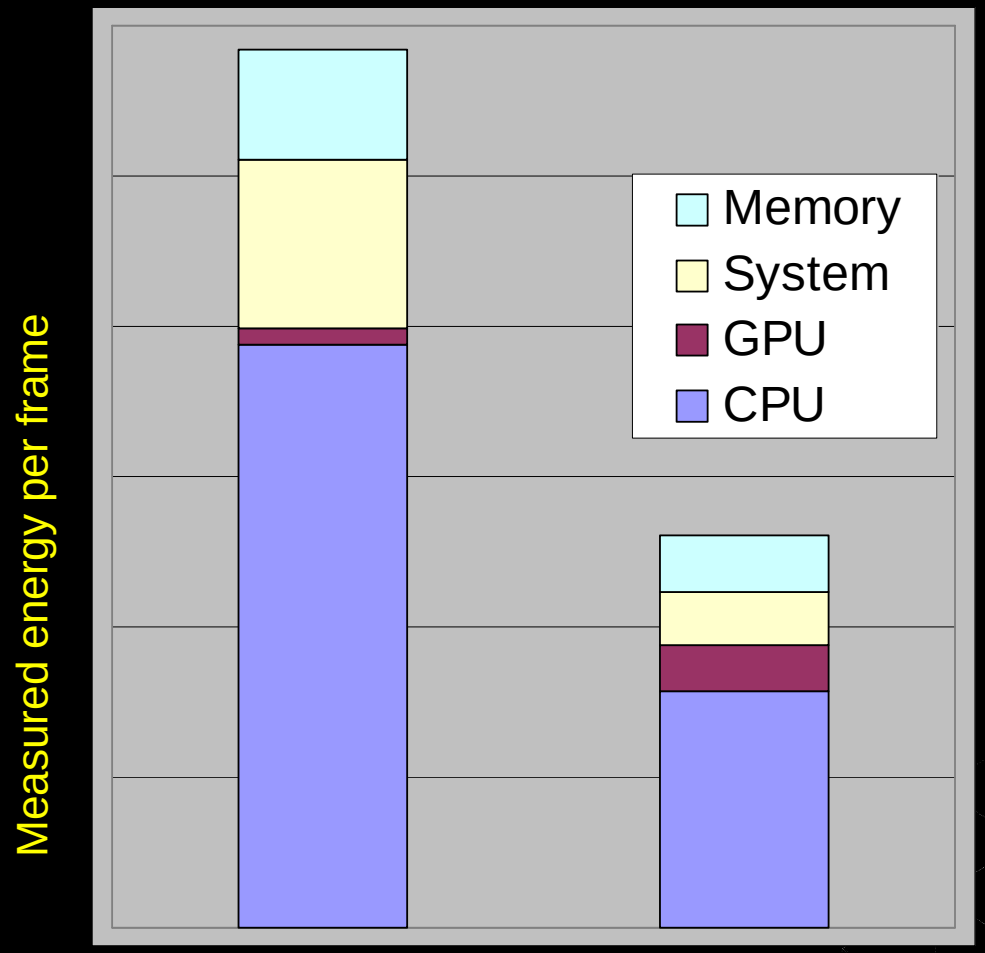
smaller is better

Where does the energy get spent? Breakdown…

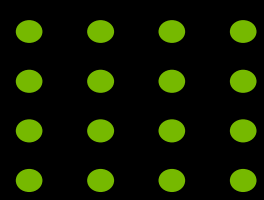
Last slides graph detailed…



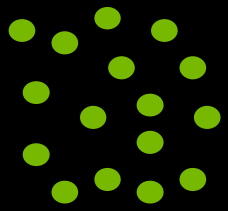
- CPU <u>dominates</u> power consumption
- GPU quite efficient when GPU path rendering



Better Quality on GPU



☹ regular grid
on **CPU** sub-optimal antialiasing

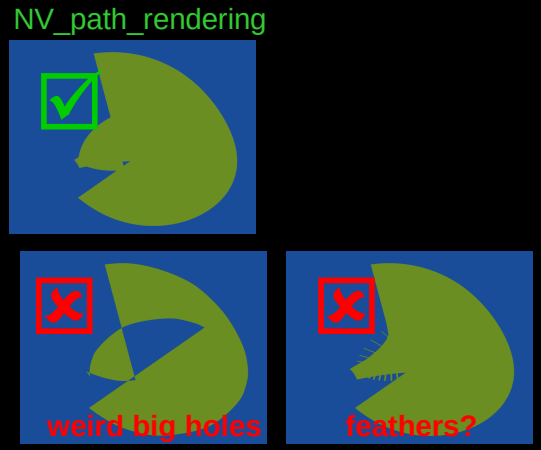


☑ jitter pattern
on **GPU** for better antialiasing

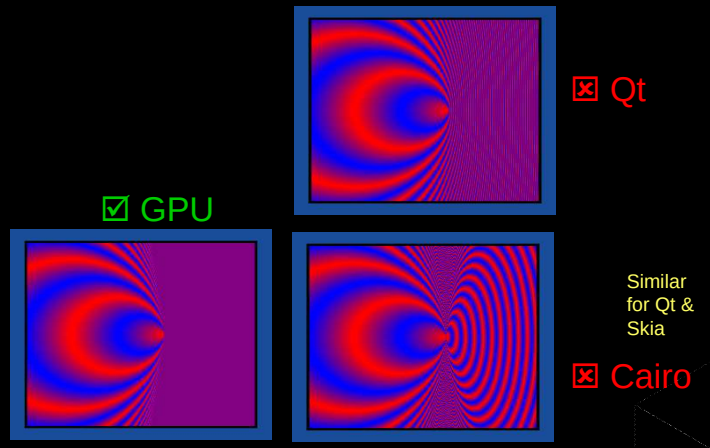
GPU Offers Jittered Sampling for Free

☹ conflation artifacts on **CPU** ☑ conflation free on GPU

Eliminate Conflation Artifacts
Multiple color samples per pixel



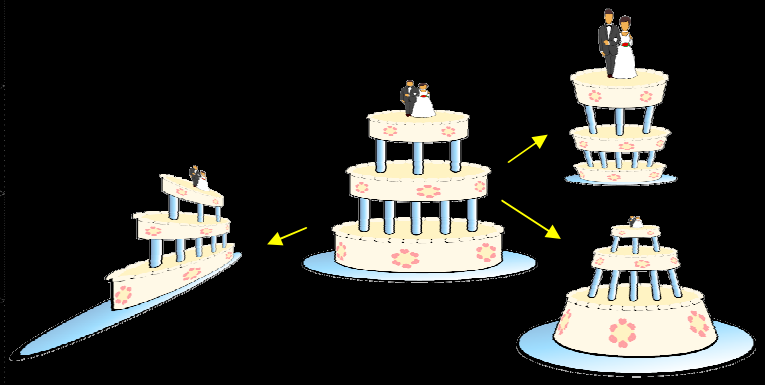
Stroking approximations avoided by GPU



Proper gradient filtering on GPU

New Path Rendering Capabilities too

2D in perspective is free

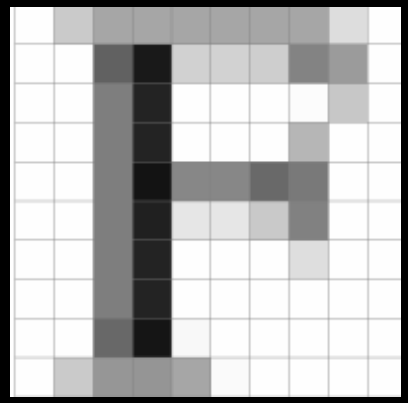


Arbitrary programmable shader on paths— *bump mapping*

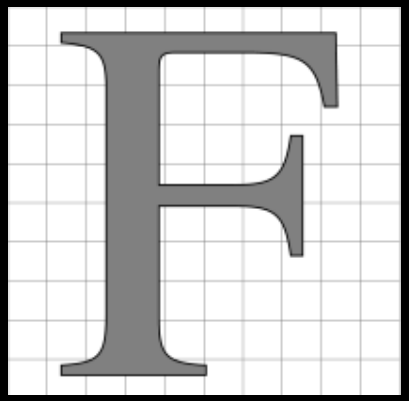
3D and vector graphics mix

Better Text

- Old way
  - CPU renderer glyphs into bitmaps
    - For every glyph, size, rotation, etc.
  - Download glyphs to texture atlas
    - Juggling lots of bitmaps

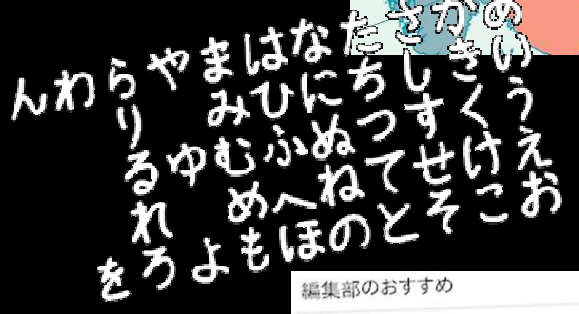


- Better way
  - Simply draw glyphs directly from their outline path
  - Simpler, faster
  - Mathematically correct



First-class, Resolution-independent Font Support

- Fonts are a standard, first-class part of all path rendering systems
  - Foreign to 3D graphics systems such as OpenGL and Direct3D, but natural for path rendering
  - Because letter forms in fonts have outlines defined with paths
    - TrueType, PostScript, and OpenType fonts all use outlines to specify glyphs
- NV_path_rendering makes font support easy
  - Can specify a range of path objects with
    - A specified font
    - Sequence or range of Unicode character points
- No requirement for applications use font API to load glyphs
  - You can also load glyphs “manually” from your own glyph outlines



Bringing Same Path Rendering Technology to All NVIDIA Platforms

- All Fermi, Kepler, and Maxwell GPUS have it!



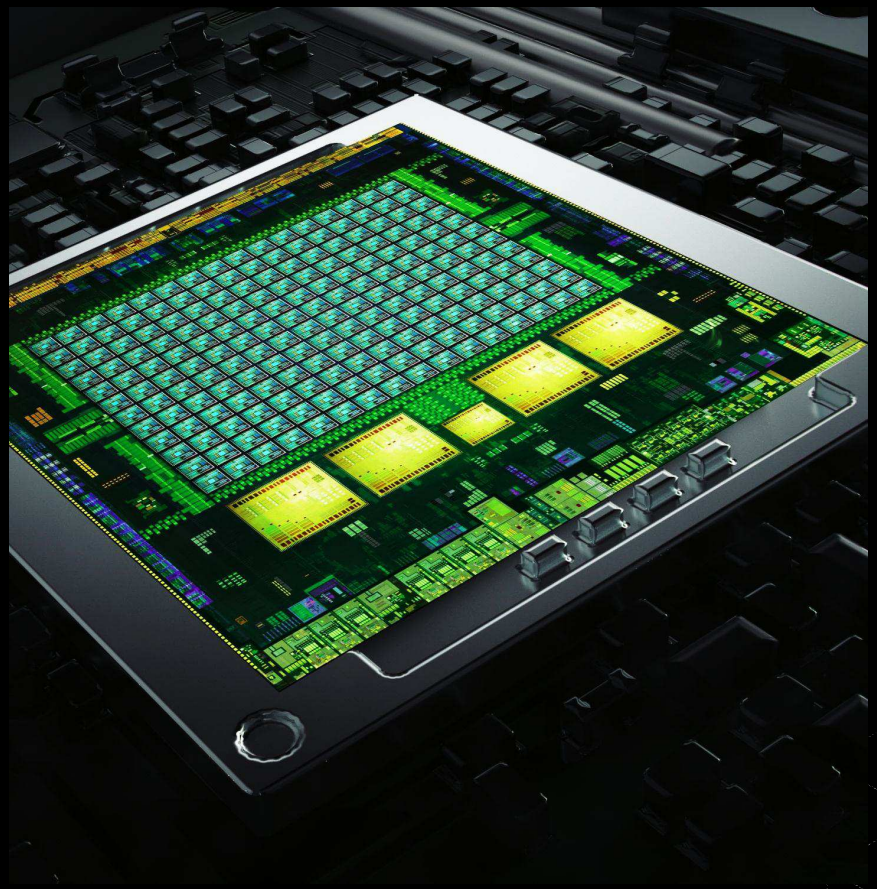


First Mobile Support: K1

Tegra K1

192-core Super Chip

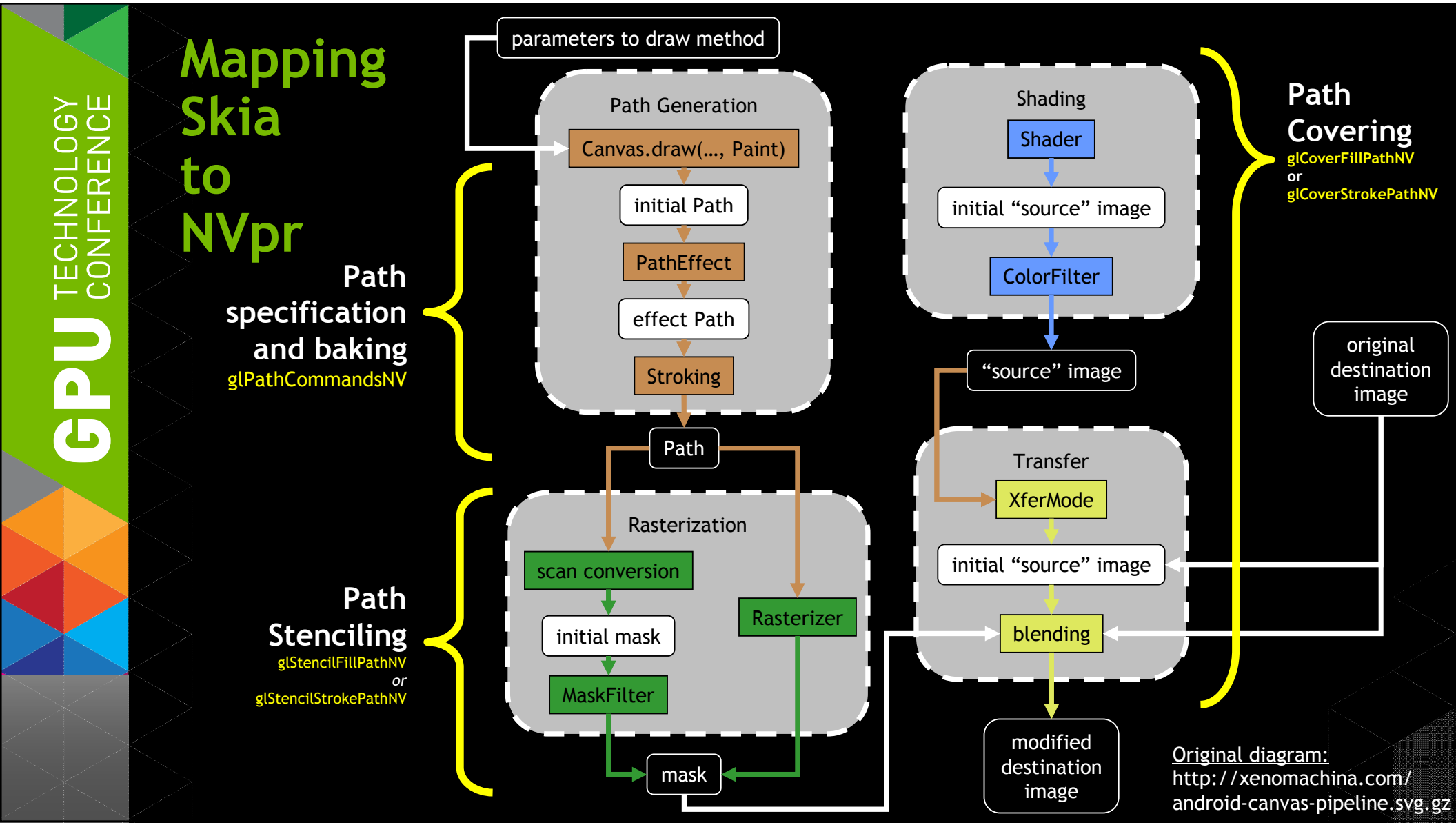
Supporting NV_path_rendering extension today on Android & Linux



Web Standards Integration

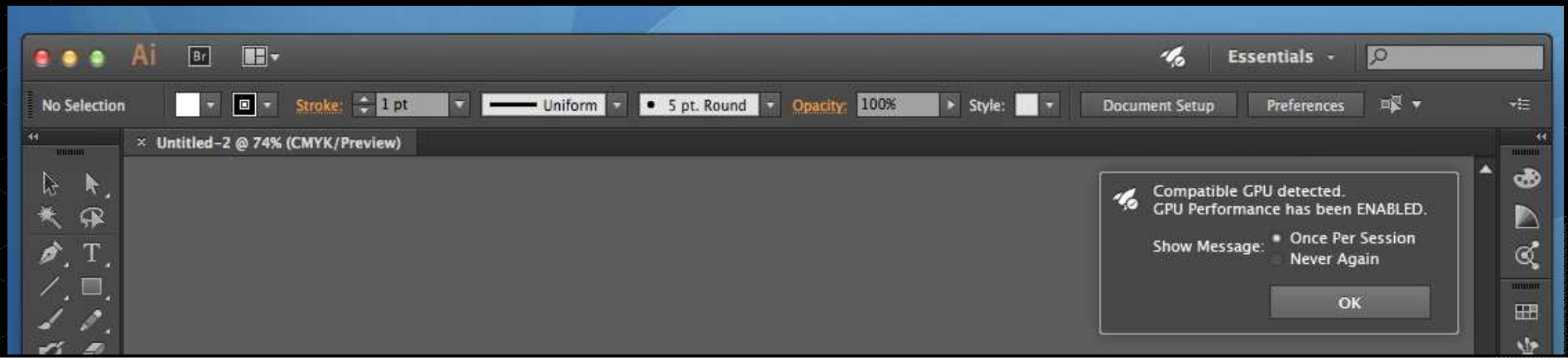
- Google's Skia API for 2D graphics
  - Used by Android graphics
  - And Chrome browser
- Now uses NV_path_rendering when available
  - Same Skia API, just uses NV_path_rendering when available on NVIDIA GPUs
  - Provides hardware-independence
  - Natural step to use by Blink-based browsers

Mapping Skia to NVpr



Content Creation Too

- Working with Adobe to GPU-accelerated Illustrator
  - Work in-progress, in beta now
  - Uses NV_path_rendering technology



GPU-acceleration of Illustrator Example

- Scene complexity
  - ~11,000 paths
  - ~2000 transparent objects
  - ~2000 gradients
- **CPU vs. GPU at rendering same scene**
  - **CPU:** Intel Xeon E3-1240
  - **GPU:** NVIDIA GeForce GTX 780 Ti

Resolution	1680x 1050	3840x 2160
CPU (ms)	178	608
GPU (ms)	38	55
Gain	**~4.7x**	**~11x**

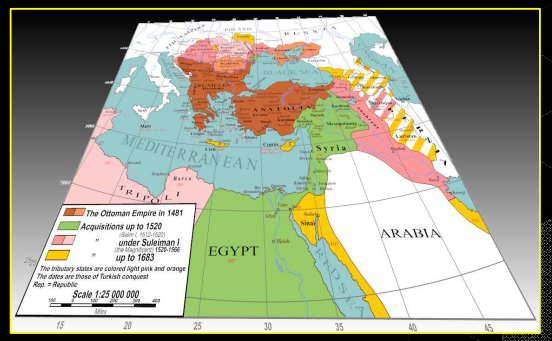
S4867 - The Path to Fast Vector Art Rendering in Adobe Illustrator

- **Presenter:** Vineet Batra
  Senior Computer Scientist, Adobe
- **Day:** Wednesday, March 26, 2014
- **Time:** 16:30 - 16:55
- **Location:** Room 211B
- **Session Level:** Intermediate
- **Session Type:** Talk
- **Tags:** Media & Entertainment Summit; Recommended Press Session – Media & Entertainment

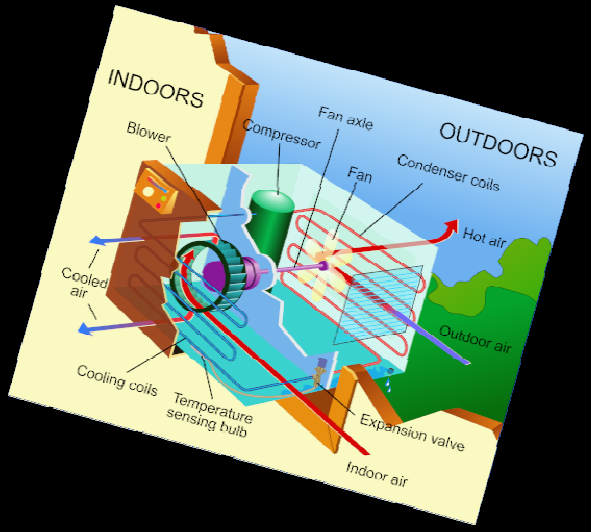
This talk covers a real-world application of NVIDIA's path rendering technology (NVPR) for accelerating 2D vector graphics, based on Adobe PDF model. We shall demonstrate the use of this technology for real-time, interactive rendering in Adobe Illustrator CC. The substantial performance improvement is primarily attributed to NV_path_rendering's ability to render complex cubic Bezier curves independently of device resolution. Further, we shall also discuss the use of NVIDIA's Blend extension to support compositing of transparent artwork in conformance with the Porter-Duff model using 8X-multisampling and per-sample fragment Shaders. Using these technologies, we achieve performance of 30 FPS when rendering and scaling a complex artwork consisting of a hundred thousand cubic Bezier curves with ten thousand blend operations per frame using GTX 780 TI graphics card.

Conclusions

- NVIDIA is GPU-accelerating path rendering
  - High-performance & power-efficient
  - Full feature set, matching established standards
  - First-class solution, done as OpenGL extension
  - Now available on Tegra mobile GPUs
- Working to improve web implementations
  - Skia now has NV_path_rendering support
    - Apps can target a vendor-independent API
  - Demonstrated prototype of web browser
- Also working on content creation too



Questions?



S4810 - NVIDIA Path Rendering: Accelerating Vector Graphics for the Mobile Web

- **Day:** Tuesday, March 25, 2014
- **Time:** 15:30 - 15:55
- **Location:** Room LL21C
- **Session Level:** All
- **Session Type:** Talk
- **Tags:** Mobile Summit; Real-Time Graphics Applications; In-Vehicle Infotainment (IVI) & Safety; Media & Entertainment

Come see how NVIDIA is transforming your web browser into a fully GPU-accelerated experience. NVIDIA Path Rendering provides GPU-acceleration for web graphics standards such as Scalable Vector Graphics (SVG), HTML 5 Canvas, PDF documents, and font rendering. On mobile devices, screen resolutions and densities vary so vector graphics is a natural way to deploy 2D graphics experience such as games, maps, and traditional web pages.

Watch as we demonstrate accelerated SVG viewers and web browsers on Tegra devices. We do this with an OpenGL extension available on all of NVIDIA's latest desktop and mobile GPUs.