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Evolution of Graphics-Development & Innovations

Rohan Somni, Tarush Jain
Department of Information Technology, University of Pune, India
rohan.somni@gmail.com
jaintarush@gmail.com

ABSTRACT

Graphics are now an integral part in many scientific, and entertainment fields. Radical discoveries and developments are still being made. Combinations of techniques and technology from different scientific fields are the primary reasons for these advancements. In this paper we highlight some of the key developments, and technological innovations that have taken place to enable graphical technology to progress to where it is today, covering both software for consoles as well as handheld devices and tablets. We attempt to be succinct, but technically so, in describing a few key aspects of applications and technologies which are now ubiquitous, or which will be in the near future. We describe both staples like DirectX and hardware tessellation as well as relatively new concepts like the Grid and Retina displays for smartphones

Indexing terms/Keywords

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1. INTRODUCTION

Visual representation or communication of information has played a critical role in all applications since the evolution of “graphics”. Using computer graphics-may it be in the form of 3D models, pie charts, graphs, or images is the easiest way for analysis and comprehension of data. There has been an astounding amount of development in this field in the last decade. We highlight and explain some of the key innovations and notable technologies that have brought graphics to where it is today.

2. THE TIMELINE OF DEVELOPMENT

The overall development of graphical technology was the result of incremental development brought on by the advent of key features or products developed over the years. The following compilation attempts to highlight some of those important developments and applications which were new, or used a combination of existing techniques to obtain unique results.

- OpenGL
- DirectX
- Hardware Tessellation
- High Dynamic Range Imaging
- Peripheral Component Interconnect Express
- Grid
- Tegra
- Retina Display (High resolution displays)

2.1 OPENGL

OpenGL (Open **G**raphics **L**ibrary) is a multiplatform, cross language API for rendering computer graphics. The API is typically used to interact with a GPU, to achieve accelerated rendering. OpenGL was released in January 1992 and is widely used in CAD scientific visualization, information visualization, flight simulation, and games. Prior to OpenGL, any company developing a graphical application typically had to rewrite the graphics part of it for each operating system platform and had to be cognizant of the graphics hardware as well. With OpenGL, an application can create the same effects in any operating system using any OpenGL-adhering graphics adapter. OpenGL specifies a set of "commands" or immediately executed functions. Each command directs a drawing action or causes special effects. A list of these commands can be created for repetitive effects. Built-in OpenGL capabilities include hidden surface removal, antialiasing, texture mapping, pixel operations, and atmospheric effects.

The latest version of OpenGL – 4.3 is supported by Nvidia’s GeForce 400 series graphic cards and later. The version was released in July 2013.

2.2 DIRECTX

DirectX is a Microsoft developed collection of APIs for handling multimedia, game programming and video options for Windows platforms. Currently, DirectX is the major prerequisite for running all AAA console games which are graphics intensive. It provides abstraction in the form of interfaces that enable developers to take advantage of hardware features without concerning themselves with the implementation details of that specific hardware.

DirectX, introduced in 1995, provided an intermediate layer that translated generic hardware commands into specific commands for particular pieces of hardware. In particular, DirectX allowed multimedia applications to take advantage of hardware acceleration features supported by graphics accelerators. Currently, DirectX sees the most use in Windows games that require full-color graphics, 3D animation, or complex audio.

The main components of DirectX are:

DirectDraw for 2D raster graphics, Direct3D for manipulating and displaying 3D objects, DirectShow as an architecture for streaming media, DirectInput for data retrieval in background applications and DirectSound /DirectMusic for sound effects and music control.

The latest base version of DirectX- DirectX 11 features tessellation and multithreading support to better utilize multi core processors when playing resource intensive games.

2.3 HARDWARE TESSELLATION

Hardware tessellation is primarily a process in which simple geometry is used repeatedly to approximate the desired graphical shape. 3D objects can be modeled using precise mathematical formulae which results in an almost infinite level of detail, but video hardware cannot process these models efficiently. This is why an alternative method called tessellation is used. For example a torus (donut shape) can be represented by a multitude of small triangles using tessellation.

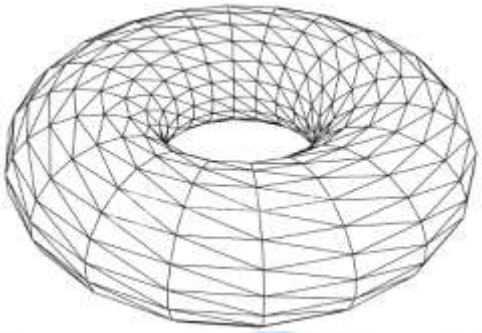


Fig 2.3: A tessellated torus

Current hardware has enough processing power to produce as many triangles as required to model the required object. But to mimic the appearance of curved objects using flat edges requires the use of a huge quantity of triangles, or other any constituent shapes. Here, the processing power of the hardware is directly related to the rate of shapes produced, or frame rate. Faster hardware performs rendering more efficiently, leading to higher frame rates and smoother gameplay, assuming 3D rendering in a game, for example, Temple Run.

Hardware tessellation takes advantage of geometry shaders to perform hardware-assisted tessellation in real time. Essentially, it provides a mechanism to take a mathematically defined 3D model and transform it into a tessellated format that the video card can render efficiently. Traditionally, game developers had performed tessellation at the studio and shipped the tessellated models with the game. Hardware tessellation allows the deferring of this process until the game is running on the destination computer. This results in reduction of the hard disk space the game requires, and also enables the configuration options seen in today's applications and games- the ability to control the game's graphics and level of detail based on your computer's specifications and capabilities.

Fig 2.3.1: Difference in game visuals with the tessellation toggle off and on.

2.4 HDR

High-dynamic-range imaging (HDRI or HDR) is a set of methods used in imaging and photography to capture a greater dynamic range between the lightest and darkest areas of an image than current standard digital imaging methods or photographic methods. HDR images can represent more accurately the range of intensity levels found in real scenes, from direct sunlight to faint starlight, and is often captured by way of a plurality of differently exposed pictures of the same subject matter. HDR methods provide higher dynamic range from the imaging process. Non-HDR cameras take pictures at one exposure level with a limited contrast range. This results in the loss of detail in bright or dark areas of a picture, depending on whether the camera had a low or high exposure setting. HDR compensates for this loss of detail by taking multiple pictures at different exposure levels and intelligently stitching them together to produce a picture that is representative in both dark and bright areas. HDR is also used to refer to display of images derived from HDR imaging in a way that exaggerates contrast for artistic effect. The two main sources of HDR images are computer renderings and merging of multiple low-dynamic-range (LDR) or standard-dynamic-range (SDR) photographs. HDR images can also be acquired using special image sensors, like oversampled binary image sensor. Tone mapping methods, which reduce

overall contrast to facilitate display of HDR images on devices with lower dynamic range, can be applied to produce images with preserved or exaggerated local contrast for artistic effect. An HDR (High Dynamic Range) image stores pixel values that span the whole tonal range of real-world scenes. Therefore, an HDR image is encoded in a format that allows the largest range of values, e.g. floating-point values stored with 32 bits per color channel. Another characteristic of an HDR image is that it stores linear values. This means that the value of a pixel from an HDR image is proportional to the amount of light measured by the camera. In this sense, HDR images are scene-referred, representing the original light values captured for the scene. The two most popular formats for storing HDR images, OpenEXR and Radiance, offer a mechanism for characterizing the image.

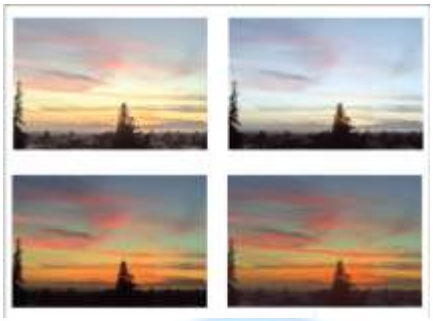


Fig 2.4: Color contrast using HDR

2.5 PCI EXPRESS

PCI Express (Peripheral Component Interconnect Express), officially abbreviated as PCIe, is a high-speed serial computer expansion bus standard designed to replace the older PCI, PCI-X, and AGP bus standards. PCIe has numerous improvements over the aforementioned bus standards, including higher maximum system bus throughput, lower I/O pin count and smaller physical footprint, better performance-scaling for bus devices, a more detailed error detection and reporting mechanism (Advanced Error Reporting (AER)), and native hot-plug functionality. More recent revisions of the PCIe standard support hardware I/O virtualization. The PCIe electrical interface is also used in a variety of other standards, most notably ExpressCard, a laptop expansion card interface. Format specifications are maintained and developed by the PCI-SIG (PCI Special Interest Group), a group of more than 900 companies that also maintain the conventional PCI specifications. PCIe 3.0 is the latest standard for expansion cards that is in production and available on mainstream personal computers.

PCI Express operates in consumer, server, and industrial applications, as a motherboard-level interconnect (to link motherboard-mounted peripherals), a passive backplane interconnect and as an expansion card interface for add-in boards. In virtually all modern (as of 2012) PCs, from consumer laptops and desktops to enterprise data servers, the PCIe bus serves as the primary motherboard-level interconnect, connecting the host system-processor with both integrated-peripherals (surface-mounted ICs) and add-on peripherals (expansion cards.) In most of these systems, the PCIe bus co-exists with one or more legacy PCI buses, for backward compatibility with the large body of legacy PCI peripherals.

2.6 NVIDIA GRID™

NVIDIA GRID™ technology offers the ability to offload graphics processing from the CPU to the GPU in virtualized environments, allowing the data center manager to deliver true PC graphics-rich experiences to more users for the first time. GRID boards feature the NVIDIA Kepler architecture that, for the first time, allows hardware virtualization of the GPU. This means multiple users can share a single GPU, improving user density while providing true PC performance and compatibility. NVIDIA's patented low-latency remote display technology greatly improves the user experience by reducing the lag that users feel when interacting with their virtual machine. With this technology, the virtual desktop screen is pushed directly to the remoting protocol. The Kepler GPU includes a high-performance H.264 encoding engine capable of encoding simultaneous streams with superior quality. This provides a giant leap forward in cloud server efficiency by offloading the CPU from encoding functions and allowing the encode function to scale with the number of GPUs in a server. NVIDIA GRID boards have an optimized multi-GPU design that helps to maximize user density. GRID K1 boards, which include four Kepler-based GPUs and 16GB of memory, are designed to host the maximum number of concurrent users. GRID K2 boards, which include two higher end Kepler GPUs and 8GB of memory, deliver maximum density for users of graphics-intensive applications. GRID GPUs are designed to provide data center-class power efficiency, including the revolutionary new streaming multiprocessor, called "SMX". The result is an innovative, proven solution that delivers revolutionary performance per-watt for the enterprise data center.

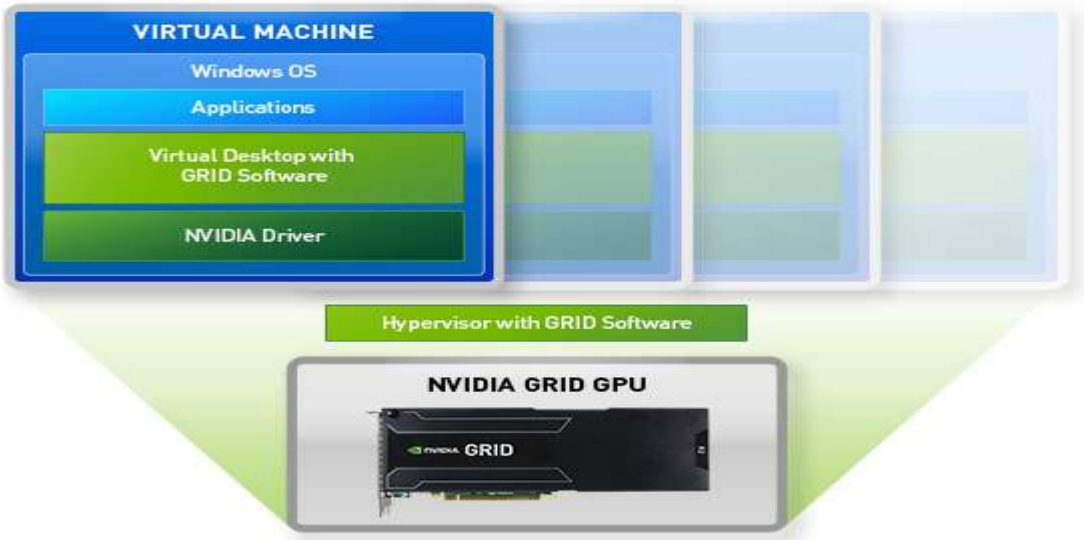
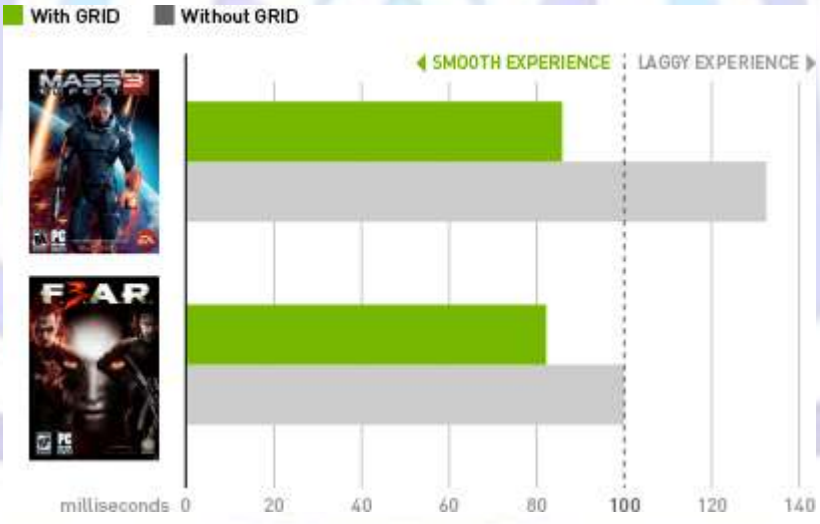


Fig 2.6: Architecture of the Grid GPU

The NVIDIA GRID™ technology provides Gaming-as-a-Service(GaaS). The NVIDIA GRID portfolio of technologies leverages the power of the GPU and the world's best graphics applications to deliver GPU-accelerated applications and games over the network to any user. NVIDIA GRID leverages some of this same technology to render and stream games from the cloud. GRID enables up to 48 HD-quality game streams from a single server using GPU virtualization technology. NVIDIA GRID™ technology reduces latency by 30ms, enhancing the cloud gaming experience.



MOBILE DEVICE AND TABLET TECHNOLOGY:

2.7 TEGRA

Tegra is a system on a chip (SoC) series developed by Nvidia for mobile devices such as smartphones, personal digital assistants, and mobile Internet devices. The Tegra integrates an ARM architecture central processing unit (CPU), graphics processing unit (GPU), northbridge, southbridge, and memory controller onto one package. The series emphasizes low power consumption and high performance for playing audio and video.

Tegra processors enhance multimedia, gaming, multitasking, battery life, while also providing improved graphics. Tegra's graphics cores are architected for ultra-fast, ultra-smooth performance, giving visually rich experiences. Tegra powered devices provide accelerated web with superior graphics. Tegra processors feature powerful computational ability

for mobile gaming graphics providing hyper-realistic gameplay. The Tegra 4 features a quad core CPU with an additional 5th core for background OS tasks and power saving functionality, as well as 72 GPU cores.

This series and its formidable processing power is the primary reason why near console quality game graphics can and are being brought to handheld mobile devices and tablets. High end smartphones from HTC, Motorola, and others as well as tablets like the Google Nexus feature Tegra processors.

2.8 RETINA DISPLAY

Retina Display technology is a brand name trademarked by Apple to represent their extremely high density liquid crystal displays used in the iPhone 4 onwards and iPad 3 onwards. The underlying concept of the Retina Display is the sheer density of pixels present on the screen- it's so high the human high cannot distinguish individual pixels.

The fourth and fifth generation phones have a density of 326 ppi (pixels per inch), and using the assumption of near 20/20 vision and a viewing distance of approximately 10" from the screen, all images appear to be crystal clear and very high resolution. In reality, just increasing pixel density may result in the blurring of the image. A pixel is made up of 3 subpixels: red, blue, and green with signals telling respective pixels to light up, forming colors. Retina Display technology crams 4x pixels in the same space, which may have potentially led to cross overs and distortion. This was solved using a technology called Super High Aperture(SHA) which adds a resin layer on top of the transistors, and adding vertical space between pixels and the signal effectively creating another plane. This reduces unwanted capacitor coupling, and does not result in affected image quality.

This was the first of its kind in smartphone displays and provided a new level of visual attractiveness. Other companies have now also come out with high resolution displays, namely Samsung and HTC.

Fig 2.8: Retina Display pixel (4x)

Fig 2.8.1: Standard pixel

3. APPLICATIONS

The effect of the development above mentioned technologies on graphics can best be seen by comparing the quality and depth of console and mobile game graphic throughout the years. The "smartphone" market is relatively new, but drastic PC graphics improvements can be seen through the course of two decades. Consider the example of a classic FPS (First Person Shooter):

Fig 3: DOOM (1993)

Fig 3.1: DOOM 3 (2004)

The improvement from the pixelated graphics of the original to the decent 3D rendering and shadow effects to the 2nd sequel a decade later is clearly seen, but It pales in comparison to the improvements in the last decade shown in the image below-featuring breathtaking realistic graphics with dynamic lighting, ambient shadows and atmospheric effects, intricate environment design and ragdoll physics.

Fig 3.3: Modern Warfare (2012)

Fig 3.4: Skyrim (2012)

The explosion of growth in the smartphone market is and frequency of quality upgrades is yet another example of the exponential rate of development of graphics and technology as is shown by the following images, which at first glance may actually be mistaken for console games.

Fig 3.5: Infinity Blade 2 (2012)

Fig 3.6: N.O.V.A (2013)

4. THE FUTURE

Development has accelerated in the last few years, but is still nowhere near its pinnacle. With advancements in various fields like cloud computing, information visualization, sensing and transmission, 3D information is the new future. It has been incorporated into numerous fields of life, from security to entertainment. Integrating depth perception into such applications can provide an even richer media interface. Interactive 3D multimedia systems may replace the traditional hardware. Improvements in 3D sensing and image processing will also benefit medical fields, increasing the clarity of

diagnoses and precision of operations. High quality in-built facial recognition and fingerprint sensing in smartphones may also be a development in the near future.

Ultimately, we feel the seamless blending of different disciplines and graphical applications will lead to further advancements for science and technology.

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AUTHORS’ BIOGRAPHY

Rohan Somni and Tarush Jain are both undergrad students in their final year. Both are currently pursuing their Bachelor’s Degree in Information Technology at MIT College of Engineering, under the University of Pune, India. They have published two papers in international journals together. Their major fields of interest are Data Analytics and Operating Systems respectively, with both sharing a common interest in Computer Graphics and its applications.

Rohan Somni

Tarush Jain