

What was the OpenGL Architecture Review Board? What is its new name? List all of its current members (25 points).

The development of OpenGL was initiated by Silicon Graphics Inc. in 1991 to provide an open source version of their proprietary IRIS GL ('Integrated Raster Imaging System Graphics Library') with the aim of promoting their influence in the 3D graphics market (which they designed and sold a series of workstations for). SGI aimed to gain influence and profit by displacing another older open source API – PHIGS (Programmer's Hierarchical Interactive Graphics System) which was being promoted by competitors such as HP, IBM and Sun.

The OpenGL Architecture Review Board was established in 1992 as an 'independent consortium' to be responsible for directing the development of the OpenGL project (OpenGL) (SGI). In 2006 it became a part of the Khronos Group (a 'non-profit organisation that creates and maintains a multitude of graphics standards'). Under the umbrella of the Khronos Group it is called the OpenGL ARB Working Group and it continues to maintain the OpenGL standard. The Kronos Group is also responsible for the development of Vulkan, the successor API to OpenGL (Khronos, n.d.).

The 134 members of the Khronos Group are divided into three categories:

Academic (contributes without voting rights)

Ajou University
China Academy of Telecommunication Research of MIIT
Columbia University
ETRI
Imperial College London
Institute for Information Industry
ITRI
Kyungpook National University
MIT Lincoln Laboratory
National Taiwan University
National Tsing Hua University
Nihon University
Oregon State University
Politecnico di Milano
Seoul National University
Tampere University of Technology
Technische Universität Wien
Università di Bologna
University of Bristol
University of Toronto
University of Windsor

Contributor (contribute and have voting rights)

3D Incorporated
AdasWorks Kft.
Adobe
Advanced Driver Information Technology
Altera Corporation
Amazon Corporate LLC
Axell Corporation

Axis Communications AB
Basemark Oy
Beijing Pinecone Electronics Co., Ltd.
Blizzard Entertainment Inc
Broadcom Corporation
Cadence Design Systems, Inc.
Canonical Group Limited
CEVA
Codeplay Software Limited
Collabora
Continental Automotive GmbH
Coordinate International Limited
Core Avionics & Industrial
Dassault Systemes
Digital Media Professionals
Futuremark Oy
Gaijin Entertainment LLP
Harman
Hitachi Industry & Control Solutions, Ltd.
IBM Corporation
Itseez3D, Inc
KDAB Ltd.
Kishonti Kft.
LG Electronics
Linaro Limited
Los Alamos National Laboratory
Marvell
Matrox Graphics, Inc
Maximum Play, Inc.
MAXON Computer GmbH
MediaTek Inc
Mentor Graphics UK Ltd.
Microsoft Corporation
Mitsubishi Electric Corporation
Mobica Ltd
Movidius Ltd
Mozilla Corporation
NEC Solution Innovators, Ltd.
Nintendo Co., Ltd.
NXP
Oculus VR, Inc.
ON Semiconductor
Panasonic
Pixar
Presagis Canada Inc.
Red Hat, Inc.
Renesas Electronics
Rockwell Collins, Inc.
Silicon Studio Corp
Socionext, Inc.
Spreadtrum Communications
Symbio
Synopsys, Inc.
Takumi Corporation
Texas Instruments

The Brenwill Workshop Ltd.
The Qt Company
Think Silicon
Tobii Technology AB
Toshiba
Unity Technologies
Valve Corporation
VIA Alliance Semiconductor Co., Ltd.
Visteon Corporation
VMware, Inc
Wargaming (Austin), Inc.
Xilinx, Inc.
zSpace, Inc.

Individual Contributor (contribute and have voting rights)

AJ Guillon
Arnaud Masserann
Ben Gaster
Dan Baker
Erik Noreke
Hugh Perkins
Jeff Vigil
John Kessenich
Jon Leech
Kari Pulli
Koji Suginuma, Ph.D.
Mark Callow
Mikel Salazar
Patrick Cozzi
Perey Research & Consulting
Peter McGuinness
Rob Manson
Tim Lewis
Tomasz Bednarz
Tony Parisi
Uli Klumpp
Will Eastcott

Promoter (act as the 'board of directors' of the group, contribute and decide the final specification)

AMD
Apple, Inc.
ARM Limited
Epic Games, Inc.
Google, Inc.
Huawei Technologies Co. Ltd.
Imagination Technologies
Intel
NOKIA OYJ
NVIDIA Corporation
QUALCOMM
Samsung Electronics
Sony Interactive Entertainment America
Verisilicon, Inc.
(Kronos)

Explain what DirectX is, its features and differences when compared to OpenGL (30 points).

DirectX is a collection of gaming related APIs, developed and owned by Microsoft. After the debut of Windows 95 Microsoft had decided it needed to take action to make Windows more attractive to the gaming market, so they purchased a company (RenderMorphics) which had been developing their own 3D graphics API, which they renamed DirectX 1.0. Although it was not popular since it was initially unstable, the platform matured and soon Windows became the most popular PC gaming platform. Because DirectX games could not be played on non-Windows Operating Systems, it's popularity amongst game developers was a significant factor in Microsoft achieving a near-monopoly in the consumer PC market. DirectX is also used as the main graphics API for the Xbox consoles (Roy, 2002).

DirectX replaced the older Windows graphics APIs WinG and GDI before that. (Eisler, 2006). The principle difference of DirectX compared to OpenGL is that it specifically is for building video games on Windows, whereas OpenGL is cross-platform, cross-language graphics library (Anthony, 2012). DirectX is developed in C++, but supports the COM system allowing other Windows programming languages to access the API. OpenGL is developed in C, but OpenGL libraries have been developed for a huge range of other languages and platforms. DirectX originally comprised four component libraries: Direct3D, DirectDraw, DirectMusic and DirectPlay but now has 12 different libraries to support many areas of game development, for example input processing and audio.

Current DirectX Libraries: “

- DirectDraw: Used for drawing 2D graphics. (Deprecated, but still used).
- Direct3D (D3D): for 3D graphics, the main competitor to OpenGL.
- DirectPlay: network communication.
- DirectInput: Used for processing input (from mouse, keyboard, etc).
- DirectX Media: DirectShow, Direct3D retained mode, multimedia playback, streaming, etc).
- DirectMusic: playback of soundtracks (created in DirectMusic Producer).
- DirectSound: Playback and recording of waveform sound.
- DirectSound3D: (DS3D) playback of 3D sounds.
- DirectX Media Objects: Streaming objects such as encoders, decoders and effects.
- DirectSetup: Installation of DirectX components. “ (CodingUnit)

While you can largely achieve the same result as far as 3D graphics are concerned with either library, there is a big difference in the design approach of the libraries. OpenGL was created to provide a graphics API for SGI's Workstations (whereas DirectX is aimed at game development on Windows). OpenGL provides an *extension mechanism* which allows different hardware producers to add specialised features. (GraphicsWikia) DirectX gives developers greater control of hardware, because it doesn't take responsibility for managing resources like OpenGL. Microsoft/DirectX was often first to implement cutting edge features because it worked closely with GPU manufactures, however at present OpenGL is generally considered just as capable as DirectX (Everything You Need to Know About DirectX in 2016, 2016). There are other libraries such as the GLUT windowing library which provide additional capabilities on top of OpenGL.

Enlist the main features of the 2.x, 3.x, 4.0 & 4.5 versions of OpenGL (20 points).

OpenGL 2.x added:

- Vertex and Fragment Shaders
- Multiple render targets
- Pixel buffer objects
- sRGB textures

OpenGL 3.x added:

- New context creation mechanism
- Vertex Array Objects, Framebuffer Objects
- Conditional Rendering
- Texture Compression
- Array Textures
- Uniform Buffer Objects
- Buffer Textures, Rectangle Textures
- Geometry Shaders
- Dual source blending
- Occlusion Queries
- Shading language versions 1.4 – 3.3

Open GL 4.0 added:

- Indirect drawing
- Tessellation
- New buffer texture formats
- Transform feedback objects
- Shading language 4.0

Open GL 4.5 added:

- Direct State Access
- Flush Control
- Robustness
- DirectX porting tools

(OpenGL, 2015) (OpenGL, 2014) (Howard)

Research the main graphics processors manufacturers. Include a table indicating the features of three recent products for each manufacturer, specifying which OpenGL version they support (25 points).

The three main graphics processor manufactures are AMD, Intel and Nvidia.



AMD is an international semi-conductor manufacturer based in the US that designs chips for a wide range of devices, including GPUs and is the only significant rival of Intel in the x86 market. It's 2006 acquisition of GPU maker ATI significantly boosted it's market share in GPUs.

Name	Core Clock MHz	Memory Bandwith GB/s	OpenGL Support	Additional Features
Radeon RX 480	1120	256	4.5 + Vulkan	Polaris Architecture AMD LiquidVR™* 5.8 TFLOPS peak performance AMD FREESYNC™*
Radeon Pro Duo	1000	1024	4.5	AMD LiquidVR™ High Bandwidth Memory Dual Core AMD FREESYNC™
Radeon R9 Fury X	1050	512	4.5	AMD LiquidVR™ High Bandwidth Memory

*AMD LiquidVR is the brand name for a set of features optimizing performance for Virtual Reality graphics

* AMD FreeSync is the brand name for an adaptive synchronization technology for LCD displays that support a dynamic refresh rate aimed at reducing screen tearing.

(AMD Product Information, 2016) (Wikipedia, 2016)



Intel is an American multinational technology company, and was responsible for producing the first ever commercial microprocessor. Intel does not produce standalone GPUs, but integrates graphics chipsets into their CPUs.

Name	Core Clock MHz	Memory Bandwidth GB/s	OpenGL Support	Additional Features
HD Graphics 405	400-740	25.6	4.3	Intel Gen8 Architecture Intel® Clear Video Technology*
Iris Pro Graphics 6200	300-1150	25.6	4.4	Broadwell Architecture Intel® Clear Video Technology
Iris Pro Graphics 5200	200-1300	25.6	4.3	Broadwell Architecture Intel® Clear Video Technology

* Intel Clear Video Technology is a collection of video playback and enhancement features
(Wikipedia, 2016) (Intel, 2016)



Nvidia, also a US company, invented the GPU in 1999 and since then have been specialists in their design and manufacture. They also developed a parallel processing architecture, CUDA (Compute Unified Device Architecture), that enables GPUs (which already have powerful parallel capabilities for graphics matrix calculations) to take on the work which formally required high powered CPUs.

Name	Core Clock MHz	Memory Bandwith GB/s	OpenGL Support	Additional Features
NVIDIA TITAN X	1417	480	4.5	Pascal™ architecture SLI® TECHNOLOGY* CUDA* G-SYNC*
GeForce GTX 1080	1607	320	4.5 + Vulkan	Pascal™ architecture SLI® TECHNOLOGY* CUDA G-SYNC
GeForce GTX Titan X	1000	336	4.5 + Vulkan	Maxwell architecture CUDA G-SYNC

*SLI Technology is a method of increasing available transfer bandwidth

*CUDA is a parallel processing technology

*G-SYNC increases display 'smoothness' by 'by synchronizing display refresh rates to the GPU'

(Wikipedia, 2016) (Nvidia, 2016)

Works Cited

- AMD Product Information. (2016, August 15). Retrieved from <http://www.amd.com/en-us/products/graphics/radeon-rx-series/radeon-rx-480>
- Anthony, S. (2012, August 2). *Valve: OpenGL is faster than DirectX — even on Windows*. Retrieved from ExtremeTech: <http://www.extremetech.com/gaming/133824-valve-opengl-is-faster-than-directx-even-on-windows>
- CodingUnit. (n.d.). *The History Of DirectX*. Retrieved August 15, 2016, from CodingUnit: <https://www.codingunit.com/the-history-of-directx>
- Eisler, C. (2006, Feb 20). *DirectX Then and Now (Part 1)*. Retrieved from Craig Eisler: <http://craig.theeislers.com/2006/02/20/directx-then-and-now-part-1/>
- Everything You Need to Know About DirectX in 2016*. (2016, May 11). Retrieved from makeuseof: <http://www.makeuseof.com/tag/everything-need-know-directx-2016/>
- GraphicsWikia. (n.d.). *Direct3D vs OpenGL*. Retrieved August 15, 2016, from GraphicsWikia: http://graphics.wikia.com/wiki/Direct3D_vs._OpenGL
- Howard, S. (n.d.). *OpenGL version implementation history*. Retrieved August 15, 2016, from <http://stevenhoward.org/opengl/versions.html>
- Khronos. (n.d.). *Homepage*. Retrieved from Khronos.org: <https://www.khronos.org>
- Kronos. (n.d.). *Kronos Members List*. Retrieved August 15, 2016, from Khronos.org: <https://www.khronos.org/members/contributors>
- Nvidia. (2016, August 15). Retrieved from NVidia Corporate: <http://www.nvidia.com/object/citizenship-report-company-overview.html>
- OpenGL. (2014, August 11). *OpenGL Documentaion*. Retrieved from https://www.opengl.org/documentation/current_version/
- OpenGL. (2015, May 6). *History of OpenGL*. Retrieved from OpenGL : https://www.opengl.org/wiki/History_of_OpenGL#OpenGL_1.0_.281992.29
- OpenGL. (n.d.). *About the ARB*. Retrieved from OpenGL.org: <https://www.opengl.org/archives/about/arb/>
- Roy, P. (2002, February 24). *Direct3D vs. OpenGL*. Retrieved from http://www.gamedev.net/page/resources/_/technical/graphics-programming-and-theory/direct3d-vs-opengl-which-api-to-use-when-whe-r1775
- SGI. (n.d.). *SGI OpenGL Overview*. Retrieved August 15, 2016, from SGI: <http://www.sgi.com/tech/opengl/?/overview.html>
- Wikipedia. (2016, August 1-). *Comparison of OpenGL and Direct3D*. Retrieved from Wikipedia: https://en.wikipedia.org/wiki/Comparison_of_OpenGL_and_Direct3D#Comparison

Wikipedia. (2016, August 12). *Khronos Group*. Retrieved from https://en.wikipedia.org/wiki/Khronos_Group#Members

Wikipedia. (2016, August 12). *List of AMD GPUs*. Retrieved from https://en.wikipedia.org/wiki/List_of_AMD_graphics_processing_units#Radeon_RX_400_Series

Wikipedia. (2016, August 12). *List of Intel GPUs*. Retrieved from https://en.wikipedia.org/wiki/List_of_Intel_graphics_processing_units#Ninth_generation

Wikipedia. (2016, August 12). *List of Nvidia GPUs*. Retrieved from https://en.wikipedia.org/wiki/List_of_Nvidia_graphics_processing_units#GeForce_10_Series