

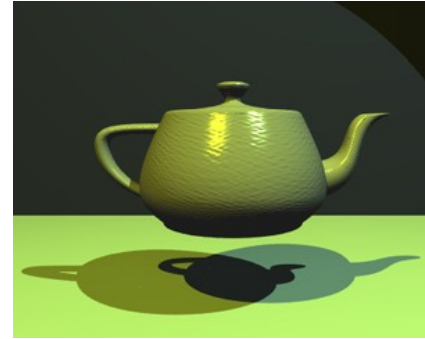
Computer graphics

- A brief look

wis0027@vsb.cz

What exactly is CG?

- Images etc. created with computers



What exactly is CG?

- Images etc. created with computers
- UI, 3D rendering, Animation, Data visualization,...

What exactly is CG?

- Images etc. created with computers
- UI, 3D rendering, Animation, Data visualization,...
- Term created in 1960

What exactly is CG?

- Images etc. created with computers
- UI, 3D rendering, Animation, Data visualization,...
- Term created in 1960
- Becomes commercialized in the 80s

What exactly is CG?

- Images etc. created with computers
- UI, 3D rendering, Animation, Data visualization,...
- Term created in 1960
- Becomes commercialized in the 80s
- 3D Quality increases in the 90s and 2000s



By https://www.gog.com/game/unreal_tournament_goty (Original copyright holder: Epic Games),
Fair use, <https://en.wikipedia.org/w/index.php?curid=51911965>

What exactly is CG?

- Images etc. created with computers
- UI, 3D rendering, Animation, Data visualization,...
- Term created in 1960
- Becomes commercialized in the 80s
- 3D Quality increases in the 90s and 2000s
- Specialized hardware

What exactly is CG?

- Images etc. created with computers
- UI, 3D rendering, Animation, Data visualization,...
- Term created in 1960
- Becomes commercialized in the 80s
- 3D Quality increases in the 90s and 2000s
- Specialized hardware
- SIGGRAPH

Modern 3D Graphics

- **Pixels**

Displaying stuff

- A matrix of colors



By Kprateek88 - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=4635158>

Displaying stuff

- A matrix of colors
- R, G and B

Displaying stuff

- A matrix of colors
- R, G and B
- Width x Height x Color depth

Displaying stuff

- A matrix of colors
- R, G and B
- Width x Height x Color depth
- x Frame rate

Displaying stuff

- A matrix of colors
- R, G and B
- Width x Height x Color depth
- x Frame rate
- $1920 \times 1080 @ 60 \text{ (24b)} = \sim 3 \text{ Gbps}$

Modern 3D Graphics

- **Pixels**
- **Vertices and Triangles (/ Polygons)**

Representing a thing

- **Vertices**

Representing a thing

- **Vertices**
 - X, Y and Z coordinates

Representing a thing

- **Vertices**
 - X, Y and Z coordinates
 - Point cloud

Representing a thing

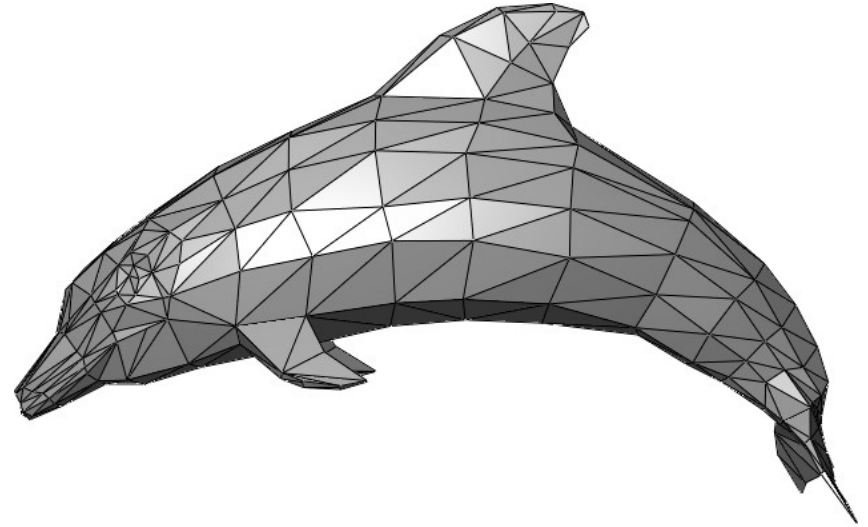
- **Vertices**
 - X, Y and Z coordinates
 - Point cloud
- **Triangles**

Representing a thing

- **Vertices**
 - X, Y and Z coordinates
 - Point cloud
- **Triangles**
 - Three indices

Representing a thing

- **Vertices**
 - X, Y and Z coordinates
 - Point cloud
- **Triangles**
 - Three indices
 - Surface / Shell



Representing a thing

- **Vertices**
 - X, Y and Z coordinates
 - Point cloud
- **Triangles**
 - Three indices
 - Surface / Shell
- **Polygons**

Representing a thing

- **Vertices**
 - X, Y and Z coordinates
 - Point cloud
- **Triangles**
 - Three indices
 - Surface / Shell
- **Polygons**
 - Usually end up triangulated

Modern 3D Graphics

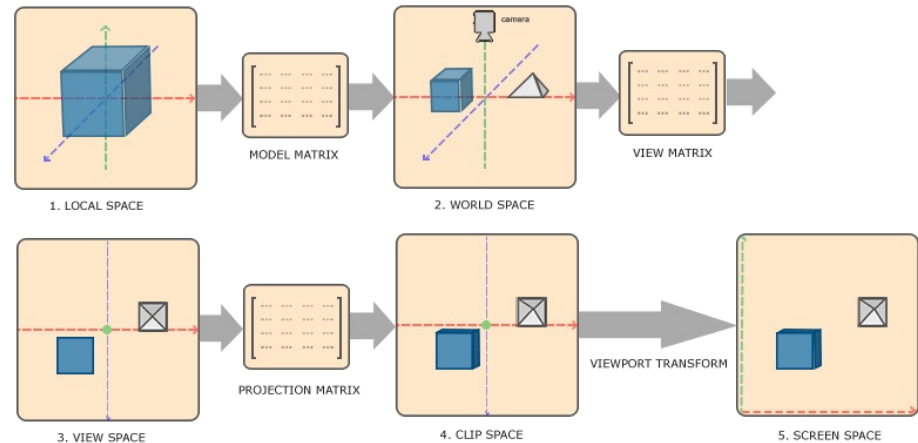
- **Pixels**
- **Vertices and Triangles (/ Polygons)**
- **Translations / Projections**

Putting it all (in the scene) together

- Transformation matrices

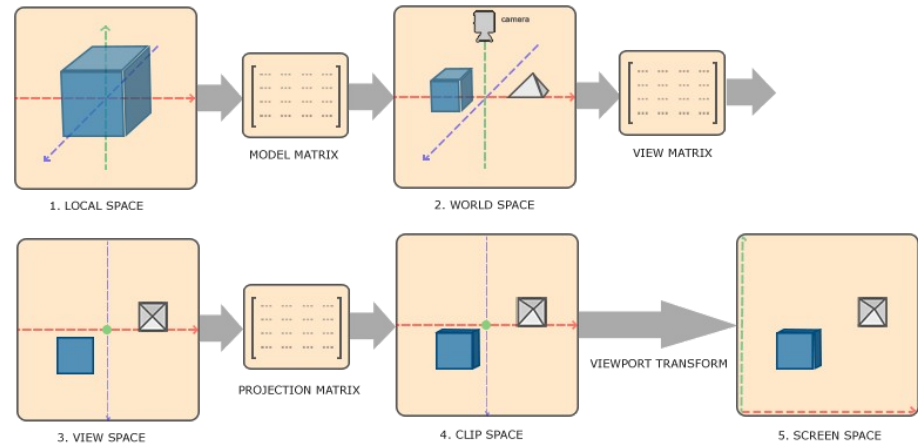
Putting it all (in the scene) together

- Transformation matrices
- Model space → World space → Camera space



Putting it all (in the scene) together

- Transformation matrices
- Model space → World space → Camera space
- Camera space → Clip space → Screen space



Putting it all (in the scene) together

- Transformation matrices
- Model space → World space → Camera space
- Camera space → Clip space → Screen space
- Translation, Scaling, Rotation

Putting it all (in the scene) together

- Transformation matrices
- Model space → World space → Camera space
- Camera space → Clip space → Screen space
- Translation, Scaling, Rotation
- Projection (mostly Perspective)

Putting it all (in the scene) together

- Transformation matrices
- Model space → World space → Camera space
- Camera space → Clip space → Screen space
- Translation, Scaling, Rotation
- Projection (mostly Perspective)
- Clipping

Modern 3D Graphics

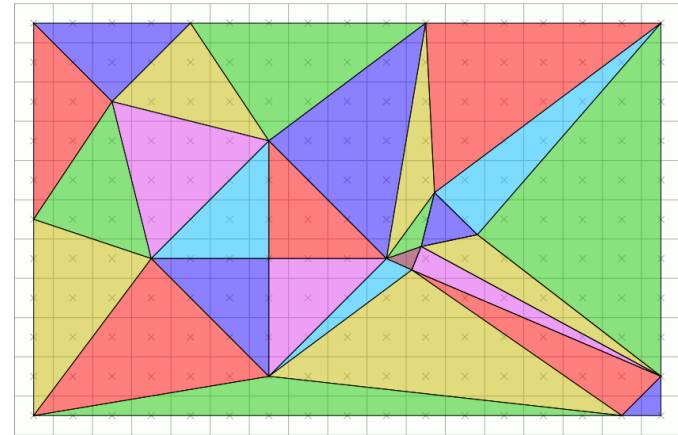
- **Pixels**
- **Vertices and Triangles (/ Polygons)**
- **Translations / Projections**
- **Rasterization**

2.5D → 2D

- **Determine which pixels overlap a triangle**

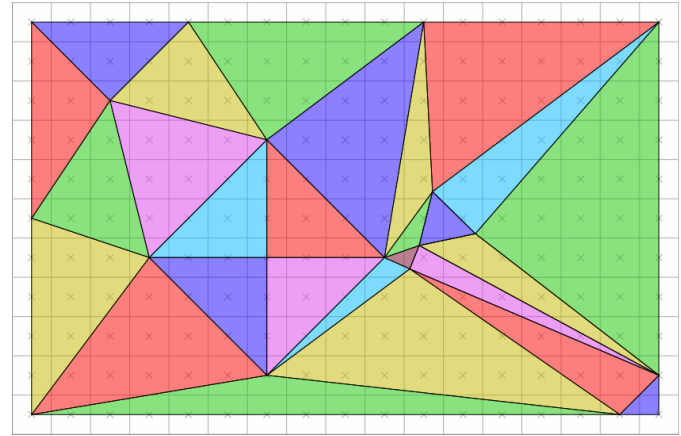
2.5D → 2D

- **Determine which pixels overlap a triangle**
 - Color the edges, then fill the inside



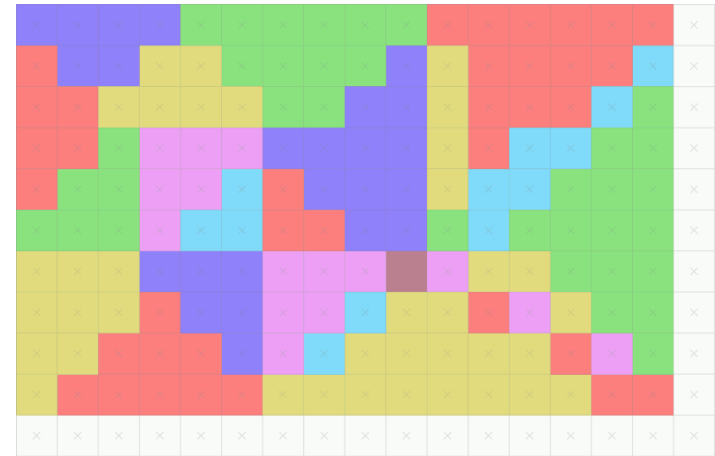
2.5D → 2D

- **Determine which pixels overlap a triangle**
 - Color the edges, then fill the inside
 - Or check if a pixel's center is inside the triangle



2.5D → 2D

- **Determine which pixels overlap a triangle**
 - Color the edges, then fill the inside
 - Or check if a pixel's center is inside the triangle
 - Or witchcraft



2.5D → 2D

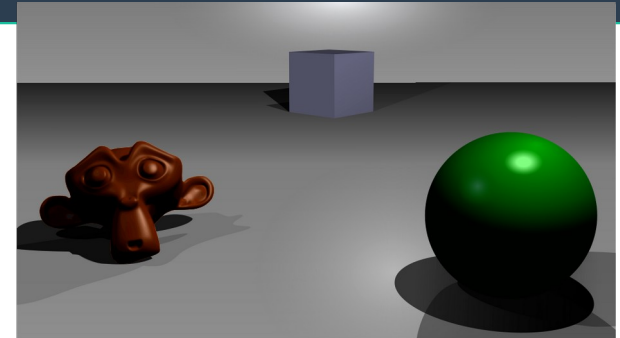
- **Determine which pixels overlap a triangle**
 - Color the edges, then fill the inside
 - Or check if a pixel's center is inside the triangle
 - Or witchcraft
- **More triangles on a single pixel?**

2.5D → 2D

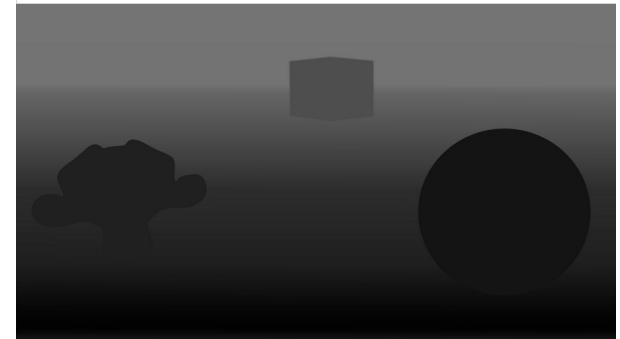
- **Determine which pixels overlap a triangle**
 - Color the edges, then fill the inside
 - Or check if a pixel's center is inside the triangle
 - Or witchcraft
- **More triangles on a single pixel?**
 - Reverse painter

2.5D → 2D

- **Determine which pixels overlap a triangle**
 - Color the edges, then fill the inside
 - Or check if a pixel's center is inside the triangle
 - Or witchcraft
- **More triangles on a single pixel?**
 - Reverse painter
 - Z-Buffer



A simple three-dimensional scene



Z-buffer representation

By -Zeus- - Own work, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=7355760>

Modern 3D Graphics

- **Pixels**
- **Vertices and Triangles (/ Polygons)**
- **Translations / Projections**
- **Rasterization**
- **Shading / Lighting**

Optifine, or Sodium?

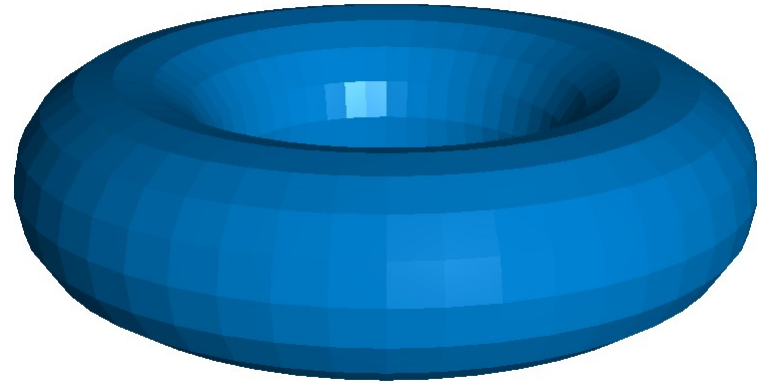
- **Shading doesn't add shadows**

Optifine, or Sodium?

- **Shading doesn't add shadows**
- **Normal vectors**

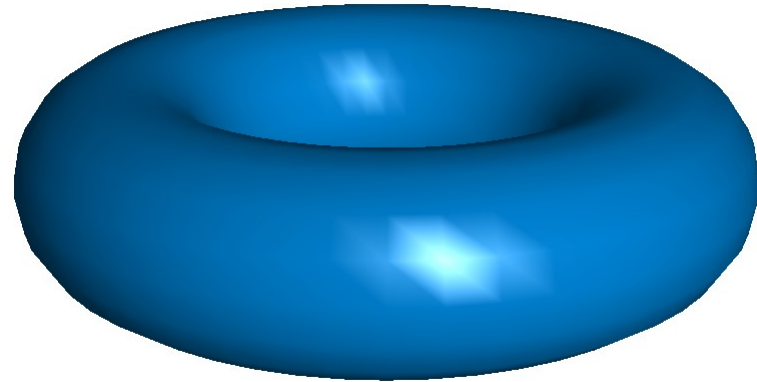
Optifine, or Sodium?

- Shading doesn't add shadows
- Normal vectors
- Flat shading



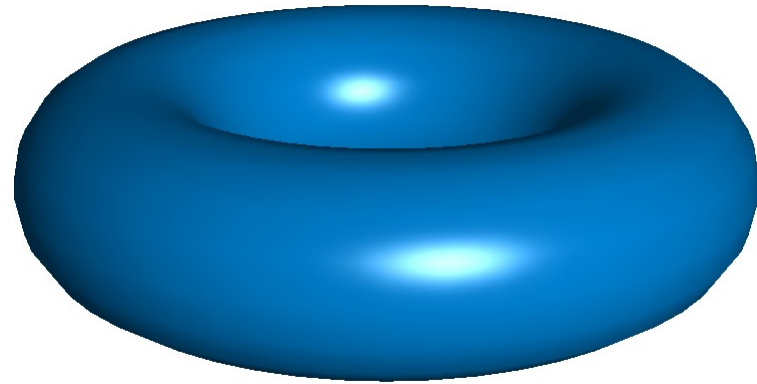
Optifine, or Sodium?

- Shading doesn't add shadows
- Normal vectors
- Flat shading
- Gouraud shading



Optifine, or Sodium?

- Shading doesn't add shadows
- Normal vectors
- Flat shading
- Gouraud shading
- Phong shading



Optifine, or Sodium?

- **Shading doesn't add shadows**
- **Normal vectors**
- **Flat shading**
- **Gouraud shading**
- **Phong shading**
- **Ambient, Directional, Point, Spotlight**

Optifine, or Sodium?

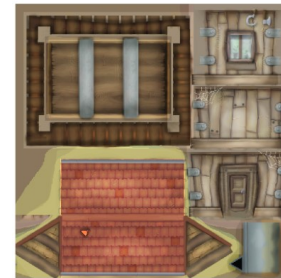
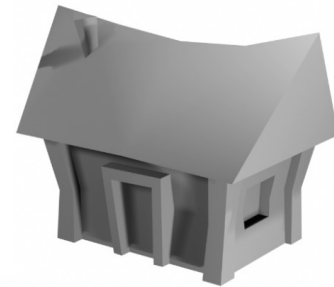
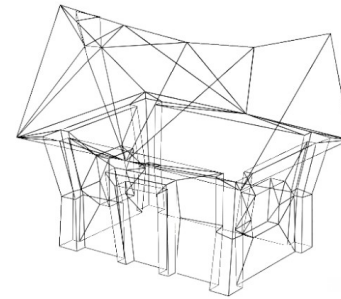
- **Shading doesn't add shadows**
- **Normal vectors**
- **Flat shading**
- **Gouraud shading**
- **Phong shading**
- **Ambient, Directional, Point, Spotlight**
- **Diffusion, Specular**

Modern 3D Graphics

- **Pixels**
- **Vertices and Triangles (/ Polygons)**
- **Translations / Projections**
- **Rasterization**
- **Shading / Lighting**
- **Texture mapping**

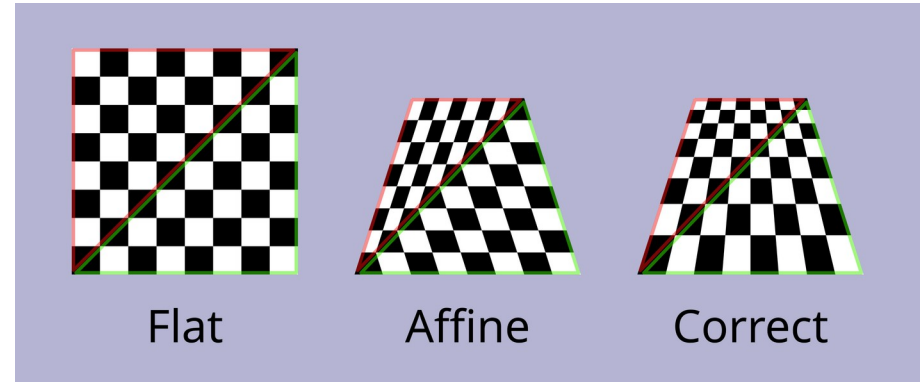
Adding some detail

- UV coordinates



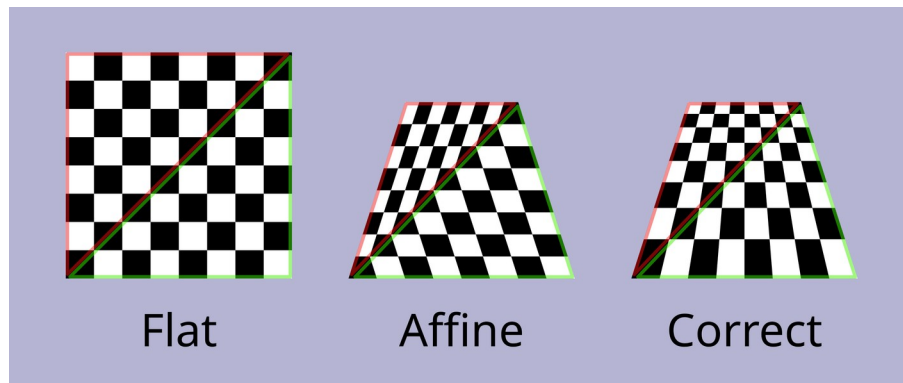
Adding some detail

- UV coordinates
- Affine mapping (LERPing)



Adding some detail

- UV coordinates
- Affine mapping (LERPing)
- Perspective correctness

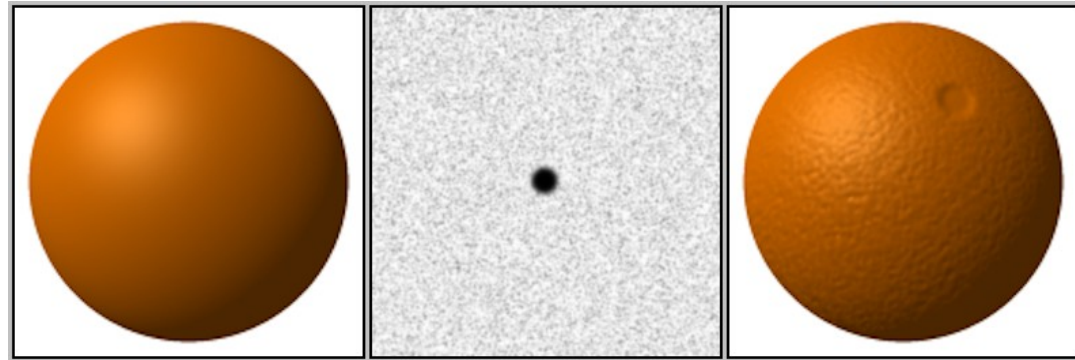


Adding some detail

- UV coordinates
- Affine mapping (LERPing)
- Perspective correctness
- Texture maps

Adding some detail

- UV coordinates
- Affine mapping (LERPing)
- Perspective correctness
- Texture maps
- Bump / Normal mapping



By Bump-map-demo-smooth.png, Orange-bumpmap.png and Bump-map-demo-bumpy.png: Original uploader was Brion VIBBER at en.wikipedia Later version(s) were uploaded by McLoaf at en.wikipedia. derivative work: GDallimore (talk) – Bump-map-demo-smooth.png, Orange-bumpmap.png and Bump-map-demo-bumpy.png, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=11747953>

Adding some detail

- UV coordinates
- Affine mapping (LERPing)
- Perspective correctness
- Texture maps
- Bump / Normal mapping
- Materials

Adding some detail

- **UV coordinates**
- **Affine mapping (LERPing)**
- **Perspective correctness**
- **Texture maps**
- **Bump / Normal mapping**
- **Materials**
- **Baking**

Modern 3D Graphics

- **Pixels**
- **Vertices and Triangles (/ Polygons)**
- **Translations / Projections**
- **Rasterization**
- **Shading / Lighting**
- **Texture mapping**
- **Anti-aliasing**

How sharp is too sharp?

- **Problem: A pixel is covered by single triangle**

How sharp is too sharp?

- **Problem:** A pixel is covered by single triangle
- **Solution:** Make it not

How sharp is too sharp?

- Problem: A pixel is covered by single triangle
- Solution: Make it not
- SSAA → MSAA



From: <https://www.gamedesigning.org/gaming/anti-aliasing/>

How sharp is too sharp?

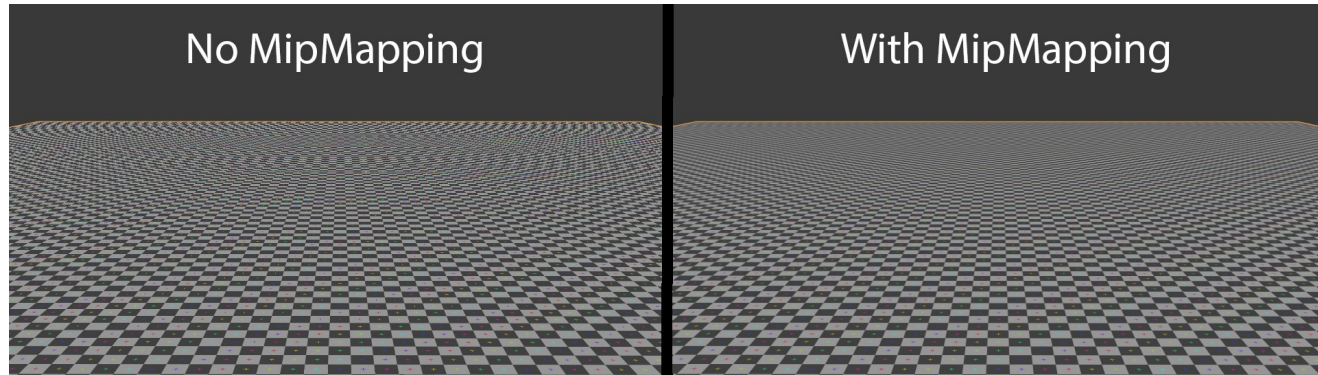
- **Problem: A pixel is covered by single triangle**
- **Solution: Make it not**
- **SSAA → MSAA**
- **FXAA**

How sharp is too sharp?

- Problem: A pixel is covered by single triangle
- Solution: Make it not
- SSAA → MSAA
- FXAA
- TAA, DLAA / DLSS

How sharp is too sharp?

- Problem: A pixel is covered by single triangle
- Solution: Make it not
- SSAA → MSAA
- FXAA
- TAA, DLAA / DLSS
- Mipmapping

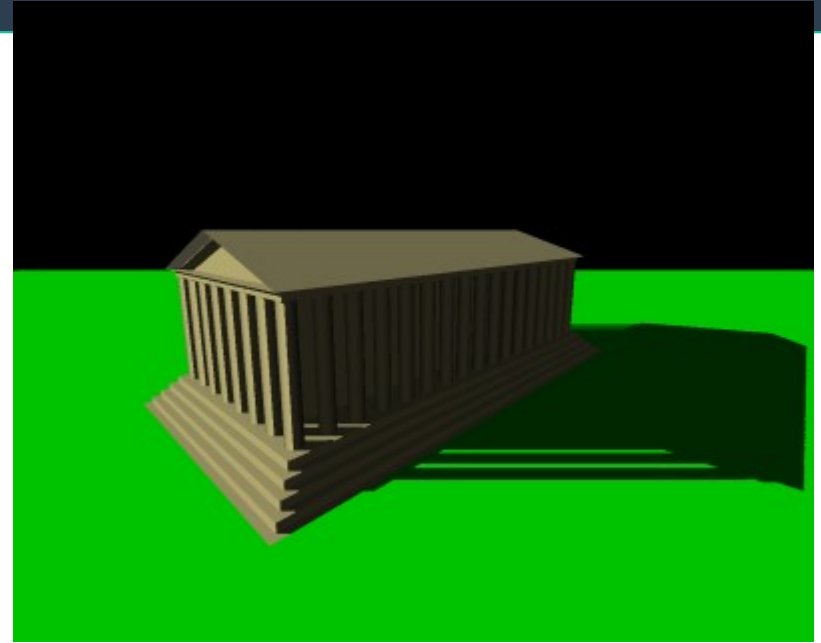


Modern 3D Graphics

- **Pixels**
- **Vertices and Triangles (/ Polygons)**
- **Translations / Projections**
- **Rasterization**
- **Shading / Lighting**
- **Texture mapping**
- **Anti-aliasing**
- **Post-processing**

Effects that happen after

- SSAO, Particles, Shadow mapping



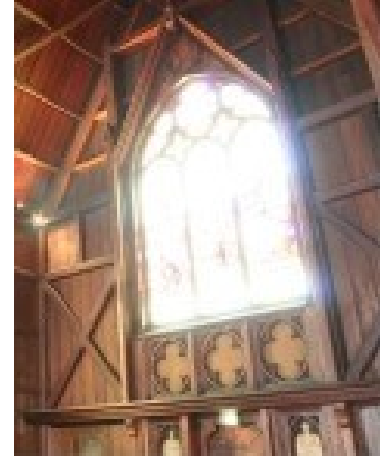
By Praetor alpha at the English-language Wikipedia, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=9016274>

Effects that happen after

- SSAO, Particles, Shadow mapping
- Fog, God rays, Lens flare, Vignette

Effects that happen after

- SSAO, Particles, Shadow mapping
- Fog, God rays, Lens flare, Vignette
- Bloom, Blur, Chromatic aberration, DOF



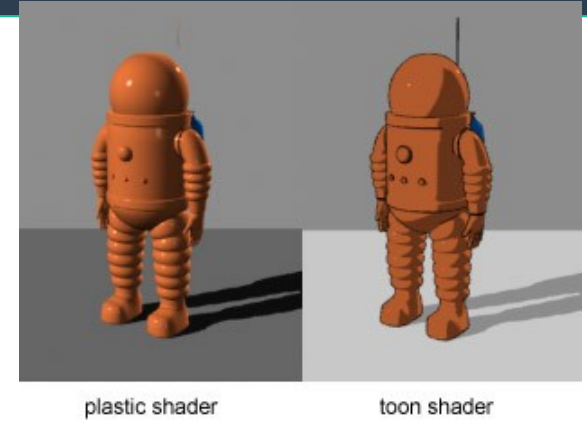
By The original uploader was Rerdavies at English Wikipedia. - Transferred from en.wikipedia to Commons., CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=8103739>

Effects that happen after

- SSAO, Particles, Shadow mapping
- Fog, God rays, Lens flare, Vignette
- Bloom, Blur, Chromatic aberration, DOF
- Contrast, Color correction, Sharpness

Effects that happen after

- SSAO, Particles, Shadow mapping
- Fog, God rays, Lens flare, Vignette
- Bloom, Blur, Chromatic aberration, DOF
- Contrast, Color correction, Sharpness
- Cel shading, Posterization, Film grain, Distortion



CC BY 2.0, <https://commons.wikimedia.org/w/index.php?curid=1291108>

Effects that happen after

- SSAO, Particles, Shadow mapping
- Fog, God rays, Lens flare, Vignette
- Bloom, Blur, Chromatic aberration, DOF
- Contrast, Color correction, Sharpness
- Cel shading, Posterization, Film grain, Distortion
- Upscaling

Modern 3D Graphics

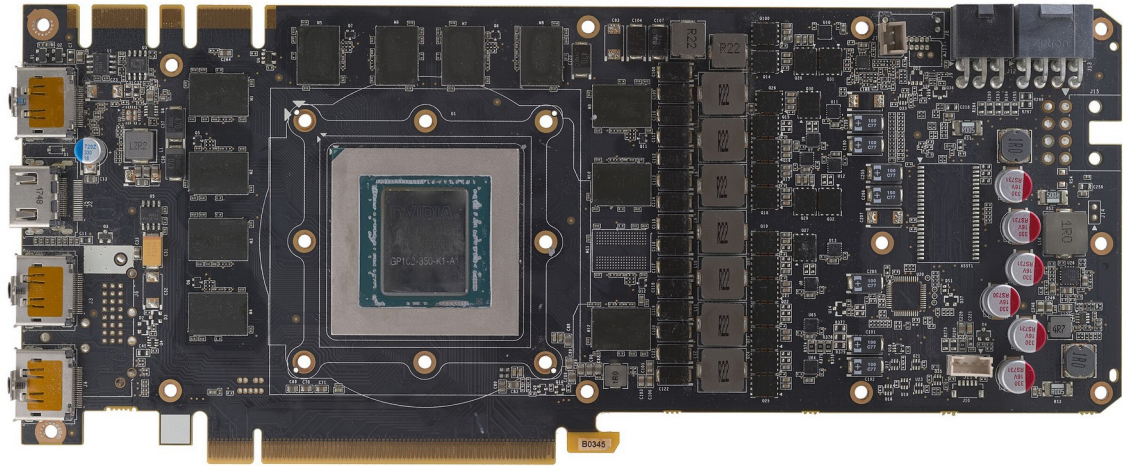
- **Pixels**
- **Vertices and Triangles (/ Polygons)**
- **Translations / Projections**
- **Rasterization**
- **Shading / Lighting**
- **Texture mapping**
- **Anti-aliasing**
- **Post-processing**

The number cruncher

- **CPUs: Few universal cores**

The number cruncher

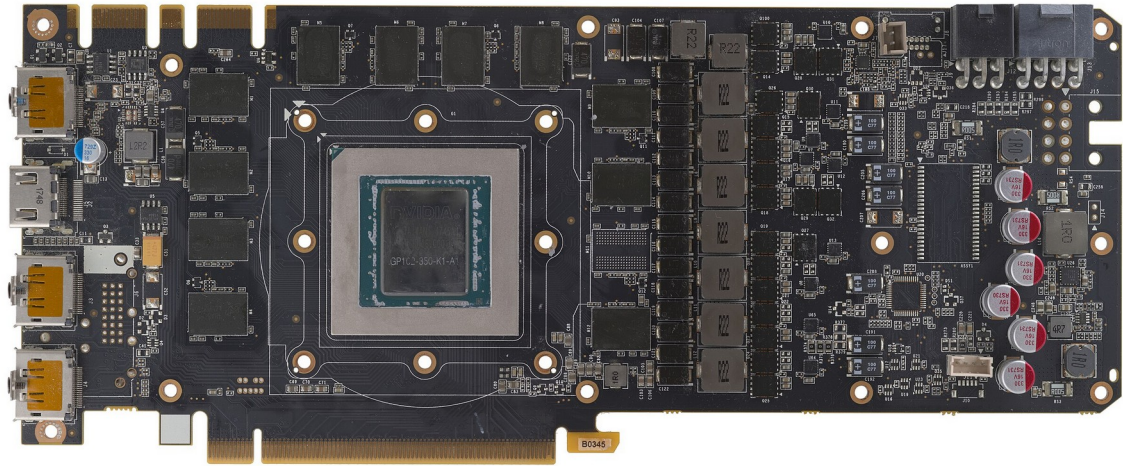
- CPUs: Few universal cores
- GPUs: Thousands of tiny calculators



By Phiarc - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=129124142>

The number cruncher

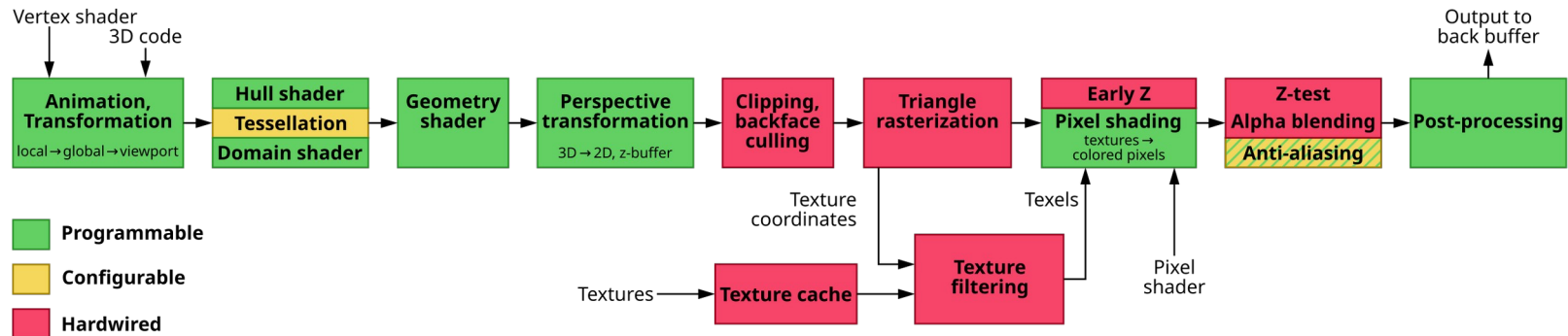
- CPUs: Few universal cores
- GPUs: Thousands of tiny calculators
- VRAM



By Phiarc - Own work, CC BY-SA 4.0, <https://commons.wikimedia.org/w/index.php?curid=129124142>

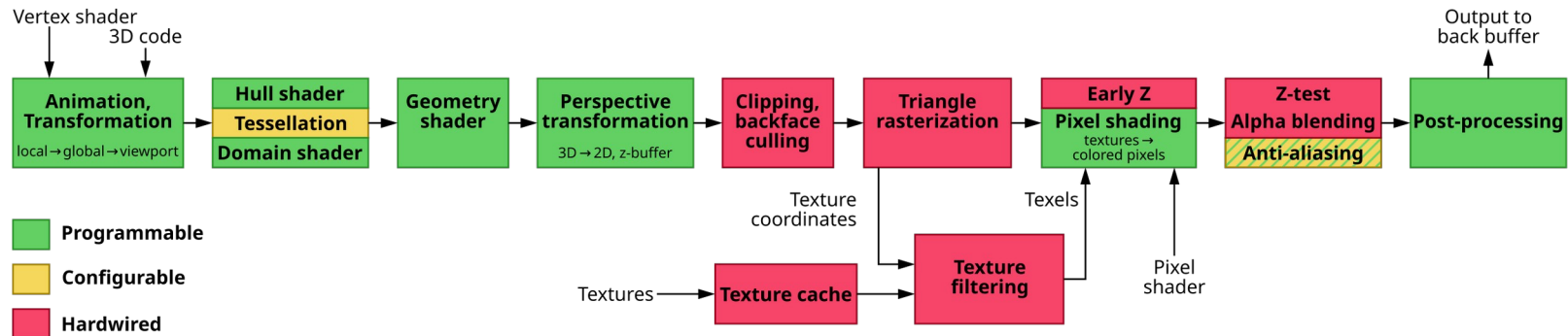
The number cruncher

- CPUs: Few universal cores
- GPUs: Thousands of tiny calculators
- VRAM
- Pipeline



The number cruncher

- CPUs: Few universal cores
- GPUs: Thousands of tiny calculators
- VRAM
- Pipeline
- Shaders

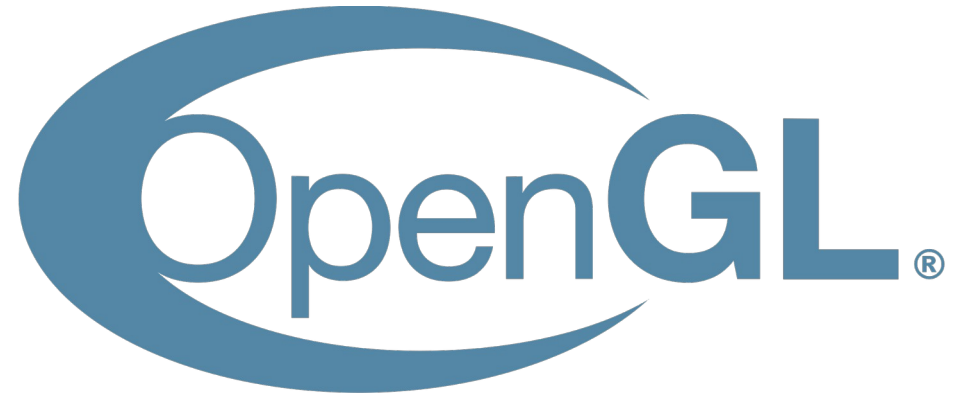


The number cruncher

- **CPUs: Few universal cores**
- **GPUs: Thousands of tiny calculators**
- **VRAM**
- **Pipeline**
- **Shaders**
- **Driver**

The number cruncher

- **CPUs: Few universal cores**
- **GPUs: Thousands of tiny calculators**
- **VRAM**
- **Pipeline**
- **Shaders**
- **Driver**
- **Graphics API**



Recap

- **Computer graphics is a vast field**

Recap

- **Computer graphics is a vast field**
- **3D objects are represented by triangles**

Recap

- **Computer graphics is a vast field**
- **3D objects are represented by triangles**
- **Those are converted to pixels**

Recap

- **Computer graphics is a vast field**
- **3D objects are represented by triangles**
- **Those are converted to pixels**
- **Their color is based on lights, textures,...**

Recap

- **Computer graphics is a vast field**
- **3D objects are represented by triangles**
- **Those are converted to pixels**
- **Their color is based on lights, textures,...**
- **The resulting image can be further modified**

Recap

- **Computer graphics is a vast field**
- **3D objects are represented by triangles**
- **Those are converted to pixels**
- **Their color is based on lights, textures,...**
- **The resulting image can be further modified**
- **GPUs are insane**



QnA time

The end