centre adscrit a:
UNIVERSITAT DE BARCELONA

Computer Graphics

1. Introduction to computer graphics

Dr Joan Llobera – joanllobera@enti.cat
Dr Jesús Ojeda – jesusojeda@enti.cat

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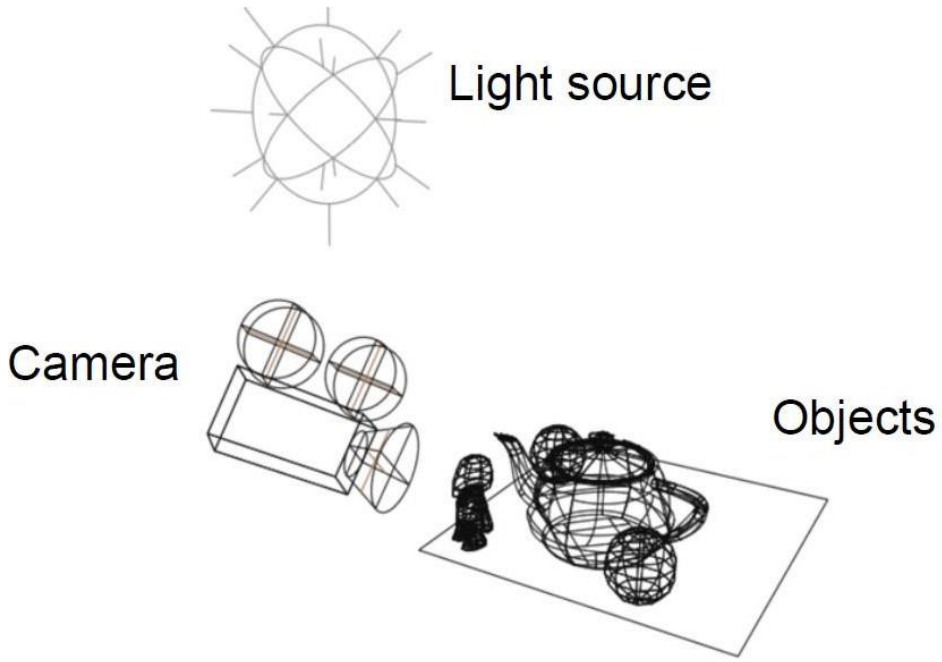
Outline

1. What is computer graphics?
2. Computer graphics model
3. Image Formation
4. The rendering pipeline

1. What is computer graphics?



1. What is computer graphics?

Definition:

- The process of creating images with a computer
- It involves hardware, software and applications

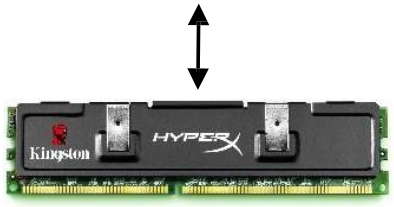
Applications

- Visualizing information
- Scientific Visualization
- Games
- Design
- User interfaces

2. Computer graphics model

Input devices

CPU



CPU memory

GPU

GPU memory

Framebuffer

Output device

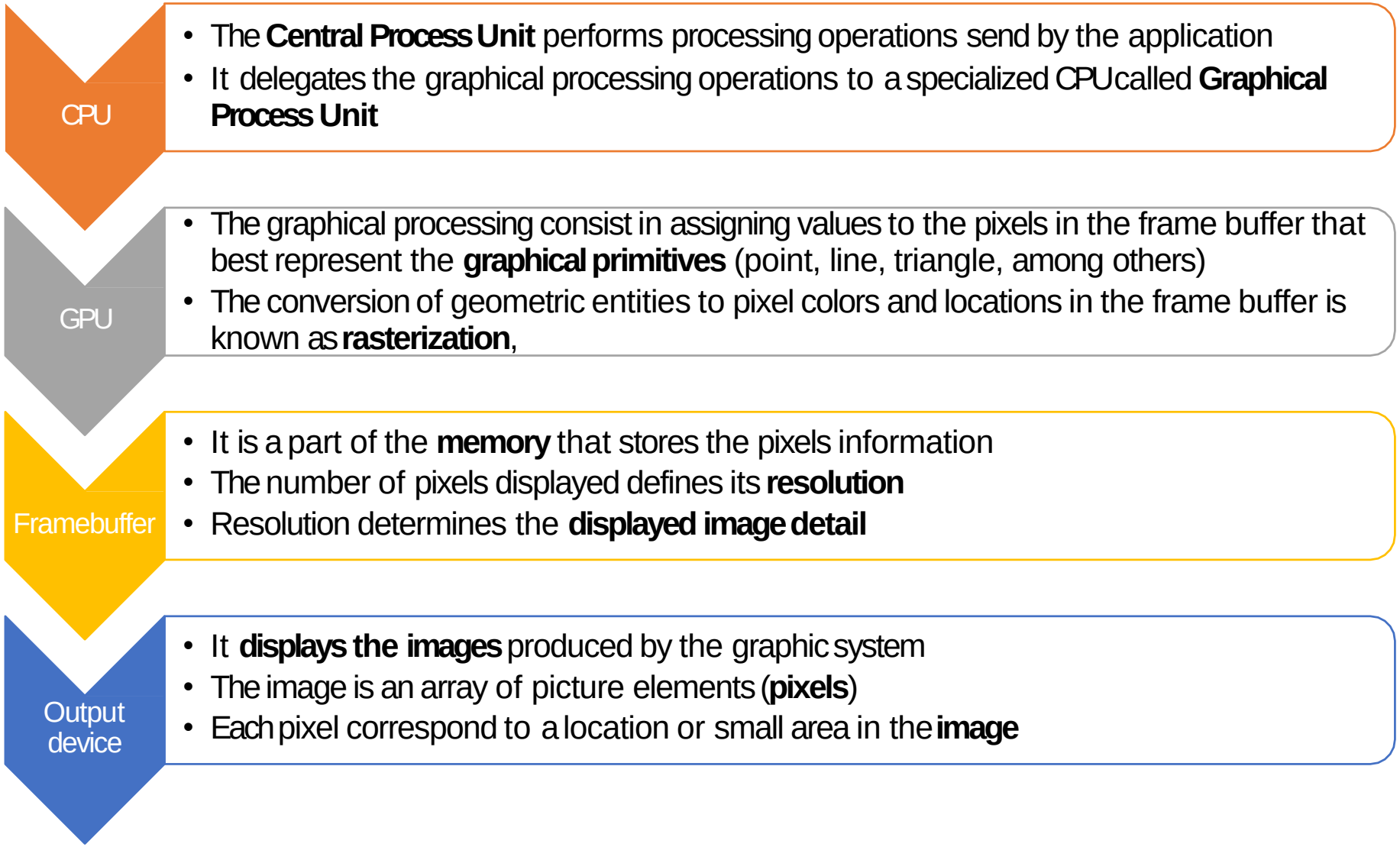
2. Computer graphics model

Examples:

- Workstations
- Laptops
- XBOX, Wii, playstation
- Mobile Phones
- …

CRT TV are not computer graphics systems

2. Computer graphics model



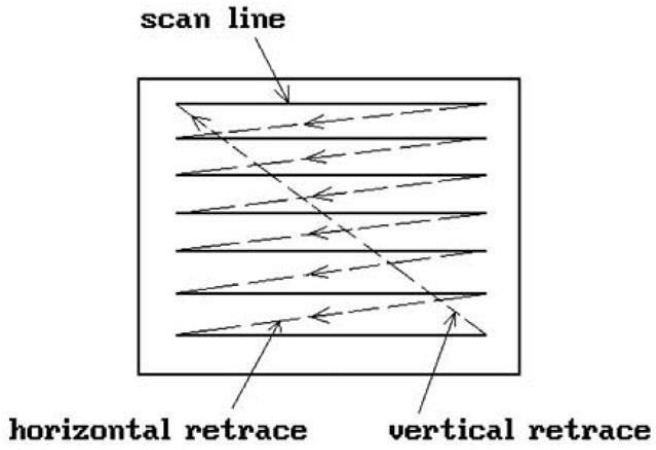
2. Computer graphics model

- The **frame buffer** is the core element and its main **characteristics** are:
  - The **resolution** is the number of pixels that will be drawn on the screen and determines the **detail of the image**
  - The **depth** (or also called the **precision**) defines the number of bits that are used for representing the information of a pixel and determines the **color displayed**
    Examples: 8 bit, HDR (up to 12 bits)

Source: https://www.cnet.com/news/hdr10-vs-dolby-vision-vs-hlg-how-do-hdr-formats-compare/

2. Computer graphics model

The **frame rate** (or also known as frame frequency and frames per second (FPS)) is the frequency (rate) at which an imaging device produces unique consecutive images called frames



The **refresh rate** is the number of times in a second that a display hardware updates its buffer.

- In a non-interlaced (or progressive) system, the pixels are displayed row by row, or scan line by scan line, at the refresh rate.
- In an interlaced display, odd rows and even rows are refreshed alternately

2. Computer graphics model

2. Computer graphics model

- The frame rate and the refresh rate are independent!
- Specific strategies need to be designed to synchronize both

2. Computer graphics model

Summary:

1. What does a computer graphics model look like
2. Input, CPU, GPU, Frame Buffer. Display
3. The Frame Buffer:
   - Characteristics (resolution+depth)
   - Frame rate and refresh rate

3.Image formation

We need to:

- Represent (and move) geometry
- Represent (and change) colour

The main elements are:

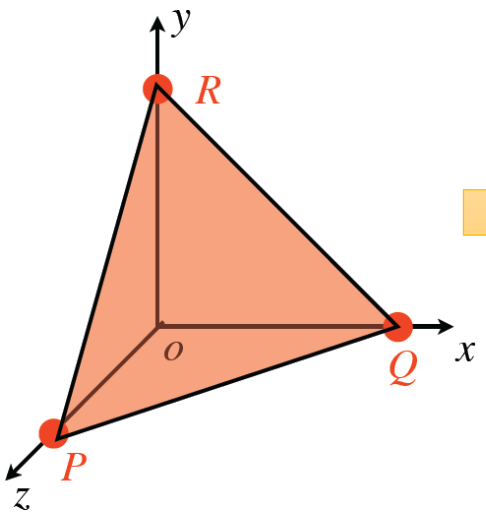
1. Objects
2. Viewer
3. Light Source

These three elements are independent!

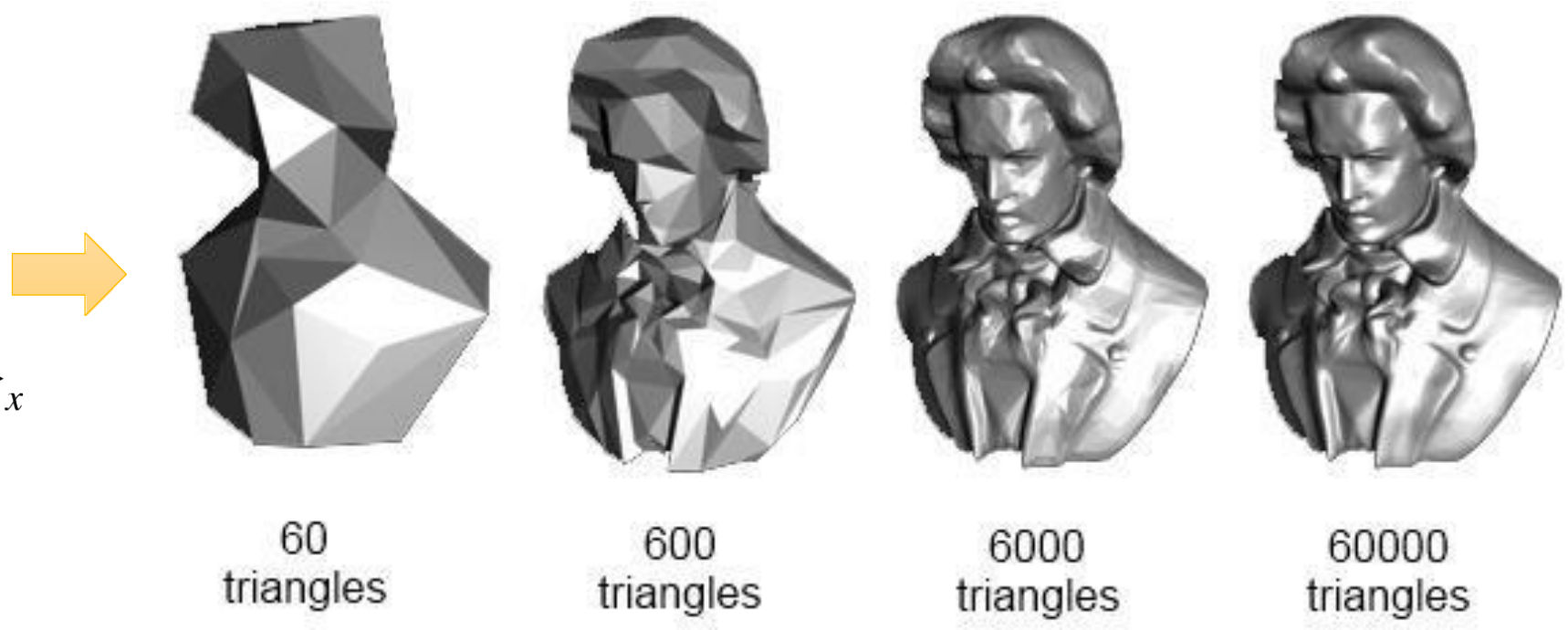
3 Image Formation

1. Objects
   - Formed of points, lines and polygons
   - Their existence is independent from the image-formation process
   - Specified with **vertices** and drawn with **triangles**

3 Image Formation



R, P and Q define a triangle composed by 3 vertices



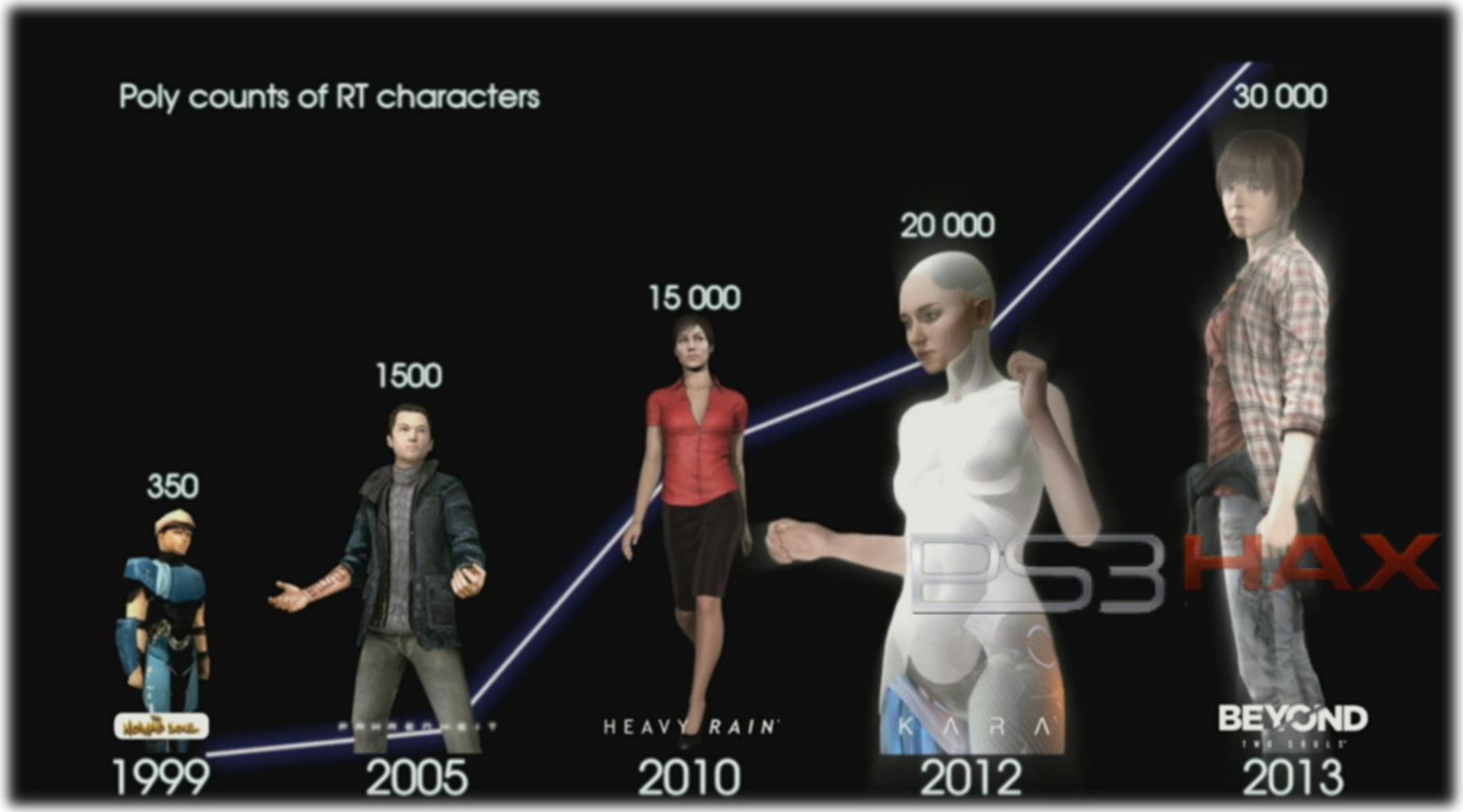
60 triangles

600 triangles

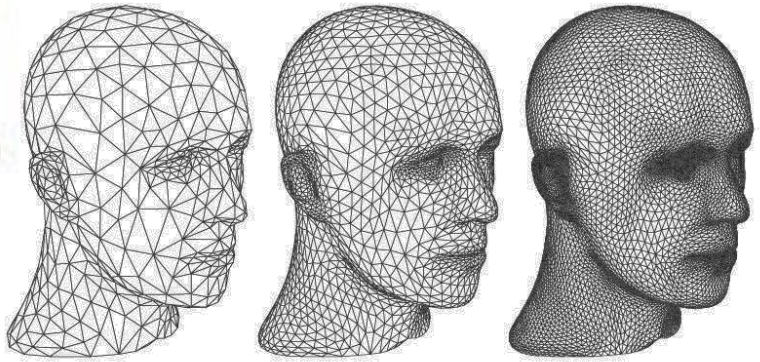
6000 triangles

60000 triangles

3 Image Formation



3 Image Formation

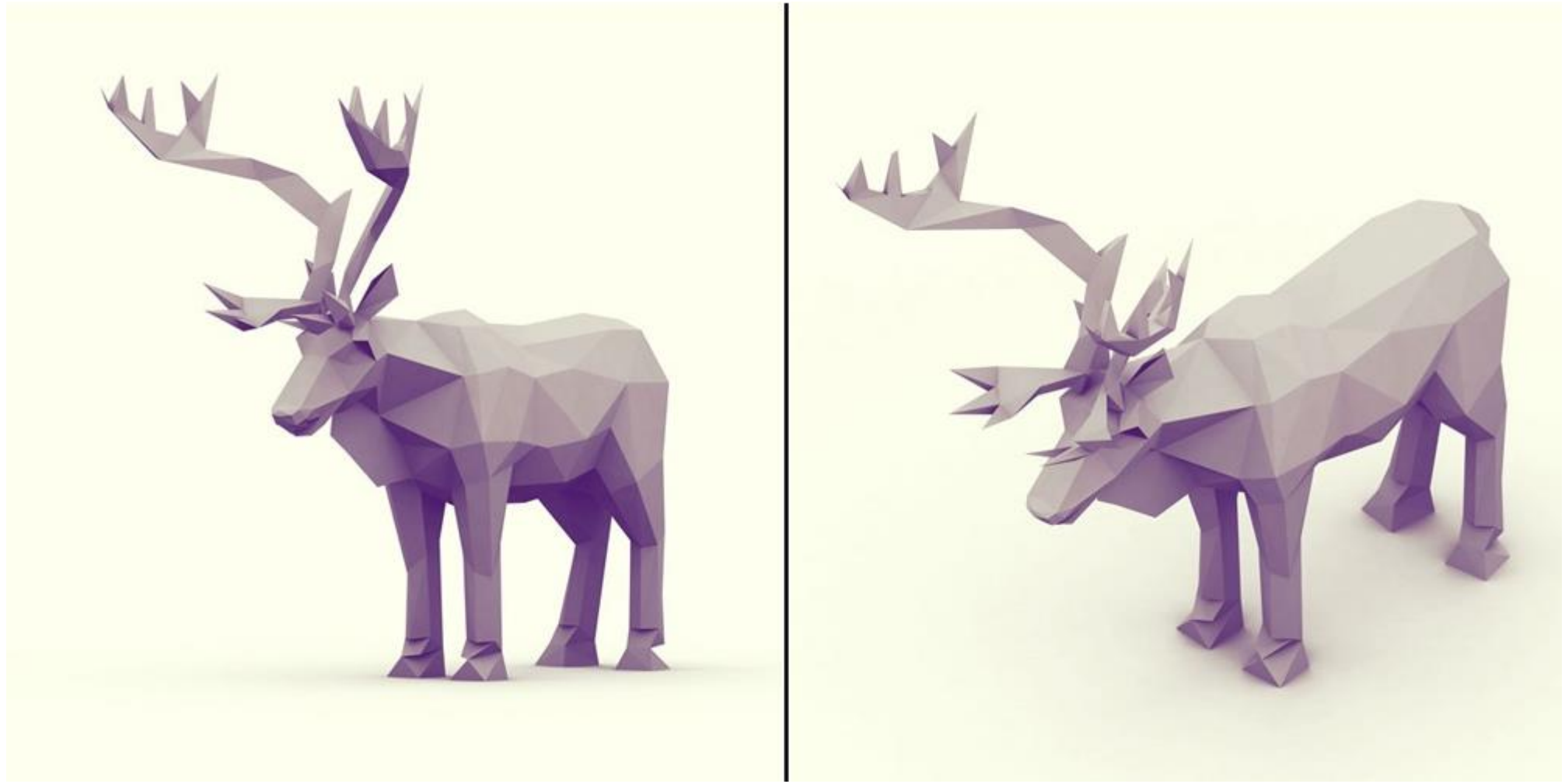


Original/Source
Common Model

Wii U
Max LOD Result

PS4/X720
Max LOD Result

3 Image Formation



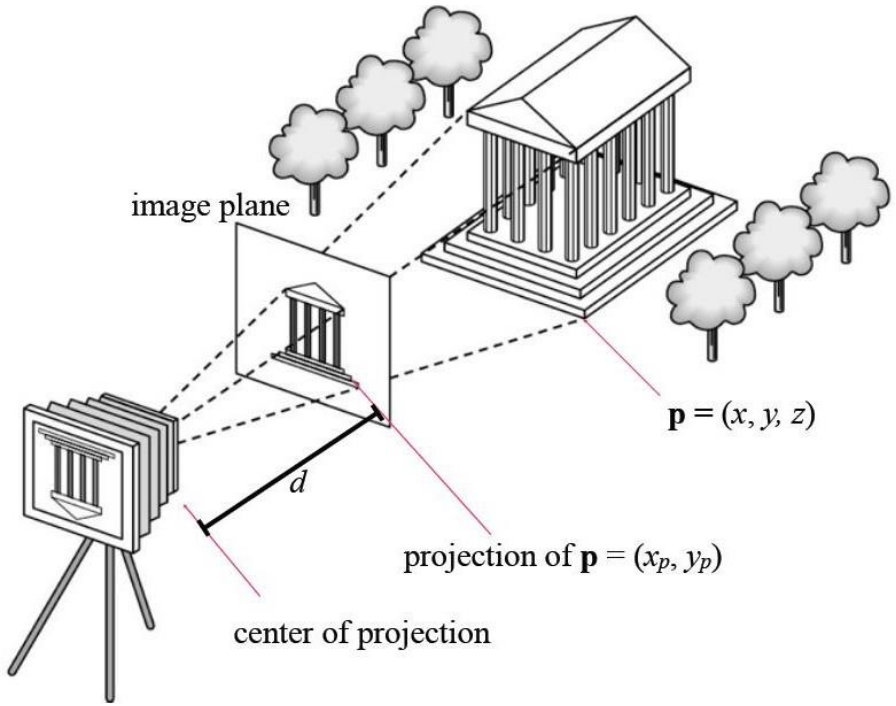
3 Image Formation

1. Objects
   - Formed of points, lines and polygons
   - Their existence is independent from the image-formation process
   - Specified with **vertices** and drawn with **triangles**

   - Character realism is associated with the number of polygons
   - The number of polygons matters
   - However, low-poly can also be creatively interesting

3 Image Formation

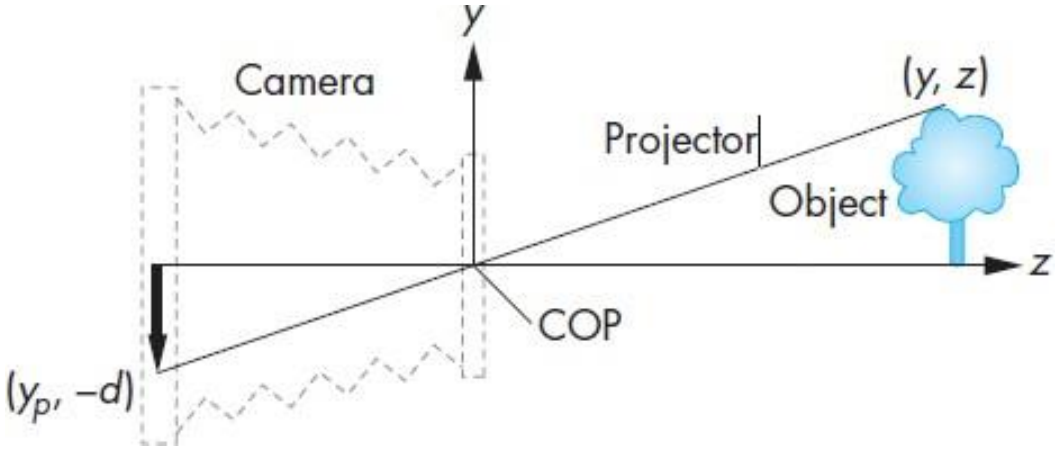
2. Viewer

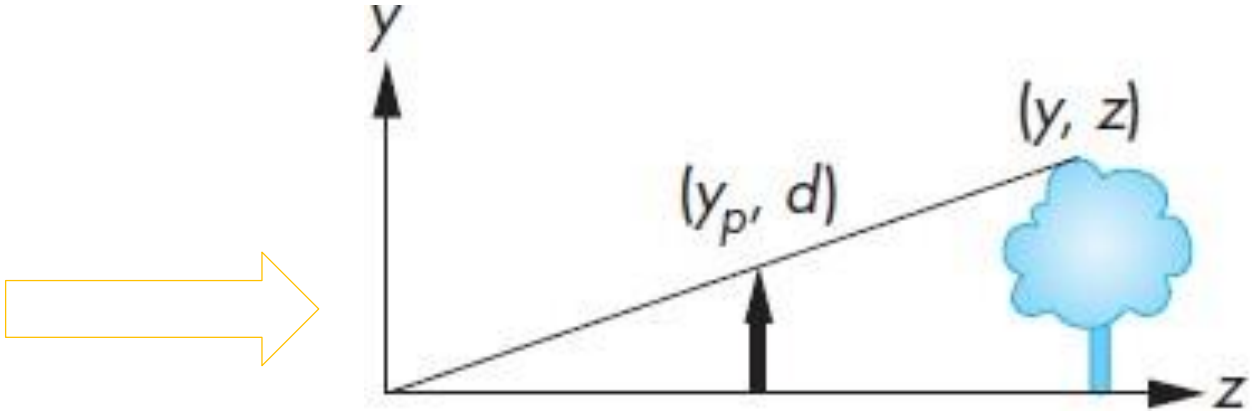


1. The objects interact but the viewer only films
2. The camera has a position, an orientation and a vision field

3 Image Formation

2. Viewer

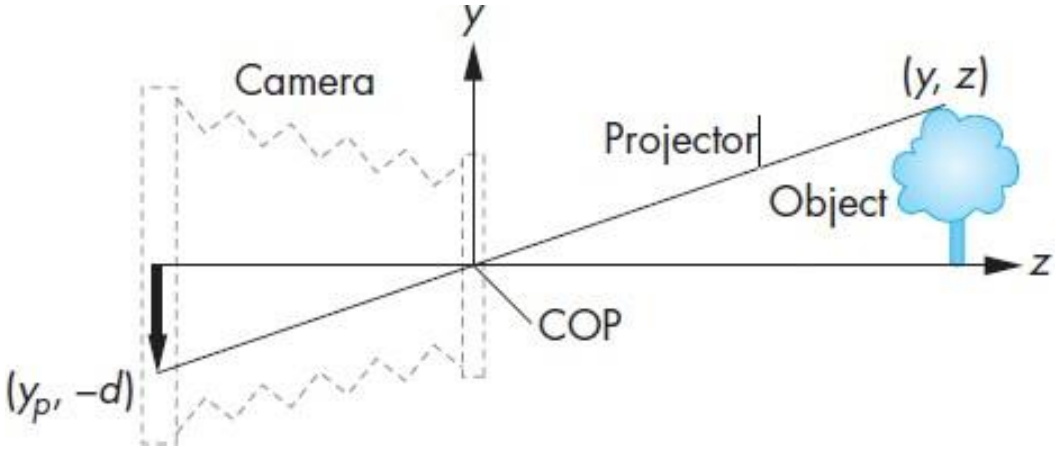


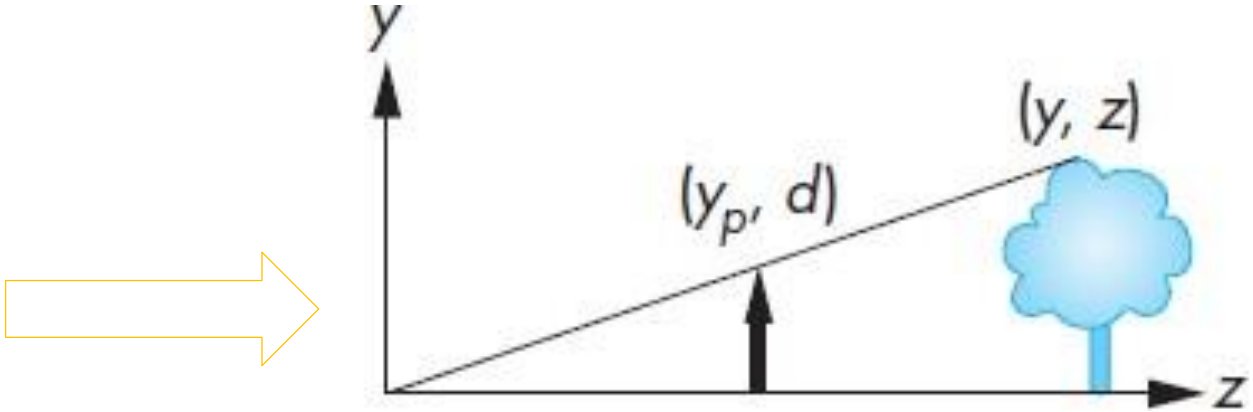


$$\tan \propto = \frac{y}{z} = \frac{y_p}{d}$$

3 Image Formation

2. Viewer



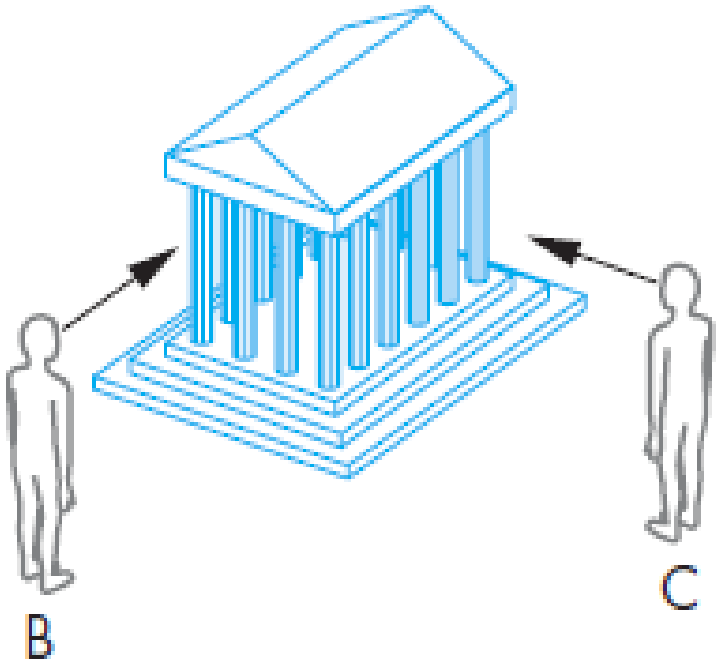


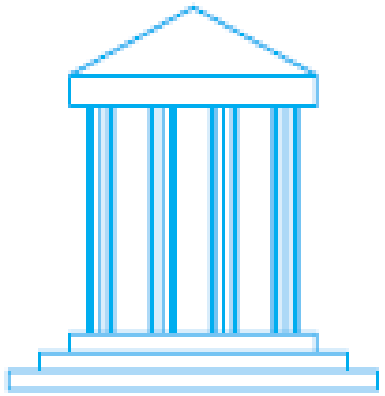
Perspective

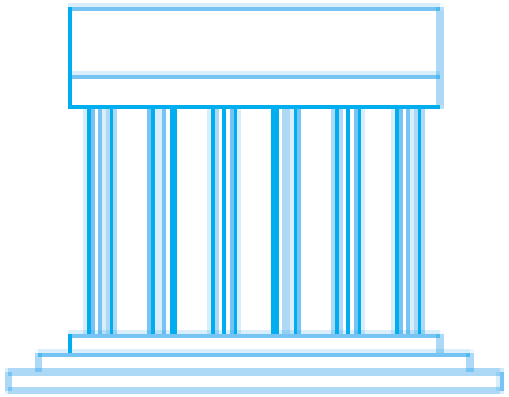
$$\tan \propto = \frac{y}{z} = \frac{y_p}{d}$$

3 Image Formation

2. Viewer







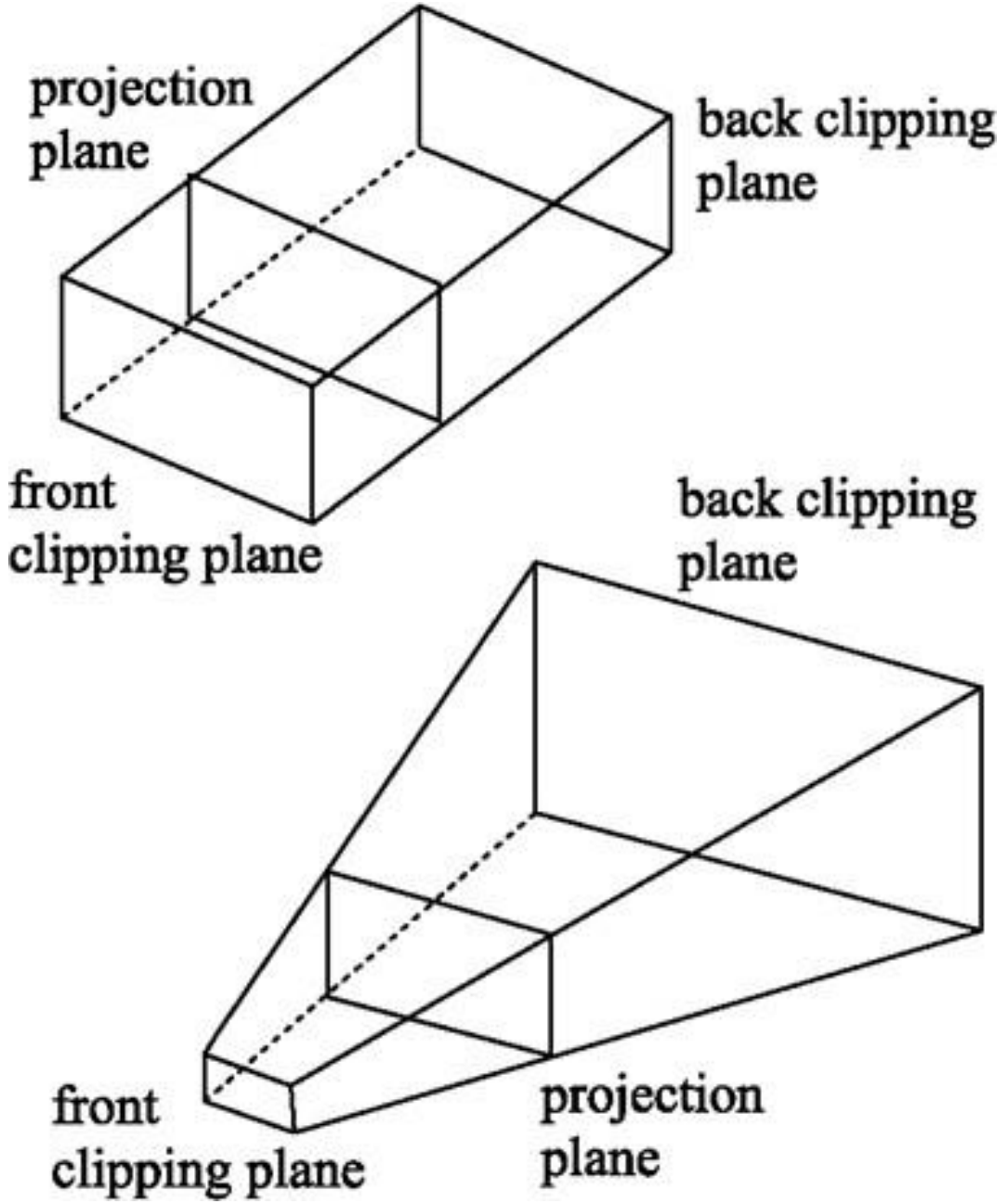
Orthographic

3 Image Formation

Orthographic

vs

Perspective



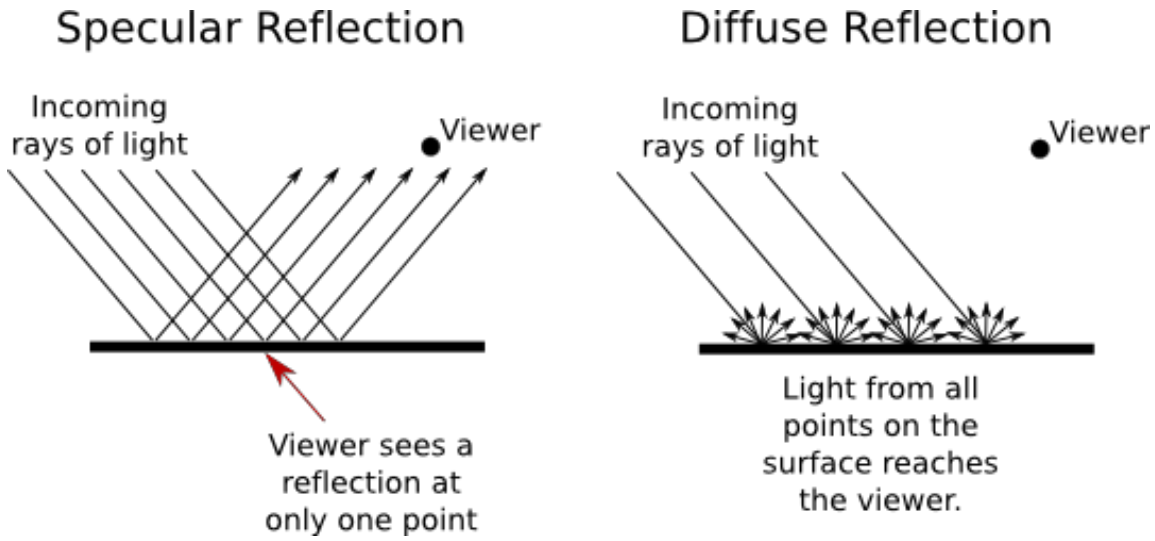
3 Image Formation

3. Lighting

An object is covered by a material which has, at least:

- **Absorption**: color properties
- **Scattering:** Diffuse and/or specular

Intensity and direction of light, plus the materials determines result

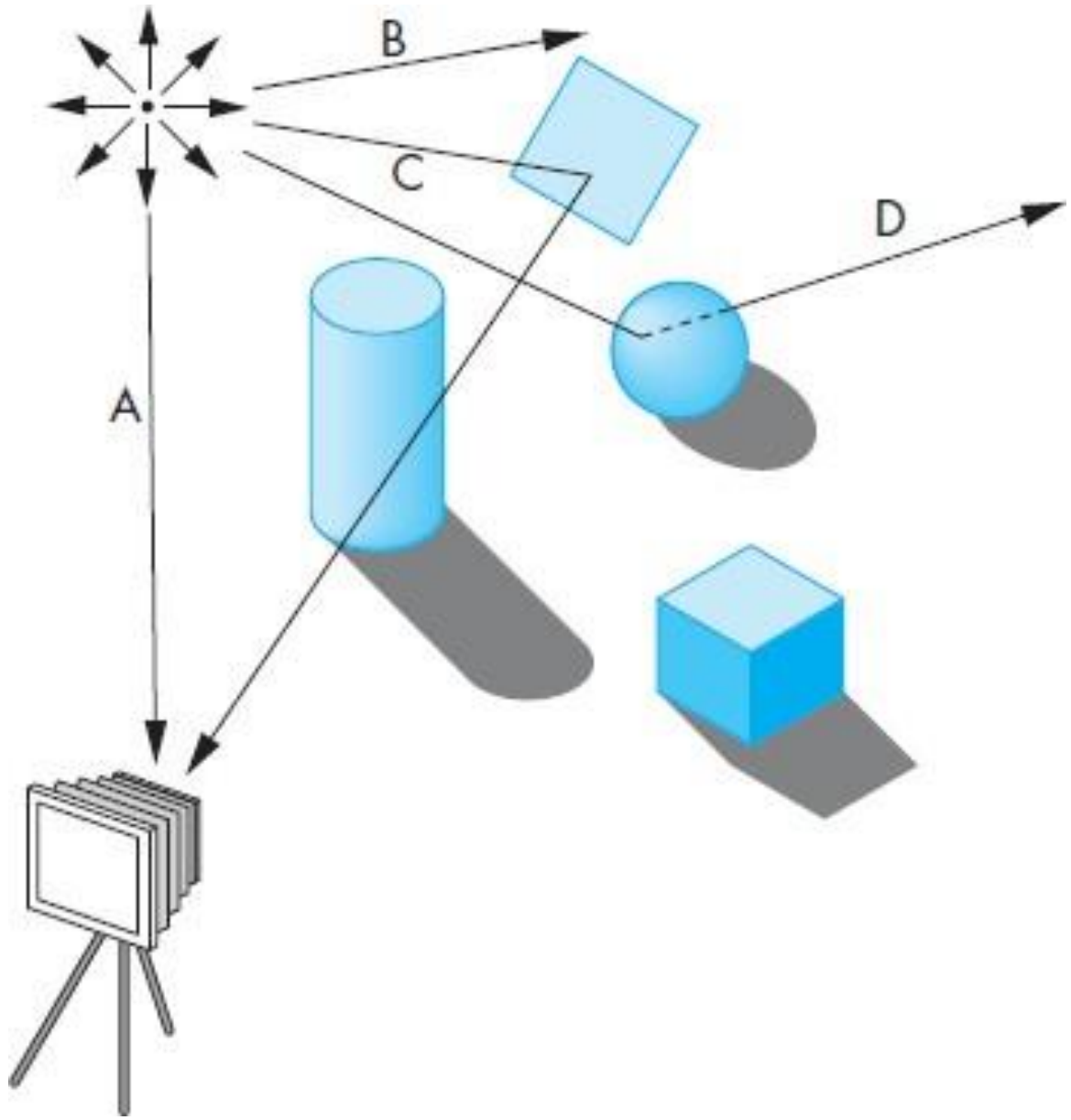


3 Image Formation

3. Lighting

We can consider:

- Only direct illumination
- Direct and indirect illumination

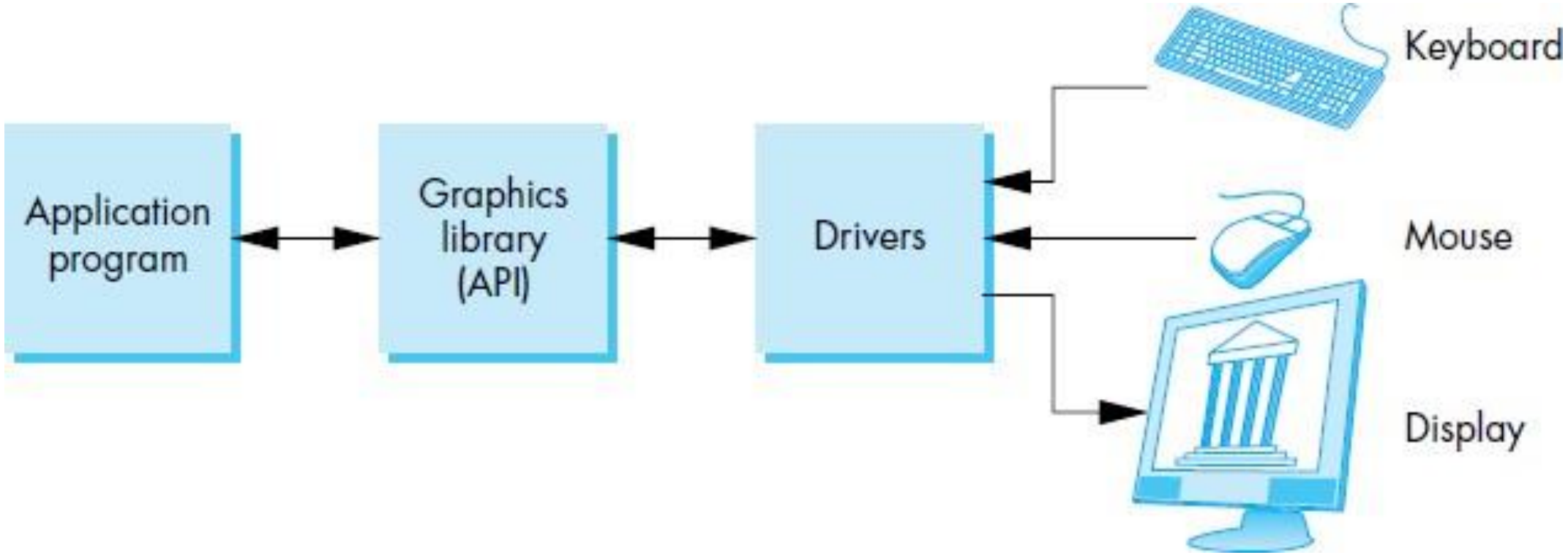


3.Image formation

Summary:

1. **Objects**
   are pixels and triangles
2. **Viewer** is a perspective or orthographic projection
3. **Lighting** is defined by
   Material properties
   and Light sources

4. The rendering pipeline

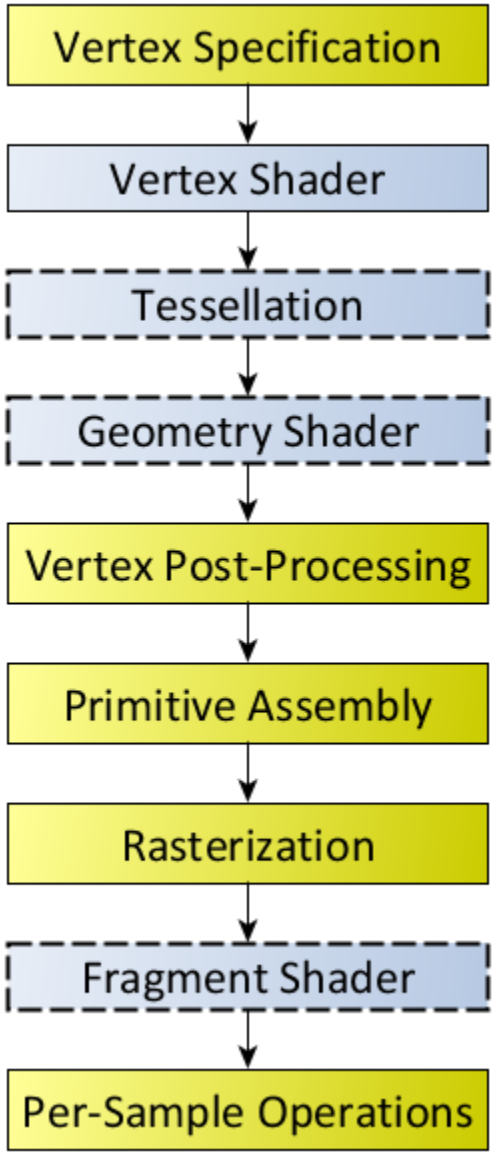


4. The rendering pipeline

Pràctica 1. El pipeline clàssic
El meu primer *vertex shader*
Introducció del *fragment shader*.
Pintar un objecte i col·locar una càmera.
Phong rendering model, Toon rendering

Pràctica 2. Geometria
Generació de geometria en la targeta gràfica. El meu primer *geometry shader* (per a fer aquesta pràctica caldrà haver completat la primera pràctica de Mecànica)

Pràctica 3. OpenGL avançat
Introducció de *frame buffer objects, stencil buffer, depth buffer.*
Optimització de computació gràfica en OpenGL 4



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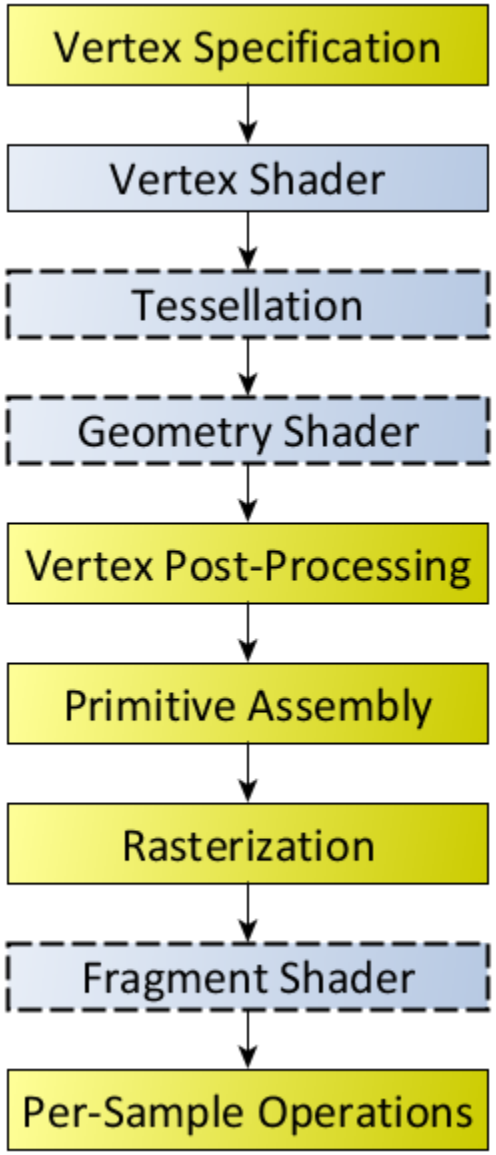

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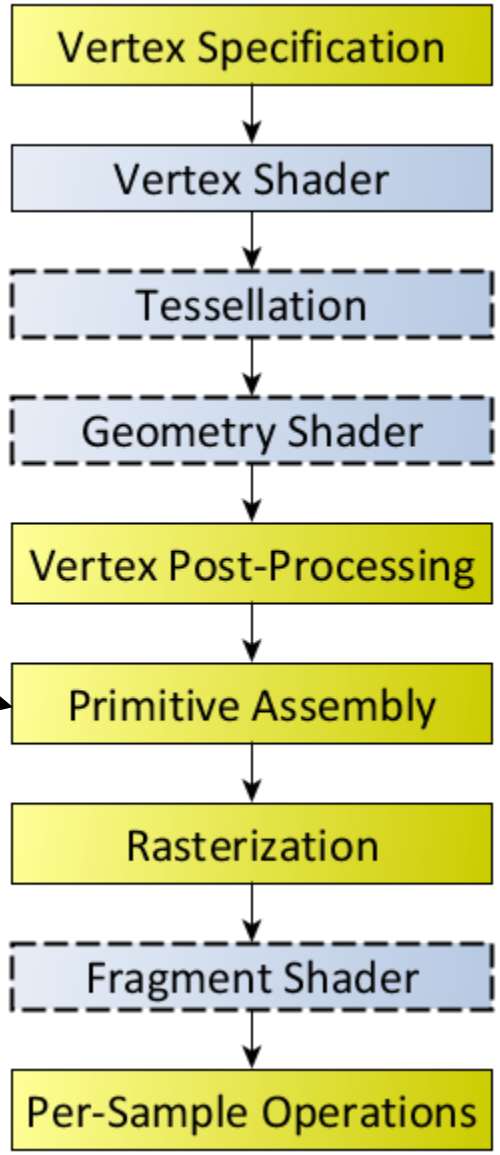

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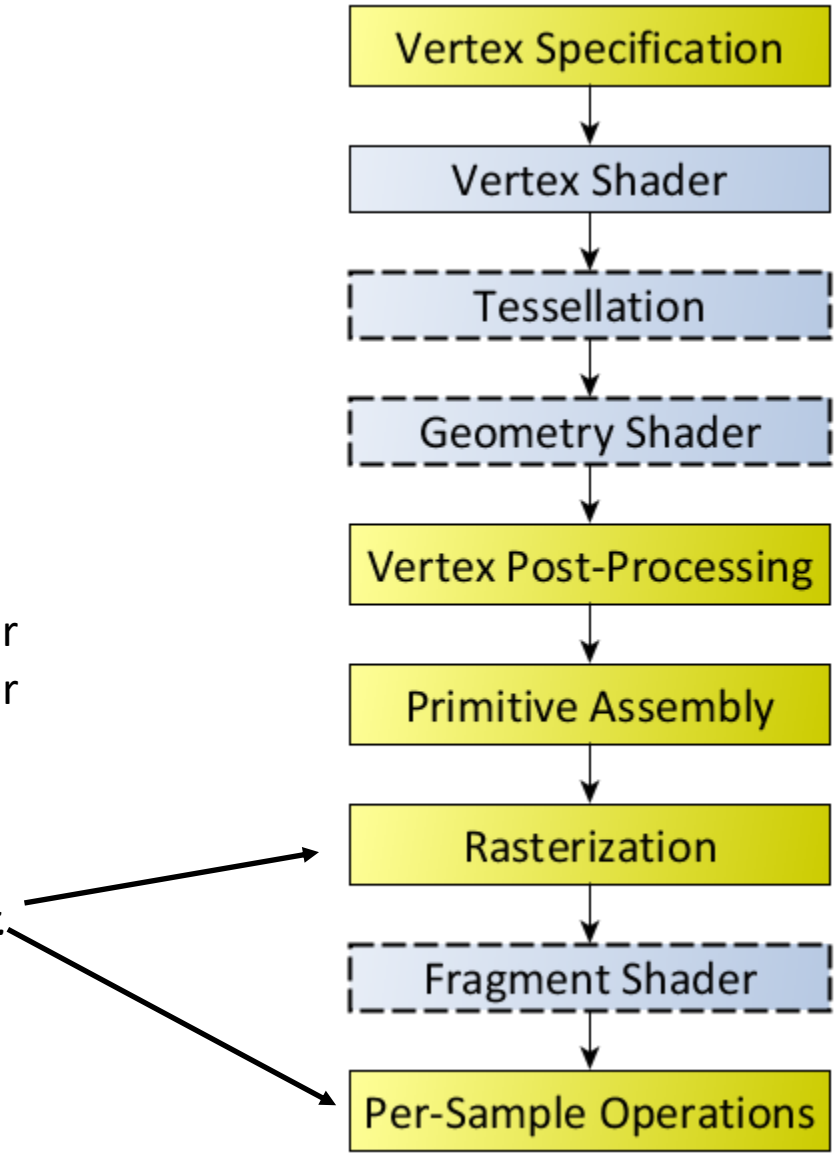

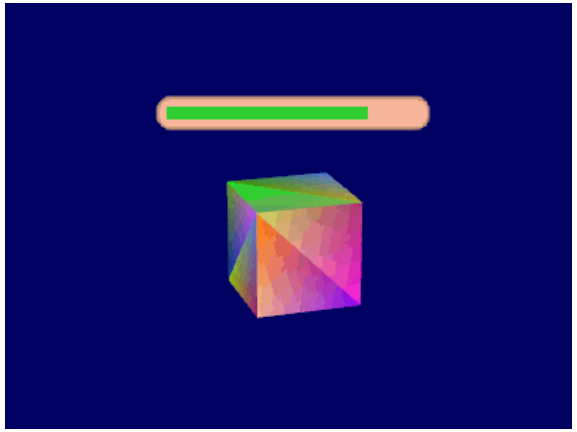

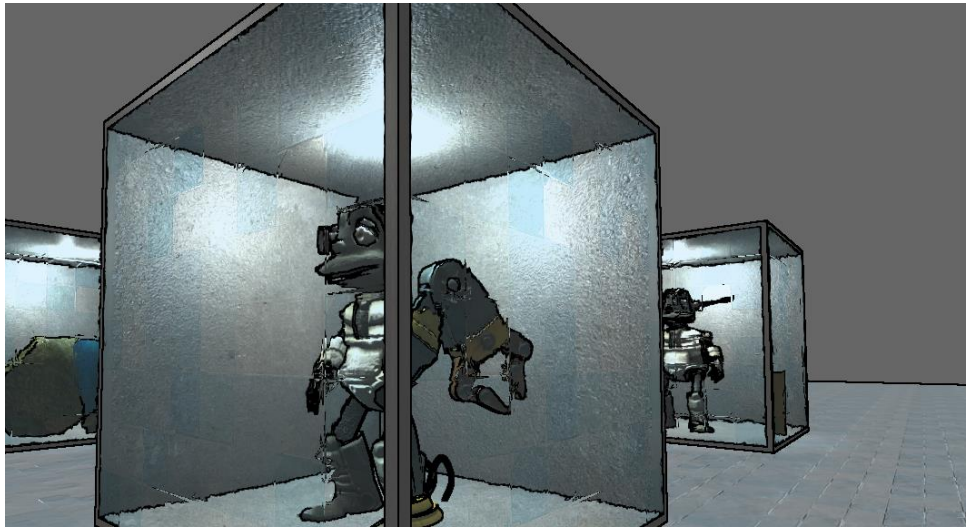

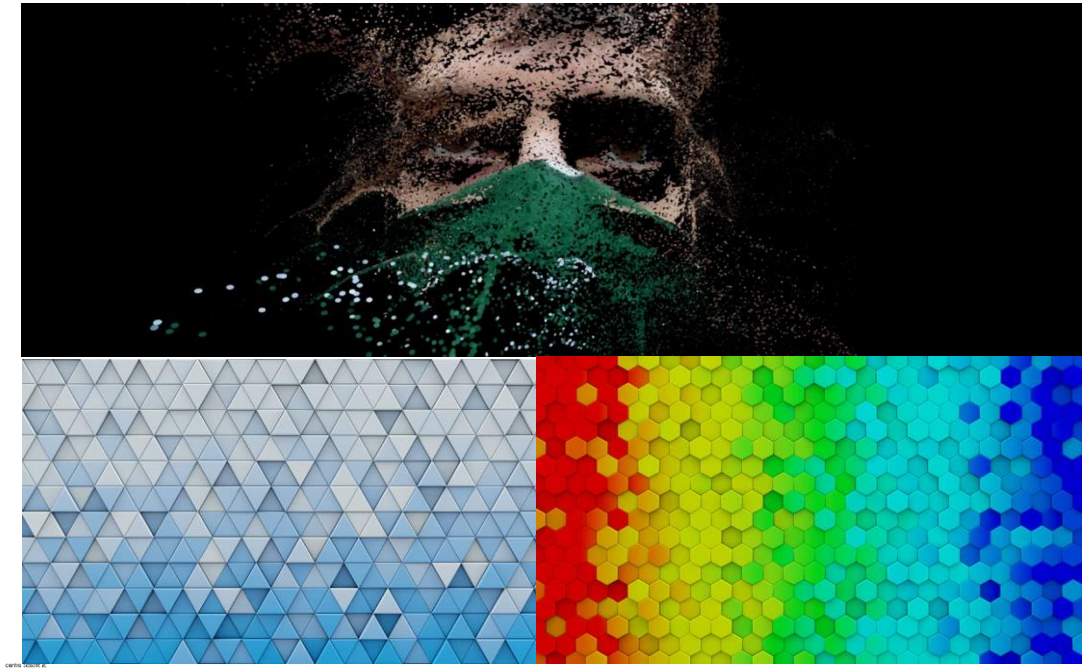

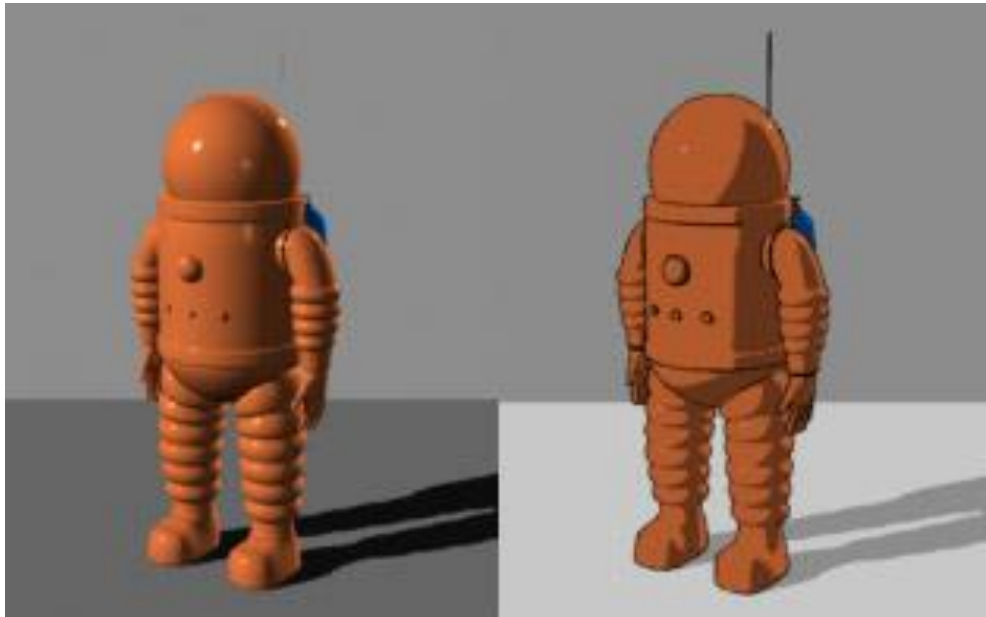

Resources

- [Angel2011] Edward Angel, Dave Shreiner (2011) *Interactive Computer Graphics: A Top-down Approach Using Opengl*, 6th Edition. Pearson education

- [Khronos,2018] https://www.khronos.org/opengl/wiki/Rendering_Pipeline_Overview, accessed 02/2018