

Introduction to Computer Graphics

Concepts

Scenes

Computer Graphics

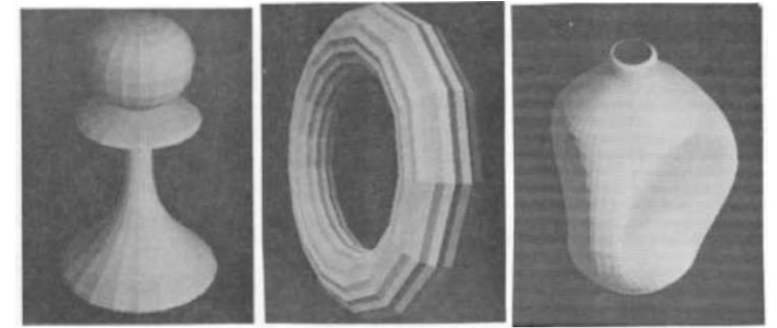
Concerned with generating images with a computer

- Small field until the 1980's
- Mostly hacks & cheats

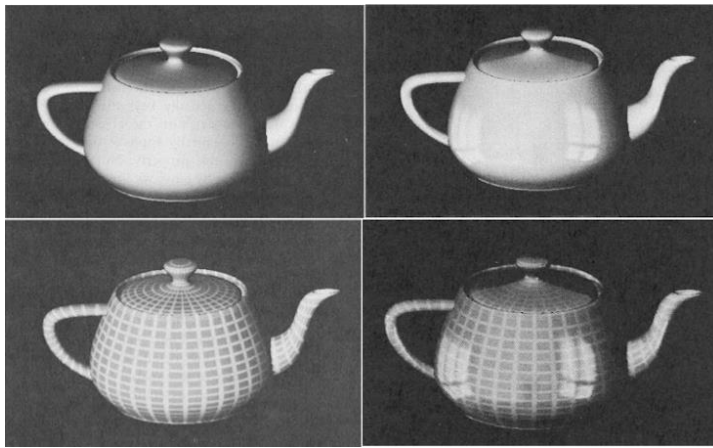
Processing power increased tremendously

- More and more advanced techniques

Nowadays its own field of applied mathematics



Newell 1972 [wikipedia]

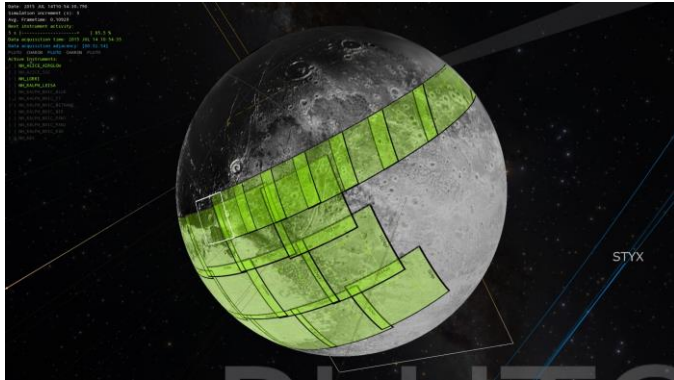


Utah teapot by Newell and Blinn 1975



[wikipedia]

Application Areas



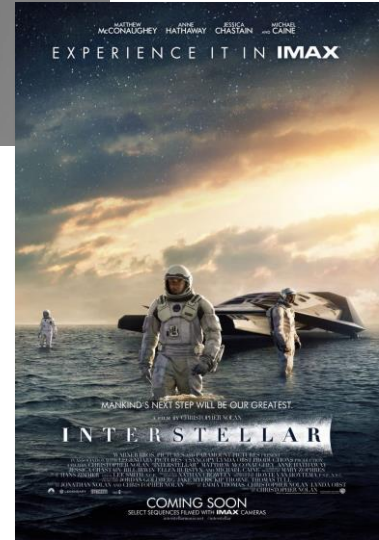
Data visualization



Architecture



Design / CAD



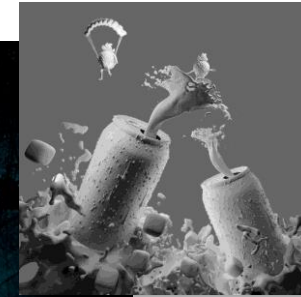
Movies



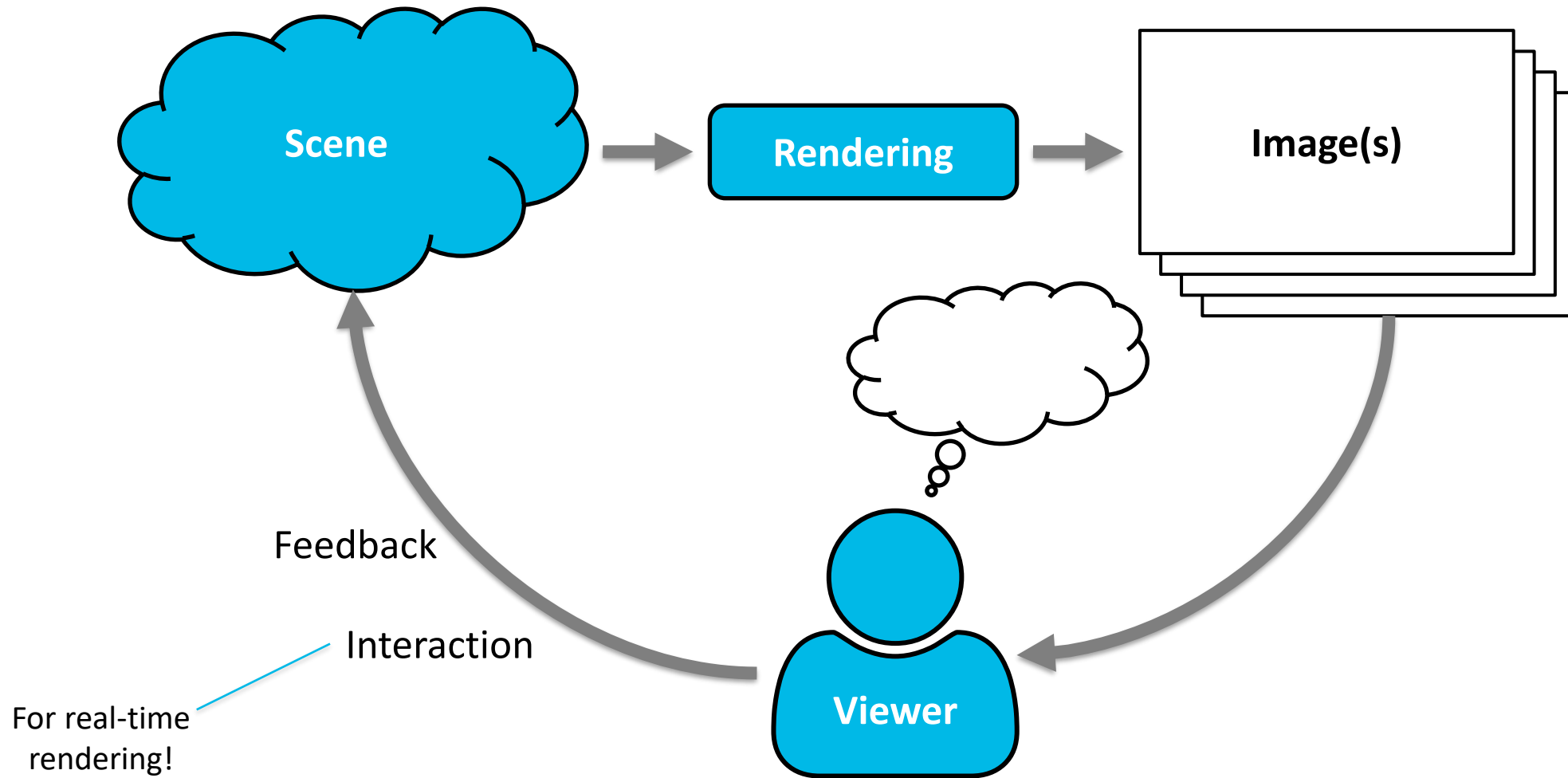
Video games



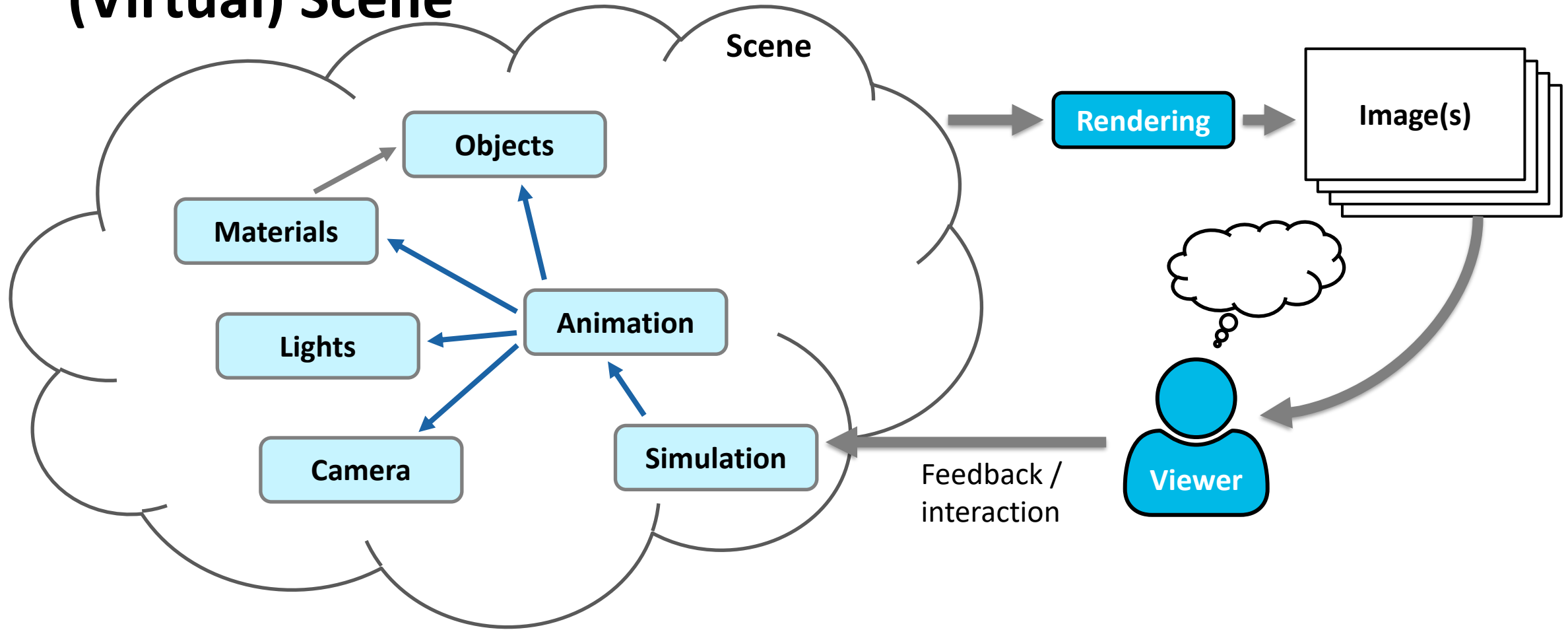
Advertising



Computer Graphics Pipeline (conceptually)



(Virtual) Scene



Scenes can be large and complex

- Requires careful design to be efficient and useful

Camera

Projection from 3D (scene) to 2D (image)

Central perspective projection

- “Pinhole camera” with no lenses
- Others possible (orthographic, stereo, fish-eye, ...)

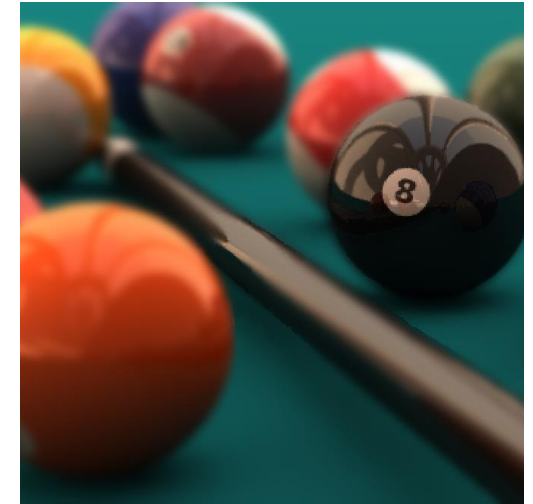
No imperfections like in real cameras

- Out of focus, lens distortions, color aberrations
- Depth of field, bokeh, motion blur, glare
- ...

Additional efforts needed to simulate those



Macro photography with
depth of field

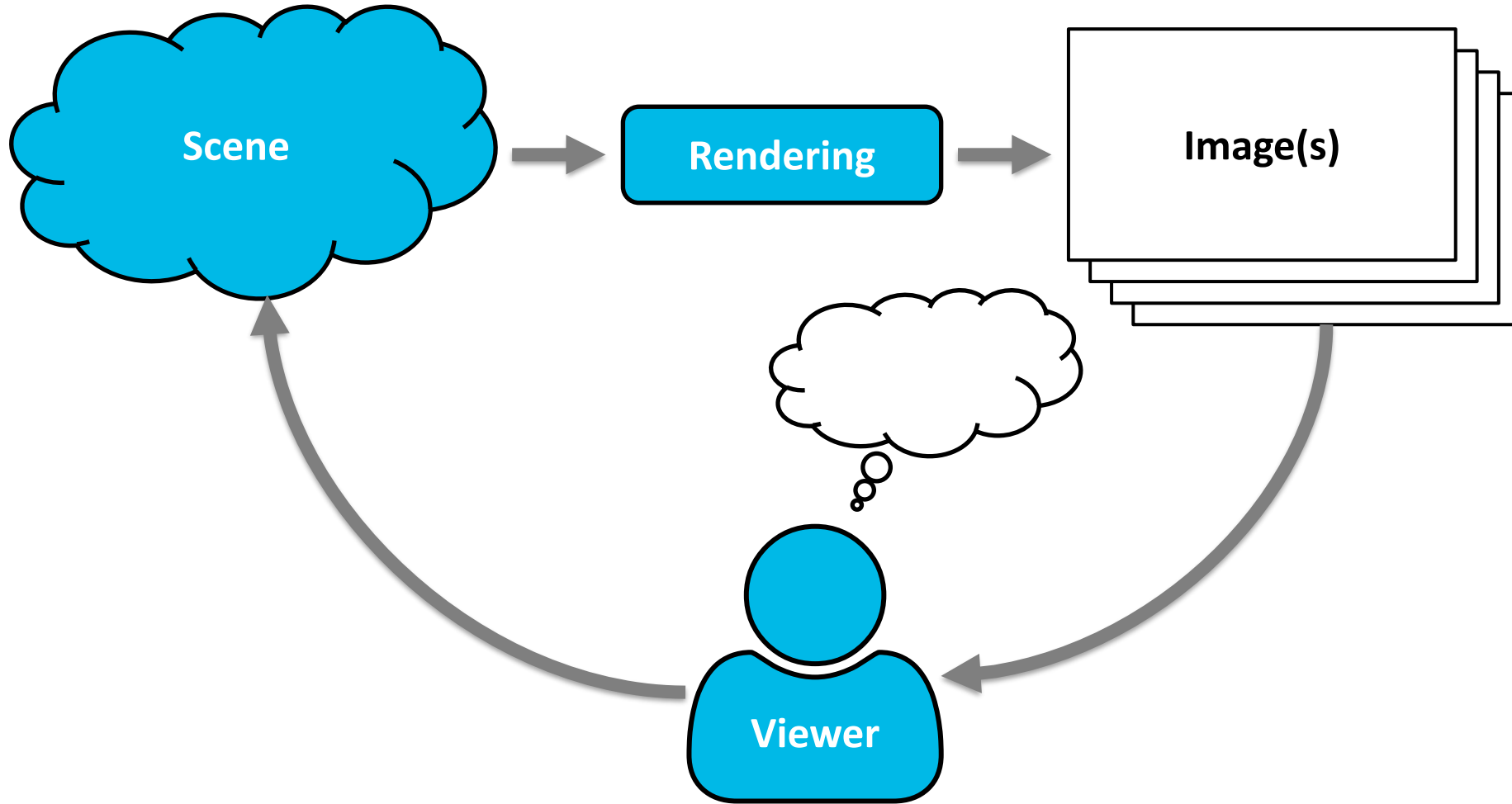


Computer-generated
scene



Artificial lens flare

How quickly should we render (or show) images?



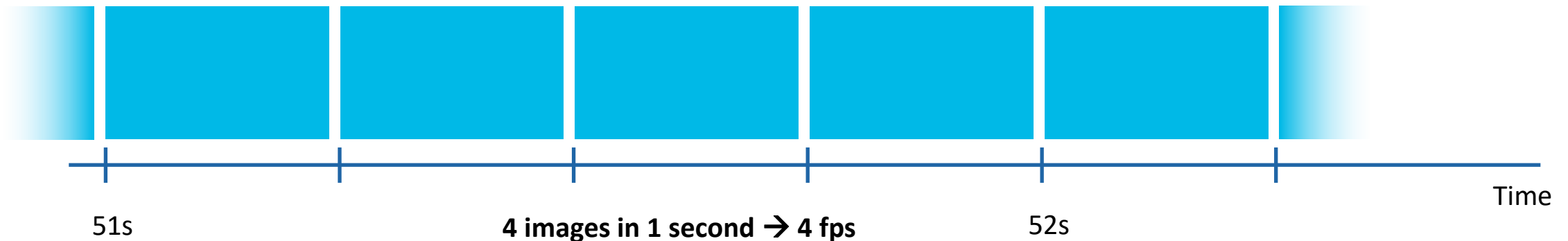
Frame Rate

Number of shown images per time period

- Typically given in **frames per second** (fps)
- Sometimes in **Hertz** (Hz)

Also used when recording & capturing images

| Format | Frame rate |
|-----------------|---------------------------------|
| Cinema / movies | 24 fps |
| Computer games | ≥ 30 fps |
| Animated Gifs | 12-15 fps ... |
| Videos | 30 fps, 60 fps, 120 fps |
| TV | 50 Hz (PAL) 59.999 Hz (NTSC) |

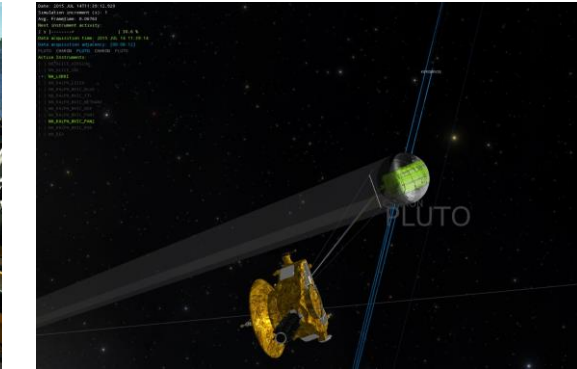


Comparing Frame Rates

Real-time Graphics vs. Offline Rendering



← more fps

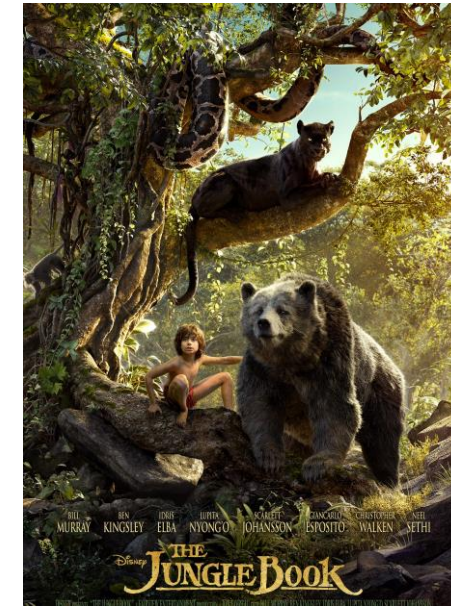


**Real Time
Rendering**

15-20 frames
per second



**Offline
Rendering**



less fps →
(minutes, hours, ...)

more realistic →

Humans perceive up to 10-12 individual images per second

Higher *frame rate* perceived as motion

- Determines time available for generating each image ($25 \text{ fps} \cong 40 \text{ ms}$ per image)
- Transition between real-time and offline rendering is blurry (depending on context)

Real-time Graphics vs. Offline Rendering (cont.)

Needs to be fast & interactive

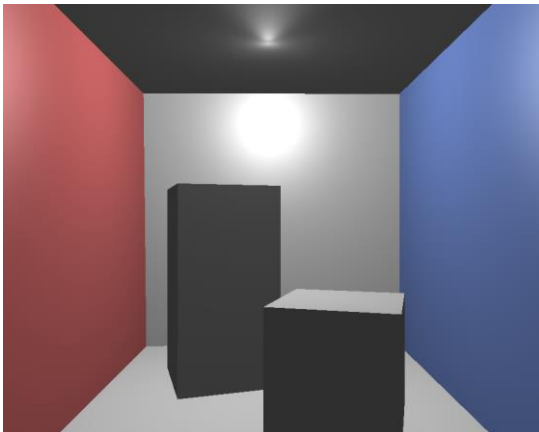
- 16ms per image at 60 fps

Everything computed on-the-fly

- Rendering, simulations, interactions
- Often on a single computer

Local illumination (approximation)

Less detailed geometry and textures



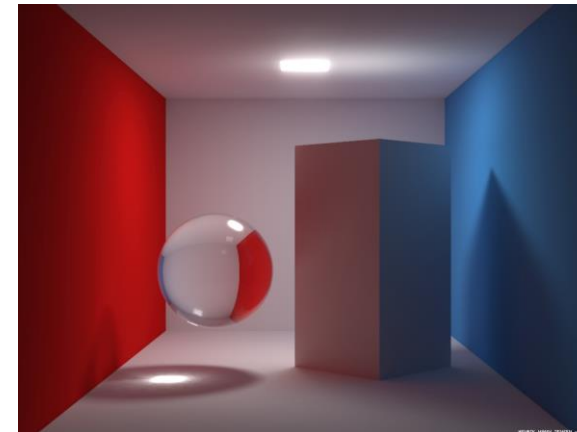
Very high visual quality

Physically-based rendering

- **Global** illumination

Takes time

- Minutes or hours per image
- Computed on single machine or compute clusters



Cornell Box by Henrik Wann Jensen,
graphics.Stanford.edu





Local illumination

Global illumination

Latest GPUs simulate some global effects in real time

- Reflections and refractions
- Global illumination
- ...

Faked reflections

Reflections via ray tracing

[NVIDIA RTX]

CYBERPUNK
2077

Summary

– Introduction to Computer Graphics –

Computer graphics is ubiquitous

- Animation, images, advertising, movies, games

Scenes hold the necessary information

- Objects, materials, lights, camera, animation, simulation...

Images are generated by rendering virtual scenes

Difference between real-time graphics and offline rendering

Coming up next

Hierarchical transformations

Scene graphs