The Real-Time Graphics Pipeline

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The Key Idea

Basic task in computer graphics is ***render*** 3-dimensional objects:

- given a scene composed of geometric objects in 3d space;
- produce a 2d image showing the objects from a specific viewpoint.

Two methods of rendering:

- ***object-order rendering***: for each object, which pixels are influenced by it?
  - Example: rasterisation.
- ***image-order rendering***: for each pixel, which object is influenced by it?
  - Example: ray-tracing.

Real-Time Rendering

Real-time rendering refers to the process of rendering a scene in less than $1/30^{\text{th}}$ of a second (i.e., refresh rate > 30 Hz).

- Real-time rendering refers to rendering that is fast enough to allow for the user's ***real-time interaction***.
- As little as 15 ms of temporal delay can slow and interfere with the interactivity.

So speed is essential for interactivity:

- For a 1080p image at 90 Hz, an image-order rendering iteration would need to be performed 186,624,000 times per second.
- Object-order rendering is (usually) faster in this case.

The Graphics Pipeline

The main function of the ***graphics pipeline*** is:

- Given a virtual camera, 3d objects, light sources, etc., render a 2d image;
- Object locations and shapes determined by their geometry, environment, camera placement, etc.;
- Object appearance affected by material, light sources, shading, etc.

Some key ideas regarding the pipeline are:

- Consists of several states, with each making up part of a larger task;
- The states execute in parallel, with each stage dependent on the result from the previous.

Pipeline Stages

The main stages of the pipeline are:

- Given a virtual camera, 3d objects, light sources, etc., render a 2d image;

Tables and Figures

- Use `tabular` for basic tables — see Table 1, for example.
- You can upload a figure (JPEG, PNG or PDF) using the files menu.
- To include it in your document, use the `includegraphics` command (see the comment below in the source code).

Examples

Some examples of commonly used commands and features are included, to help you get started.

Item	Quantity
Widgets	42
Gadgets	13

Table 1: An example table.

Readable Mathematics

Let $X_1, X_2, \ldots, X_n$ be a sequence of independent and identically distributed random variables with $\mathrm{E}[X_i] = \mu$ and $\mathrm{Var}[X_i] = \sigma^2 < \infty$, and let

$$S_n = \frac{X_1 + X_2 + \cdots + X_n}{n} = \frac{1}{n} \sum_{i}^{n} X_i$$

denote their mean. Then as n approaches infinity, the random variables $\sqrt{n}(S_n - \mu)$ converge in distribution to a normal $\mathcal{N}(0, \sigma^2)$.