

Shader

Introduction

What are Shaders?

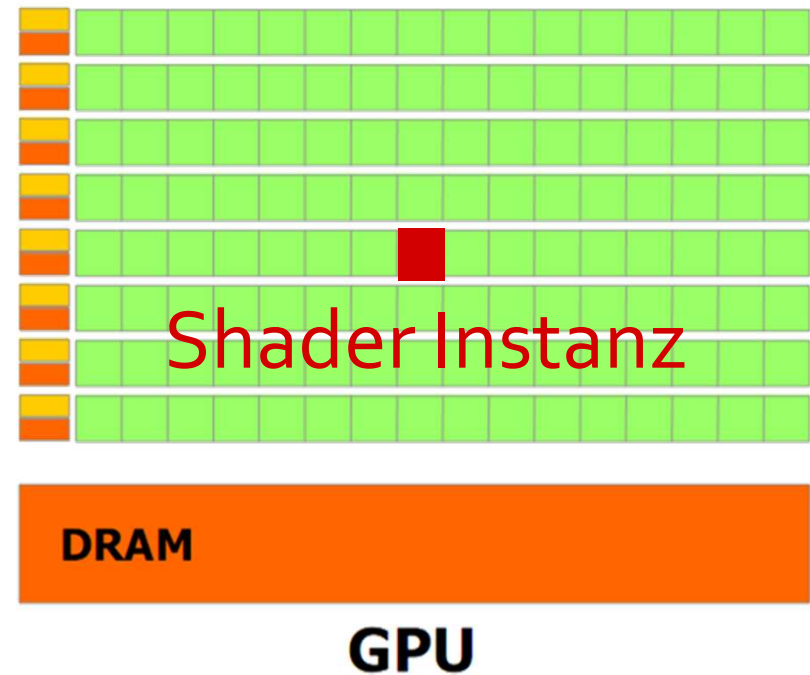
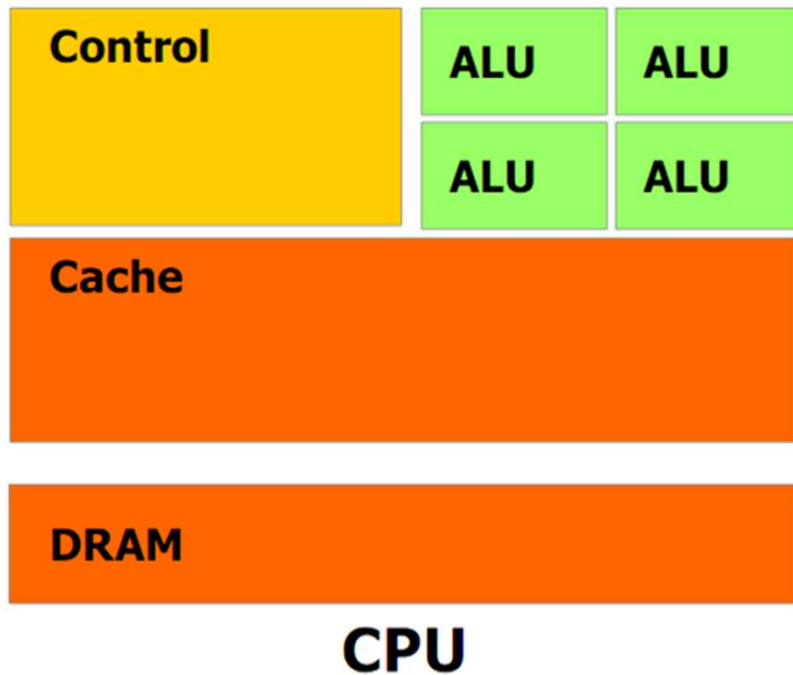
- Program
- Originally
 - „to shade“ (engl.): etwas schattieren (ge)
 - RenderMan, Pixar
 - Implements rendering effect
- Today
 - Executed on **GPU**
 - Many instances in **parallel** (>> 1000)
 - Processes stream of data „**stream programming**“

GPU = Graphics Processing Unit



Hardware comparison

- CPU uses more transistors for control and buffering
- GPU uses more transistors for processing



What are Shaders?

- Wikipedia:

„A shader in the field of computer graphics is a set of software instructions, which is used primarily to calculate rendering effects on graphics hardware with a high degree of flexibility.“

Why not use the CPU?

- CPUs are „general purpose“
 - Execute different tasks
- Programmed with general purpose languages
 - C++, Java, ...
- Not particularly good at graphics tasks
 - Repeated similar largely independent tasks

Why not use the CPU?

- GPU (Graphics Processing Unit)
 - Processes tens of millions of vertices per second
 - Rasterizes billions of pixels per second
- Cannot execute arbitrary, general purpose programs like the CPU
- Need for (specialized) language for programming the GPU
 - a shader language!

Assembly or high-level....

Assembly

```
...
DP3 R0, c[11].xyzx, c[11].xyzx;
RSQ R0, R0.x;
MUL R0, R0.x, c[11].xyzx;
MOV R1, c[3];
MUL R1, R1.x, c[0].xyzx;
DP3 R2, R1.xyzx, R1.xyzx;
RSQ R2, R2.x;
MUL R1, R2.x, R1.xyzx;
ADD R2, R0.xyzx, R1.xyzx;
DP3 R3, R2.xyzx, R2.xyzx;
RSQ R3, R3.x;
MUL R2, R3.x, R2.xyzx;
DP3 R2, R1.xyzx, R2.xyzx;
MAX R2, c[3].z, R2.x;
MOV R2.z, c[3].y;
MOV R2.w, c[3].y;
LIT R2, R2;
...
```

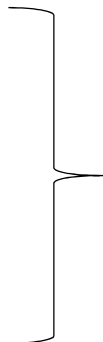
or

GLSL

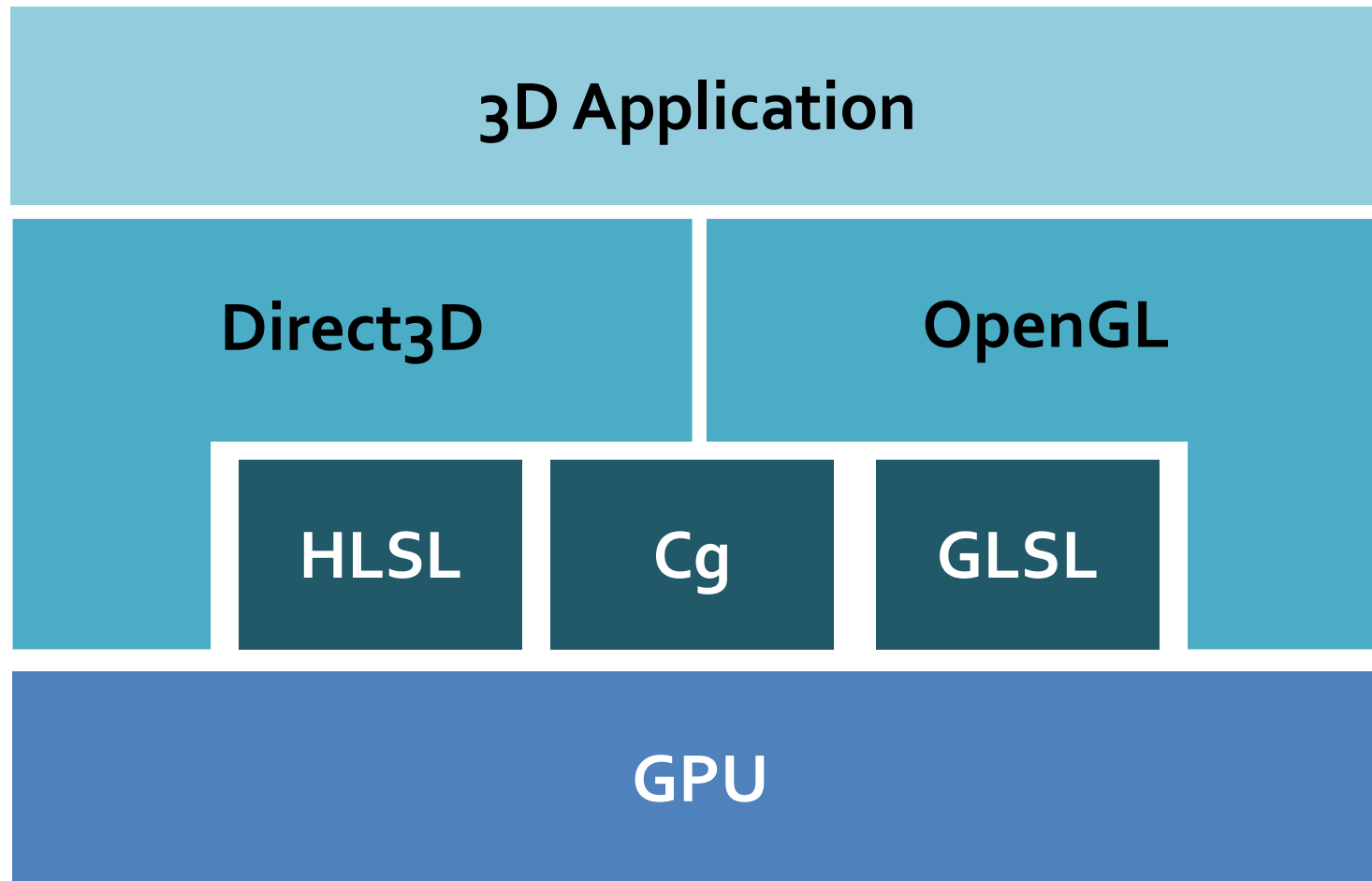
```
...
vec4 cPlastic =
    Ca +
    Cd * dot(Nf, normalize(L)) +
    Cs * pow(max(0,
dot(Nf,normalize(H))),
    phongExp);
...
```



High-level Shader Languages

- **HLSL** (Direct3D)
 - **Cg** (Direct3D, OpenGL)
 - **GLSL** (OpenGL)
- 
- very similar to C++/C#
- We focus on GLSL
 - Concepts easy to transfer to other shading languages

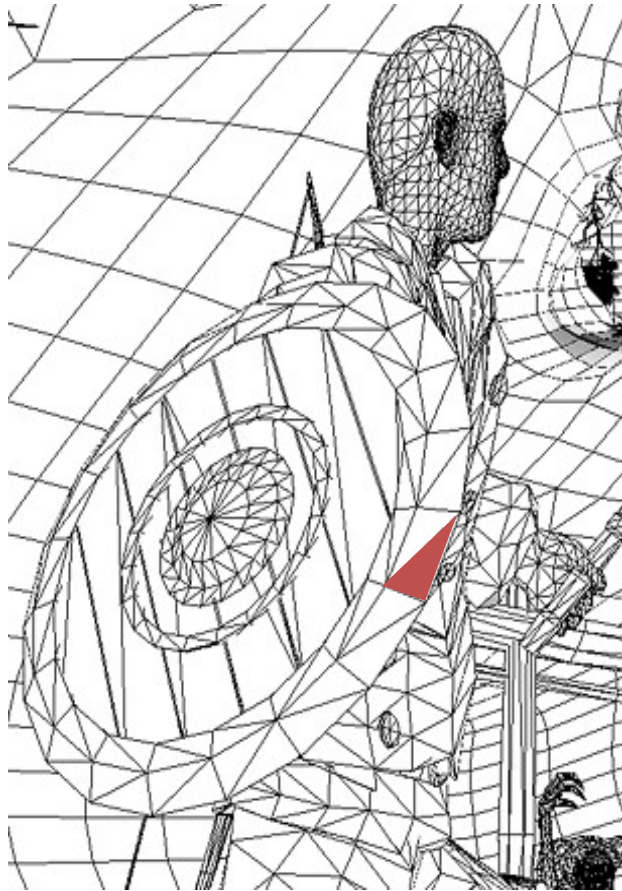
Application & API Layers



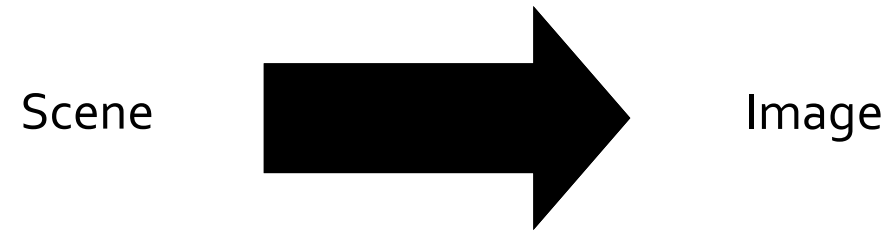
Shader

Principles

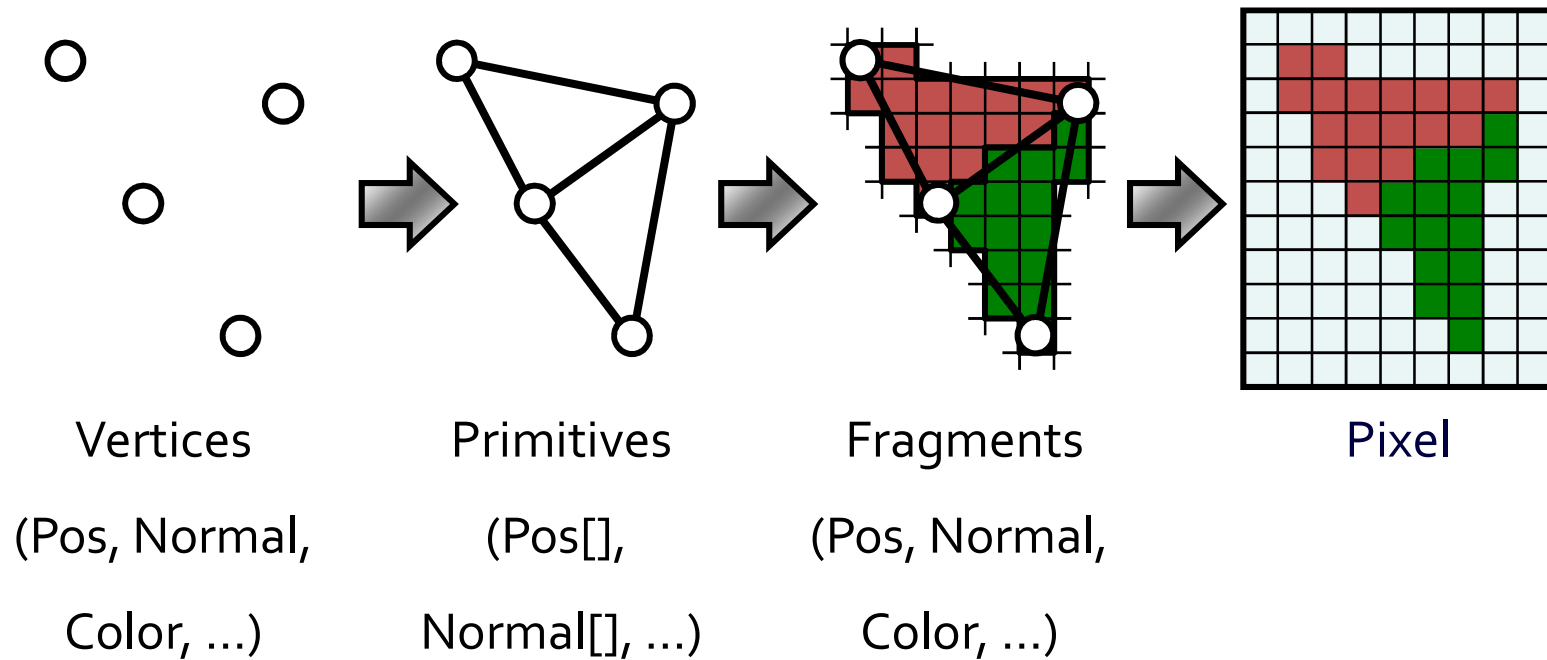
Rendering



Rendering by Graphics Hardware

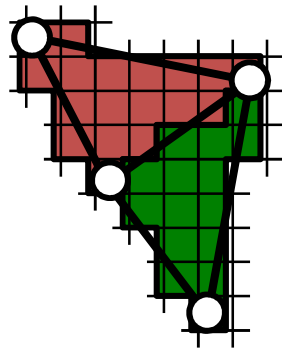


Rendering by Graphics Hardware

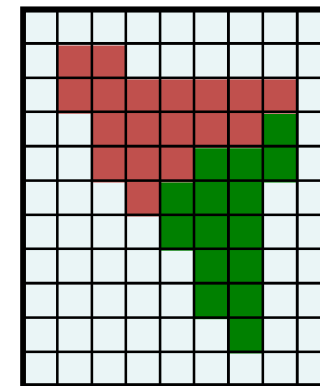


Fragment = „potential pixel“

- For each pixel that a primitive covers a fragment is created
- If a fragment passes the various rasterization tests (Stencil Test, Depth Test ...) it updates a pixel in the frame buffer.

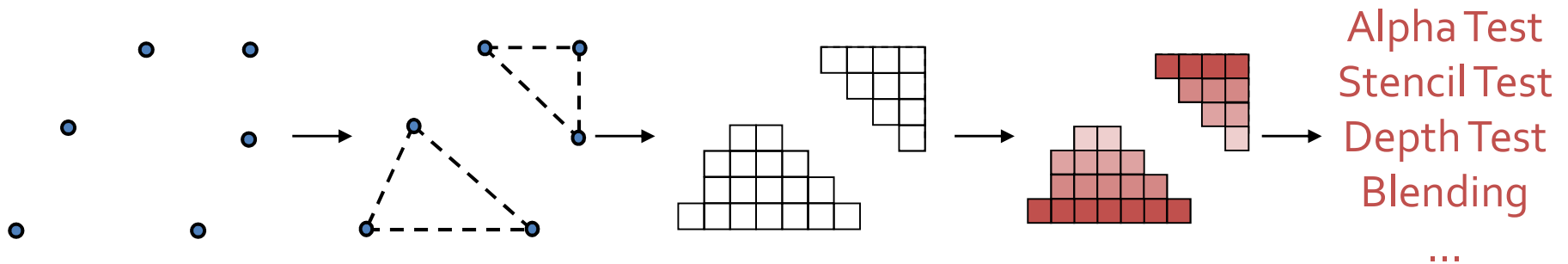
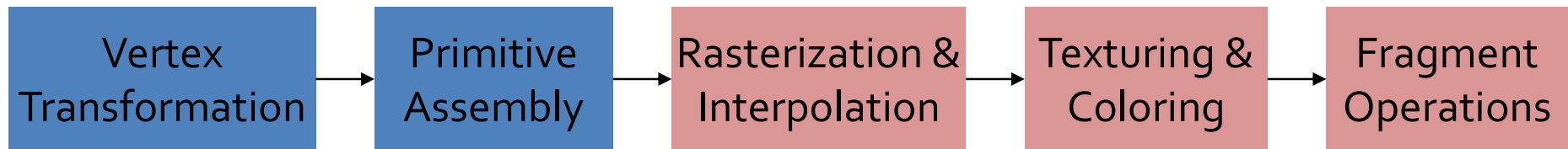


Fragments (Pos, Normal, Color, ...)

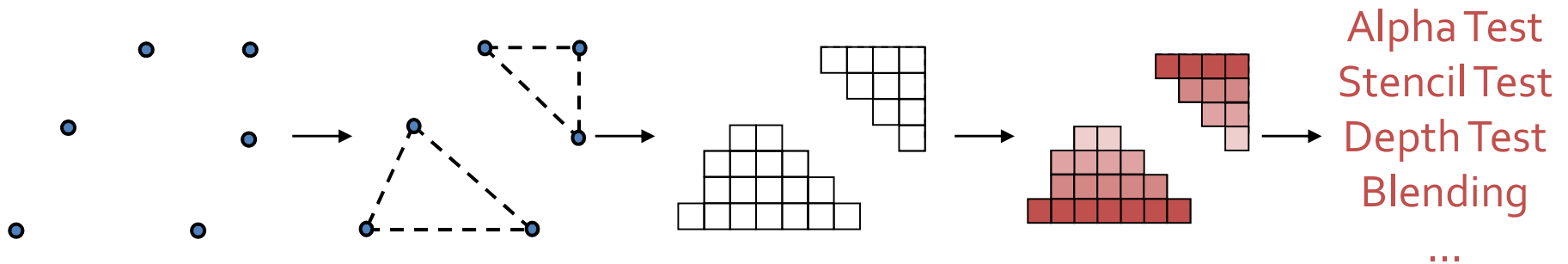
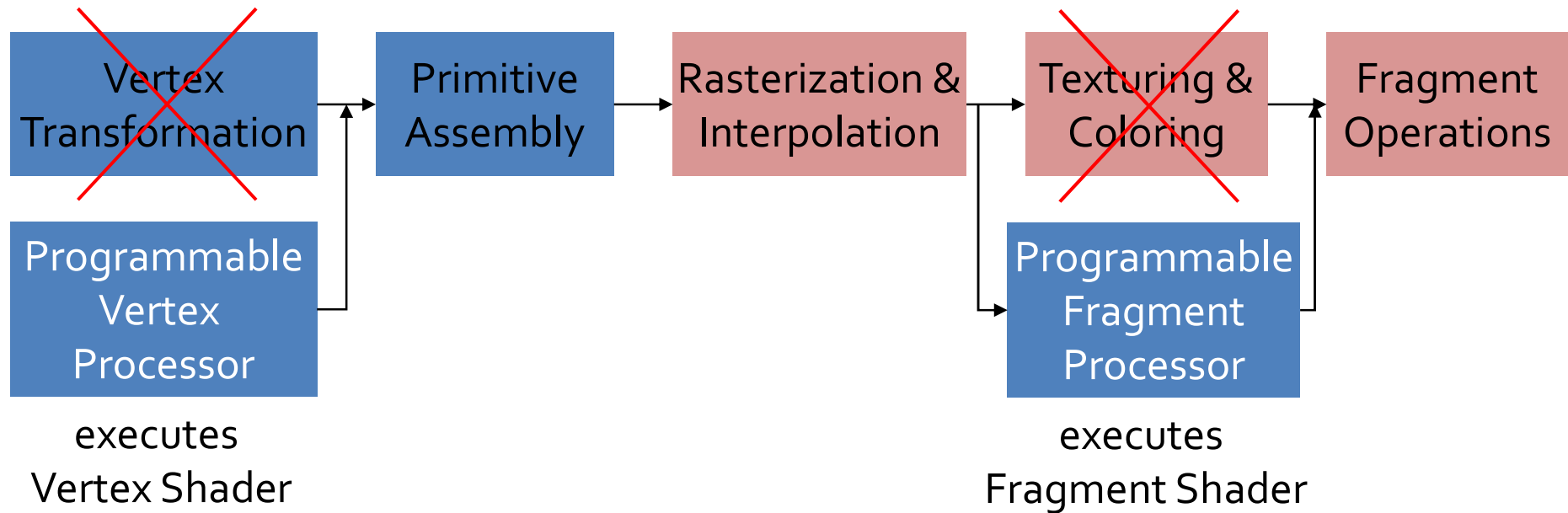


Pixel (Color)

The Hardware 3D Pipeline



The Hardware 3D Pipeline

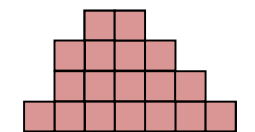
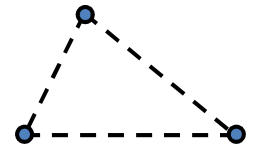
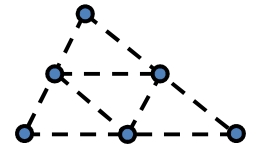


The Hardware 3D Pipeline

- Vertex and Fragment Shaders replace parts of the fixed function pipeline
- Implement replaced functionality yourself
 - Transformation & Lighting
 - Texturing & Coloring
- Gain freedom and flexibility how to implement

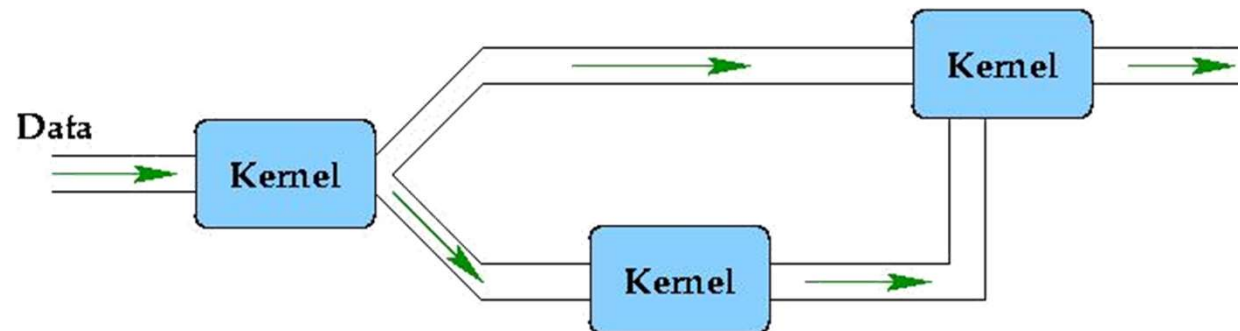
Types of Shader

- Vertex Shader
 - Per vertex
- Tessellation Shader
 - Per patch
 - Introduced with DirectX 11 / OpenGL 4
- Geometry Shader
 - Per primitive (i.e. Triangle)
 - Introduced with DirectX 10 / OpenGL 3.2
- Fragment Shader (aka Pixel Shader)
 - Per fragment

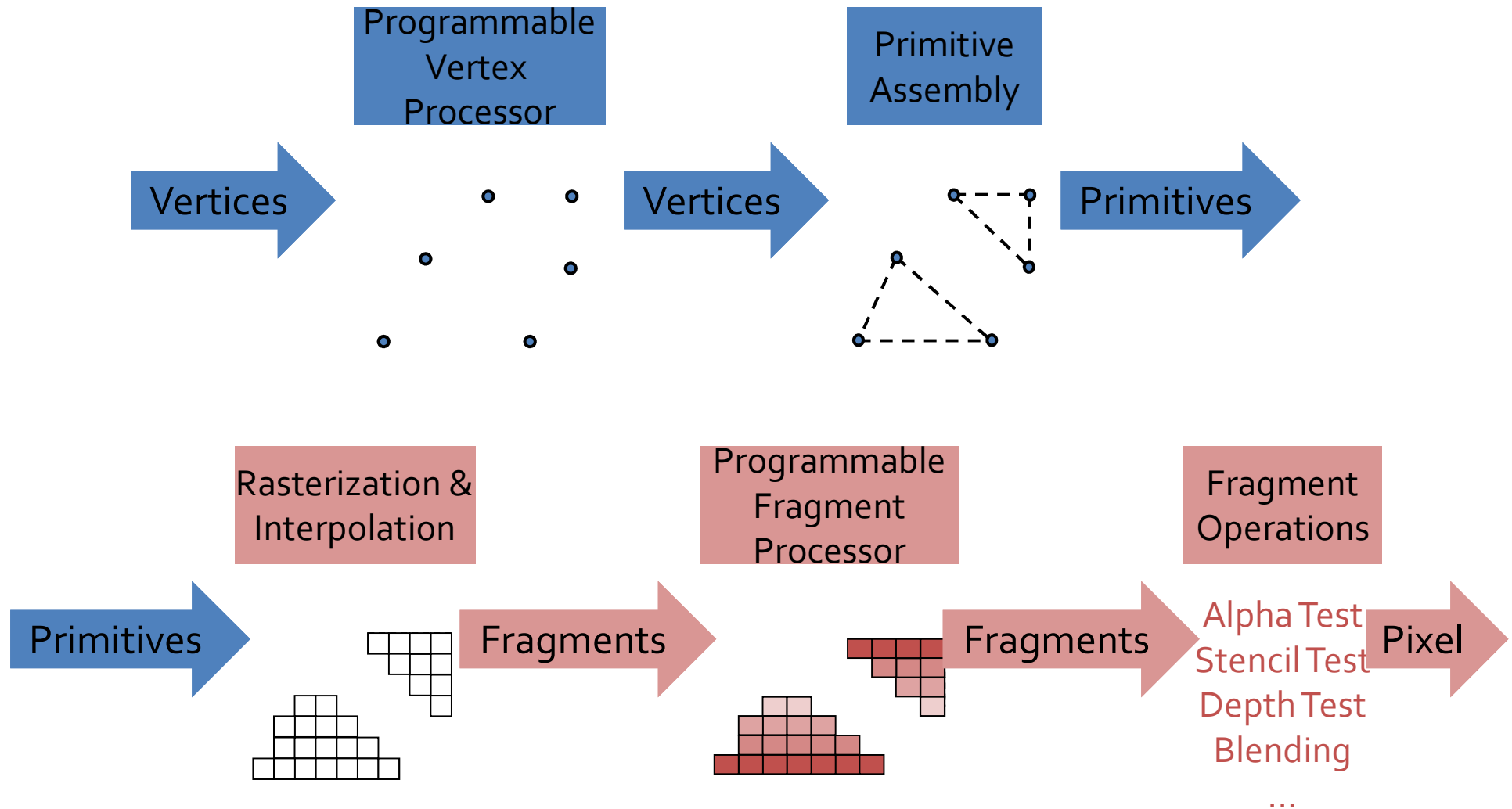


Stream programming

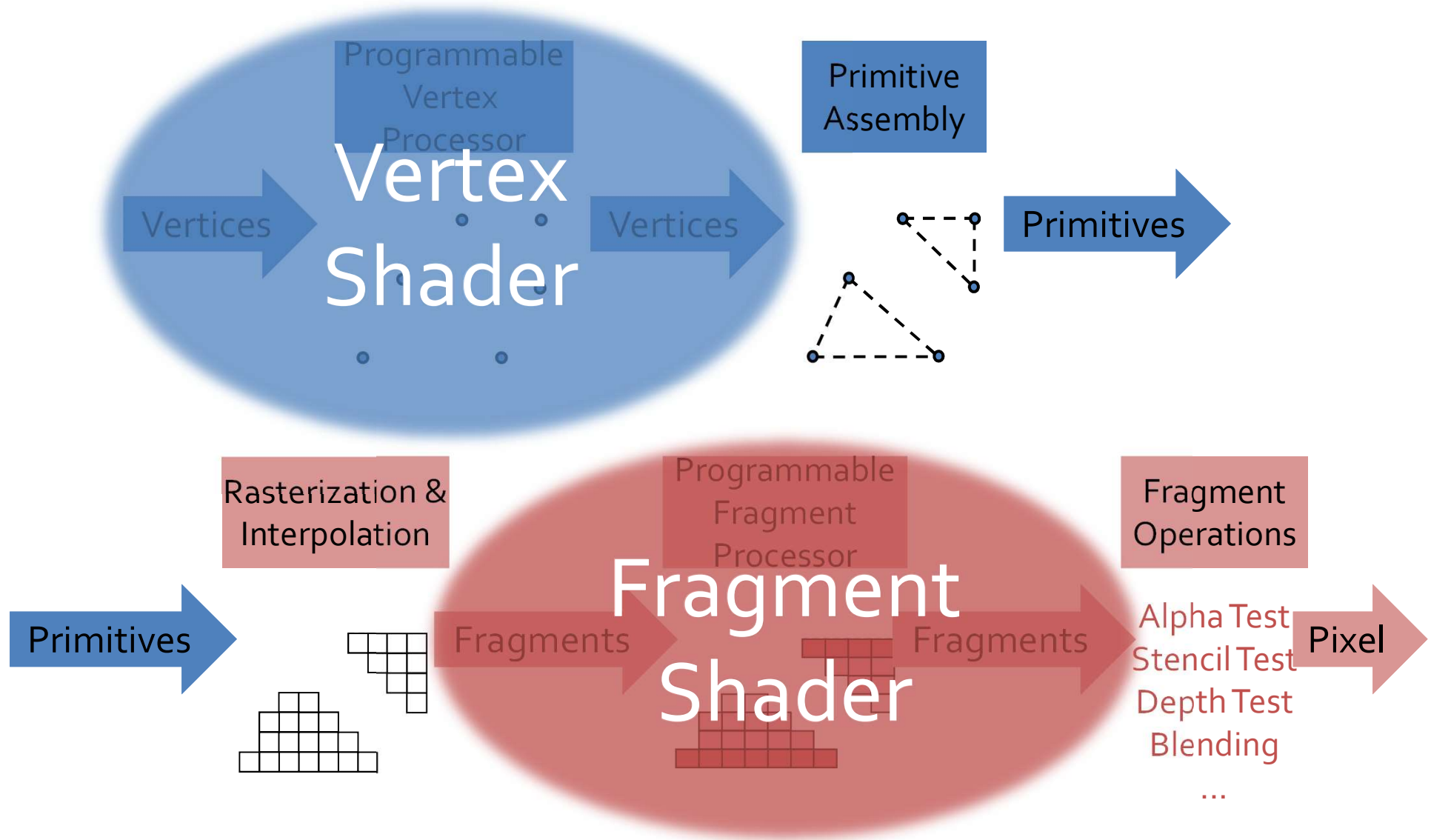
- **Stream:** sequence of data
 - Scalars, vektors, colors, ...
 - Example: { (pos, color); (pos, color); ... }
- Shader ("kernel") program
 - Each processes one element of input stream
 - **Read only**
 - Creates output stream
 - **Write only**



The Hardware 3D Pipeline as a stream



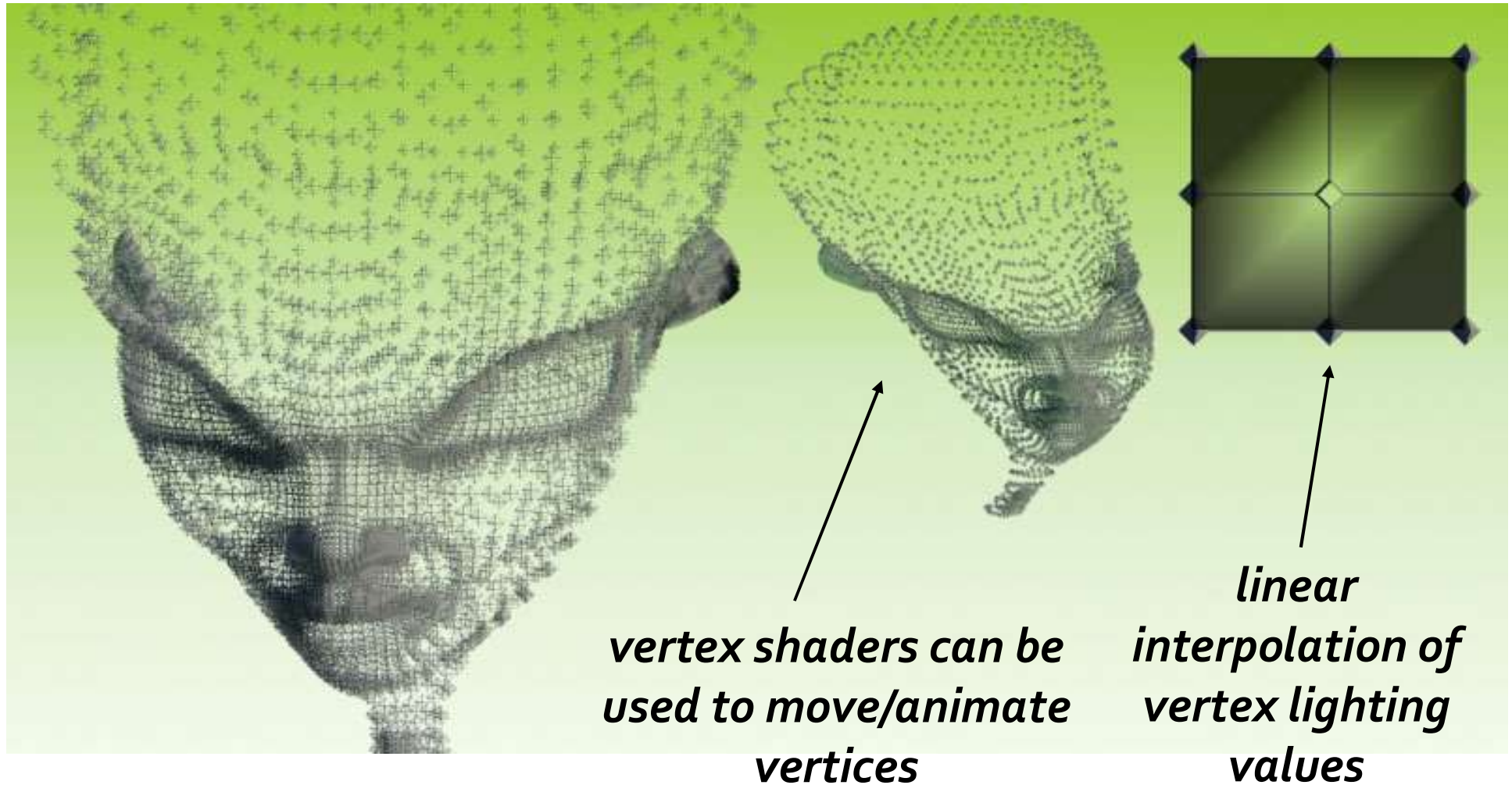
The Hardware 3D Pipeline as a stream



Shader

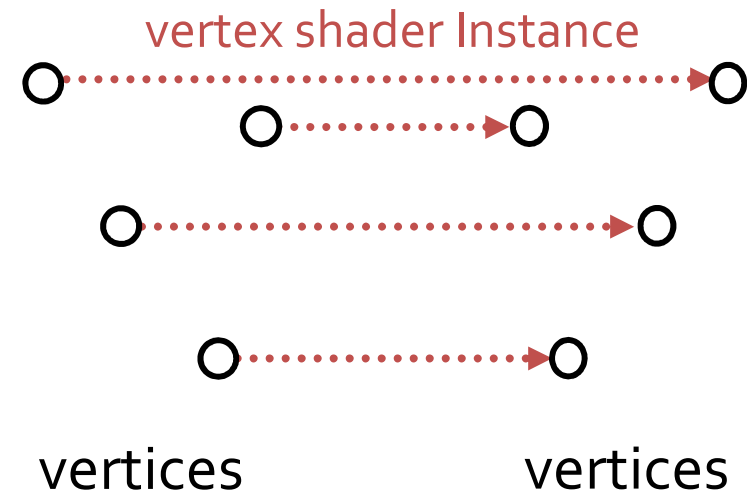
Vertex and Fragment Shader

Vertex shader



Vertex shader

- Input stream: vertices
- Output stream: vertices



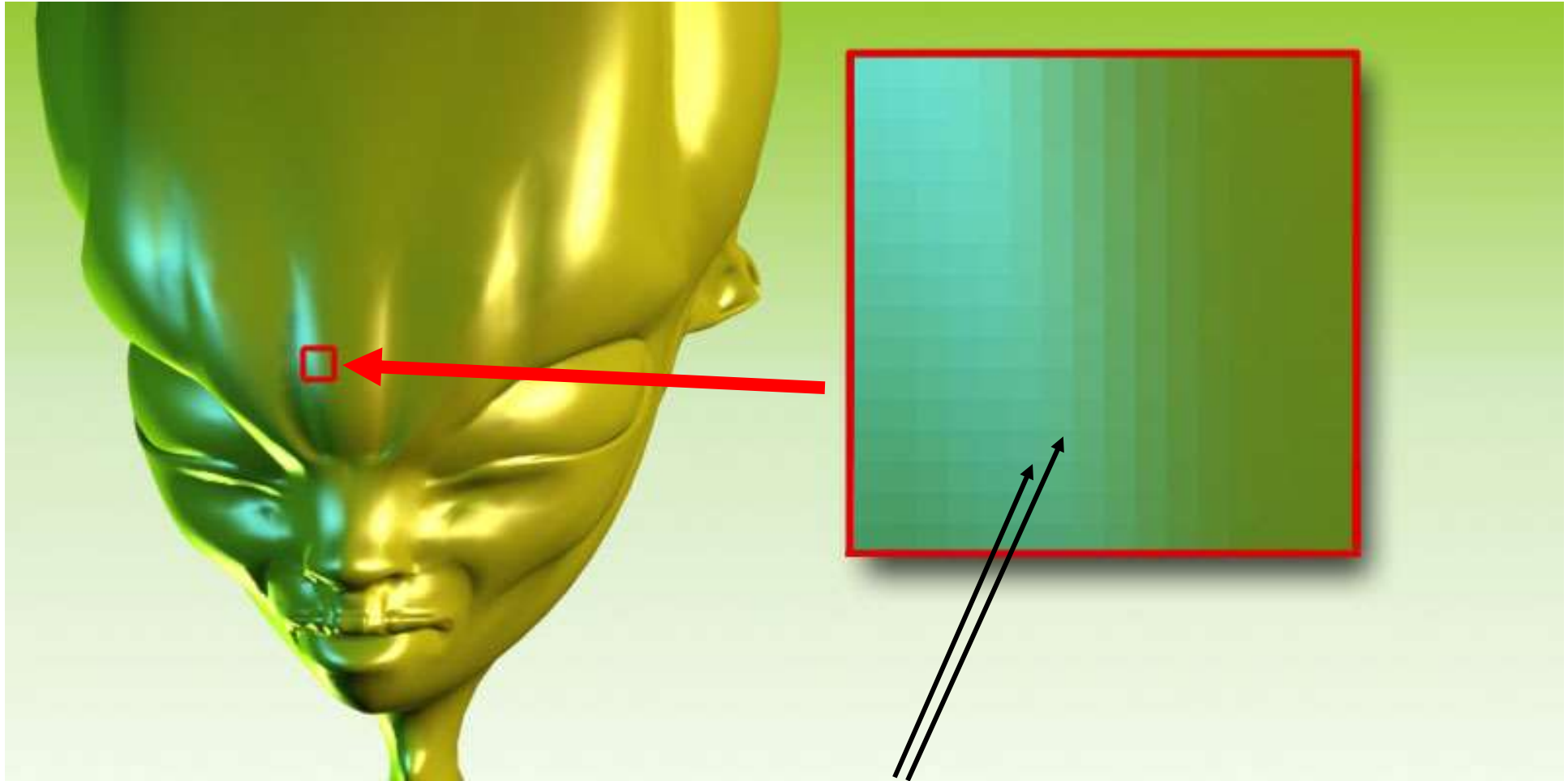
- One instance processes one vertex
- No knowledge of neighbouring vertices

Typical applications

- Transformation of vertices
 - Object space \rightarrow clipping space
 - Animation
 - Particle systems
 - Displacement Mapping
- Lighting
 - Per vertex lighting
 - Cartoon shader
 - ...



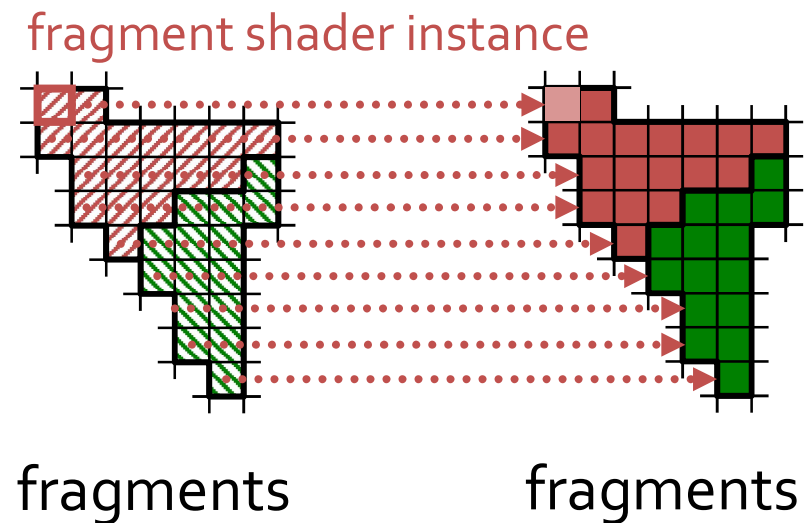
Fragment shader



Each fragment is calculated individually

Fragment shader

- Input stream: fragments
- Output stream: fragments



- One instance processes one fragment
- No knowledge of neighbouring fragments

Application - per fragment lighting

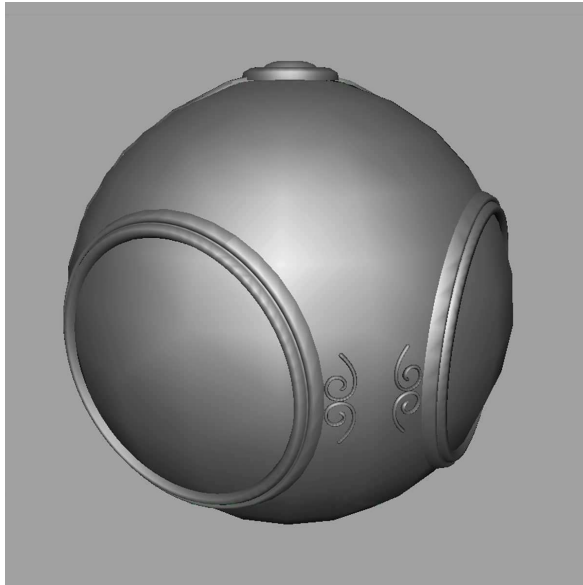


per vertex



per fragment

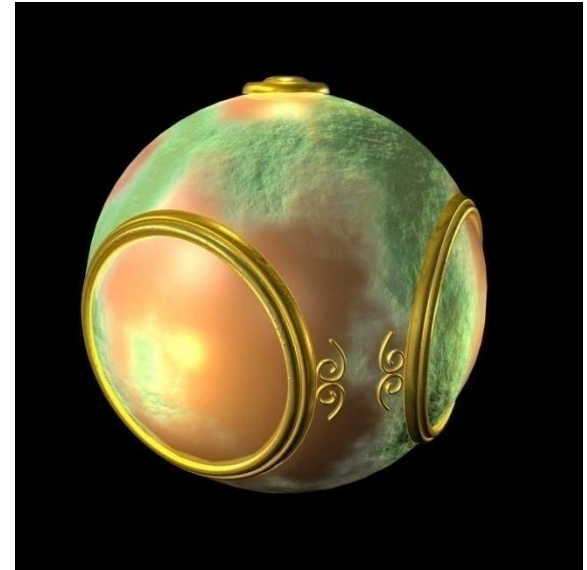
Application - texture mapping



smooth shading



environment
mapping



bump mapping

Interpolation

