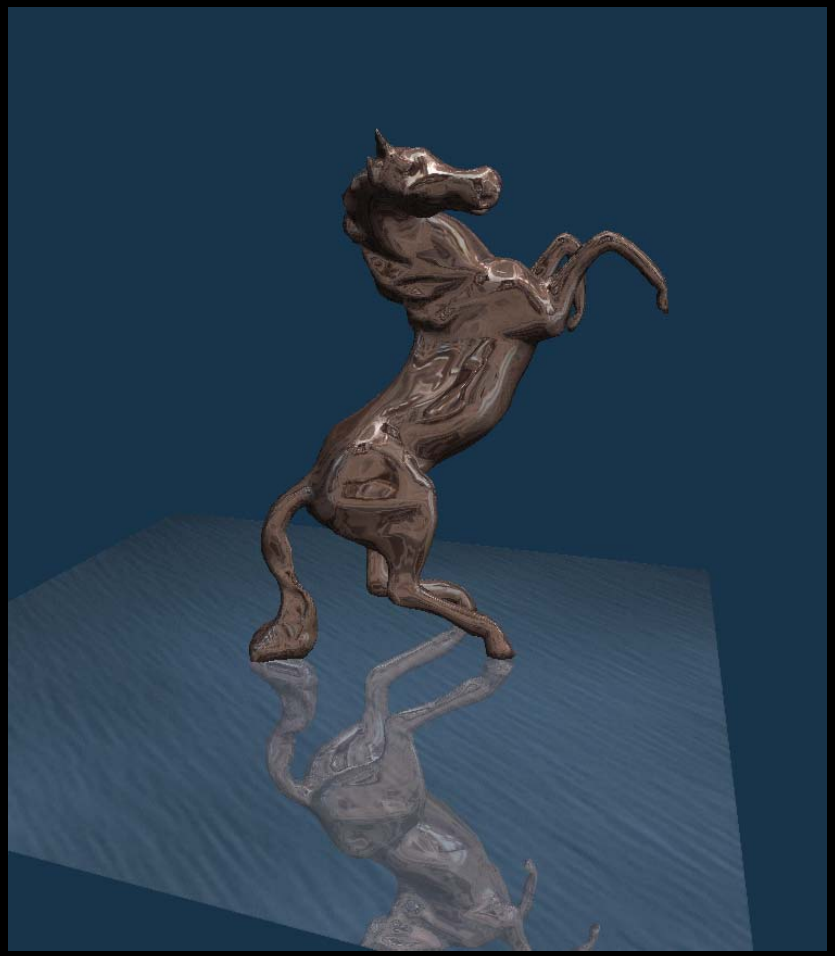
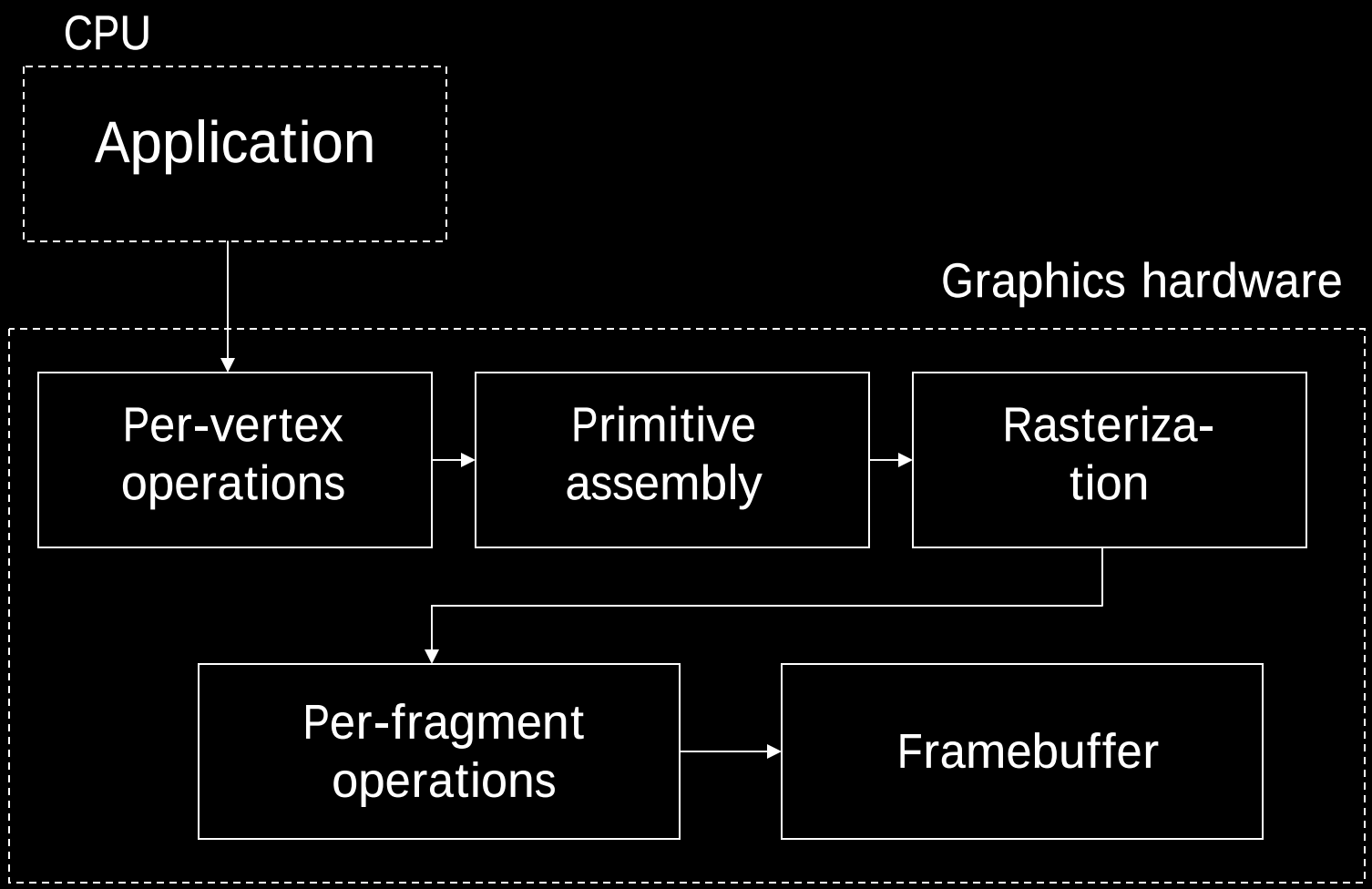


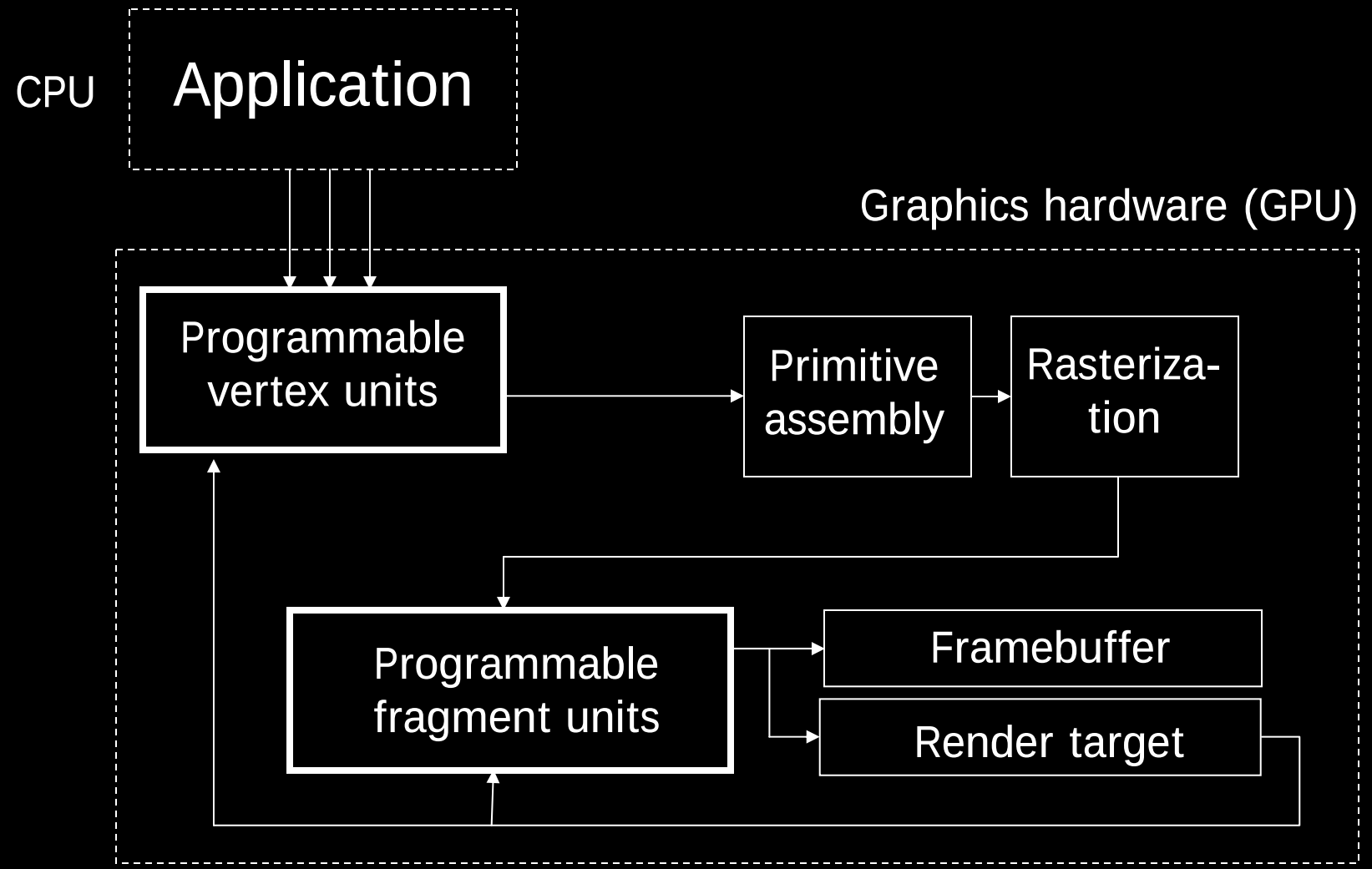
OpenGL

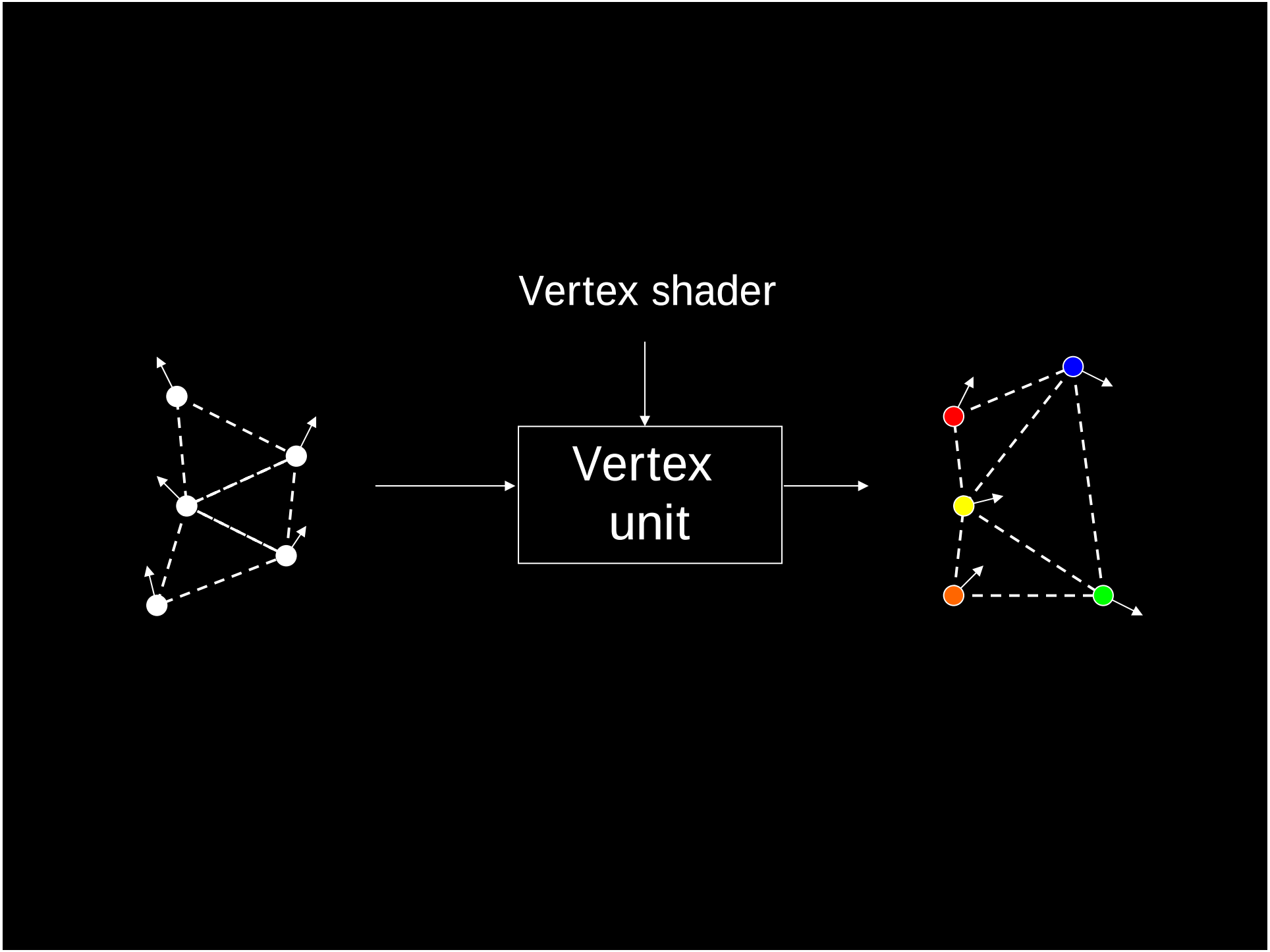
Gustav Taxén
gustavt@csc.kth.se

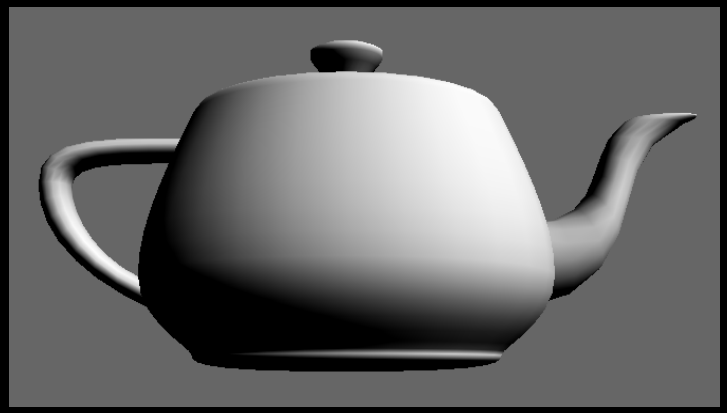
Fixed-function pipeline

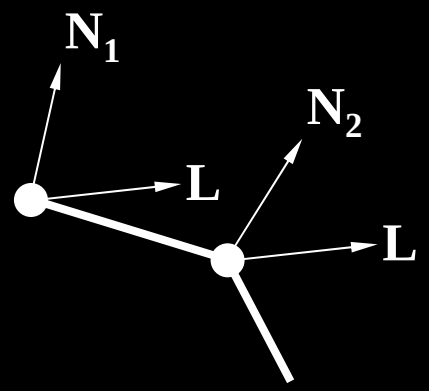


Programmerbar pipeline

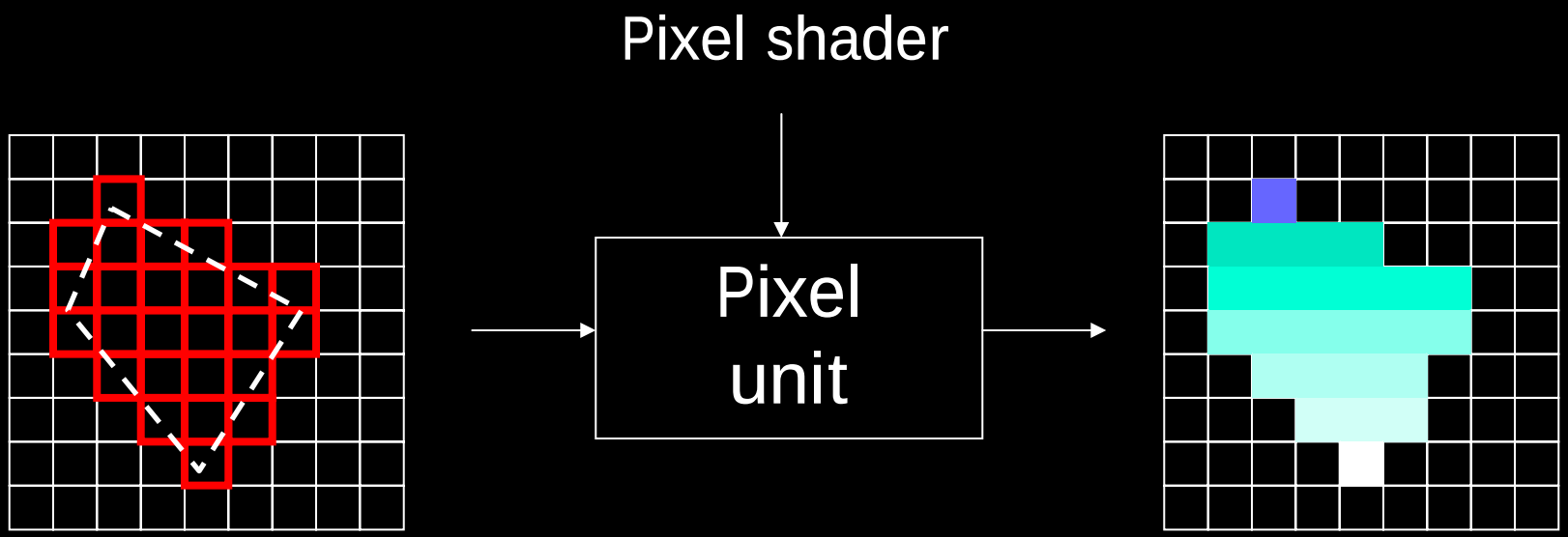


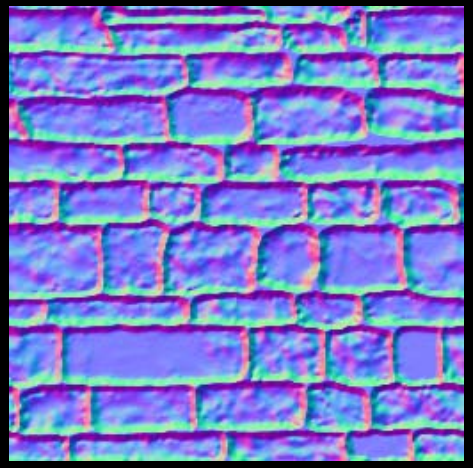

Vertex shader
Vertex
unit






```
float3 main(float3 N : NORMAL,
            uniform float3 L)
{
  float d = dot(N, L);
  return float3(d, d, d);
}
```

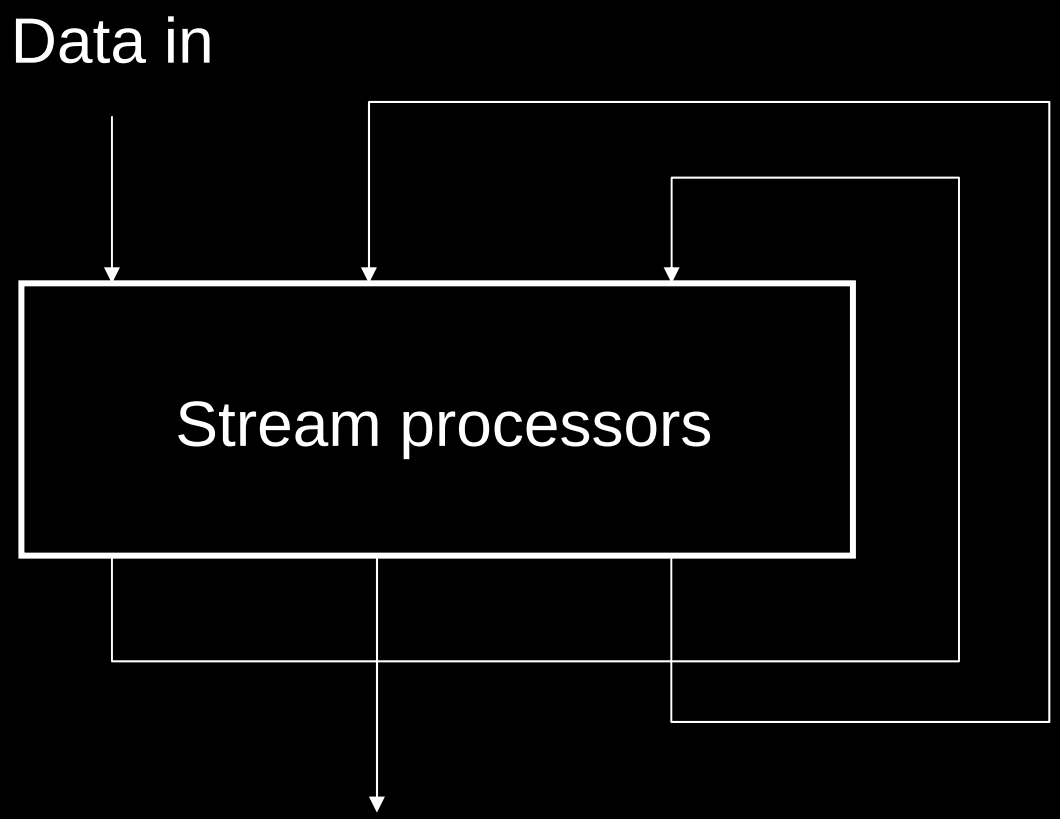

Pixel shader
Pixel
unit



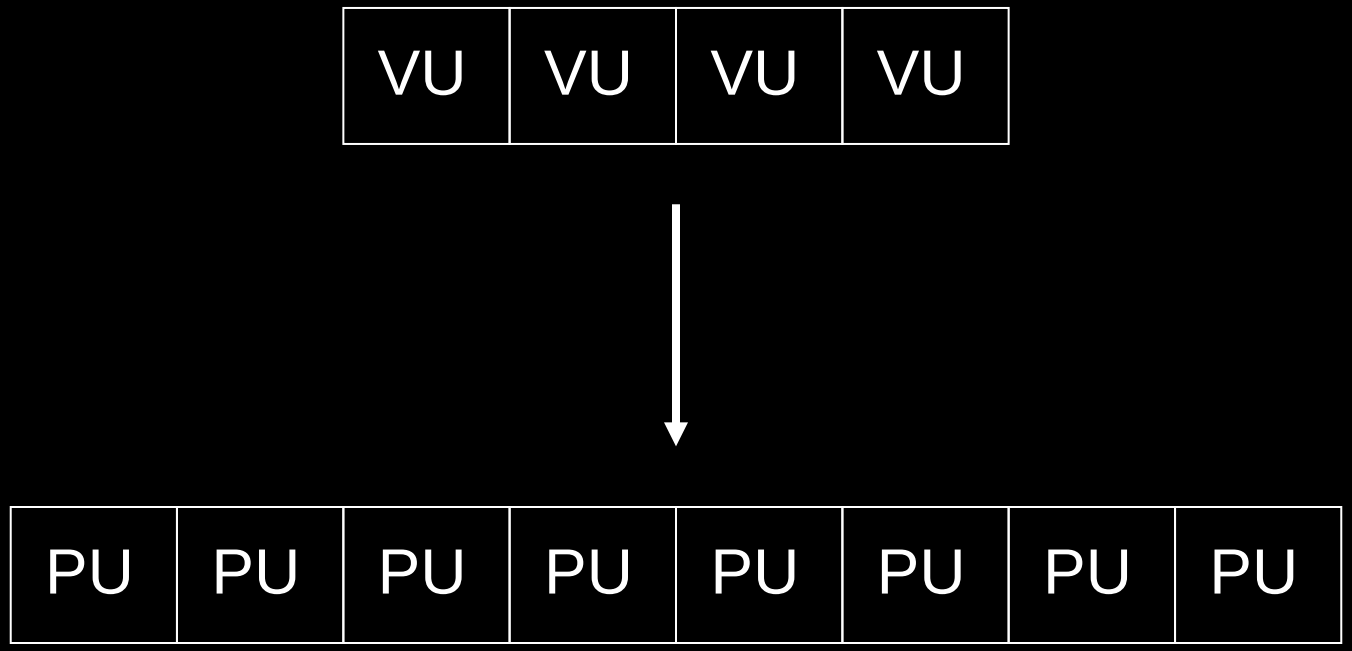
http://nehe.gamedev.net

```
float3 main(float2 uv : TEXCOORD0,
            sampler2D normalMap,
            uniform float3 L)
{
  float3 N = tex2D(normalMap, uv);
  float d = dot(N, L);
  return float3(d, d, d);
}
```

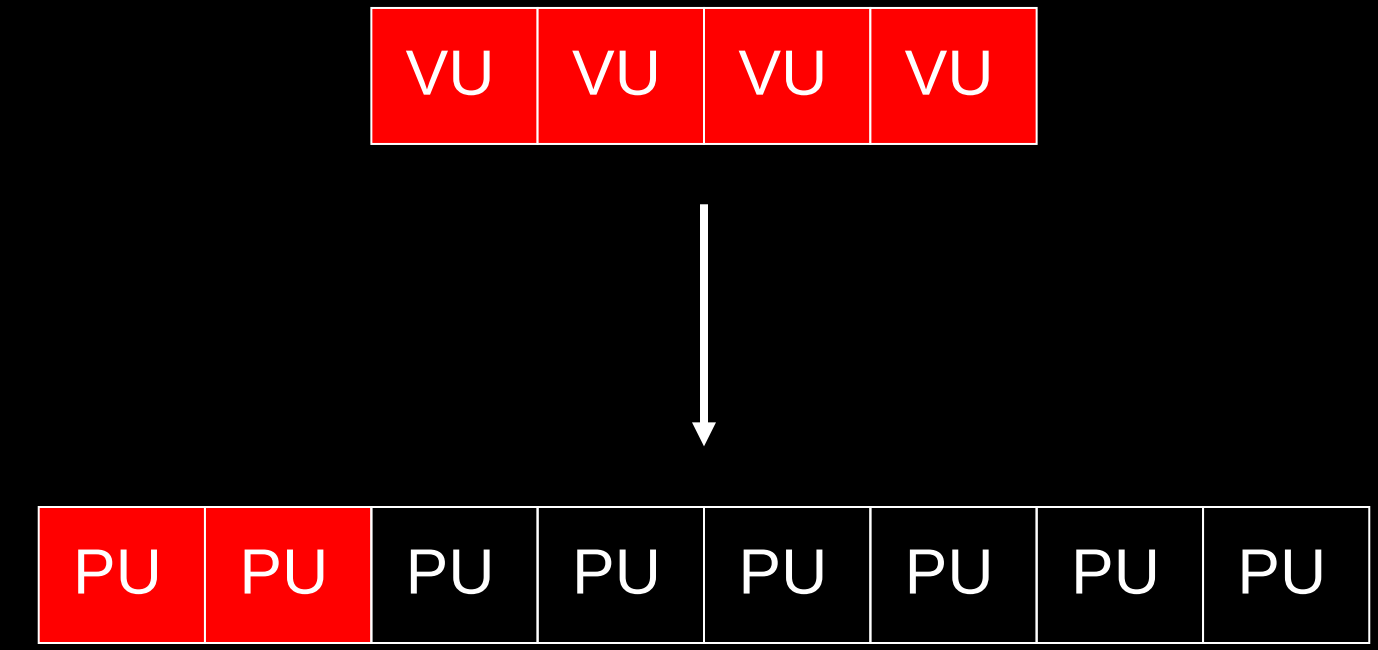
Stream processors



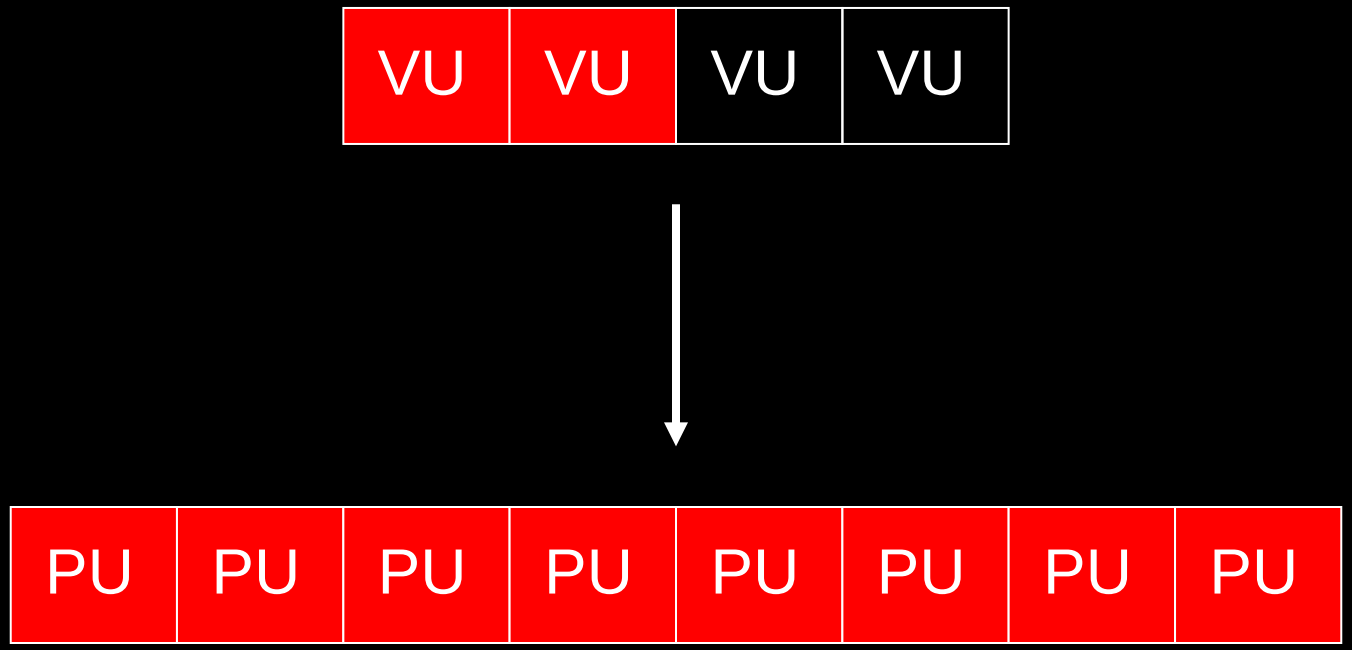
4 Vertex Units + 8 Pixel Units



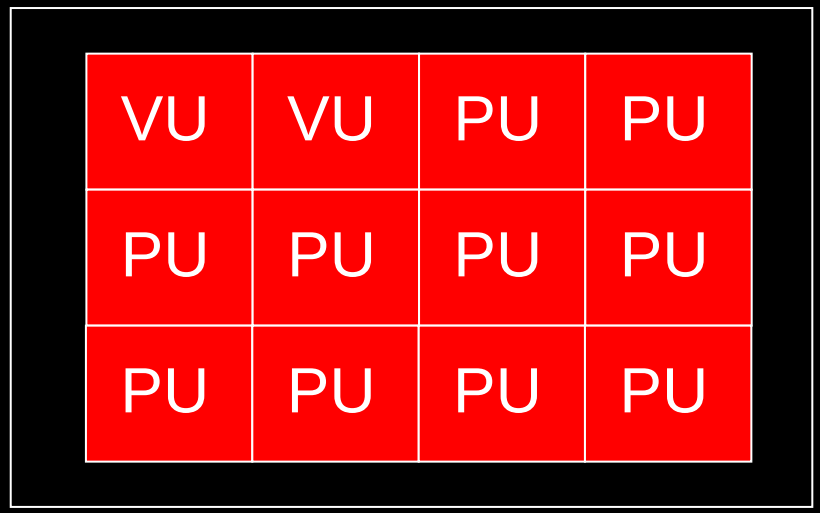
Vertex-intensive application

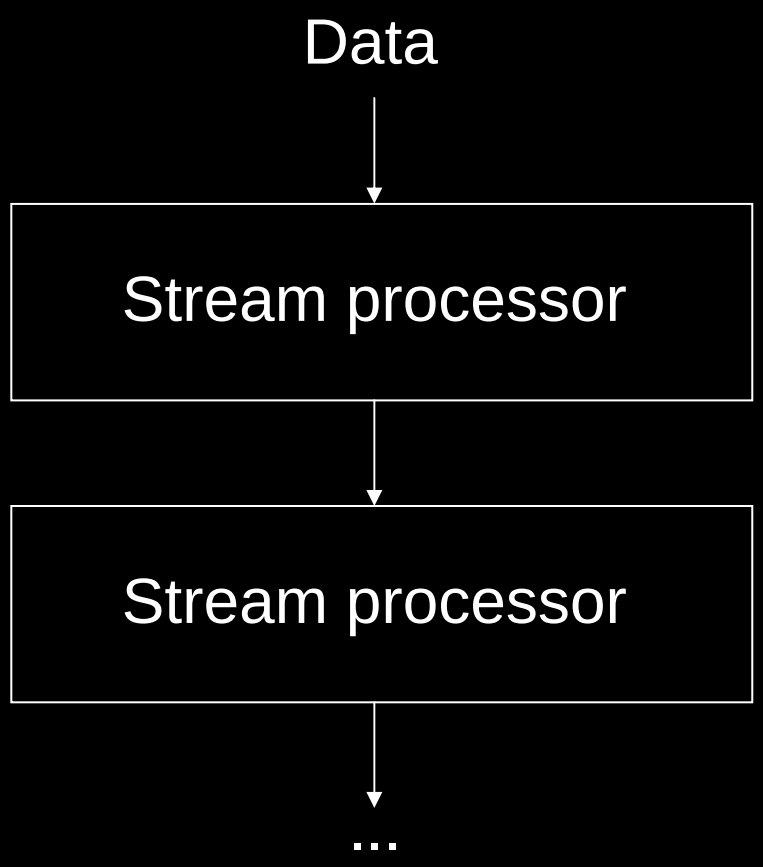


Pixel-intensive application



12 stream processors

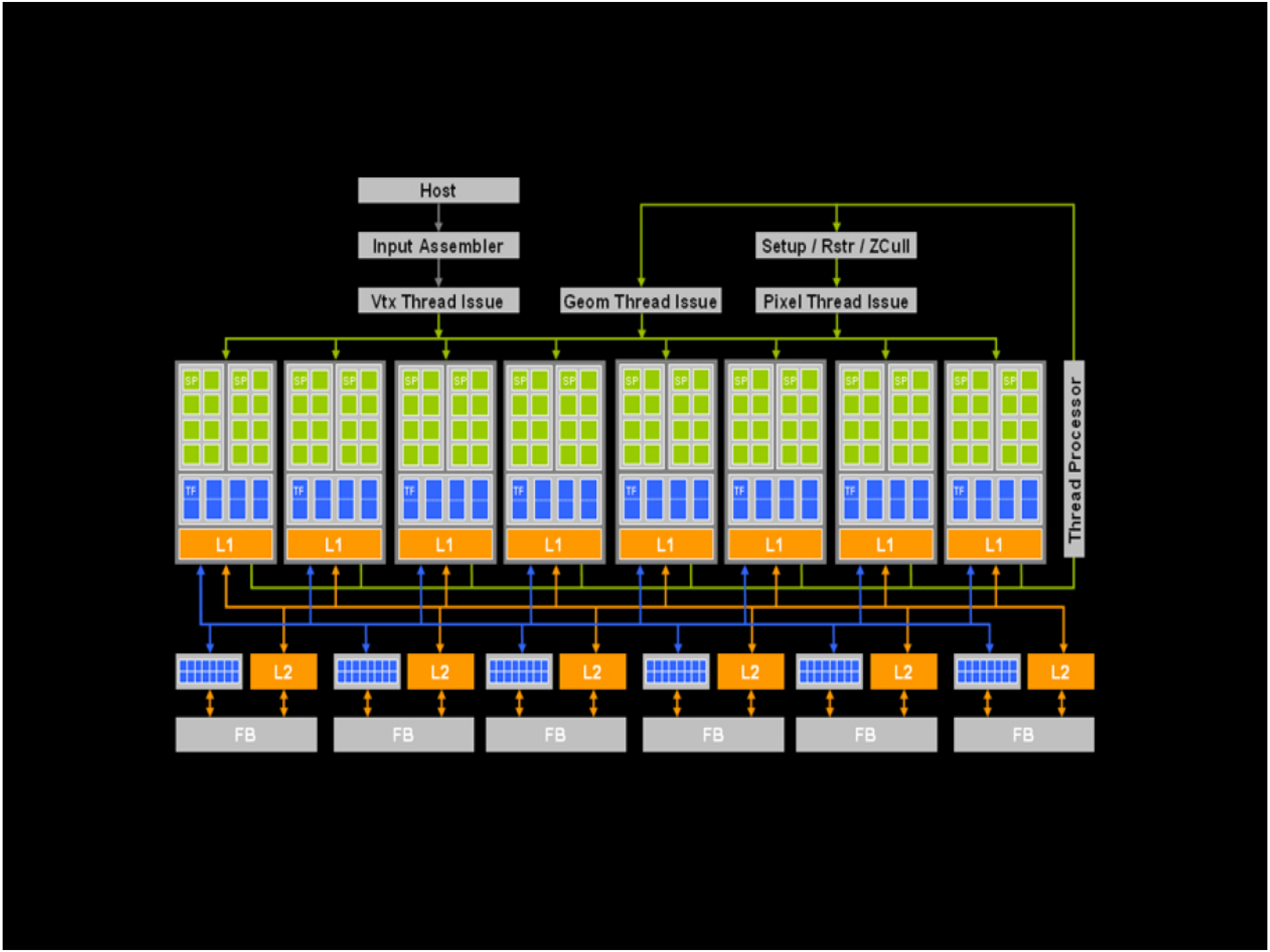


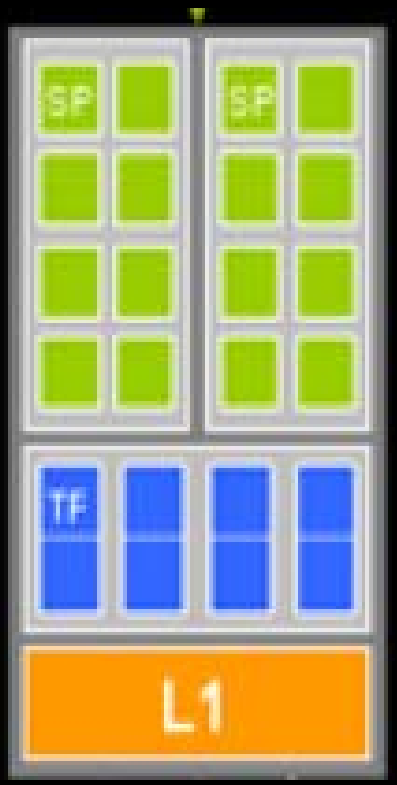


- Limited instruction set
  - Optimized for 4D float vectors
- Inefficient branching
- Small, fast RAM
- Small, fast cache
- Excellent for SIMD ops

nVidia GeForce 8800

- 128 stream processors @ 1.35 GHz
- 2560 x 1600
- 16x antialiasing using multisampling
- Up to 8 render targets, up to FP32 (128 bit) formats
- SLI (x2)
- Full support for Direct3D 10, OpenGL 2.0 and CUDA
- Blue-Ray-, HD-DVD-codecs
- API for physics (Quantum Effects)

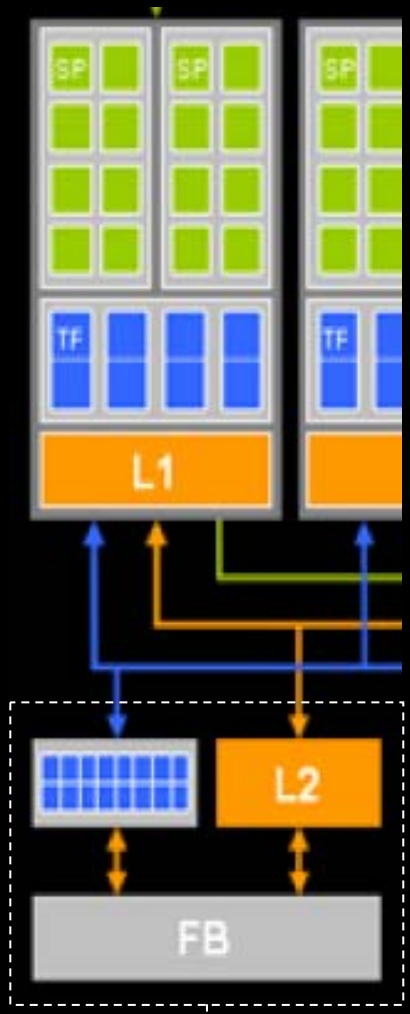

Host
Input Assembler
Vtx Thread Issue
Geom Thread Issue
Setup / Rstr / ZCull
Pixel Thread Issue
Thread Processor
SP
TF
L1
L2
FB



Stream processors

Texture lookup and filtering

Level 1 cache

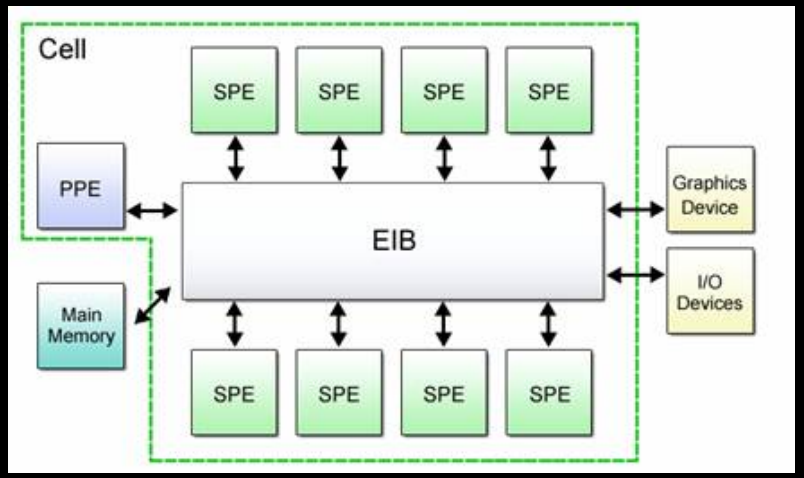


General purpose registers

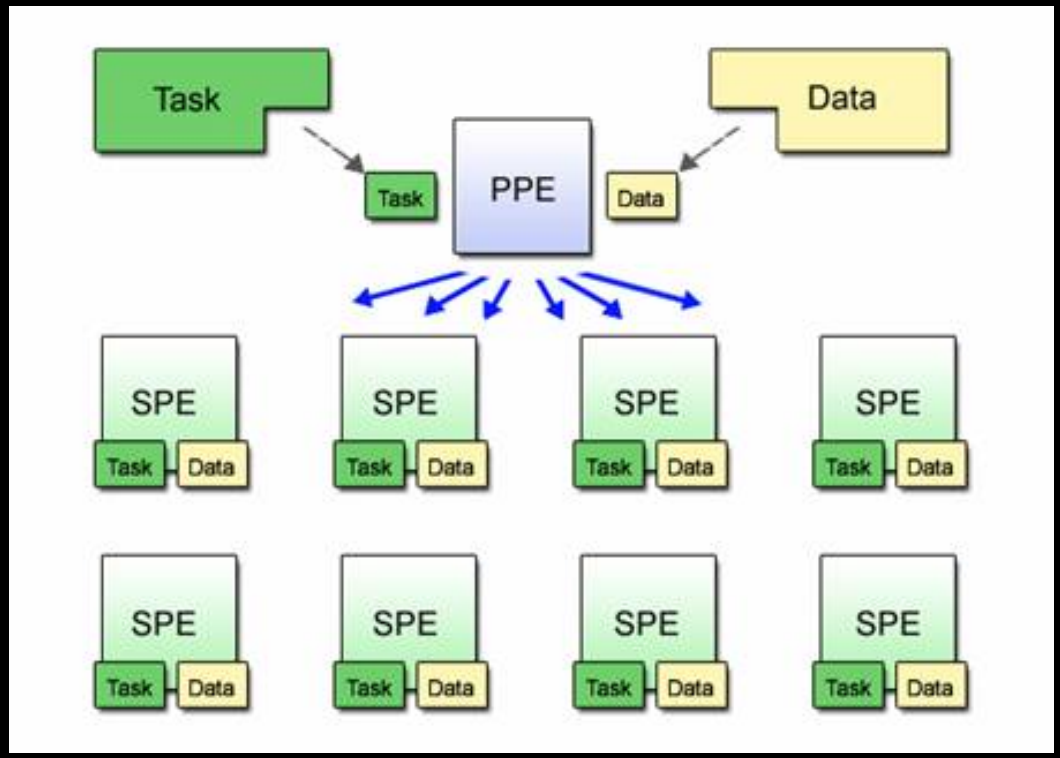
Level 2 cache

Frame buffer

Raster ops



- PowerPC Processor Element (PPE)
  - Memory management, task management
- Synergistic Processor Unit (SPU)
  - Special instruction set
  - 128 bytes memory (prog + data)
  - 8 Synergistic Processing Elements (SPE)
  - Designed for SIMD-algorithms
- Element Interconnect Bus (EIC)
  - Primary memory bus


Task
Data
PPE
Task
Data
SPE
Task
Data
SPE
Task
Data
SPE
Task
Data
SPE
Task
Data
SPE
Task
Data
SPE
Task
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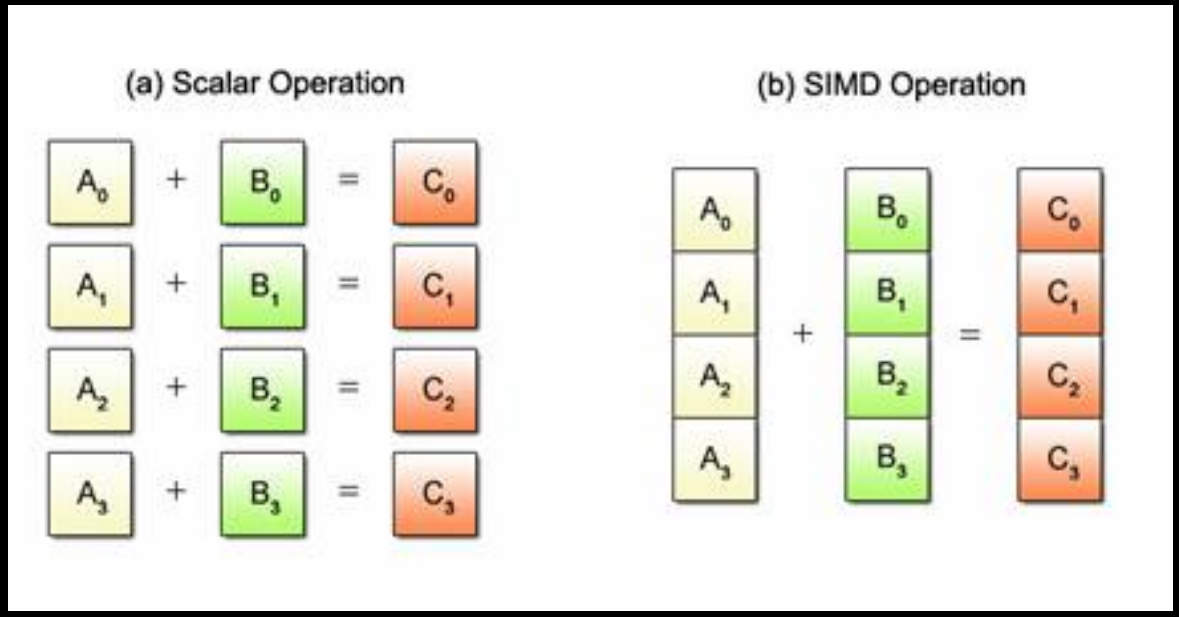
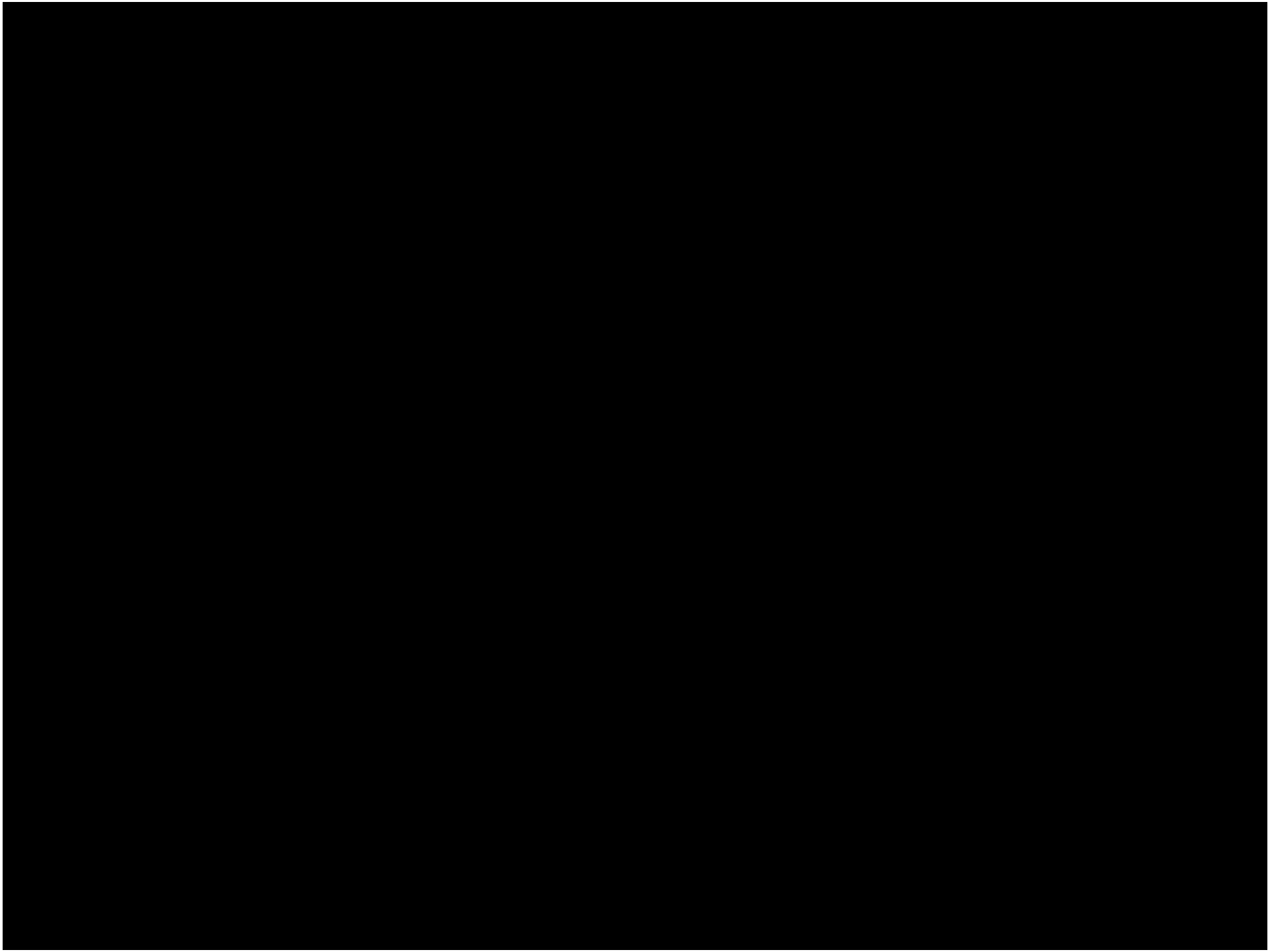
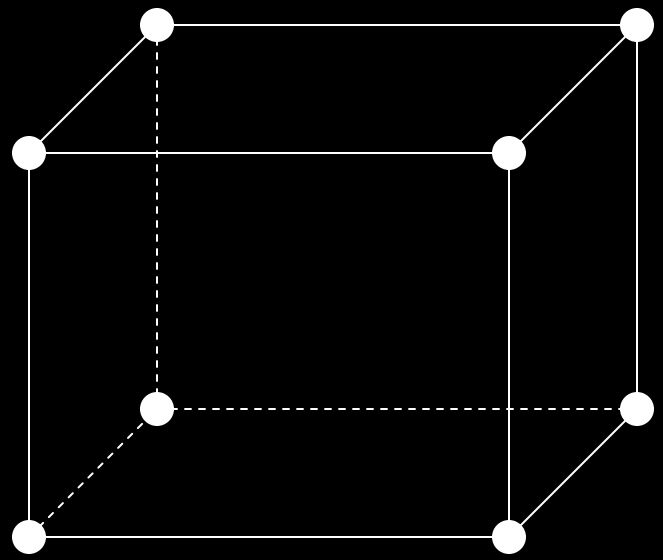
Data



Cell BE uses a vector datatype with 16 bytes
Extended C/C++ provides access



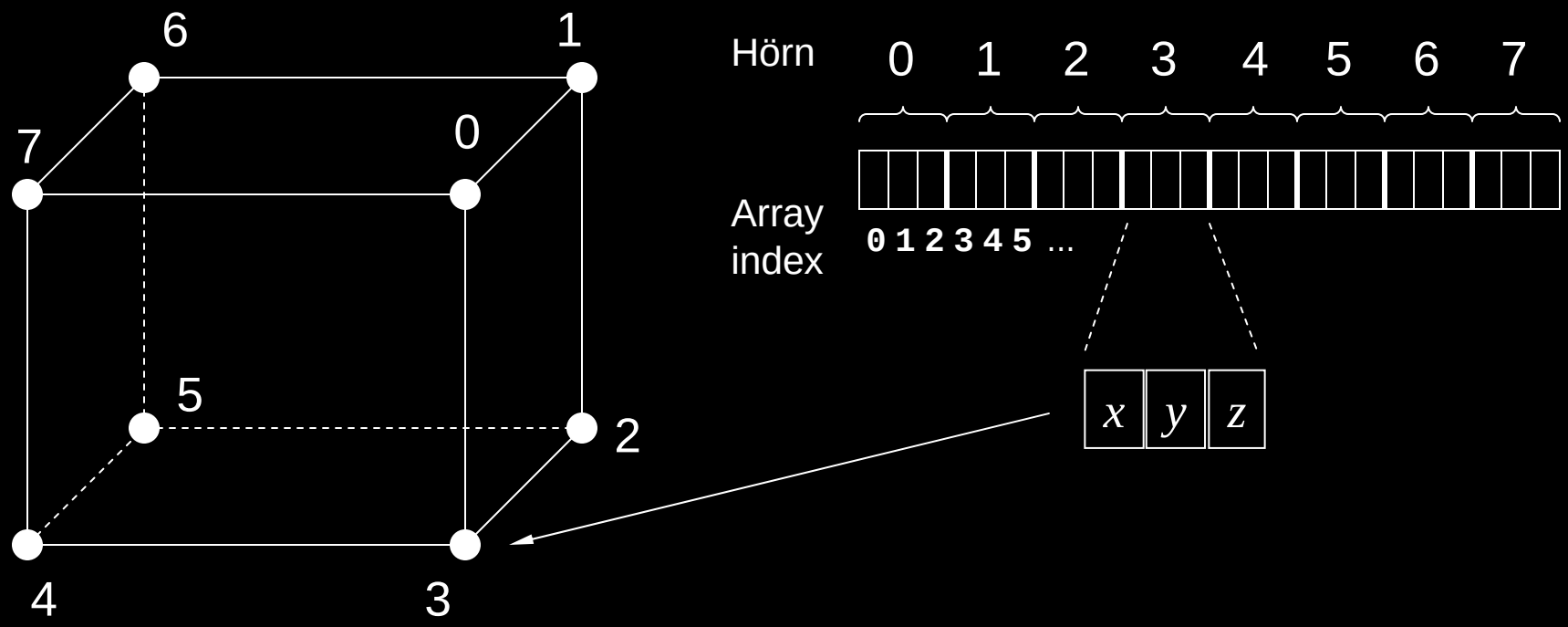
Geometrispecifikation



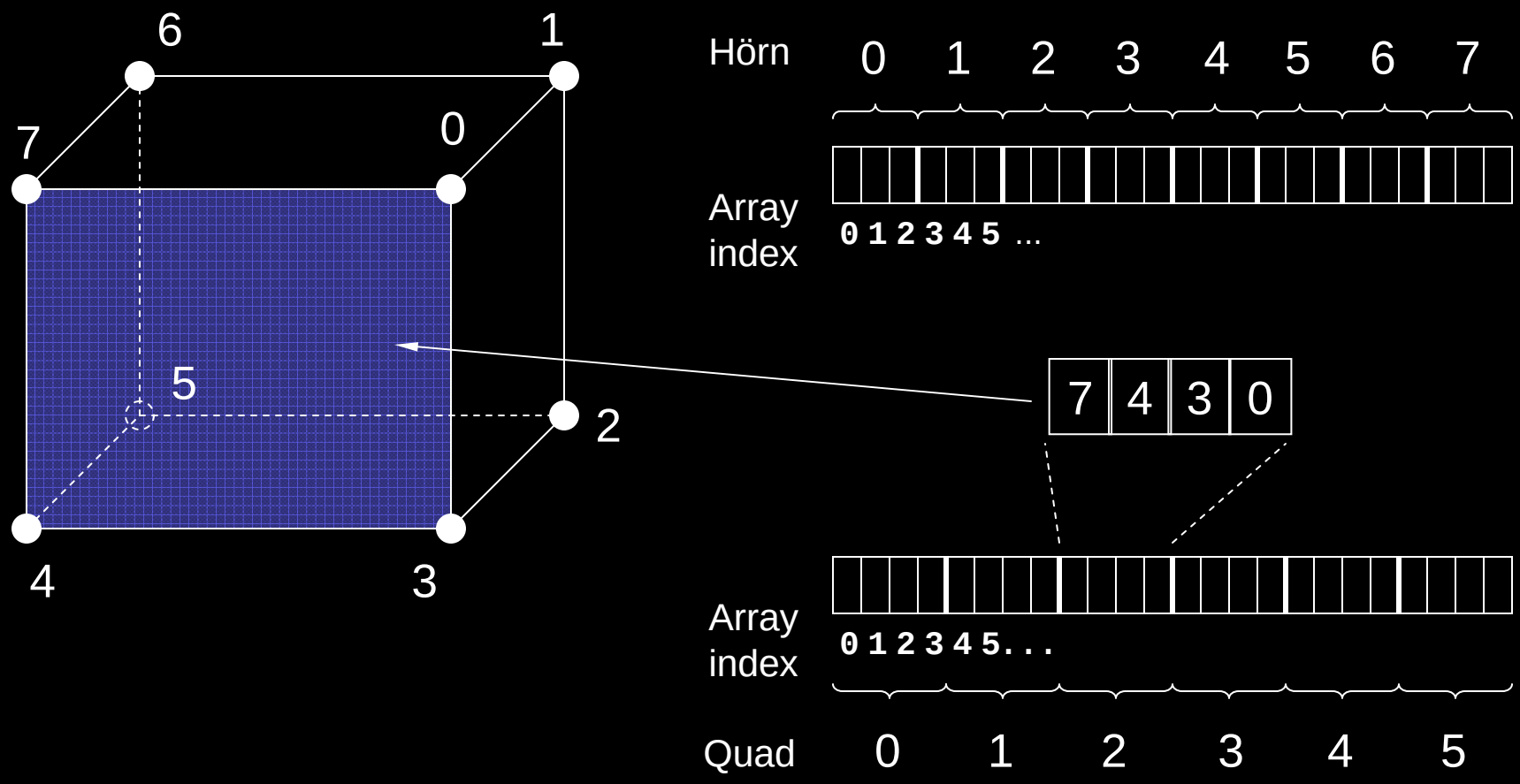
```
glBegin(GL_QUADS);
glVertex3f(...);
...
glEnd();
```

6 sidor x 4 hörn per sida: 24 hörn + 24 funktionsanrop

Vertex arrays

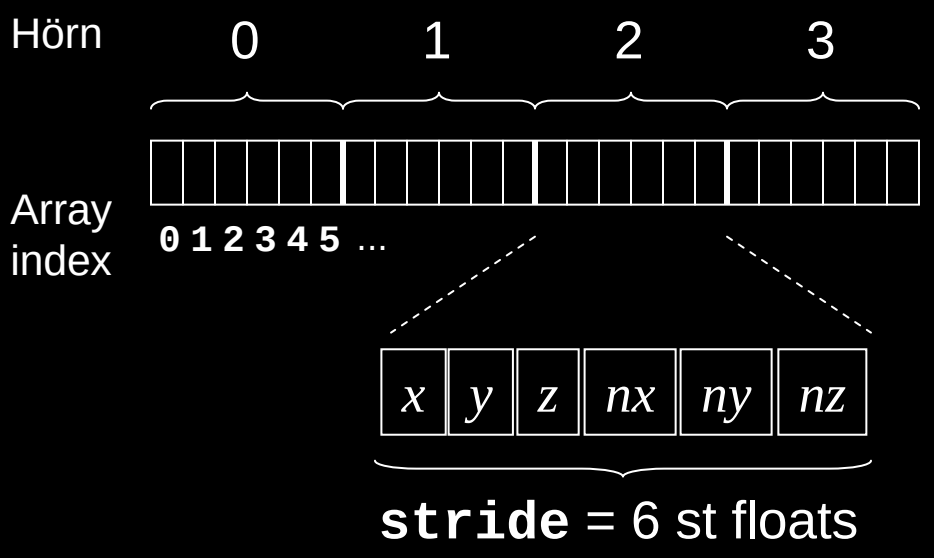


Indexerade primitiver

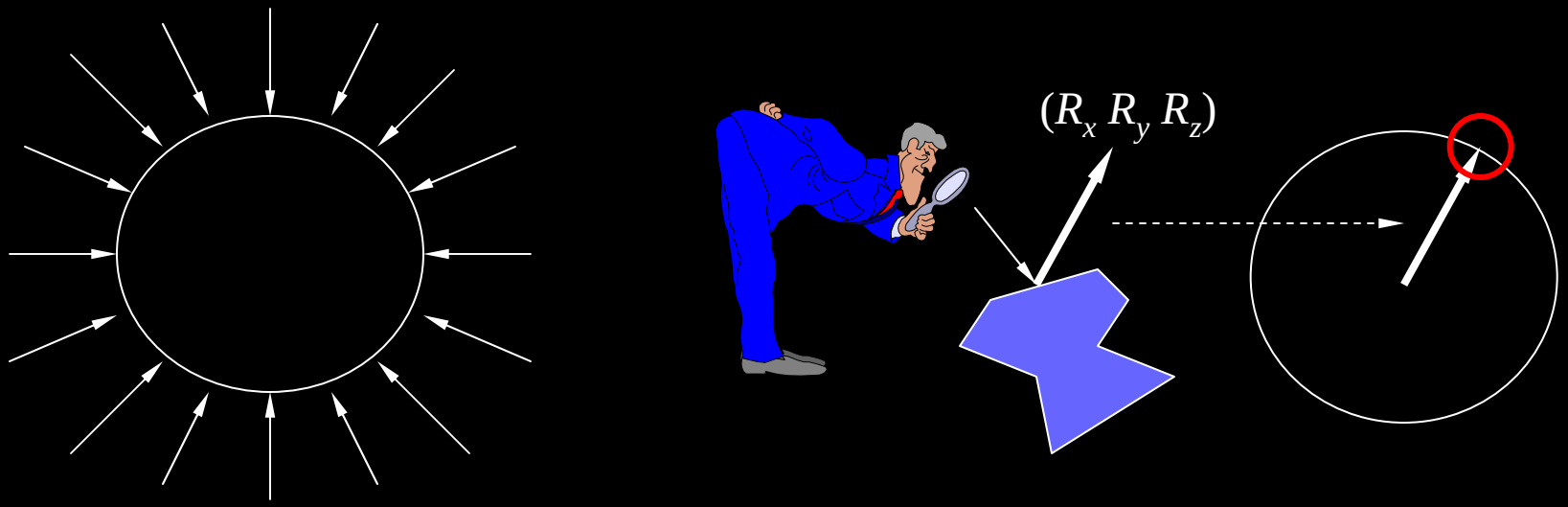


8 hörn, **2** funktionsanrop!

Interleaved vertex arrays

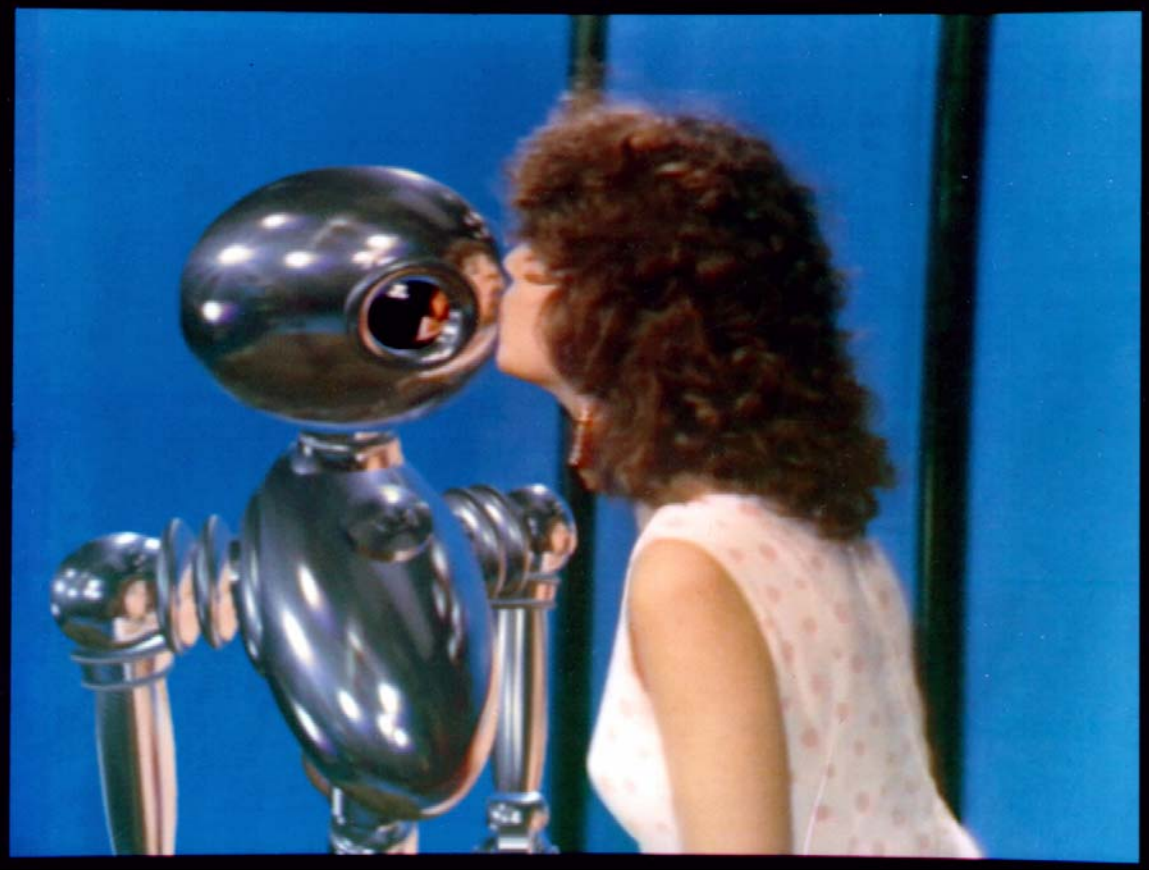


Reflection mapping



Jim Blinn, 1976

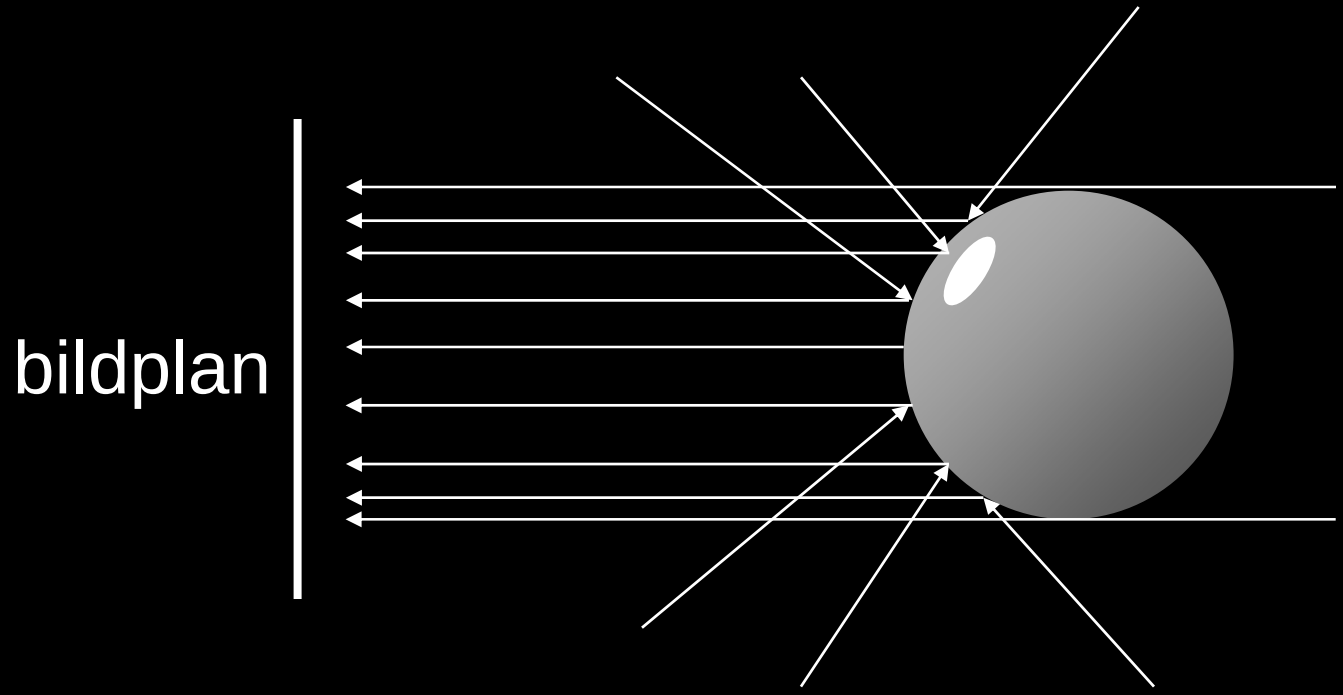
Gene Miller, Michael Shou m.fl. 1982-1983



Interface, Lance Williams, 1985

Terminator 2, 1991

Sphere mapping



Sphere mapping

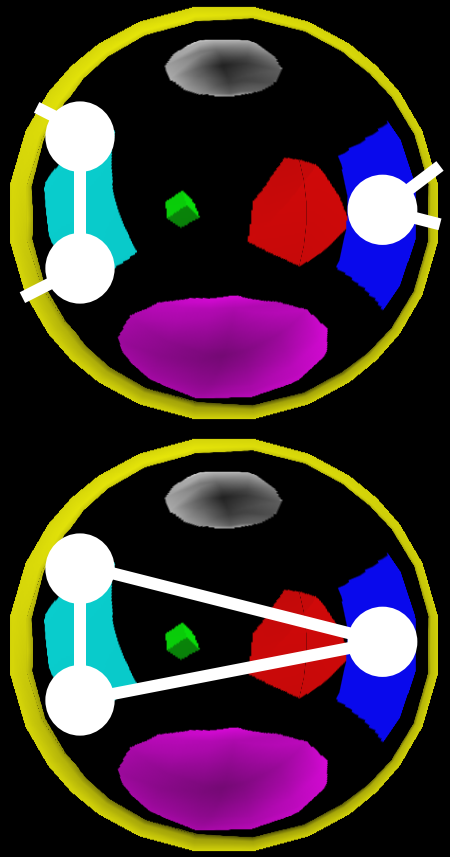
Från reflektionsvektor $\boldsymbol{R} = (R_x\ R_y\ R_z)$ till texturkoordinater (s, t):

$$s = \frac{R_x}{m} + \frac{1}{2}, \quad t = \frac{R_y}{m} + \frac{1}{2}$$

$$m = 2\left(R_x^2 + R_y^2 + \left(R_z + 1\right)^2\right)^{1/2}$$

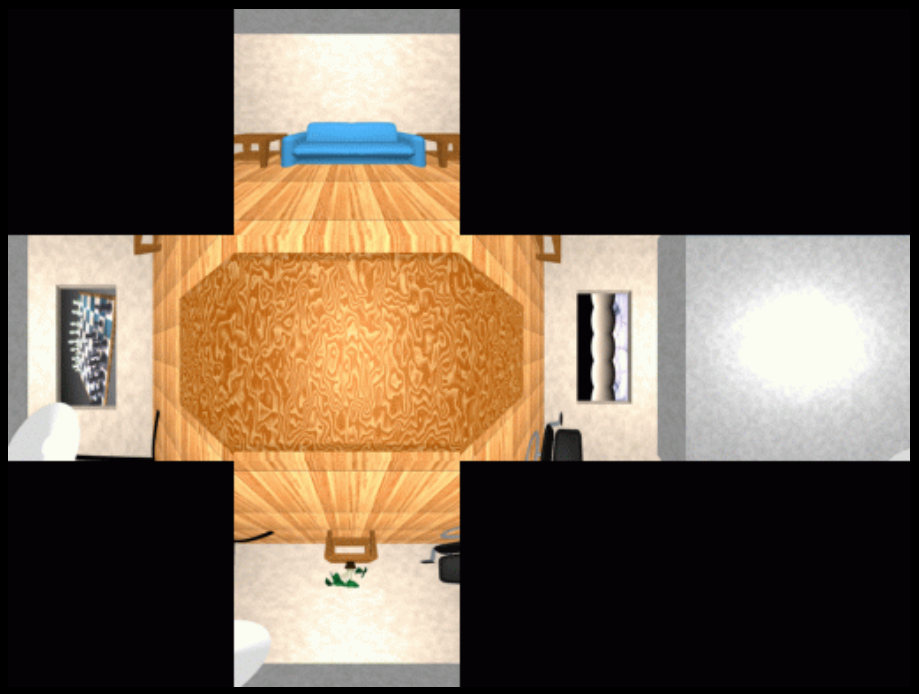
Sphere mapping - problem

Kraftigt varierande upplösning beroende på riktning.

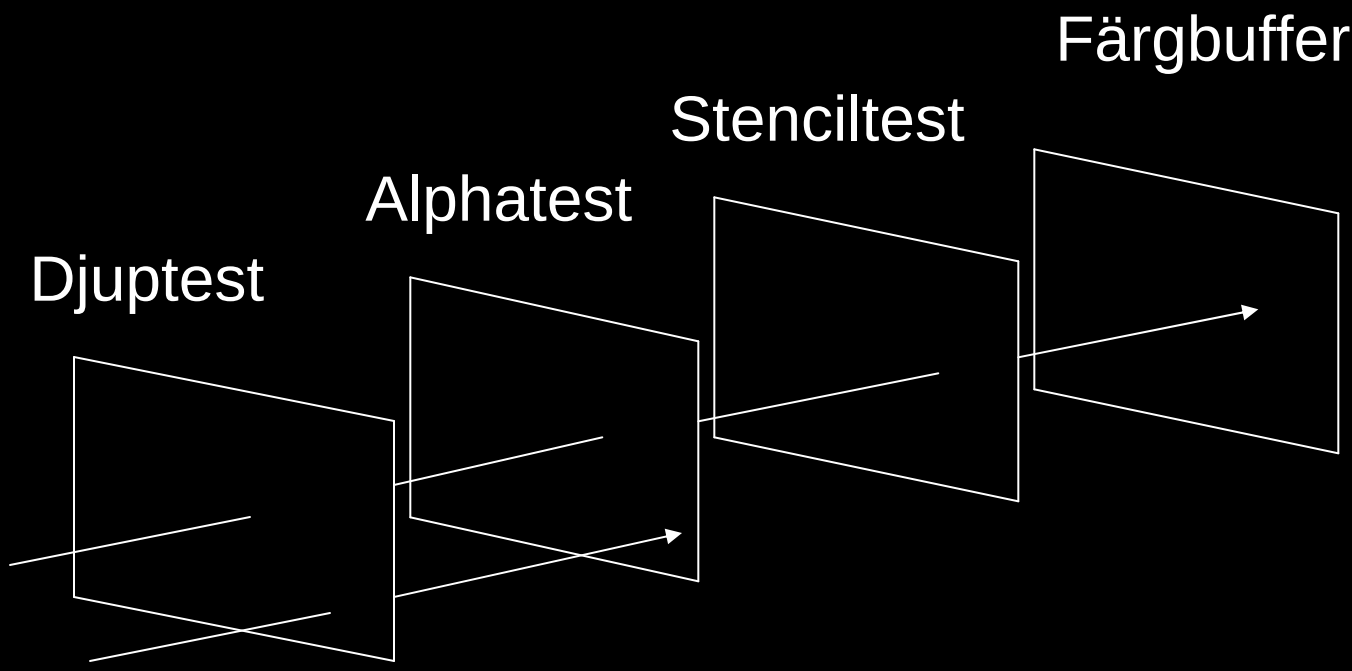


Problem med textur-interpolation för riktningar “bakåt”.

Cube mapping

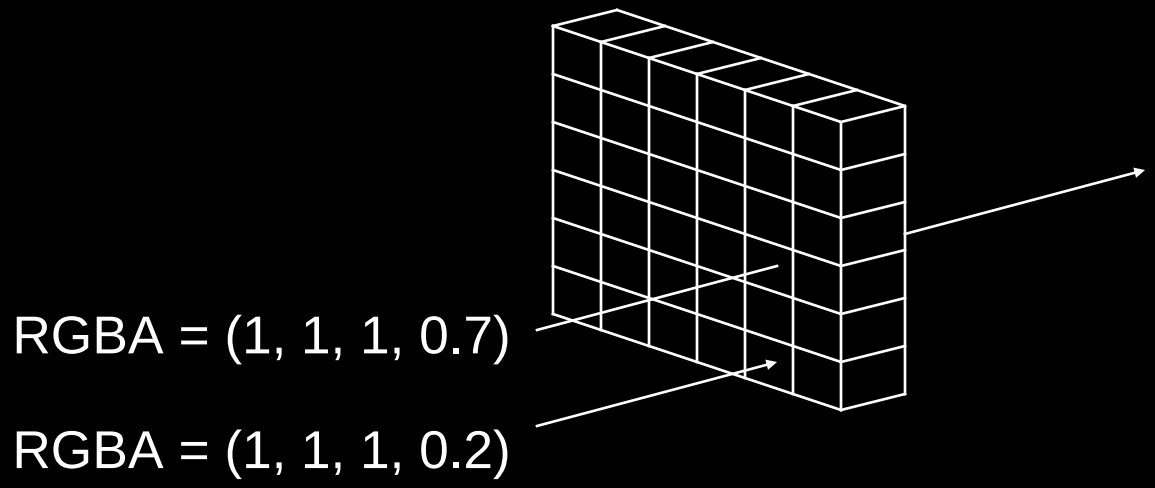


Buffertester i OpenGL

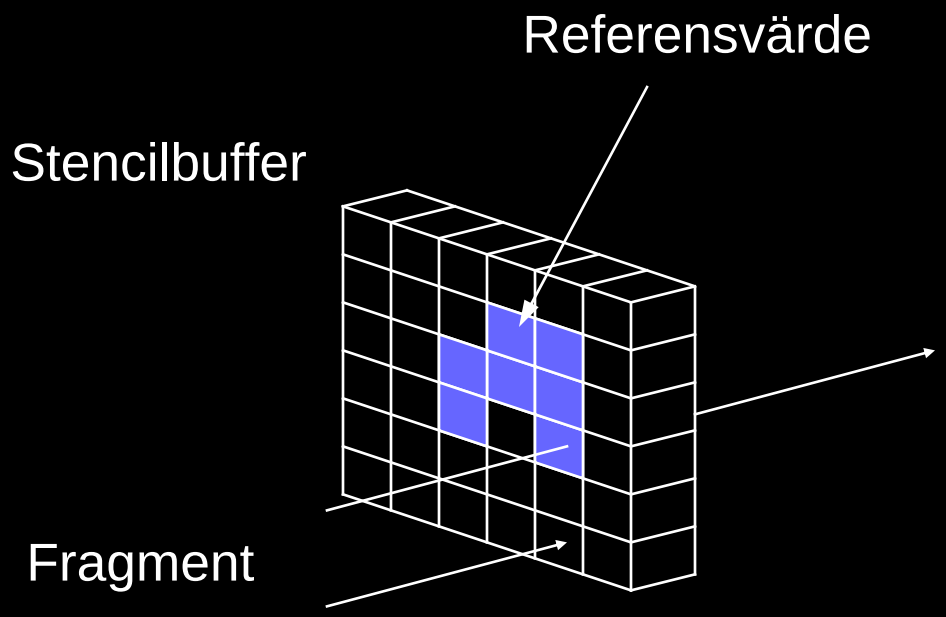


Alphatest

```
glAlphaFunc(GL_GREATER,0.5);
glEnable(GL_ALPHA_TEST);
```



Stenciltest



Stenciltest

- **`glStencilFunc()`** - konfigurerar stenciltestet
- **`glStencilOp()`** - bestämmer vad som ska hända med referensvärdet när testet utförs

```
glStencilFunc(GL_EQUAL, 1, ~0);
```

Stenciltestet ska returnera
TRUE om referensvärdet är lika med 1

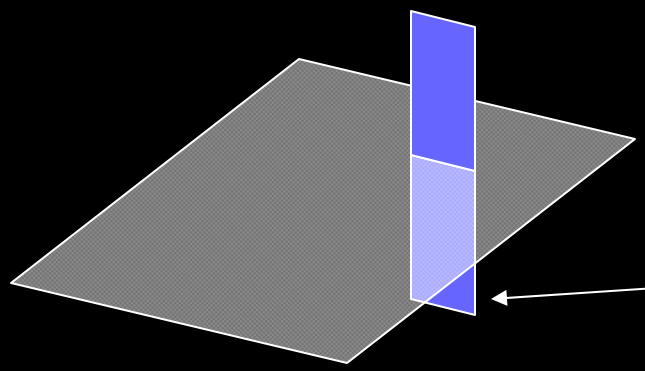
~0 är en *bitmask* och anger vilka
bitar i referensvärdet som ska beaktas
(**~0 = 0xFF** för 8 bitar)

```
glClear(GL_STENCIL_BUFFER_BIT);

glEnable(GL_STENCIL_TEST);
glStencilFunc(GL_ALWAYS, 1, ~0);
glStencilOp(GL_REPLACE, GL_REPLACE, GL_REPLACE);
glColorMask(GL_FALSE, GL_FALSE,
            GL_FALSE, GL_FALSE);

/* draw something here */

glColorMask(GL_TRUE, GL_TRUE, GL_TRUE, GL_TRUE);
glStencilFunc(GL_EQUAL, 1, ~0);
glStencilOp(GL_KEEP, GL_KEEP, GL_KEEP);
glColorMask(GL_TRUE, GL_TRUE, GL_TRUE, GL_TRUE);

/* draw something else here */
```

Fyll i stencilbuffern utan att uppdatera färg-buffern

Rita scenen utan att uppdatera stencil-buffern

Stenciltest och labben



Denna del
måste klippas
bort...

Färgblandning

$$R_{out} = R_{in} \cdot S_R + R_{bildbuffert} \cdot D_R$$
$$G_{out} = G_{in} \cdot S_G + G_{bildbuffert} \cdot D_G$$
$$B_{out} = B_{in} \cdot S_B + B_{bildbuffert} \cdot D_B$$

där (S_R, D_R), (S_G, D_G) och (S_B, D_B) kallas *blandningsfaktorer*.

```
glBlendFunc(GL_SRC_ALPHA,
            GL_ONE_MINUS_SRC_ALPHA);
```

S_R ←

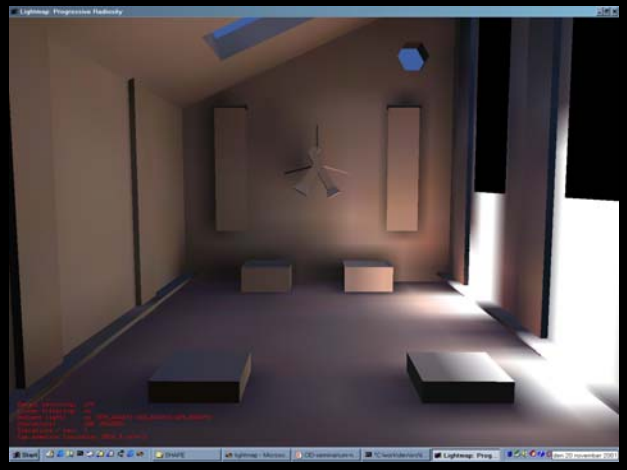
D_R ←

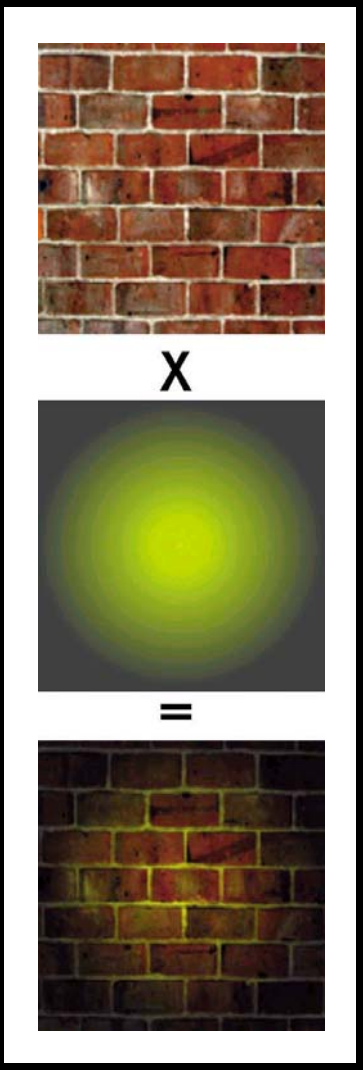
$$R_{out} = R_{in} \cdot A_{in} + R_{bildbuffert} \cdot (1 - A_{in})$$

Steg 1:
Rita gul triangel.

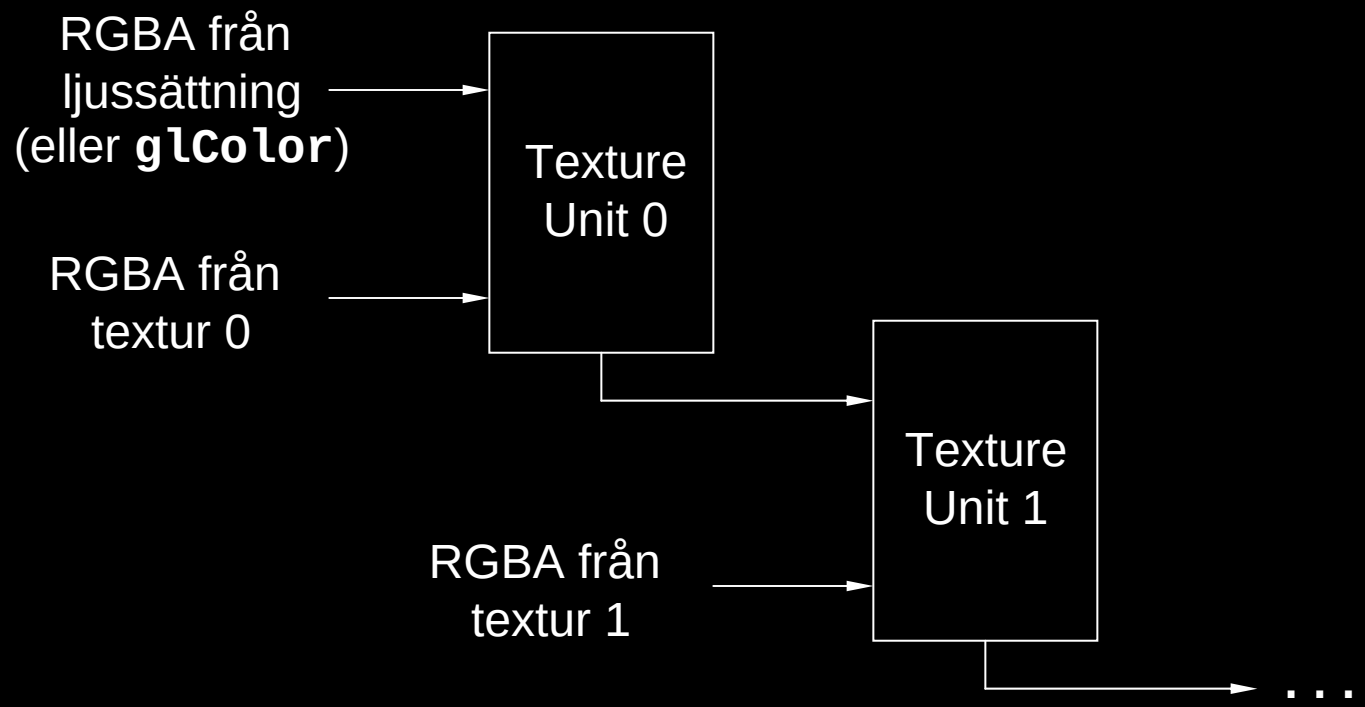
Steg 2:
`glEnable(GL_BLEND);`
Rita blå triangel
med A < 1.

Multitexturing





Multitexturing



```
#include <glew.h>



/* Aktivera enhet 0 och ladda textur */

glActiveTextureARB(GL_TEXTURE0_ARB);
glEnable(GL_TEXTURE_2D);
glBindTexture(GL_TEXTURE_2D, ...);



/* Aktivera enhet 1 och ladda textur */

glActiveTextureARB(GL_TEXTURE1_ARB);
glEnable(GL_TEXTURE_2D);
glBindTexture(GL_TEXTURE_2D, ...);
```

```
glBegin(GL_TRIANGLES);


glMultiTexCoord2fARB(GL_TEXTURE0_ARB, 0.0, 0.0);
glMultiTexCoord2fARB(GL_TEXTURE1_ARB, 0.1, 0.2);
glVertex3f(0.0, 0.0, 0.0);


glMultiTexCoord2fARB(GL_TEXTURE0_ARB, 1.0, 0.0);
glMultiTexCoord2fARB(GL_TEXTURE1_ARB, 0.6, 0.2);
glVertex3f(1.0, 0.0, 0.0);


glMultiTexCoord2fARB(GL_TEXTURE0_ARB, 0.5, 1.0);
glMultiTexCoord2fARB(GL_TEXTURE1_ARB, 0.3, 0.5);
glVertex3f(0.5, 1.0, 0.0);


glEnd();
```

Debugging

```
if (glGetError() != GL_NO_ERROR)
{
   /* Något är fel! */
}
```

Labb - FAQ

- Maya lagrar absoluta sökvägar till texturfiler – ändra i RTG-filen om det behövs
- Se till att dina texturer är 2^n x 2^m