CS 380 - GPU and GPGPU Programming
Lecture 4: GPU Architecture 2

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Reading Assignment #2 (until Sep 14)

Read (required):

- Orange book (GLSL), chapter 4 (*The OpenGL Programmable Pipeline*)
- Brief GLSL overview:

`https://en.wikipedia.org/wiki/OpenGL_Shading_Language`

- GPU Gems 2 book, chapter 30 (*The GeForce 6 Series GPU Architecture*) available online:

`http://download.nvidia.com/developer/GPU_Gems_2/GPU_Gems2_ch30.pdf`

Programming Assignments: Schedule (tentative)

Assignment #1:

- Querying the GPU (OpenGL/GLSL and CUDA) — due Sep 7

Assignment #2:

- Phong shading and procedural texturing (GLSL) — due Sep 21

Assignment #3:

- Image Processing with GLSL — due Oct 5

Assignment #4:

- Image Processing with CUDA
- Convolutional layers with CUDA — due Oct 26

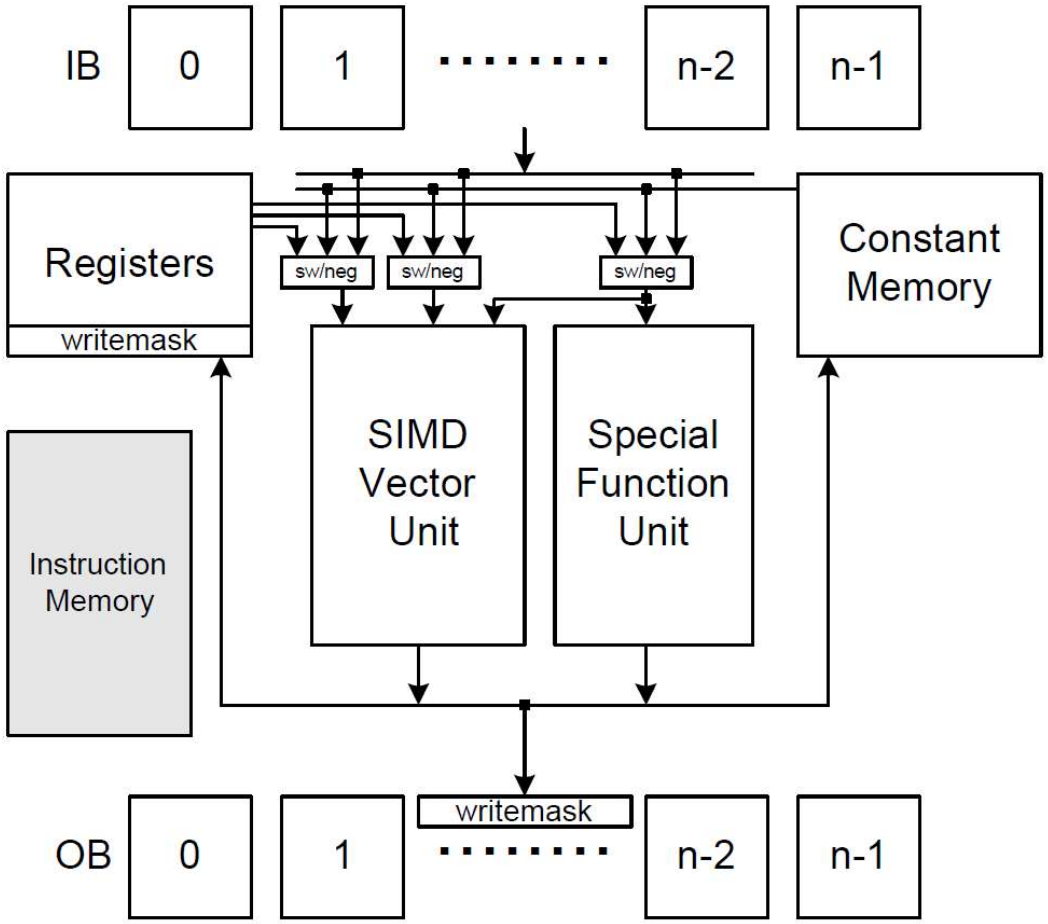
Assignment #5:

- Linear Algebra (CUDA) — due Nov 16

Legacy Vertex Shading Unit (1)

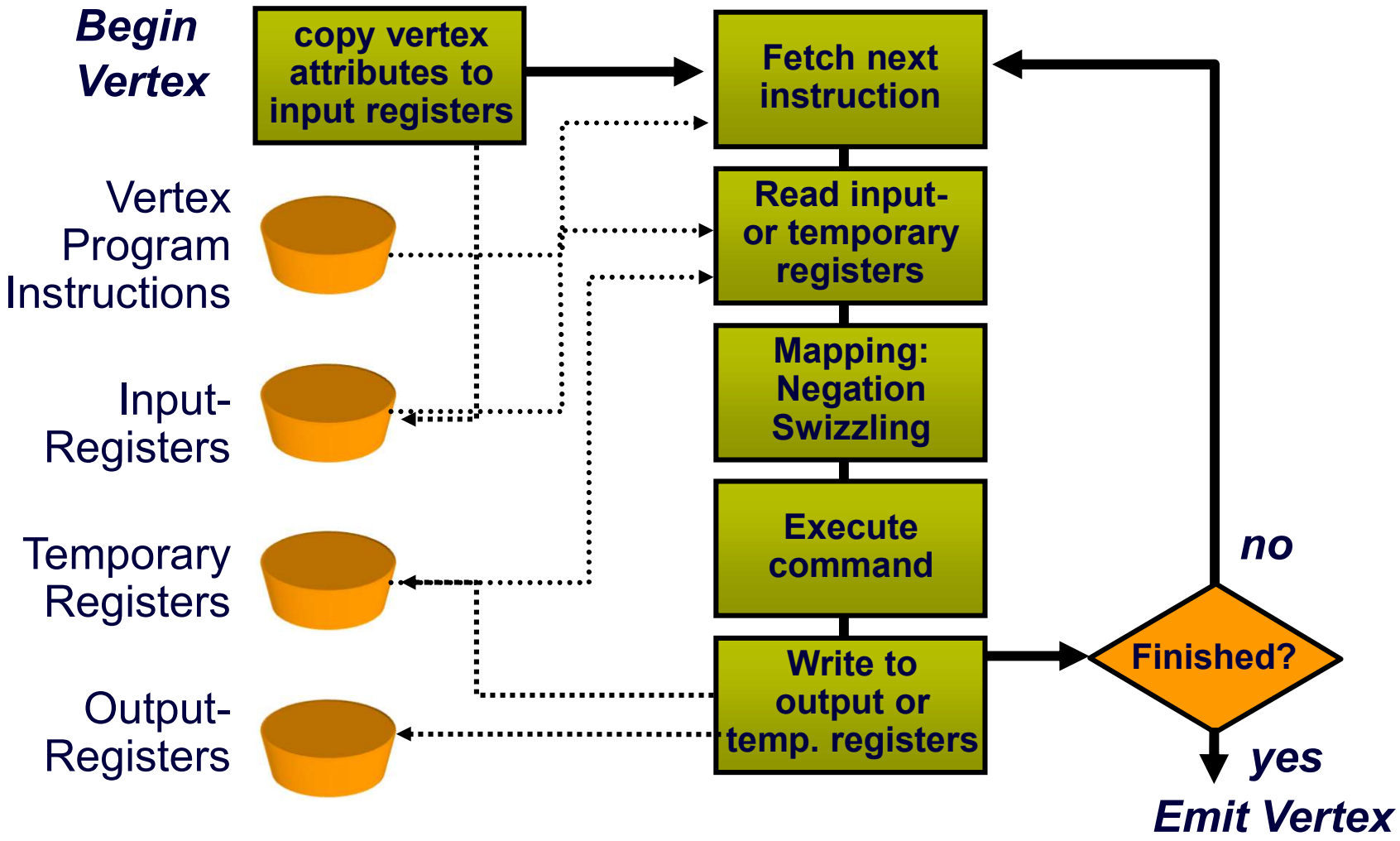
Geforce 3 (NV20), 2001

- floating point 4-vector vertex engine
- still very instructive for understanding GPUs in general



Lindholm et al., A User-Programmable Vertex Engine, SIGGRAPH 2001

Vertex Processor



Legacy Vertex Shading Unit (2)

Input attributes

Vertex Attribute Register	Conventional Per-vertex Parameter	Conventional Per-vertex Parameter Command	Conventional Component Mapping
0	Vertex position	`glVertex`	*x,y,z,w*
1	Vertex weights	`glVertexWeightEXT`	*w,0,0,1*
2	Normal	`glNormal`	
3	Primary color	`glColor`	*r,g,b,a*
4	Secondary color	`glSecondaryColorEXT`	*r,g,b,1*
5	Fog coordinate	`glFogCoordEXT`	*f,0,0,1*
6	-	-	-
7	-	-	-
8	Texture coord 0	`glMultiTexCoordARB(GL_TEXTURE0…)`	*s,t,r,q*
9	Texture coord 1	`glMultiTexCoordARB(GL_TEXTURE1…)`	*s,t,r,q*
10	Texture coord 2	`glMultiTexCoordARB(GL_TEXTURE2…)`	*s,t,r,q*
11	Texture coord 3	`glMultiTexCoordARB(GL_TEXTURE3…)`	*s,t,r,q*
12	Texture coord 4	`glMultiTexCoordARB(GL_TEXTUER4…)`	*s,t,r,q*
13	Texture coord 5	`glMultiTexCoordARB(GL_TEXTUER5…)`	*s,t,r,q*
14	Texture coord 6	`glMultiTexCoordARB(GL_TEXTUER6…)`	*s,t,r,q*
15	Texture coord 7	`glMultiTexCoordARB(GL_TEXTUER7…)`	*s,t,r,q*

Code examples

```
DP4 o[HPOS].x, c[0], v[OPOS];
```

```
MUL R1, R0.zxyw, R2.yzxw ;
MAD R1, R0.yzxw, R2.zxyw, -R1;
```

swizzling!

Legacy Vertex Shading Unit (3)

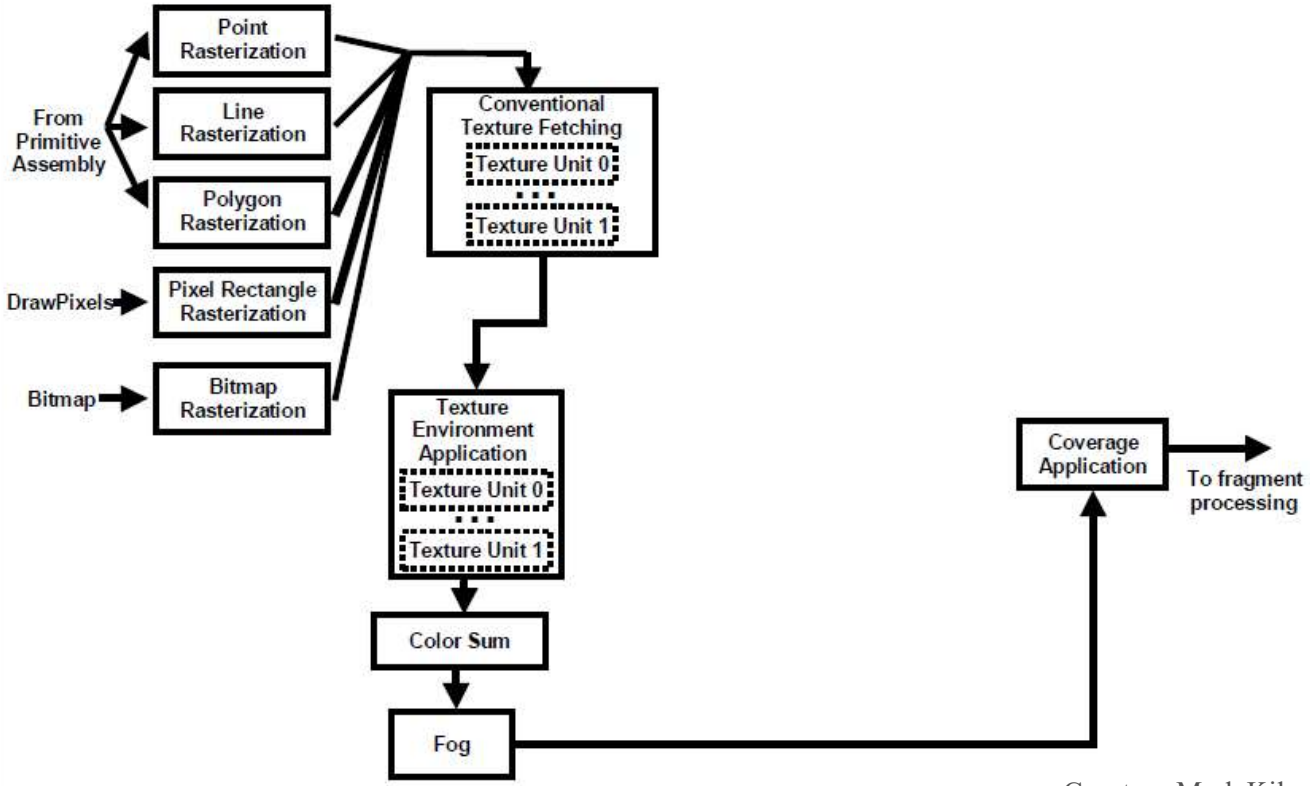
Vector instruction set, very few instructions; no branching yet!

OpCode	Full Name	Description
MOV	Move	vector -> vector
MUL	Multiply	vector -> vector
ADD	Add	vector -> vector
MAD	Multiply and add	vector -> vector
DST	Distance	vector -> vector
MIN	Minimum	vector -> vector
MAX	Maximum	vector -> vector
SLT	Set on less than	vector -> vector
SGE	Set on greater or equal	vector -> vector
RCP	Reciprocal	scalar-> replicated scalar
RSQ	Reciprocal square root	scalar-> replicated scalar
DP3	3 term dot product	vector-> replicated scalar
DP4	4 term dot product	vector-> replicated scalar
LOG	Log base 2	miscellaneous
EXP	Exp base 2	miscellaneous
LIT	Phong lighting	miscellaneous
ARL	Address register load	miscellaneous

Fast Forward to Programm. Fragment Shading

Core OpenGL Fragment Texturing & Coloring

< 1999



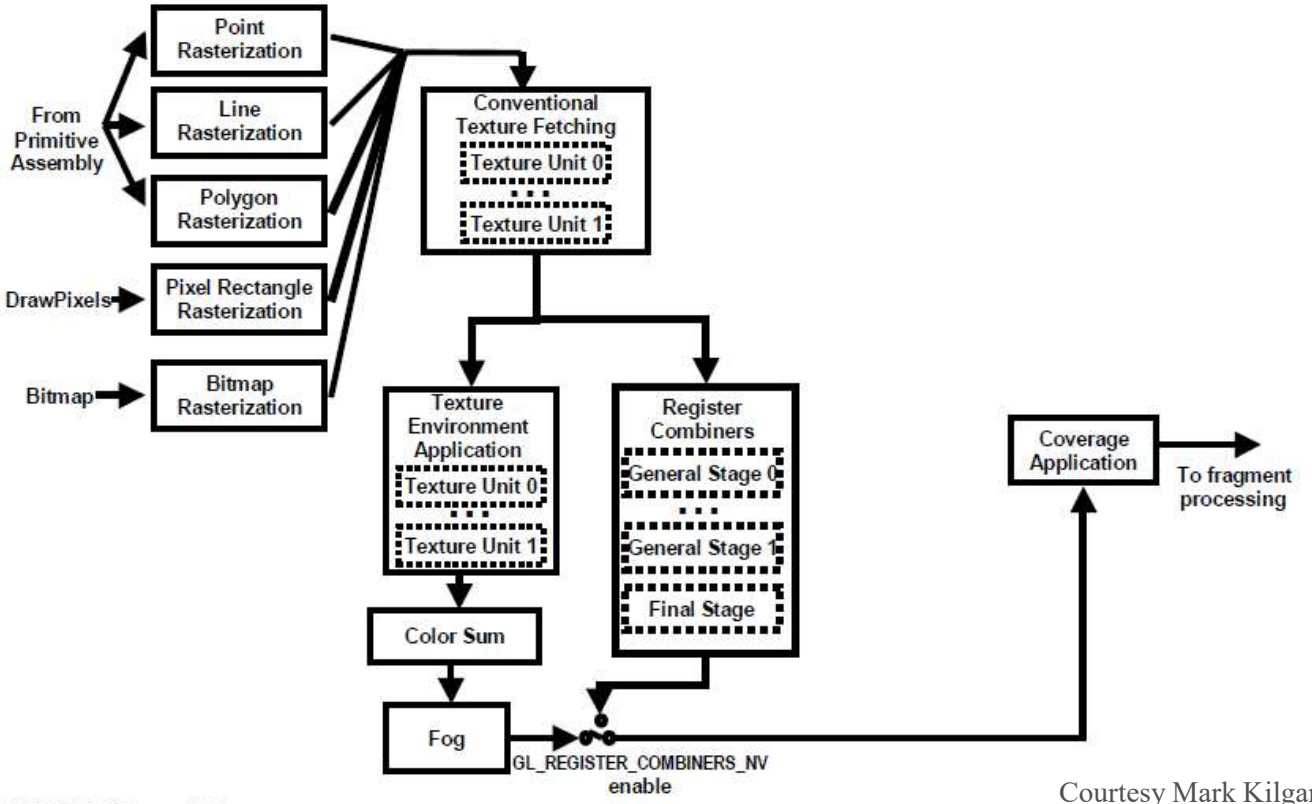
Courtesy Mark Kilgard

NVIDIA Proprietary

Fast Forward to Programm. Fragment Shading

NV10 OpenGL Fragment Texturing & Coloring

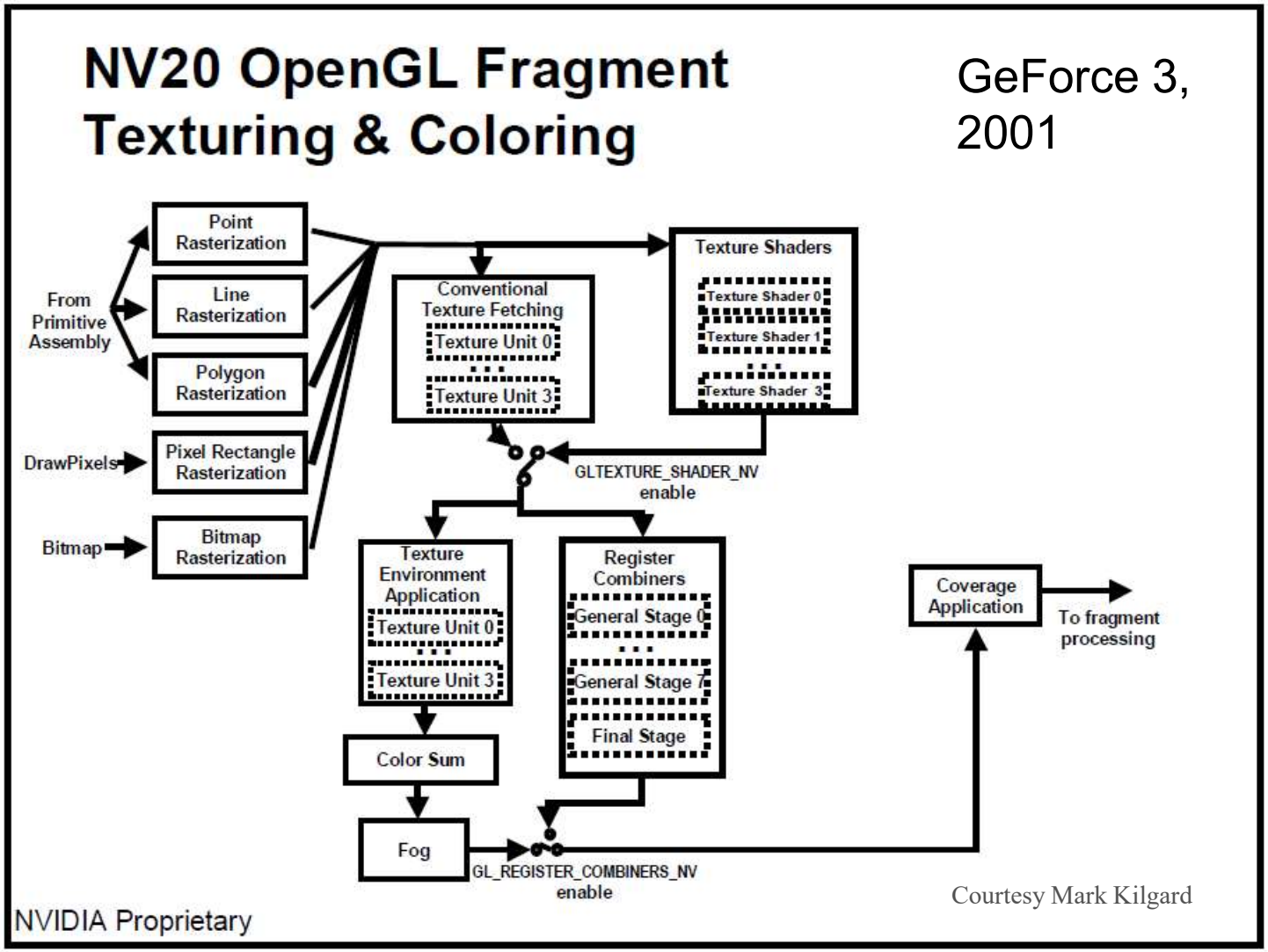
GeForce 256, 1999



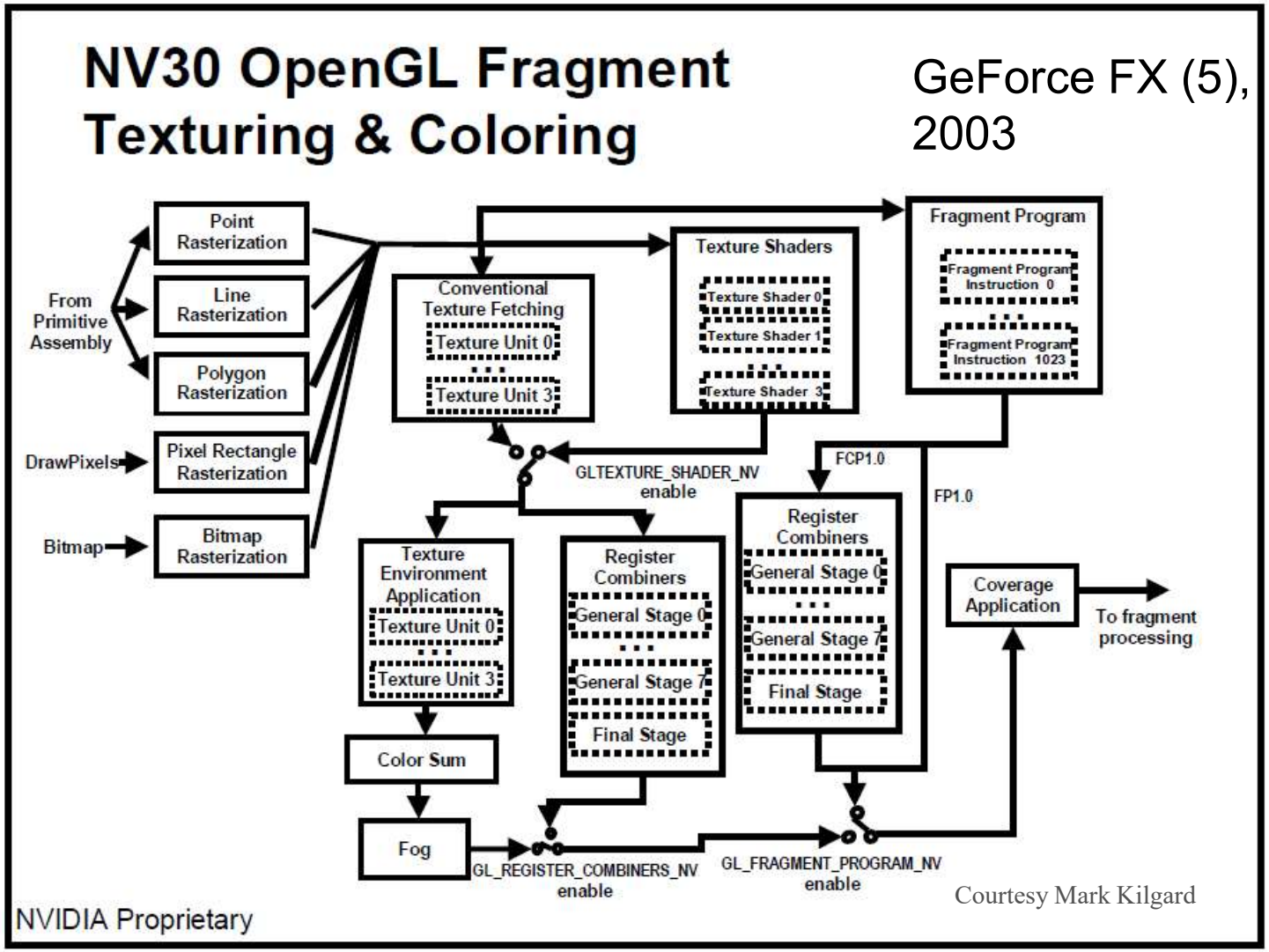
NVIDIA Proprietary

Courtesy Mark Kilgard

Fast Forward to Programm. Fragment Shading



Fast Forward to Programm. Fragment Shading

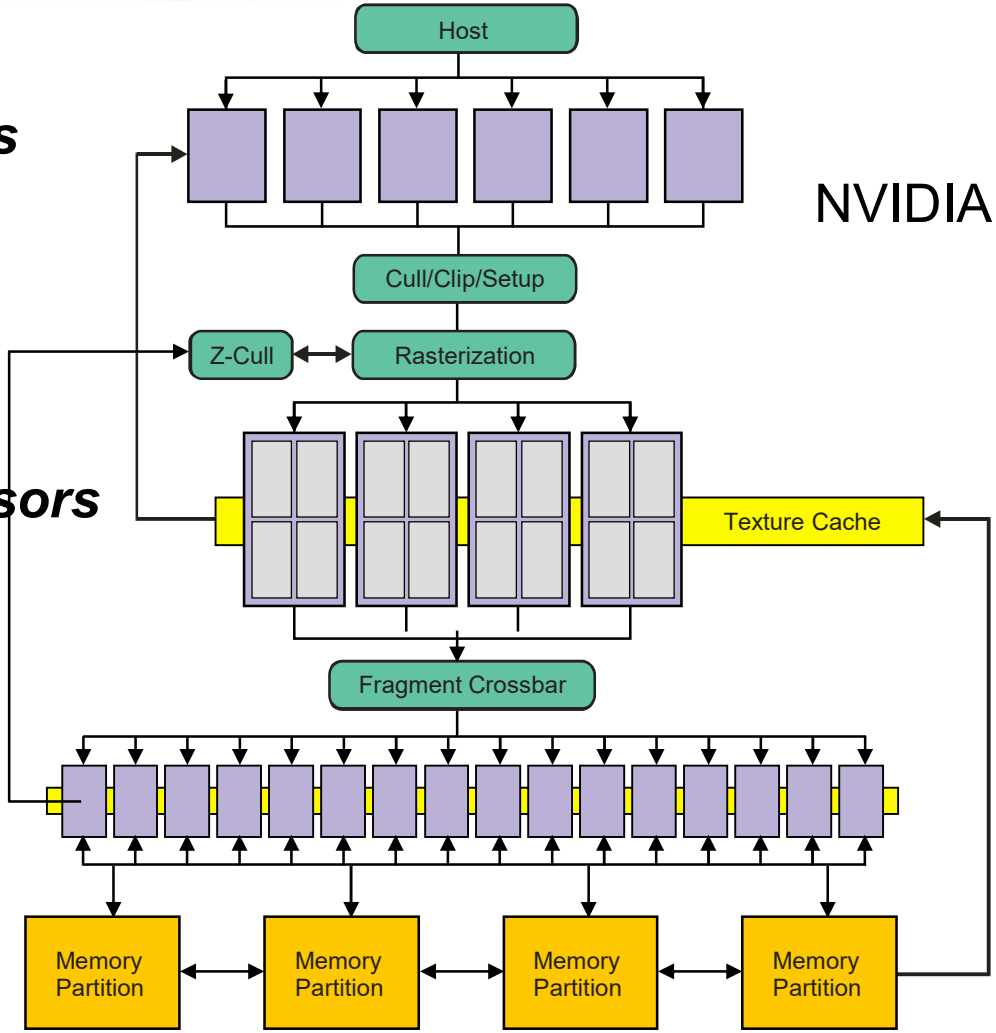


GPU Structure Before Unified Shaders

Vertex Processors

Fragment Processors

Memory Access
Z-Compare and Blending

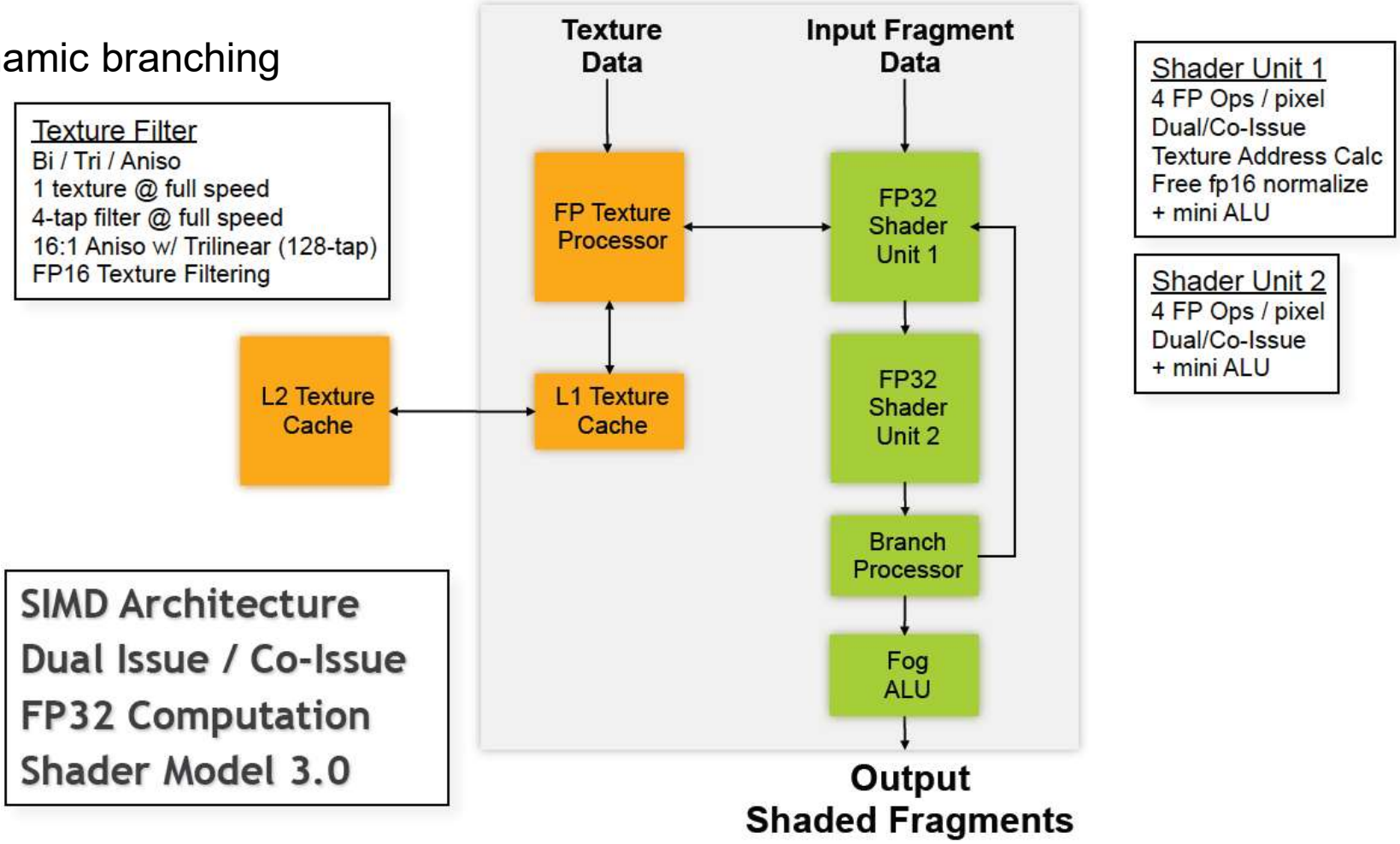


Example
NVIDIA Geforce 6/7,
2004, 2005

Legacy Fragment Shading Unit (1)

GeForce 6 (NV40), 2004

- dynamic branching

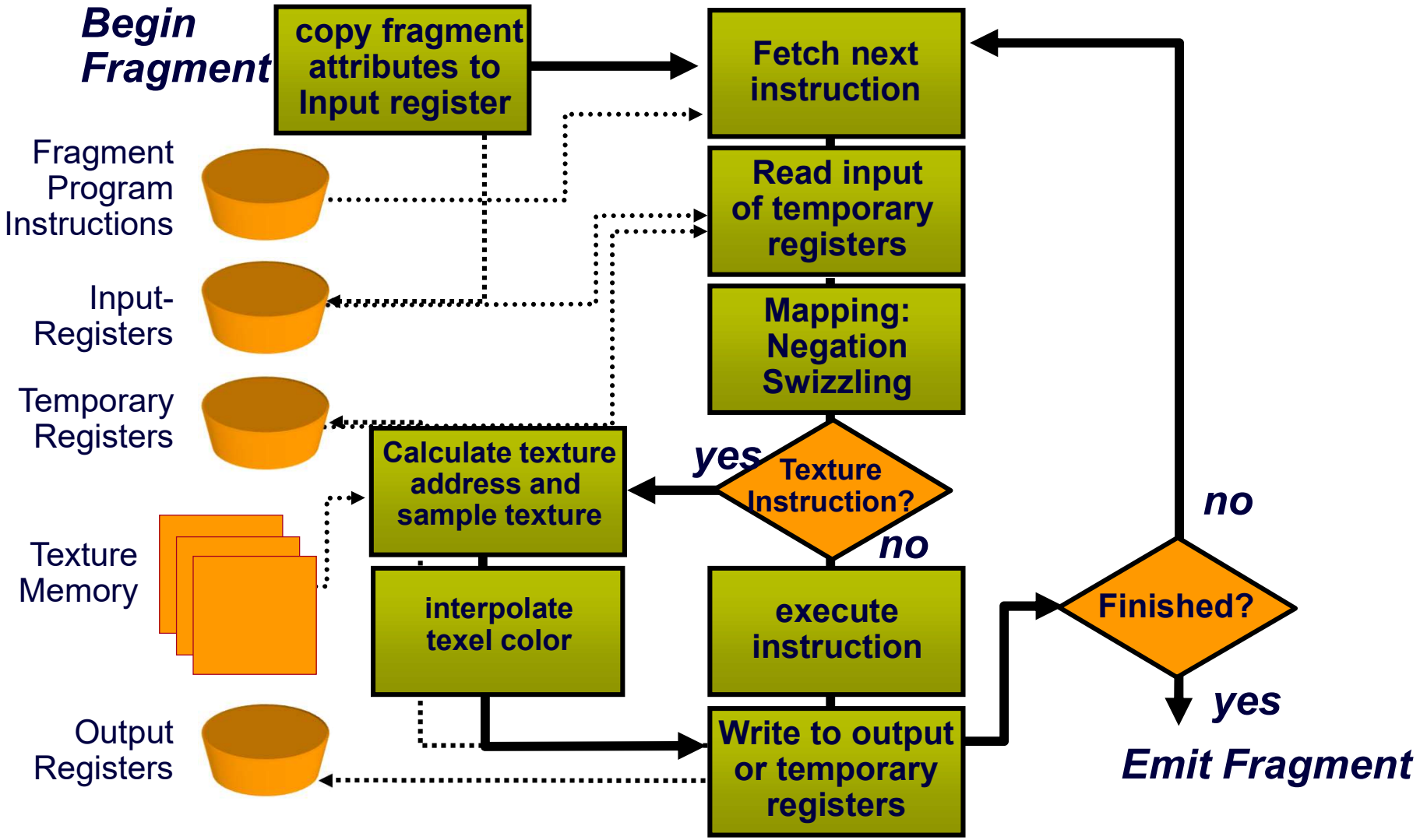


Legacy Fragment Shading Unit (2)

Example code

```
!!ARBfp1.0

ATTRIB unit_tc = fragment.texcoord[ 0 ];
PARAM  mvp_inv[]  = { state.matrix.mvp.inverse };
PARAM  constants  = {0, 0.999, 1, 2};

TEMP pos_win, temp;

TEX pos_win.z, unit_tc, texture[ 1 ], 2D;

ADD pos_win.w, constants.y, -pos_win.z;
KIL pos_win.w;

MOV result.color.w, pos_win.z;

MOV pos_win.xyw, unit_tc;
MAD pos_win.xyz, pos_win, constants.a, -constants.b;

DP4 temp.w, mvp_inv[ 3 ], pos_win;
RCP temp.w, temp.w;

MUL pos_win, pos_win, temp.w;

DP4 result.color.x, mvp_inv[ 0 ], pos_win;
DP4 result.color.y, mvp_inv[ 1 ], pos_win;
DP4 result.color.z, mvp_inv[ 2 ], pos_win;

END
```

Fragment Processor



A diffuse reflectance shader

```
sampler mySamp;
Texture2D<float3> myTex;
float3 lightDir;

float4 diffuseShader(float3 norm, float2 uv)
{
  float3 kd;
  kd = myTex.Sample(mySamp, uv);
  kd *= clamp( dot(lightDir, norm), 0.0, 1.0);
  return float4(kd, 1.0);
}
```

Independent, but no explicit parallelism

Compile shader

1 unshaded fragment input record

```
sampler mySamp;
Texture2D<float3> myTex;
float3 lightDir;

float4 diffuseShader(float3 norm, float2 uv)
{
  float3 kd;
  kd = myTex.Sample(mySamp, uv);
  kd *= clamp ( dot(lightDir, norm), 0.0, 1.0);
  return float4(kd, 1.0);
}
```

```
<diffuseShader>:
sample r0, v4, t0, s0
mul  r3, v0, cb0[0]
madd r3, v1, cb0[1], r3
madd r3, v2, cb0[2], r3
clmp r3, r3, l(0.0), l(1.0)
mul  o0, r0, r3
mul  o1, r1, r3
mul  o2, r2, r3
mov  o3, l(1.0)
```

1 shaded fragment output record

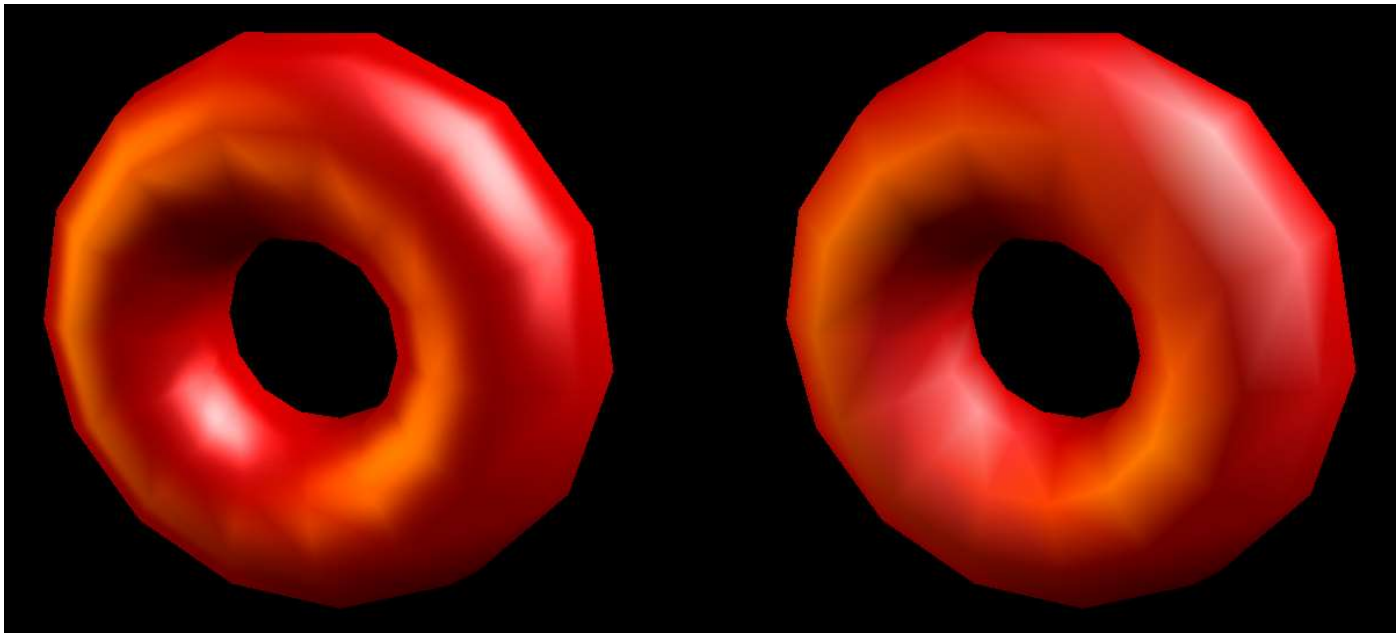
Per-Pixel(Fragment) Lighting

Simulating smooth surfaces by calculating illumination for each fragment

Example: specular highlights (Phong illumination/shading)

Phong shading:
per-fragment evaluation

Gouraud shading:
linear interpolation from vertices



Per-Pixel Phong Lighting (Cg)

```
void main(float4 position  : TEXCOORD0,
          float3 normal    : TEXCOORD1,

      out float4 oColor     : COLOR,

  uniform float3 ambientCol,
  uniform float3 lightCol,
  uniform float3 lightPos,
  uniform float3 eyePos,
  uniform float3 Ka,
  uniform float3 Kd,
  uniform float3 Ks,
  uniform float  shiny)
{
```

Per-Pixel Phong Lighting (Cg)

```
  float3 P = position.xyz;
  float3 N = normal;
  float3 V = normalize(eyePosition - P);
  float3 H = normalize(L + V);

  float3 ambient = Ka * ambientCol;

  float3 L         = normalize(lightPos - P);
  float  diffLight = max(dot(L, N), 0);
  float3 diffuse   = Kd * lightCol * diffLight;

  float specLight = pow(max(dot(H, N), 0), shiny);
  float3 specular = Ks * lightCol * specLight;

  oColor.xyz = ambient + diffuse + specular;
  oColor.w = 1;
}
```

Thank you.