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Computação Gráfica

Aula 18: Pipeline Gráfico

Immediate Mode vs Retained Mode

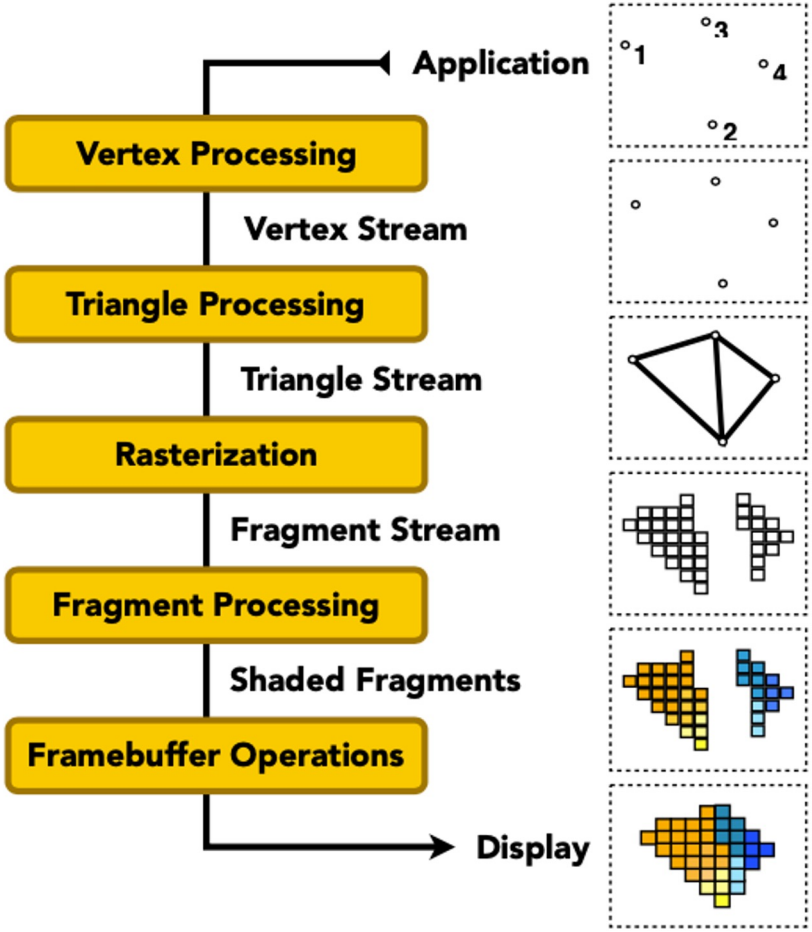
No modo imediato (Immediate Mode) da API gráfica, a aplicação envia todos os comandos de desenho a cada quadro (obsoleto para OpenGL).

```
glBegin(GL_TRIANGLES);
    glVertex3f( 0.0f, 1.0f, 0.0f);
    glVertex3f(-1.0f,-1.0f, 0.0f);
    glVertex3f( 1.0f,-1.0f, 0.0f);
glEnd();
glTranslatef(3.0f,0.0f,0.0f);
```

No modo retido (Retained Mode) da API gráfica, o prepara todos os dados da cena, e para cada vez que um novo quadro é desenhado, a biblioteca gráfica usa esses dados para desenhar a cena.

```
Int bufferIDs[] = new int[2];
gl.glGenBuffers(2, bufferIDs,0);
gl.glBindBuffer(GL_ARRAY_BUFFER, bufferIDs[0]);
glBufferData(GL_ARRAY_BUFFER, sizeof(MyVertex)*3, &pvertex[0].x, GL_STATIC_DRAW);
glDrawElements(GL_TRIANGLES, 3, GL_UNSIGNED_SHORT, BUFFER_OFFSET(0));
```

Pipeline de Rasterização



Vértices no espaço 3D

Vértices posicionados em coordenadas da tela

Triângulos posicionados em coordenadas da tela

Fragmentos

Fragmentos tonalizados

Imagem (pixels)

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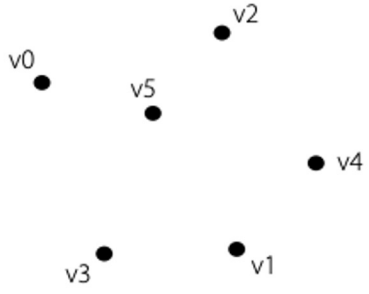
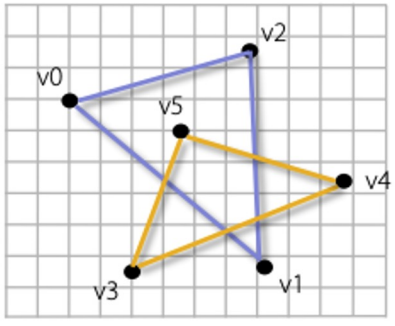
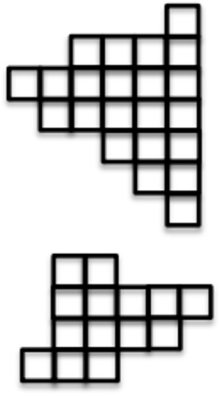
Entidades na Pipeline



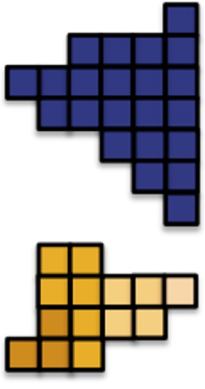
Vertices



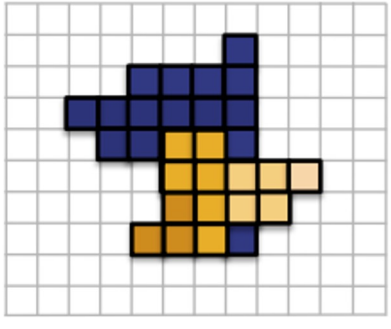
Primitives



Fragments



Fragments (shaded)



Pixels

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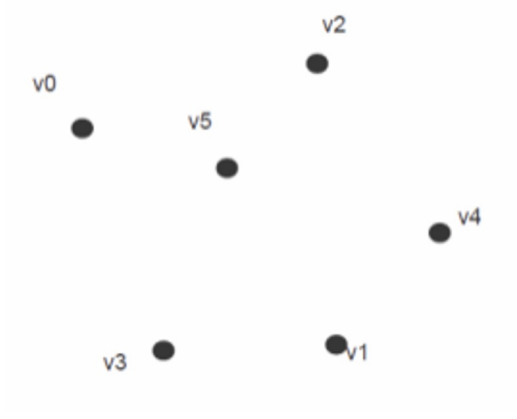
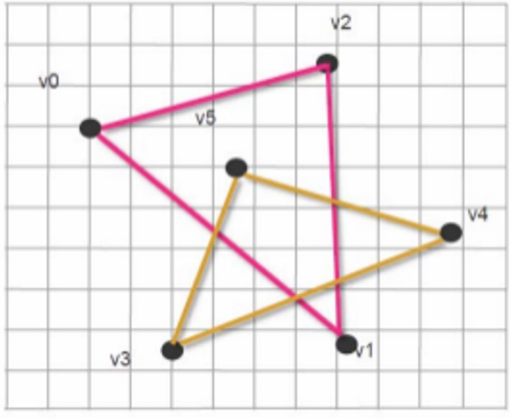
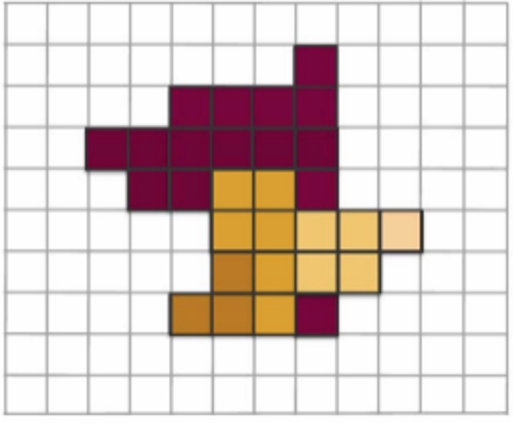
Como os Shaders são Invocados



Vertex Shader
invocado 6 vezes



Geometry Shader
invocado 2 vezes

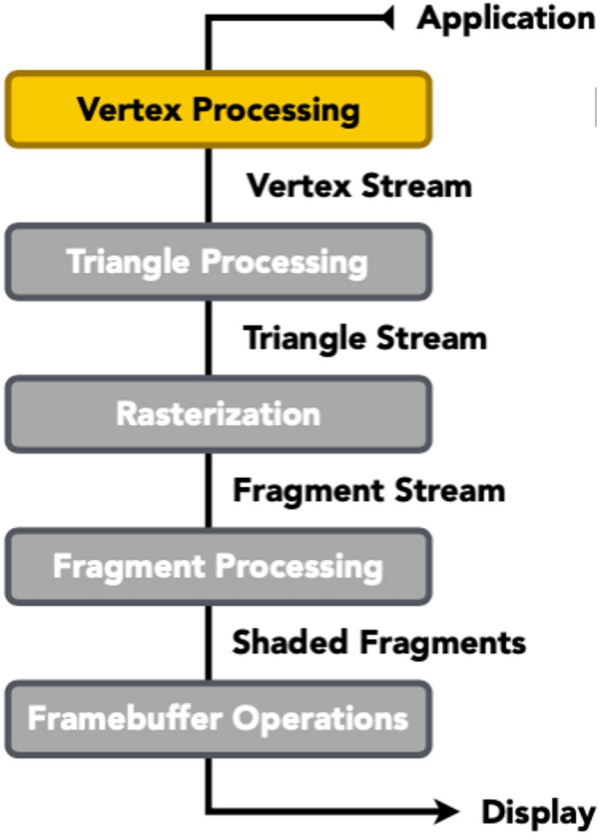


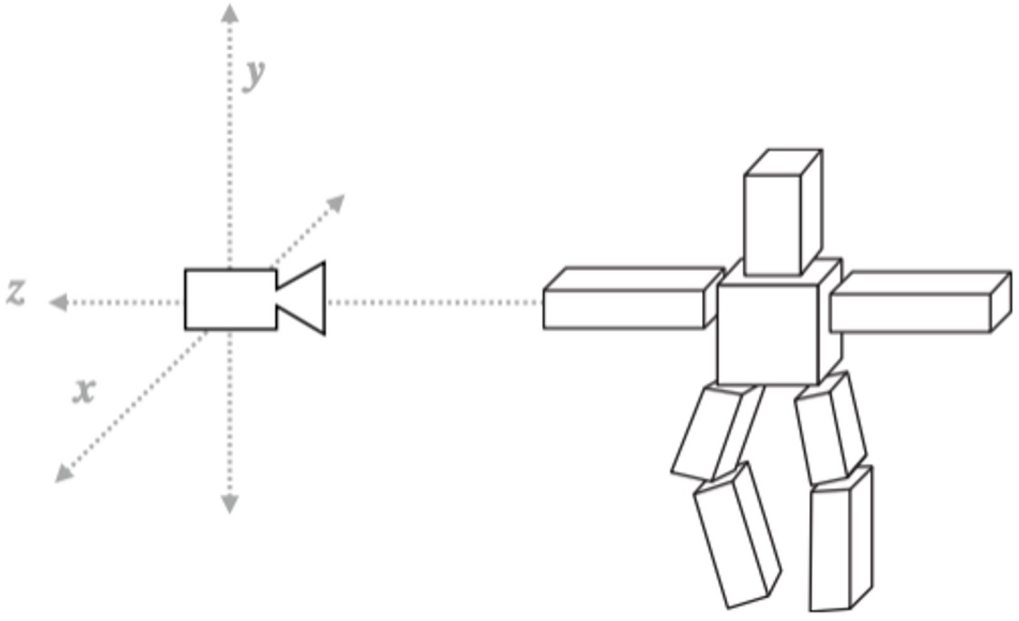
Fragment Shader
invocado 35 vezes

(para os fragmentos
ocultos também)

fonte: https://eclass.aueb.gr/modules/document/file.php/INF143

Transformações Geométricas e Visualização





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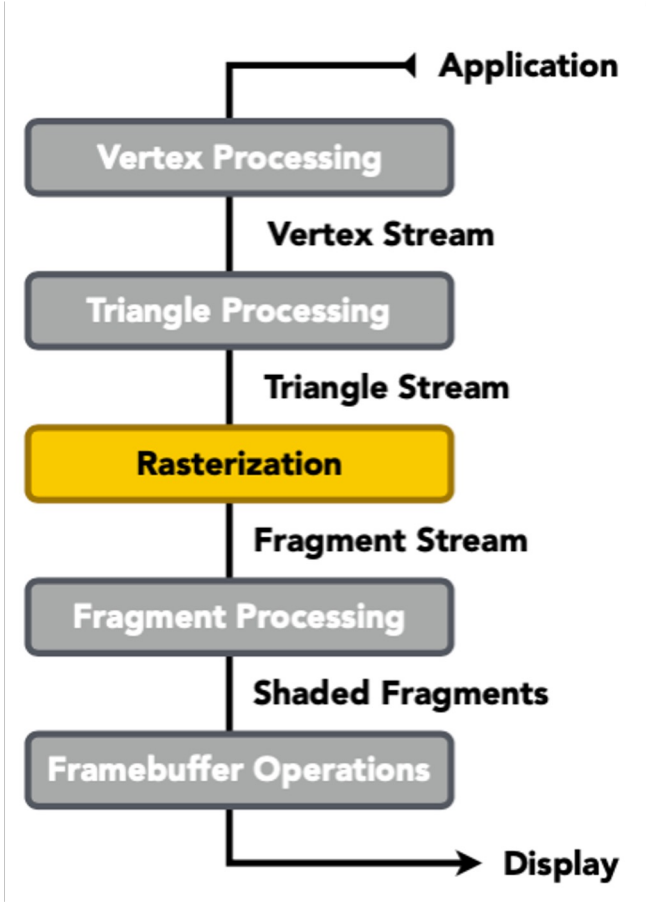
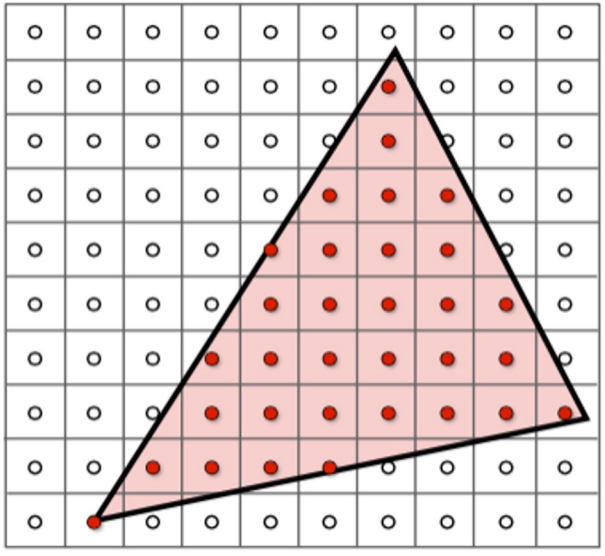
Amostrando os Triângulo





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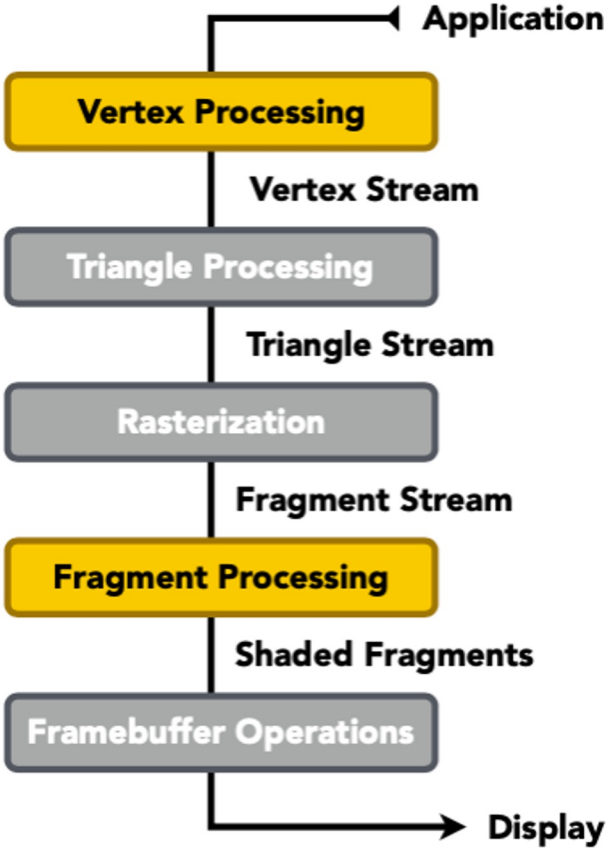
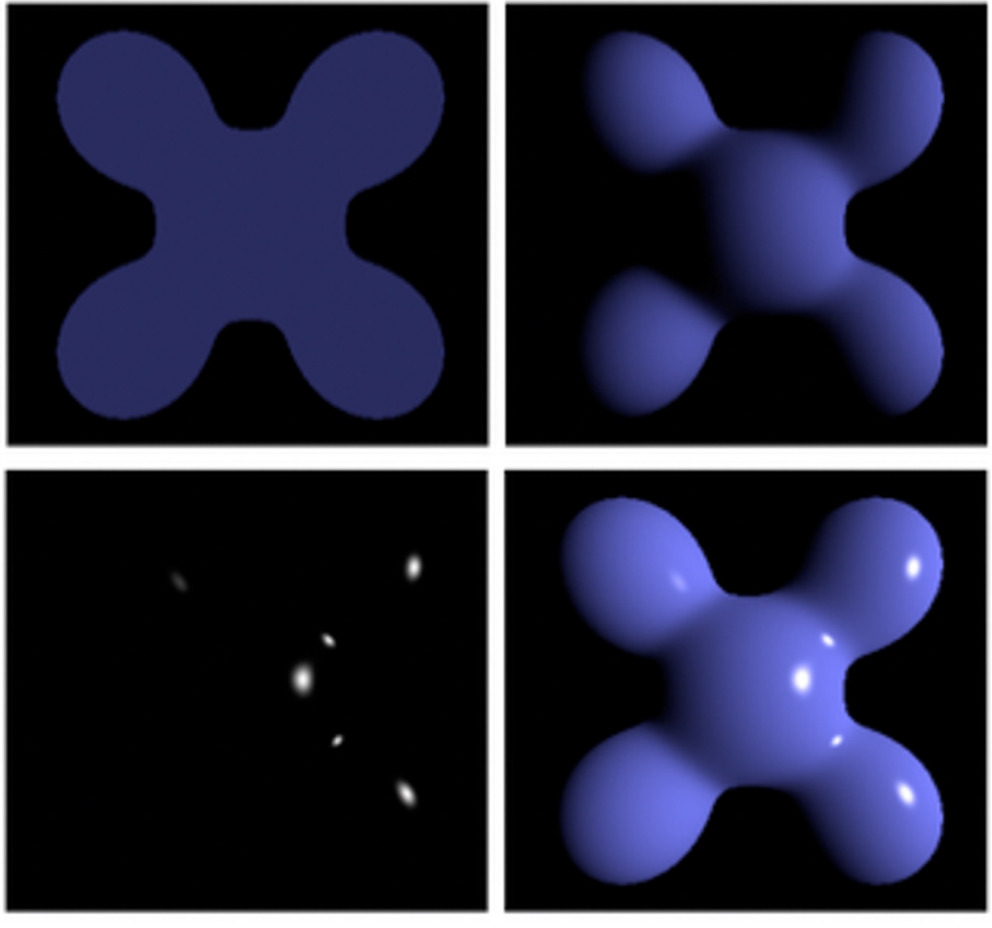
Avaliando a Função de Shading





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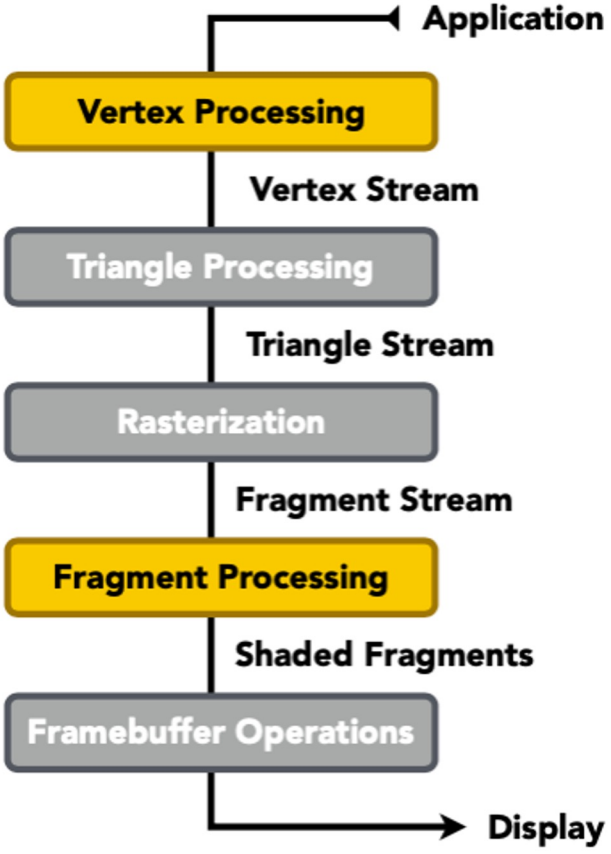
Mapeamento de Texturas



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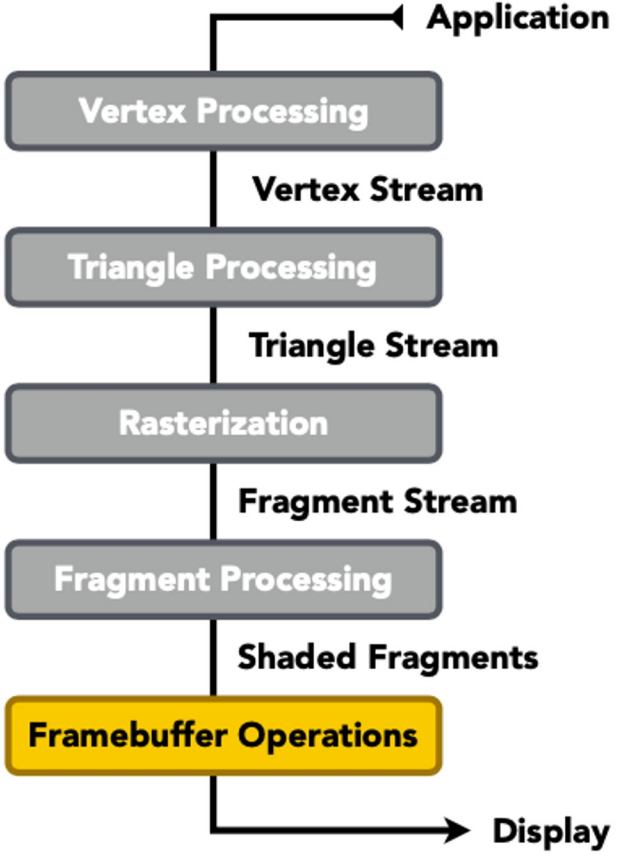
Teste de Visibilidade do Z-Buffer



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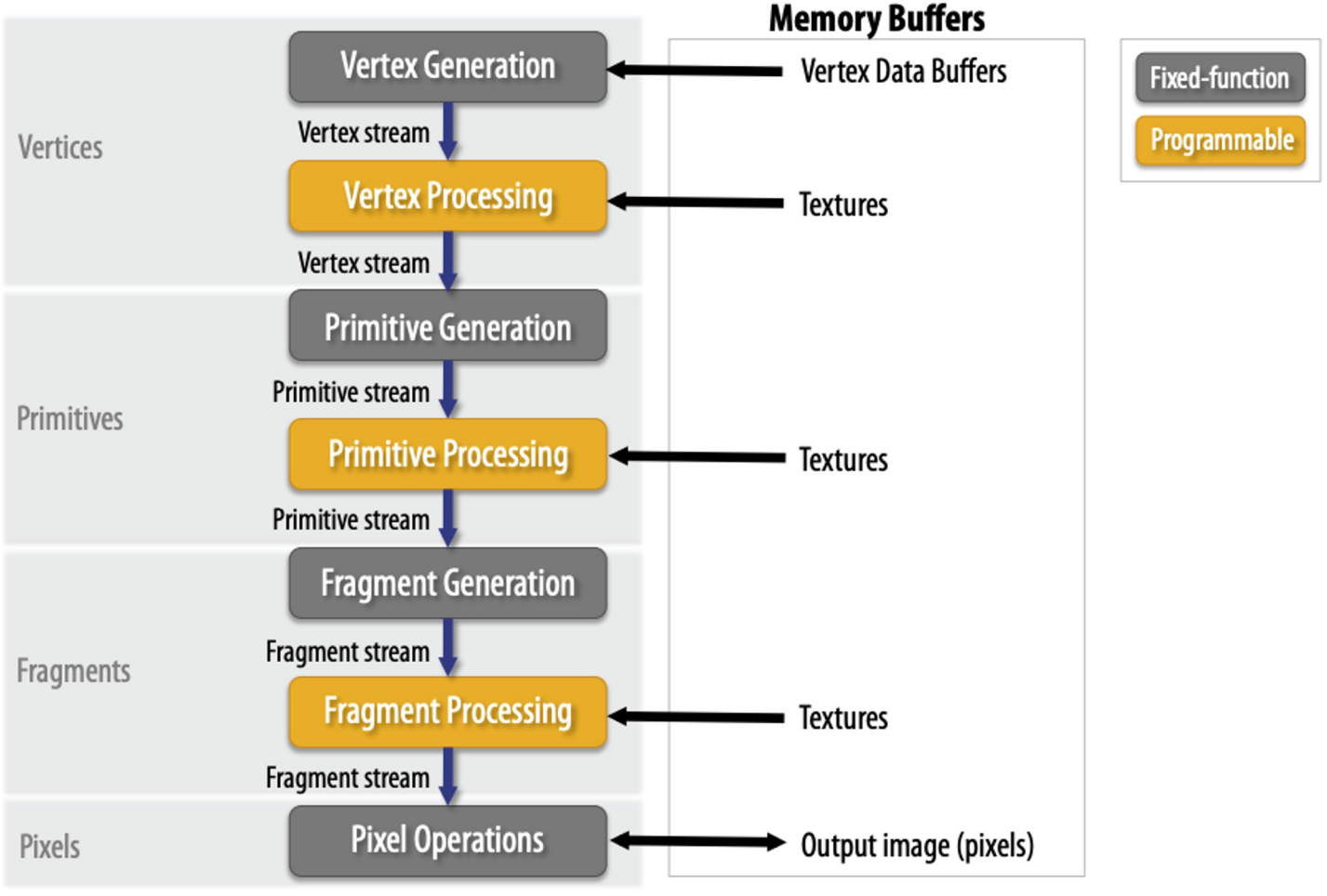
Visão do Pipeline



fonte: https://www.cs.cmu.edu/afs/cs/academic/class/15462-f11/www/lec_slides/lec19.pdf

Objetivo: Cenas 3D complexas em tempo real

Centenas de milhares a milhões de triângulos em uma cena
Cálculos complexos de vértices e fragmentos nos shaders
Alta resolução (2-4 megapixels + supersampling)
30-60 quadros por segundo (ainda mais alto para VR)

Unrecord - Official Early Gameplay Trailer

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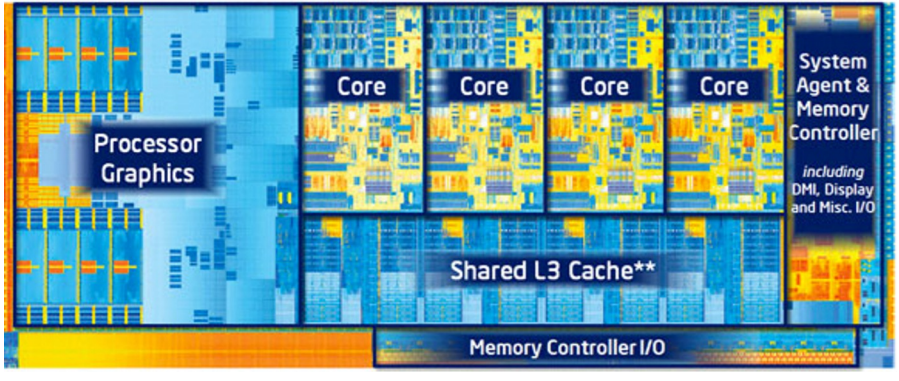
Implementações de Pipelines Gráficos : GPUs

Processadores especializados para executar cálculos de pipeline de gráficos

Placas discretas de GPU
NVIDIA GeForce 3090



GPU Integrada:
(Parte do die da CPU Intel)

Shaders Programáveis

Estágios de processamento de vértice e fragmento do programa
Descrever a operação em um único vértice (ou fragmento)

Exemplo de programa de shader em GLSL

```
uniform sampler2D myTexture;
uniform vec3 lightDir;
varying vec2 uv;
varying vec3 norm;

void diffuseShader() {
   vec3 kd;
   kd = texture(myTexture, uv);
   kd *= clamp(dot(-lightDir, norm), 0.0, 1.0);
   gl_FragColor = vec4(kd, 1.0);
}
```

A função é executada uma vez por fragmento.

- Exibe a cor da superfície na posição de amostra da tela do fragmento atual.
- Este *shader* executa uma pesquisa de textura para obter a cor do material da superfície no ponto e, em seguida, executa um cálculo de iluminação difusa.

Compilação de um Shader

1 fragmento de entrada não processado

```
sampler mySampler;
Texture2D<float3> myTexture;
float3 lightDir;

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

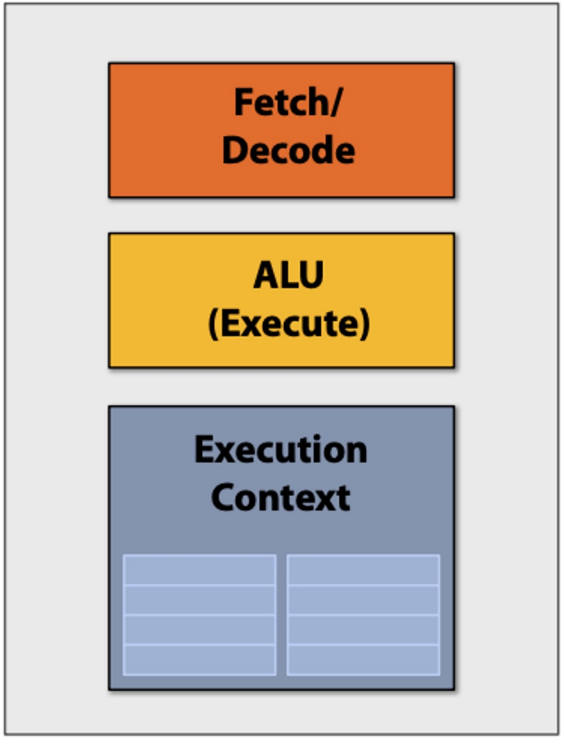
```
<diffuseShader>:
sample r0, v4, t0, s0
mul  r3, v0, cb0[0]
madd r3, v1, cb0[1], r3
madd r3, v2, cb0[2], r3
clmp r3, r3, l(0.0), l(1.0)
mul  o0, r0, r3
mul  o1, r1, r3
mul  o2, r2, r3
mov  o3, l(1.0)
```

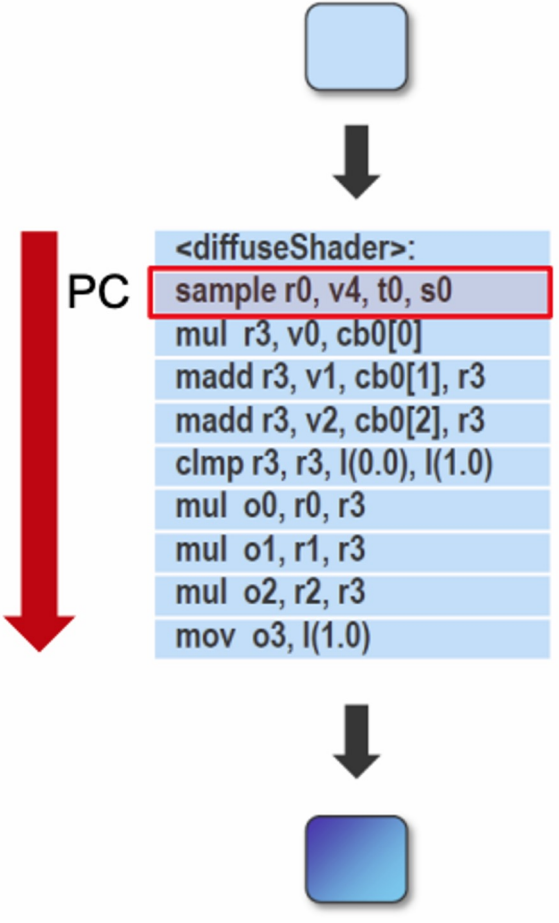
1 fragmento de saída processado

fonte: https://eclass.aueb.gr/modules/document/file.php/INF143

Mapeamento do Shader no HW

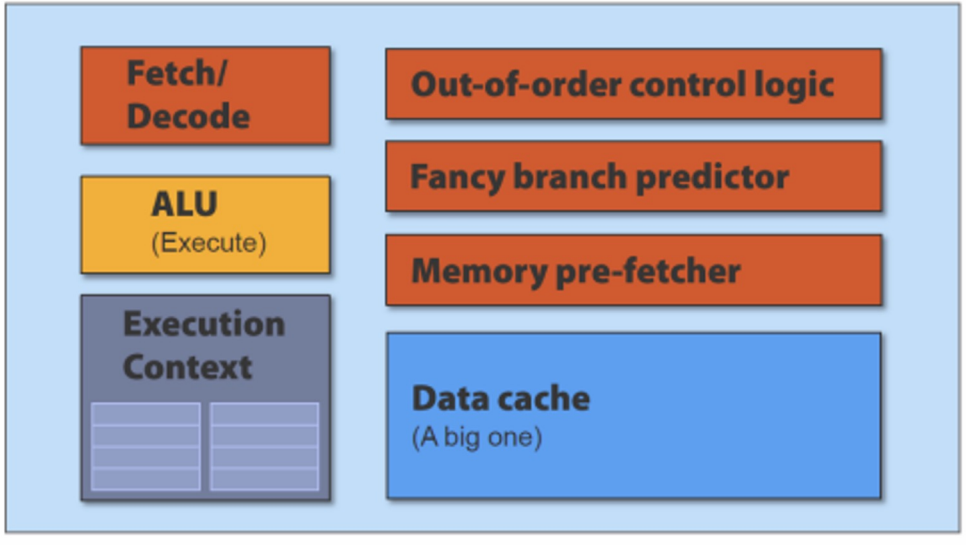
Execute o Shader em um único core:





Mapeamento do Shader no HW

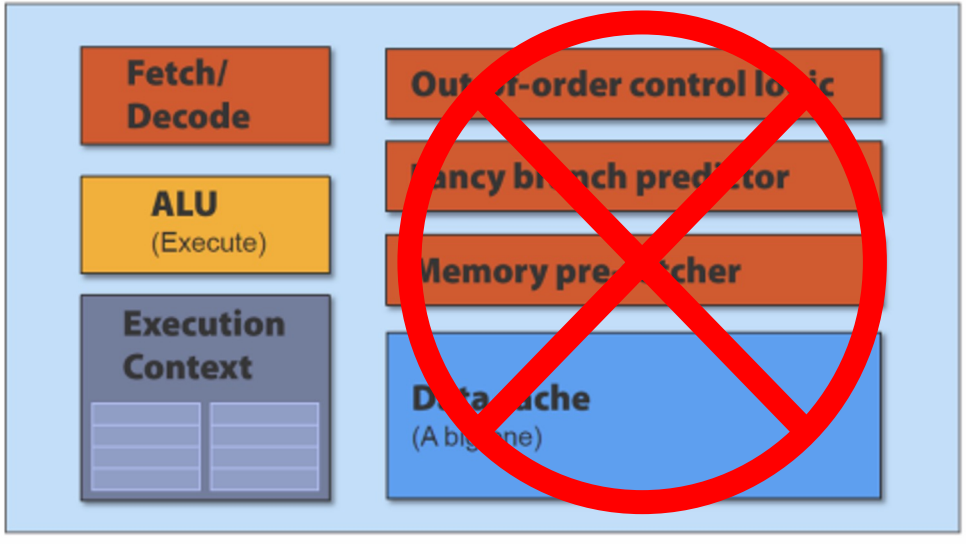
Um *core* de CPU



- Otimizado para acesso de baixa latência aos dados em cache
- Lógica de controle para execução fora de ordem e especulativa
- Grande cache L2

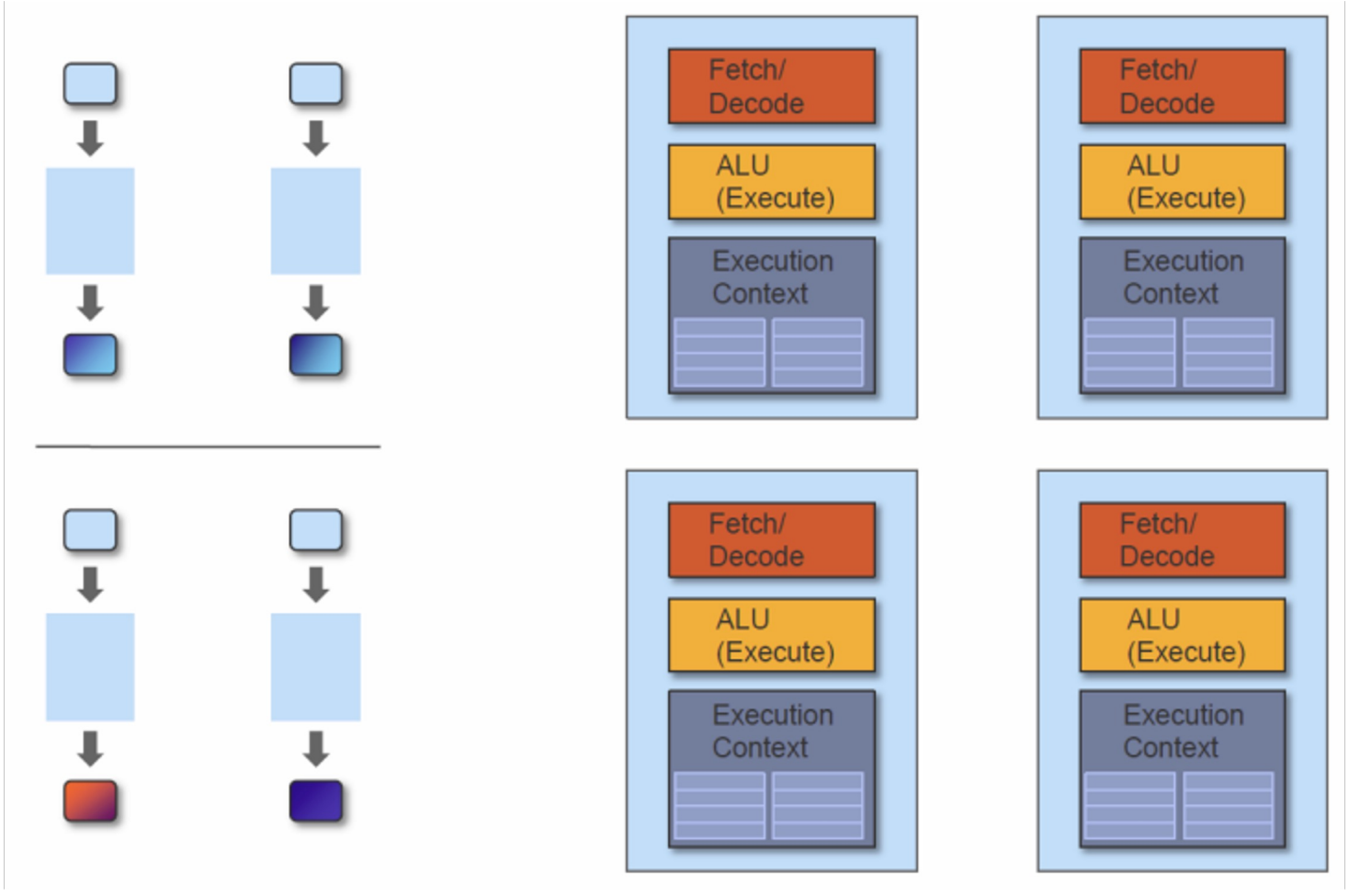
Reduzindo os Cores

Um *core* de GPU



- Otimizado para computação paralela de dados
- Arquitetura tolerante à latência de memória
- Mais cálculos por mais transistores em ALUs
- Redução dos circuitos principais de controle

Múltiplas Threads



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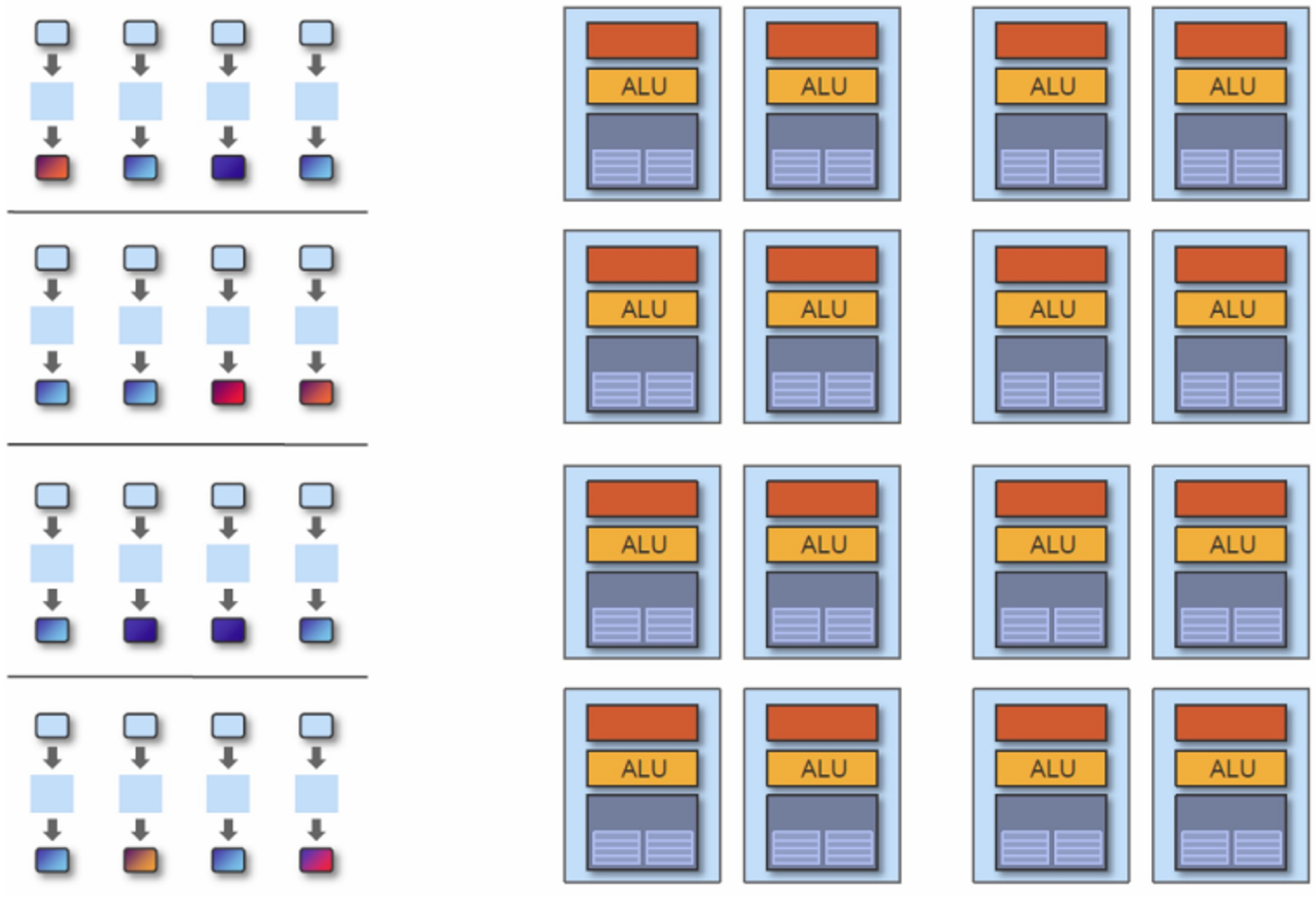
GPUs com muitos *Cores*



16 cores = 16 fluxos de instruções simultâneos

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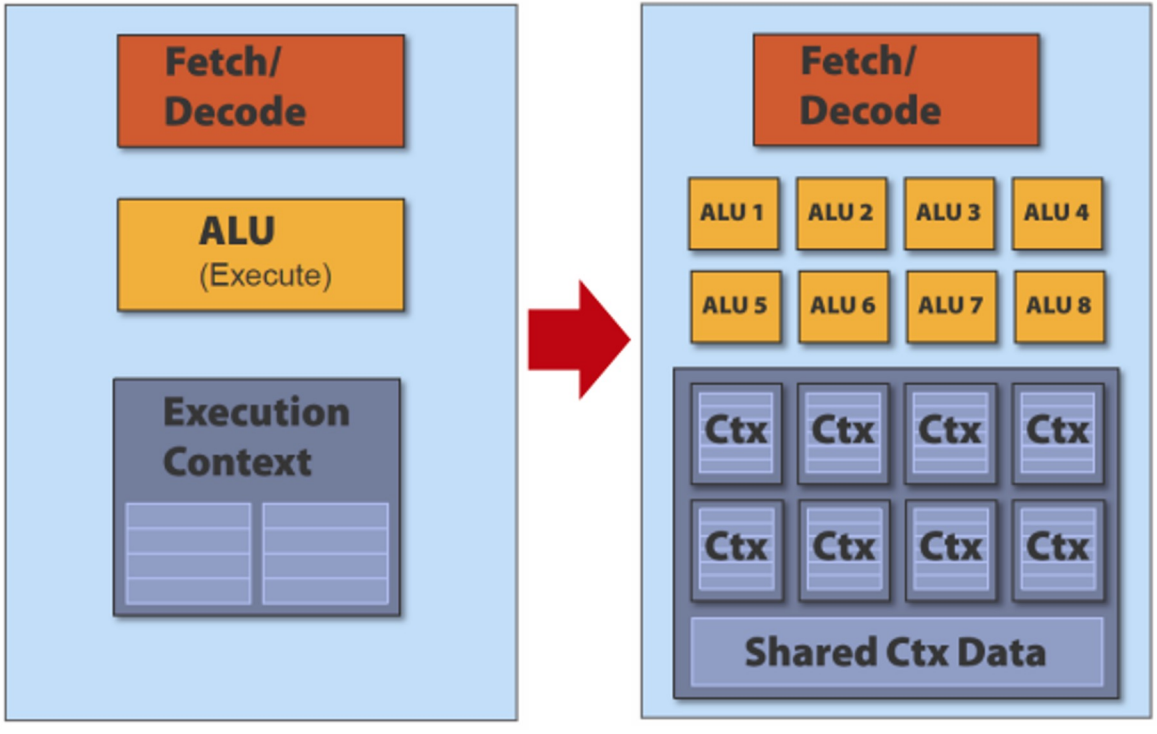
Múltiplos dados (SIMD)

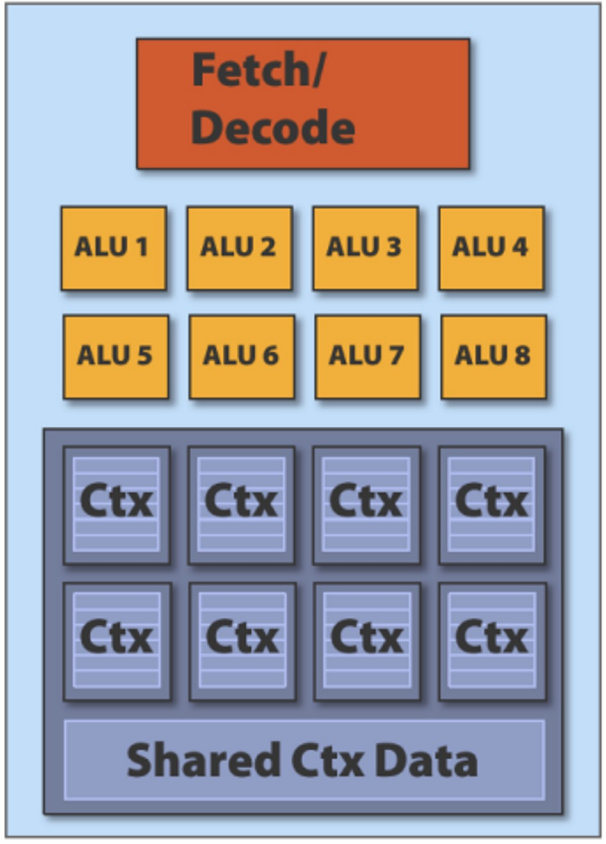
Shaders são inerentemente executados muitas vezes, repetidas vezes em vários registros de seus fluxos de dados de entrada.

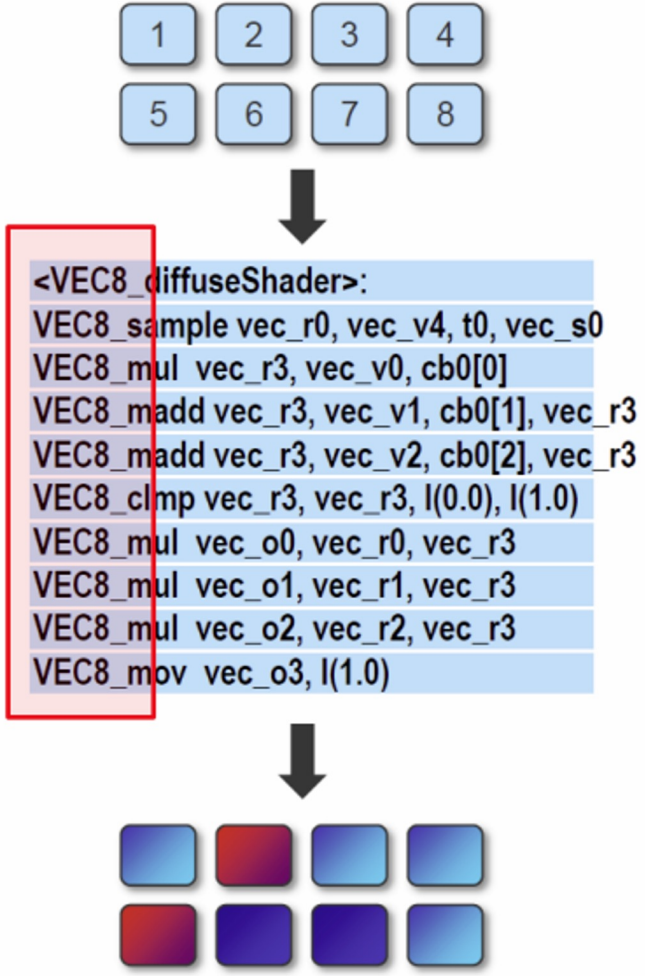


Amortize o custo / complexidade do gerenciamento de instruções para várias ALUs.

Compartilhe a unidade de instrução.

SIMD Cores: Vectorized Instruction Set





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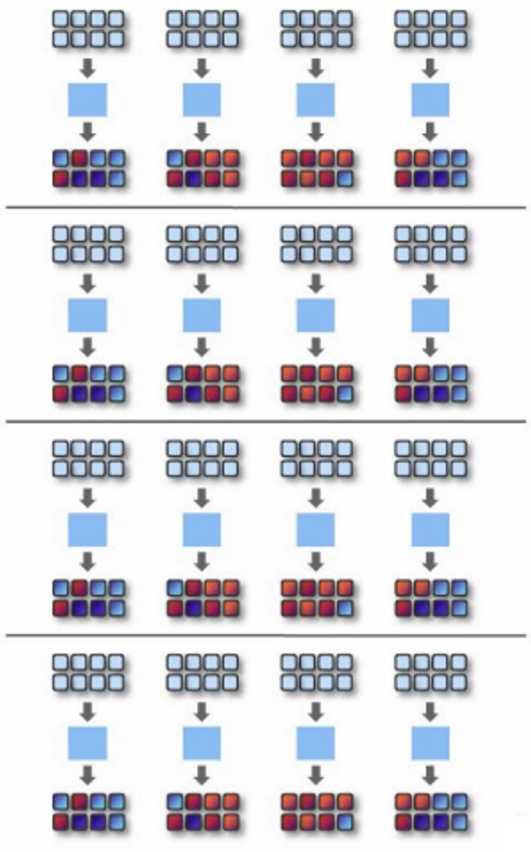
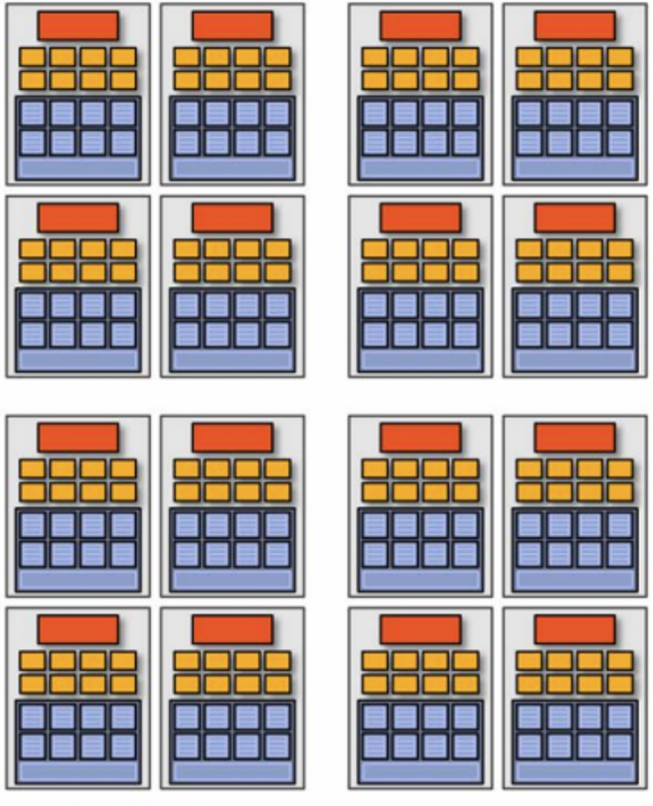
Adicionando tudo: vários núcleos SIMD

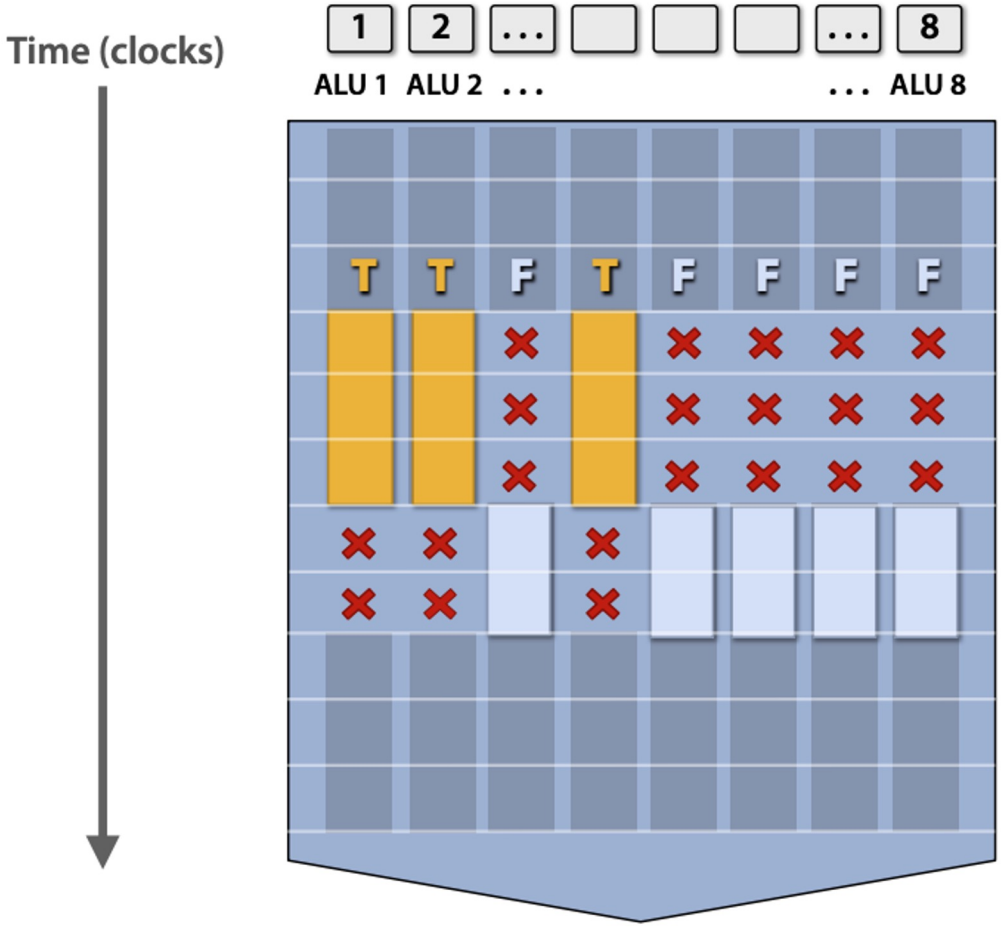
Neste exemplo: 128 dados processados simultaneamente





16 cores = 128 ALUs = 16 fluxos de instruções simultâneos

Condicionais / Branches




```
<unconditional
 shader code>

if (x > 0) {
    y = pow(x, exp);
    y *= Ks;
    refl = y + Ka;
} else {
    x = 0;
    refl = Ka;
}

<resume unconditional
 shader code>
```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Computação Gráfica

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