A CG Basic Knowledge Talk

@ IBM & 缘木轩 Club, SYSU

ABOUT ME

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- 15级软件工程（数字媒体）
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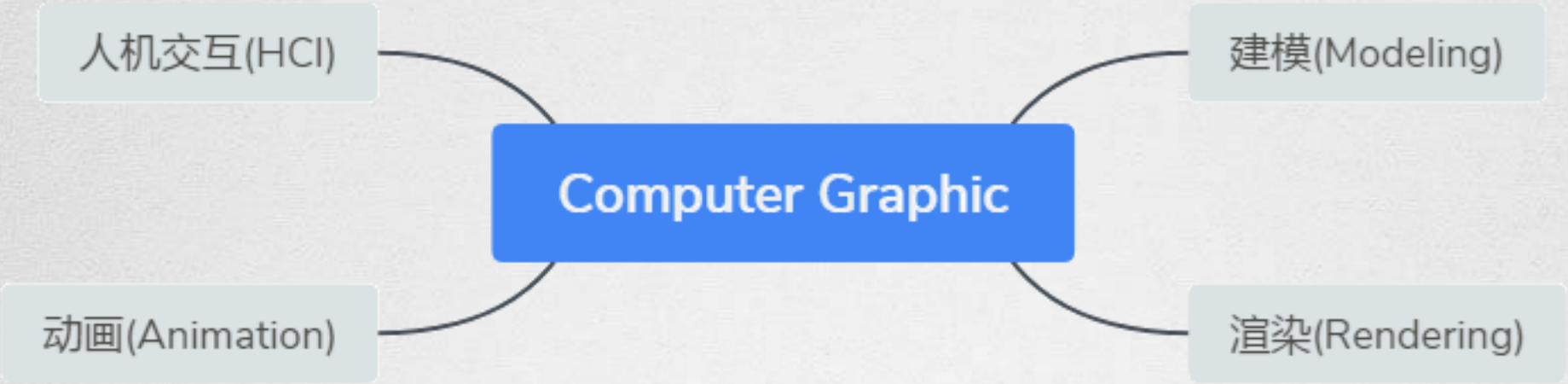
- https://github.com/longjj

计算机图形学是什么?



研究计算机在硬件和软件的帮助下创建计算机图形的科学学科。

- OpenGL? DirectX? …

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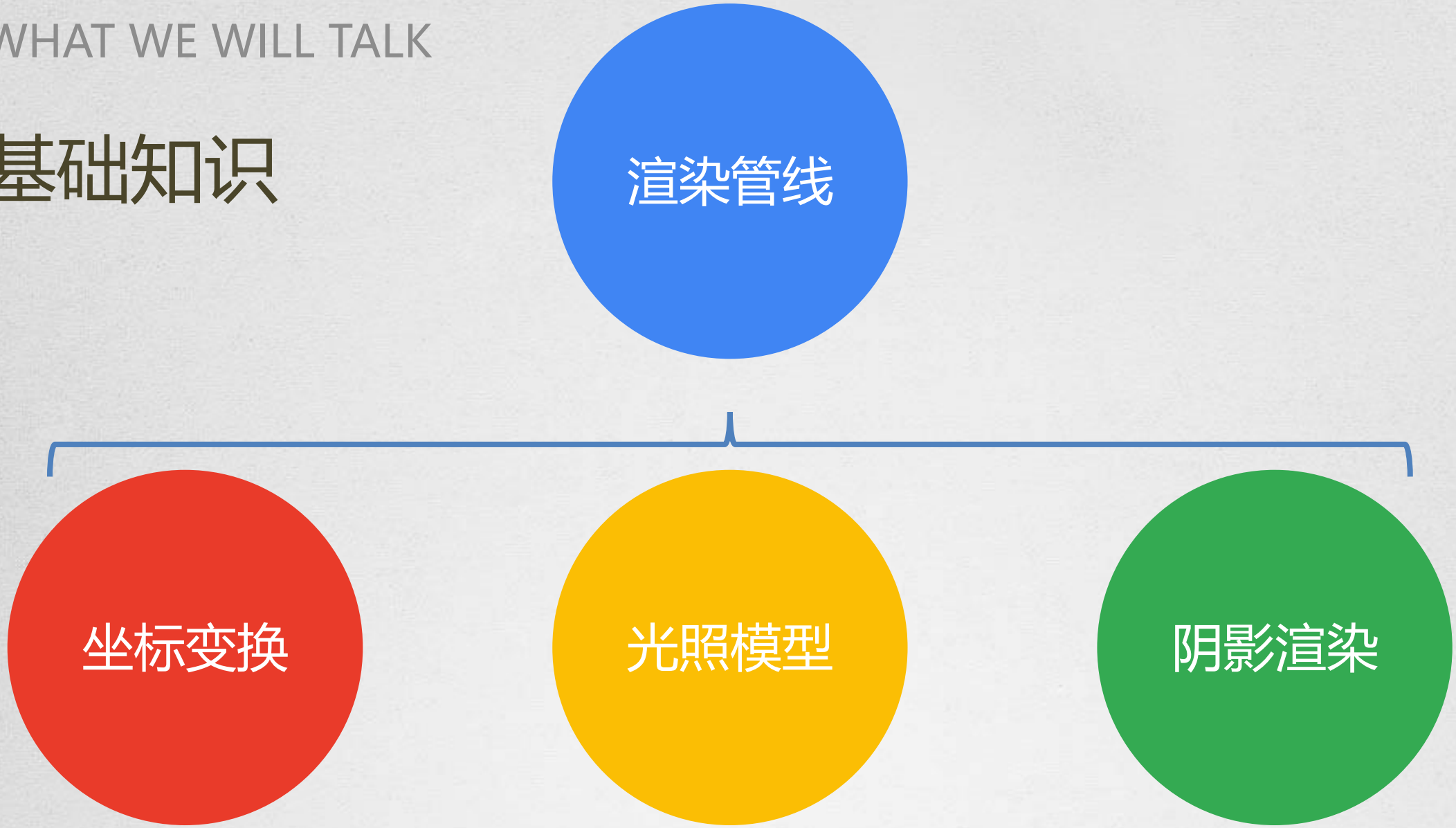
API调用

- OpenGL
- DirectX (Windows)
- Vulkan
- …

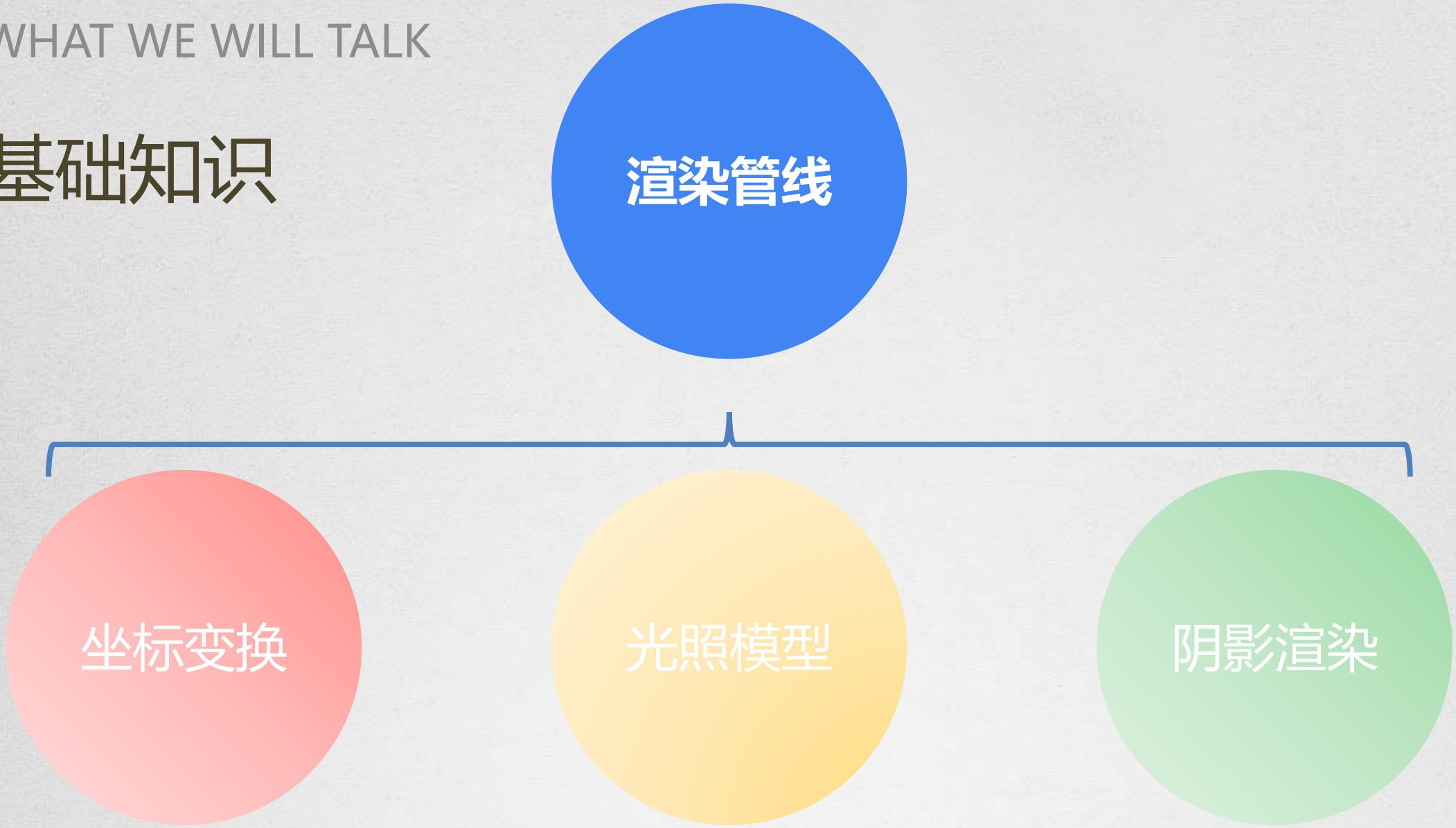
WHAT WE WILL TALK

基础知识



WHAT WE WILL TALK

基础知识



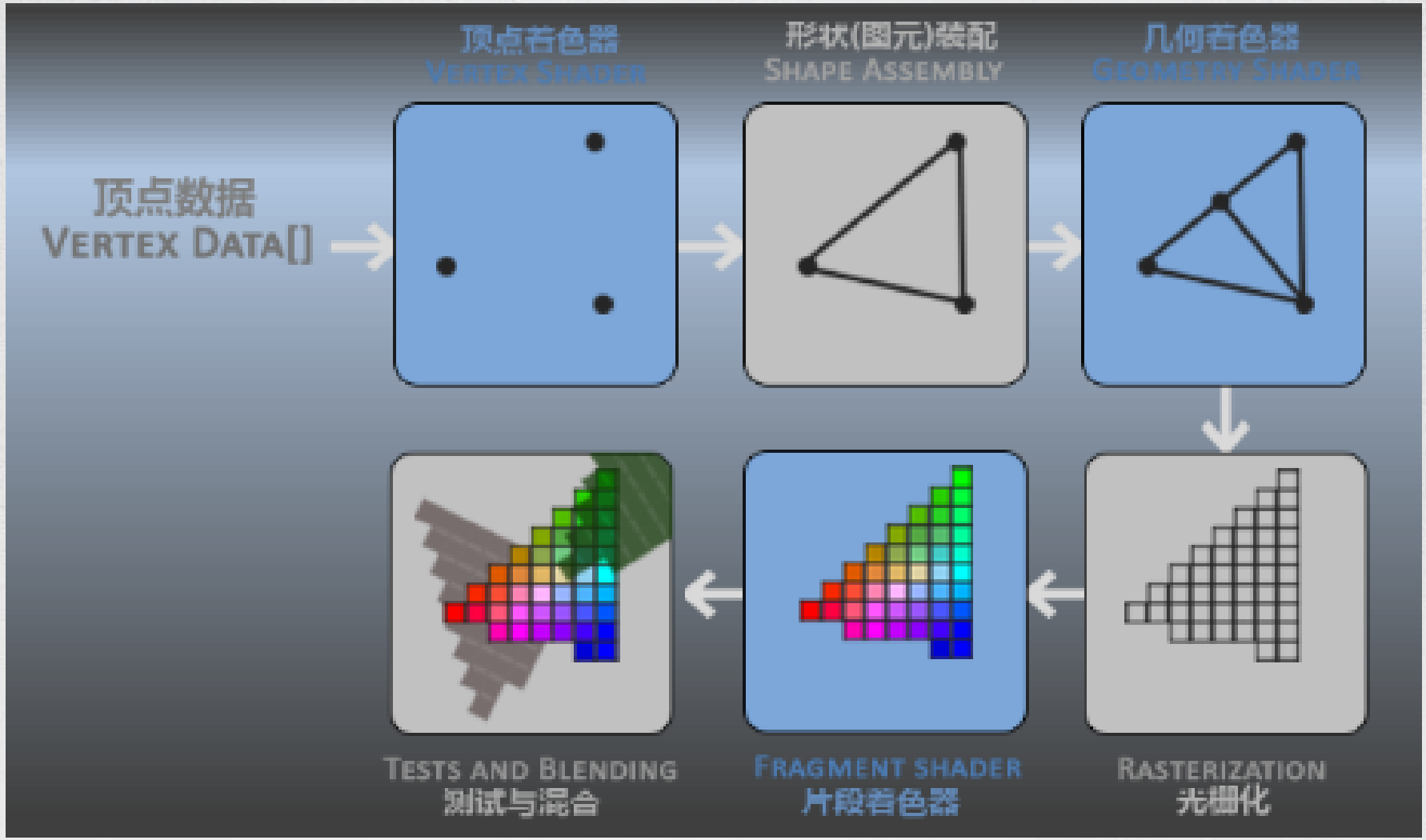
渲染管线主要做的两件事情

- 1. 3D坐标 → 2D坐标
- 2. 2D坐标 → 有颜色的像素

2D 坐标 ≠ 2D 像素

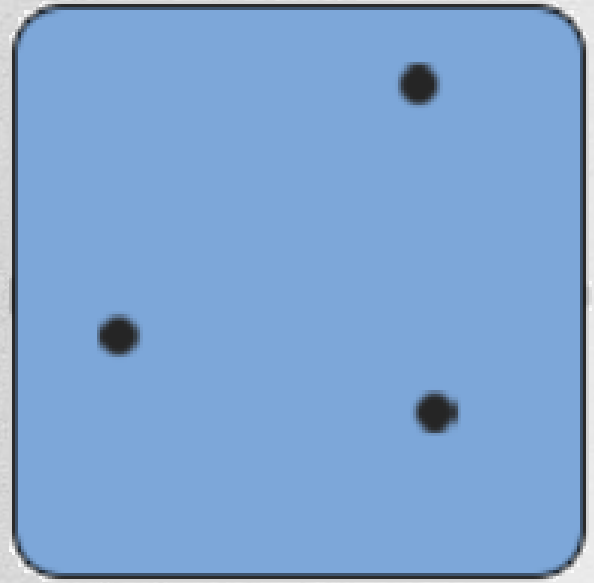
Rendering Pipeline

渲染流程图

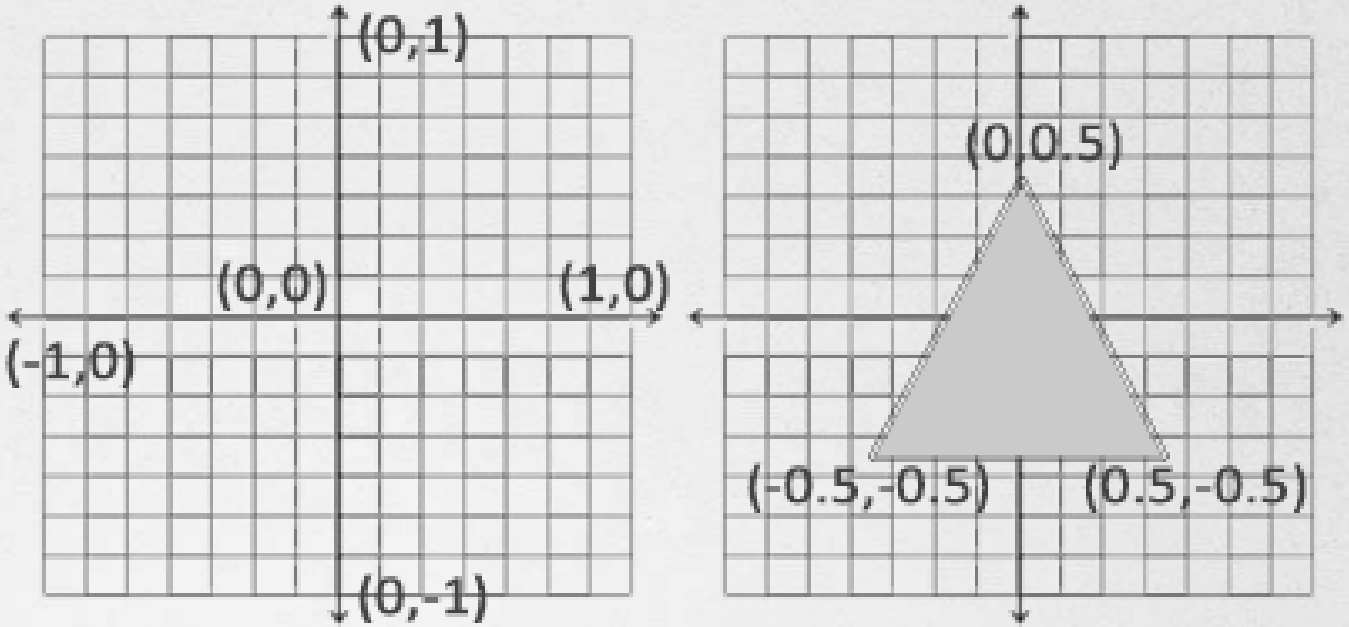


Rendering Pipeline

顶点着色器
VERTEX SHADER

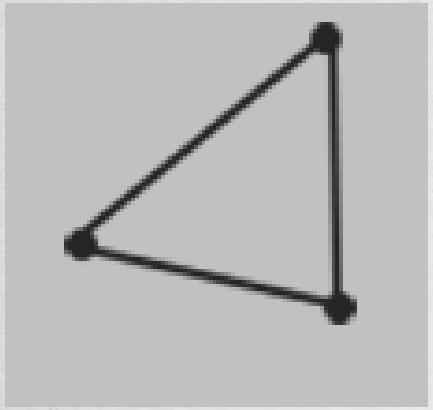


标准化设备坐标
(Normalized Device Coordinates, NDC)



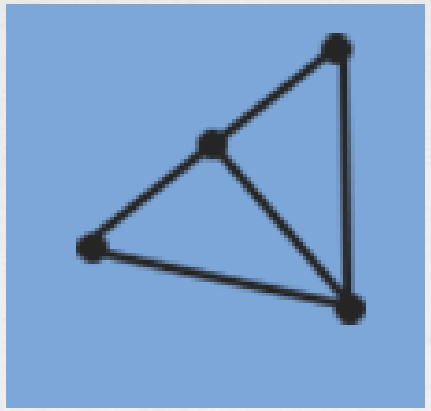
Rendering Pipeline

形状(图元)装配阶段



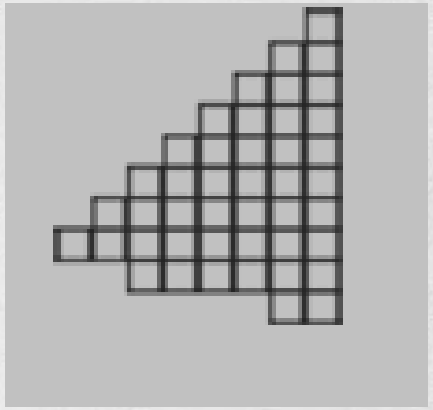
图元装配阶段将顶点着色器输出的所有顶点作为输入，将所有的点装配成指定图元的形状；

几何着色器



几何着色器把图元式的一系列顶点的集合形作为输入，它可以通过产生新顶点构造出新的（或是其它的）图元来生成其他形状。

光栅化阶段



光栅化阶段把图元映射为最终屏幕上相应的像素，生成供片段着色器使用的片段(Fragment)。在片段着色器运行之前会执行裁切(Clipping)。

暂停一下

图元(Primitive): 提示 OpenGL 对顶点数据进行渲染的渲染类型。

Eg. GL_POINTS、 GL_TRIANGLES、 GL_LINE_STRIP。

片段(Fragment): OpenGL 中的一个片段是 OpenGL 渲染一个像素所需的所有数据。

Rendering Pipeline

片段着色器

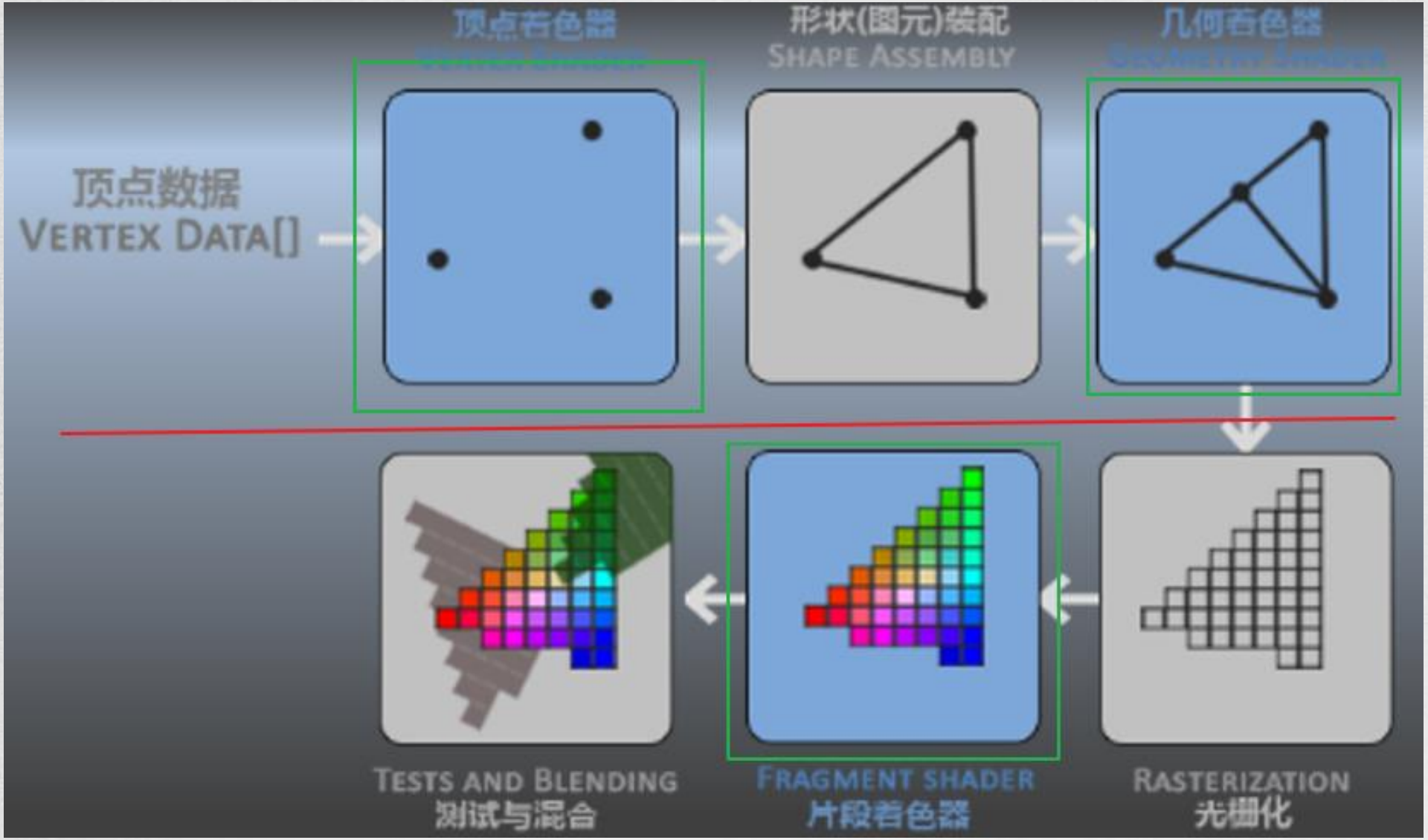
计算一个像素的最终颜色，这也是所有OpenGL高级效果产生的地方。

- Lighting
- Shading

测试与混合阶段

- 检测片段的对应的深度值，用它们来判断这个像素是其它物体的前面还是后面，决定是否应该丢弃。
- 检查alpha值（透明度）并对物体进行混合(Blend)。

Rendering Pipeline



GLSL

in / out

Communication between shaders

Layout

Vertex data input

uniform

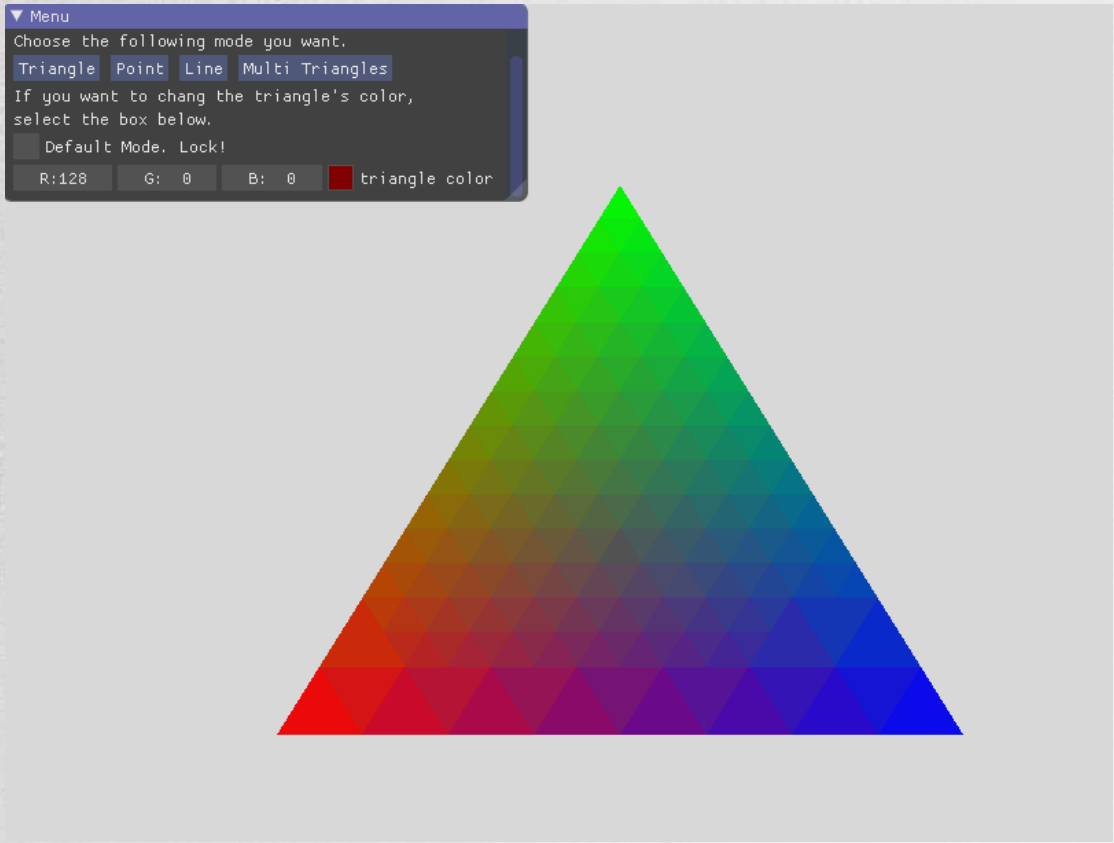
Variables controlled by Main()

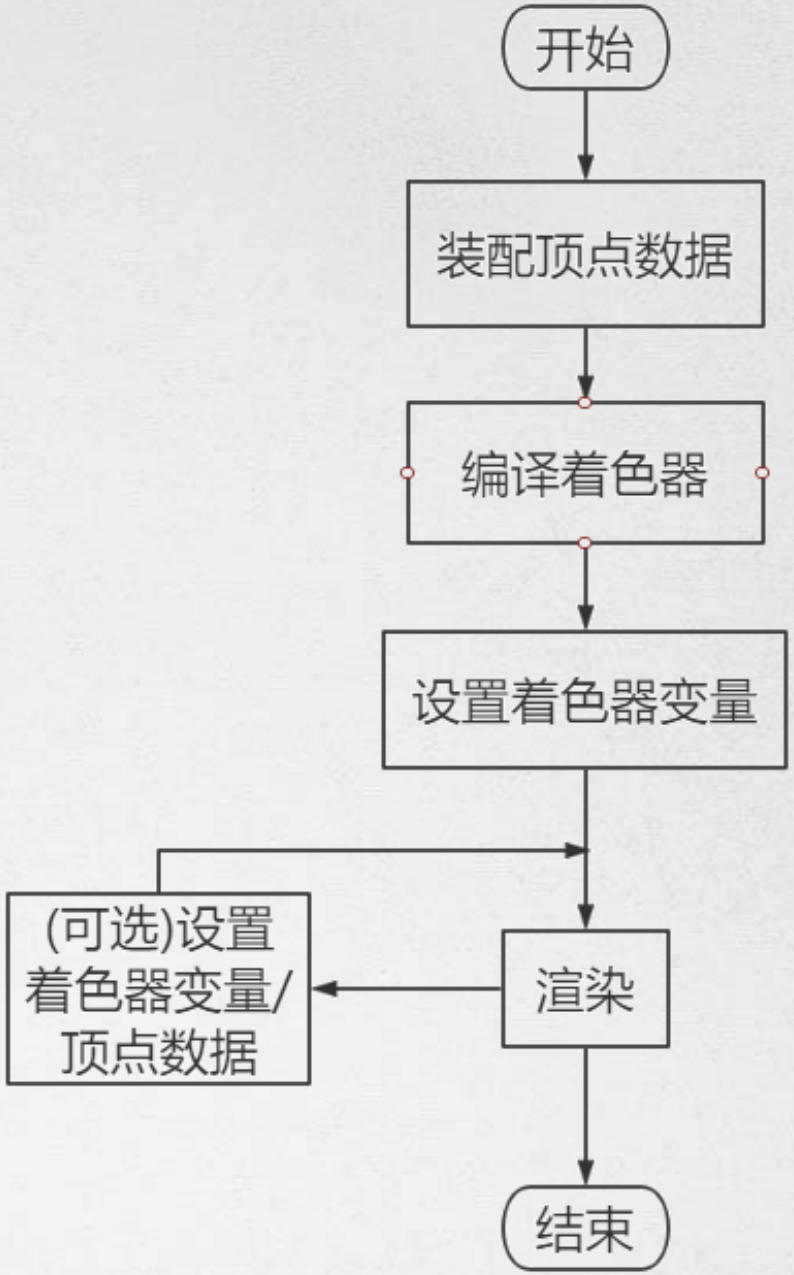
gl_Position / FragColor

Some predefined variables

Rendering Pipeline

基本程序流程





WHAT WE WILL TALK

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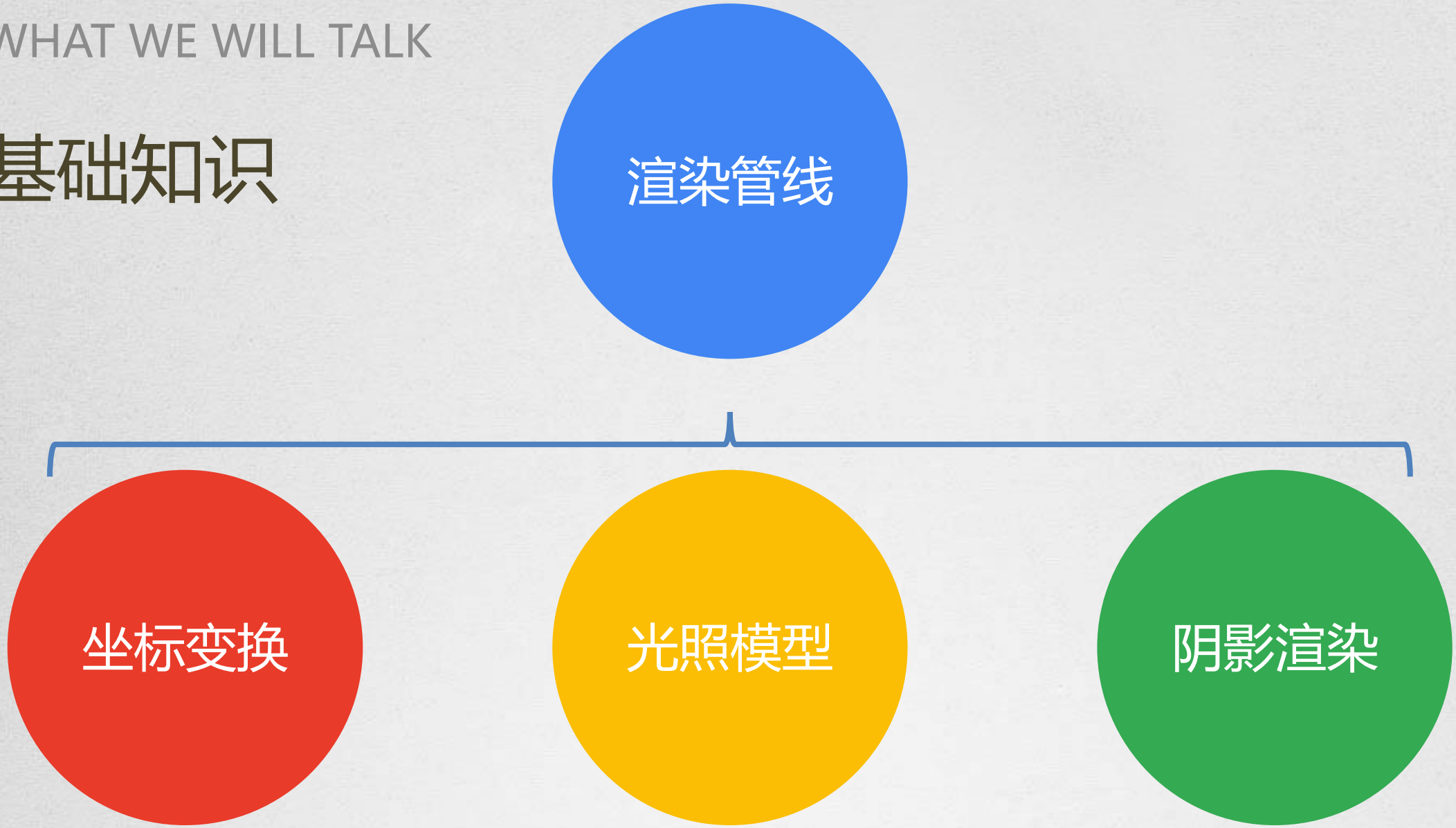

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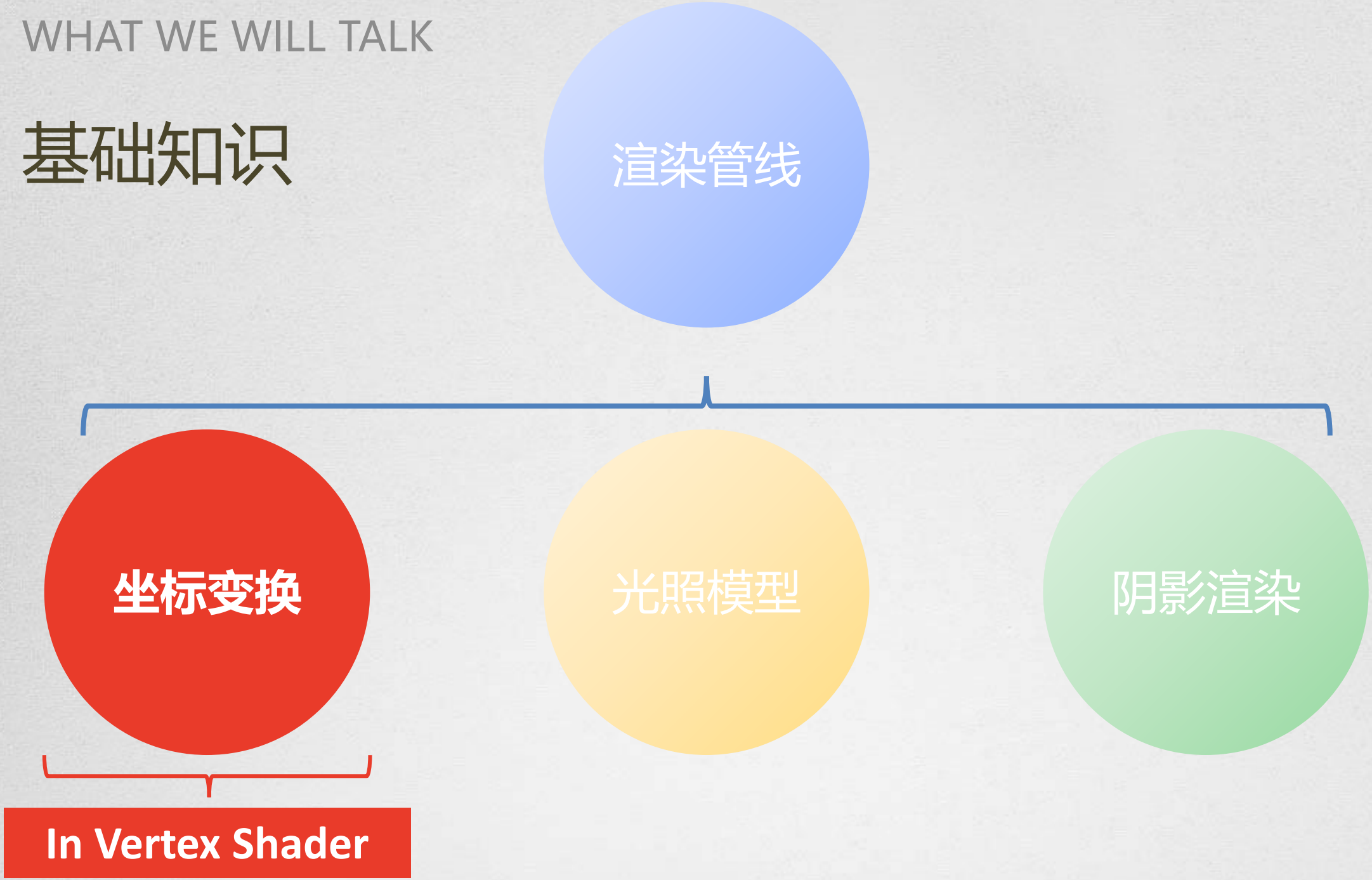
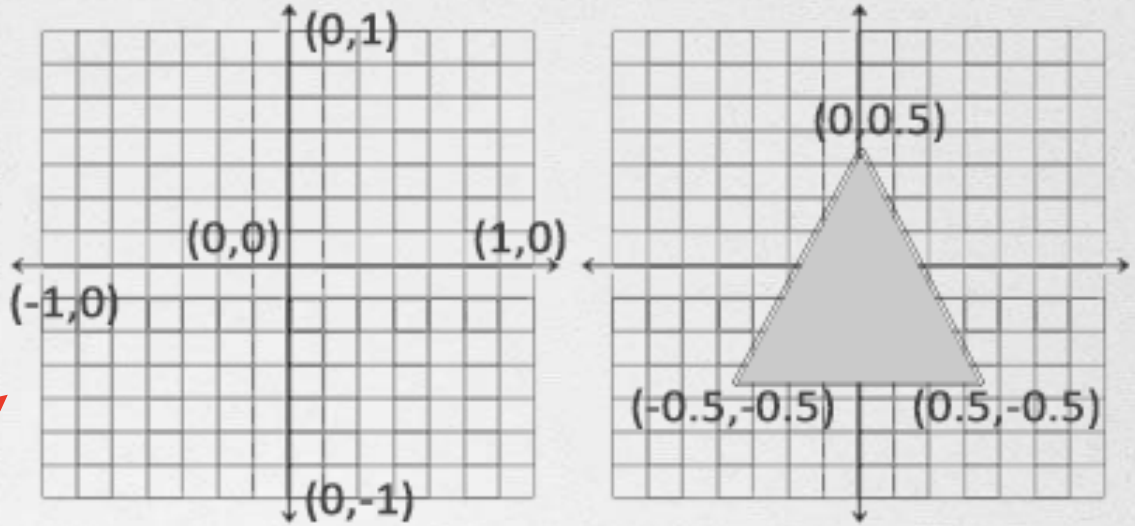


缘由

1. 不够直观

2. 动态渲染

标准化设备坐标
(Normalized Device Coordinates, NDC)



Homogeneous Coordinates

2D Point:

$$\begin{bmatrix} x \\ y \end{bmatrix} \rightarrow \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

2D Vector:

$$\begin{bmatrix} x \\ y \end{bmatrix} \rightarrow \begin{bmatrix} x \\ y \\ 0 \end{bmatrix}$$

Why Homogeneous Coordinates

Transformation in 2D:

$$\begin{bmatrix} x' \\ y' \\ w \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ w \end{bmatrix}$$

$$M = \begin{bmatrix} a & b & t_x \\ c & d & t_y \\ 0 & 0 & 1 \end{bmatrix} = \left[\begin{array}{cc|c} \multicolumn{2}{c|}{A} & \mathbf{t} \\ \hline 0 & 0 & 1 \end{array}\right]$$

2D → 3D Rotation Example (around X axis)

2D

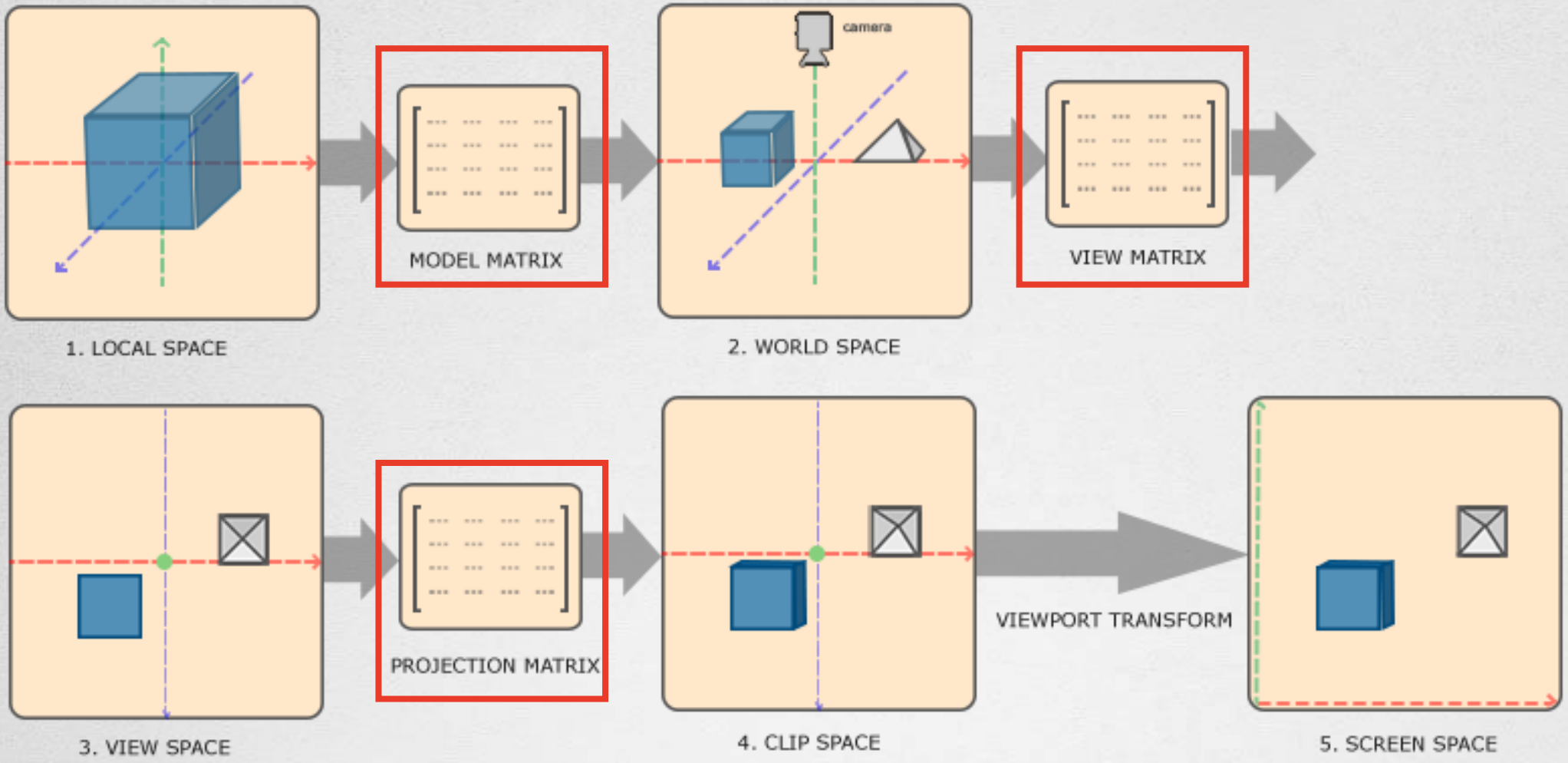
$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

3D

$$\begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos\theta & -\sin\theta & 0 \\ 0 & \sin\theta & \cos\theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \bullet \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix}$$

Transformation

3 Important Matrices



Implementation

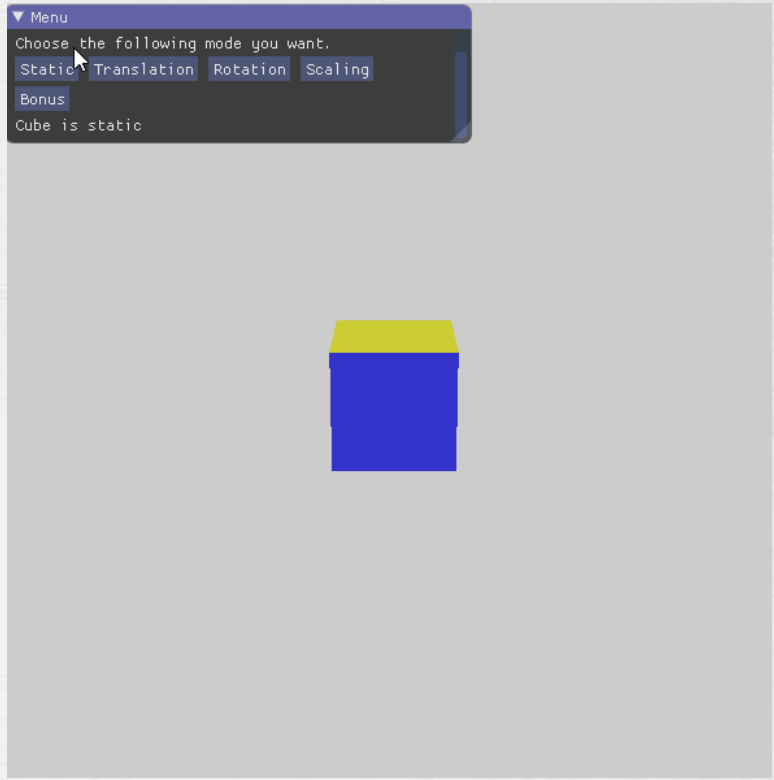
$$V_{clip} = M_{projection} \cdot M_{view} \cdot M_{model} \cdot V_{local}$$

```
#version 330 core

layout (location = 0) in vec3 aPos;
layout (location = 1) in vec3 aColor;

out vec4 vColor;
uniform mat4 model;
uniform mat4 view;
uniform mat4 projection;

void main() {
    gl_Position = projection * view * model * vec4(aPos, 1.0);
    vColor = vec4(aColor, 1.0);
}
```



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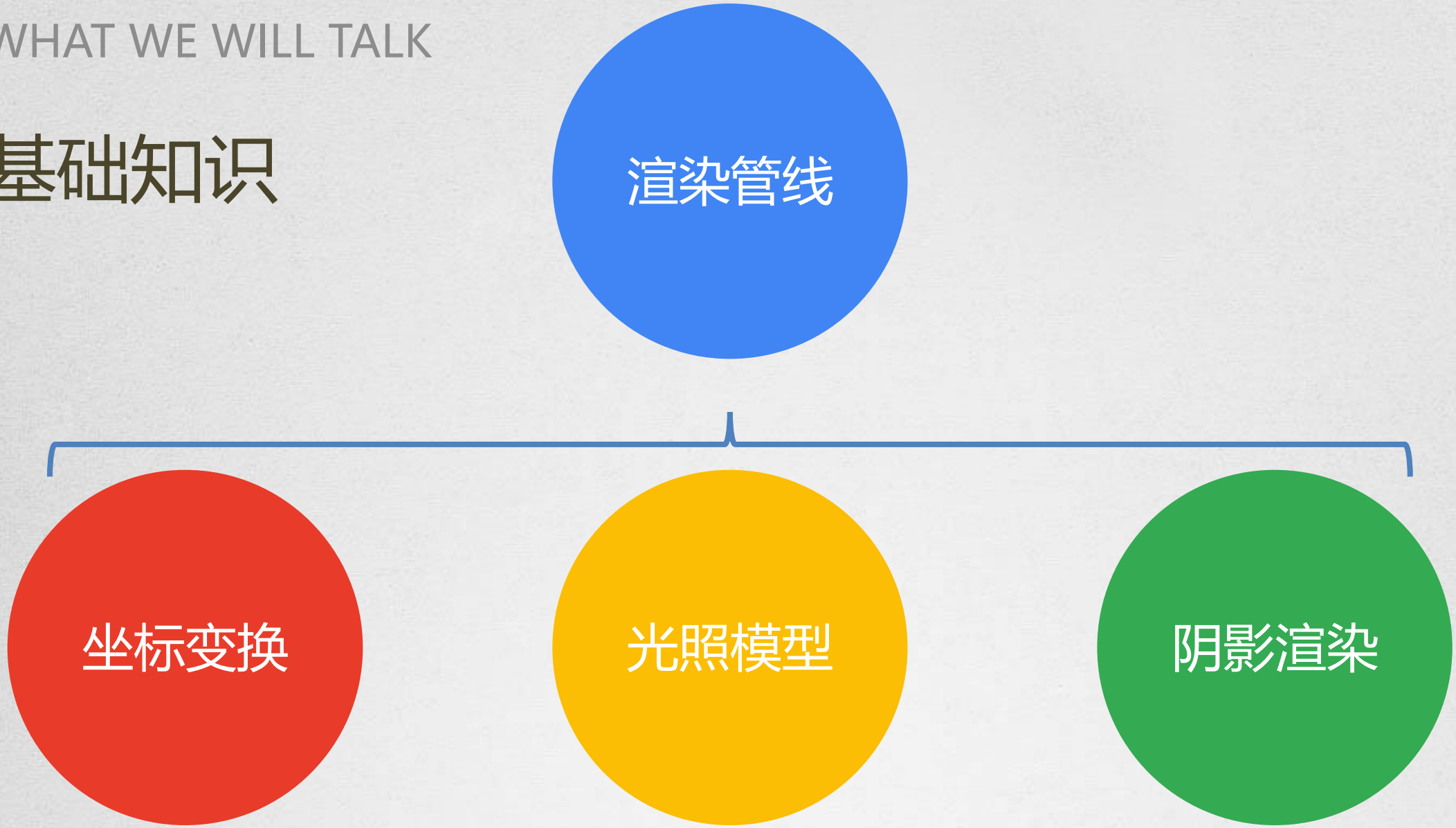

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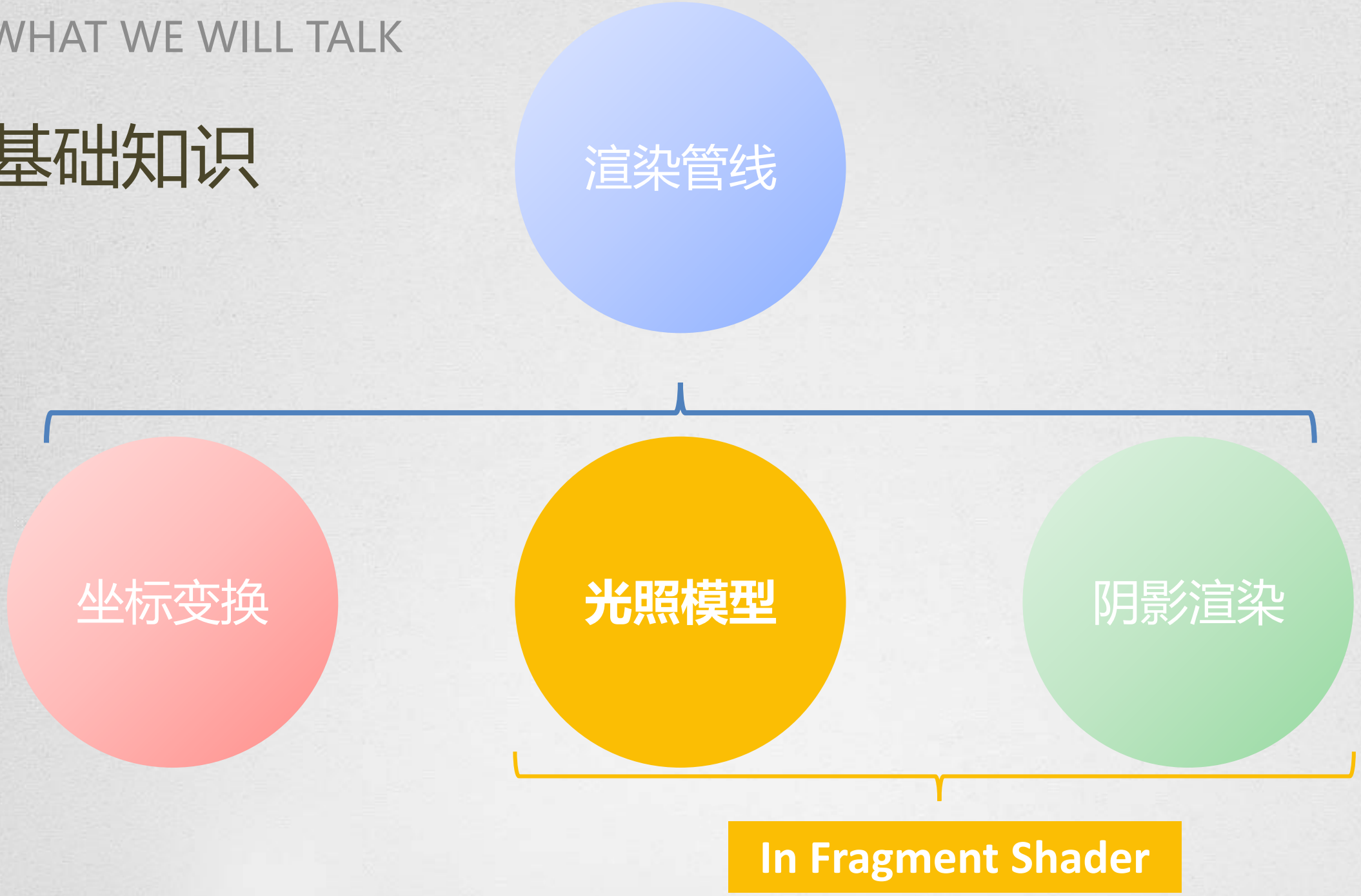
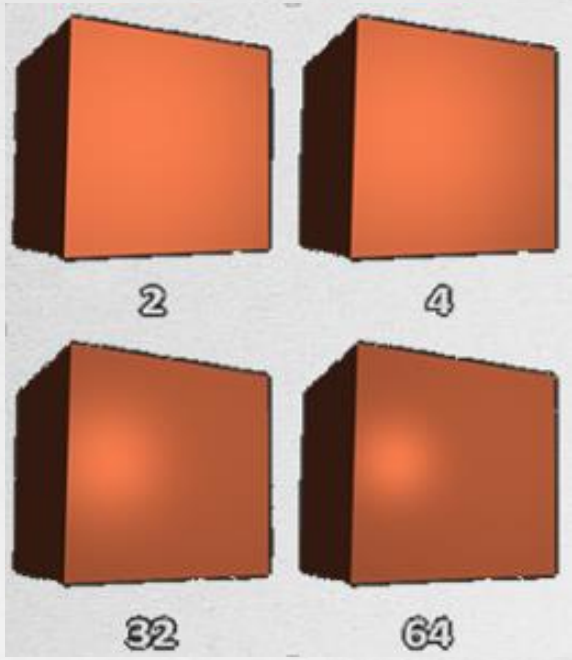


光照模型分类

全局光照明模型
(复杂)

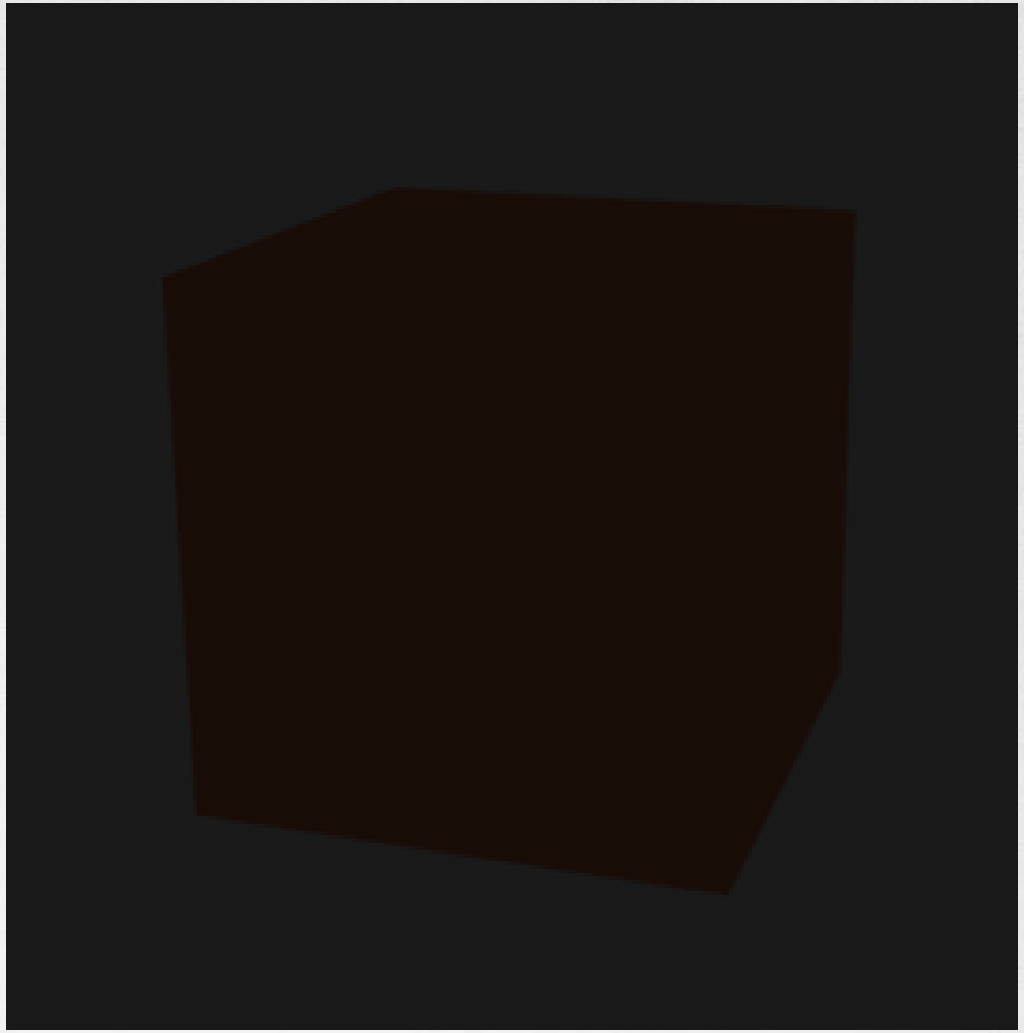


局部光照明模型
(简单)

Light = 环境光 + 漫反射光 + 镜面光

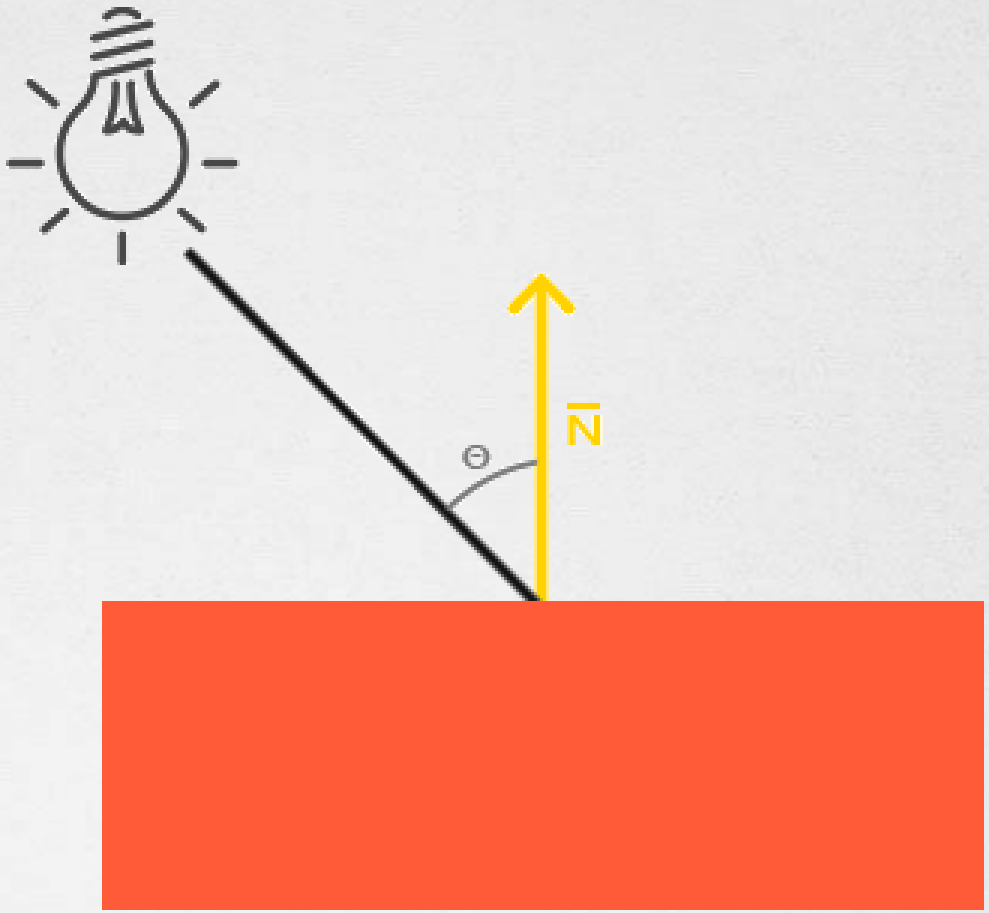
环境光照

一般为常量

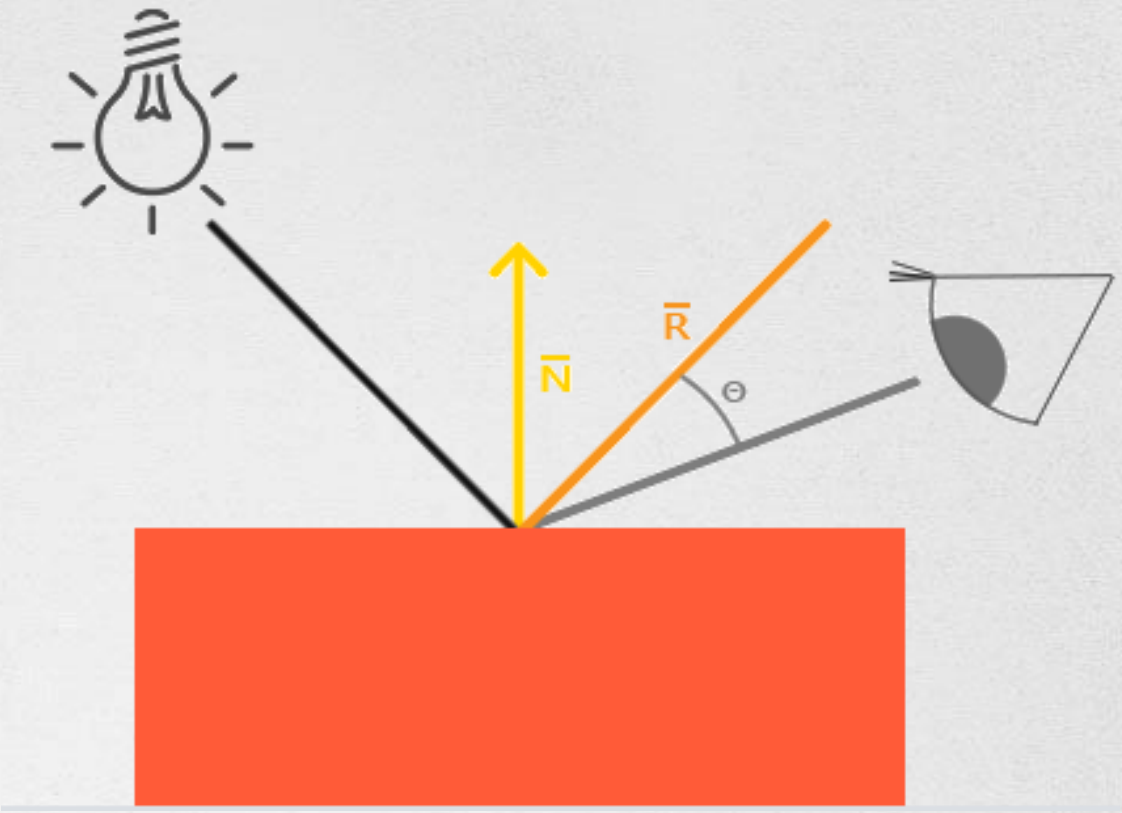


漫反射光照

- 法向量
- 定向的光线
- 法线矩阵(Normal Matrix)



镜面光照



specularStrength 由材质决定

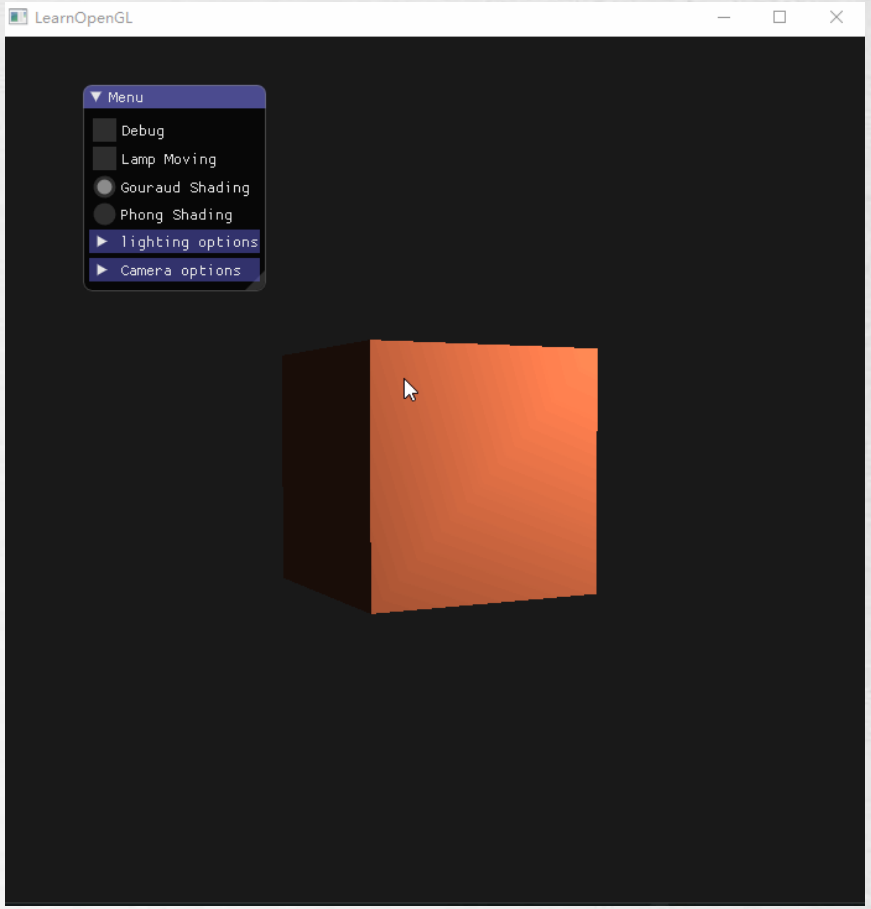
```
float specularStrength = 0.5;
float spec = pow(max(dot(viewDir, reflectDir), 0.0), 32);
vec3 specular = specularStrength * spec * lightColor;
```

两种局部光照模型

Light = 环境光 + 漫反射光 + 镜面光

Gouraud: 将上式放在顶点着色器中计算

Phong : 将上式放在片段着色器中计算



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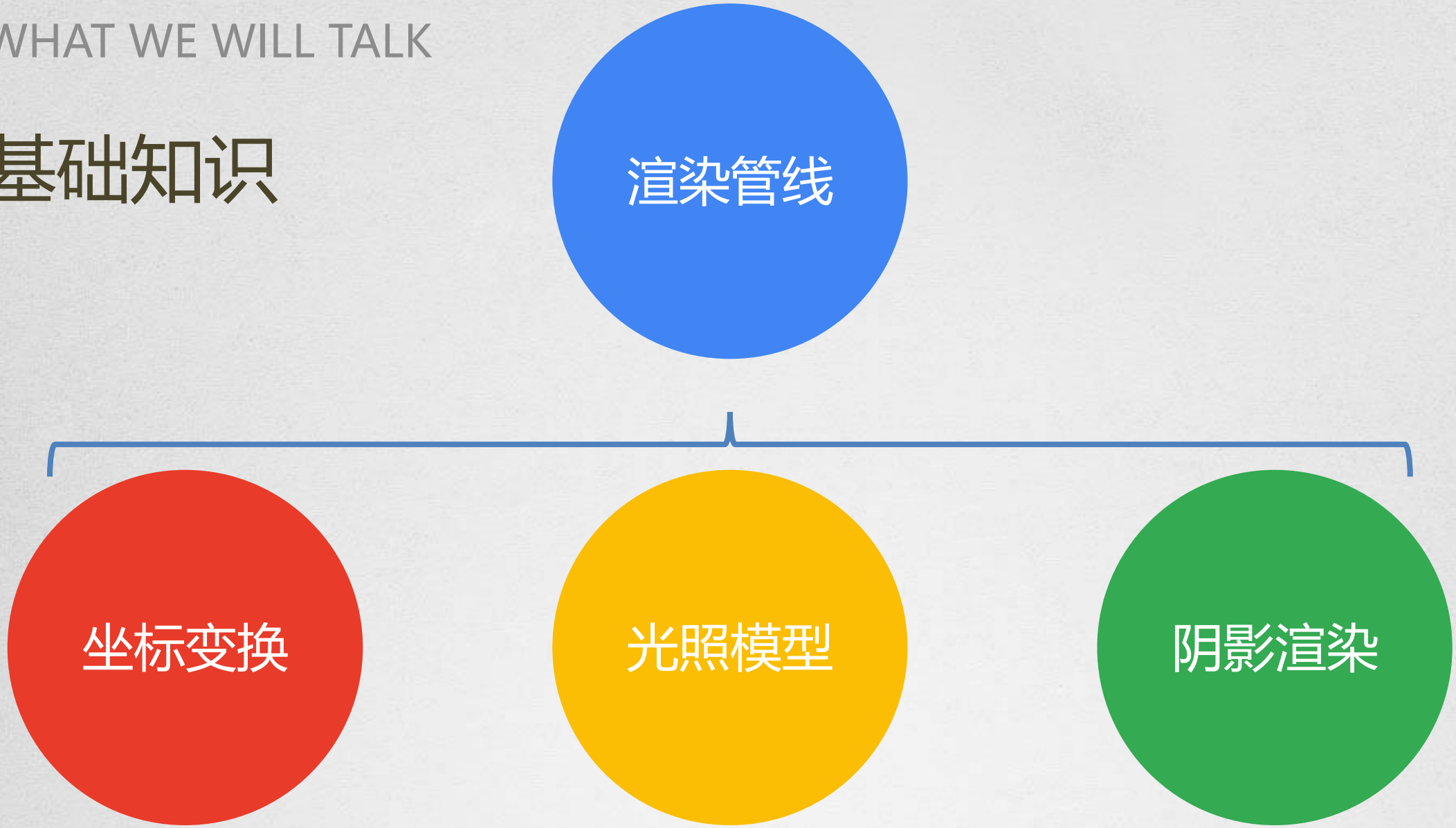

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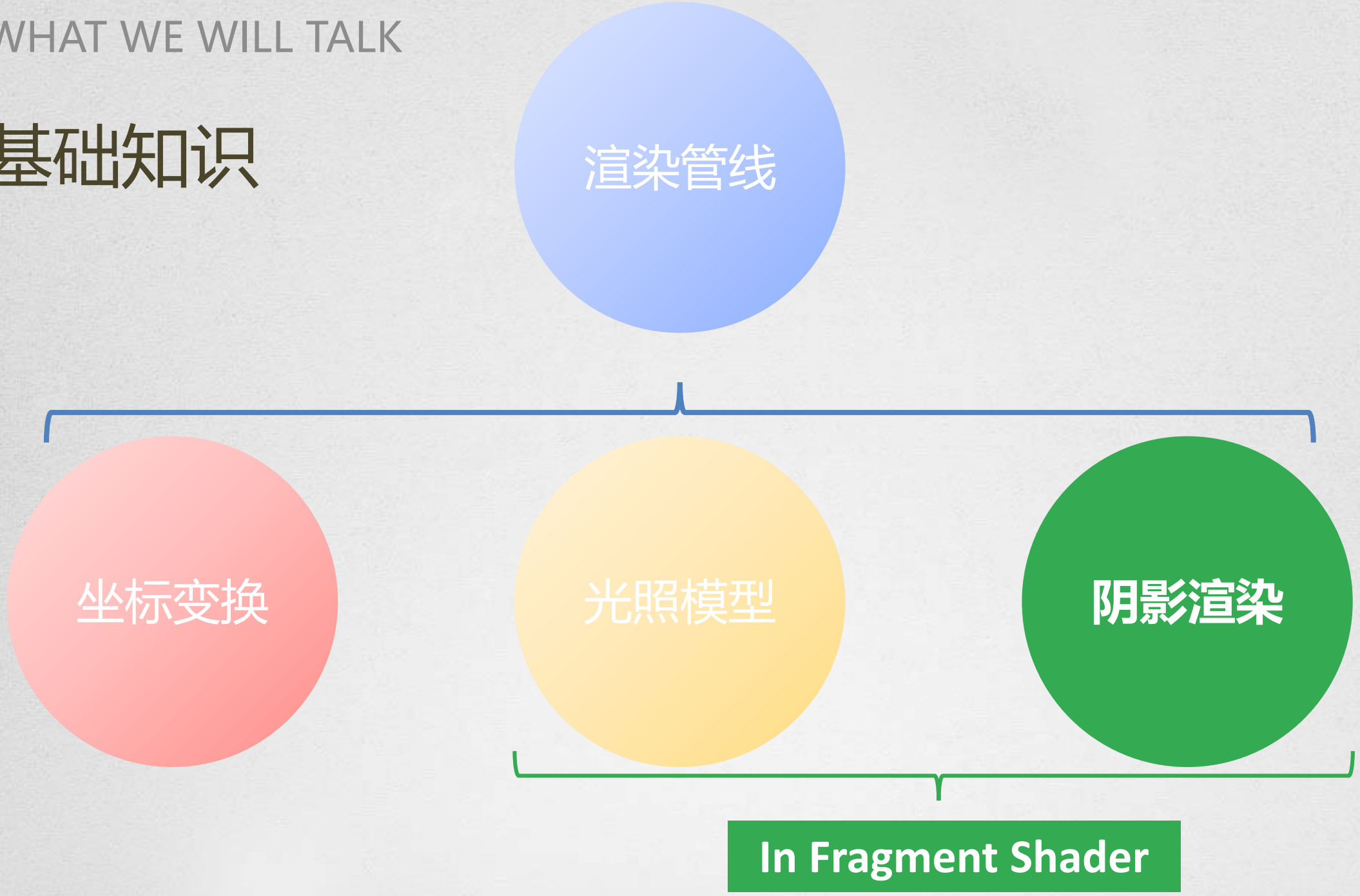
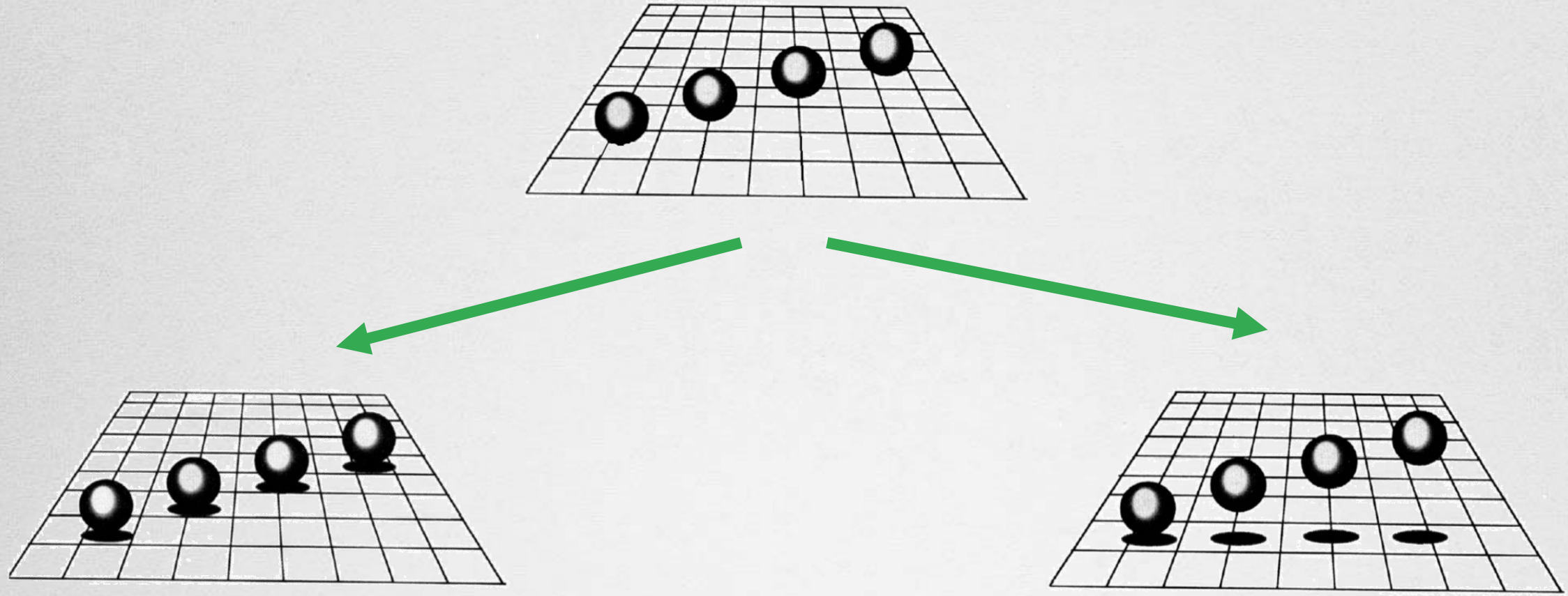
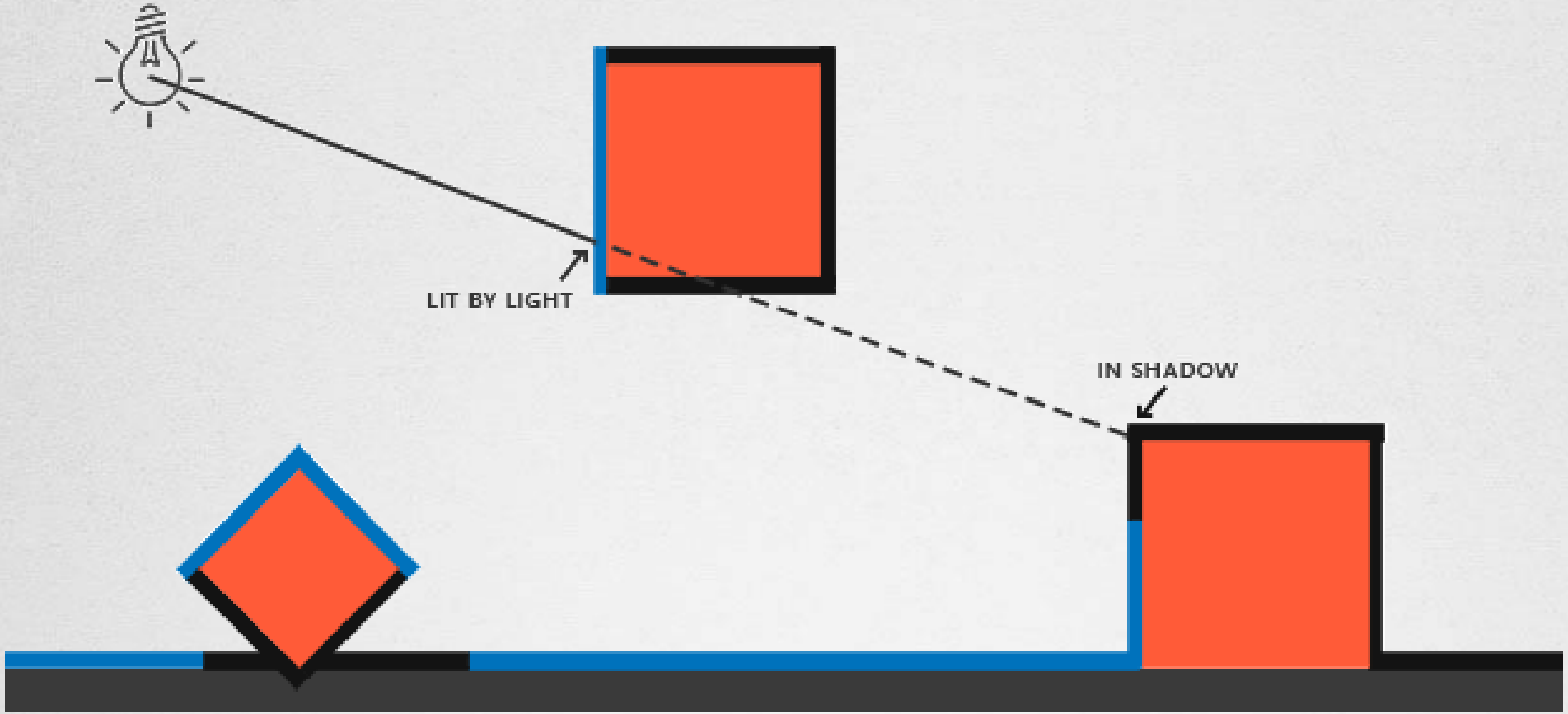


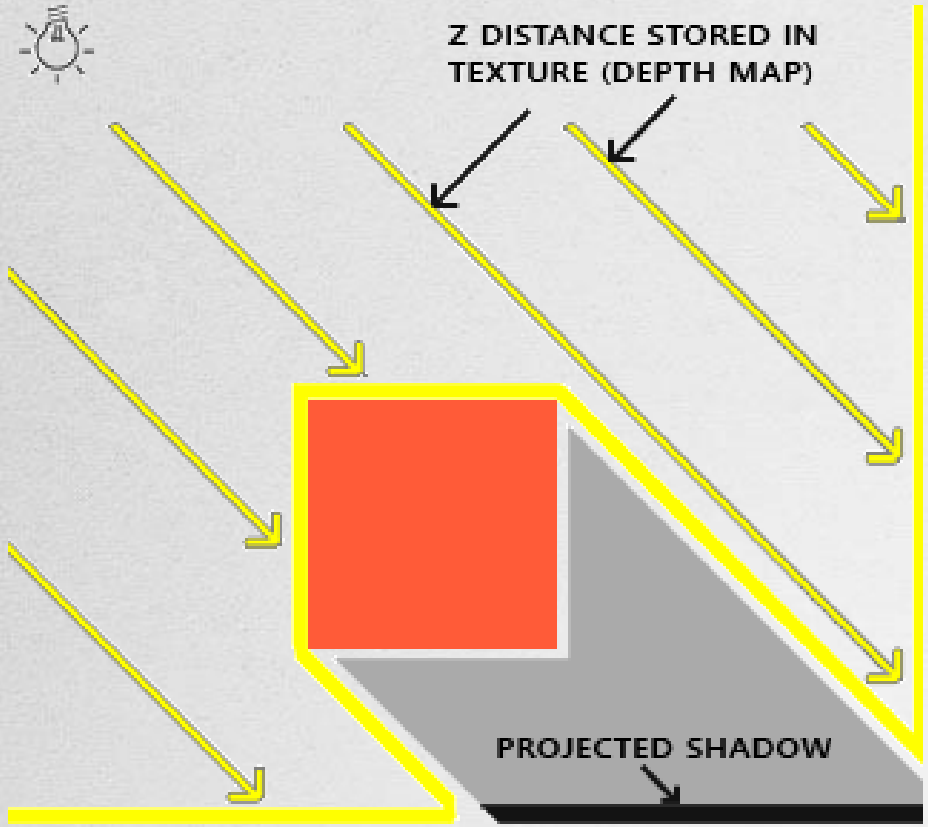
Why shadow is important?



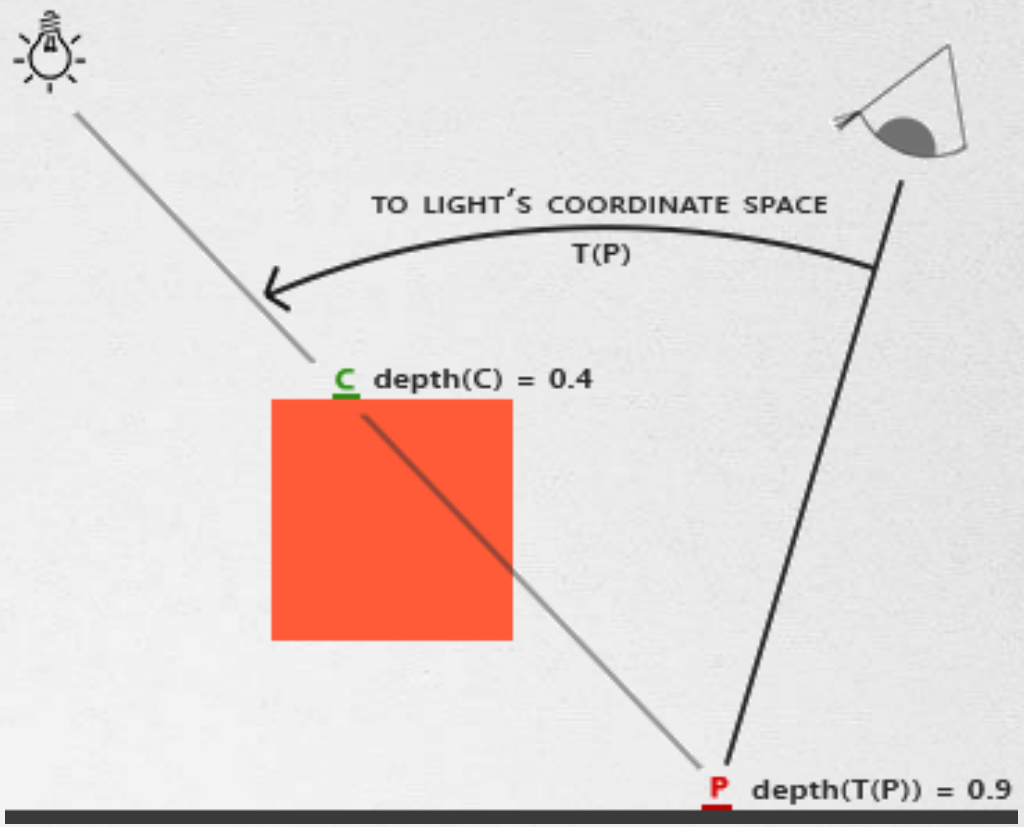
Basic shadow rendering



Shadow Mapping

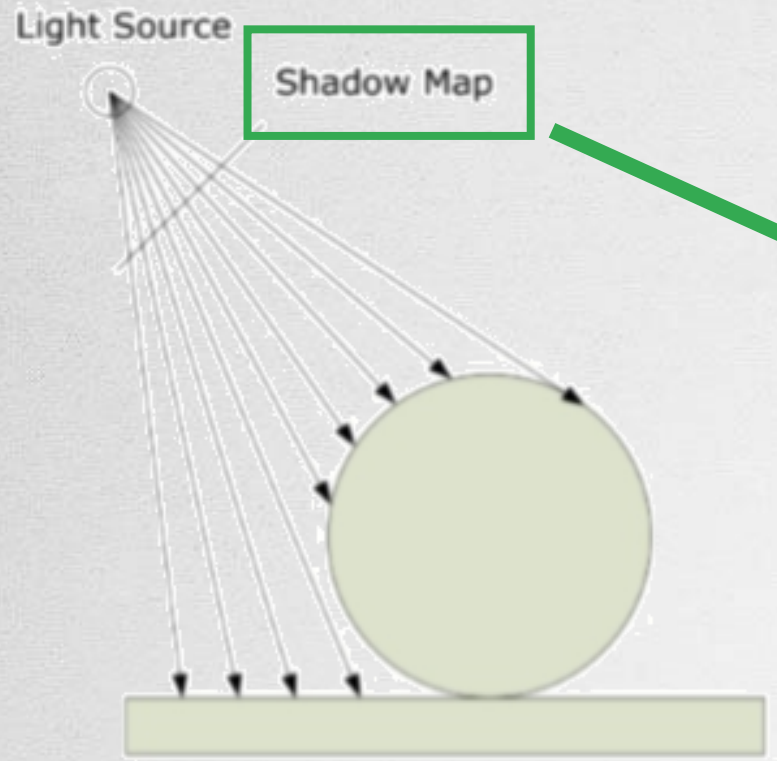


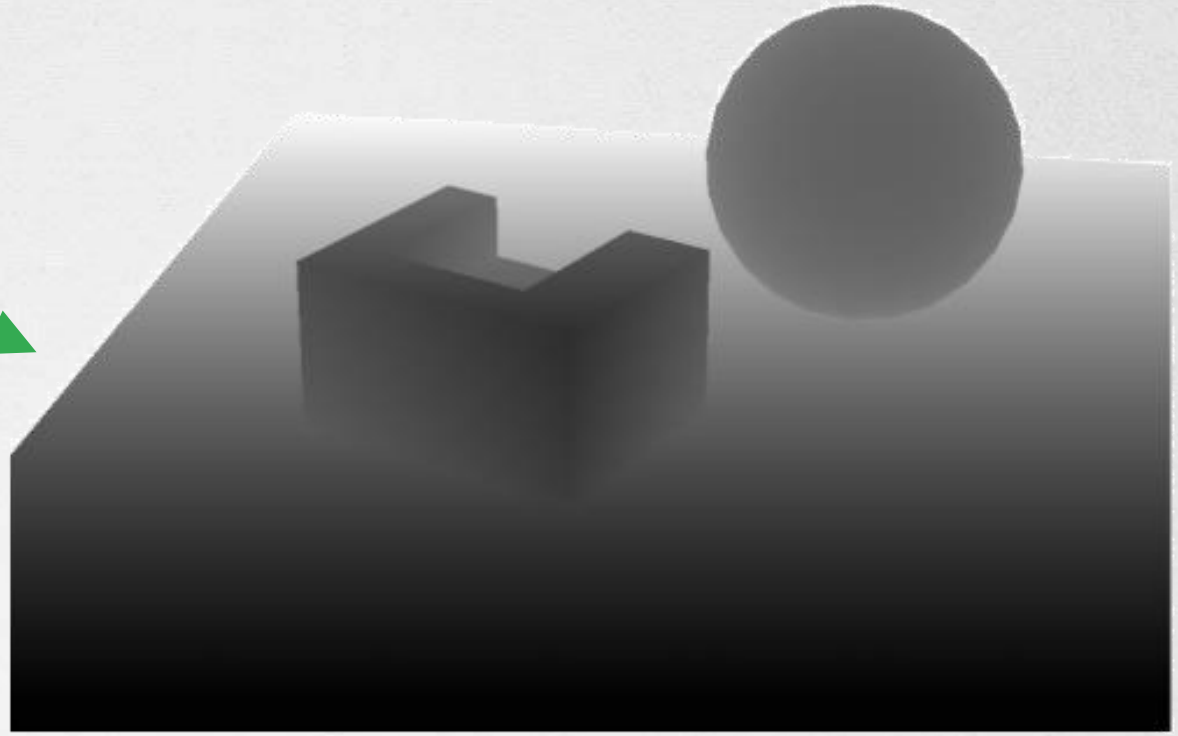
Step 1



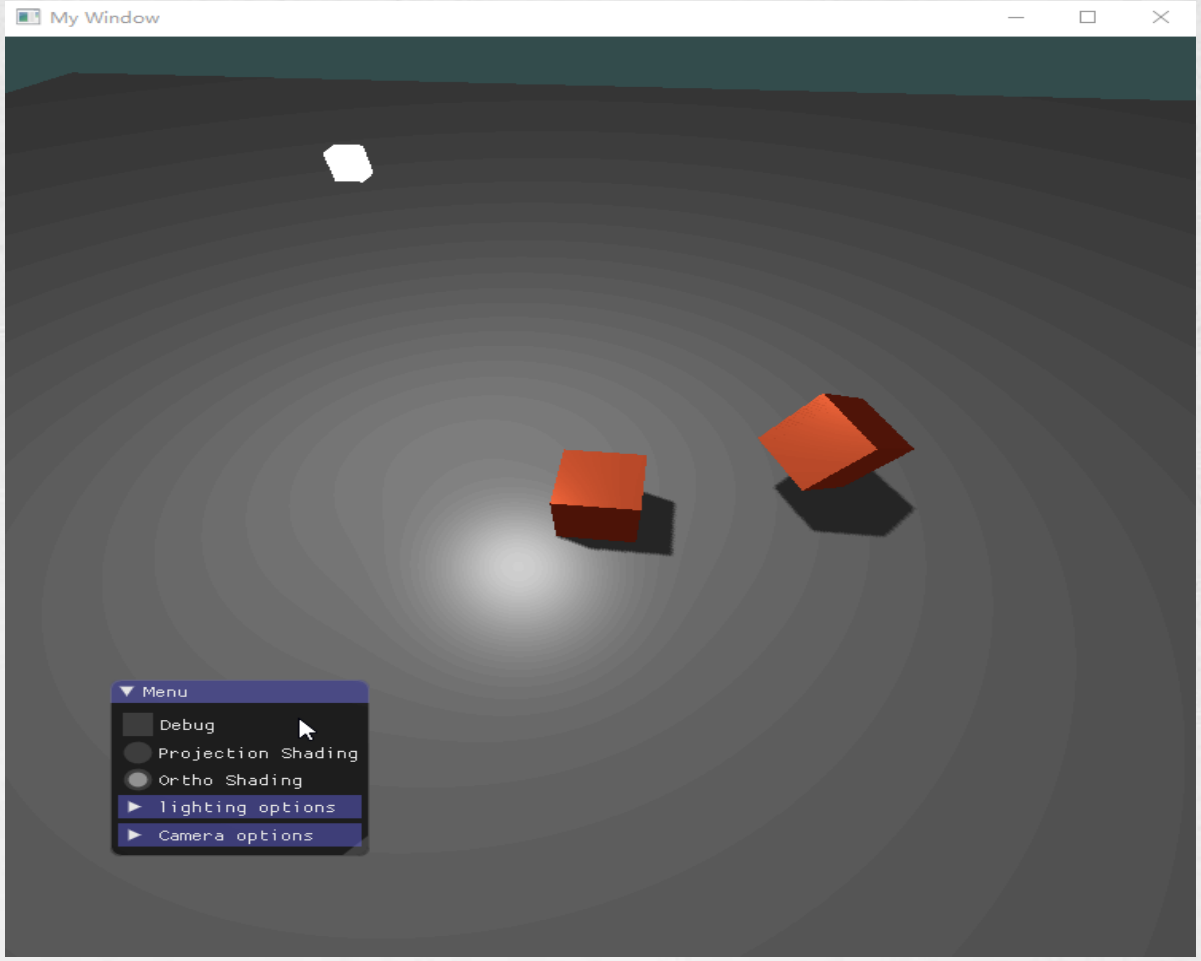
Step 2

Step 1 details





Step 2 Demo


My Window
Menu
Debug
Projection Shading
Ortho Shading
lighting options
Camera options

What’s not included …

本次分享没有涉及到的内容

- 纹理映射
- 曲线绘制
- 阴影优化方法
- More …

Main Reference

- Learn-OpenGL-CN: https://learnopengl-cn.github.io/
- Courseware of Computer Graphics 2018 by A.prof. Chengying Gao, Sysu.
- Demo from my own homework.

Q&A

Thank You