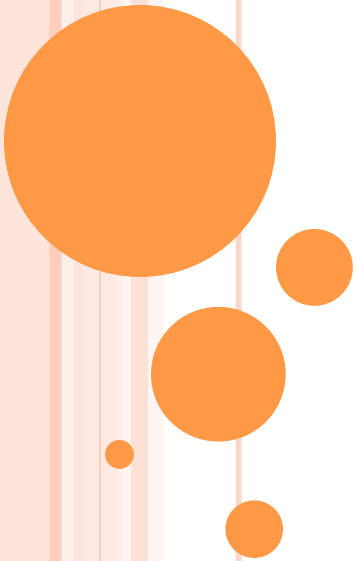
Texture Mapping & GLSL



15-462 Computer Graphics

Written by: Chun How Tan

Feb 21, 2012

Overview

- Announcements
- Texture Mapping
- GLSL Shader Language

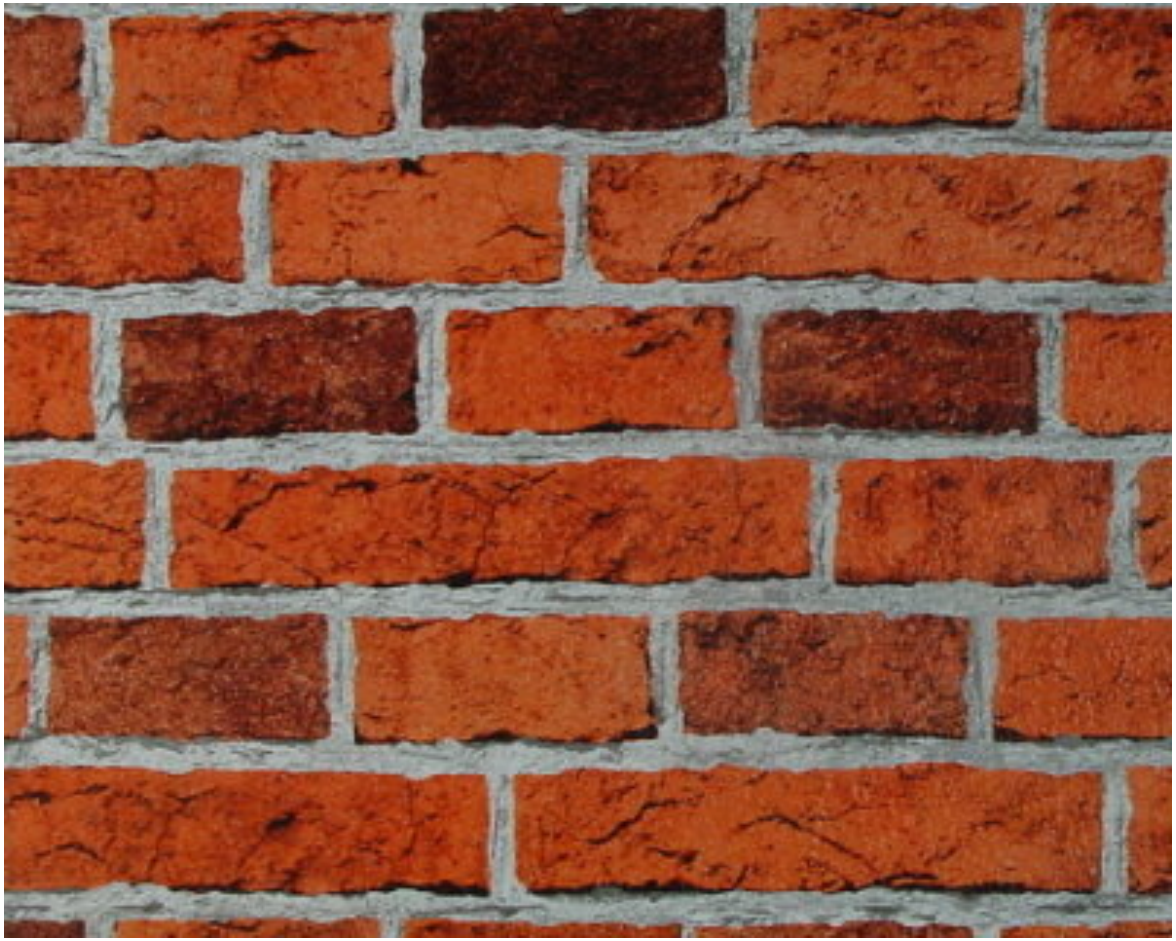
Announcements

- Project 2 is Due Today.
- Project 3 also goes out Today.

Overview

- Announcements
- Texture Mapping
- GLSL Shader Language

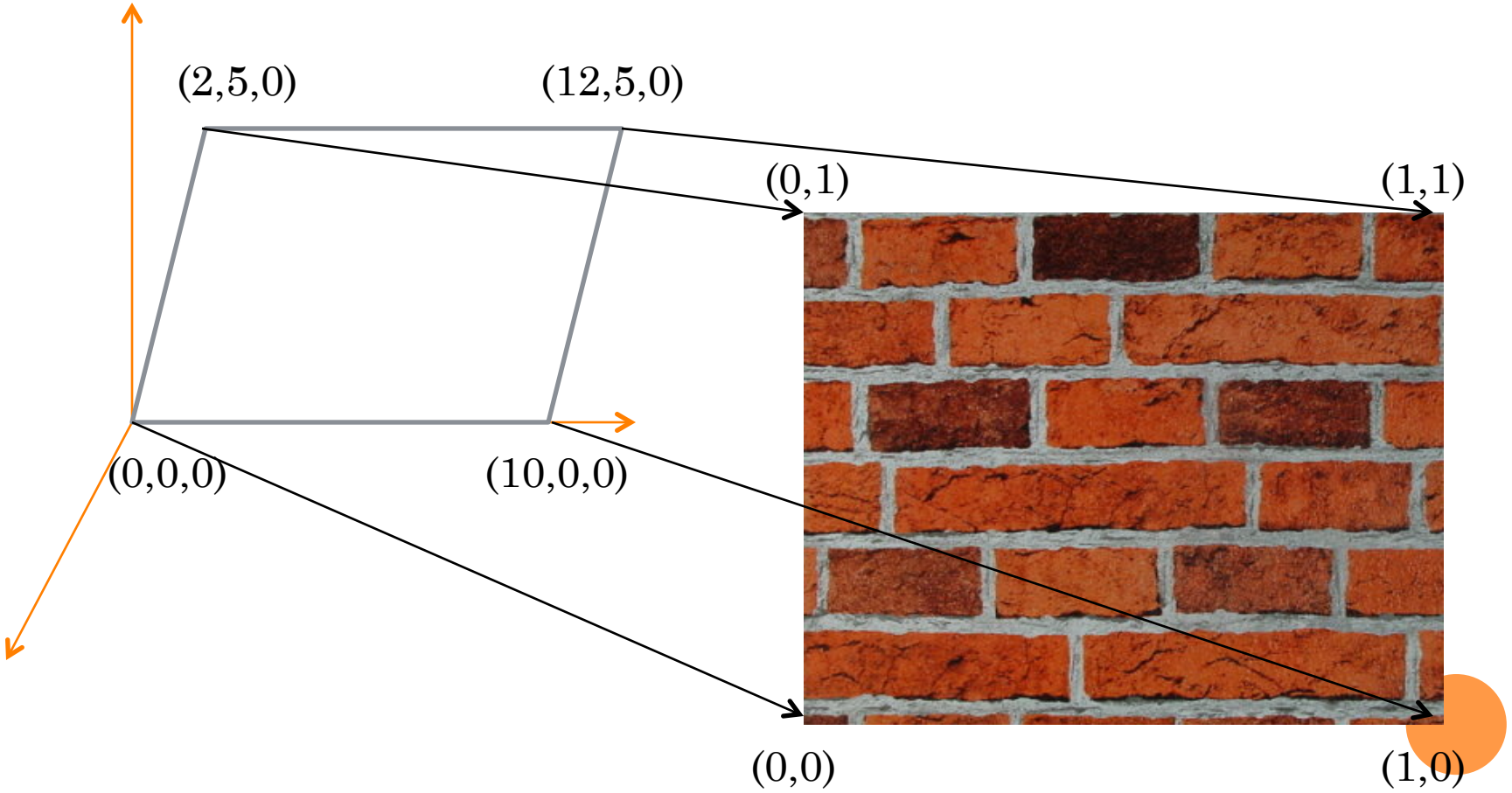
Texture Mapping



What is a Texture?

- A texture is just a bitmap image
- 2D array – texture[height][width][4]
- Pixels of the texture are called texels
- Texture coordinates are in 2D, in the range [0,1]

Texture Mapping



Texture Mapping In OpenGL: Rendering

```
glEnable(GL_TEXTURE_2D);
glBegin(GL_QUADS);
   glTexCoord2f(0.0, 0.0); glVertex3f(0.0, 0.0, 0.0);
   glTexCoord2f(1.0, 0.0); glVertex3f(10.0, 0.0, 0.0);
   glTexCoord2f(1.0, 1.0); glVertex3f(12.0, 5.0, 0.0);
   glTexCoord2f(0.0, 1.0); glVertex3f(2.0, 5.0, 0.0);
glEnd();
glDisable(GL_TEXTURE_2D);
```

Texture Mapping In OpenGL

/* Specifies the texture to be used */

void glTexImage2D(GLenum target, GLint level, GLint internalFormat, GLsizei width, GLsizei height, GLint border, GLenum format, GLenum type, const GLvoid *texture);

Texture Mapping In OpenGL: Initialize

```
/* loads image */
size_t brick_width = 32, brick_height = 32;
unsigned char *brick_texture = load_image(…);

/* Generates and binds a texture object */
GLuint texture_id;
glGenTexture(1, &texture_id);
glBindTexture(GL_TEXTURE_2D, texture_id);

/* Defines the texture */
glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA,
   brick_width, brick_height, 0, GL_RGBA,
   GL_UNSIGNED_BYTE, brick_texture);
```

Texture Object

- A texture object stores texture data in OpenGL.
- Can easily switch between different texture images without reloading the images, by binding different texture objects.
- Big performance gain

```
/* For Texture Object */
void glGenTextures(GLsizei n, GLuint
   *textureNames);
void glBindTexture(GLenum target, GLuint
   textureName);
```

Color Blending

- Final pixel color = f(texture color, object color)
  - GL_REPLACE – use texture color
  - GL_BLEND – linear combination of 2 colors

- Eg. glTexEnvf(GL_TEXTURE_ENV, GL_TEXTURE_ENV_MODE, GL_REPLACE);

Interpolating Color

- For a given texture coordinate (s, t), look into the texture image to get color.

- What if the (s, t) does not correspond to a pixel in texture image?

Interpolating Color

- For a given texture coordinate (s, t), look into the texture image to get color.

- What if the (s, t) does not correspond to a pixel in texture image?

- glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_NEAREST);
- glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, GL_LINEAR);

Useful Resources: Texture Mapping

- OpenGL Programming Guide, Version 1.1

http://www.glprogramming.com/red/chapter09.html

Overview

- Announcements
- Texture Mapping
- GLSL Shader Language

Motivation For Programmable Shaders

- The GPU is basically a bunch of small processors.
- Back before shaders, the portion of the graphics pipeline that handled lighting and texturing was hardcoded into what we call the Fixed-Functionality Pipeline.
  - Must use Blinn-Phong shading, model view etc.
- But now, we can write our own shaders to change the way the pipeline works
- OpenGL Fixed-Functionality is now implemented on shaders

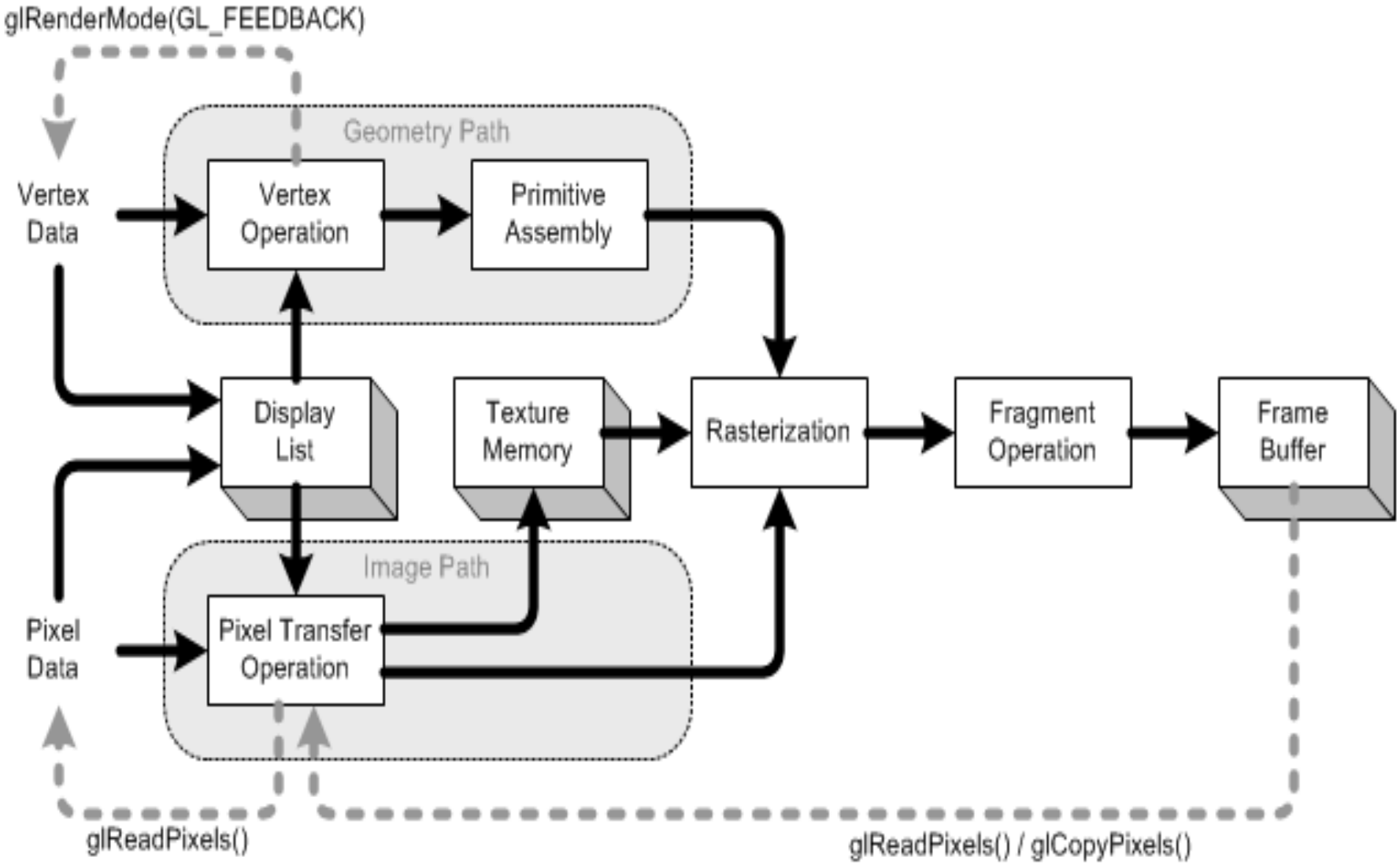
Shader

- A shader is a program that basically rewrites a portion of the graphics pipeline.

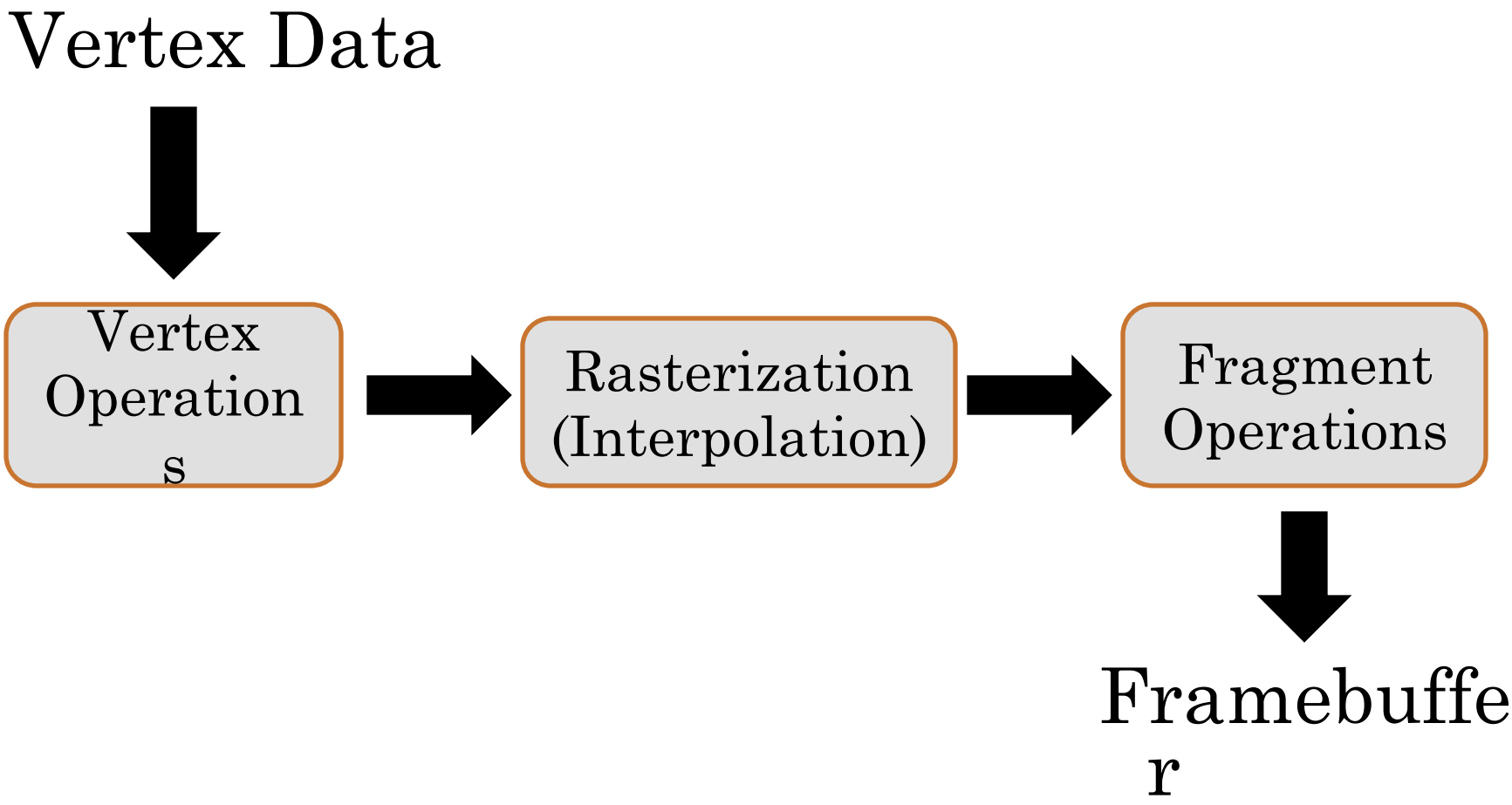
- Used in different places of graphics pipeline – vertex shader, fragment shader etc.

- Can be written in different languages
  - OpenGL's GLSL
  - Microsoft HLSL
  - Nvidia's Cg

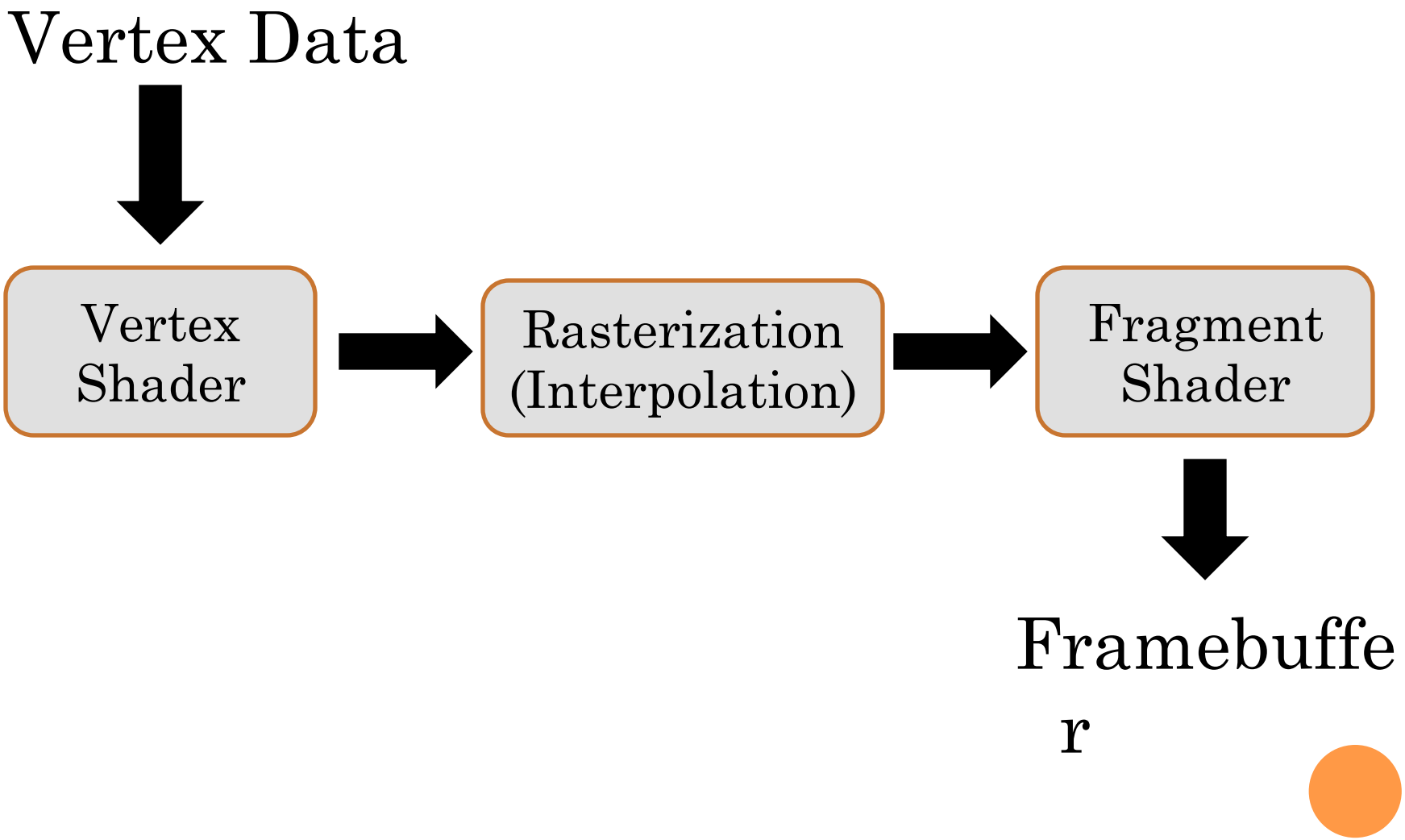
OpenGL Pipeline



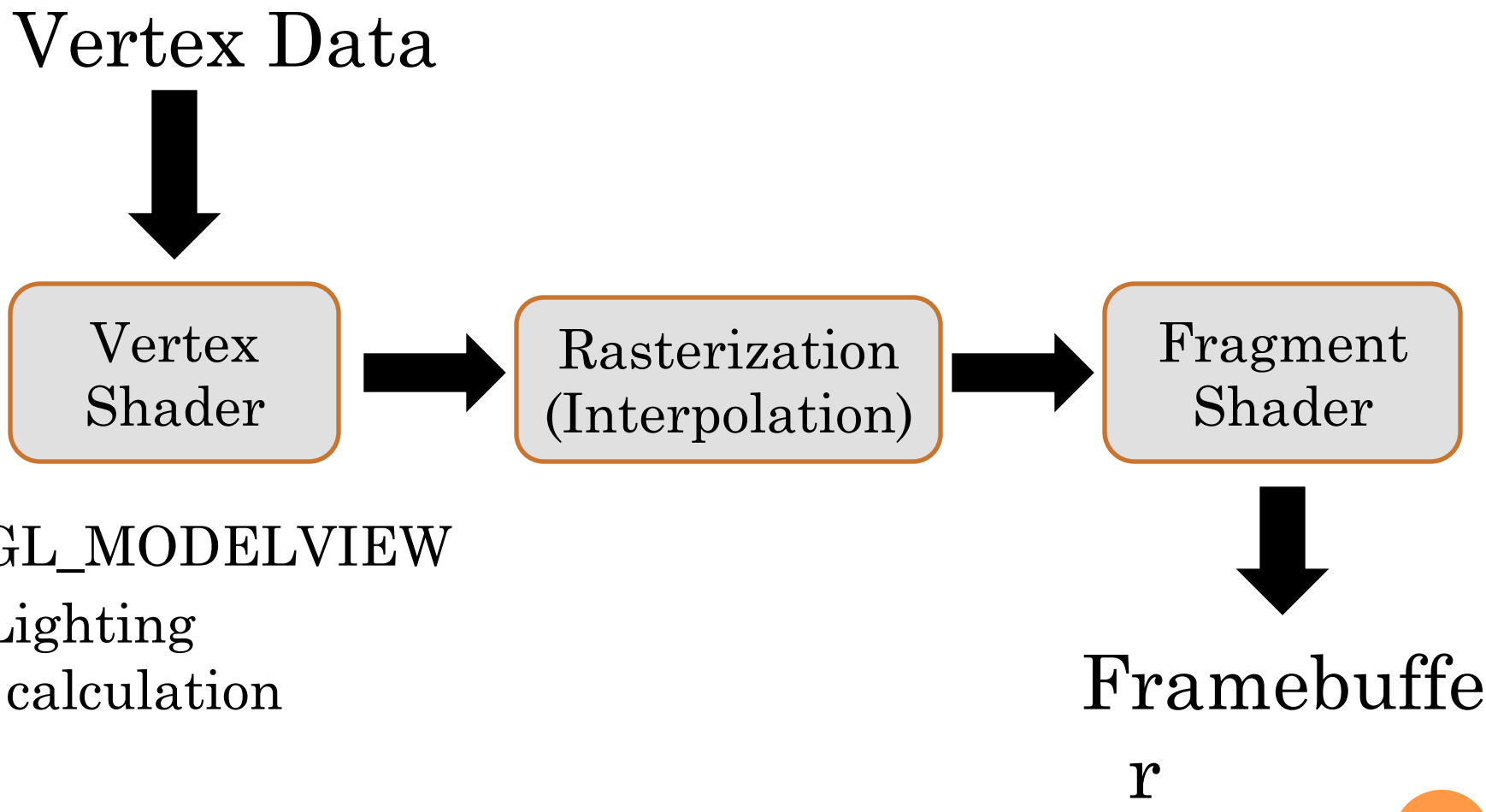
OpenGL Pipeline (Simplified)



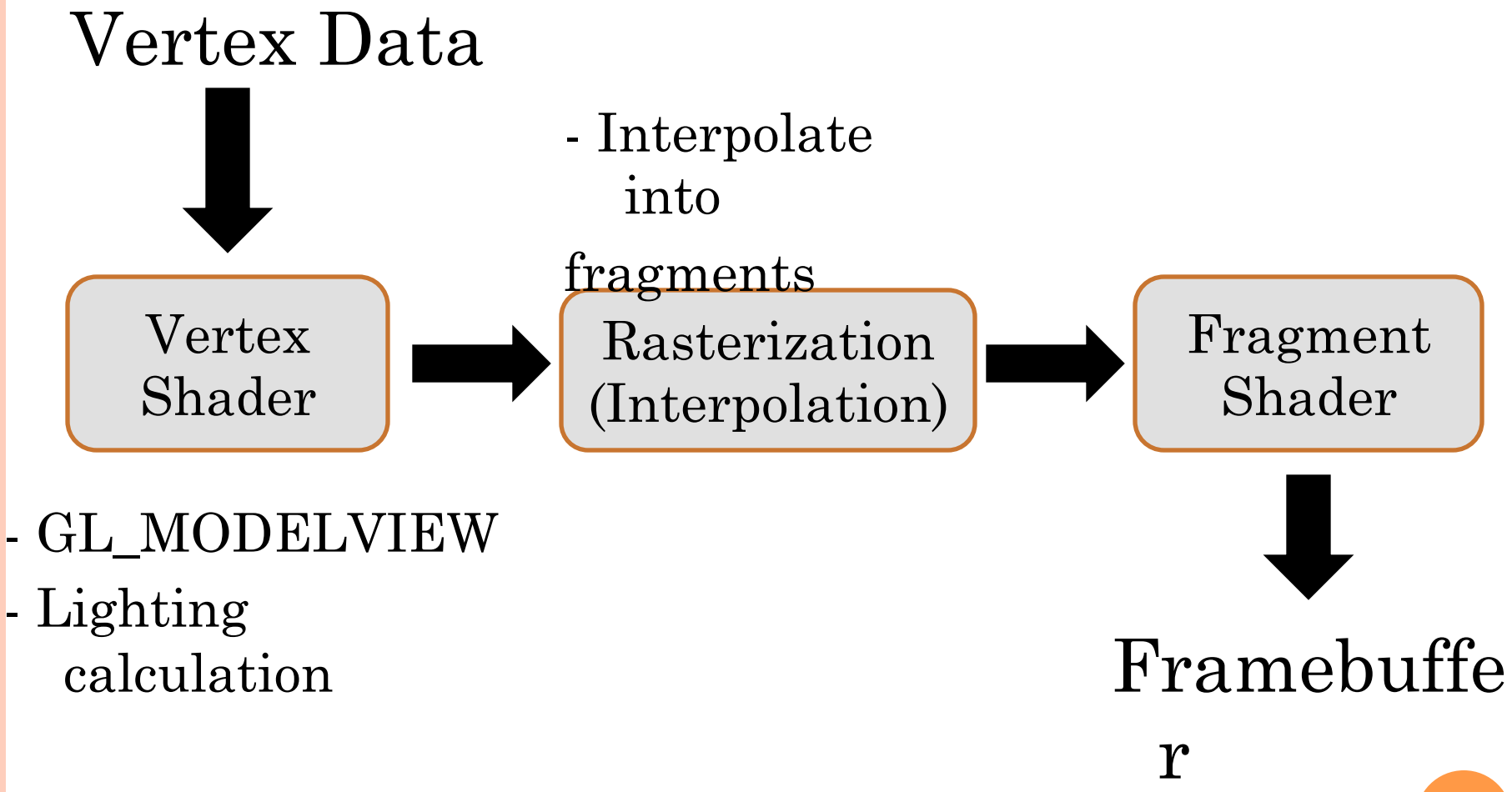
OpenGL Pipeline (Simplified)



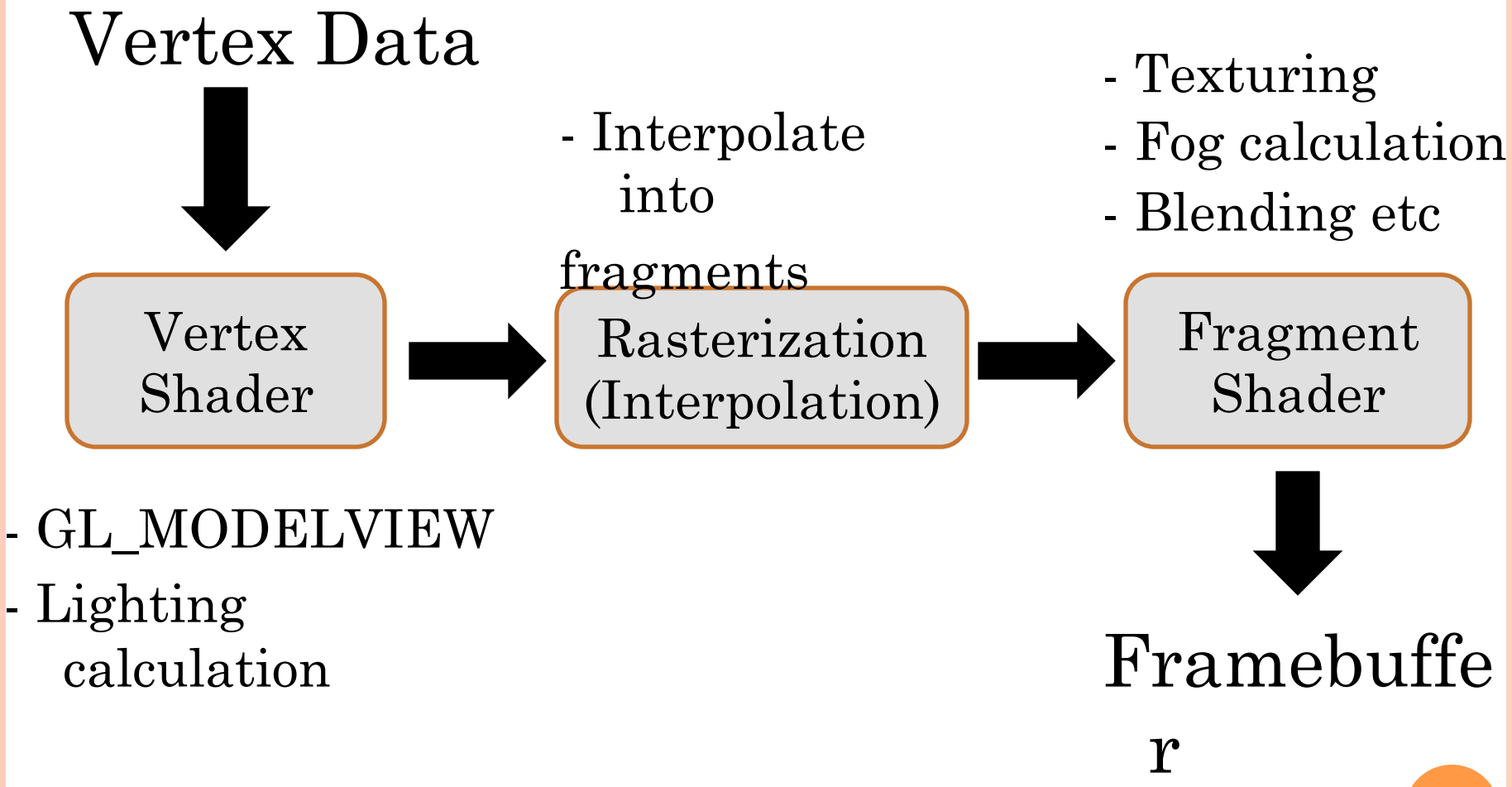
OpenGL Pipeline (Simplified)



OpenGL Pipeline (Simplified)



OpenGL Pipeline (Simplified)



Projects

- Project 1 & Project 2 – use fixed functionality in OpenGL

- Project 3 – write your own shaders

Shaders

- Vertex Shader
  - Operates on vertex data(normal, position, tex_coord)
  - One vertex at a time
- Fragment Shader
  - A fragment is the smallest unit being shaded
  - One fragment at a time

Shader Programming

- Syntax looks like C language
- int, bool, float etc
- vec2, vec3, mat3, mat4 etc

Variable Types

- const
- attribute
  - Written in OpenGL application, passed to vertex shader.
  - Read-only in vertex shader. Only accessible in vertex shader.
- varying
  - written in vertex shader, interpolated and read-only in fragment shader
- uniform
  - written in OpenGL application, passed to vertex and fragment shaders.
  - Read-only in both shaders

Sample code: Vertex Shader

```
/*Sample vertex shader*/
attribute float shift; /*Attribute values passed from OpenGL program*/
varying vec3 norm;     /*Varying values written in vertex shader
                           and read only in fragment shader*/
void main(void){
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex * shift;
  norm = gl_Normal;
}
```

Sample code: Vertex Shader

```
/*Sample vertex shader*/
attribute float shift; /*Attribute values passed from OpenGL program*/
varying vec3 norm;     /*Varying values written in vertex shader
                           and read only in fragment shader*/
void main(void){
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex * shift;
  norm = gl_Normal;
}
```

Sample code: Vertex Shader

```
/*Sample vertex shader*/
attribute float shift; /*Attribute values passed from OpenGL program*/
varying vec3 norm;     /*Varying values written in vertex shader
                           and read only in fragment shader*/
void main(void){
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex * shift;
  norm = gl_Normal;
}
```

Sample code: Vertex and Fragment Shaders

```
/*Sample vertex shader*/
attribute float shift; /*Attribute values passed from OpenGL program*/
varying vec3 norm;     /*Varying values written in vertex shader
                           and read only in fragment shader*/
void main(void){
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex * shift;
  norm = gl_Normal;
}


/*Sample fragment shader*/
varying vec3 norm;
uniform vec3 color; /*Uniform values passed from OpenGL program and
                      read only in fragment shader*/
const vec3 black = vec3(0.0, 0.0, 0.0);

void main(void){
  if(length(norm) >= 1)
    glFragColor = vec4(color, 1.0);
  else
    glFragColor = vec4(black, 1.0);
}


/*Note: This is just a demo, and did nothing useful*/
~
~
```

Sample code: Vertex and Fragment Shaders

```
/*Sample vertex shader*/
attribute float shift; /*Attribute values passed from OpenGL program*/
varying vec3 norm;     /*Varying values written in vertex shader
                           and read only in fragment shader*/
void main(void){
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex * shift;
  norm = gl_Normal;
}


/*Sample fragment shader*/
varying vec3 norm;
uniform vec3 color; /*Uniform values passed from OpenGL program and
                      read only in fragment shader*/
const vec3 black = vec3(0.0, 0.0, 0.0);

void main(void){
  if(length(norm) >= 1)
    glFragColor = vec4(color, 1.0);
  else
    glFragColor = vec4(black, 1.0);
}


/*Note: This is just a demo, and did nothing useful*/
~
~
```

Sample code: Vertex and Fragment Shaders

```
/*Sample vertex shader*/
attribute float shift; /*Attribute values passed from OpenGL program*/
varying vec3 norm;     /*Varying values written in vertex shader
                           and read only in fragment shader*/
void main(void){
  gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex * shift;
  norm = gl_Normal;
}


/*Sample fragment shader*/
varying vec3 norm;
uniform vec3 color; /*Uniform values passed from OpenGL program and
                      read only in fragment shader*/
const vec3 black = vec3(0.0, 0.0, 0.0);

void main(void){
  if(length(norm) >= 1)
    glFragColor = vec4(color, 1.0);
  else
    glFragColor = vec4(black, 1.0);
}


/*Note: This is just a demo, and did nothing useful*/
~
~
```

Sample code: OpenGL Application

```
/*OpenGL Program*/

void somethingOpenGL(){
  /*Creates an empty program object and returns its handle*/
  GLhandleARB shader = glCreateProgramObjectARB();

  /*Create shader - a helper function in P3*/
  create_shader(shader, "shaders/vert.glsl", "shaders/frag.glsl");

  /*Get locations for the uniform variables in shader program*/
  int color_loc = glGetUniformLocationARB(shader, "color");

  /*Bind the shader with the vertex shaders and fragment shaders written*/
  glUseProgramObjectARB( shader );

  /*Pass in the uniform values to the shader*/
  glUniform3fARB(color_loc, 1.0, 1.0, 1.0);

  /*Unbind the shader*/
  glUseProgramObjectARB ( 0 );
}
```

Built-In Variables & Functions

- Built-in variables:

  Vertex Shader – gl_Normal, gl_Vertex, gl_Color etc

  Fragment Shader – gl_Color, gl_FragCoord etc

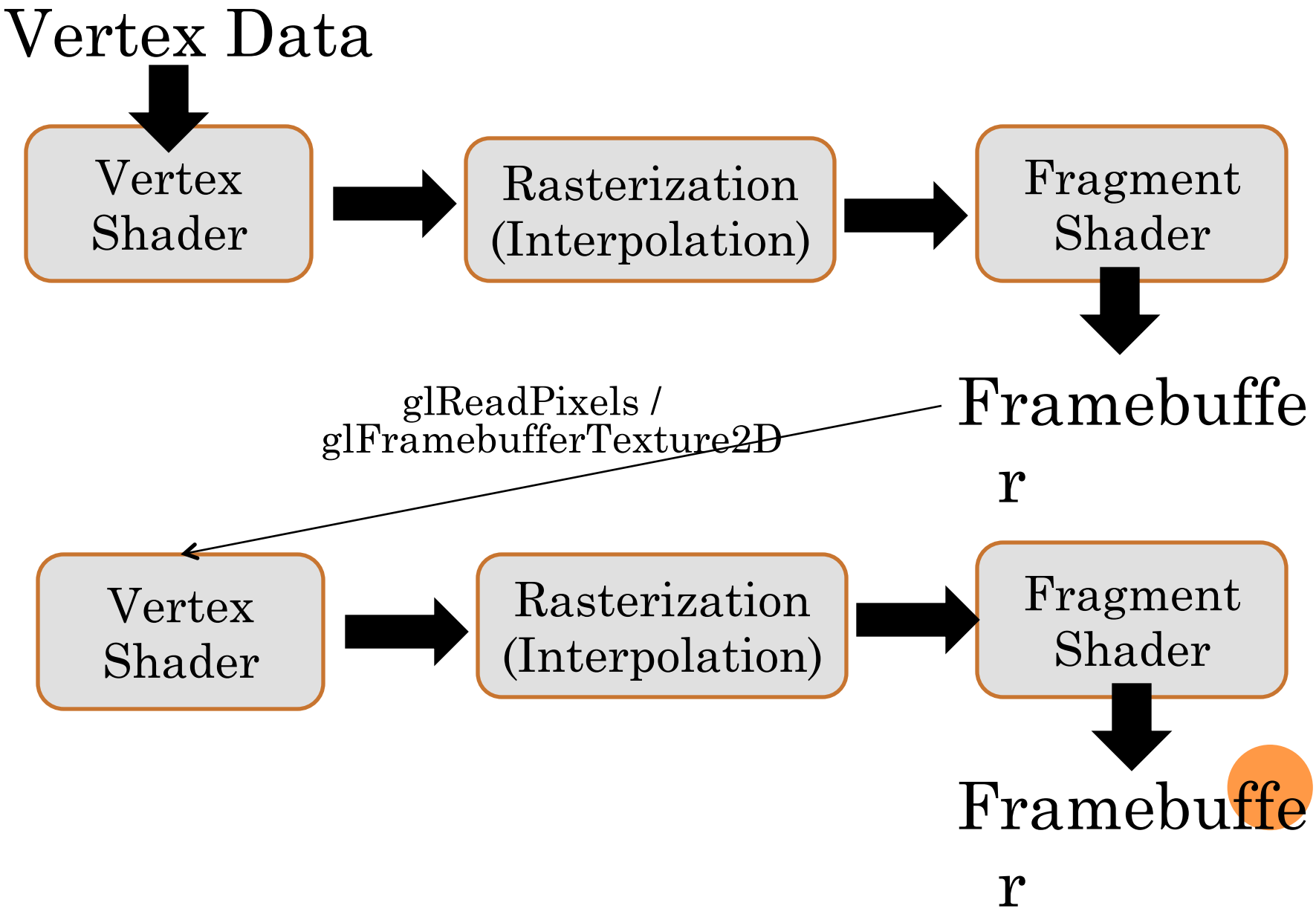
- Built-in functions:

  Trigonometry – sin, cos, atan, radians etc

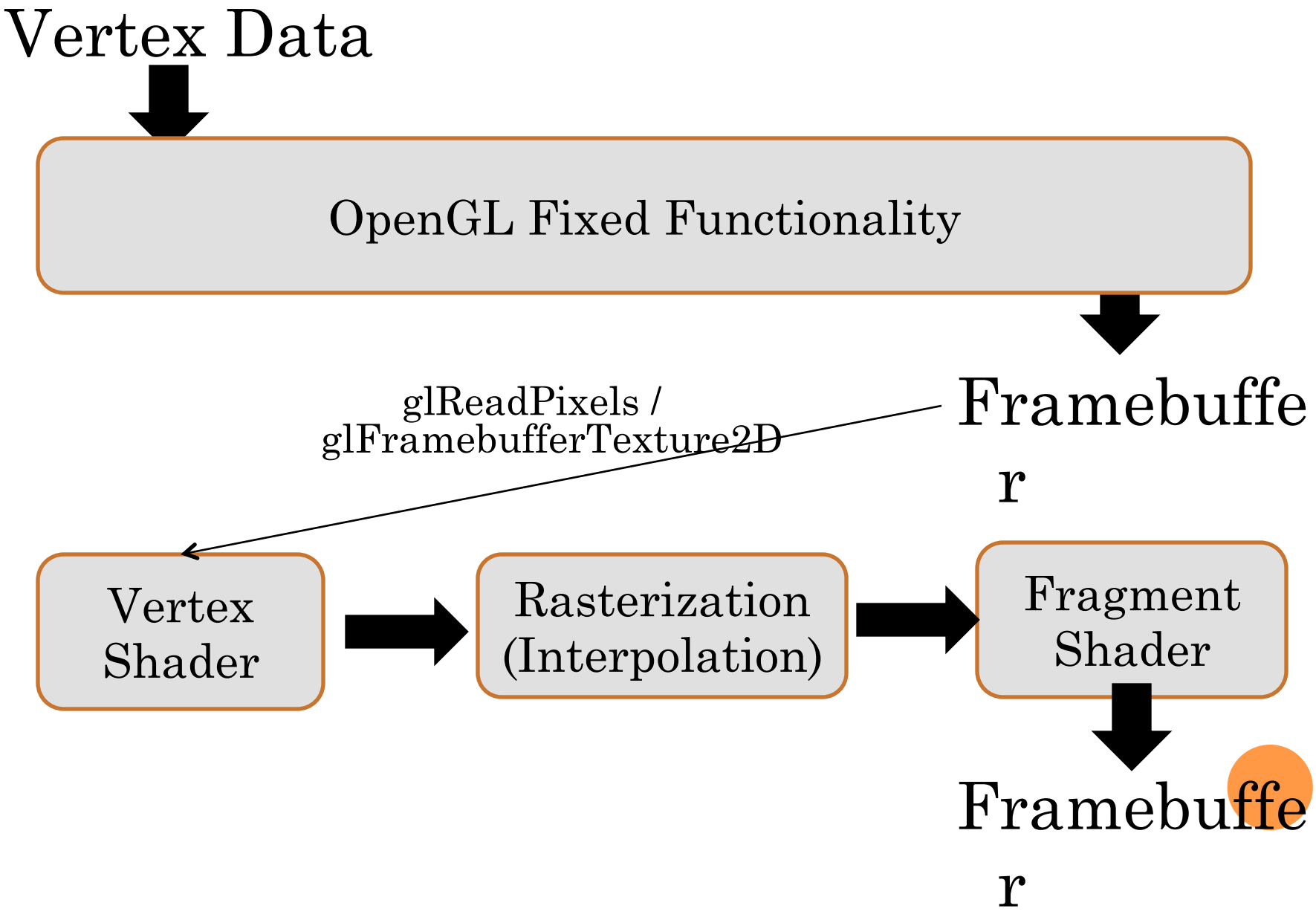
  Geometry – length(vec), normalize(vec) etc

- Refer to OpenGL Shading Language (GLSL) Quick Reference Guide for a complete list (will be on website)

OpenGL Pipeline (Multi-pass)



OpenGL Pipeline (Multi-pass)



Multi-Pass Rendering

- There are multiple ways to copy data in Framebuffer to textures.

- glReadPixels(GLint x, GLint y, GLsizei width, GLsizei height, GLenum format, GLenum type, GLvoid *data)

- Use framebuffer objects

FrameBuffer Objects

- Used to capture images that would normally be drawn to the screen.

- Faster and more efficient compared to glReadPixels

Sample Code: FrameBuffer

```
GLuint fbo;
GLuint colorTexID, depthTexID;
/* Bind colorTexID and depthTexID to texture objects */

/* Create Framebuffer object */
glGenFramebuffers(1, &fbo);

/* Bind the framebuffer object to the textures */
glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, fbo);
glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_COLOR_ATTACHMENT0_EXT,
        GL_TEXTURE_RECTANGLE_ARB, colorTexID, 0);
glFramebufferTexture2DEXT(GL_FRAMEBUFFER_EXT, GL_DEPTH_ATTACHMENT_EXT,
        GL_TEXTURE_RECTANGLE_ARB, depthTexID, 0);

/* Render scene using fixed functionality or shaders */
render();
/* Unbind the fbo */
glBindFramebufferEXT(GL_FRAMEBUFFER_EXT, 0);
```

Useful Resources: GLSL

- GLSL Quick Reference Guide: http://www.cs.cmu.edu/afs/cs/academic/class/15462-s10/www/proj/glslref.pdf
- GLSL Full Language Specification:

  http://www.opengl.org/registry/doc/GLSLangSpec.Full.1.20.8.pdf
- GLSL Tutorials:

  http://www.lighthouse3d.com/opengl/glsl/

  http://www.opengl.org/sdk/docs/tutorials/TyphoonLabs/