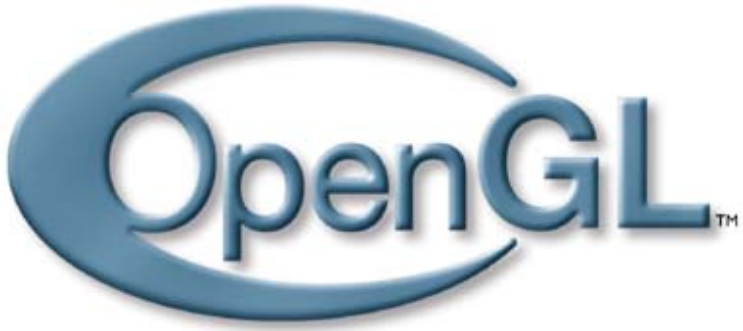


Introduction to OpenGL

Ensimag 3D Graphics, 2015

Planning

Available at

https://intranet.ensimag.fr/KIOSK/Matieres/4MMG3D/index.html

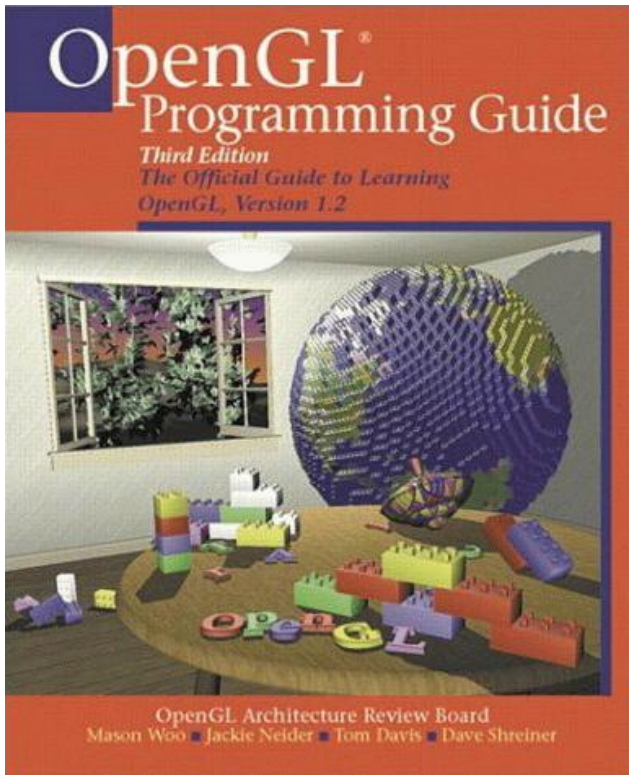
Plan

References

D. Shreiner, M. Woo, J. Neider, T. Davis
OpenGL Programming Guide

aka the red book

http://opengl-redbook.com



Plan

What is it?

- API (Application Programming Interface) for graphics hardware
- Non-dependant on the architecture or programming language
- Developped in 1989 (GL) by Silicon Graphics, extended to other architectures in 1993 (OpenGL)
- About 250 commands

Things it can NOT do

- Can NOT create nor manage a *viewer*
- Can NOT manage complex objects : only 3 types of geometric primitives (points, lines, polygons)

Things it can NOT do

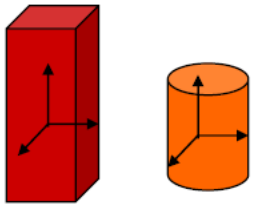
- Can NOT create nor manage a *viewer*
- Can NOT manage complex objects : only 3 types of geometric primitives (points, lines, polygons)

- $\Rightarrow$ **Additional libraries needed :**
  - **GLU :** *openGL Utility library* : more complex 3D models
  - **GLUT :** *openGL Utility Toolkit* : viewer
  - **QGLViewer :** *Qt library handling OpenGL*
  - ...

Plan

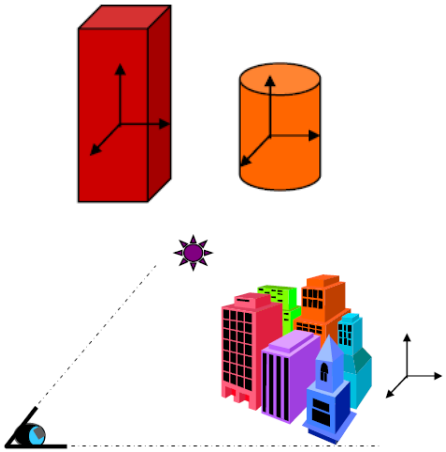
Plan

Graphics Pipeline



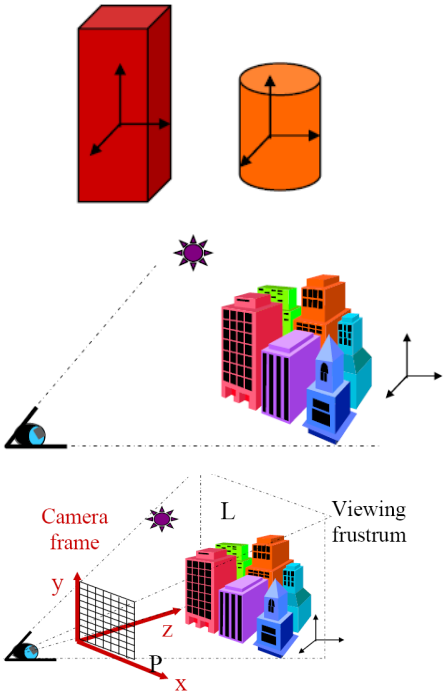
1. Create 3D models (modeling)

Graphics Pipeline



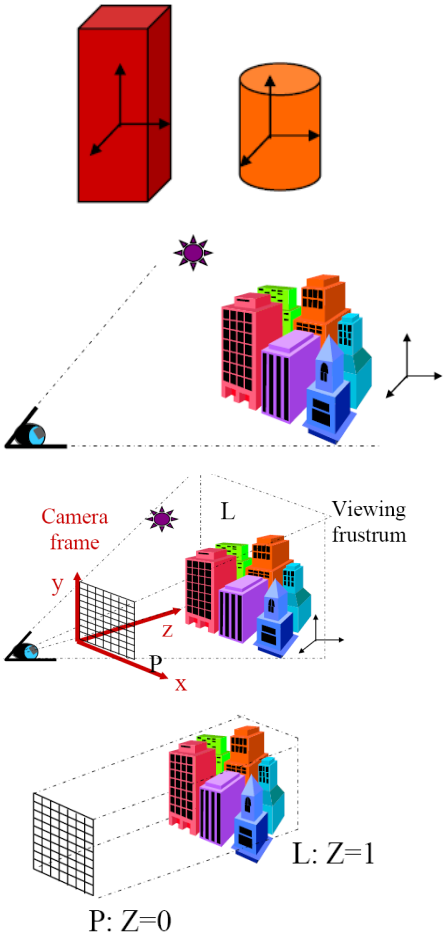
1. Create 3D models (modeling)
2. Build the scene from instances of models placed in a world frame (modeling transformation)

Graphics Pipeline



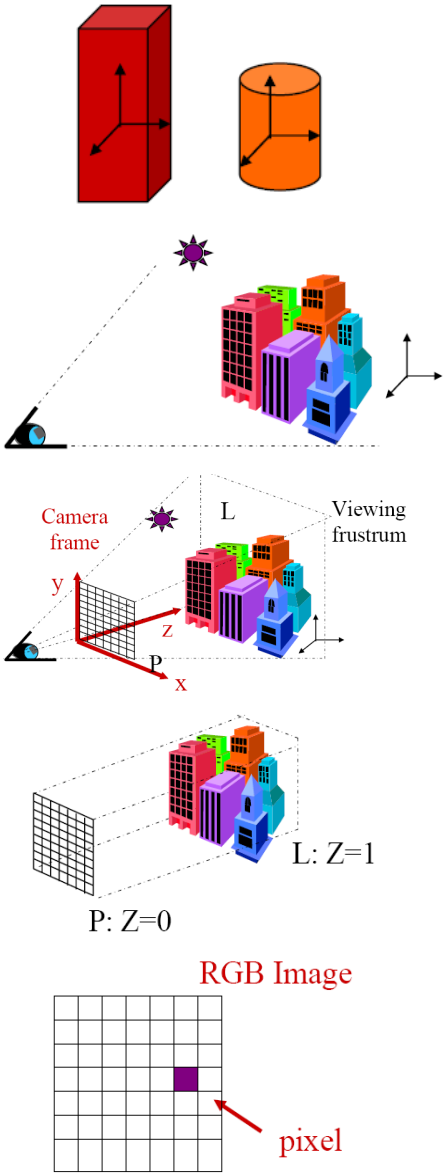
1. Create 3D models (modeling)
2. Build the scene from instances of models placed in a world frame (modeling transformation)
3. Convert to camera frame (culling, frustrum)

Graphics Pipeline



1. Create 3D models (modeling)
2. Build the scene from instances of models placed in a world frame (modeling transformation)
3. Convert to camera frame (culling, frustrum)
4. Convert to screen frame (projection)

Graphics Pipeline



1. Create 3D models (modeling)
2. Build the scene from instances of models placed in a world frame (modeling transformation)
3. Convert to camera frame (culling, frustrum)
4. Convert to screen frame (projection)
5. Compute image (rasterization)

Plan

OpenGL Pipeline

Create OpenGL context

OpenGL Pipeline

Create OpenGL context
Loop :

OpenGL Pipeline

Create OpenGL context
Loop :

1. Manage mouse/keyboard events

OpenGL Pipeline

Create OpenGL context
Loop :

1. Manage mouse/keyboard events
2. Display

OpenGL Pipeline

Create OpenGL context
Loop :

1. Manage mouse/keyboard events
2. Display
    1. Clear screen

OpenGL Pipeline

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Loop :

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    1. Clear screen
    2. Viewpoint

OpenGL Pipeline

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    3. For each object :

OpenGL Pipeline

Create OpenGL context
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2. Display
    1. Clear screen
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Loop :

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It's a state machine!

State machine = each parameter retains its value and is used with that value until being explicitely changed

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- **modes :** shading mode, matrix manipulated ...
- **booleans :** lights on/off, blend colors, ...

It's a state machine!

State machine = each parameter retains its value and is used with that value until being explicitely changed

Parameters can be :

- **modes :** shading mode, matrix manipulated ...
- **booleans :** lights on/off, blend colors, ...
- **scalar values :** colors, viewpoint, ...

Plan

OpenGL Syntax - 1/2

Reminder :

- **modes :** `gl[MODE]Mode(GL_VALUE)`

OpenGL Syntax - 1/2

Reminder :

- **modes :** `gl[MODE]Mode(GL_VALUE)`
- **booleans :** `glEnable(GL_VALUE)`

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- **scalar values :**

```
glColor3f(1.0,1.0,1.0);
```

  - **gl** : OpenGL command ...

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  - **f** : ... of type float.

OpenGL Syntax - 1/2

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  $\Rightarrow$ OpenGL constants start with **GL_**
- **scalar values :**

```
glColor3f(1.0,1.0,1.0);
```

  - **gl** : OpenGL command ...
  - **3** : ... that has 3 arguments ...
  - **f** : ... of type float.

```
glColor3fv(color_array);
```

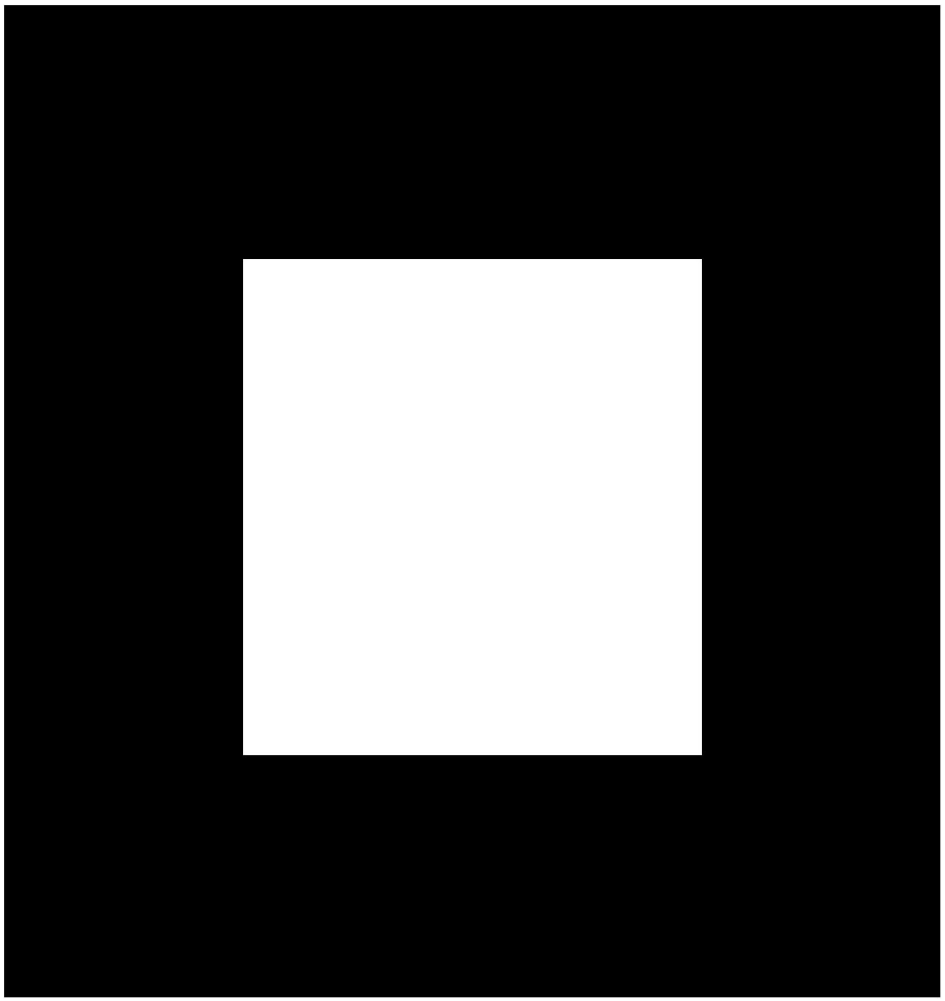
$\Rightarrow$ The argument is a **v**ector (or array) of 3 floats
(`GLfloat color_array[] = { 1.0,0.0,0.0 } ;`)

OpenGL Syntax - 2/2

OpenGL suffixes and types

b	integer (8 bits)	signed char	GLbyte
s	integer (16 bits)	short	GLshort
i	integer (32 bits)	int ou long	GLint
f	real (32 bits)	float	GLfloat
d	real (64 bits)	double	GLdouble
ub	unsigned integer (8 bits)	unsigned char	GLubyte
us	unsigned integer (16 bits)	unsigned long	GLushort
ul	unsigned integer (32 bits)	unsigned int ou long	GLuint

Basic example - the Square



Basic example - the Code

Display :

Basic example - the Code

Display :

```
void display () {
```

Basic example - the Code

Display :

```
void display () {
```

1. Clear screen

Basic example - the Code

Display :

```
void display () {
```

1. Clear screen

```
    glClear(GL_COLOR_BUFFER_BIT);
```

Basic example - the Code

Display :

```
void display () {
```

1. Clear screen

   ```
   glClear(GL_COLOR_BUFFER_BIT);
   ```

2. Viewpoint

Basic example - the Code

Display :

```
void display () {
```

1. Clear screen

```
glClear(GL_COLOR_BUFFER_BIT);
```

2. Viewpoint

```
glMatrixMode(GL_PROJECTION);
glOrtho(0.0,1.0,0.0,1.0,-1.0,1.0);
```

Basic example - the Code

Display :

```
void display () {
```

1. Clear screen
   ```
   glClear(GL_COLOR_BUFFER_BIT);
   ```
2. Viewpoint
   ```
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   glOrtho(0.0,1.0,0.0,1.0,-1.0,1.0);
   ```
3. For each object :

Basic example - the Code

Display :

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void display () {
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   ```
   glClear(GL_COLOR_BUFFER_BIT);
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   ```
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   ```
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   ```
3. For each object :
   1. Place object

   ```
   glMatrixMode(GL_MODELVIEW);
   ```

Basic example - the Code

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   ```
   glClear(GL_COLOR_BUFFER_BIT);
   ```
2. Viewpoint
   ```
   glMatrixMode(GL_PROJECTION);
   glOrtho(0.0,1.0,0.0,1.0,-1.0,1.0);
   ```
3. For each object :
   1. Place object
      ```
      glMatrixMode(GL_MODELVIEW);
      ```
   2. Modify state machine

Basic example - the Code

Display :

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void display () {
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      ```
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3. For each object :
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      ```
      glMatrixMode(GL_MODELVIEW);
      ```
   2. Modify state machine
      ```
      glColor3f(1.0,1.0,1.0);
      ```
   3. Draw
      ```
      glBegin(GL_POLYGON);
          glVertex3f(0.25,0.25,0.0);
          glVertex3f(0.75,0.25,0.0);
          glVertex3f(0.75,0.75,0.0);
          glVertex3f(0.25,0.75,0.0);
      glEnd();
      ```

Basic example - the Code

Display :

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void display () {
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   ```
   glClear(GL_COLOR_BUFFER_BIT);
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   ```
   glMatrixMode(GL_PROJECTION);
   glOrtho(0.0,1.0,0.0,1.0,-1.0,1.0);
   ```
3. For each object :
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      ```
      glMatrixMode(GL_MODELVIEW);
      ```
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      ```
      glColor3f(1.0,1.0,1.0);
      ```
   3. Draw
      ```
      glBegin(GL_POLYGON);
          glVertex3f(0.25,0.25,0.0);
          glVertex3f(0.75,0.25,0.0);
          glVertex3f(0.75,0.75,0.0);
          glVertex3f(0.25,0.75,0.0);
      glEnd();
      glFlush(); // Execute OpenGL commands in hold
      ```

```
}
```

Plan

Plan

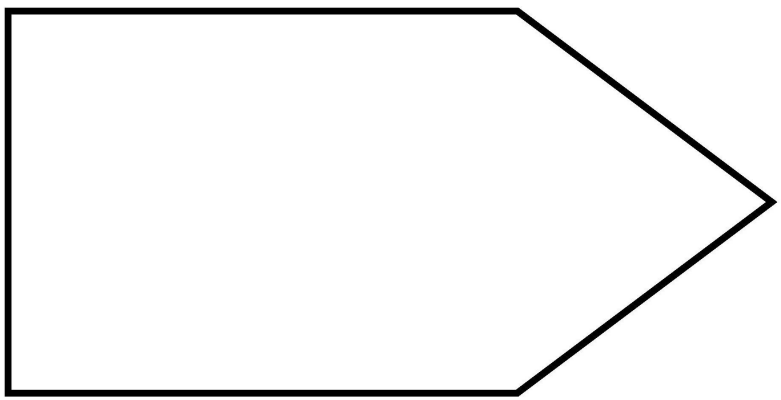
Procedural modeling

Complex object : combination of elementary elements :

1. Points (vertices) : coordinates in a given reference frame
2. Lines : segments
3. Polygons : simple convex polygons

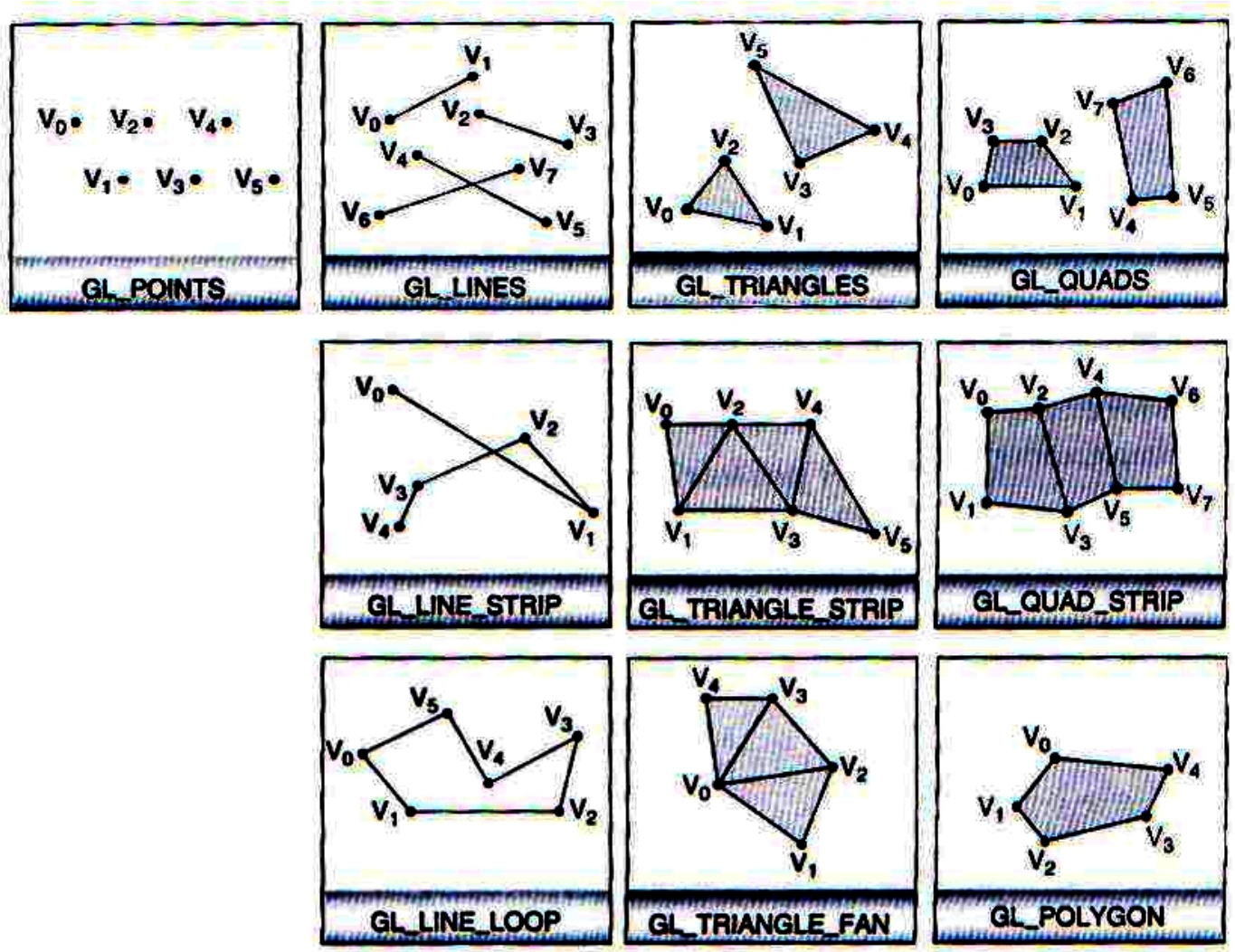
Example - planar pentagon

```
glBegin(GL_POLYGON);
   glVertex2f(0.0, 0.0);
   glVertex2f(0.0, 3.0);
   glVertex2f(4.0, 3.0);
   glVertex2f(6.0, 1.5);
   glVertex2f(4.0, 0.0);
glEnd();
glFlush();
```



Plan

OpenGL primitives



Parameters

- Point size (in pixels) : `glPointSize(2.0);`
- Line width (in pixels) : `glLineWidth(3.0);`

Parameters

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- Line width (in pixels) : `glLineWidth(3.0);`
- Line drawing : many stippling styles
- Different renderings for front and back faces :

```
glPolygonMode(GL_FRONT,GL_FILL);
glPolygonMode(GL_BACK,GL_LINE);
```

Parameters

- Point size (in pixels) : `glPointSize(2.0);`
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- The color, normal, . . . , at each vertex can be specified
- . . .

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- The color, normal, . . . , at each vertex can be specified
- . . .

- Get current values : `glGetFloatv(GL_LINE_WIDTH);`

Immediate definition of an objet

Each vertices and polygons are directly defined.
Example of a triangle :

```
glBegin(GL_POLYGON);
   glNormal3fv(n0);
   glVertex3fv(v0);
   glNormal3fv(n1);
   glVertex3fv(v1);
   glNormal3fv(n2);
   glVertex3fv(v2);
glEnd();
```

Beware of the order : parameter (i.e. normal) before coordinates (state machine)

Non immediate methods : Arrays

- Vertex-related data (coordinates, normals, colors, ...) can also be stored in arrays in the CPU memory

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- Object are then defined with a reduced number of primitives
  - `glDrawArrays(GL_QUADS, 0, 24)`
  - `glDrawElements(GL_POLYGON, 5, GL_UNSIGNED_INT, vertices)`

Non immediate methods : Arrays

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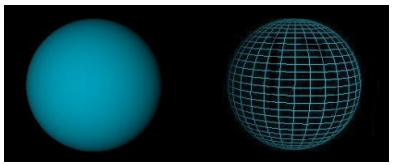
- Polygons refer to vertices through indices in these arrays
- Object are then defined with a reduced number of primitives
  - `glDrawArrays(GL_QUADS, 0, 24)`
  - `glDrawElements(GL_POLYGON, 5, GL_UNSIGNED_INT, vertices)`
- Advanced methods (non studied in this course)
  - Display lists
  - Vertex Buffer Objects (VBO) : arrays are directly stored in the graphics card memory.

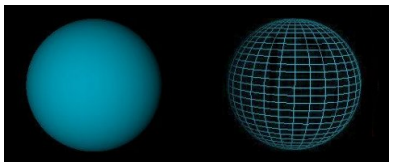
Plan

GLUT primitives - 1/2



```
glutSolidSphere(radius, slices, stacks)
glutWireSphere(radius, slices, stacks)
```

GLUT primitives - 1/2



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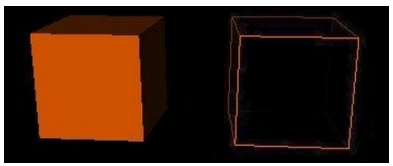
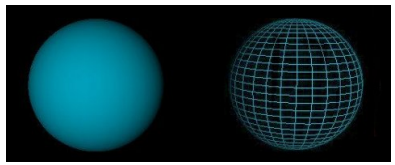


```
glutSolidCube(size)
glutWireCube(size)
```

GLUT primitives - 1/2



```
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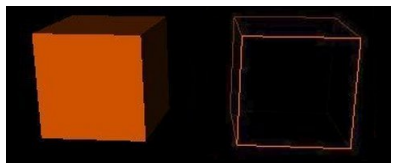
glutWireSphere(radius, slices, stacks)
```



```
glutSolidCube(size)
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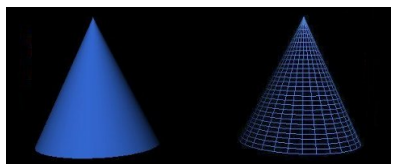
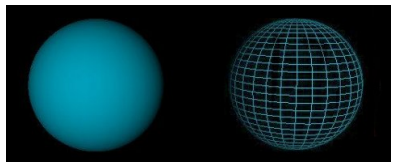


```
glutSolidCone(base, height, slices, stacks)
glutWireCone(base, height, slices, stacks)
```

GLUT primitives - 1/2



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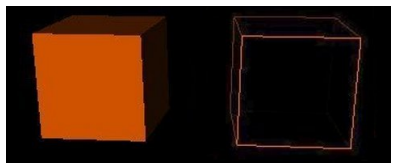
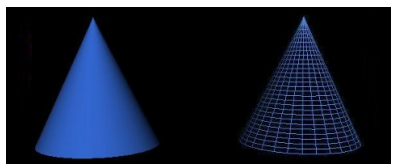
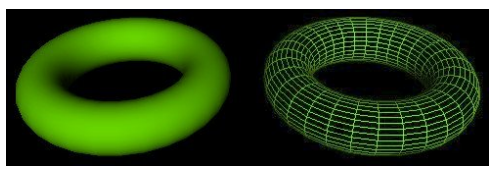


```
glutSolidCube(size)
glutWireCube(size)
```



```
glutSolidCone(base, height, slices, stacks)
glutWireCone(base, height, slices, stacks)
```



```
glutSolidTorus(innerRadius, outerRadius,
nsides, rings)
glutWireTorus(innerRadius, outerRadius,
nsides, rings)
```

GLUT primitives - 2/2

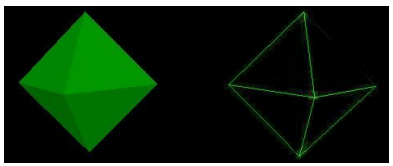
`glutSolidTetrahedron()`

`glutWireTetrahedron()`

GLUT primitives - 2/2

`glutSolidTetrahedron()`

`glutWireTetrahedron()`



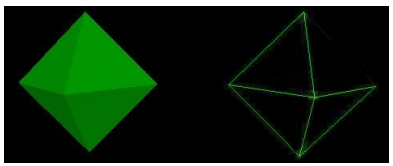
`glutSolidOctahedron()`

`glutWireOctahedron()`

GLUT primitives - 2/2

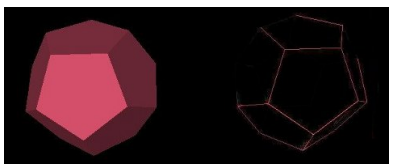
`glutSolidTetrahedron()`

`glutWireTetrahedron()`



`glutSolidOctahedron()`

`glutWireOctahedron()`



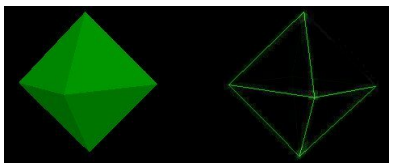
`glutSolidDodecahedron()`

`glutWireDodecahedron()`

GLUT primitives - 2/2

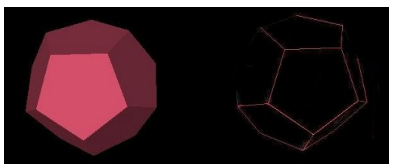
`glutSolidTetrahedron()`

`glutWireTetrahedron()`



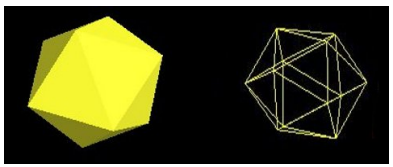
`glutSolidOctahedron()`

`glutWireOctahedron()`



`glutSolidDodecahedron()`

`glutWireDodecahedron()`



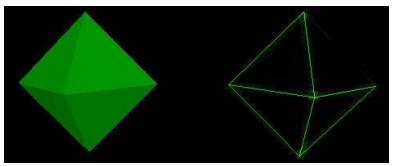
`glutSolidIcosahedron()`

`glutWireIcosahedron()`

GLUT primitives - 2/2

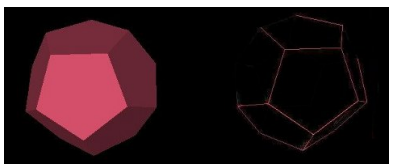
`glutSolidTetrahedron()`

`glutWireTetrahedron()`



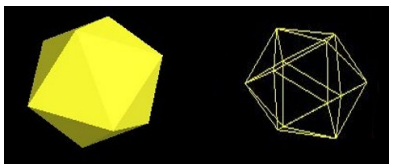
`glutSolidOctahedron()`

`glutWireOctahedron()`



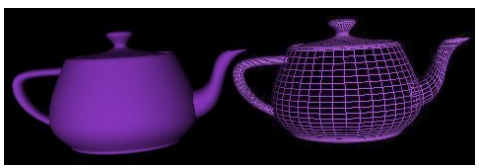
`glutSolidDodecahedron()`

`glutWireDodecahedron()`



`glutSolidIcosahedron()`

`glutWireIcosahedron()`



`glutSolidTeapot(size)`

`glutWireTeapot(size)`

Remark : There is no `Cylinder` primitive.

Plan

Conclusion :

- Done :
  - General process
  - Modeling : geometric primitives
- Highlights :
  - State machine
  - Primitives
  - the redbook
- To do :
  - lab
  - modeling complex objects with primitives