Introduction to OpenGL

Estelle Duveau - estelle.duveau@inria.fr

MoSIG1, Introduction to Computer Graphics, 25/02/2009

Planning

- **Lecture :** introduction to OpenGL
  Lab : first steps in OpenGL and modeling - 25/02/2009
- **Lecture/Lab :** transformations and hierarchical modeling - 04/03/2009
- **Lecture :** lights and materials in OpenGL - 11/03/2009
- **Lab :** lights and materials in OpenGL - 18/03/2009
- **Lecture :** textures in OpenGL
  Lab : textures in OpenGL - 25/03/2009
- **Lab :** procedural animation - 01/04/2009
- **Lab :** physical animation : particle systems - 08/04/2009
- **Lab :** physical animation : collisions - 22/04/2009

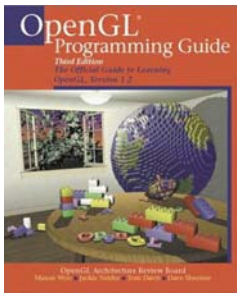
Plan

References

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

aka the red book

http://opengl-redbook.com



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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

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 ...
  `glShadeMode(GL_FLAT); glShadeMode(GL_SMOOTH);`
- **booleans :** lights on/off, blend colors, ...
  `glEnable(GL_LIGHT0); glDisable(GL_LIGHT1);`
- **scalar values :** colors, viewpoint, ...
  `glColor3f(0.0,0.0,0.0); glNormal3f(1.0,0.0,0.0);`

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)

- ⇒ **Additional libraries needed :**
  - **GLU :** *openGL Utility library* : more complex 3D models
  - **GLUT :** *openGL Utility Toolkit* : viewer

Example : OpenGL with GLUT

```
int main(int argc, char** argv){
   glutInit(&argc,argv);
   glutInitDisplayMode(GLUT_SINGLE|GLUT_RGB);
   glutInitWindowSize(250,250);
   glutInitWindowPosition(100,100);
   glutCreateWindow("hello"); // not yet displayed
   init(); // to define with OpenGL
   glutDisplayFunc(display);
   glutMouseFunc(mouse);
   glutKeyboardFunc(keyboard);
         // call back functions to define with OpenGL
   glutMainLoop; // Let's go! Scene displayed
   return 0;
}
```


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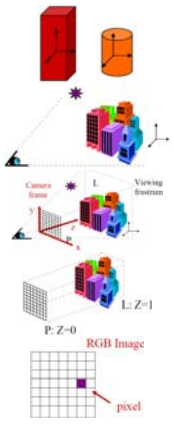
Graphics Pipeline



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)

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OpenGL Pipeline

Create OpenGL context
Loop :

1. Manage mouse/keyboard events
2. Display
   1. Clear screen
   2. Viewpoint
   3. For each object :
      1. Place object
      2. Modify state machine
      3. Draw

Basic example - 1/2

Display :

```
void display () {
```

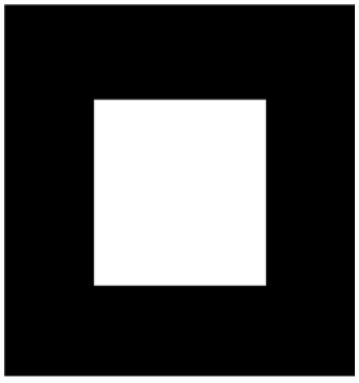
1. Clear screen
   ```
   glClear(GL_COLOR_BUFFER_BIT);
   ```
2. Viewpoint
   ```
   glMatrixMode(GL_PROJECTION);
   glOrtho(0.0,1.0,0.0,1.0,-1.0,1.0);
   ```
3. For each object :
   1. Place object
      ```
      glMatrixMode(GL_MODELVIEW);
      ```
   2. Modify state machine
      ```
      glColor3f(1.0,1.0,1.0);
      ```
   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();
      glFlush(); // Execute OpenGL commands in hold
      ```

```
}
```


Basic example - 1/2

```
void display () {
   glClear(GL_COLOR_BUFFER_BIT);
   glMatrixMode(GL_PROJECTION);
   glOrtho(0.0,1.0,0.0,1.0,-1.0,1.0);
   glMatrixMode(GL_MODELVIEW);
   glColor3f(1.0,1.0,1.0);
   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();
}
```


Basic example - 2/2



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OpenGL Syntax - 1/2

Reminder :

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

  ⇒ 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

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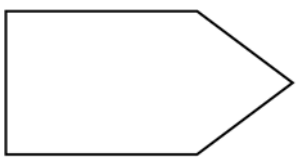
Procedural modeling

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();
```



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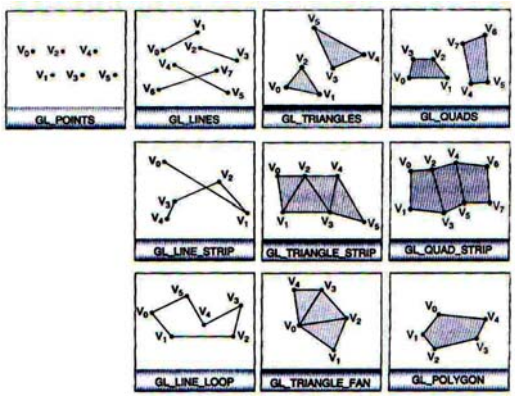
Geometric primitives



Parameters

- Point size (in pixels) : `glPointSize(2.0);`
- 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);`
- Culling : `glCullFace(GL_BACK);` : back-faces non-visible
- The color, normal, . . . , at each vertex can be specified
- . . .
- Get current values : `glGetFloatv(GL_LINE_WIDTH);`

Example : normals

```
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

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Arrays

- An array for each type of data : coordinates, normal, color, texture, . . .
- Create an array : `glEnableClientState(GL_NORMAL_ARRAY);`
- Use that array :
  `glColorPointer(3,GL_FLOAT,5*sizeof(GLfloat),color);`
  → *stride* = offset (in bytes) between 2 consecutive data elements
- Access an element `glArrayElement(0);` : done in all active arrays
- Access several elements :
  `glDrawElements(GL_POLYGON,5,GL_UNSIGNED_INT,vertices);`
- Also `glMultiDrawElements(...)`, `glDrawRangeElements(...)` , . . .

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Conclusion :

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