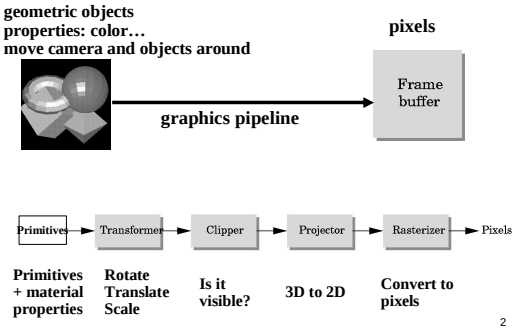
More on the graphics pipeline
Event driven programming
Nintendo Wii (Michael De Rosa)

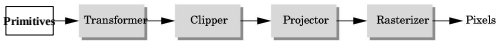
Review



2

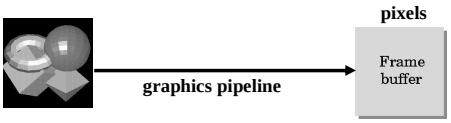
Outline

- Double Buffering
- Hidden Surface Removal
- Back-Face Culling



3

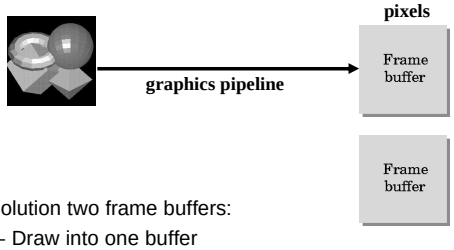
Double Buffering: Screen Refresh



- Common: 60-100 Hz
- Flicker if drawing overlaps screen refresh
- Problem during animation
- Example (cube_single.c)

4

Double Buffering: Screen Refresh



- Solution two frame buffers:
  - Draw into one buffer
  - Swap and display, while drawing into other buffer
- Desirable frame rate >= 30 fps (frames/second)

5

Enabling Modes

- glutInitDisplayMode (GLUT_SINGLE);
- glutInitDisplayMode (GLUT_DOUBLE);

- draw your scene
- glutSwapBuffers ();

6

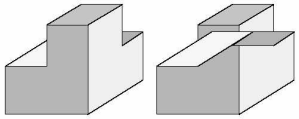
Outline

- Double Buffering
- Hidden Surface Removal
- Back-Face Culling

7

Hidden Surface Removal

- What is visible after clipping and projection?



8

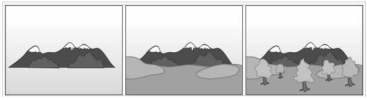
Hidden Surface Removal

- Object-space vs image-space approaches
- Object space: depth sort (Painter's algorithm)
- Image space: ray cast (z-buffer algorithm)

We'll get back to this later in the semester in much more detail!

9

Painters Algorithm

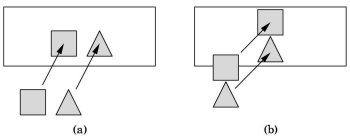


- Render back-to-front
- "Paint" over invisible polygons
- How to sort and how to test overlap?

10

Depth Sorting

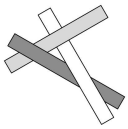
- First, sort by furthest distance z from viewer
- If minimum depth of A is greater than maximum depth of B, A can be drawn before B
- If either x or y extents do not overlap, A and B can be drawn independently



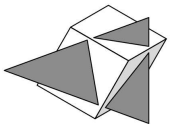
11

Some Difficult Cases

- Sometimes cannot sort polygons!



Cyclic overlap



Piercing Polygons

- One solution: compute intersections and subdivide
- Do while rasterizing (difficult in object space)

12

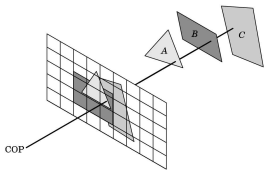
Painter's Algorithm Assessment

- Strengths
  - Simple (most of the time)
  - Handles transparency well
  - Sometimes, no need to sort (e.g., heightfield)
- Weaknesses
  - Clumsy when geometry is complex
  - Sorting can be expensive

13

Image-Space Approach

- Raycasting: intersect ray with polygons

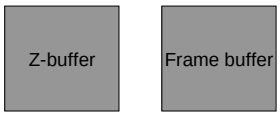


- O(k) worst case (often better) where k=# of objects

14

The z-Buffer Algorithm

- z-buffer with depth value z for each pixel
- Before writing a pixel into framebuffer
  - Compute distance z of pixel origin from viewer
  - If closer write and update z-buffer, otherwise discard



15

z-Buffer Algorithm Assessment

- Strengths
  - Simple (no sorting or splitting)
  - Independent of geometric primitives
- Weaknesses
  - Memory intensive (but memory is cheap now)
  - Tricky to handle transparency and blending

16

Depth Buffer in OpenGL

- glutInitDisplayMode (GLUT_DEPTH);
- glEnable (GL_DEPTH_TEST);
- glClear (GL_DEPTH_BUFFER_BIT);

17

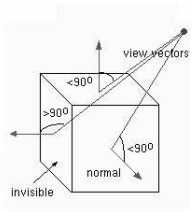
Outline

- Double Buffering
- Hidden Surface Removal
- Back-Face Culling

18

Back-Face Culling

Eliminate polygons not facing the viewer



glCullFace(GL_BACK);

19

More on the graphics pipeline
Event driven programming
Nintendo Wii (Michael De Rosa)

Interactive Graphics Applications

- Games
- Simulation-based training
  - pilot training
- Windows-based programs

21

Control-driven programming

```
main()
    while user does not press quit
        draw cube
        check if mouse pressed
        if mouse pressed
            change axis of rotation

        check if key pressed
        …..
```

Continuous polling of user commands → wasting machine resources

Many actions performed by user are non-application specific

22

Event-driven programming

GUI program should remain idle by default
Do not waste machine resources
Become active only in presence of events
Automatically take care of standard actions

main() ⟶ MainEventLoop()

```
Initialization
loop forever
    wait for next event
    process event
```

23

Event-driven programming

GUI program should remain idle by default
Do not waste machine resources
Become active only in presence of events
Automatically take care of standard actions

```
register event service routines with GUI
wait for next event
process event
```

24

GLUT

- Initialization
  - Open window
  - Set display mode
  - Register call backs
- Enter main loop
  - glutMainLoop();

25

Types of Callbacks

- Display ( ): when window must be drawn
- Idle ( ): when no other events to be handled
- Keyboard (…): key
- Menu (...): after selection from menu
- Mouse (…): mouse
- Motion (...): mouse movement
- Reshape (int w, int h): window resize
- Any callback can be NULL

26

Example: Rotating Color Cube

- Draw a color cube
- Rotate it about x, y, or z axis, depending on left, middle or right mouse click
- Stop when space bar is pressed
- Quit when q or Q is pressed

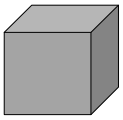
27

Step 1: Defining the Vertices

- Use parallel arrays for vertices and colors

```
/* vertices of cube about the origin */
GLfloat vertices[8][3] =
  {{-1.0, -1.0, -1.0}, {1.0, -1.0, -1.0},
   {1.0, 1.0, -1.0}, {-1.0, 1.0, -1.0}, {-1.0, -1.0, 1.0},
   {1.0, -1.0, 1.0}, {1.0, 1.0, 1.0}, {-1.0, 1.0, 1.0}};

/* colors to be assigned to edges */
GLfloat colors[8][3] =
  {{0.0, 0.0, 0.0}, {1.0, 0.0, 0.0},
   {1.0, 1.0, 0.0}, {0.0, 1.0, 0.0}, {0.0, 0.0, 1.0},
   {1.0, 0.0, 1.0}, {1.0, 1.0, 1.0}, {0.0, 1.0, 1.0}};
```



28

Step 2: Set Up

- Enable depth testing and double buffering

```
int main(int argc, char **argv)
{
   glutInit(&argc, argv);

   /* double buffering for smooth animation */
   glutInitDisplayMode(GLUT_DOUBLE | GLUT_DEPTH | GLUT_RGB);

   ...   /* window creation and callbacks here */

   glEnable(GL_DEPTH_TEST);
   glutMainLoop();
}
```

29

Step 3: Install Callbacks

- Create window and set callbacks

```
glutInitWindowSize(500, 500);
glutCreateWindow("cube");
glutReshapeFunc(myReshape);
glutDisplayFunc(display);
glutIdleFunc(spinCube);
glutMouseFunc(mouse);
glutKeyboardFunc(keyboard);
```

30

Step 4: Reshape Callback

- Enclose cube, preserve aspect ratio

```
void myReshape(int w, int h)
{
   GLfloat aspect = (GLfloat) w / (GLfloat) h;
   glViewport(0, 0, w, h);
   glMatrixMode(GL_PROJECTION);
   glLoadIdentity();
   if (w <= h) /* aspect <= 1 */
     glOrtho(-2.0, 2.0, -2.0/aspect, 2.0/aspect, -10.0, 10.0);
   else /* aspect > 1 */
     glOrtho(-2.0*aspect, 2.0*aspect, -2.0, 2.0, -10.0, 10.0);
   glMatrixMode(GL_MODELVIEW);
}
```

31

Step 5: Display Callback

- Clear, rotate, draw, flush, swap

```
GLfloat theta[3] = {0.0, 0.0, 0.0};
void display(void)
{
   glClear(GL_COLOR_BUFFER_BIT| GL_DEPTH_BUFFER_BIT);
   glLoadIdentity();
   glRotatef(theta[0], 1.0, 0.0, 0.0);
   glRotatef(theta[1], 0.0, 1.0, 0.0);
   glRotatef(theta[2], 0.0, 0.0, 1.0);
   colorcube(); glFlush();
   glutSwapBuffers();
}
```

32

Step 6: Drawing Faces

- Call face(a, b, c, d) with vertex index
- Orient consistently

```
void colorcube(void)
{
   face(0,3,2,1);
   face(2,3,7,6);
   face(0,4,7,3);
   face(1,2,6,5);
   face(4,5,6,7);
   face(0,1,5,4);
}
```

33

Step 7: Drawing a Face

- Use vector form of primitives and attributes

```
void face(int a, int b, int c, int d)
{glBegin(GL_POLYGON);
   glColor3fv(colors[a]);
   glVertex3fv(vertices[a]);
   glColor3fv(colors[b]);
   glVertex3fv(vertices[b]);
   glColor3fv(colors[c]);
   glVertex3fv(vertices[c]);
   glColor3fv(colors[d]);
   glVertex3fv(vertices[d]);
  glEnd(); }
```

34

Step 8: Animation

- Set idle callback

```
void spinCube()
{
   /* spin cube delta degrees about selected axis */
   theta[axis] += delta;
   if (theta[axis] > 360.0) theta[axis] -= 360.0;


   /* display result */
   glutPostRedisplay();
}
```

35

Step 9: Change Axis of Rotation

- Mouse callback

```
void mouse(int btn, int state, int x, int y)
{
   if (btn==GLUT_LEFT_BUTTON
      && state == GLUT_DOWN) axis = 0;

   if (btn==GLUT_MIDDLE_BUTTON
      && state == GLUT_DOWN) axis = 1;

   if (btn==GLUT_RIGHT_BUTTON
      && state == GLUT_DOWN) axis = 2;
}
```

36

Step 10: Toggle Rotation or Exit

- Keyboard callback

```
void keyboard(unsigned char key, int x, int y)
{
    if (key=='q' || key == 'Q') exit(0);
    if (key==' ') {stop = !stop;};
    if (stop)
        glutIdleFunc(NULL);
    else
        glutIdleFunc(spinCube);
}
```

37

More on the graphics pipeline
Event driven programming
Nintendo Wii (Michael De Rosa)

Nintendo Wii

- PowerPC CPU @ 729 MHz
- ATI GPU @ 243 MHz
- 88 MB RAM
- WiFi
- Bluetooth

39

Wii Controller

- Wiimote
  - Position sensing (via IR triangulation)
  - 3 axis accelerometer
  - 12 buttons
  - Speaker
  - Vibration
  - Nonvolatile storage
- Nunchuk
  - 3 axis accelerometer
  - 2 buttons
  - Analog joystick

40

Input Channels
- Accelerometer readings (x6)
- Button state (x14)
- Position
- Joystick angle & deflection
- Wireless connection status

41

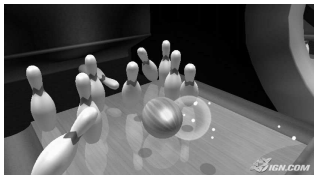
Wii Sports Bowling

- Depress B button (starts approach)
- Swing controller back, then forward
- Release B button (releases ball)
- Spin can be applied by tilting the controller

42

Callbacks for Bowling

- glutDisplayFunc(display); [to display the scene]
- glutKeyboardFunc(keyboard); [to start/stop the swing]
- glutMotionFunc(mouse); [to control swing params]
- Any others?



43

The Importance of Interaction Design

- The Wii has significantly less processing/graphics power than the PS3 (and no high def. output)
- Wii sold 600k units over Christmas (vs. 491k for PS3)
- Wii was on the annual “Hot Toy” list

- 05-650 Interface and Interaction Design
- 53-500 Fundamentals of Entertainment Technology

44

Tech Demo