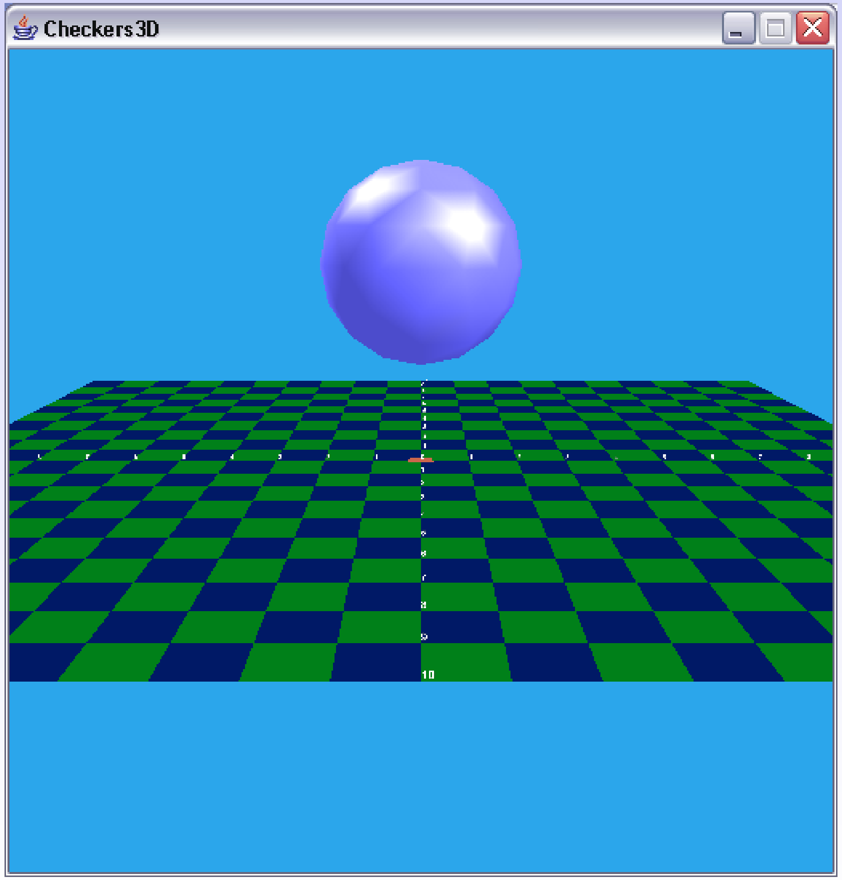
Computer Game Technologies

3D Graphics Programming

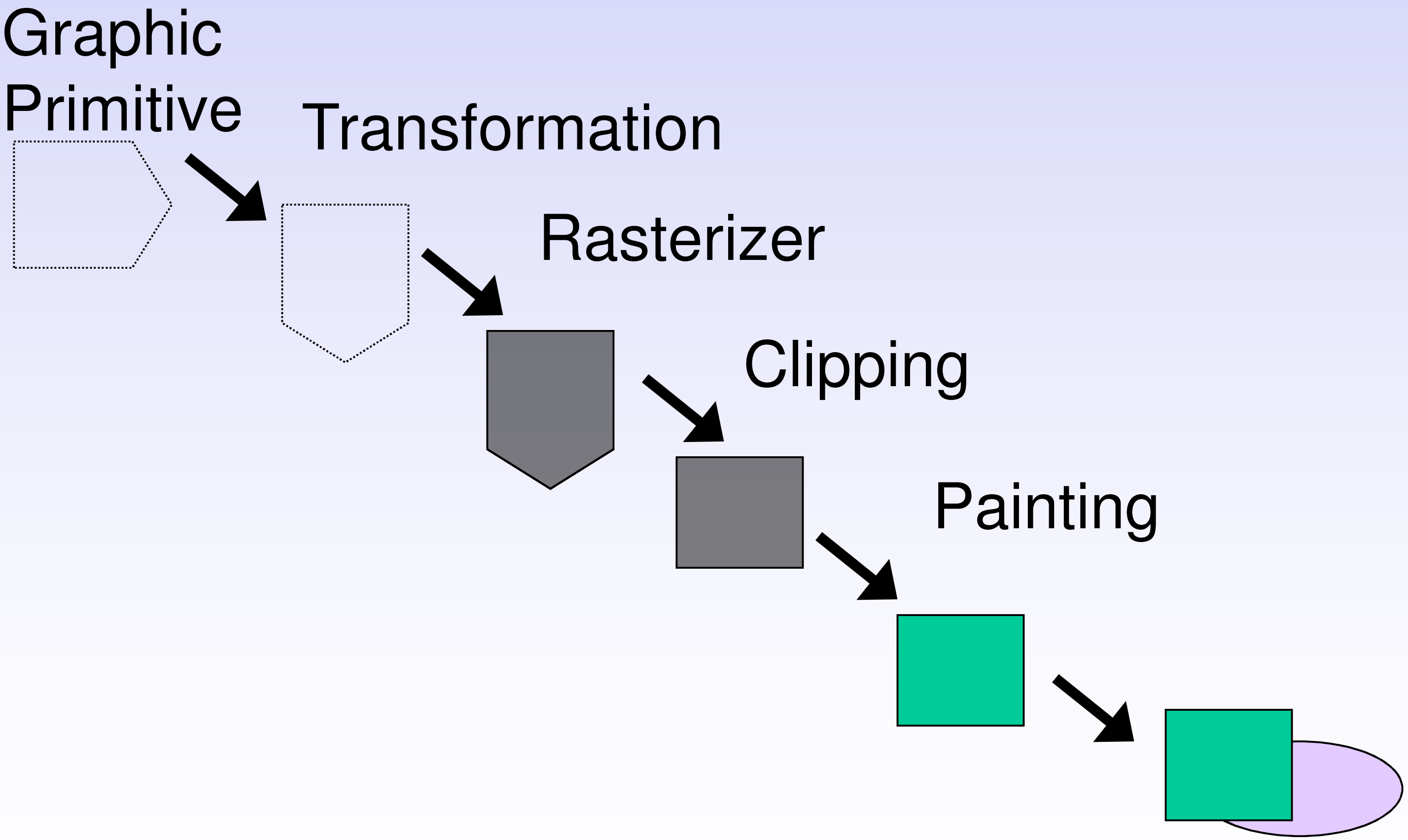
How Do We Program Graphics in 3D?

- Much like in 2D but with an extra (Z) dimension
- BUT need to worry about viewer (camera or eye) position
- Realistic 3D determined by lighting
- Ultimately must generate 2D view of 3D scene



2D Graphics Pipeline

- Turns vector-based 2D objects into pixel colours

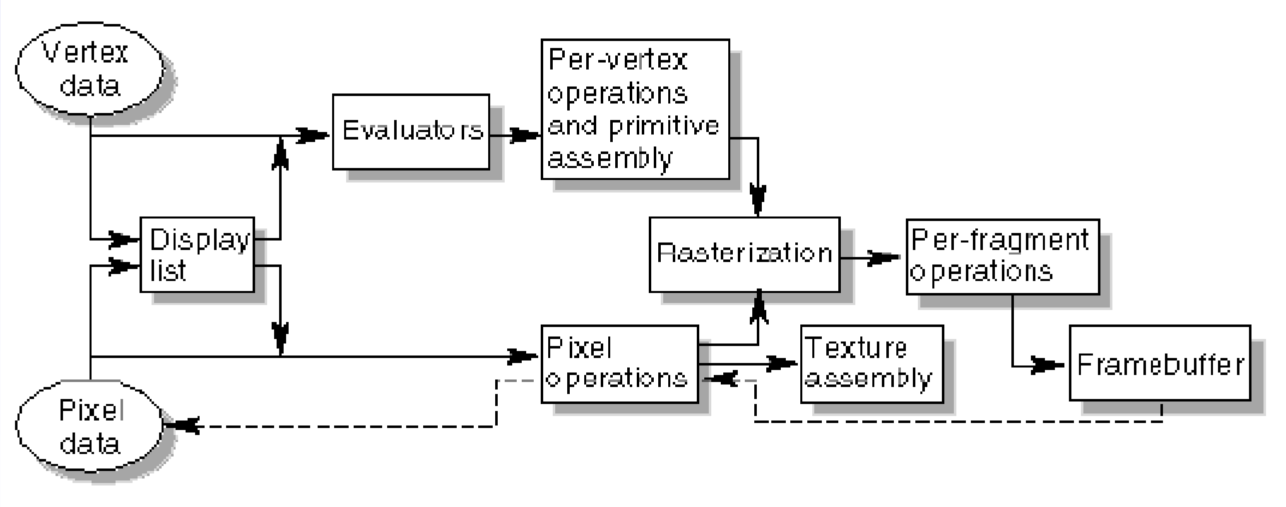


3D Graphics Pipeline

- Turns 3D objects into screen pixels
- 3D objects (usually) defined by vertices
  - Complex object approximated by flat, triangular surfaces defined by 3 vertices
- Colour of each vertex determined
  - Intrinsic colour plus lighting effects
- Non-vertex colours determined by interpolation
  - Shading model
- Objects mapped to 2D viewing window
  - Rasterization
  - Face culling and hidden surface removal
  - Texture mapping

3D Graphics Libraries

- Direct X
- OpenGL
- Equivalent to Java2D in the 3D world
- OpenGL graphics pipeline



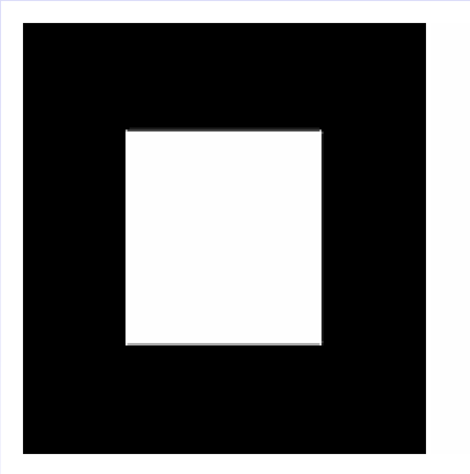
(OpenGL Programming Guide Fig. 1-2)

Hardware versus Software

- A software 3D renderer implements 3D graphics drawing entirely in software, presenting a final pixel screen buffer to the video card
  - See e.g. DGJ
- 3D graphics video cards support DirectX and OpenGL functions in hardware
- Standard operations on vertices
  - Vectors and matrices
- GPUs are more powerful than CPUs at what they do!
  - NVIDIA GeForce GTX 1080 achieves 8800 Gflops
  - 10-20 Gflops for current CPUs
  - Moving to be more general purpose processors
  - Parallel processing

OpenGL Example

```
Example 1-1 : Chunk of OpenGL Code
#include <whateverYouNeed.h>
main() {
InitializeAWindowPlease();
glClearColor (0.0, 0.0, 0.0, 0.0);
glClear (GL_COLOR_BUFFER_BIT);
glColor3f (1.0, 1.0, 1.0);
glOrtho(0.0, 1.0, 0.0, 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();
UpdateTheWindowAndCheckForEvents();
}
```

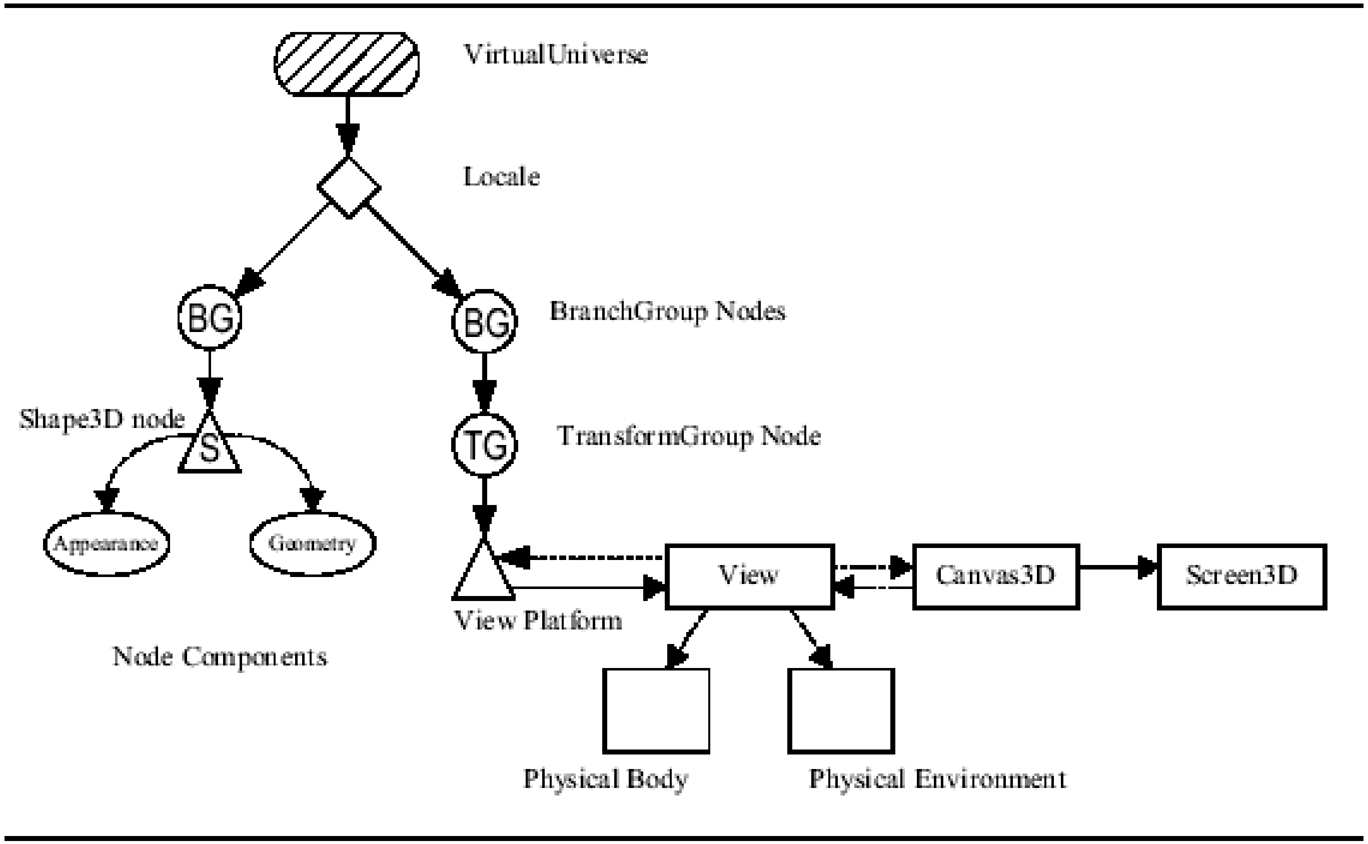


(OpenGL Programming Guide Fig. 1-1)

Java 3D

- Higher level approach
- Based on the concept of a **scene graph**
- Specifies elements of the 3D world
  - Visible objects
  - Lighting
  - Camera
- Java 3D renderer handles the low level details of drawing a 3D scene
  - Retained mode (scene graph) versus immediate mode
- Built on top of DirectX or OpenGL
  - Java bindings available e.g. JOGL

Java 3D Scene Graph Example

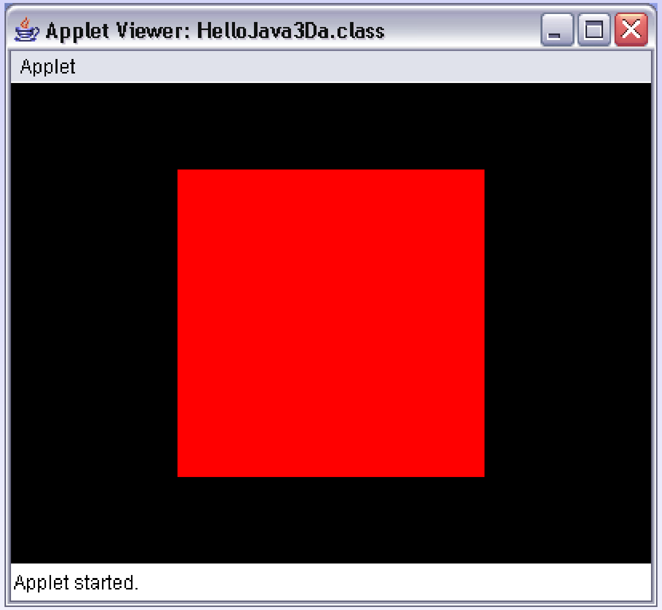


(Java 3D Tutorial Fig. 1-2)

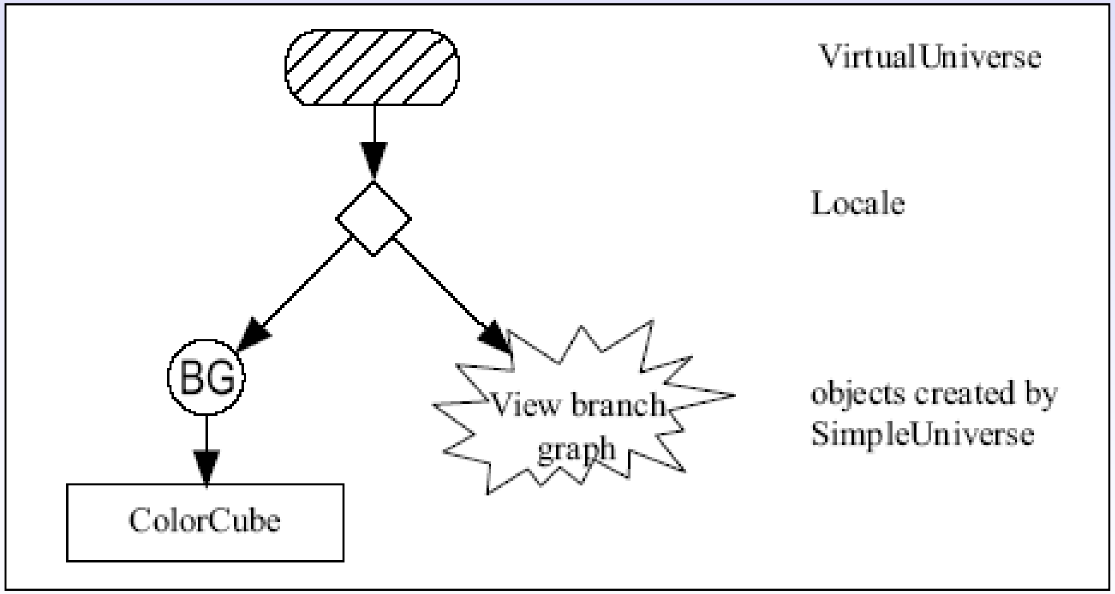
Java 3D Components

- A virtual 3D universe
- Camera (or viewer) position in that universe
- Lights
  - As many as needed
  - Different locations and properties
- Background
- Objects in the 3D world
  - Scenery
  - Game sprites
  - Position and appearance
- Objects can share properties
  - Appearance
  - Transformations

A First Java 3D Example



The Scene Graph



(Java 3D Tutorial Fig. 1-11)

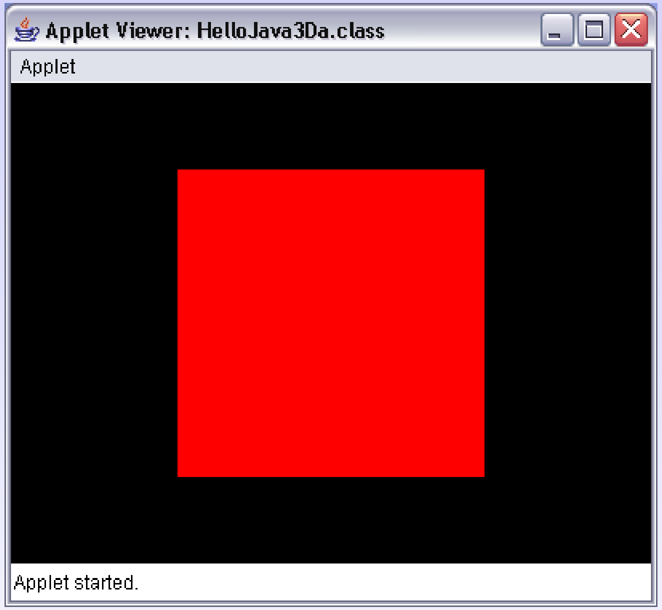
Java 3D Example Code

```
public class HelloJava3Da extends Applet {
    public HelloJava3Da() {
        setLayout(new BorderLayout());
        GraphicsConfiguration config =
           SimpleUniverse.getPreferredConfiguration();

        Canvas3D canvas3D = new Canvas3D(config);
        add("Center", canvas3D);

        BranchGroup scene = createSceneGraph();

        // SimpleUniverse is a Convenience Utility class
        SimpleUniverse simpleU = new SimpleUniverse(canvas3D);

       // This will move the ViewPlatform back a bit so the
       // objects in the scene can be viewed.
        simpleU.getViewingPlatform().setNominalViewingTransform();

        simpleU.addBranchGraph(scene);
    } // end of HelloJava3Da (constructor)
```

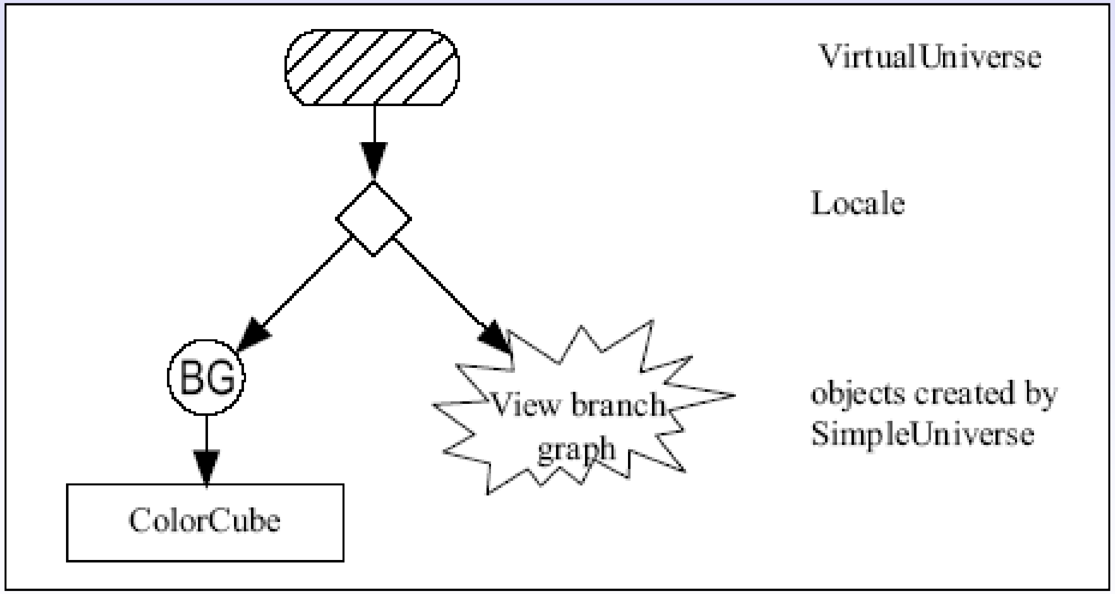
Java 3D Example Code (2)

```
public BranchGroup createSceneGraph() {
      // Create the root of the branch graph
      BranchGroup objRoot = new BranchGroup();

      objRoot.addChild(new ColorCube(0.4));

      return objRoot;
   } // end of CreateSceneGraph method of HelloJava3Da

   //  The following allows this to be run as an application
   //  as well as an applet

   public static void main(String[] args) {
      Frame frame = new MainFrame(new HelloJava3Da(), 256, 256);
   } // end of main (method of HelloJava3Da)

} // end of class HelloJava3Da
```

A First Java 3D Example (again)



The Scene Graph

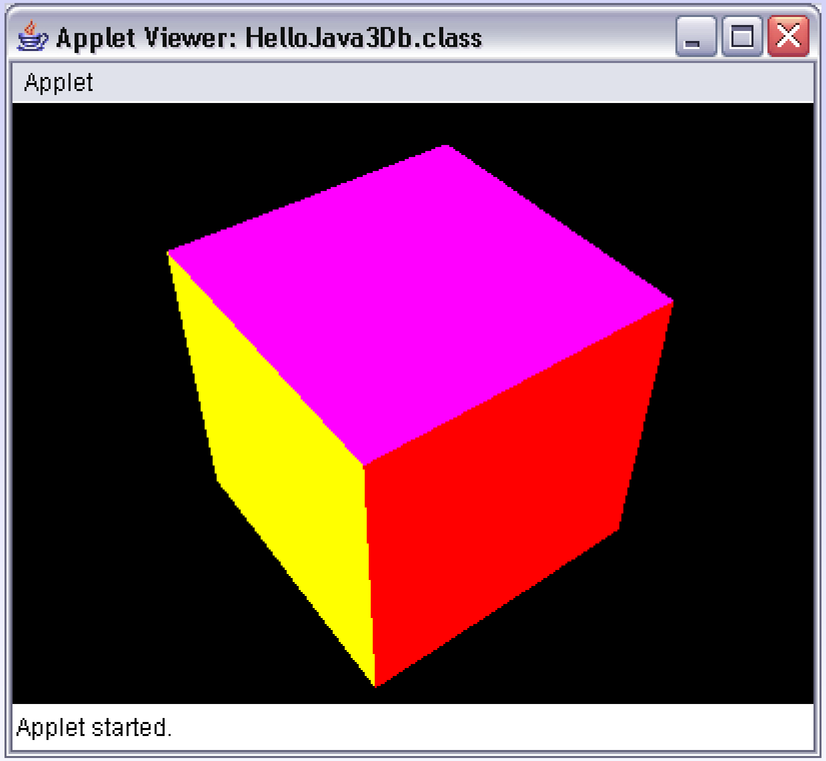


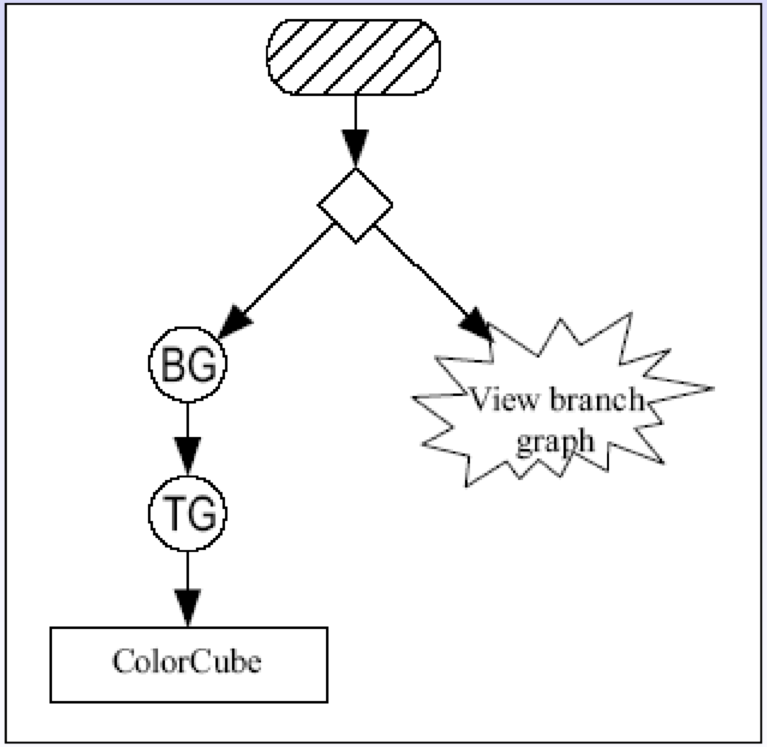
(Java 3D Tutorial Fig. 1-11)

Java 3D Example: Modification 1

```
public BranchGroup createSceneGraph() {
      // Create the root of the branch graph
      BranchGroup objRoot = new BranchGroup();

      // rotate object has composited transformation matrix
      Transform3D rotate = new Transform3D();
      Transform3D tempRotate = new Transform3D();

      rotate.rotX(Math.PI/4.0d);
      tempRotate.rotY(Math.PI/5.0d);
      rotate.mul(tempRotate);

      TransformGroup objRotate = new TransformGroup(rotate);

      objRoot.addChild(objRotate);
      objRotate.addChild(new ColorCube(0.4));
      // Let Java 3D perform optimizations on this scene graph.
      objRoot.compile();

      return objRoot;
   } // end of CreateSceneGraph method of HelloJava3Db
```

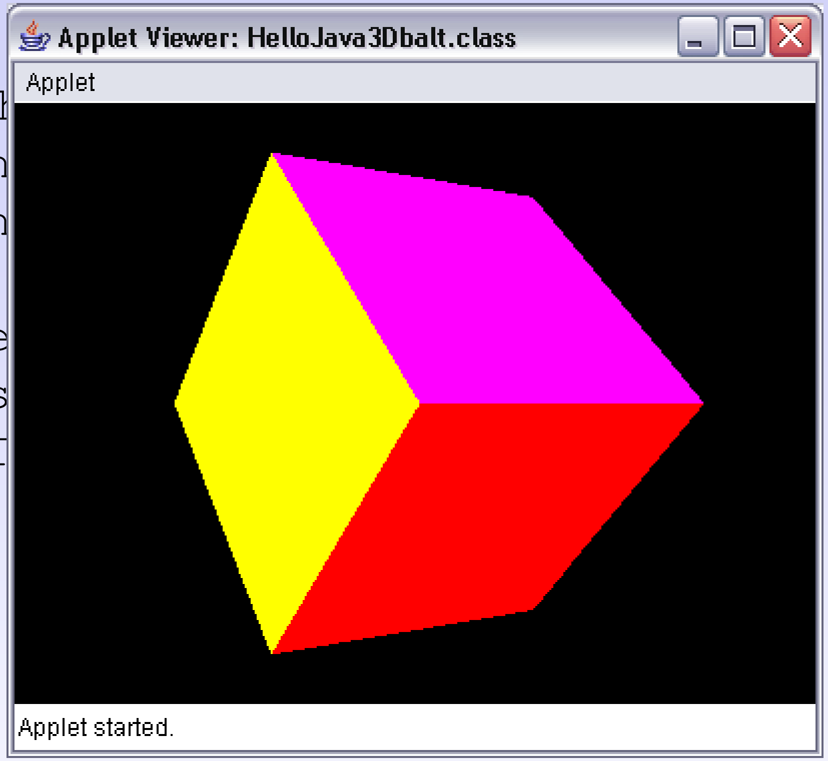
Java 3D Example: Modification 1 (2)





(Java 3D Tutorial Fig. 1-14)

Java 3D Example: Modification 1a




```
public BranchGroup createSceneGraph
    // Create the root of the bran
    BranchGroup objRoot = new Bran

    // rotate object has composite
    Transform3D rotate = new Trans
    Transform3D tempRotate = new T

    rotate.rotX(Math.PI/4.0d);
    tempRotate.rotY(Math.PI/5.0d);
    tempRotate.mul(rotate);

    TransformGroup objRotate = new TransformGroup(tempRotate);

    objRoot.addChild(objRotate);
    objRotate.addChild(new ColorCube(0.4));
    // Let Java 3D perform optimizations on this scene graph.
     objRoot.compile();

    return objRoot;
} // end of CreateSceneGraph method of HelloJava3Dbalt
```

Java 3D Example: Modification 2

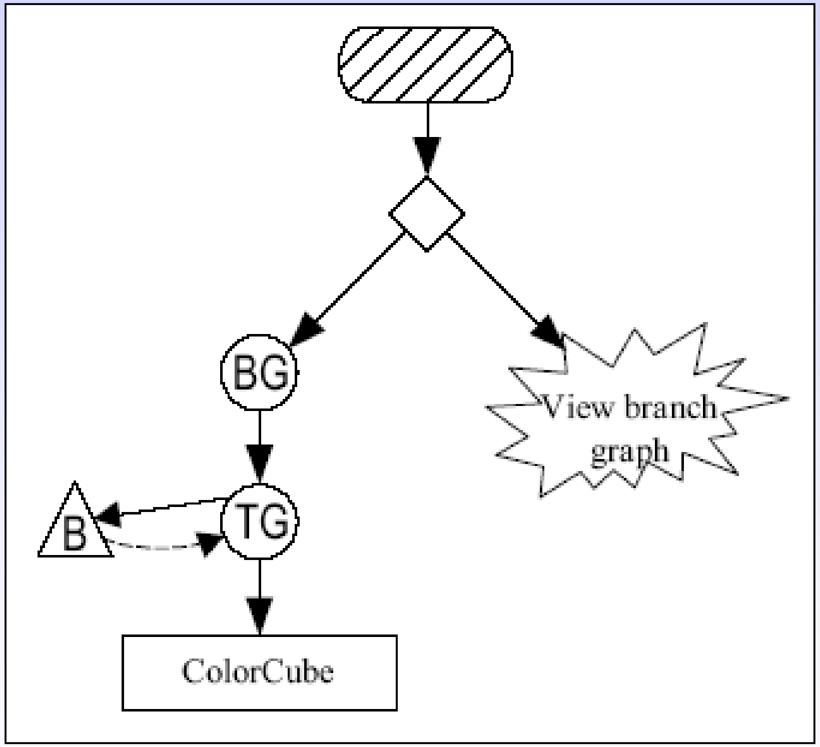
```
public BranchGroup createSceneGraph() {
  // Create the root of the branch graph
  BranchGroup objRoot = new BranchGroup();

  // Create the transform group node and initialize it to
  // the identity. Add it to the root of the subgraph.
  TransformGroup objSpin = new TransformGroup();
  objSpin.setCapability(TransformGroup.ALLOW_TRANSFORM_WRITE);
  objRoot.addChild(objSpin);

  // Create a simple shape leaf node, add it to
  // the scene graph.
  // ColorCube is a Convenience Utility class
  objSpin.addChild(new ColorCube(0.4));

    …
```

Java 3D Example: Modification 2 (2)

```
 // Create a new Behavior object that will perform the desired
 // operation on the specified transform object and add it into
 // the scene graph.
 Alpha rotationAlpha = new Alpha(-1, 4000);

 RotationInterpolator rotator =
           new RotationInterpolator(rotationAlpha, objSpin);

 // a bounding sphere specifies a region a behavior is active
 // create a sphere centered at the origin with radius of 100
 BoundingSphere bounds = new BoundingSphere();
 rotator.setSchedulingBounds(bounds);
 objSpin.addChild(rotator);

 return objRoot;
} // end of CreateSceneGraph method
```

Java 3D Example: Modification 2 (3)

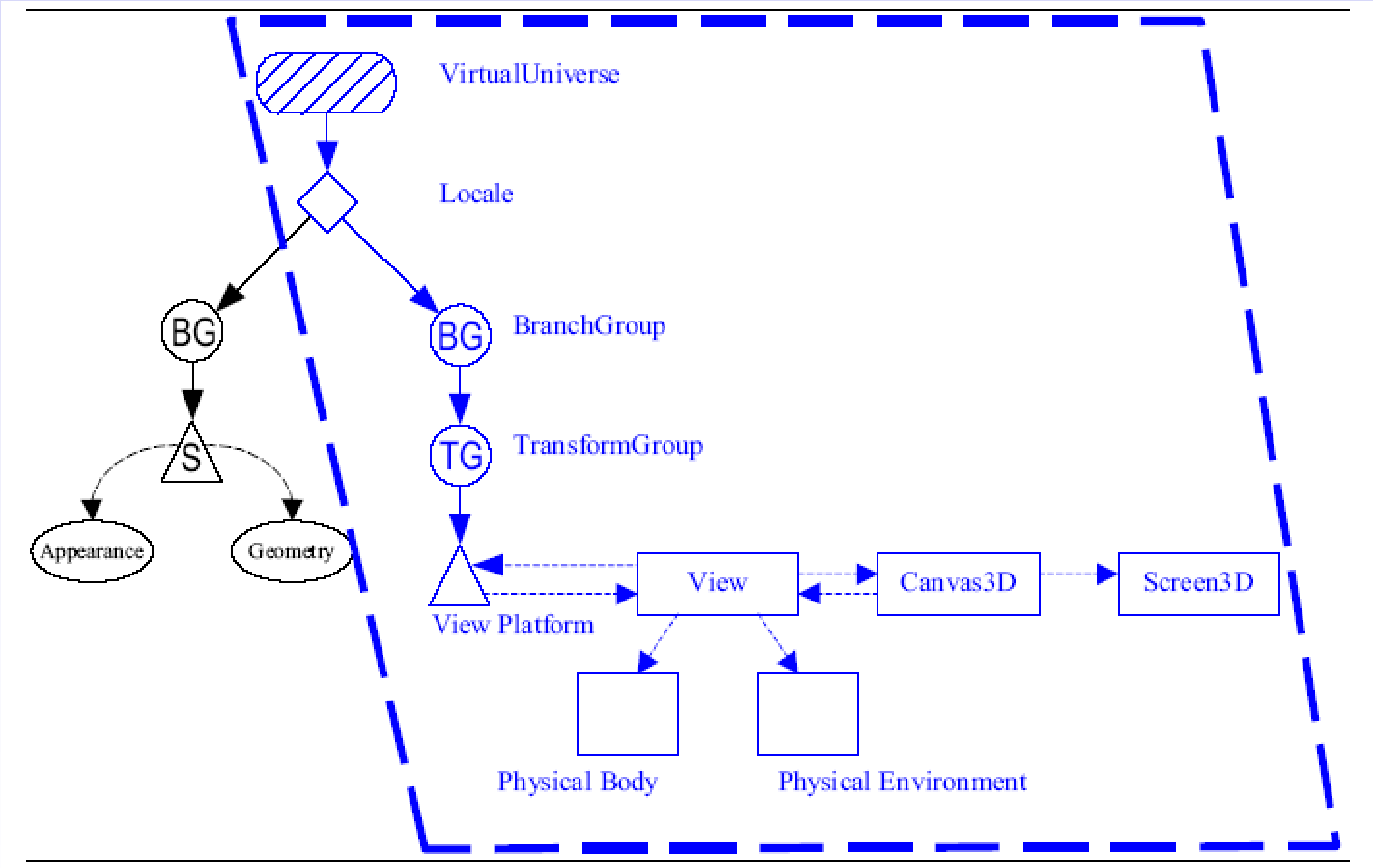
- **Capability** to change transform dynamically
    - `ALLOW_TRANSFORM_WRITE`
- Alpha object counts time
    - Loop continuously with period of 4 seconds
- Rotation interpolator **behaviour** linearly updates rotation for 360degs
- **Scheduling bounds** specify when behaviour is active



(Java 3D Tutorial Fig. 1-18)

The Simple Universe

- Utility class that provides a virtual 3D universe
- Canvas3D is the place everything is drawn to



(Java 3D Tutorial Fig. 1-7)

The Java 3D Rendering Loop

- The rendering loop is intrinsic to Java 3D
- Renderer starts running in an infinite loop when an instance of View becomes live in the virtual universe
  - E.g. on creation of a SimpleUniverse
- Renderer executes the following loop:

```
while(true) {
    Process input
    If (request to exit) break
        Perform Behaviors
        Traverse the scene graph
        and render visual objects
}
Cleanup and exit
```

Figure 1-10 Conceptual Renderer Process

The End