## Graphical Programming (1)

- programs to process and manipulate graphical objects and data
- early standards: PHIGS, GKS
- 2D, 3D graphics libraries
- level of abstraction
  - low-level API: OpenGL
  - scene graph API: Java3D

## Graphical Programming (2)

- X-Windows
  - X-protocol, Xlib, window manager
- OSF/Motif
  - widgets, gadgets, window manager
- MS-Windows
- RenderMan
- OpenGL
- Direct3D

## Graphical Programming (3)

- OpenInventor, VRML, X3D
  - scene graph oriented
  - engines, sensors, manipulators
- IRIS Performer
- Java3D

## OpenGL / Windows System

What is OpenGL?

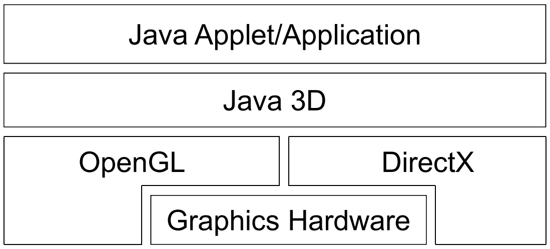
- OpenGL is a hardware-independent interface to the graphics hardware

OpenGL does not provide rendering context management functions or means to manage user input

→ Interface between OS and OpenGL needed:

- WGL / Microsoft Windows
- GLX / UNIX's X-Windows (direct and indirect rendering)
- GLUT / OS independent

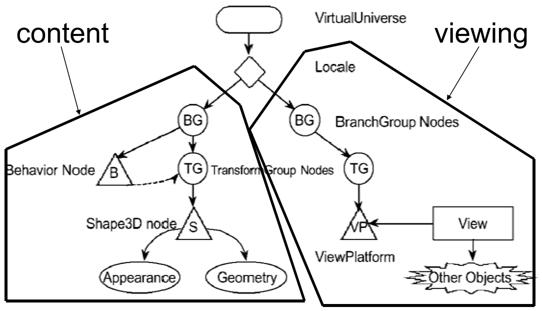
## Java3D



## Scenegraph

- Hierarchical structure
- Corresponds to logical structure of the scene
- Easy design and manipulation of complex scenes

# J3D-Scenegraph



# The Renderer

- Double buffering, RGB(A)
- Infinite loop: Traverse Graph
- Take care of transparency
- Regions of influence of fog, lights, sound
- Optimized for rendering (display list)

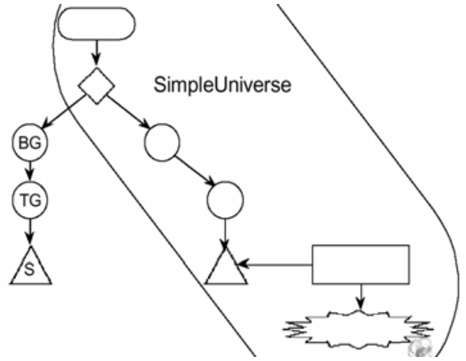
# Node States - Capabilities

- Node created: all operations legal
- *Live*: Node inserted into scene
  - *capabilities* specify permitted operations (r / w / modify)
    `setCapability(ALLOW_TRANSFORM_WRITE);`
- *Compiled* (optional):
  Optimized by renderer
  - modifications restricted
- Capabilities fixed if live or compiled

# Java3D Node Types

- Group nodes
  - `addChild(...)`
  - ◆ BranchGroup
    - only detachable/relocable node
    - grouping of Shapes
  - ◆ TransformGroup
    - transform applied to all children

# Hello3D! / Scenegraph



# Hello3D! / Constructor

```
...
Canvas3D c=new Canvas3D(null);
aWindow.add(c);
BranchGroup content=createSceneGraph();
SimpleUniverse u=new SimpleUniverse(c);
u.addBranchGraph(content);//now “live”
...
```

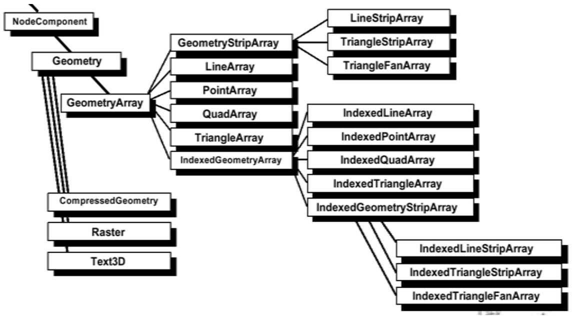
## Hello3D! Content

```
Public BranchGroup createSceneGraph(){
  BranchGroup objRoot=new BranchGroup();
  Transform3D spin=new Transform3D();
  Transform3D tmpspin=new Transform3D();
  spin.rotX(Math.PI/4.0d);
  tmpspin.rotY(Math.PI/5.0d);
  spin.mul(tmpspin);
  TransformGroup objTrans=new
               TransformGroup(spin);
  objRoot.addChild(objTrans);
  objTrans.addChild(new ColorCube());
  return objRoot();}
```

## Java3D Node Types

- Shape3D
  - defines object within the scene
  Contains:
  - ◆ Geometry
    - polygon related information
  - ◆ Attributes
    - material definition
    - rendering mode (wireframe, …)

## Geometry Nodes



## Geometry Nodes

Geometry definition:

- coordinates
- optional: normals
- optional: RGB(A) color
- optional: texture coord. (u/v[/w])
- for indexed types: indices

## Helper Classes

- `com.sun.j3d.utils.*`
  - SimpleUniverse:
    fast viewing model setup
  - Mouse-> Transform mapping
    for interactions
  - Simple geometrical Objects
    (cube, …)

## Helper Classes

- `javax.vecmath.*`
  - Tuple/Point/Vector 2/3/4D d/float
    with corresponding operations
  - Matrix 3/4D d/float
  - Quaternion classes
- `javax.media.j3d.Transform3D`
  - 4D matrix + helper func. for CG:
    orth/persp. Projection,
    scale, rotate, translate, …

## Appearance

Defines attributes for rendering geometry of an object
- polygon attributes: pts/wirefr./fill
- culling
- rendering attrib.: z-buff., $\alpha$-blend.
- transp./color (if not per vertex)
- material (reflection coefficients)
- texture images

## Lighting

Light source nodes require Bounds delimiting the area of influence

- ■ Ambient
- ■ Directional (infinitely distant)
- ■ PointLight (spot light)

## Behaviors

“Events” for the scenegraph

- ■ Action executed if criteria met:
  - time triggered, kbd & mouse events, picking of objects, collision, frames elapsed
- ■ Boolean combination of criteria
- ■ Bounded area of relevance
- ■ `processStimulus()`

## Behaviors

- ■ Influence transform. / geometry
- ■ Examples:
  - Mouse controlled navigation
  - Interpolator: time->value
  - ProximitySensor
  - Collision reaction
  - Picking: Click -> list of Shape3Ds below mouse

## Viewing Model

- ■ Supports multiple Canvas3D -> stereo rendering, (Cave!)
- ■ Support for tracking.
- ■ Detailed description of viewer’s eyes/ears configuration

## Java3D - Further Material

Java 3D API specification documentation & tutorial:

`https://java3d.dev.java.net/`