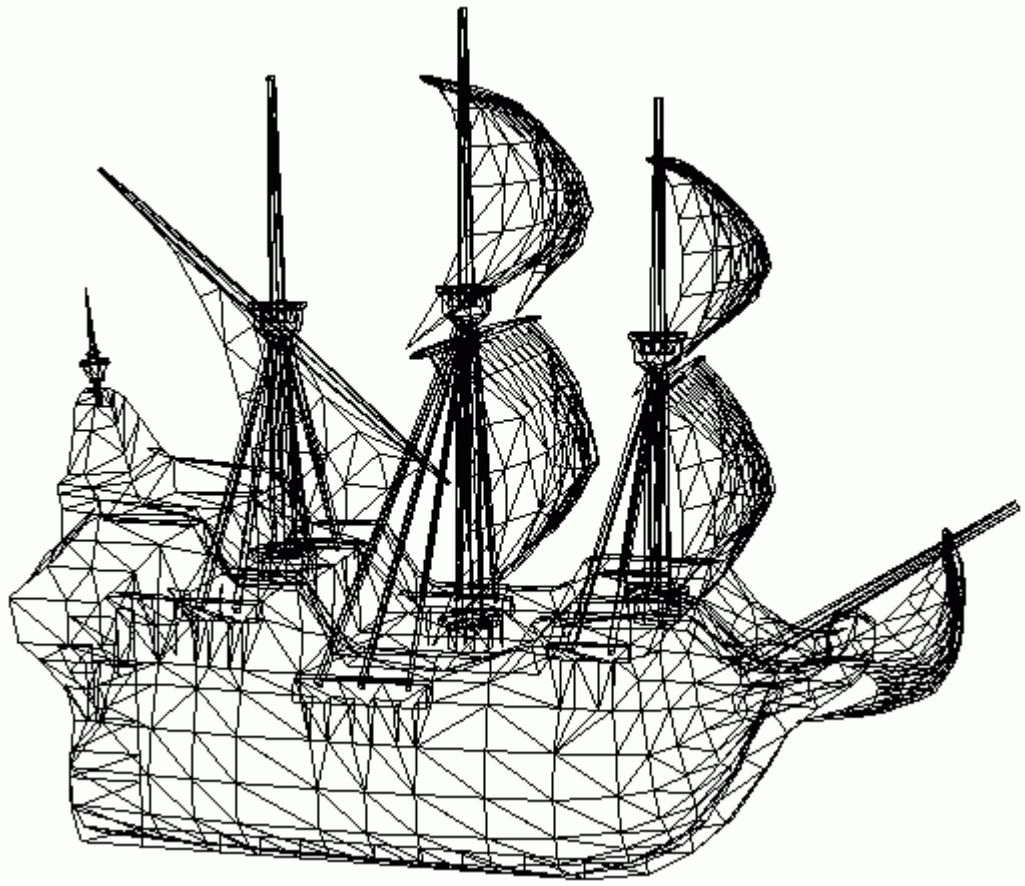
# Getting Started with the Java 3D™ API

## Chapter 3
## Easier Content Creation



Dennis J Bouvier

tutorial v1.6 (Java 3D API v1.2.1)

© 1999-2001 Sun Microsystems, Inc.
2550 Garcia Avenue, Mountain View, California 94043-1100 U.S.A
All Rights Reserved.

The information contained in this document is subject to change without notice.

SUN MICROSYSTEMS PROVIDES THIS MATERIAL "AS IS" AND MAKES NO WARRANTY OF ANY KIND, EXPRESSED OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE. SUN MICROSYSTEMS SHALL NOT BE LIABLE FOR ERRORS CONTAINED HEREIN OR FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES (INCLUDING LOST PROFITS IN CONNECTION WITH THE FURNISHING, PERFORMANCE OR USE OF THIS MATERIAL, WHETHER BASED ON WARRANTY, CONTRACT, OR OTHER LEGAL THEORY).

THIS DOCUMENT COULD INCLUDE TECHNICAL INACCURACIES OR TYPOGRAPHICAL ERRORS. CHANGES ARE PERIODICALLY MADE TO THE INFORMATION HEREIN; THESE CHANGES WILL BE INCORPORATED IN NEW EDITIONS OF THE PUBLICATION. SUN MICROSYSTEMS, INC. MAY MAKE IMPROVEMENTS AND/OR CHANGES IN THE PRODUCT(S) AND/OR PROGRAM(S) DESCRIBED IN THIS PUBLICATION AT ANY TIME.

Some states do not allow the exclusion of implied warranties or the limitations or exclusion of liability for incidental or consequential damages, so the above limitations and exclusion may not apply to you. This warranty gives you specific legal rights, and you also may have other rights which vary from state to state.

Permission to use, copy, modify, and distribute this documentation for NON-COMMERCIAL purposes and without fee is hereby granted provided that this copyright notice appears in all copies.

Java, JavaScript, Java 3D, HotJava, Sun, Sun Microsystems, and the Sun logo are trademarks or registered trademarks of Sun Microsystems, Inc. All other product names mentioned herein are the trademarks of their respective owners.

# Table of Contents

# List of Figures



# List of Tables



# List of Code Fragments

# List of Reference Blocks

# Preface to Chapter 3

This document is one part of a tutorial on using the Java 3D API. You should be familiar with Java 3D API basics to fully appreciate the material presented in this Chapter. Additional chapters and the full preface to this material are presented in the Module 0 document available at:
`http://java.sun.com/products/javamedia/3d/collateral`

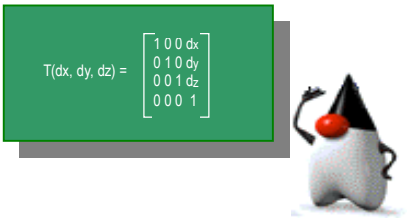
**New for Java 3D API version 1.2**

This chapter of the tutorial has been updated to include new features in Java 3D API release version 1.2. You may notice the tag **`<new in 1.2>`** to the right of some section headings and in some reference blocks in this chapter. This tag indicates the that tutorial topic is new in the API release version 1.2. Note that since chapters are updated and released individually not all of the tutorial chapters may reflect the latest version of the Java 3D API.

# Cover Image

The cover image is of a galleon as modeled in an `obj` file and rendered by Java 3D. The Java 3D program that produced the rendering, `ObjLoadApp.java`, is a modification of the `ObjLoad.java` example program discussed in Section 3.3. The program source code for `ObjLoad.java` and the galleon model file are available with the JDK 1.2 distribution.

# CHAPTER 3
# Easier Content Creation




## Chapter Objectives

After reading this chapter, you'll be able to:

- Use GeometryInfo to specify geometry as arbitrary polygons
- Use loader classes to load geometry from files into Java 3D worlds
- Use Text2D to add text to Java 3D worlds
- Use Text3D to add geometric text to Java 3D worlds
- Specify colors, images, or geometry for background
- Use the UserData field of SceneGraphObject class for a variety of applications

As the third chapter of the "Getting Started" Module, Chapter Three presents easier ways of creating visual content. Chapters one and two present the basic ways of creating virtual worlds, which includes creating visual objects from geometry classes. It only takes a little programming to learn that creating complex visual content one triangle at a time is tedious. Fortunately, there are a variety of easier ways to produce visual content. This chapter surveys a number of content creation methods and content issues beyond creating simple geometry.

## 3.1 What is in this Chapter

If you want to create a large or complex visual object, a great deal of code is required to just specify coordinates and normals. If you are concerned about performance, you spend more time, and code, to specify the geometry in as few triangle strips as possible. Geometry coding, fraught with details, can de a big sink on your development time. Fortunately, there are ways to create visual objects that require less code, resulting in fewer mistakes, and quiet often taking much less time.

Section 3.2 presents the GeometryInfo utility class, used to automate some details of hand coded geometry. GeometryInfo, along with the Triangulator, Stripifier, and NormalGeneration classes allows you to specify visual object geometry as arbitrary polygons. These classes convert the polygons to

triangles, make strips of the triangles, and compute normals for the triangles at runtime, potentially saving you much coding time.

Section 3.3 presents content loader classes, or "Loaders" as they are commonly referred to. Loaders, one alternative to hand coded geometry, create Java 3D visual objects from files created with 3D modeling software. Loaders exist today for Alias `obj` files, `VRML` files, Lightwave files, Autocad `dfx` files, and a variety of other 3D file formats. New loaders are in development as well. The most important feature is the ability to write custom loaders for Java 3D, which is discussed in some detail in section 3.4.

The next three sections present specific content creation techniques. Sections 3.5 and 3.6 present the Text2D utility and Text3D classes, respectively. These two classes represent two easy ways to add textual contents to your virtual world. Section 3.7 presents the Background class. The Background class allows you to specify a color, image or geometry as the background for a virtual world.

The next section doesn't have as much to do with content. Section 3.8 discusses the use of the UserData field of SceneGraphObject class.

Of course, the Chapter concludes with a summary and Self-Test exercises for the adventurous.

## 3.2 GeometryInfo

If you don't have access to geometric model files, or geometric modeling software, you have to create your geometry by hand. As mentioned in the chapter introduction, hand coding geometry often requires much time and is an error prone activity. As you know, when you specify geometry through the core classes, you are limited to triangles and quads. Using the GeometryInfo utiltity class can ease the time and tedium of geometry creation. Instead of specifying each triangle, you can specify arbitrary polygons, which can be concave, non-planer polygons - even with holes[1]. The GeometryInfo object, and other utility classes, convert the geometry into a triangular geometry that Java 3D can render.

For example, if you wanted to create a car in Java 3D, instead of specifying triangles, you can specify the profile of the car as a polygon in a GeometryInfo object. Then, using a Triangulator object, the polygon can be subdivided into triangles. The left image of Figure 3-1 shows a profile of a car as polygon. The right image is the polygon subdivided into triangles[2].

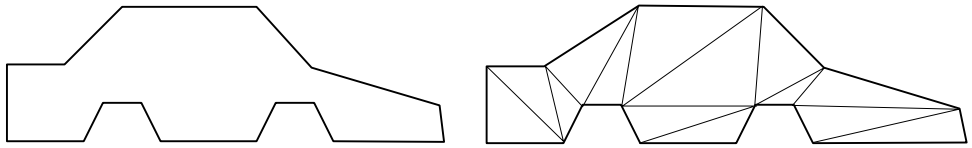


**Figure 3-1 A GeometryInfo Polygon and One Possible Triangulation**

[1] While you can specify non-planar polygons in GeometryInfo, and a Triangulator object will create a surface from it; non-planar contours do not specify a unique surface. In other words, if you specify a non-planar contour, you may not get the surface you want from Triangulator.

[2] Note that the figure does not necessarily represent the quality of the triangulation produced by the Triangulator class.

If you are interested in performance, and who isn't, use a Stripifier object to convert the triangles to triangle strips. If you want to *shade* the visual object, use the NormalGenerator to calculate surface normal vectors for the geometry[3].

An example program, `GeomInfoApp.java`, using the GeometryInfo, Triangulator, Stripifier, and NormalGeneration classes to create a car is included in the `examples/easyContent` directory. Figure 3-2 shows two renderings produced by `GeomInfoApp.java`. In both renderings the blue outlines shows the contours specified in the GeometryInfo object. The red triangles (filled and shaded on the left, outline on the right) were computed by the GeometryInfo object with Triangulation, NormalGeneration, and Stripification done automatically.

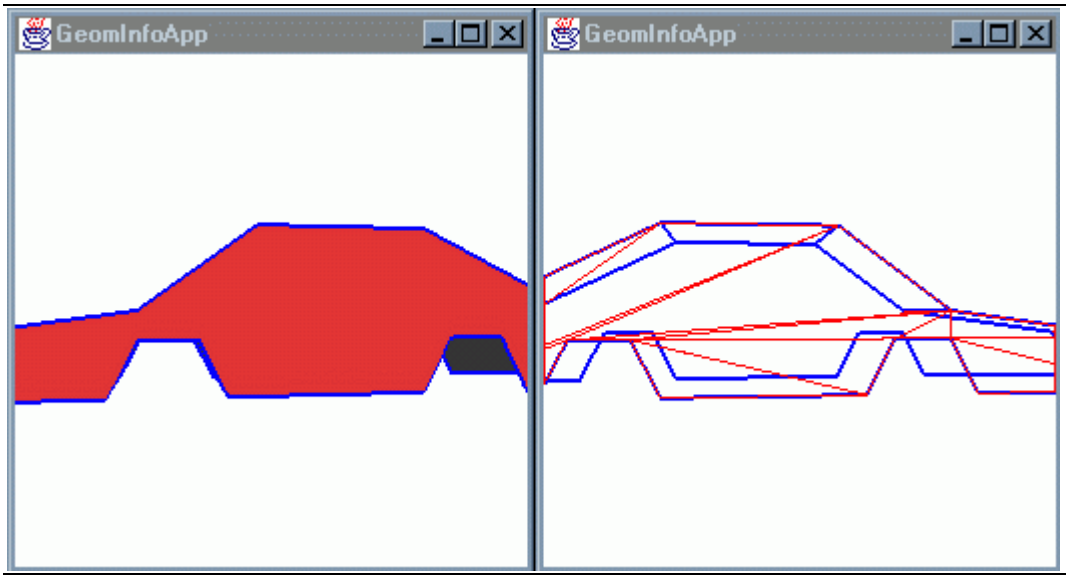



**Figure 3-2 Two Renderings of a Car (facing opposite directions) Created Using GeometryInfo**

A single planar polygon, similar to the one in shown in Figure 3-1, specifies the profile of the car (each side) in the GeomInfoApp example. Quadrilaterals specify the hood, roof, trunk lid, and other surfaces of the car.

### 3.2.1 Simple GeometryInfo Example

Using a GeometryInfo object is as easy as using core GeomertryArray classes, if not easier. In creating a GeomertyInfo object, simply specify the type of geometry you are going to need. The choices are `POLYGON_ARRAY`, `QUAD_ARRAY`, `TRIANGLE_ARRAY`, `TRIANGLE_FAN_ARRAY`, and `TRIANGLE_STRIP_ARRAY`. Then set the coordinates and strip counts for the geometry. You don't have to tell the GeometryInfo object how many coordinates are in the data; it will be automatically calculated.

Code Fragment 3-1 shows an example GeometryInfo application. Lines 1 through 3 of Code Fragment 3-1 show creating a GeometryInfo object and the initial geometry specification.

[3] If you are unfamiliar with the term *shade* as used in the context of computer graphics, check the glossary and read the introductory sections of Chapter 6.

After having created the GeometryInfo object, the other classes may be used. If you want to use the NormalGenerator, for example, first create a NormalGenerator object, then pass the GeometryInfo object to it. Lines 8 and 9 of Code Fragment 3-1 do just that.

```
1.      GeometryInfo gi = new GeometryInfo(GeometryInfo.POLYGON_ARRAY);
2.      gi.setCoordinates(coordinateData);
3.      gi.setStripCounts(stripCounts);
4.
5.      Triangulator tr = new Triangulator();
6.      tr.triangulate(gi);
7.
8.      NormalGenerator ng = new NormalGenerator();
9.      ng.generateNormals(gi);
10.
11.     Stripifier st = new Stripifier();
12.     st.stripify(gi);
13.
14.     Shape3D part = new Shape3D();
15.     part.setAppearance(appearance);
16.     part.setGeometry(gi.getGeometryArray());
```

**Code Fragment 3-1 Using GeometryInfo, Triangulator, NormalGenerator, and Stripifier Utilities.**

### 3.2.2 Using GeometryInfo

There are right ways, and more importantly, wrong ways to use GeometryInfo and related utility classes. For example, you should not use the Stripifier before the NormalGenerator. If using both a Stripifier and NormalGenerator, always use the NormalGenerator first. Using the proper order of operations avoids many extra calculations and yields better results.

The NormalGenerator and Stripifier only work on indexed triangles. No matter what format (e.g., POLYGON_ARRAY, QUAD_ARRAY, …) of data sent to the GeometryInfo object it is automatically converted to indexed triangles internally when using either of these utilities. When the work of the utility is done, the triangles are stitched back together. As a result, some geometry may change. That is, if your application provided TRIANGLE_STRIP_ARRAY data, then used the NormalGenerator, the result might be different strips. However, if the original data were POLYGON_ARRAY, the resulting geometry is always triangular. Also note, you don't have to explicitly call the triangulator before using the NormalGenerator or Stripifier.

### 3.2.3 Classes for GeometryInfo

The GeometryInfo and related classes are members of the `com.sun.j3d.util.geometry` package and are subclasses of Object. Figure 3-3 shows the hierarchy for these classes.

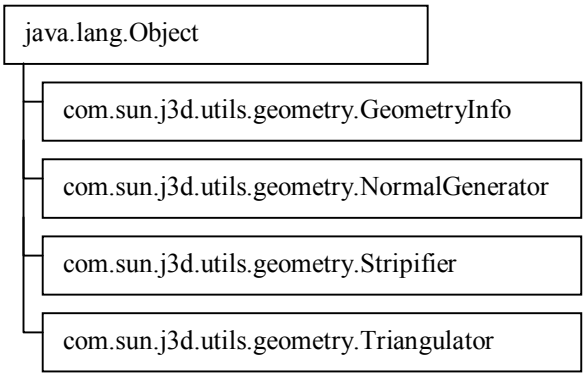



**Figure 3-3 Class Hierarchy for the GeometryInfo Utility Class, and Related Classes**

The GeometryInfo class has only one constructor and in this constructor you specify the kind of geometry to be specified by the coordinate data. The following reference block gives more detail.

**GeometryInfo Constructor Summary**

Package: `com.sun.j3d.utils.geometry`
Extends: `java.lang.Object`

The GeometryInfo object is where you put your geometry if you want to use the Java 3D utility libraries. Once you have your data in the GeometryInfo object, you can send it to any (or all) of several utilities to have operations performed on it, such as generating normals or turning it into long strips for more efficient rendering ("stripifying"). Geometry is loaded just as it is in the Java 3D GeometryArray object, but there are fewer options for getting data into the object. GeometryInfo itself contains some simple utilities, such as calculating indices for non-indexed data ("indexifying") and getting rid of unused data in your indexed geometry information ("compacting").

**`GeometryInfo(int primitive)`**
Construct a GeometryInfo object, where primitive is one of

| | |
|---|---|
| `POLYGON_ARRAY` | possibly multi-contour, possibly non-planar polygons |
| `QUAD_ARRAY` | each set of four vertices forms an independent quad |
| `TRIANGLE_ARRAY` | each set of three vertices form an independent triangle |
| `TRIANGLE_FAN_ARRAY` | the stripCounts array indicates how many vertices to use for each triangle fan. |
| `TRIANGLE_STRIP_ARRAY` | that the stripCounts array indicates how many vertices to use for each triangle strip. |

The GeometryInfo class has many methods. Most methods are for setting (or getting) coordinate, color, index, normal, or texture coordinate data. Most applications will only use a few of available methods. However, it is convienient to be able to specify geometry to any level of detail and have the rest computed.

**GeometryInfo Method Summary (partial list)**

**`void recomputeIndices()`**
Redo indexes to guarantee connection information. Only intended to be used on incorrectly indexed coordinates.

**`void reverse()`**
Reverse the order of all lists.

**`void setColorIndices(int[] colorIndices)`**
Sets the array of indices into the Color array.

**`void setColors(Color3f[] colors)`**
Sets the colors array.

**`void setColors(Color4f[] colors)`**
Sets the colors array. There are other setColors methods.

**`void setContourCounts(int[] contourCounts)`**
Sets the list of contour counts.

**`void setCoordinateIndices(int[] coordinateIndices)`**
Sets the array of indices into the Coordinate array.

**`void setCoordinates(Point3f[] coordinates)`**
Sets the coordinates array.

**`void setCoordinates(Point3d[] coordinates)`**
Sets the coordinates array. There are other setCoordinates methods.

**`void setNormalIndices(int[] normalIndices)`**
Sets the array of indices into the Normal array.

**`void setNormals(Vector3f[] normals)`**
Sets the normals array.

**`void setNormals(float[] normals)`**
Sets the normals array.

**`void setStripCounts(int[] stripCounts)`**
Sets the array of strip counts.

**`void setTextureCoordinateIndices(int[] texCoordIndices)`**
Sets the array of indices into the TextureCoordinate array.

**`void setTextureCoordinates(Point2f[] texCoords)`**
Sets the TextureCoordinates array. There are other setTextureCoordinates methods.

Each of the GeometryInfo 'helper' classes are used in a way similar to the GeometryInfo class. The following reference blocks show the constructors and methods for Triangulator, Stripifier, and NormalGenerator, in that order. This is the order in which they would be used for a POLYGON_ARRAY.

The Triangulator utility is only used with POLYGON_ARRAY geometry. GeometryInfo objects with other primitive geometry would only use Stripifier and NormalGenerator, as appropriate.

The default constructor of the Triangulator class simply creates a Triangulation object. See the reference block for more information.

**Triangulator Constructor Summary**

Package: `com.sun.j3d.utils.geometry`
Extends: `java.lang.Object`

Triangulator is a utility for turning arbitrary polygons into triangles so they can be rendered by Java 3D. Polygons can be concave, nonplanar, and can contain holes (see GeometryInfo).

**`Triangulator()`**
Creates a new instance of the Triangulator.

The only method of the Triangulator class is to triangulate a polygon array GeometryInfo object.

**Triangulator Method Summary**

**`void triangulate(GeometryInfo gi)`**
This routine converts the GeometryInfo object from primitive type `POLYGON_ARRAY` to primitive type `TRIANGLE_ARRAY` using polygon decomposition techniques.

The only constructor of the Stripifier class creates a stripification object[4].

**Stripifier Constructor Summary**

Package: `com.sun.j3d.utils.geometry`
Extends: `java.lang.Object`

The Stripifier utility will change the primitive of the GeometryInfo object to Triangle Strips. The strips are made by analyzing the triangles in the original data and connecting them together.

For best results Normal Generation should be performed on the GeometryInfo object before Stripification.

**`Stripifier()`**
Creates the Stripifier object.

The only method of the Stripifier class is to stripify the geometry of a GeometryInfo class.

**Stripifier Method Summary**

**`void stripify(GeometryInfo gi)`**
Turn the geometry contained in the GeometryInfo object into an array of Triangle Strips.

The NormalGenerator class has two constructors. The first constructs a NormalGenerator with a default value for the crease angle. The second constructor allows the specification of a crease angle with the construction of the NormalGenerator object. See the reference block below.

[4] Each paragraph introduces a new word into the English language.

**NormalGenerator Constructor Summary**

Package: `com.sun.j3d.utils.geometry`
Extends: `java.lang.Object`

The NormalGenerator utility will calculate and fill in the normals of a GeometryInfo object. The calculated normals are estimated based on an analysis of the indexed coordinate information. If your data isn't indexed, index lists will be created.

If two (or more) triangles in the model share the same coordinate index then the normal generator will attempt to generate one normal for the vertex, resulting in a "smooth" looking surface. If two coordinates don't have the same index then they will have two separate normals, even if they have the same position. This will result in a "crease" in your object. If you suspect that your data isn't properly indexed, call GeometryInfo.recomputeIndexes().

Of course, sometimes your model has a crease in it. If two triangles' normals differ by more than creaseAngle, then the vertex will get two separate normals, creating a discontinuous crease in the model. This is perfect for the edge of a table or the corner of a cube, for instance.

**`NormalGenerator()`**
Construct a NormalGenerator with the default crease angle (0.76794 radians, or 44°).

**`NormalGenerator(double radians)`**
Construct a NormalGenerator with a specified crease angle in radians.

The methods for the NormalGenerator class include ones for setting and getting the crease angle, and computing normals for the geometry of a GeometryInfo object. See the NormalGenerator Constructor Summary reference block for a discussion of crease angle.

**NormalGenerator Method Summary**

**`void generateNormals(GeometryInfo geom)`**
Generate normals for the GeometryInfo object.

**`double getCreaseAngle()`**
Returns the current value of the crease angle, in radians.

**`void setCreaseAngle(double radians)`**
Set the crease angle in radians.

## 3.3 Loaders

A loader class reads 3D scene files (not Java 3D files) and creates Java 3D representations of the file's contents that can be selectively added to a Java 3D world and augmented by other Java 3D code. The utility `com.sun.j3d.loaders` package provides the means for loading content from files created in other applications into Java 3D applications. Loader classes implement the loader interface defined in the utility `com.sun.j3d.loaders` package.

Since there are a variety of file formats for the purpose of representing 3D scenes (e.g., `.obj`, `.vrml`, etc.) and there will always be more file formats, the actual code to load a file is not part of Java 3D or of the loaders package; only the interface for the loading mechanism is included. With the interface definition, the Java 3D user can develop file loader classes with the same interface as other loader classes.

Note that while loaders are often referred to as 'file loaders' the file to load may not have to be local; many loaders are capable of loading a remote file via a URL.

### 3.3.1 Simple Example of Using a Loader

Without a class that actually reads a file, it is not possible to load content from a file. With a loader class it is easy. Figure 3-4 presents the recipe for using a loader.

0. find a loader (if one is not available, write one: see section 3.4)
1. import the loader class for your file format (see Section 3.3.2 to find a loader)
2. import other necessary classes
3. declare a Scene variable (don't use the constructor)
4. create a loader object
5. load the file in a try block, assigning the result to the Scene variable
6. insert the Scene into the scene graph

**Figure 3-4 Recipe for Using a Loader**

A loader example based on the ObjectFile class is distributed with JDK 1.2. It is found in `jdk1.2/demo/java3d/ObjLoad`. Code Fragment 3-2 presents a excerpt from the code from this demo.

The ObjectFile class is distributed in the `com.sun.j3d.loaders` package as an example file loader. Other loaders are available (some are listed in Table 3-1).

**Class ObjectFile**

Package: `com.sun.j3d.loaders`
Implements: `Loader`

The ObjectFile class implements the Loader interface for the Wavefront .obj file format, a standard 3D object file format created for use with Wavefront's Advanced Visualizer ™. Object Files are text based files supporting both polygonal and free-form geometry (curves and surfaces). The Java 3D .obj file loader supports a subset of the file format, but it is complete enough to load almost all commonly available Object Files. Free-form geometry is not supported.

Code Fragment 3-2 is annotated with numbers corresponding to the loader usage recipe given in Figure 3-4.

```
17.   import com.sun.j3d.loaders.objectfile.ObjectFile;          ❶
18.   import com.sun.j3d.loaders.ParsingErrorException;         ❷
19.   import com.sun.j3d.loaders.IncorrectFormatException;      ❷
20.   import com.sun.j3d.loaders.Scene;                         ❷
21.   import java.applet.Applet;
22.   import javax.media.j3d.*;
23.   import javax.vecmath.*;
24.   import java.io.*;                                         ❷
25.
26.   public class ObjLoad extends Applet {
27.
28.       private String filename = null;
29.
30.       public BranchGroup createSceneGraph() {
31.         // Create the root of the branch graph
32.         BranchGroup objRoot = new BranchGroup();
33.
34.   ❸     ObjectFile f = new ObjectFile();
35.   ❹     Scene s = null;
```

```
36.    ❺      try {
37.             s = f.load(filename);
38.           }
39.           catch (FileNotFoundException e) {
40.             System.err.println(e);
41.             System.exit(1);
42.           }
43.           catch (ParsingErrorException e) {
44.             System.err.println(e);
45.             System.exit(1);
46.           }
47.           catch (IncorrectFormatException e) {
48.             System.err.println(e);
49.             System.exit(1);
50.           }
51.
52.    ❻      objRoot.addChild(s.getSceneGroup());
53.         }
```

**Code Fragment 3-2 An Excerpt from `jdk1.2/demo/java3d/ObjLoad/ObjLoad.java`.**

This program goes on to add behaviors (the default spin, or the mouse interaction - covered in Chapter 4) and lights (Chapter 6) to provide a shaded rendering of the object model. Of course, you can do many other things with the model in a Java 3D program such as add animations, add other geometry, change the color of the model, and so on.

A Lightwave loader example is available with the JDK 1.2 distribution and is found at `jdk1.2/demos/java3d/lightwave/Viewer.java`. This loader will load the lights specified in a Lightwave `lws` file.

### 3.3.2 Publicly Available Loaders

A variety of loader classes exist for Java 3D. Table 3-1 lists file formats for which loaders are publicly available. At the time of this writing, at least one loader class is available for each of the file formats listed in Table 3-1.

**Table 3-1 Publicly Available Java 3D Loaders**

| File Format | Description |
|---|---|
| 3DS | 3D-Studio |
| COB | Caligari trueSpace |
| DEM | Digital Elevation Map |
| DXF | AutoCAD Drawing Interchange File |
| IOB | Imagine |
| LWS | Lightwave Scene Format |
| NFF | WorldToolKit NFF format |
| OBJ | Wavefront |
| PDB | Protein Data Bank |
| PLAY | PLAY |
| SLD | Solid Works (prt and asm files) |
| VRT | Superscape VRT |
| VTK | Visual Toolkit |
| WRL | Virtual Reality Modeling Language |

For a current list of loader classes, check the web. For that matter, loader classes can be downloaded from the web. Loaders can be found by following links from the Java 3D home page, or check the references section of this tutorial for a web address.

### 3.3.3 Loader Package Interfaces and Base Classes

The number and variety of loaders exist because the Java 3D designers made it easy to write a loader[5]. Loader classes are implementations of the Loader Interface which lowers the level of difficulty in writing a loader. More importantly, the interfaces make the various loader classes consistent in their interface.

As in the example, a program loading a 3D file actually uses both a loader and a scene object. The loader reads, parses, and creates the Java 3D representation of the file's contents. The scene object stores the scene graph created by the loader. It is possible to load scenes from more than one file (of the same format) using the same loader object creating multiple scene objects. Files of different formats can be combined in one Java 3D program using the appropriate loader classes.

The following reference block lists the interfaces in the `com.sun.j3d.loaders` package. A loader implements the loader interface and uses a class that implements the scene interface.

| com.sun.j3d.loaders Interface Summary | |
|---|---|
| **Loader** | The Loader interface is used to specify the location and elements of a file format to load. |
| **Scene** | The Scene interface is a set of methods used to extract Java 3D scene graph information from a file loader utility. |

In addition to the interfaces, the `com.sun.j3d.loaders` package provides base implementations of the interfaces.

| com.sun.j3d.loaders Class Summary | |
|---|---|
| **LoaderBase** | This class implements the Loader interface and adds constructors. This class is extended by the authors of specific loader classes. |
| **SceneBase** | This class implements the Scene interface and extends it to incorporate methods used by loaders. This class is also used by programs that use loader classes. |

The methods defined in the this interface are used by programmers using loader classes.

[5] Having the loader interface and base class actually makes it easy to write a loader for a simple file format. It also makes it possible to write a loader for a complex file format.

**Interface Loader Method Summary**

Package: `com.sun.j3d.loaders`

The Loader interface is used to specify the location and elements of a file format to load. The interface is used to give loaders of various file formats a common public interface. Ideally the Scene interface will be implemented to give the user a consistent interface to extract the data.

**`Scene load(java.io.Reader reader)`**
This method loads the Reader and returns the Scene object containing the scene.

**`Scene load(java.lang.String fileName)`**
This method loads the named file and returns the Scene object containing the scene.

**`Scene load(java.net.URL url)`**
This method loads the named file and returns the Scene object containing the scene.

**`void setBasePath(java.lang.String pathName)`**
This method sets the base path name for data files associated with the file passed into the load(String) method.

**`void setBaseUrl(java.net.URL url)`**
This method sets the base URL name for data files associated with the file passed into the load(URL) method.

**`void setFlags(int flags)`**
This method sets the load flags for the file.

| | |
|---|---|
| **LOAD_ALL** | This flag enables the loading of all objects into the scene. |
| **LOAD_BACKGROUND_NODES** | This flag enables the loading of background objects into the scene. |
| **LOAD_BEHAVIOR_NODES** | This flag enables the loading of behaviors into the scene. |
| **LOAD_FOG_NODES** | This flag enables the loading of fog objects into the scene. |
| **LOAD_LIGHT_NODES** | This flag enables the loading of light objects into the scene. |
| **LOAD_SOUND_NODES** | This flag enables the loading of sound objects into the scene. |
| **LOAD_VIEW_GROUPS** | This flag enables the loading of view (camera) objects into the scene. |

LoaderBase class provides an implementation for each of the three `load()` methods of Interface Loader. LoaderBase also implements two constructors. Note the three loader methods return a Scene object.

**LoaderBase Constructor Summary**

Package: `com.sun.j3d.loaders`
Implements: `Loader`

This class implements the Loader interface. The author of a file loader would extend this class. The user of a file loader would use these methods.

**`LoaderBase()`**
Constructs a Loader with default values for all variables.

**`LoaderBase(int flags)`**
Constructs a Loader with the specified flags word.

In addition to the constructors listed in the reference block above, the methods listed in the following reference block are used by programmers using any loader class.

In writing a loader, the author of the new loader class can extend the LoaderBase class defined in the `com.sun.j3d.loaders` package. The new loader class then uses the SceneBase class of the same package.

There should be little need for future loaders to subclass SceneBase, or to implement Scene directly, as the functionality of a SceneBase is fairly straightforward. SceneBase class is responsible for both the storage and retrieval of data created by a loader while reading a file. The storage methods (used only by Loader authors) are all of the `add*` routines. The retrieval methods (used primarily by Loader users) are all of the `get*` routines.

In extending the loader base class, most of the work will be writing methods that recognize the various types of content that can be represented in the file format. Each of these methods then create the corresponding Java 3D scene graph component and store it in the scene object. The SceneBase constructor is listed in the following reference block. Other relevant reference blocks appear in the previous section.

**SceneBase Constructor Summary**

Package: `com.sun.j3d.loaders`

Implements: `Scene`

This class implements the Scene interface and extends it to incorporate utilities that could be used by loaders. This class is responsible for both the storage and retrieval of data from the Scene

**`SceneBase()`**
Create a SceneBase object - there should be no reason to use this constructor except in the implementation of a new loader class.

**SceneBase Method Summary (partial list: loader users' methods)**

In a departure from the normal formatting of a reference block, this reference block simply lists the methods.

```
Background[] getBackgroundNodes()
Behavior[] getBehaviorNodes()
java.lang.String getDescription()
Fog[] getFogNodes()
float[] getHorizontalFOVs()
Light[] getLightNodes()
java.util.Hashtable getNamedObjects()
BranchGroup getSceneGroup()
Sound[] getSoundNodes()
TransformGroup[] getViewGroups()
```

As mentioned above, one of the most important features of loaders is that you can write your own - which means that all other Java 3D users can too!

## 3.4 Writing a Loader

Writing a loader is a complex task that not all Java 3D applications developers will undertake. Even if you have no plan to write a loader you may find this section (in particular section 3.4.1) informative in a variety of ways:

- when using a loader
- understanding the use of GeometryInfo
- understanding of the ObjectLoader implementation

However, if these reasons don't invite your attention and you have no intention of writing a loader now, you can skip to the next section.

For those interested in creating a file loader, the rest of this section continues with an overview of some of the complexities of writing a file loader, followed by the construction of a simple file loader, concluding with the analysis of the structure of the OBJLoader of the Java 3D Utilities.

### 3.4.1 What Loaders do

Before undertaking the complex task of writing a loader, it may benefit the programmer to think about the some of the things a loader can do. Obviously, the fundamental task of a loader is to read a geometry file and produce a scene graph that represents the contents of the file. However, there are other possible features of a loader. For example, a loader could:

- can calculate surface normals for polygonal data,
- translate geometry be centered at the origin,
- scale it to fit in the range –1 to 1 along each axis,
- smooth geometry,
- make geometry more efficient by stripifying (see section 3.2.2) the data, or
- construct multiple representations of geometry for use with a LOD (see the glossary and/or chapter 5) behavior.

Some of these features are implemented in the available loaders. Some of these features are accomplished using the GeometryInfo class and related Java 3D Utility classes (section 3.2).

Of course, a loader doesn't have to implement all these features; a loader could simply create the geometry as represented in a file. This is what the first example loader presented in this section will do. Later there is a discussion of getting a loader to do some of the features on this list.

### 3.4.2 Basic Loader Construction

Writing a loader is an involved process that begins with detailed knowledge of the file format the new loader is for. Loader writing also involves using the use of Java streams, which is beyond the scope of this tutorial.

There are several ways to approach writing a file loader. The appropriate way depends on the intended use of the loader. For maximum flexibility consider using the SceneBase and LoaderBase classes described in the previous section. A loader built on these classes allow the user to choose which portions of a file to use in an application. This is the standard method for developing a file loader. The alternative involves creating application specific loaders without the SceneBase and LoaderBase classes.

Another variable in creating a file loader is the sort of information contained in the file to be loaded. Some file formats are very simple; others are much more complex. The simplest files are stand-alone and contain only geometry. More complex file formats could reference other files and/or contain a scene graph description. Correspondingly, a file loader class could involve a few hundred to a few thousand lines of code.

The complexity of creating a file loader is eased through the use of software 'layers'. The number of layers may vary based on the complexity of the file format. Table 3-2 shows one possible set of layers. Other organizations are possible and reasonable.

**Table 3-2 A Possible Set of Software Layers in a File Loader.**

| Layer / Level | Function |
|---|---|
| tokenizer | Convert characters into tokens (information items) |
| object | Convert visual/aural tokens of the file into scene graph objects (e.g., geometry, lights, textures, …) |
| scene | Convert lists scene graph objects into a scene graph(s) |
| file | deal with issues of opening files and URLs |

## Tokenizer

The lowest layer of a the tokenizer. This layer reads the file and tokenizes the file content. A **token** is the smallest unit of information in the file. Examples of a token include a number, a word, or a single character. Tokens compose the larger information items. For example, the location of a geometry vertex could be composed of three (i.e., x, y, z) number tokens.

## Object

The object layer creates graphical objects from tokens of the file. Some 'objects' could be vertices, normals, polygons, lights, textures, or any scene object represented in the Java 3D API. These objects are the components of a scene.

## Scene

The collection of graphical objects composes a scene or scenes. Usually, this layer of software is simple. The exception is a loader for a file format that represents a scene graph. Two such file formats are the Open Inventor and the OOGL List format.

## File

This layer of the software handles the issues of resource naming (i.e., URL or filename) and other details necessary for loading a scene. This layer has little to do with the geometric or aural information of a file.

### 3.4.3 Creating a very simple File Loader

The first task is to select a file format to write a loader for. Usually this selection is done by virtue of some outside influence (e.g., there is some existing file you want to read). The second task is to gather information. A formally written file format specification and some example files are both necessary.

For this tutorial a well documented 3D file format for which no loader was known to exist is selected. In fact, the selection is not of one file format but of a family of file formats – those belonging to the OOGL family of file formats.

The OOGL file formats refer to the "Object Oriented Graphics Library". This library is used for more than just file formats; the library is used by Geomview, an interactive 3D graphics object viewer application. More information on Geomview is found at `www.geomview.org`. The OOGL family of file formats are also referred to as the 'Geom File Formats', or 'Geom View File Formats'.

## About the QUAD File Format

Again, the first step in writing a file loader is knowing about the file format. This task is much easier when the file format has been documented in a public place. If you don't have the definition, a web search may yield some useful information. The alternative is to decode the format from a collection of examples. The process of decoding the format is typically fraught with much trial and error, and not explained here.

Availability of documentation was one of the criteria used in selecting the QUAD file format for this tutorial. The format is well documented in section four of the Geomview documentation, also found online. Section four presents the following information about all OOGL file formats:

> Most OOGL object file formats are free-format ASCII – any amount of white space (blanks, tabs, newlines) may appear between tokens (numbers, key words, etc.). Line breaks are almost always insignificant, with a couple of exceptions as noted. Comments begin with # and continue to the end of the line; they're allowed anywhere a newline is.

Among the OOGL collection of file formats is the QUAD file format. This format defines a collection of quadrilaterals. Reading from the "OOGL Geom File Formats Tutorial" one finds additional information on the QUAD file format:

> The header "QUAD" identifies the file type. A QUAD file is a list of 4*n vertices where n is the number of quadrilaterals. The vertices in this file are simple: just the x, y, and z coordinates of the point.

For example, Figure 3-5 shows the content of a QUAD file of a single quadrilateral. Specifically, the quadrilateral is a single square in the xy plane at z=0.

```
QUAD
-1 -1 0
 1 -1 0
 1  1 0
-1  1 0
```

**Figure 3-5 "square.quad" a very simple QUAD file.**

The QUAD file format can be more complex than the example of Figure 3-5, but the goal of this section is to develop a simple file loader and for this a simple file format is needed. For more information on the QUAD file format, refer to sections 4.2.1 and 4.1.3 of the Geomview documentation.

Now that the file format is well understood, the implementation of a loader is possible. Table 3-3 shows the classes and relationship among classes in the implementation of a simple quad file loader. This table represents only one possible implementation plan.

Table 3-3 includes a layer not discussed earlier: the application layer. This layer is the software that you would write utilizing the loader. Each of the class names in bold correspond to the filenames found in the `examples/loader` directory of the examples jar.

**Table 3-3 Classes in the Implementation of the SimpleQuadFileLoader**

| Layer / Level | Implementation |
|---|---|
| tokenizer | **QuadFileParser** |
| object | **SimpleQuadObject** imports QuadFileParser |
| scene | **SimpleQuadScene** extends SimpleQuadObject |
| file | **SimpleQuadFileLoader** extends SimpleQuadScene implements Loader |

| application | **SimpleQuadLoad** imports SimpleQuadFileLoader |
|---|---|

In the following subsections, the individual classes will be implemented. For this project, the pieces are created one layer at a time beginning at the lowest layer (tokenizer). The code of this project is not all original – much of it comes from the existing ObjectLoader utility of the Java 3D API distribution. However, the code here is simplified in many ways to facilitate understanding.

## Implementing the Tokenizer Layer

The first step in creating a loader is constructing the tokenizer. This involves customizing the StreamTokenizer utility class. The StreamTokenizer reads a character stream and converts the stream of characters into a stream of tokens. You may want to read about the StreamTokenizer before continuing to read about the loader.

For the example loader the StreamTokenizer is customized by extending it to a class called QuadFileParser. The QuadFileParser has the following methods.

**Table 3-4 Methods and Constructor of the Tokenizer Layer Implementation: `QuadFileParser.java`**

| **method / constructor** | **description / purpose** |
|---|---|
| `void setup()` | used to specify the parameters for the tokenizer (e.g., which characters are legal in a 'word token') ; called by the constructor |
| `boolean getToken()` | method for getting the next token from the Reader; this method uses the nextToken() method of StreamTokenizer and catches exceptions thrown by nextToken() |
| `void printToken()` | print token value and information to System.out; used for debugging |
| `QuadFileParser(Reader r)` | constructor calls setup and associates the tokenizer with the Reader object |

The setup() method is the place for the QUAD file specific code. This is the place where file format specific settings for the tokenizer are made. The relevant customizations of the tokenizer includes:

- which characters have special meaning,
- if newline characters are significant, and
- which character, if any, indicates a comment.

The file format description provides this information.

Code Fragment 3-3 shows some of the code creating the parser for the QUAD file format.

```
1.    class QuadFileParser extends StreamTokenizer {
2.
3.      // setup
4.      //    Sets up StreamTokenizer for reading OOGL file formats.
5.      void setup()
6.      {
7.        resetSyntax();
8.
9.        // EOL chars are insignificant in QUAD file
10.       eolIsSignificant(false);
11.
12.       wordChars('A','z');
```

```
13.
14.       // have StreamTokenizer parse numbers (makes double-precision)
15.       parseNumbers();
16.
17.       // Comments begin with # to end of line
18.       commentChar('#');
19.
20.       // Whitespace characters delineate words and numbers
21.       // blanks, tabs, and newlines are whitespace in OOGL
22.       whitespaceChars('\t', '\r');   // ht, lf, ff, vt, cr
23.       whitespaceChars(' ', ' ');     // space
24.     } // End of setup
25.
26.     /* getToken
27.      * Gets the next token from the stream.  Puts one of the four
28.      * constants (TT_WORD, TT_NUMBER, TT_EOL, or TT_EOF) and the token
29.      * value into ttype token object.
30.      * The value of this method is in the catching of exceptions in this
31.      * central location.
32.      */
33.     boolean getToken()
34.     {
35.       int t;
36.       boolean done = false;
37.
38.       try {
39.         t = nextToken();
40.       }
41.       catch (IOException e) {
42.         System.err.println(
43.           "IO error on line " + lineno() + ": " + e.getMessage());
44.         return false;
45.       }
46.
47.       return true;
48.     } // End of getToken
49.
50.     // QuadFileParser constructor
51.       QuadFileParser(Reader r)
52.     {
53.       super(r);
54.       setup();
55.     } // end of QuadFileParser
56.   } // End of file QuadFileParser.java
```

**Code Fragment 3-3 Some Tokenizer Methods for QUAD file loader: `QuadFileParser.java`**

The tokenizer for the QUAD file loader could be simpler. For example, the `nextToken()` method of the base class (i.e., StreamTokenizer) could be used without 'extending' it with `getToken()`. However, `getToken()` does add the functionality of catching exceptions and reporting errors at this layer. Also, the `printToken()` method, being primarily for debugging, could be considered unnecessary.

If you were to use the code here as a start for your own file format you would primarily change the setup method as appropriate for your file format. Also, keep in mind that the StreamTokenizer does not recognize scientific notation and only returns numeric values as type double.

Having completed the tokenizer layer, the loader construction turns to the next layer up, the object layer.

## Implementing the Object Layer

The purpose of the object layer is to convert the stream of tokens provided by the tokenizer into graphical objects. In this case, the job is reasonably simple in that there is basically only one kind of graphical object, the geometry composed of quadrilaterals. However, there is still some complexity to this problem. One difficulty arises from not knowing how many quadrilaterals are in the source. More discussion of this difficulty comes later. For the moment, lets look at the implementation.

The object layer is implemented as SimpleQuadObject. Refer back to Table 3-3 (page 3-16) to see how if fits in the implementation plan. Table 3-5 lists the methods of the SimpleQuadObject.

**Table 3-5 The Methods of the Object Layer Implementation: `SimpleQuadObject.java`**

| method | description / purpose |
|---|---|
| `boolean readVertex(QuadFileParser st)` | read a single vertex of a QUAD file which includes x, y, and z coordinate values, and possibly other per vertex values (e.g., surface normal, color, etc.) |
| `boolean readQuad(QuadFileParser st)` | read a quadrilateral from the QUAD file which simply is to read four vertices |
| `void readQuadFile(QuadFileParser st)` | read a QUAD file, which is to verify the internal file tag, determine the composition of the vertices, and read all the quadrilaterals |

The goal of this class/layer is to collect tokens in to graphical objects. In this case, the graphical objects are really vertices. The collection of the vertices is into an ArrayList object (declared on line 9 in Code Fragment 3-4). Using an ArrayList allows the size to grow at runtime. In the scene layer the array list will be converted to an array and then to a geometry object.

Being a class that will be extended, there could be protected data members. The only one that appears in this code is flags. It is not used by the code and was left in as an example of where a data member used at multiple layers would be declared.

Code Fragment 3-4 lists most of the implementation of the object layer implementation for this loader. Of course, the complete implementation is included in the examples jar.

```
1.    import QuadFileParser;
2.    // many other imports omitted in tutorial text
3.
4.    public class SimpleQuadObject
5.    {
6.      protected int flags;
7.      protected int fileType = 0;        // what properties vertices have
8.
9.      // constants for indicating file type
10.
11.     protected static final int COORDINATE = GeometryArray.COORDINATES;
12.
13.     // lists of points are read from the .quad file into this array. . .
14.     protected ArrayList coordList;          // Holds Point3f
15.
```

```
16.   /**
17.    * readVertex reads one vertex's coordinate data
18.    */
19.     boolean readVertex(QuadFileParser st)
20.     {
21.       Point3f p = new Point3f();
22.
23.       st.getToken();
24.       if(st.ttype == st.TT_EOF)
25.         return false; // reached end of file
26.       p.x = (float)st.nval;
27.
28.       st.getToken();
29.       p.y = (float)st.nval;
30.
31.       st.getToken();
32.       p.z = (float)st.nval;
33.
34.       // Add this vertex to the array
35.       coordList.add(p);
36.
37.       return true;
38.     } // End of readVertex
39.
40.
41.   /**
42.    * readQuad reads four vertices of the correct type (which in this
43.    * version is always just coordinate data).
44.    */
45.     boolean readQuad(QuadFileParser st)
46.     {
47.       int v;
48.       boolean result = false;
49.
50.       for(v=0; v < 4; v++)
51.         result = readVertex(st);
52.
53.       return result;
54.
55.     } // End of readQuad
56.
```

```
57.     /*
58.      * readFile
59.      *
60.      *    Read the model data from the file.
61.      */
62.     void readQuadFile(QuadFileParser st)
63.     {
64.       // verify file type
65.
66.       st.getToken();
67.       if(st.sval.equals("QUAD") || st.sval.equals("POLY"))
68.         fileType = COORDINATE;
69.       else
70.         throw new ParsingErrorException("bad file type: "+st.sval);
71.
72.       // read vertices
73.
74.       while (readQuad(st);
75.
76.     } // End of readFile
77.
78.   } // End of class SimpleQuadObject
79.
80.   // End of file SimpleQuadObject.java
```

**Code Fragment 3-4 Methods of the Object Layer: `SimpleQuadObject.java`**

If there were other graphical per vertex information (e.g., surface normal vectors, color, texture coordinates) to read from a file format additional ArrayLists could be used to store that information. This additional information would also be converted to the appropriate arrays in the scene layer to make the corresponding geometry objects.

It is at this layer where much of the file format specific work is done. If you are writing your own loader, you would have to implement the methods for reading all possible data of the file.

For this example, the object layer is done. Having completed the object layer, the loader construction turns to the next layer up, the scene layer.

## Implementing the Scene Layer

The scene layer is implemented as SimpleQuadScene. Refer back to Table 3-3 (page 3-16) to see how it fits in the overall loader implementation plan. Table 3-6 lists the methods of the SimpleQuadScene. Table 3-6 lists the methods implemented in SimpleQuadScene and shown in Code Fragment 3-5.

**Table 3-6 Methods of the Scene Layer Implementation: `SimpleQuadScene.java`**

| method | description / purpose |
|---|---|
| `SceneBase makeScene()` | taking the ArrayList of coordinate data created at the object layer, create the corresponding geometry object and scene graph to contain it |
| `Point3f[] objectToPoint3fArray(ArrayList in)` | convert an ArrayList to a Point3f array; used by makeScene() to create the geometry object |
| `Scene load(Reader reader)` | 1. create a QuadFileParser object<br>2. invoke QuadFileLoad (scene layer)<br>3. invoke makeScene |

```
1.    class SimpleQuadScene extends SimpleQuadObject
2.    {
3.      // coordList is converted to an arrays for creating geometry
4.      //
5.      private Point3f coordArray[] = null;
6.
7.      private Point3f[] objectToPoint3fArray(ArrayList inList)
8.      {
9.        Point3f outList[] = new Point3f[inList.size()];
10.
11.       for (int i = 0 ; i < inList.size() ; i++) {
12.         outList[i] = (Point3f)inList.get(i);
13.       }
14.       return outList;
15.     } // End of objectToPoint3fArray
16.
17.
18.     private SceneBase makeScene()
19.     {
20.       // Create Scene to pass back
21.       SceneBase scene = new SceneBase();
22.       BranchGroup group = new BranchGroup();
23.       scene.setSceneGroup(group);
24.
25.       // the model will be one Shape3D
26.       Shape3D shape = new Shape3D();
27.
28.       coordArray = objectToPoint3fArray(coordList);
29.
30.       QuadArray qa = new QuadArray(coordArray.length, fileType);
31.       qa.setCoordinates(0, coordArray);
32.
33.       // Put geometry into Shape3d
34.       shape.setGeometry(qa);
35.
36.       group.addChild(shape);
37.       scene.addNamedObject("no name", shape);
38.
39.       return scene;
40.     } // end of makeScene
41.
42.   public Scene load(Reader reader) throws FileNotFoundException,
43.                                          IncorrectFormatException,
44.                                          ParsingErrorException
45.     {
46.       // QuadFileParser does lexical analysis
47.       QuadFileParser st = new QuadFileParser(reader);
48.
49.       coordList = new ArrayList();
50.
51.       readQuadFile(st);
52.
53.       return makeScene();
54.     } // End of load(Reader)
55.   } // End of class SimpleQuadScene
56.   // End of file SimpleQuadScene.java
```

**Code Fragment 3-5 Methods of the Scene Layer: `SimpleQuadScene.java`**

This implementation is about as simple as a loader can be. The `makeScene()` method takes the geometry provided in the Quad file and creates a single QuadArray object from it. This QuadArray object is the sole geometric object in a new Shape3D object to form the scene.

It is, however, at this layer than many of the 'advanced loader features' suggested in Section 3.4.1 "What Loaders do" (page 3-14) can be implemented. For example, stripifying and generating surface normal vectors can be added at this layer by passing the coordinate information to a GeometryInfo (see Section 3.2) object and having the desired operations (e.g., stripifying) performed.

Many of the other advanced loader features suggested in Section 3.4.1 can also be implemented at this layer. However, for the simple example, we have done all that is necessary and having completed the scene layer, the loader construction now moves to the next layer up, the file layer.

## Implementing the File Layer

The file layer of the loader is standard fare. The majority of the code is exactly the same as the code for the ObjectLoader utility provided with the Java 3D API utilities. In fact, the author of a file loader could avoid using this code or writing code like this by using the LoaderBase class discussed in Section 3.3.3.

The file layer is implemented as SimpleQuadFileLoader. Refer back to Table 3-3 (page 3-16) to see how it fits in the overall loader implementation plan. This layer is generic in that it contains nothing specific to the QUAD file format. Also note that since the resulting class implements the Loader interface, the list of methods of SimpleQuadFileLoader is the same as those listed in the Loader Interface Method Summary (page 3-12).

The implementation of the file layer completes the construction of the loader. An application uses a loader. In the examples jar is the SimpleQuadLoad application which uses the SimpleQuadFileLoader.

## Assembling the layers

As the implementation was designed, the pieces implemented in the previous subsections form a complete loader. However, the series of 'extends' may confuse some readers (hopefully not).

An alternative implementation combines the object and scene layers into one class which uses the tokenizer layer and extends the LoaderBase.

## Moving to a more complete loader

There are many QUAD file format details ignored in the simple loader implementation. For example, a QUAD file may have data presented in scientific notation. The StreamTokenizer does not handle this. Modifications to the tokenizer layer would accommodate this QUAD file feature.

A QUAD file may also include surface normal vectors, color, and/or texture coordinate information per vertex. To accommodate this requires changes at the object and scene levels.

A QUAD file may include the contents of another file. This possibility raises the level of difficulty a bit. This would require changes at all levels.

However, the improvements of general interest involve interpretations of the file contents such as stripifying, computing surface normal vectors, etc. Loader features such as these are easily provided using the GeometryInfo and related utilities at the scene layer. The ObjectLoader is an example of a file loader which implements these features.

The next level of sophistication in a loader is to be able to load a family of related file formats. The LightWave loader implements such features.

At this point, you should have sufficient information to implement your own loader for a file format. If not, now you have an idea why writing a good loader is a difficult undertaking.

## 3.5 Text2D

There are two ways to add text to a Java 3D scene. One way uses the Text2D class and the other way uses the Text3D class. Obviously, one significant difference is that Text2D objects are two dimensional and Text3D objects are three dimensional. Another significant difference is how these objects are created.

Text2D objects are rectangular polygons with the text applied as a texture (texturing is the subject of Chapter 7). Text3D objects are 3D geometric objects created as an extrusion of the text. See Section 3.6 for more information on the Text3D class and related classes.

As a subclass of Shape3D, instances of Text2D can be children of group objects. To place a Text2D object in a Java 3D scene, simply create the Text2D object and add it to the scene graph. Figure 3-6 presents this simple recipe.

1. Create a Text2D object
2. Add it to the scene graph

**Figure 3-6 Recipe for Text2D**

Text2D objects are implemented using a polygon and a texture. The polygon is transparent so that only the texture is visible. The texture is of the text string set in the named typeface with the specified font parameters[6]. The typefaces available on your system will vary. Typically, Courier, Helvetica, and TimesRoman typefaces will be available, among others. Any font available in the AWT is available to you for Text2D (and Text3D) applications. Using a Text2D object is straightforward as demonstrated in the next section.

### 3.5.1 Simple Text2D Example

Code Fragment 3-6 shows an example of adding a Text2D object to a scene. The Text2D object is created on lines 21 through 23. In this constructor, the text string, color, typeface, size, and font style are specified. The Text2D object is added to the scene graph on line 24. Note the import statement for Font (line 5) used for the font style constants.

```
1.    import java.applet.Applet;
2.    import java.awt.BorderLayout;
3.    import java.awt.Frame;
4.    import java.awt.event.*;
5.    import java.awt.Font;
6.    import com.sun.j3d.utils.applet.MainFrame;
7.    import com.sun.j3d.utils.geometry.Text2D;
8.    import com.sun.j3d.utils.universe.*;
9.    import javax.media.j3d.*;
10.   import javax.vecmath.*;
11.
12.   //   Text2DApp renders a single Text2D object.
```

[6] A font is a specific typeface set at a size with a set of font style attributes. Refer to the glossary for definitions of font and typeface.

```
13.
14.   public class Text2DApp extends Applet {
15.
16.     public BranchGroup createSceneGraph() {
17.       // Create the root of the branch graph
18.       BranchGroup objRoot = new BranchGroup();
19.
20.       // Create a Text2D leaf node, add it to the scene graph.
21.       Text2D text2D = new Text2D("2D text is a textured polygon",
22.                                  new Color3f(0.9f, 1.0f, 1.0f),
23.                                  "Helvetica", 18, Font.ITALIC));
24.       objRoot.addChild(text2D);
```

**Code Fragment 3-6 A Text2D Object Created (excerpt from Text2DApp.java)**

`Text2DApp.java` is a complete program that includes the above Code Fragment. In this example, the Text2D object rotates about the origin in the scene. As the application runs you can see, by default, the textured polygon is invisible when viewed from behind.


**Figure 3-7 Image from Text2DApp.java**

Some attributes of a Text2D object can be changed by modifying the referenced appearance bundle and/or Geometry NodeComponent. Code Fragment 3-7 shows the code to make **`text2d,`** the Text2D object created in Code Fragment 3-6, two-sided through modification of its appearance bundle.

```
25.     Appearance textAppear = text2d.getAppearance();
26.
27.     // The following 4 lines of code make the Text2D object 2-sided.
28.     PolygonAttributes polyAttrib = new PolygonAttributes();
29.     polyAttrib.setCullFace(PolygonAttributes.CULL_NONE);
30.     polyAttrib.setBackFaceNormalFlip(true);
31.     textAppear.setPolygonAttributes(polyAttrib);
```

**Code Fragment 3-7 Making a Two-sided Text2D Object.**

The texture created by one Text2D object can be applied to other visual objects as well. Since the application of textures to visual objects is the subject of Chapter 7, the details on this are left until then.

### 3.5.2 Classes Used in Creating Text2D Objects

The only class needed is the Text2D class. As you can see from Figure 3-8, Text2D is a utility class which extends Shape3D.

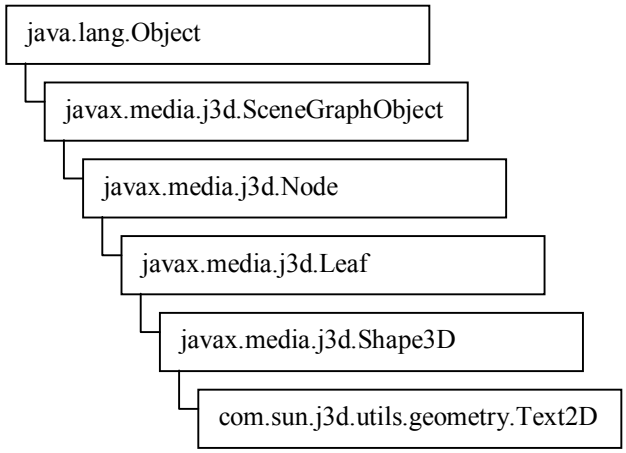



**Figure 3-8 The Class Hierarchy for Text2D**

In the Text2D constructor, the text string, typeface, font size, and font style are specified.

**Text2D Constructor Summary**

Package: `com.sun.j3d.utils.geometry`

This class creates a texture-mapped rectangle which displays the text string sent in by the user, given the appearance parameters also supplied by the user. The size of the rectangle (and its texture map) is determined by the font parameters passed in to the constructor. The resulting Shape3D object is a transparent (except for the text) rectangle located at (0, 0, 0) and extending up the positive y-axis and out the positive x-axis.

**`Text2D(java.lang.String text, Color3f color, java.lang.String fontName, int fontSize, int fontStyle)`**
Constructor.

With the Text2D constructor, there is one method. This method sets a scale factor to create Text2D objects larger or smaller than the specified point size. The scale factor is only utilized when the text is specified. Also note the rectangle scale factor is specified as a fraction over 256.

**Text2D Method Summary**

**`void setRectangleScaleFactor(float newScaleFactor)`**
Sets the scale factor used in converting the image width/height to width/height values in 3D. The rectangle scale factor starts out at 1/256. To double the size of the Text2D, use a factor of 2/256.

**`void setString(java.lang.String text)`** **`<new in 1.2>`**
Specifies a new text string for the Text2D object.

## 3.6 Text3D

Another way to add text to a Java 3D virtual world is to create a Text3D object for the text. Where Text2D creates text with a texture, Text3D creates text using geometry. The textual geometry of a Text3D object is an extrusion of the font.

Creating a Text3D object is a little more involved than creating a Text2D object. The first step is to create a Font3D object of the desired typeface, size, and font style. Then a Text3D object for a particular string is made using the Font3D object. Since the Text3D class is a subclass of Geometry, the Text3D

object is a NodeComponent that is referenced by one or more Shape3D object(s). Figure 3-9 summarizes the process of adding Text3D objects to a scene graph.

1. Create a Font3D object from an AWT Font
2. Create Text3D for a string using the Font3D object, optionally specifying a reference point
3. Reference the object from a Shape3D object added to the scene graph

**Figure 3-9 Recipe for Creating a Text3D Object**

### 3.6.1 Simple Text3D Example

Code Fragment 3-8 shows the basic construction of a Text3D object. The Font3D object is created on lines 19 and 20. The typeface used here is "Helvetica". Just like with Text2D, any typeface available in the AWT can be used for Font3D and therefore Text3D objects. This Font3D constructor (lines 19 and 20 of Code Fragment 3-8) also sets the font size to 10 points and uses the default extrusion.

The statement on lines 21 and 22 create a Text3D object using the newly created Font3D object for the string "3DText" while specifying a reference point for the object. The last two statements create a Shape3D object for the Text3D object and add it to the scene graph. Note the import statement for Font (line 5) is necessary since a Font object is used in the Font3D creation.

```
1.    import java.applet.Applet;
2.    import java.awt.BorderLayout;
3.    import java.awt.Frame;
4.    import java.awt.event.*;
5.    import java.awt.Font;
6.    import com.sun.j3d.utils.applet.MainFrame;
7.    import com.sun.j3d.utils.universe.*;
8.    import javax.media.j3d.*;
9.    import javax.vecmath.*;
10.
11.   //   Text3DApp renders a single Text3D object.
12.
13.   public class Text3DApp extends Applet {
14.
15.     public BranchGroup createSceneGraph() {
16.       // Create the root of the branch graph
17.       BranchGroup objRoot = new BranchGroup();
18.
19.       Font3D font3d = new Font3D(new Font("Helvetica", Font.PLAIN, 10),
20.                           new FontExtrusion());
21.       Text3D textGeom = new Text3D(font3d, new String("3DText"),
22.                                new Point3f(-2.0f, 0.0f, 0.0f));
23.       Shape3D textShape = new Shape3D(textGeom);
24.       objRoot.addChild(textShape);
```

**Code Fragment 3-8 Creating a Text3D Visual Object**

Figure 3-10 shows a Text3D object illuminated to illustrate the extrusion of the type. In the figure, the extrusion is shown in gray while the type is shown in black. To recreate this figure in Java 3D, a Material object and a DirectionalLight is necessary. Since Chapter 6 covers these topics, they are not discussed here. You can't set the color of the individual vertices in the Text3D object since you don't have access to the geometry of the Text3D object.


**Figure 3-10 The Default Reference Point and Extrusion for a 3DText Object**

The text of a Text3D object can be oriented in a variety of ways. The orientation is specified as a path direction. The choices are right, left, up, and down. See Table 3-7 and the Text3D reference blocks (beginning on page 3-12) for more information.

Each Text3D object has a reference point. The reference point for a Text3D object is the origin of the object. The reference point for each object is defined by the combination of the path and alignment of the text. Table 3-7 shows the effects of path and alignment specification on the orientation of the text and placement of the reference point.

The placement of the reference point can be defined explicitly overriding the path and alignment positioning. See the Text3D reference blocks (beginning on page 3-12) for more information.

**Table 3-7 The Orientation of Text and Position of the Reference Point for Combinations of Text3D Alignment and Path**

| | **ALIGN_FIRST (default)** | **ALIGN_CENTER** | **ALIGN_LAST** |
|---|---|---|---|
| **PATH_RIGHT (default)** | Text3D | Text3D | Text3D |
| **PATH_LEFT** | D3txeT | D3txeT | D3txeT |
| **PATH_DOWN** | T<br>e<br>x<br>t | T<br>e<br>x<br>t | T<br>e<br>x<br>t |
| **PATH_UP** | t<br>x<br>e<br>T | t<br>x<br>e<br>T | t<br>x<br>e<br>T |

Text3D objects have normals. The addition of an appearance bundle that includes a Material object to a Shape3D object referencing Text3D geometry will enable lighting for the Text3D object.

### 3.6.2 Classes Used in Creating Text3D Objects

This section presents reference material for the three classes used in creating Text3D objects: Text3D, Font3D, and FontExtrusion, in that order. Figure 3-11 shows the class hierarchy for Text3D class.

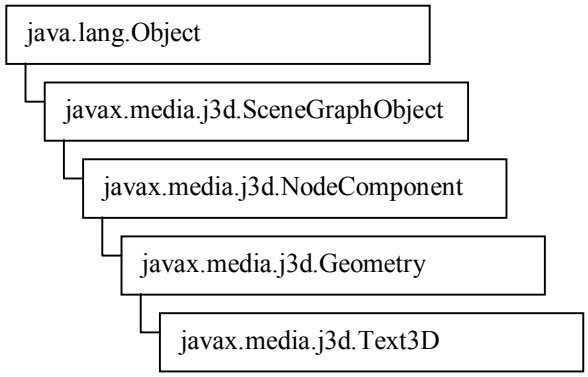



**Figure 3-11 Class Hierarchy for Text3D**

The Text3D class defines a number of constructors. Each constructor allows you to specify none, some, or all of the attributes of a Text3D object. The following reference block lists the constructors, along with the default values, for Text3D.

**Text3D Constructor Summary**

A Text3D object is a text string that has been converted to 3D geometry. The Font3D object determines the appearance of the Text3D NodeComponent object. Each Text3D object has a position - a reference point placing the Text3D object. The 3D text can be placed around this position using different alignments and paths.

**`Text3D()`**
Creates an empty Text3D object. The default values used for this, and other constructors as appropriate, are:

```
font 3D            null
string             null
position           (0,0,0)
alignment          ALIGN_FIRST
path               PATH_RIGHT
character spacing  0.0
```

**`Text3D(Font3D font3D)`**
Creates a Text3D object with the given Font3D object.

**`Text3D(Font3D font3D, String string)`**
Creates a Text3D object given a Font3D object and a string.

**`Text3D(Font3D font3D, String string, Point3f position)`**
Creates a Text3D object given a Font3D object and a string. The position point defines a reference point for the Text3D object. Its position is defined relative to the lower left front corner of the geometry.

**Text3D(Font3D font3D, String string, Point3f position, int alignment, int path)**
Creates a Text3D object given a Font3D object and a string.

| | |
|---|---|
| **ALIGN_CENTER** | alignment: the center of the string is placed on the position point. |
| **ALIGN_FIRST** | alignment: the first character of the string is placed on the position point. |
| **ALIGN_LAST** | alignment: the last character of the string is placed on the position point. |
| **PATH_DOWN** | path: succeeding glyphs are placed below the current glyph. |
| **PATH_LEFT** | path: succeeding glyphs are placed to the left of the current glyph. |
| **PATH_RIGHT** | path: succeeding glyphs are placed to the right of the current glyph. |
| **PATH_UP** | path: succeeding glyphs are placed above the current glyph. |

See Table 3-7 for examples.

The Text3D class also defines a number of methods. Each allows you to modify (set) the attributes of the Text3D object. This class also defines corresponding `get*` methods. The following reference block lists the `set*` methods for the Text3D class.

**Text3D Method Summary**

**void setAlignment(int alignment)**
Sets the text alignment policy for this Text3D NodeComponent object.

**void setCharacterSpacing(float characterSpacing)**
Sets the character spacing to be used when constructing the Text3D string.

**void setFont3D(Font3D font3d)**
Sets the Font3D object used by this Text3D NodeComponent object.

**void setPath(int path)**
Sets the node's path direction.

**void setPosition(Point3f position)**
Sets the node's reference point to the supplied parameter.

**void setString(java.lang.String string)**
Copies the character string from the supplied parameter into the Text3D node.

The following reference block lists the Capabilities of the Text3D class.

**Text3D Capabilities Summary**

| | |
|---|---|
| **ALLOW_ALIGNMENT_READ \| WRITE** | allow reading (writing) the text alignment value. |
| **ALLOW_BOUNDING_BOX_READ** | allow reading the text string bounding box value |
| **ALLOW_CHARACTER_SPACING_READ \| WRITE** | allow reading (writing) the text character spacing value. |
| **ALLOW_FONT3D_READ \| WRITE** | allow reading (writing) Font3D component information. |
| **ALLOW_PATH_READ \| WRITE** | allow reading (writing) the text path value. |
| **ALLOW_POSITION_READ \| WRITE** | allow reading (writing) the text position value. |
| **ALLOW_STRING_READ \| WRITE** | allow reading (writing) the String object. |

Each Text3D object is created from a Font3D object. A single Font3D object can be used to create an unlimited number of Text3D objects[7]. A Font3D object holds the extrusion geometry for each glyph in

[7] Of course, memory constraints will limit the actual number of Text3D objects to some number significantly less than infinity.

the typeface. A Text3D object copies the geometry to form the specified string. Font3D objects can be garbage collected without affecting Text3D objects created from them.

The following reference block shows the constructor for the Font3D class.

**Font3D Constructor Summary**

Extends: `java.lang.Object`

A 3D Font consists of a Java 2D font and an extrusion path. The extrusion path describes how the edge of a glyph varies in the Z axis. The Font3D object is used to store extruded 2D glyphs. These 3D glyphs can then be used to construct Text3D NodeComponent objects. Custom 3D fonts as well as methods to store 3D fonts to disk will be addressed in a future release.

See Also: java.awt.Font, FontExtrusion, Text3D

**`Font3D(java.awt.Font font, FontExtrusion extrudePath)`**
Creates a Font3D object from the specified Font object using the default value for tessellationTolerance (0.01).

**`Font3D(java.awt.Font font, double tessellationTolerance, FontExtrusion extrudePath)`** **`<new in 1.2>`**
Creates a Font3D object from the specified Font object with the specified tessellationTolerance. The tessellationTolerance parameter corresponds to the flatness parameter in the java.awt.Shape.getPathIterator method.

The following reference block lists the methods of the Font3D class. Normally, `get*` methods are not listed in reference blocks in this tutorial. However, since the Font3D class has no `set*` methods, the Font3D get* methods are listed here. The effect of a `set*` method would be essentially the same as invoking a constructor, so to keep the class smaller, no `set*` methods are defined.

**Font3D Method Summary**

**`void getBoundingBox(int glyphCode, BoundingBox bounds)`**
Returns the 3D bounding box of the specified glyph code.

**`java.awt.Font getFont()`**
Returns the Java 2D Font used to create this Font3D object.

**`void getFontExtrusion(FontExtrusion extrudePath)`**
Copies the FontExtrusion object used to create this Font3D object into the specified parameter.

**`double getTessellationTolerance()`** **`<new in 1.2>`**
Return the tessellation tolerance with which this Font3D object was created.

The Font class is used in creating a Font3D object. The following reference block lists one constructor for Font. Other constructors and many methods are not listed in this tutorial. See the Java 3D API Specification for details.

**Font Constructor Summary (partial list)**

Package: `java.awt`

An AWT class that creates an internal representation of fonts. Font extends java.lang.Object.

**`public Font(String name, int style, int size)`**
Creates a new Font from the specified name, style and point size.
Parameters:
**`name`** - the typeface name. This can be a logical name or a typeface name. A logical name must be one of: Dialog, DialogInput, Monospaced, Serif, SansSerif, or Symbol.

**`style`** - the style constant for the Font. The style argument is an integer bitmask that may be PLAIN, or a bitwise union of BOLD and/or ITALIC (for example, `Font.ITALIC` or `Font.BOLD|Font.ITALIC`). Any other bits set in the style parameter are ignored. If the style argument does not conform to one of the expected integer bitmasks then the style is set to PLAIN.

**`size`** - the point size of the Font

The following reference block lists the constructors for the FontExtrusion class.

**FontExtrusion Constructor Summary**

Extends: `java.lang.Object`

The FontExtrusion object is used to describe the extrusion path for a Font3D object. The extrusion path is used in conjunction with a Font2D object. The extrusion path defines the edge contour of 3D text. This contour is perpendicular to the face of the text. The extrusion has its origin at the edge of the glyph with 1.0 being the height of the tallest glyph. Contour must be monotonic in x. User is responsible for data sanity and must make sure that extrusionShape does not cause intersection of adjacent glyphs or within single glyph. The output is undefined for extrusions that cause intersections.

**`FontExtrusion()`**
Constructs a FontExtrusion object with default parameters: shape = null, tessellation tolerance = 0.01.

**`FontExtrusion(java.awt.Shape extrusionShape)`**
Constructs a FontExtrusion object with the specified shape and tessellation tolerance = 0.01.

**`FontExtrusion(java.awt.Shape extrusionShape, double tessellationTolerance)`** **`<new in 1.2>`**
Constructs a FontExtrusion object with the specified shape and tessellation tolerance.

The following reference block lists the methods for the FontExtrusion class.

**FontExtrusion Method Summary**

**`java.awt.Shape getExtrusionShape()`**
Gets the FontExtrusion's shape parameter.

**`void setExtrusionShape(java.awt.Shape extrusionShape)`**
Sets the FontExtrusion's shape parameter.

**`double getTessellationTolerance()`** **`<new in 1.2>`**
Return the tessellation tolerance with which this FontExtrusion object was created.

## 3.7 Background

By default, the background of a Java 3D virtual universe is solid black. However, you can specify other backgrounds for your virtual worlds. The Java 3D API provides an easy way to specify a solid color, an image, geometry, or a combination of these, for a background.

When specifying an image for the background, it overrides a background color specification, if any. When geometry is specified, it is drawn on top of the background color or image.

The only tricky part is in the specification of a geometric background. All background geometry is specified as points on a unit sphere. Whether your geometry is a PointArray, which could represent stars light years away, or a TriangleArray, which could represent mountains in the distance, all coordinates are specified at a distance of one unit. The background geometry is projected to infinity when rendered.

Background objects have Application bounds which allows different backgrounds to be specified for different regions of the virtual world. A Background node is active when its application region intersects the ViewPlatform's activation volume.

If multiple Background nodes are active, the Background node that is "closest" to the eye will be used. If no Background nodes are active, then the window is cleared to black. However, the definition of "closest" is not specified. For closest, the background with the innermost application bounds that encloses the ViewPlatform is chosen.

It is unlikely that your application will need lit background geometry - in reality the human visual system can't perceive visual detail at great distances. However, a background geometry can be shaded. The background geometry subgraph may not contain Lights, but Lights defined in the scene graph can influence background geometry.

To create a background, follow the simple recipe given in Figure 3-12. Example backgrounds are presented in the next section.

1. Create Background object specifying a color or an image
2. Add geometry (optional)
3. Provide an Application Boundary or BoundingLeaf
4. Add the Background object to the scene graph

**Figure 3-12 Recipe for Backgrounds**

### 3.7.1 Background Examples

As explained in the previous section, a background can have either a color or an image. Geometry can appear in the background with either the color or image. This section provides an example of a solid white background. A second example shows adding geometry to a background.

## Colored Background Example

As shown in Figure 3-12, the recipe for creating a solid color background is straightforward. The lines of code in Code Fragment 3-9 correspond to the recipe steps. The besides customizing the color, the only other possible adjustment to this code would be to define a more appropriate application bounds for the background (or use a BoundingLeaf).

```
1.    Background backg = new Background(1.0f, 1.0f, 1.0f);
2.    //
3.    backg.setApplicationBounds(BoundingSphere());
4.    contentRoot.addChild(backg);
```

**Code Fragment 3-9 Adding a Colored Background**

## Geometry Background Example

Once again, the lines of code in Code Fragment 3-10 correspond to the background recipe steps shown in Figure 3-12. In this code fragment, the `createBackGraph()` method is invoked to create the background geometry. This method returns a BranchGroup object. For a more complete example, see `BackgroundApp.java` in the `examples/easyContent` directory.

```
1.    Background backg = new Background();     //black background
2.    backg.setGeometry(createBackGraph());   // add BranchGroup of background
3.    backg.setApplicationBounds(new BoundingSphere(new Point3d(), 100.0));
4.    objRoot.addChild(backg);
```

**Code Fragment 3-10 Adding a Geometric Background**

## BackgroundApp.java

To appreciate a Background, you need to experience it. `BackgroundApp.java`, a program included in the examples/easyContent directory, is a complete working application with a geometric background. This application allows you to move in the Java 3D virtual world. While moving, you can see the relative movement between the local geometry and the background geometry.

BackgroundApp uses the KeyNavigatorBehavior class provided in the utility library for viewer motion. Interaction (as implemented through behaviors) is the subject of Chapter 4, so the details of this programming is delayed until then.

KeyNavigatorBehavior responds to the arrow keys, PgUp, and PgDn keys for motion. The Alt key also plays a role (more details in Chapter 4). When you run BackgroundApp, be sure to rotate to find the "constellation", as well as travel far into the distance.

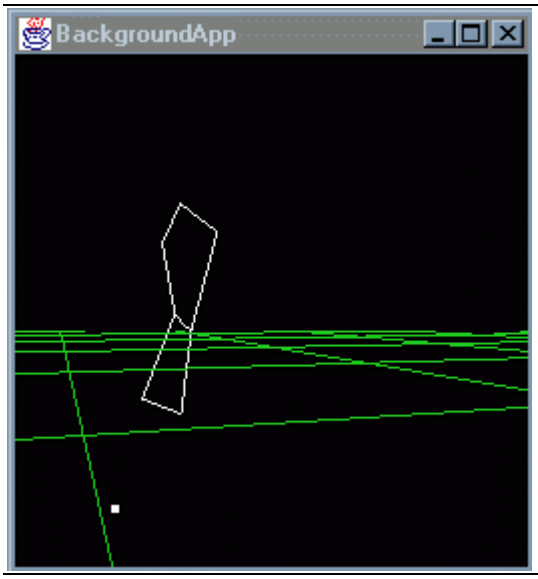



**Figure 3-13 Viewing the "Constellation" in the Background of BackgroundApp.java**

### 3.7.2 Background Class

Figure 3-14 shows the class hierarchy for Background class. As an extension of Leaf class, an instance of Background class can be a child of a Group object.

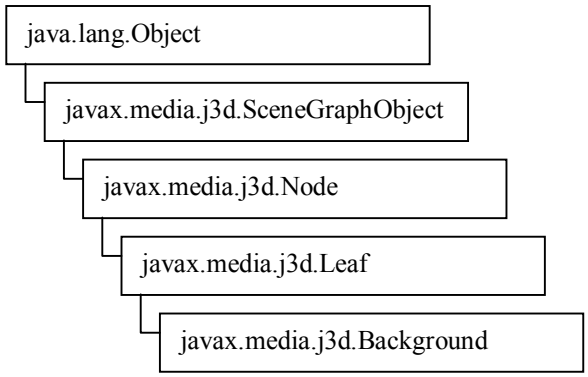



**Figure 3-14 The Class Hierarchy for Background**

Background has a variety of constructors. Background constructors with parameters allow the specification of a color or an image for a background. The following reference block gives more detail. Background Geometry can only be specified through the appropriate method.

**Background Constructor Summary**

The Background leaf node defines either a solid background color or a background image that is used to fill the window at the beginning of each new frame. It optionally allows background geometry to be referenced. Background geometry must be pre-tessellated onto a unit sphere and is drawn at infinity. It also specifies an application region in which this background is active.

**`Background()`**
Constructs a Background node with a default color (black).

**`Background(Color3f color)`**
Constructs a Background node with the specified color.

**`Background(float r, float g, float b)`**
Constructs a Background node with the specified color.

**`Background(ImageComponent2D image)`**
Constructs a Background node with the specified image.

Any attribute of a Background can be set through a method. The following reference block lists the methods of the Background class.

**Background Method Summary**

**`void setApplicationBoundingLeaf(BoundingLeaf region)`**
Set the Background's application region to the specified bounding leaf.

**`void setApplicationBounds(Bounds region)`**
Set the Background's application region to the specified bounds.

**`void setColor(Color3f color)`**
Sets the background color to the specified color.

**`void setColor(float r, float g, float b)`**
Sets the background color to the specified color.

**`void setGeometry(BranchGroup branch)`**
Sets the background geometry to the specified BranchGroup node.

**`void setImage(ImageComponent2D image)`**
Sets the background image to the specified image.

The following reference block lists the capability bits of the Background class.

**Background Capabilities Summary**

| | |
|---|---|
| `ALLOW_APPLICATION_BOUNDS_READ \| WRITE` | allow read (write) access to its application bounds |
| `ALLOW_COLOR_READ \| WRITE` | allow read (write) access to its color |
| `ALLOW_GEOMETRY_READ \| WRITE` | allow read (write) access to its background geometry |
| `ALLOW_IMAGE_READ \| WRITE` | allow read (write) access to its image |

## 3.8 User Data

Any SceneGraphObject can reference any object as user data[8]. First, you should realize that nearly every Java 3D API core class is a descendant of SceneGraphObject. The list of descendants of SceneGraphObject includes Appearance, Background, Behavior, BranchGroup, Geometry, Lights, Shape3D, and TransformGroup.

The applications for this, the UserData field, are limited only by your imagination. For example, an application may have a number of pickable objects. Each of these objects could have some text information stored in the user data object. When a user picks an object, the user data text can be displayed.

Another application could store some calculated value for a scene graph object such as its position in virtual world coordinates. Yet another application could store some behavior specific information that could control a behavior applied to a variety of objects.

**SceneGraphObject Methods (Partial List - User Data Methods)**

SceneGraphObject is a common superclass for all scene graph component objects. This includes Node, Geometry, Appearance, etc.

**`java.lang.Object getUserData()`**
Retrieves the userData field from this scene graph object.

**`void setUserData(java.lang.Object userData)`**
Sets the userData field associated with this scene graph object.

## 3.9 Chapter Summary

This chapter presents the Java 3D features for easier content creation. Loader utilities and GeometryInfo classes are the primary easy content creation techniques. These topics are covered in sections 3.2 and 3.2, respectively. Text is added to the Java 3D world using Text2D and Text3D classes in sections 3.5 and 3.6. Background is covered in detail in section 3.7. Section 3.8 presents the UserData field of the SceneGraphObject class. You are reading section 3.9.

## 3.10 Self Test

1. Using the wire frame view in the `GeomInfoApp.java` program, you can see the effect of the triangulation. Using the example program as a starting point, change the specification of the polygons to use three polygons (one for each side, and one for the roof, hood, trunk lid and other surfaces). How does the Triangulator do with this surface?

[8] This is not limited to Java 3D API classes, but any class derived from java.lang.Object.

2. The code to make the Text2D object visible from both sides is included in `Text2DApp.java`. You can uncomment the code, recompile and run it. Other experiments with this program include using the texture from the Text2D object on other visual objects. For example, try adding a geometric primitive and apply the texture to that object. Of course, you may want to wait until you read Chapter 7 for this exercise.

3. Using `Text3DApp.java` as a starting point, experiment with the various alignment and path settings. Other experiments include changing the appearance of the Text3D object.

4. Playing with the `BackgroundApp.java` example program, if you move far enough away from the origin of the virtual world the background disappears. Why does this happen? If you add another Background object to the BackgroundApp, what will the effect be?