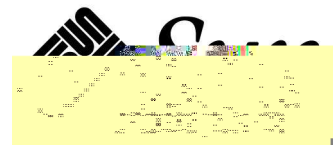


3D Application and Game Development With OpenGL[®]

java.sun.com/javaone/sf

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Presentation Goal

Show how to build leading-edge 3D applications and games using the Java™ programming language and the OpenGL® 3D API

Agenda

Introduction

JSR Update

Using JOGL With AWT and Swing

Techniques for Application Development

Optimizing JOGL Applications

Demos

Conclusion

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Introduction

- OpenGL
 - Powerful, cross-platform 3D API
 - Industry standard for writing 3D applications and games
 - On multiple platforms
 - From multiple programming languages
 - Supported by multiple vendors
 - Provides access to latest hardware features
 - Vertex and fragment programs
 - Floating-point framebuffers

Introduction

Java programming language OpenGL bindings

- A few bindings under active development
- LWJGL
 - Game-focused OpenGL binding
 - Single window
 - Usually full-screen
- JOGL
 - Integrates with AWT and Swing
- Relies on J2SE™ platform for, e.g., full-screen support
- Today's talk will use JOGL for examples

Introduction

Java programming language OpenGL bindings

- Standardization effort underway
- One Java programming language binding to OpenGL
 - Can be implemented by multiple vendors if desired
 - Being developed under the Java Community ProcessSM service
 - JSRs 231 and 239

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JSR Update

Overview

- What are JSR 231 and JSR 239
- Benefits of a JSR
- JSR 231 and JSR 239 Status

JSR 231 and 239

What they are

- JSR 231
 - Java bindings to OpenGL
 - Based on JOGL project on java.net
 - Most likely based on OpenGL 1.5
- JSR 239
 - Java bindings to OpenGL ES
 - Will use the GlueGen technology of JOGL to generate bindings
 - Most likely based on OpenGL ES 1.0
- Both being run under the Java Community Process version 2.6

Why Do a JSR?

Benefits of a JSR

- Align market around one specification
 - No need to download multiple APIs for the same binding
 - Specification and TCK ensure compliant bindings can be produced
 - Ensure all functionality of native library present
- Some industries (e.g., mobile devices) prefer JCP APIs

JSR 231 and 239

Status

- Both JSRs were filed and approved by their respective ECs
- Both Expert Groups have been formed and are meeting regularly
- EGs working together to make both APIs as similar as possible
- Both EGs hope to have EDRs late this year

JSR 231 and 239

Notes

- Both JSRs are fundamentally tracking a third-party API
- Want to track the OpenGL APIs as closely as possible
- Plan to use maintenance releases for updates
 - 30-day review period (shortest possible)

What You Can Do

More help is *ALWAYS* welcome

- Join an Expert Group
 - Specification work
 - SI work
 - TCK work
- Contribute to JOGL project on java.net
- Participate in EDRs

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Using JOGL With AWT and Swing

DirectDraw incompatibilities on Windows

- `-Dsun.java2d.noddraw=true`
- Disables Java 2D™ API's internal use of DirectDraw APIs on Windows
 - Incompatible with OpenGL
 - Frequent driver bugs arise when mixing the two APIs, even when they are used in separate windows
- Should be specified for **all** JOGL applications!
 - No harm specifying on non-Windows platforms
 - Especially for Java Web Start applications
 - Add following to resources section of JNLP file:
 - `<property name="sun.java2d.noddraw" value="true"/>`

Using JOGL With AWT and Swing

GLCanvas and GLJPanel

- GLCanvas: heavyweight AWT widget for OpenGL rendering
 - Best performance (hardware accelerated)
 - Works in most GUI situations
 - See this article on mixing lightweight and heavyweight widgets successfully:
<http://java.sun.com/products/jfc/tsc/articles/mixing/>
- JPopupMenu.
`setLightweightPopupEnabled(false);`
 - To get Swing menus to overlap GLCanvas

Using JOGL With AWT and Swing

GLCanvas and GLJPanel

- GLJPanel: lightweight Swing widget for complete compatibility with Swing UIs
 - JInternalFrames
- Currently not hardware-accelerated
 - Poor performance
- Investigating using OpenGL pbuffers to implement GLJPanel
 - Faster, but still not fast enough
 - Still has texture readback
- Experimental work underway to integrate better with Java 2D API and “JFC/Swing”

Using JOGL With AWT and Swing

Rendering and animation options

- Automatic redraws initiated by the AWT
 - For static scenes
- Call `repaint()` in animation thread
- Use Animator class or start your own thread and call `GLDrawable.display()` directly
 - Most efficient for games
 - Allows optimized OpenGL context handling on some platforms
 - As efficient as single-threaded C code

Using JOGL With AWT and Swing

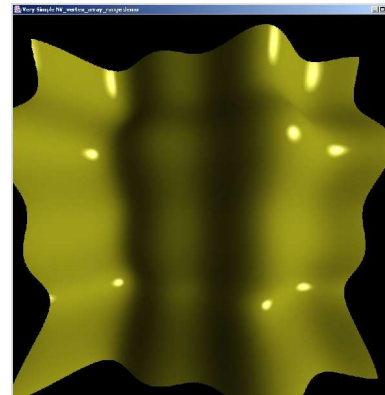
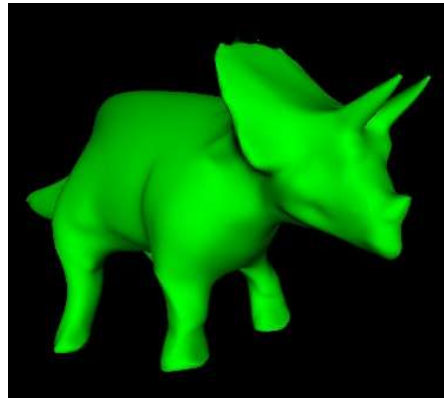
Multithreading

- AWT events like mouse and keyboard events are delivered on AWT event queue thread
- Not allowed / possible to make OpenGL calls directly inside these listeners
 - Though you can schedule or force a redraw
- Instead, pass information between these threads and any animation threads via member data
 - Use appropriate synchronization
 - Read data exactly once in your display() method
 - Avoids flickering and other artifacts during mouse interaction

Using JOGL With AWT and Swing

Examples

- See demos at <http://jogl-demos.dev.java.net/> for examples of animation, interaction, and advanced features



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- Scene graphs and game engines
- Object picking
- Shadows

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Scene Graphs and Game Engines

Overview

- Higher-level, typically object-oriented layer for applications to build on top of
- Often have hierarchical structure
 - Good for representing character animation
- Use OpenGL or similar API at the bottom
 - Ones discussed here use JOGL
- Look for extensibility
 - Ability to call out to OpenGL from within scene graph to implement leading-edge effects

Scene Graphs and Game Engines

Examples

- Xith3D: <http://www.xith.org/>
 - General-purpose scene graph, but focused on gaming and high performance
 - Designed to be nearly identical to Java 3D™ APIs
 - Supports leading-edge functionality like shadow volumes and vertex and fragment programs
- Aviatrix3D: <http://aviatrix3d.j3d.org/>
 - Focused on visualization market
 - Minimal API design
 - Also supports vertex and fragment programs

Scene Graphs and Game Engines

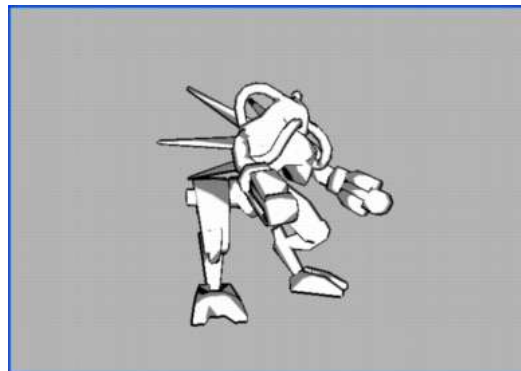
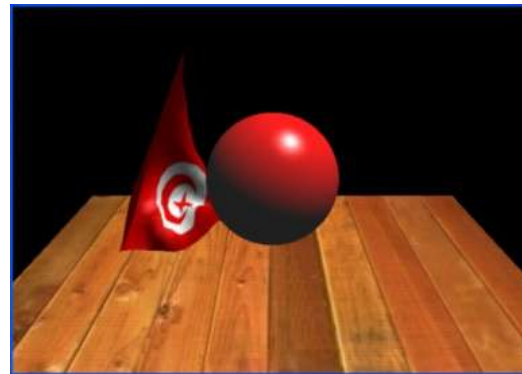
Examples

- OpenMind: <http://www.mind2machine.com/>
 - 3D game engine
 - Built-in support for 3D Studio Max ASE format
 - Supplies tool chain for developers

Scene Graphs and Game Engines

Demo

- Abdul Bezrati (a.k.a. “Java Cool Dude”)
 - Xith3D demos
 - <http://xith.org/demo/JavaCoolDude.php>



Object Picking

Using the selection buffer

- Interactive applications require the ability to pick objects in 3D
- OpenGL provides a built-in mechanism for object selection
 - Special rendering mode
- User supplies storage for results and sets up special “pick” matrix
 - View volume centered around cursor
- Any objects rendered into this view volume are reported to the user

Object Picking

Using the selection buffer

- Set up selection buffer
 - `IntBuffer buf =
 BufferUtils.newIntBuffer(1024);
 gl.glSelectBuffer(buf.capacity(), buf);`
- Switch into selection mode
 - `gl.glRenderMode(GL.GL_SELECT);`
 - Color buffer is frozen at this point and not updated until selection mode is exited
- Initialize name stack
 - `gl.glInitNames();`
- Set up pick matrix
 - `glu.gluPickMatrix(...);`

Object Picking

Using the selection buffer

- Render objects, assigning names to them

```
— int objectId = ...;  
  gl.glPushName(objectId);  
  renderObject(gl);  
  gl.glPopName();
```

- Switch out of selection mode

```
— int numHits =  
    gl.glRenderMode(GL.GL_RENDER);
```

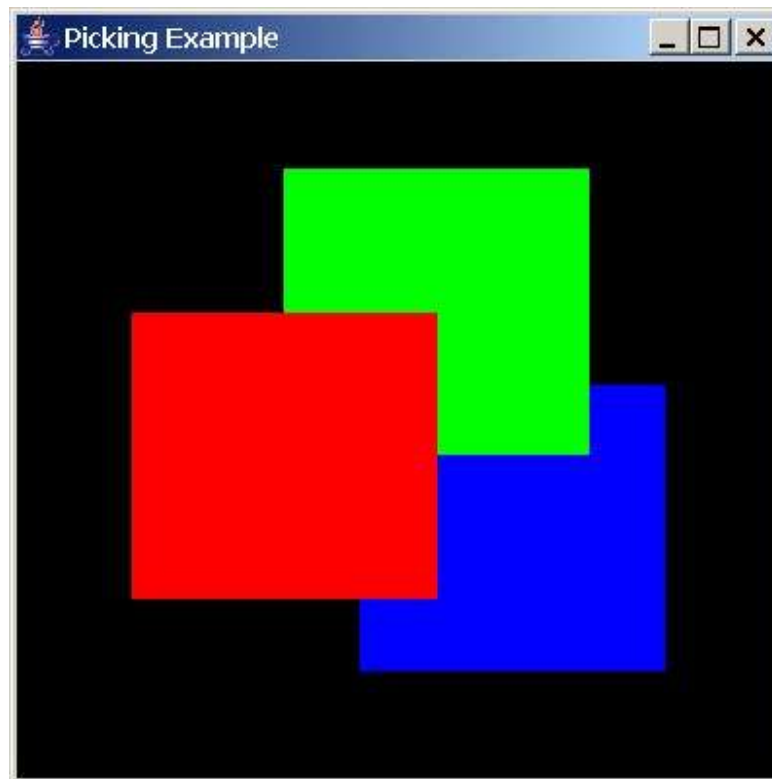
- Process hits

```
— int idx = 0;  
  while (idx < numHits) {  
    int hit = buf.get(idx++);  
    ...  
  }
```

Object Picking

Demo

- Selection buffer demo (courtesy Thomas Bladh)
 - <http://www.sm.luth.se/csee/courses/smd/159/TestPrograms/Picking.java>



Object Picking

Using the selection buffer

- Advantages
 - Easy to start working with selection buffer
 - Can reuse normal rendering code; just add names
 - Names have no effect in GL_RENDER mode
- Disadvantages
 - Still have to disambiguate multiple hits based on depth values
 - No surface normal or other information at hit site
 - Not exactly casting a ray into the scene
 - To implement dragging behavior, still need some kind of policy for motion
 - Doesn't solve problem of moving camera in response to mouse motion

Object Picking

Using Manual Linear Algebra

- Picking can also be done at the application level
 - Perform ray-triangle intersection tests using a linear algebra library
- Depending on application's representation of geometry, may be able to accelerate drastically
 - Octrees or other spatial partitioning techniques
 - Degenerate cases like vertical rays
- Have full control over information returned and response to dragging
- May require some more code

Object Picking

Using Manual Linear Algebra

- Libraries exist for adding 3D interaction
 - gleem (OpenGL Extremely Easy-To-Use Manipulators)—in jogl-demos workspace on java.net
 - Will be shown shortly
 - Most scene graphs have picking mechanisms
 - Scene graphs discussed earlier support it
 - Depending on application and library, may be very easy to integrate the two

Shadows

Why do we need shadows?

- Humans use shadows to infer spatial relationships
 - Relative positions of objects
 - Locations of light sources
 - Shape of an object
- Scene looks more natural
- Scene is easier to understand
- Shadows look cool

Shadows

Two basic techniques

- Render-to-texture shadows
 - Image-space technique
- Volumetric
 - Geometric technique

Shadows

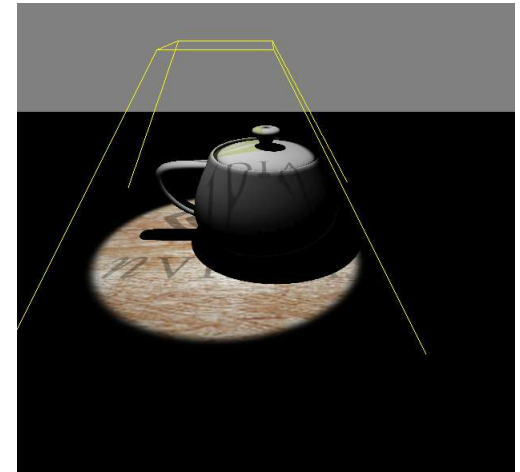
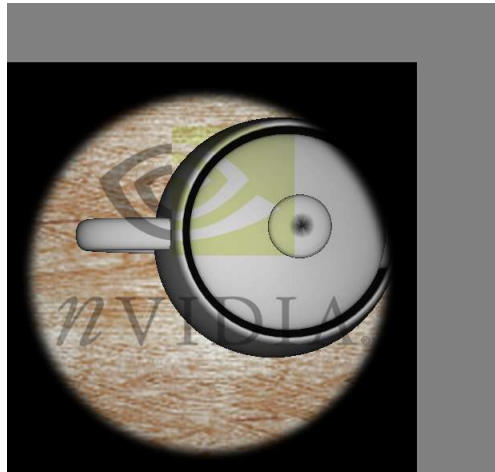
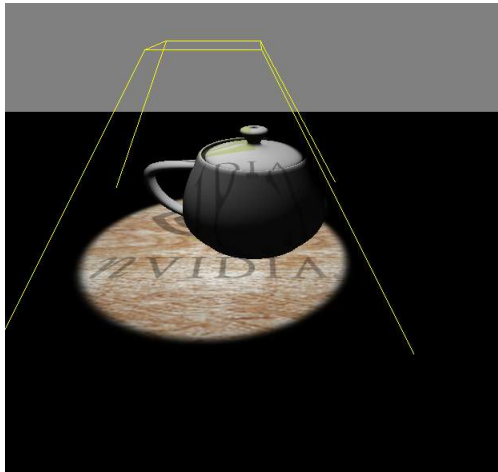
Render-to-texture shadows

- Render the scene from the light's perspective
- Store depth of rendered scene as texture
- Render scene from viewer's perspective
- Render the depth texture onto the scene
 - Careful setup of texture transform and texture-coord generation
 - Object's position maps to correct u-v texture coords in depth texture
 - Object's r texture coord maps to distance from the object to the light source
 - If r value is greater than texture value, pixel is in shadow

Shadows

Demo

- NVidia Hardware Shadow Mapping



Shadows

Render-to-texture shadows

- Advantages:
 - Performance independent of geometric complexity
 - No additional cost for animated geometry
 - Can take into account alpha-masked geometry (example: a chain-link fence)

Shadows

Render-to-texture shadows

- Disadvantages:
 - Dependent on texture resolution (aliasing)
 - Not good for long projections
 - Need special tricks to get self-shadowing to work well
 - Older hardware may not support render-to-texture in hardware
 - Fall back to slow framebuffer --> texture copy

Shadows

Volumetric shadows

- Basic idea: Use geometry to calculate volume of space that is in shadow
 - Calculate silhouette edge of object, from light's perspective
 - Extrude the silhouette away from the light
 - Objects inside this volume are in shadow from the light

Shadows

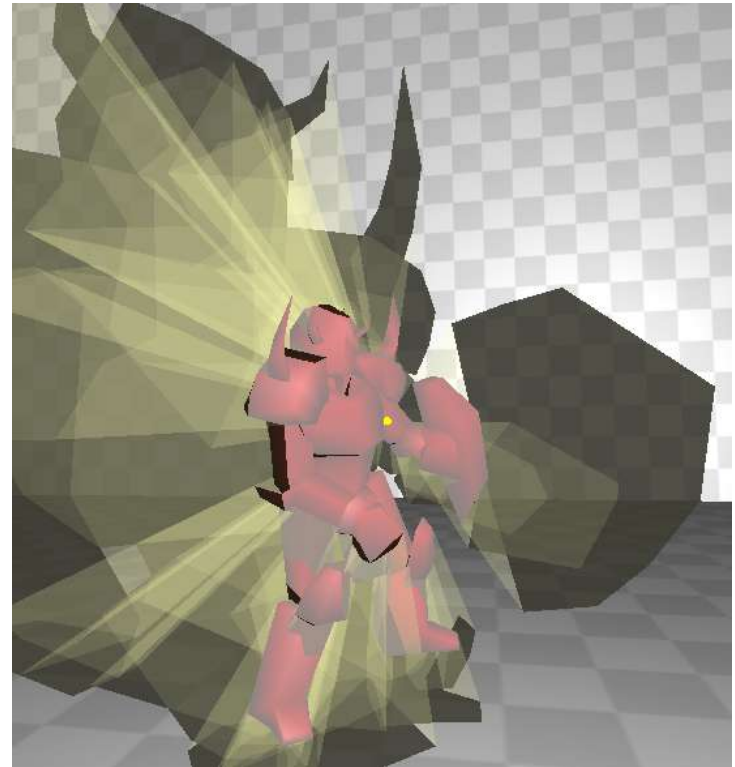
Volumetric shadows

- Uses stencil buffer for per-pixel in/out test
 - Render scene, ambient light only
 - Sets the depth buffer
 - Render shadow volumes with stencil enabled
 - Render front / back faces separately
 - If pixel passes depth test, adjust stencil value
 - Many adjustment heuristics (z-pass, z-fail)
 - If stencil value is 0 afterwards, pixel is not in shadow

Shadows

Demo

- NVidia Infinite Shadow Volumes



Shadows

Volumetric shadows

- Advantages:
 - Self-shadowing “just works”
 - No aliasing problems
 - Crisp shadows, even at infinite projection distances
 - Good for wide-open spaces

Shadows

Volumetric shadows

- Disadvantages:
 - Performance depends on scene
 - Expensive for complex objects, many lights, or many shadow receivers
 - N lights = $N+1$ render passes per shadowed object
 - Slow for non-static geometry / non-static lights
 - Silhouettes must be recalculated each frame
 - Incorrect shadows cast from alpha-masked geometry
 - Purely geometric technique
 - Many subtleties to make it work correctly for all intersections of light, viewer, and shadow volume

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Optimizing JOGL Applications

Data organization

- Application writer needs to decide how to lay out data in memory
 - Multiple Java objects in heap?
 - Primitive types and/or primitive arrays?
 - New I/O? Use memory-mapped files instead of reading them in?
- Guide decisions by how various data structures will be used and how much data they store
- When compatibility with C data structures in memory-mapped files is required, GlueGen tool can help provide access to data
 - GlueGen is in JOGL workspace on java.net

Optimizing JOGL Applications

Data organization: Grand Canyon demo

- 300 MB of terrain data visualized in real time using Java technology and OpenGL
- Multiresolution algorithm
 - More detail for terrain closer to camera
- Two components of data: geometry and texture
 - NIO used to memory-map both
 - Highest-resolution geometry mapped all of the time
 - Processed by Java code to decimate to appropriate resolution
 - Appropriate resolution textures mapped in by background thread
 - Raw data handed off to OpenGL

Optimizing JOGL Applications

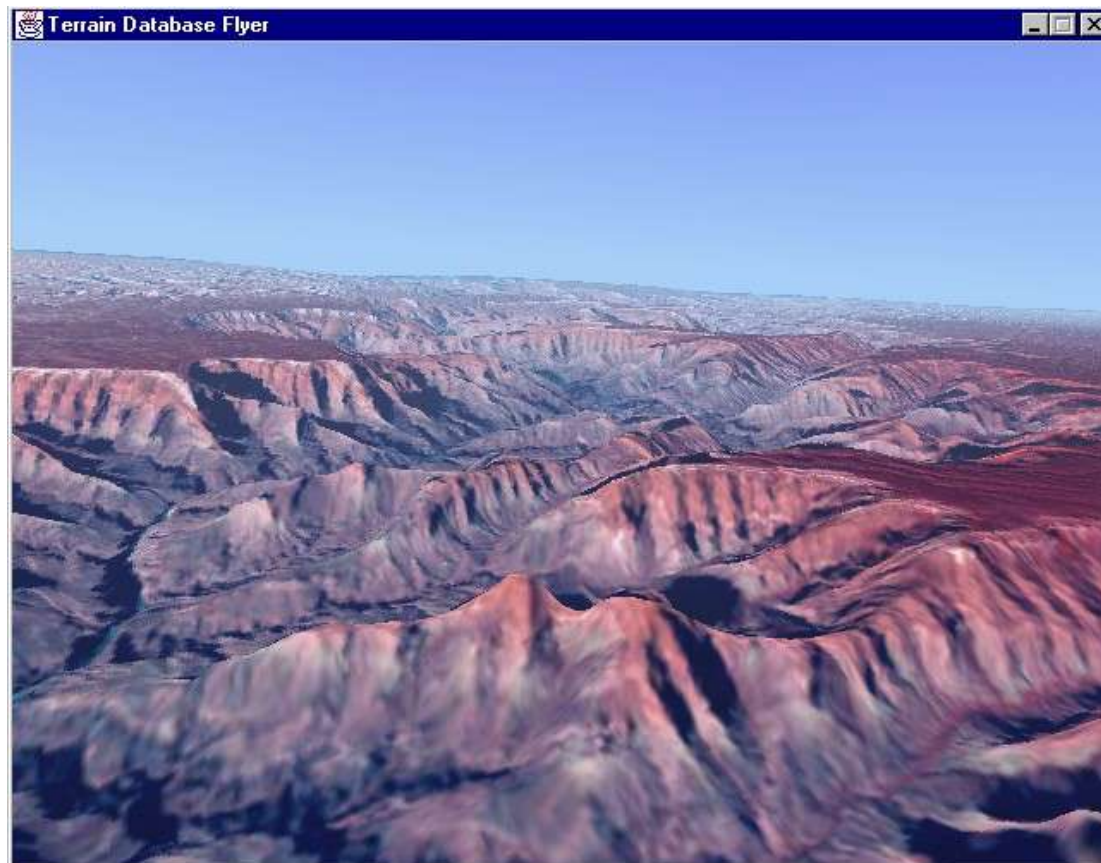
Data organization: Grand Canyon demo

- Very little data stored in Java objects heap
- Plenty of garbage generated, but all short-lived
 - No visible GC pauses
- Shows alternative to earlier programming models in Java language
 - E.g., all data read in to Java objects heap

Optimizing JOGL Applications

Demo

- Grand Canyon demo
 - <http://java.sun.com/products/jfc/tsc/articles/jcanyon/>



Optimizing JOGL Applications

Efficiency

- JNI has a non-zero cost
- All OpenGL routines are necessarily called from the Java programming language through JNI
- Minimize number of OpenGL function calls per frame
- Use vertex arrays and New I/O Float/Double/IntBuffers to store and send down geometric data to OpenGL
 - glVertexPointer, glNormalPointer, glColorPointer

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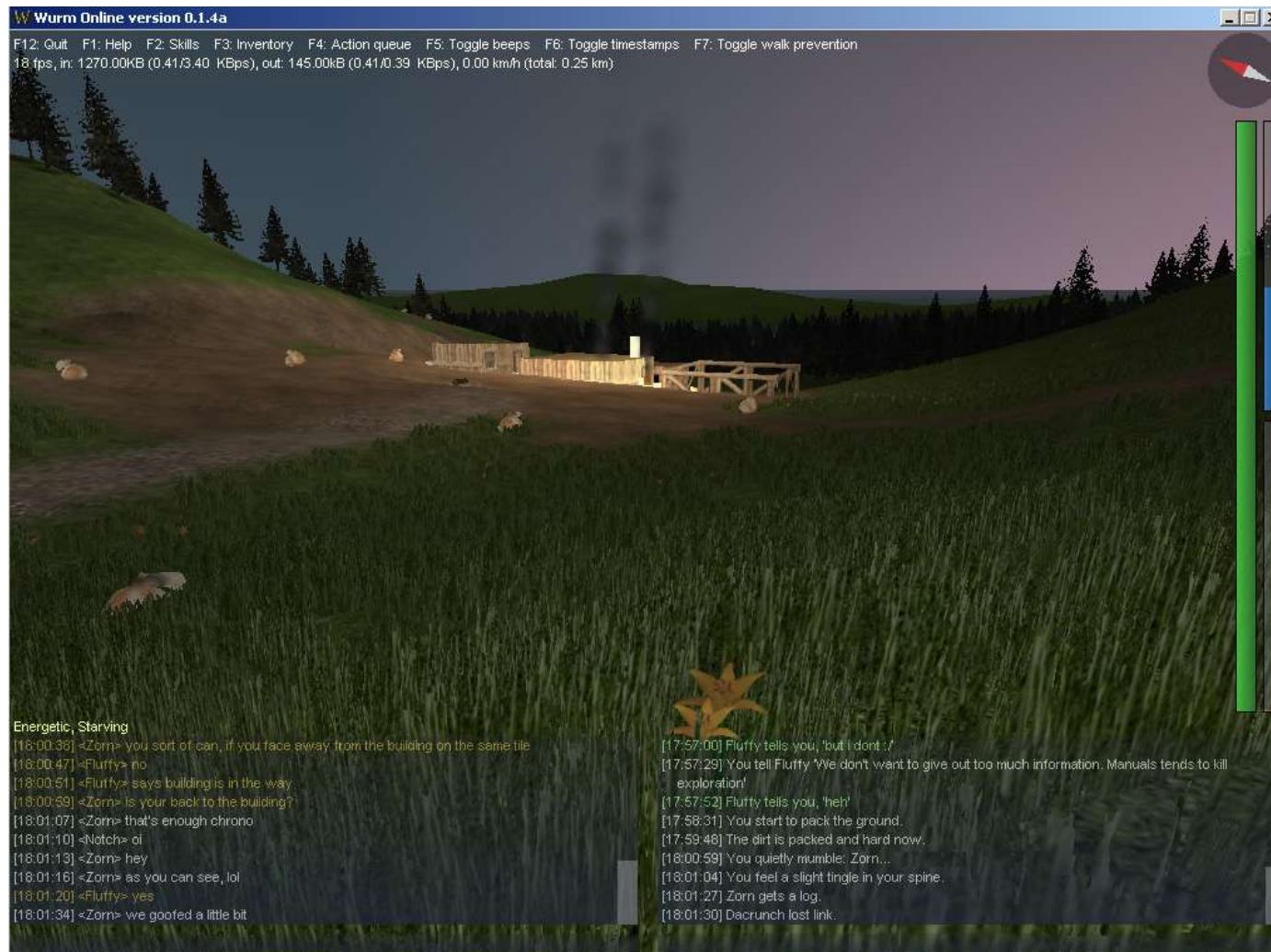
Optimizing JOGL Applications

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Demos

Wurm Online



Demos

Wurm Online

- Being developed by Mojang Specifications
- Fantasy Massively Multiplayer Online Role Playing Game written in Java language using JOGL
- <http://www.wurmonline.com/>

Demos

Max



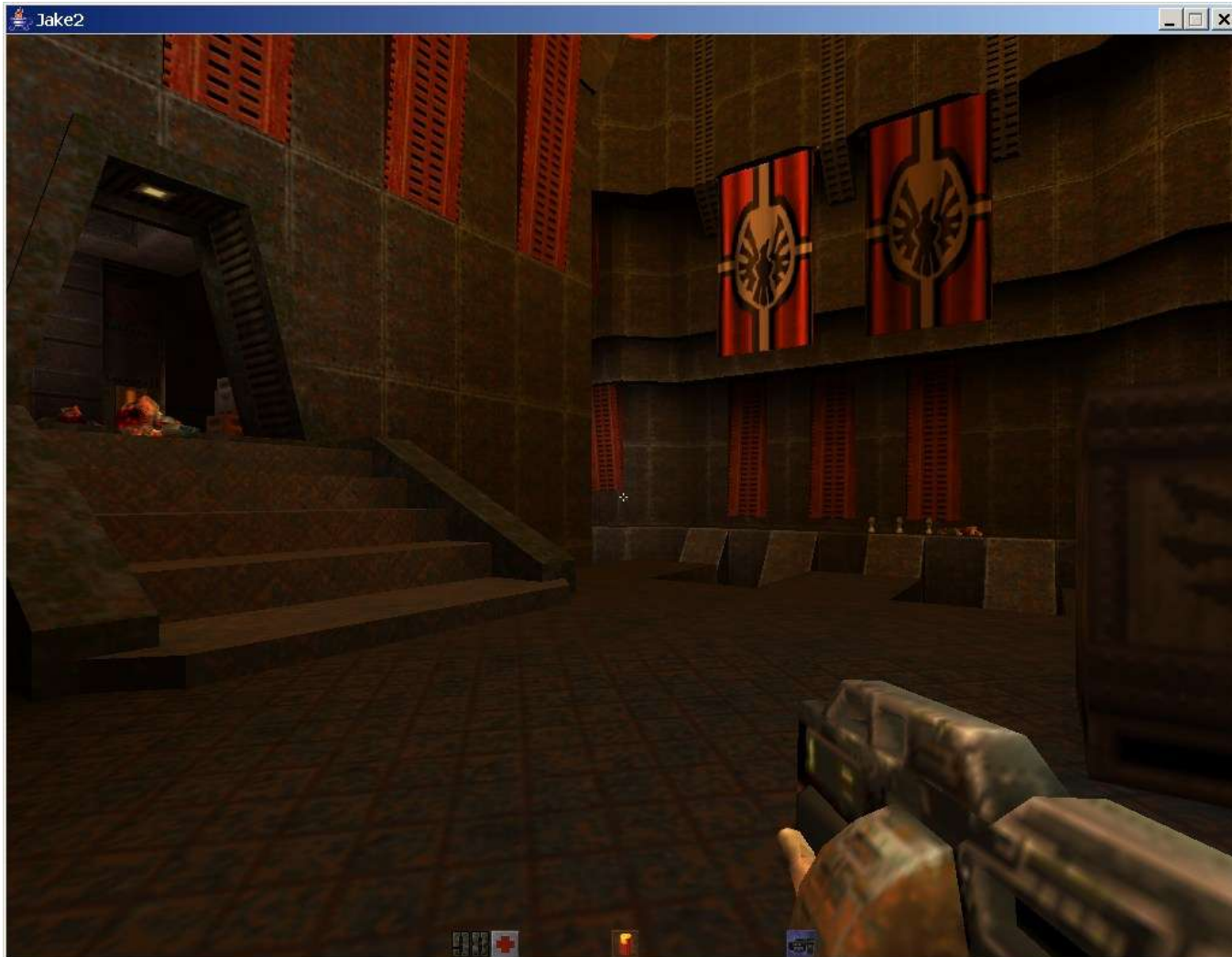
Demos

Max

- Developed by Synthetic Characters Group at The Media Lab, MIT
<http://characters.media.mit.edu/>
- Explores behavior systems that:
 - Support teasing
 - Develop expectations about people they interact with
 - Develop over time, like animals do
- Characters code base written in Java programming language
 - Small pieces of native code to interface to custom input devices

Demos

Jake2



Demos

Jake2

- Port of Quake 2 engine to Java technology and JOGL
- Done by Bytonic Software
<http://www.bytonic.de/>
- Illustrates that Java platform is capable of creating commercial-quality games
- Better than 85% of speed of original C
 - 210 fps compared to 245 fps

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Conclusion

- Java platform and OpenGL 3D API provide the tools to develop leading-edge 3D applications and games
 - High performance, portability, and safety of the Java platform
- JOGL project and JSR 231 / 239 aiming for robust, full-featured, and easy-to-use interfaces to OpenGL
- Open source; join the development community
- Use the Java programming language for your next project

For More Information

- Technical Sessions
 - TS-1338 Desktop Game Development
- BOFs
 - BOF-1241 Meet the Java 2D API Team
 - BOF-1938 Meet the AWT Team
 - BOF-3215 Java 3D API
- URLs
 - <http://jogl.dev.java.net/>
 - <http://community.java.net/games/>

Q&A



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