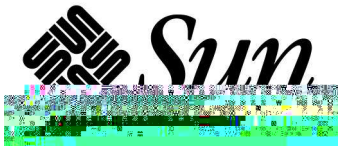
3D Application and Game Development With OpenGL®

Daniel Petersen
Kenneth Russell
Sun Microsystems, Inc.



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

Agenda

Introduction

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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 Process℠ 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 incompatibilies 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

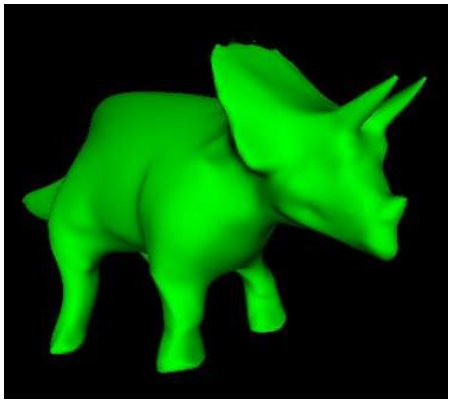
Multithreading

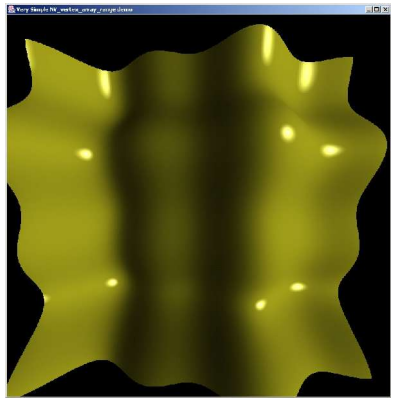
- AWT events like mouse and keyboard events are delivered on AWT event queue thread
- Not allowed / possible to make OpenGL calls directly inside these listeners
  - Though you can schedule or force a redraw
- Instead, pass information between these threads and any animation threads via member data
  - 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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Using JOGL With AWT and Swing

Techniques for Application Development

- Scene graphs and game engines
- Object picking
- Shadows

Optimizing JOGL Applications

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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

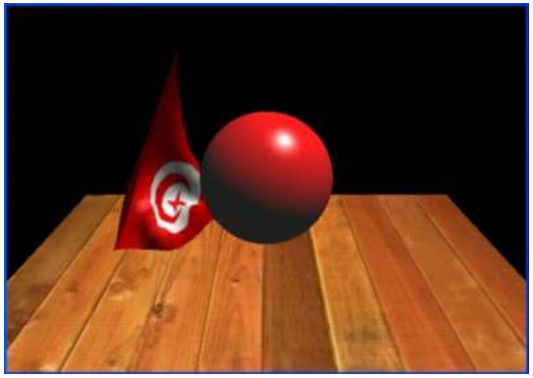
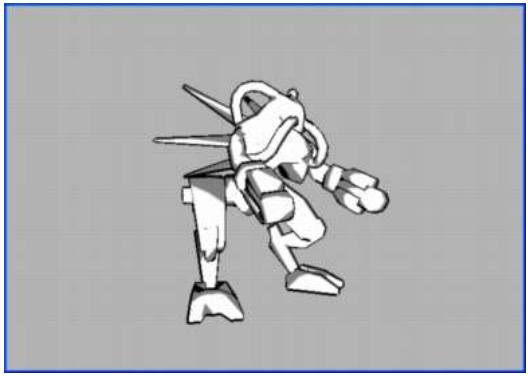
Examples

- 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

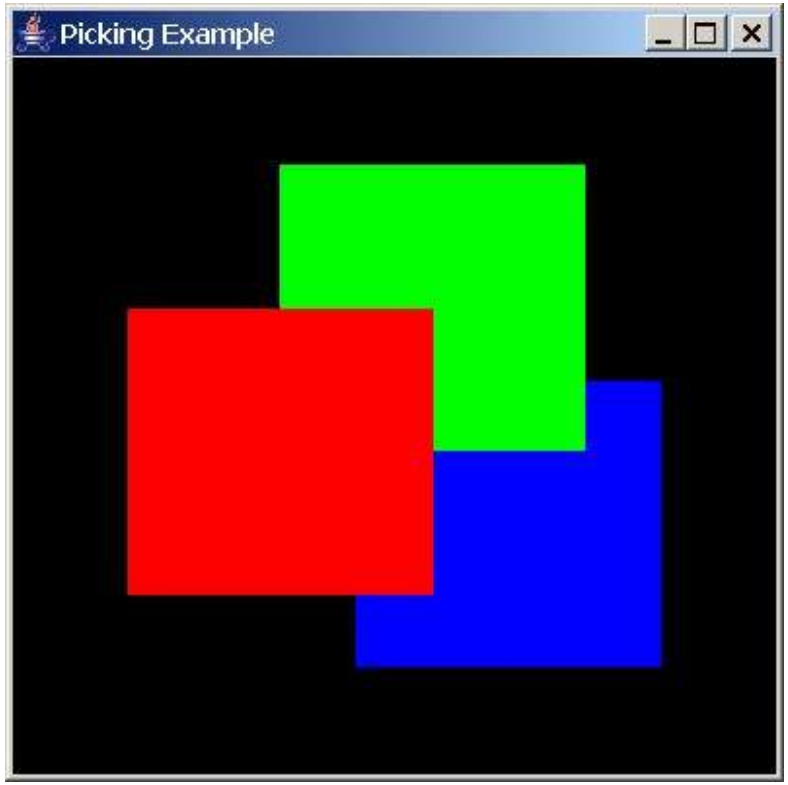
Using the selection buffer

- 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

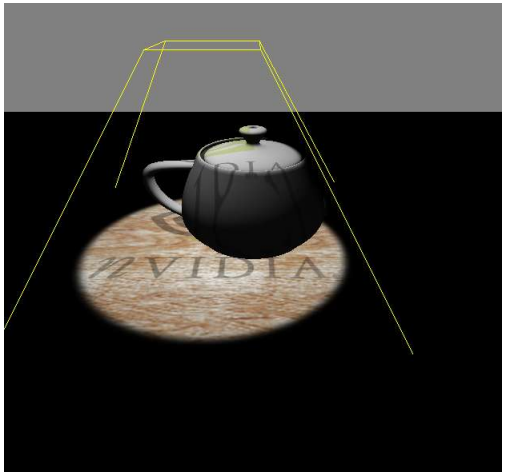
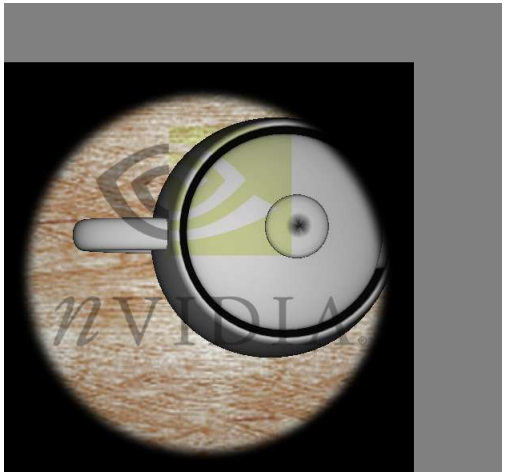
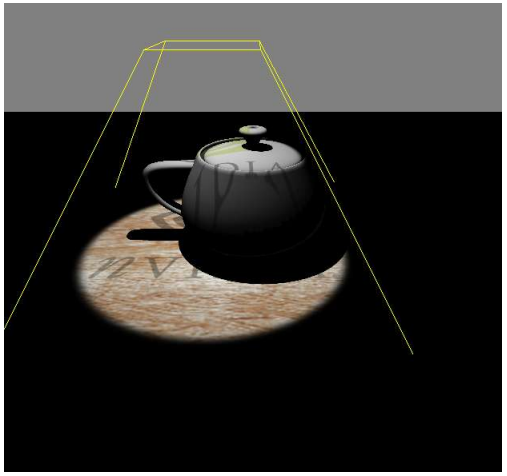
Render-to-texture shadows

- 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

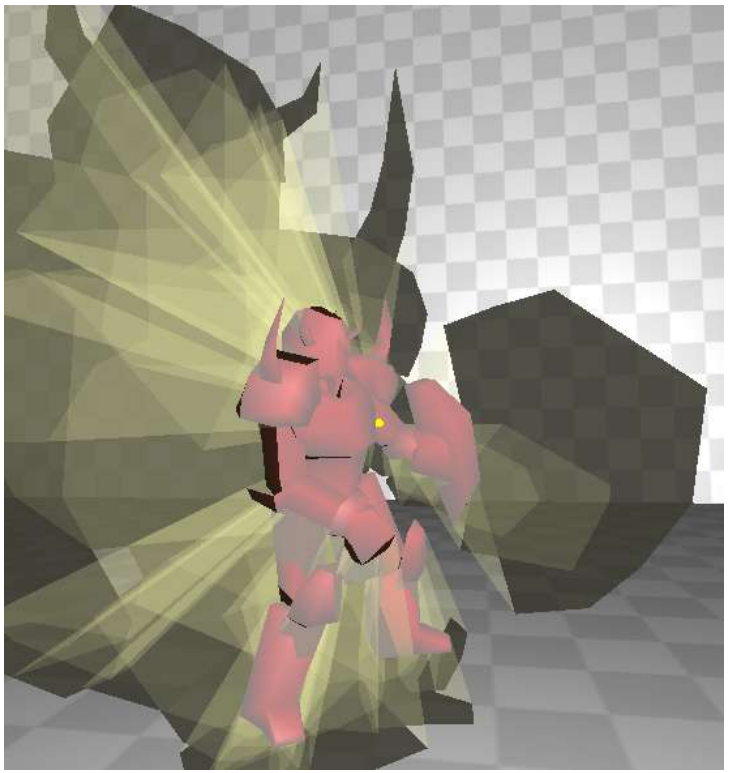
Volumetric shadows

- 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

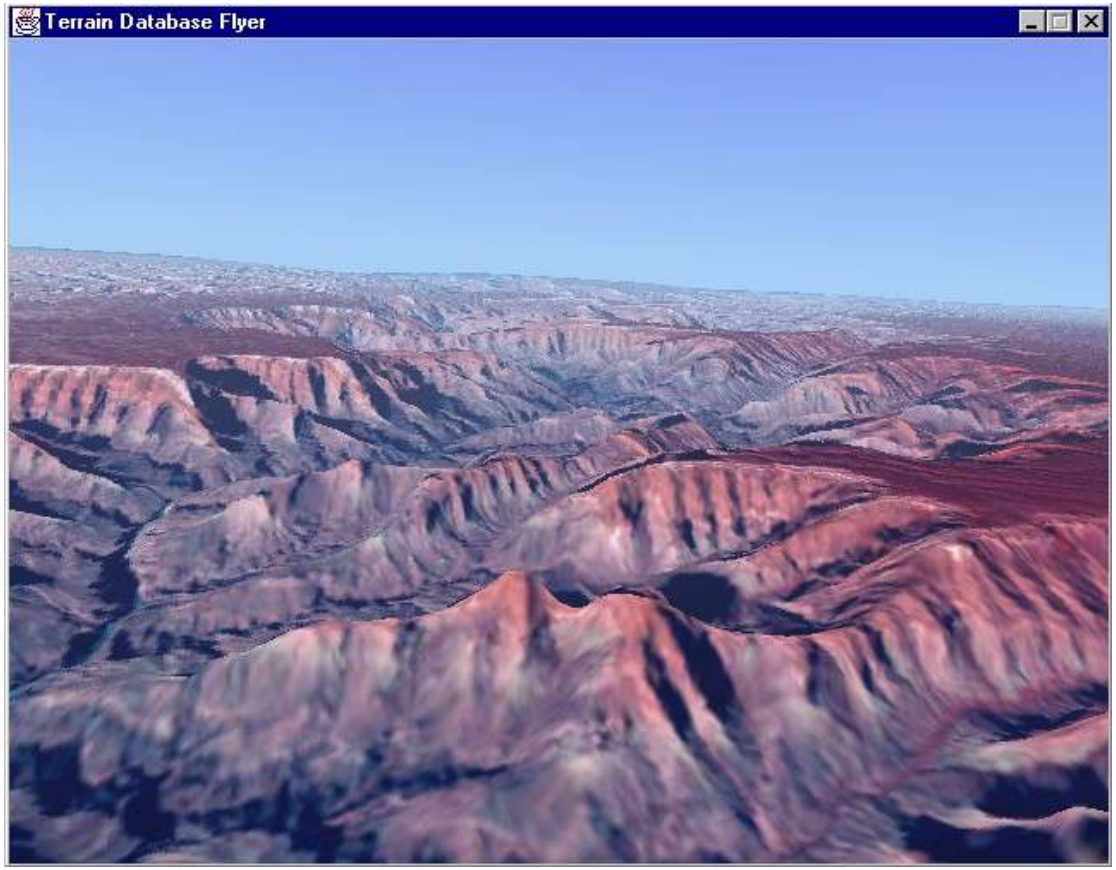
Data organization: Grand Canyon demo

- 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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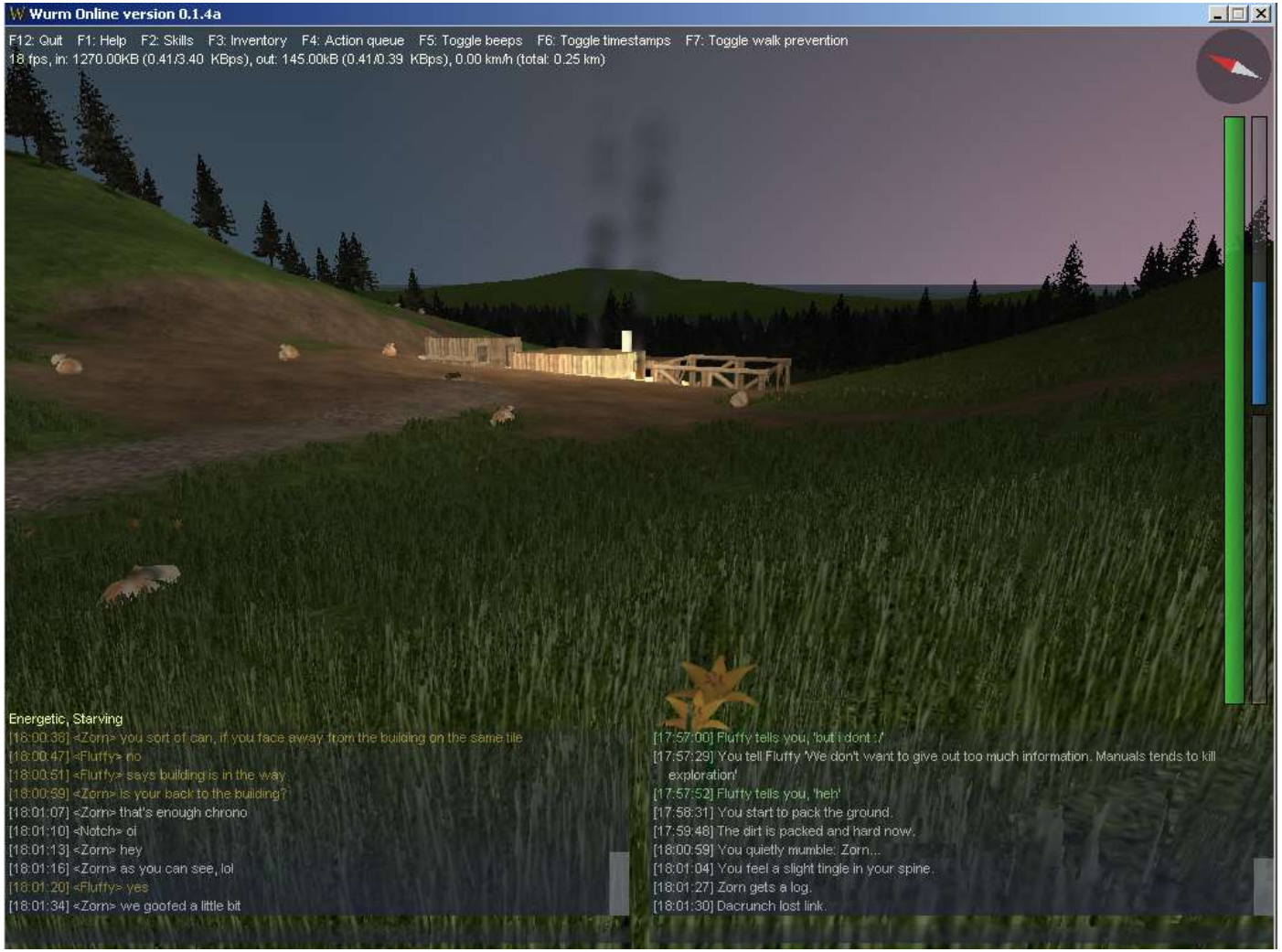
Wurm Online



MOJANG specifications

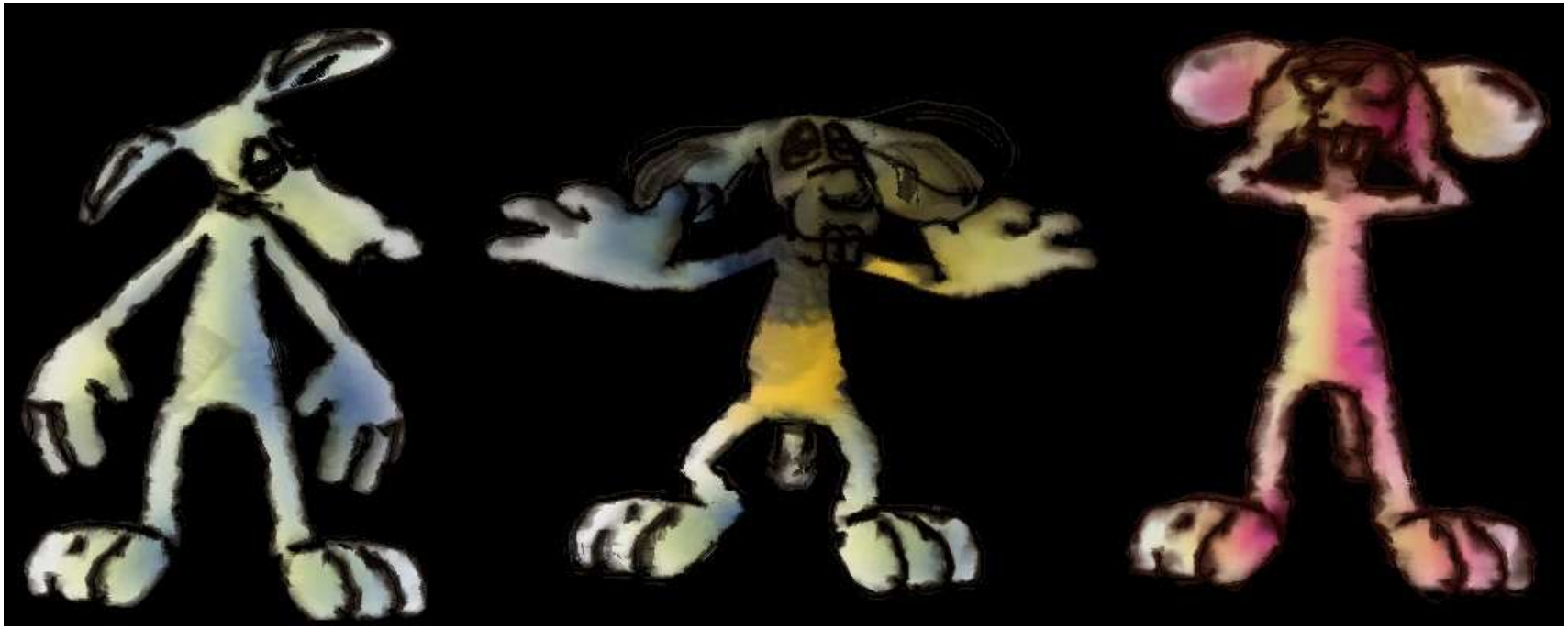
Demos

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



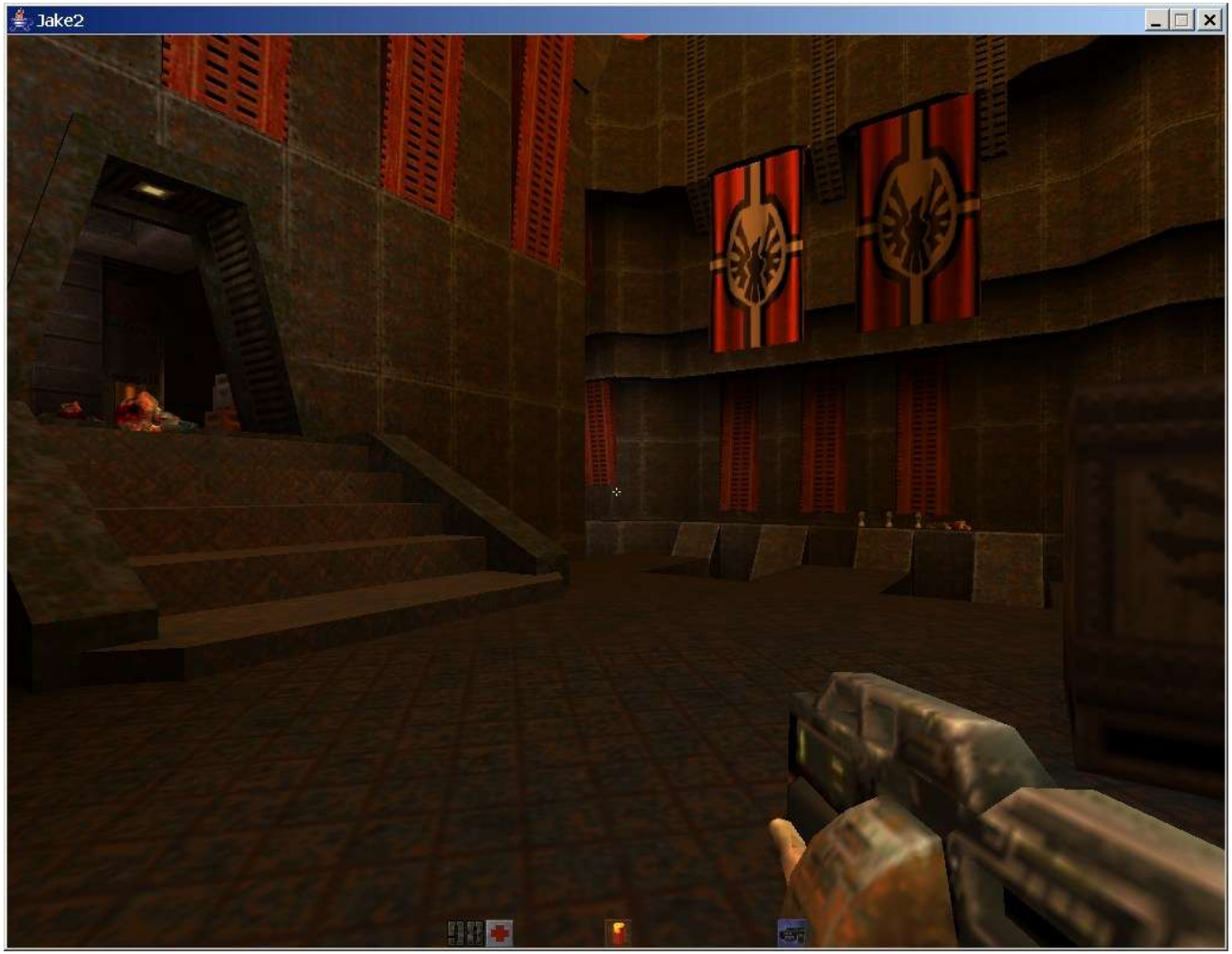
Demos

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



bytonic SOFTWARE

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

3D Application and Game Development With OpenGL®

Daniel Petersen
Kenneth Russell
Sun Microsystems, Inc.