High Performance GUIs

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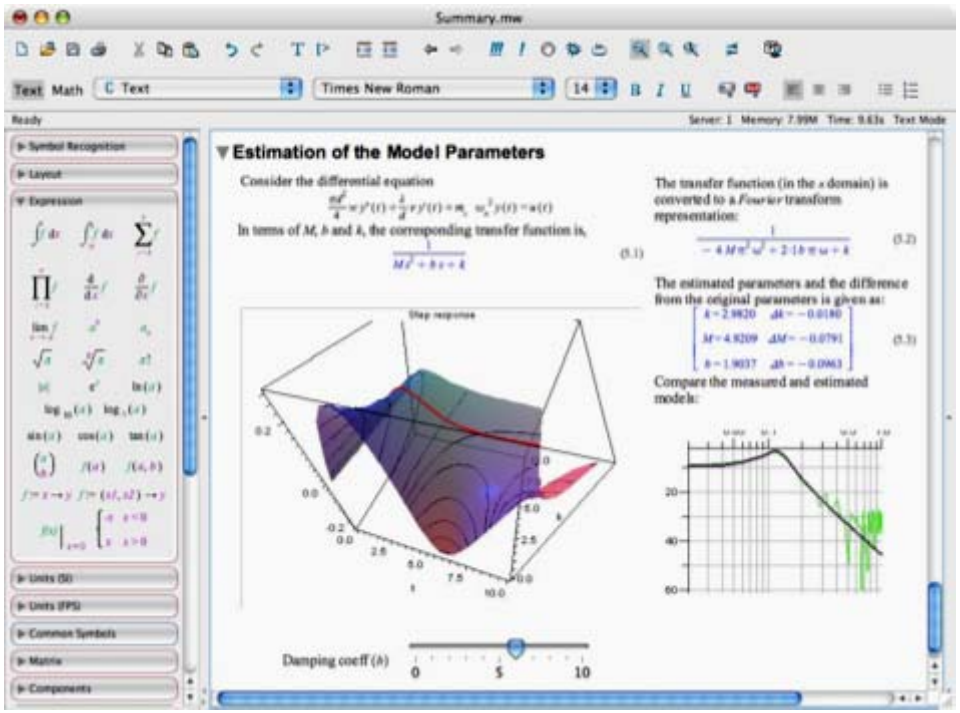
Goal

To explore the inner workings of the graphics API and demonstrate strategies for optimizing the performance of a graphical user interface

Solid Performance Is Possible in Java™ Technology



Maple 10 Worksheet

Agenda

Overview of the Graphics API

Graphics Pipeline

Graphics Primitives and Tools

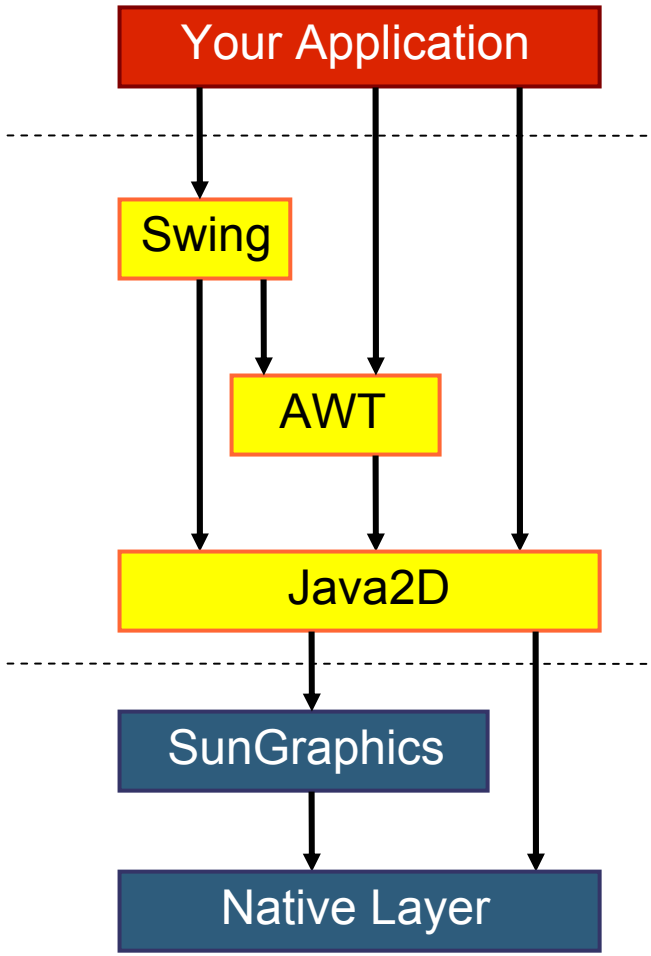
Optimization

Demo

Summary

Overview of the Graphics API

- Interact with several layers of the graphics API
- Design choices at higher levels can affect performance at lower levels
- Bottom two layers are vendor specific



Overview of the Graphics API

- At what level should I be focusing my optimization efforts?

Overview of the Graphics API

- At what level should I be focusing my optimization efforts?
  - Depending on the application, all levels may be important
    - Swing: Optimize object creation
      Set rendering flags
    - AWT: Optimize event handling
    - Java2D: Direct control over object rendering
      Graphical underpinnings to Swing and AWT

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Graphics Pipeline

- Graphics and Graphics2D are interfaces
- Vendor specific implementations for onscreen rendering
- Some optimizations are not cross-platform
  - Notable differences in Sun and Apple implementation of text and antialiasing support

Evolution of the Graphics Pipeline

- J2SE™ 1.4
  - Improved data sharing across pipelines
  - Hardware acceleration for offscreen images
  - Pluggable image I/O framework
  - OpenType fonts
- Java™ SE 6
  - Improved text antialiasing
  - Single-threaded rendering
  - Curved primitive rasterization
- J2SE™ 1.5
- Hardware acceleration using OpenGL
  - Text rendering performance
  - Improved font handling

Graphics Pipeline

- Ideally, built-in optimizations would provide necessary performance
- In reality, further optimizations are sometimes required to reduce the burden on the graphics pipeline

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Graphics Primitives and Tools

- Graphics
  - Lines
  - Polylines
  - Circles
  - Arcs
  - Text
  - Image
  - Clipping
  - Affine transforms
- Graphics2D
  - Shape
  - Composite
  - Rendering hints

Graphics Primitives and Tools

- Graphics2D offers more flexibility
- Greater choice → More ways to address performance issues
  → More potential for suboptimal solutions
- "Ockham's Razor"
  - Given a choice of two equally valid alternatives, take the simpler one

Ockham's Razor: Example

- How many ways are there to draw rectangles?

Ockham's Razor: Example

- How many ways are there to draw rectangles?
  - 1) Use java.awt.Rectangle
    - Advantages
      - Simple
      - Fast
      - Flexibility of shape API
    - Disadvantage
      - Possible loss of precision under transformation

Ockham's Razor: Example

- How many ways are there to draw rectangles?
  - 2) Use java.awt.geom.Rectangle2D
    - Advantages
      - Maintain floating point precision
      - Fast
      - Flexibility of Shape API

Ockham's Razor: Example

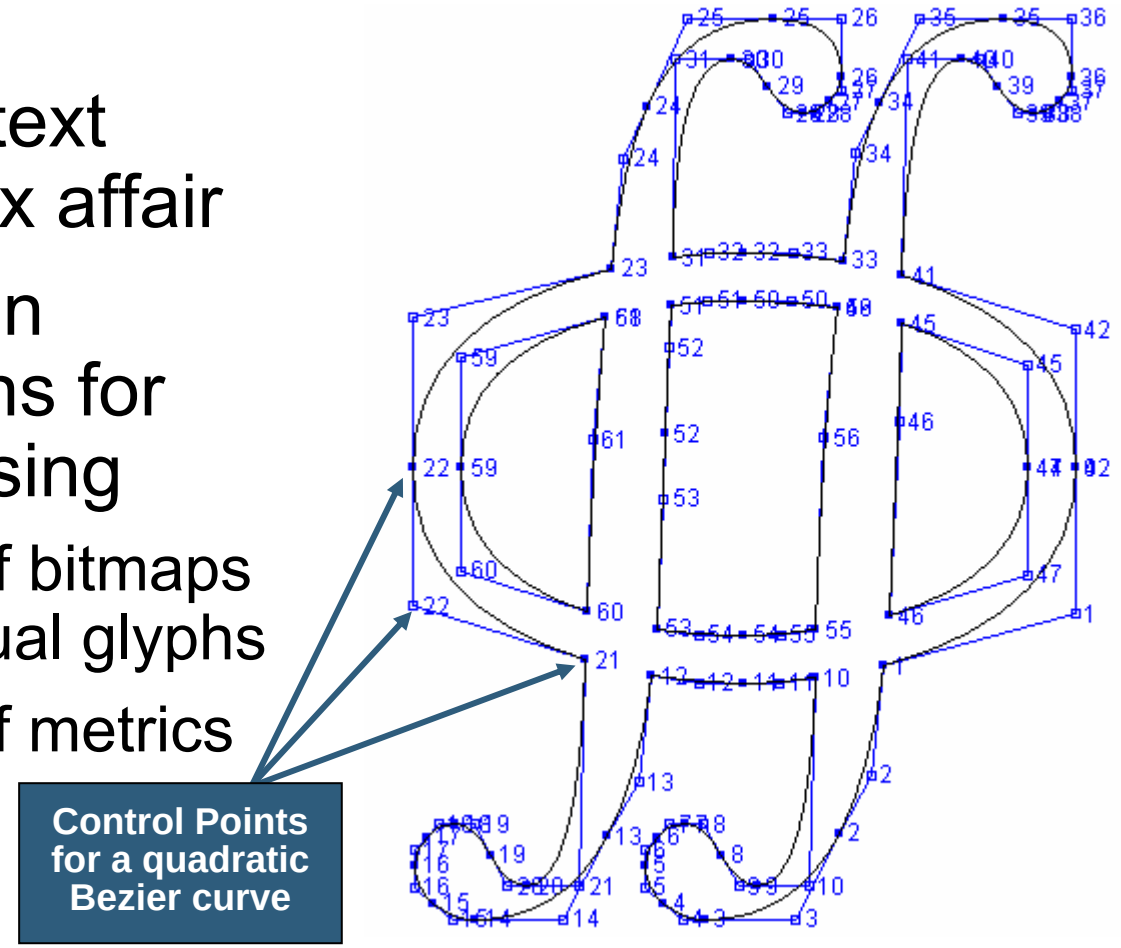
- How many ways are there to draw rectangles?
  - 3) Use java.awt.geom.GeneralPath
    - Advantage
      - Very general solution
    - Disadvantages
      - Computational complexity
      - Filling a general polynomial is much more expensive than filling a rectangle: often requires vertex sorting, winding rules…

Ockham's Razor: Example

- How many ways are there to draw a rectangle?
  - 4) Use java.awt.BasicStroke
    - WARNING: Kludge alert!!!
    - Bookkeeping to determine intersection with the clip boundary is more complex
    - Rendering algorithm is less efficient
    - Coordinates become awkward

Managing Graphics Complexity

- Rendering text is a complex affair
- Many built-in optimizations for text processing
  - Caching of bitmaps for individual glyphs
  - Caching of metrics



Control Points for a quadratic Bezier curve

Caching Tips

- Consider using cached images for repetitive non-trivial glyphs
- Consider caching size information to avoid unnecessary recalculation
  - General path iterates over the path to construct the bounds
  - Expensive if done repeatedly
- Cache = Managed Memory Leak
  - Avoid overuse
  - MRU cache
  - Weak reference

Tips for Repainting

- Consider one of the following approaches to facilitate tracking “dirty” shapes
  - Apply transform to shape rather than graphics context
  - Maintain rectangle for bookkeeping which is inverse transform applied to clip region
    - Quick mechanism for testing overlap with clip region
    - Bookkeeping in same coordinate space as shapes
- Painting a shape outside the clip region is not free
- **Don’t paint what you don’t have to!**

Computing the Inverse Transform

- Transform

$$\begin{bmatrix} x' \\ y' \\ 1 \end{bmatrix} = \begin{bmatrix} m_{1,1} & m_{1,2} & m_{1,3} \\ m_{2,1} & m_{2,2} & m_{2,3} \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} x \\ y \\ 1 \end{bmatrix}$$

- Inverse

$$\begin{bmatrix} x \\ y \end{bmatrix} = \frac{1}{\lambda} \begin{bmatrix} m_{2,2} & -m_{1,2} \\ -m_{2,1} & m_{1,1} \end{bmatrix} \begin{bmatrix} x' - m_{1,3} \\ y' - m_{2,3} \end{bmatrix}$$

$$\lambda = m_{1,1} \cdot m_{2,2} - m_{2,1} \cdot m_{1,2}$$

Rendering Hints

- Control over rendering behavior
  - Antialiasing on/off
  - Choice of interpolation algorithms
  - Render speed versus quality
- Tips
  - Consider turning off anti-aliasing for a moving object (e.g., scrolling or animation)

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Optimization

- Best strategy is application dependent
- Some are very easy to implement
- More detailed optimizations include
  - Intermediate Image
  - Spatial partitioning
  - Dynamic algorithms

Intermediate Image

- Speed versus memory tradeoff
- Often faster to render an image than a collection of objects

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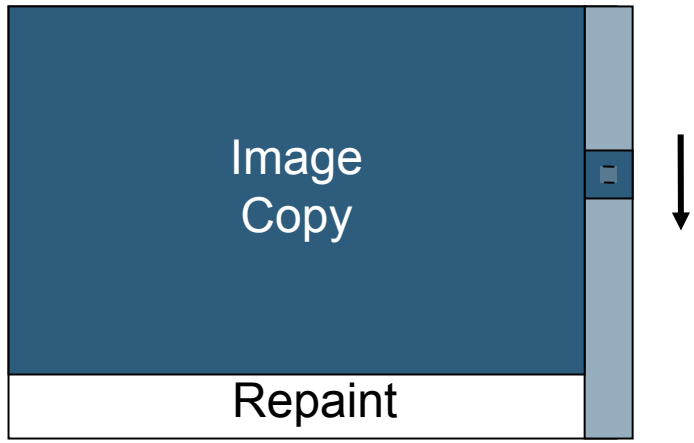
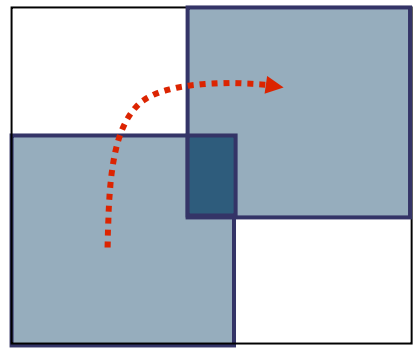
- Used by one of the scroll modes built into JViewport (BACKINGSTORE_SCROLL_MODE)
- Note: There is a more efficient mode based on copyArea (BLIT_SCROLL_MODE)



Using Intermediate Images

- Also useful in editing operations
- Create an intermediate image
  - Component without object being edited
- Component's paint renders image and overlays object



Dragging an object

Creating the Image

```
GraphicsConfiguration config =
    component.getGraphicsConfiguration();
image = config.createCompatibleImage( w, h );
```

Paint Implementation

```
public void paint( Graphics g) {
  if( image == null && useImage ) {
    image = createImage();
    Graphics imageg = image.createGraphics();
    drawContents( imageg );
    imageg.dispose();
  }
  if( image != null ) {
    g.drawImage( image, 0, 0, w, h,
      0, 0, w, h, Color.WHITE, null );
  } else {
    drawContents( g );
  }
  // additional painting not in drawContents
}
```

Bookkeeping

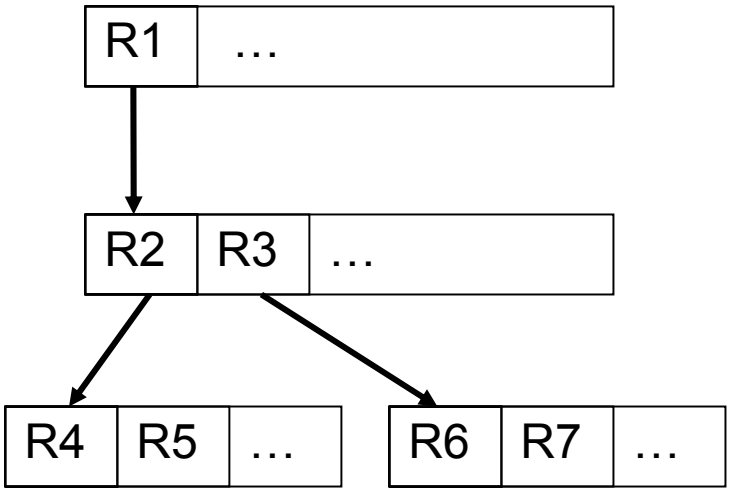
- Set image to null on a component resize to force recreation in next paint call
- For large documents, it may be necessary to discard offscreen images to save memory
- MRU and weak references may be used to help manage memory consumption

Spatial Partitioning

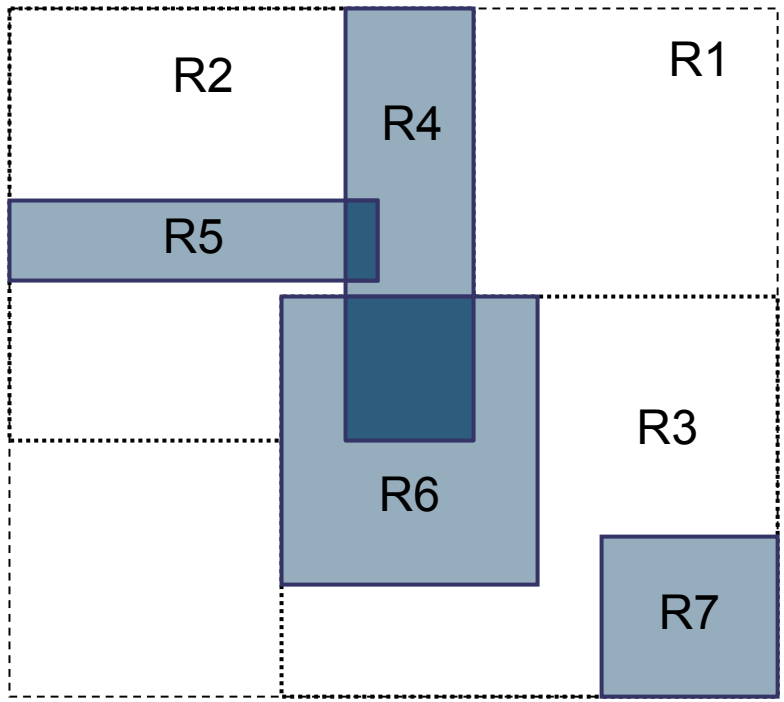
- Hierarchal organization of objects based on onscreen position
- Paint only what is necessary

```
Set N = root node
  if N intersects clip region
      if N is a branch node
          for each child in N
              recurse into child
      else
          paint leaf node
```

Spatial Partitioning



R*-tree decomposition



DEMO

Summary

- Solid performance is achievable for a graphics rich Java™ based application
- Optimization strategies built into the graphics API offer hints at how to solve related performance problems
- Useful strategies include
  - Intermediate Images
  - Spatial decomposition

For More Information

- A Scrolly, Clippy Swing Optimization
  - http://www.oreillynet.com/pub/wlg/9144?wlg=yes
- R*-Tree decompositions
  - http://www.sai.msu.su/~megera/postgres/gist/papers/Rstar3.pdf
- TS-3690 Handwriting recognition
- Demo
  - http://www.desktopjava.com

Q&A

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