Core Animation in Practice

Part 2

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Goal of This Session

To dive deeper into Core Animation

What You'll Learn

- New and overlooked APIs
- Mental model of CA performance
- High-DPI details

Selected APIs

Drop Shadows

- Shadows provide crucial depth cues in 2D user interfaces
- iPhone OS 3.2 supports the full set of CALayer shadow APIs
- New API for more efficient shadows
  - @property CGPathRef shadowPath
- Defines the opaque region of the layer
- Lets the compositor cache a shadow bitmap

Shadow Example

```
CALayer *sublayer = [CALayer layer];
sublayer.bounds = sublayer_bounds;
sublayer.backgroundColor = random_color();
```

```
sublayer.shadowOpacity = shadowsEnabled ? .5 : 0;
sublayer.shadowRadius = 10;
sublayer.shadowOffset = CGSizeMake(0, 10);
```

```
CGPathRef shadowPath
  = [UIBezierPath bezierPathWithRect:sublayer_bounds].CGPath;
sublayer.shadowPath = pathEnabled ? shadowPath : nil;
```

Shape Layers

- Most layers use bitmaps to provide their content
  - Doesn't scale well, doesn't animate well
- Use a CAShapeLayer with path for scalable/animatable content
- Performance tradeoffs
  - Uses little memory
  - Uses more CPU to render
  - No cost for transparent areas
- Best for a few large elements

Arrows Example

```
CGPathRef path0 = random_arrow();
CGPathRef path1 = random_arrow();
```

```
CGRect shape_bounds
 = CGRectUnion(CGPathGetBoundingBox(path0),
               CGPathGetBoundingBox(path1));
```

```
CAShapeLayer *sublayer = [CAShapeLayer layer];
sublayer.fillColor = random_color();
sublayer.position = random_point(…);
sublayer.bounds = shape_bounds;
```

Arrows Example

```
CABasicAnimation *anim
 = [CABasicAnimation animationWithKeyPath:@"path"];
```

```
anim.fromValue = (id)path0;
anim.toValue = (id)path1;
```

```
anim.duration = random_float() * 3 + 1;
anim.timingFunction = [CAMediaTimingFunction
functionWithName:kCAMediaTimingFunctionEaseInEaseOut];
anim.autoreverses = YES;
anim.repeatCount = HUGE_VAL;
```

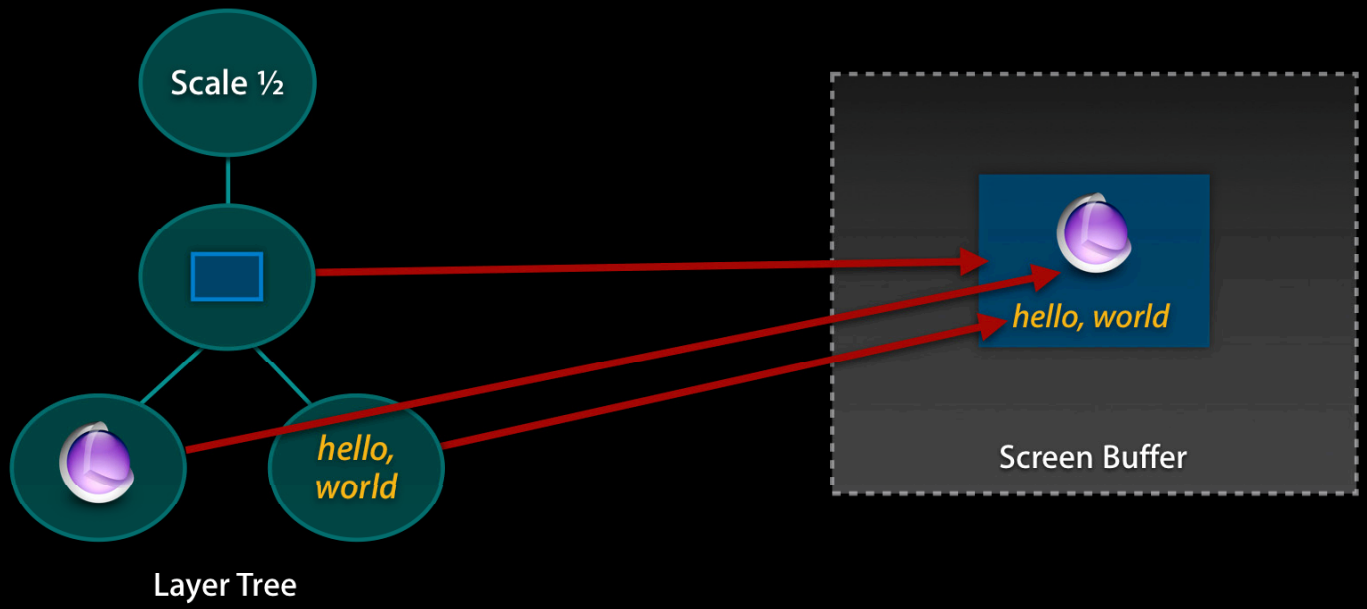
```
[sublayer addAnimation:anim forKey:nil];
```

Bitmap Caching

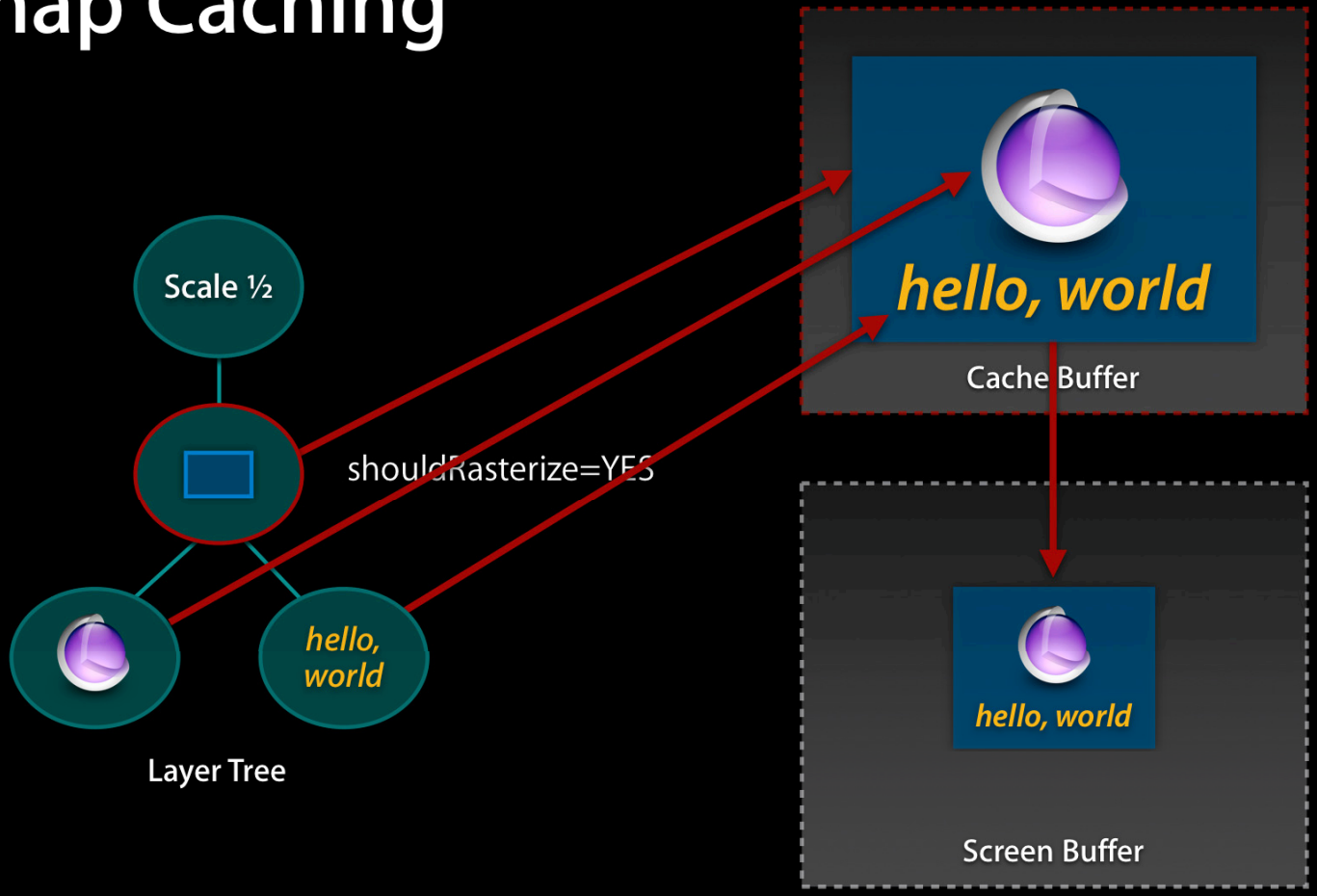
iPhone OS 3.2 or later

- Animated UIs on embedded devices can be challenging
- Can now request that a layer subtree is flattened to a bitmap
  - layer.shouldRasterize = YES
- Bitmap version will be reused when possible
  - May significantly improve performance

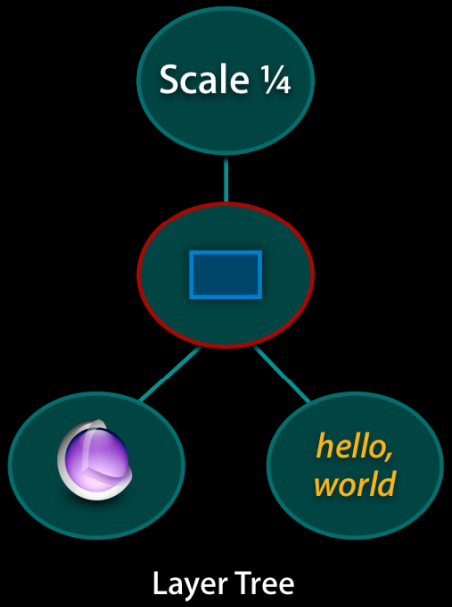
Bitmap Caching

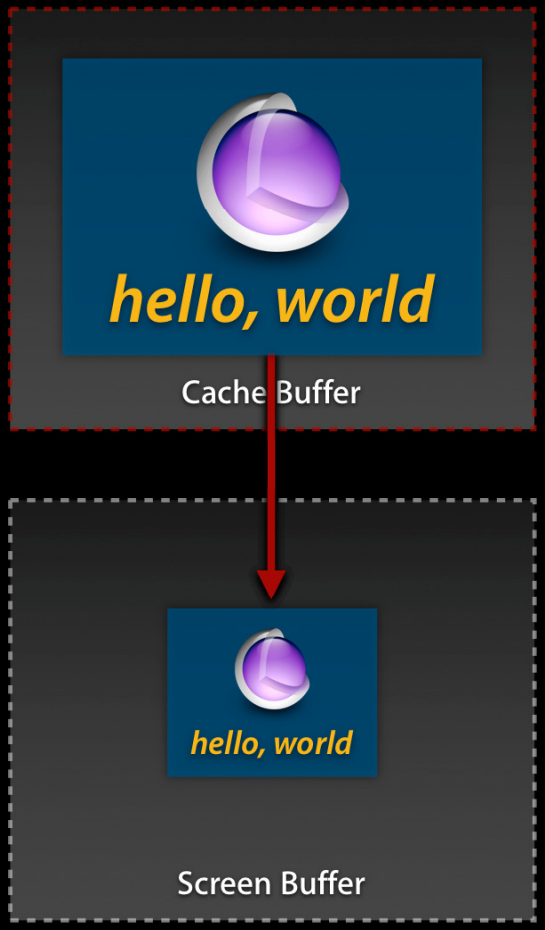


Bitmap Caching



Bitmap Caching





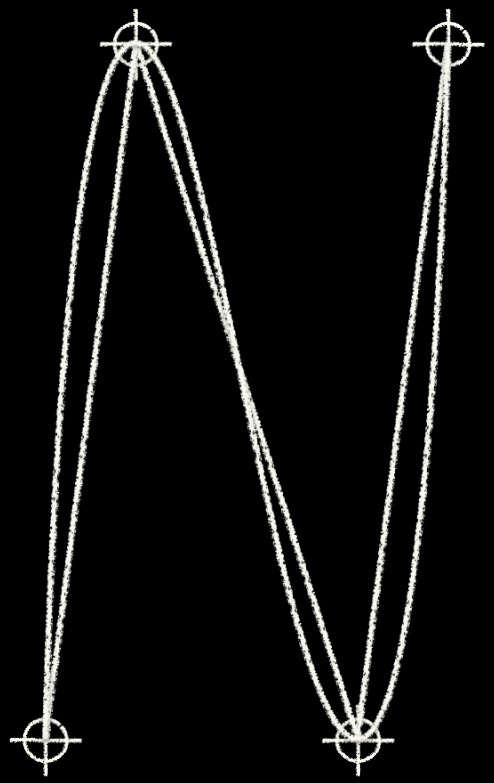
Bitmap Caching Caveats

- Devices are memory-challenged, so cache space is limited
- Caching and not-reusing is more expensive than not caching
- Rasterizing locks the layer image to a particular size
- Rasterization occurs before the mask is applied

Cubic Keyframe Interpolation

iOS 4

- Keyframe animations move properties through multiple points
- Smooth curves need timing functions or a path
- iOS 4 adds new calculation modes
  - anim.calculationMode = kCAAnimationCubic
- Will interpolate continuously through all points
  - Catmull-Rom spline, but you can customize this



Animation Functions

- Animating layer rotation has been problematic
  - Using “transform” property—angle is modulo 360°
  - Using “transform.rotation.z” property—Euler angle issues
- CAPropertyAnimation now has a valueFunction property
  - Animated property is set to a function of the interpolated value
  - layer.transform = *makeRotationMatrix*(t), where t ∈ [0…2π]

Animation Functions

```
CABasicAnimation *anim
 = [CABasicAnimation animationWithKeyPath:@"transform"];
```

```
anim.fromValue = [NSNumber numberWithDouble:0];
anim.toValue = [NSNumber numberWithDouble:2*M_PI];
```

```
anim.valueFunction
 = [CAValueFunction functionWithName:kCAValueFunctionRotateZ];
```

```
anim.duration = 2;
[layer addAnimation:anim forKey:nil];
```

Animation Completion

- Animations created explicitly can use a delegate
- Implicit animations can use a block

```
[CATransaction setCompletionBlock:^{
    // block that runs when animations have completed
    [CATransaction setDisableActions:YES];
    [layer removeFromSuperlayer];
}];
```

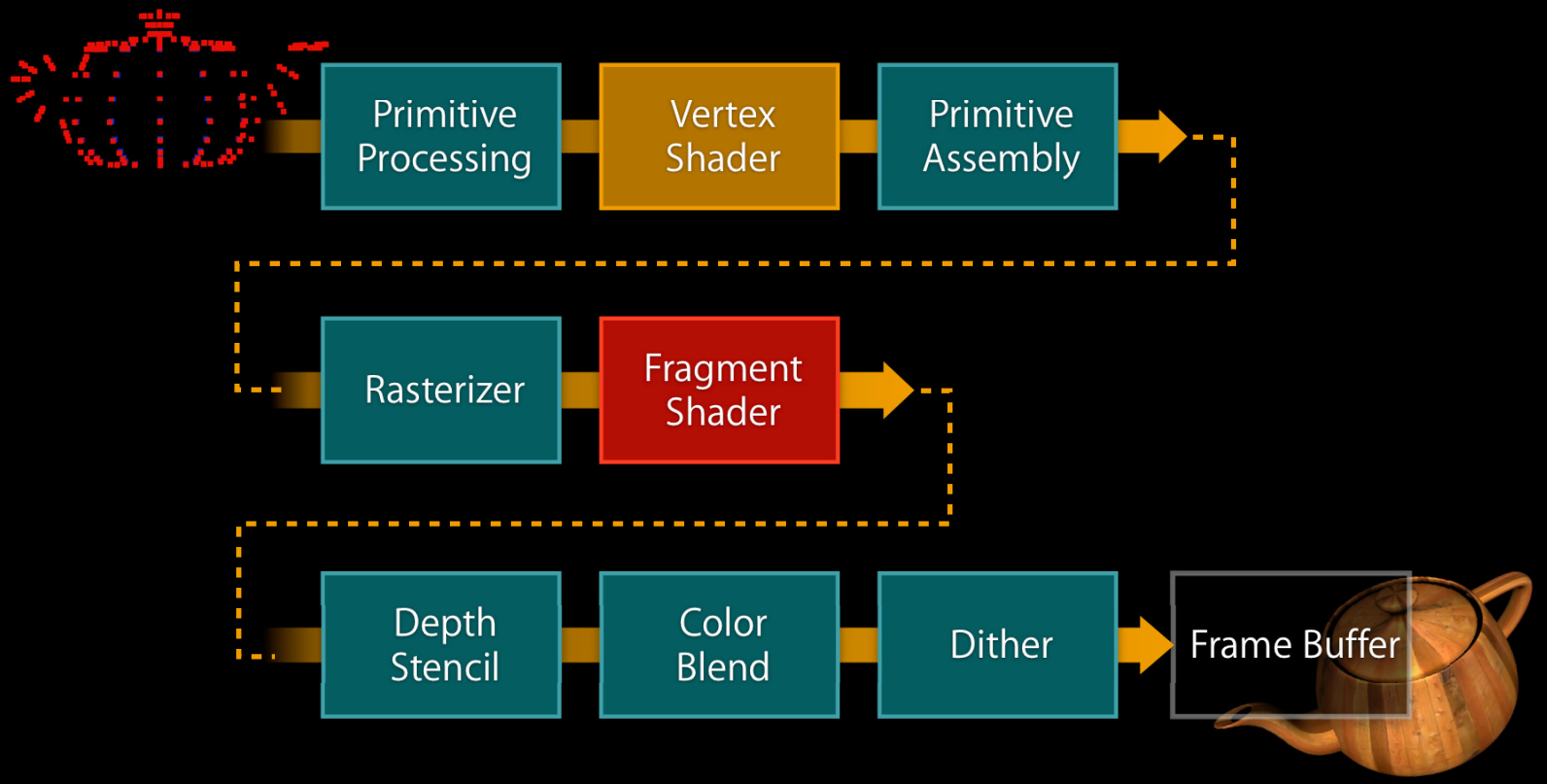
```
layer.opacity = 0;
layer.position = CGPointMake (2000, layer.position.y);
```

Summary

- Use shadowPath for high-performance shadows
- Use CAShapeLayer for scalable, animatable vector content
- Use shouldRasterize=YES for cached layers

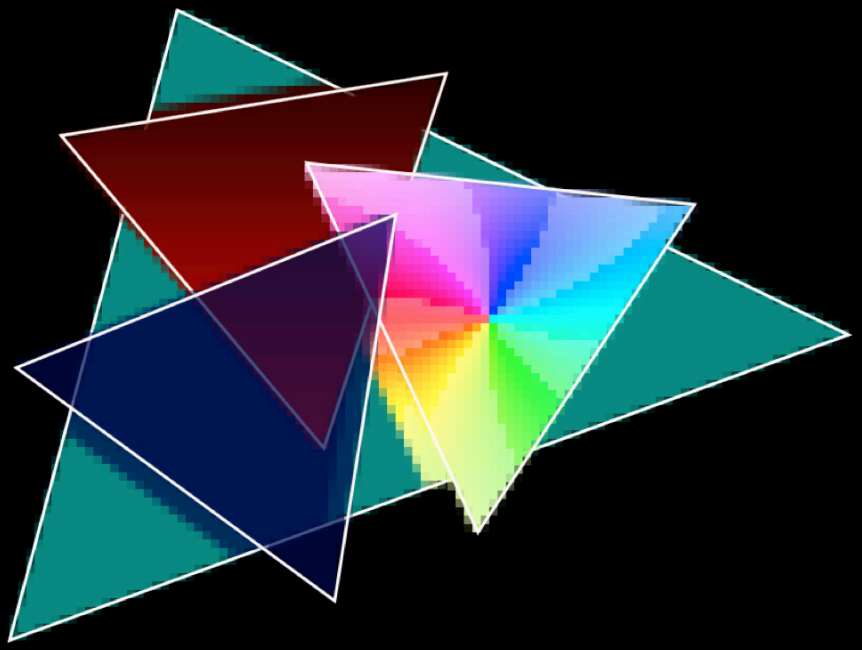
Performance

How Do GPUs Work?



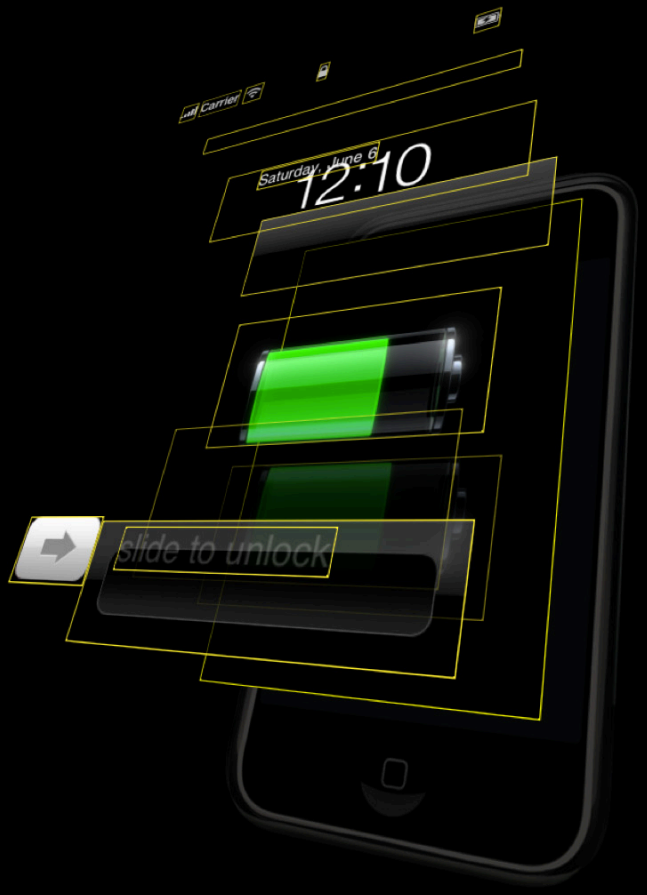
How Do GPUs Work?

- GPU converts triangles to pixels
  - Each is filled with a color or image
  - Each can “blend” over background
- Destination can also be an image



How Do We Use the GPU?

- CA translates your layers into triangles
  - "backgroundColor" is two colored triangles
  - "contents" is two triangles with an image
- Cached or masked layers draw offscreen
- Areas under opaque regions are ignored



GPU Performance Model

- What are the costs?
  - How many destination pixels?—Write bandwidth
  - How many source pixels?—Read bandwidth
  - How many buffers?—Rendering passes
- Too much non-opaque content → limited by write bandwidth
- Too many large images → limited by read bandwidth
- Too many masked layers → limited by rendering passes

Demo

Write Bandwidth

- Minimize alpha-blended pixels
- Use “Color Blended Layers” option, or CA_COLOR_OPAQUE=1
- Ensure opaque CGImageRef’s have no alpha channel
  - Set “layer.opaque = YES” for layers that draw opaque content
- Cut layers with opaque regions into multiple sublayers

Read Bandwidth

- Use images that match screen resolution
  - e.g., don't use 1024x768 image for 200x150 layer
- Use "Color Misaligned Images" option, or CA_COLOR_SUBPIXEL=1

Rendering Passes

- Ideally one rendering pass per frame
- Complex compositing features often require multiple passes
  - Masking, group opacity, filters
- Use "Color Offscreen" Instruments option, or CA_COLOR_OFFSCREEN=1
- Layer bitmap caching can hide extra passes
  - Unless the cached subtree changes during the animation!

Summary

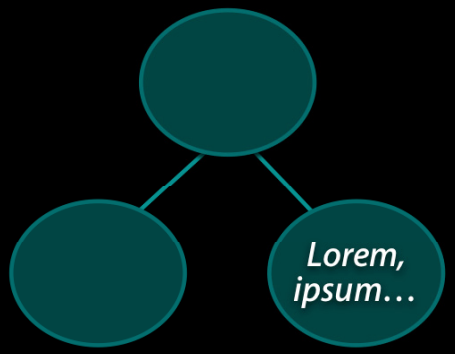
- Performance optimization algorithm

  while (fps < 60)
  - Eliminate rendering passes
  - Reduce read bandwidth
  - Reduce write bandwidth

High DPI

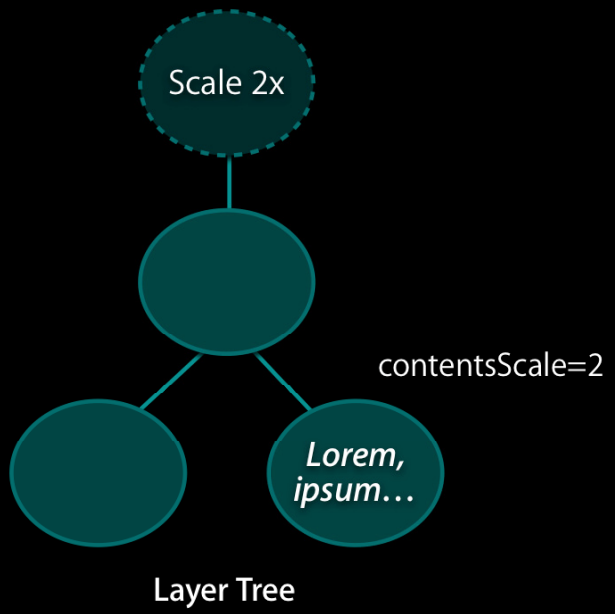
High DPI Content

iOS 4



Layer Tree

High DPI Content



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320
460

High DPI Content

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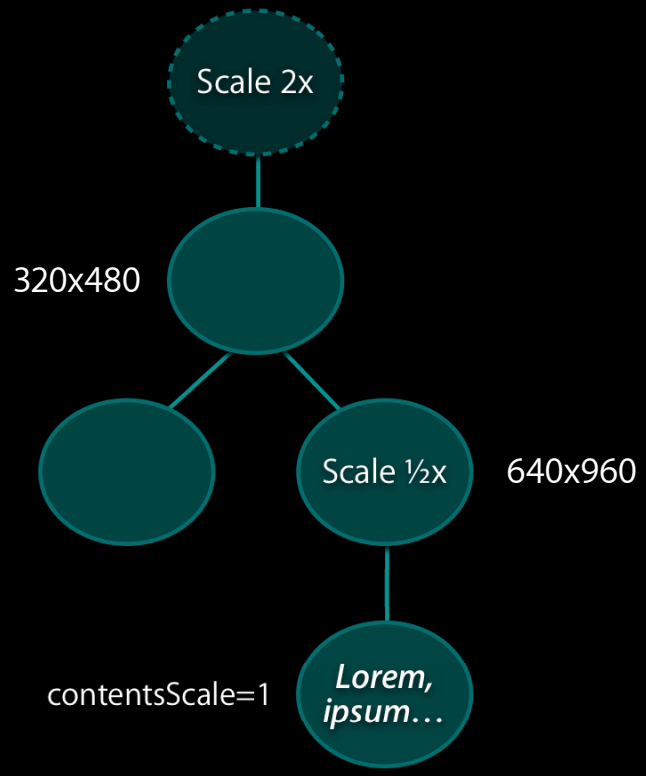
460

620

Native Pixels



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960

640

High DPI Summary

- 2x scale factor applied to your UIWindow
  - All your view geometry remains relative to 320x480
  - Use contentsScale=2 for screen-resolution content
  - When rasterizing layers, layer.rasterizationScale=2
- To get back to the native 640x960 viewport
  - Use a scale=½ matrix to cancel the implicit scale=2 matrix

Wrap-Up

Summary

- Use shadowPath whenever possible
- Use shouldRasterize whenever necessary
- Consider what your layers mean to the GPU

More Information

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Mailing List
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Documentation
http://developer.apple.com/graphicsimaging/coreanimation/

Apple Developer Forums
http://devforums.apple.com

Related Sessions

Building Animation Driven Interfaces	Pacific Heights Thursday 9:00AM
Core Animation in Practice, Part 1	Nob Hill Thursday 11:30AM

Labs

Core Animation Lab	Graphics and Media Lab D Thursday 3:15PM
Animation Lab	Application Frameworks Lab C Thursday 4:30PM
Animation Lab	Application Frameworks Lab A Friday 9:00AM


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