USING CORE ANIMATION

Nathan Eror - Free Time Studios
@neror

http://github.com/neror/CA360

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WHO AM I?

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http://www.freetimestudios.com

AGENDA

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AGENDA

- Core Animation and graphics primarily on iOS
- Numerous examples
- Get the code at github: http://github.com/neror/CA360

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WHAT IS CORE ANIMATION?

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WHAT IS CORE ANIMATION?

- Primary iOS graphics and animation API
- 2D Layer based compositing and animation framework
- Inspired by modern graphic design software
- Takes full advantage of modern GPU's
- Imperative drawing model
- Highly optimized for speed (only draws when necessary)
- Interpolates animations automatically and asynchronously

WHEN SHOULD I USE IT?

- Always try to use UIKit drawing and animation first
- Use Core Animation if you need:
  - More granular control over animation and timing
  - More flexible styling options without resorting to images
  - To move your views around in 3D space
  - To draw simple vector images quickly (and animate them)
  - To have more fun :)

UIKIT VS CORE ANIMATION

Core Animation

```
[CATransaction begin];
[CATransaction setCompletionBlock:^{
  [myView removeFromSuperview];
}];
CABasicAnimation *fadeOut = [CABasicAnimation animationWithKeyPath:@"opacity"];
fadeOut.duration = .2f;
fadeOut.toValue = [NSNumber numberWithFloat:0.f];
[myView.layer addAnimation:fadeOut forKey:nil];
[CATransaction commit];
```

UIKit Block Animations

```
[UIView animateWithDuration:.2f
                 animations:^{
                   myView.alpha = 0.f;
                 }
                 completion:^(BOOL finished){
                   [myView removeFromSuperview];
                 }];
```

FUNDAMENTALS

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CORE ANIMATION & UIKIT

UIView.h

```
UIKIT_EXTERN_CLASS @interface UIView : UIResponder<NSCoding> {
  @package
    CALayer *_layer;
}

+ (Class)layerClass;

@property(nonatomic,readonly,retain) CALayer *layer;
```

LAYER TREE

Layer Tree Methods

```
@property(readonly) CALayer *superlayer;
- (void)removeFromSuperlayer;
@property(copy) NSArray *sublayers;

- (void)addSublayer:(CALayer *)layer;
- (void)insertSublayer:(CALayer *)layer atIndex:(unsigned)idx;
- (void)insertSublayer:(CALayer *)layer below:(CALayer *)sibling;
- (void)insertSublayer:(CALayer *)layer above:(CALayer *)sibling;
- (void)replaceSublayer:(CALayer *)layer with:(CALayer *)layer2;

@property CATransform3D sublayerTransform;
```

LAYER TREE HIERARCHY

DEMO

Layer Tree

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LAYER GEOMETRY

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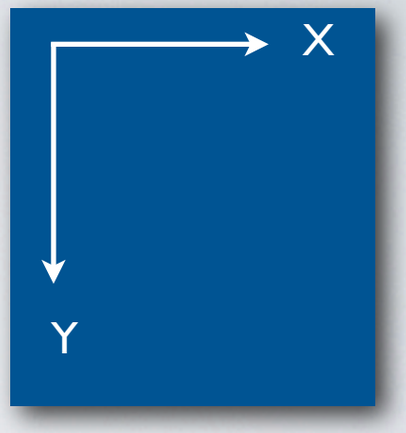
GEOMETRY & TRANSFORMS

- 2D cartesian coordinate system with origin in the top left



- Quartz2D primitive data structures (`CGPoint`, `CGRect`, etc.)

- Each layer has its own coordinate system

- All geometric properties are animatable and have a default implicit animation

- A `CALayer` is a 2D plane projected in 3D

  - The transition to the next slide is a good illustration of this

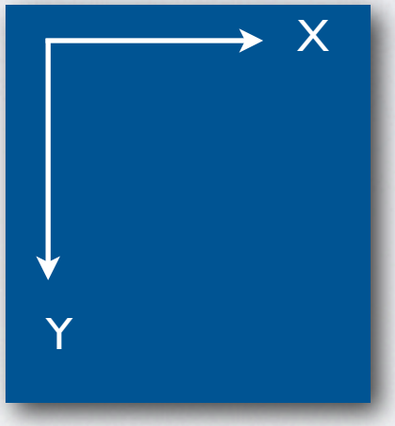
GEOMETRY & TRANSFORMS

Quartz2D Data Structures

```
struct CGPoint {
  CGFloat x;
  CGFloat y;
};
typedef struct CGPoint CGPoint;

struct CGSize {
  CGFloat width;
  CGFloat height;
};
typedef struct CGSize CGSize;

struct CGRect {
  CGPoint origin;
  CGSize size;
};
typedef struct CGRect CGRect;
```



CALayer Geometric Properties

```
@property CGRect bounds;

@property CGPoint position;

@property CGFloat zPosition;

@property CGPoint anchorPoint;

@property CGFloat anchorPointZ;

@property CATransform3D transform;

@property CGRect frame;
```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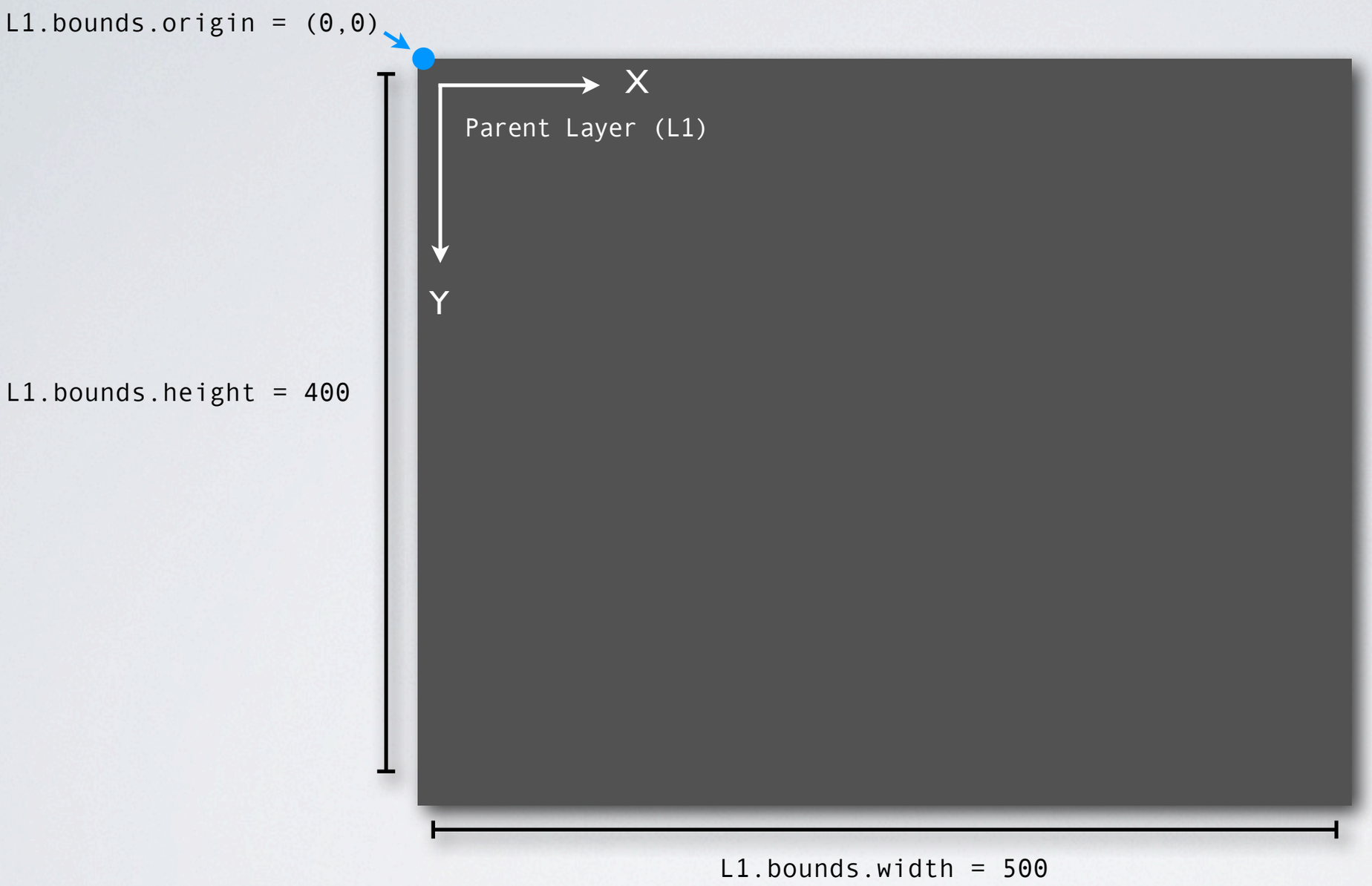
LAYER GEOMETRY



3D Transform Properties

```
L1.transform = CATransform3DIdentity
L1.sublayerTransform = CATransform3DIdentity
```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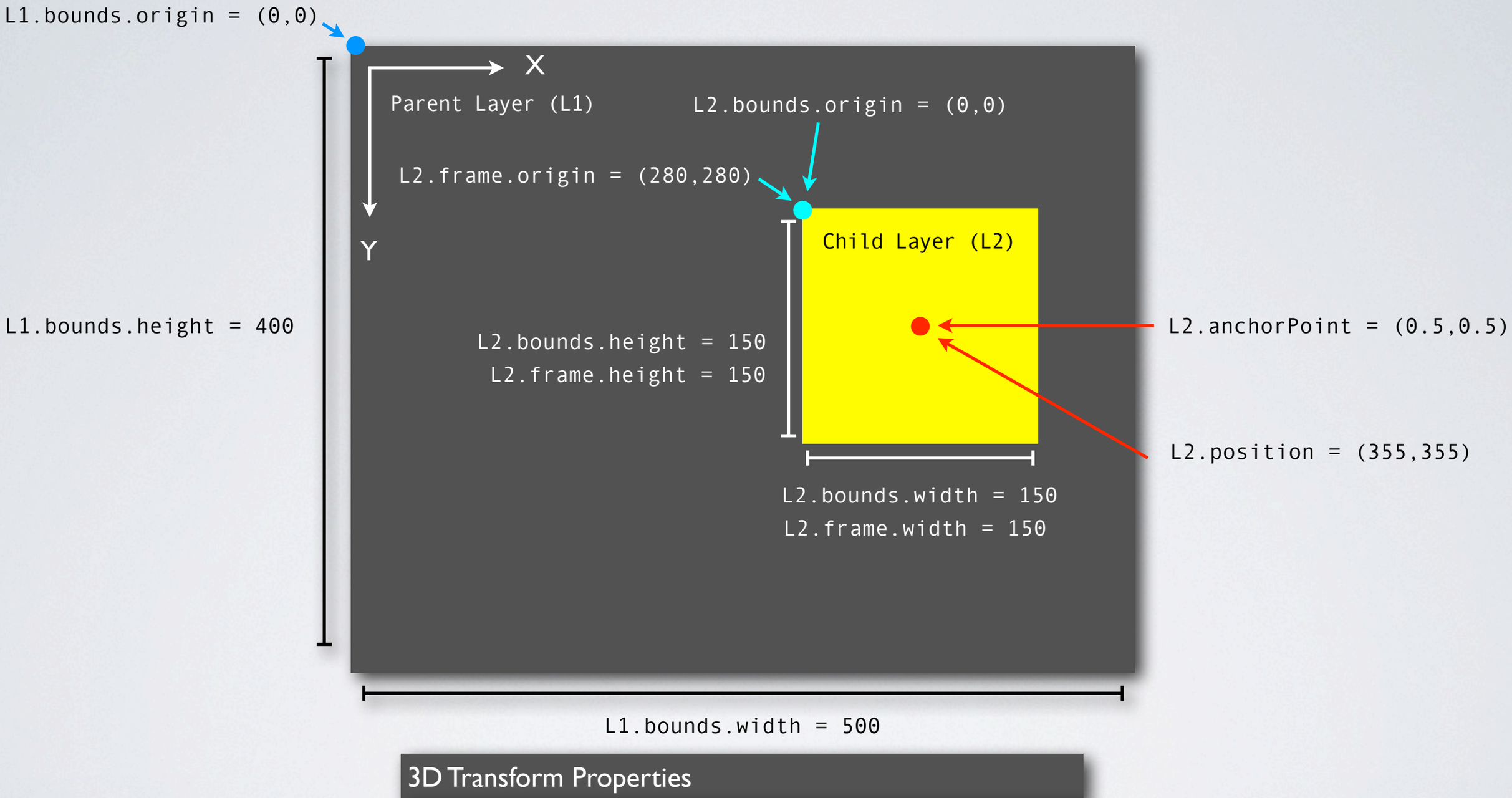
LAYER GEOMETRY



3D Transform Properties

```
L1.transform = CATransform3DIdentity
L1.sublayerTransform = CATransform3DIdentity
L2.transform = CATransform3DIdentity
```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GEOMETRY & TRANSFORMS

DEMO

Geometric Properties

GEOMETRY & TRANSFORMS

3D Transformation Matrix Data Structure

```
struct CATransform3D
{
  CGFloat m11, m12, m13, m14;
  CGFloat m21, m22, m23, m24;
  CGFloat m31, m32, m33, m34;
  CGFloat m41, m42, m43, m44;
};
typedef struct CATransform3D CATransform3D;
```

CALayer's 3D Transformation Properties

```
@property CATransform3D transform;

@property CATransform3D sublayerTransform;

@property CGPoint anchorPoint;

@property CGFloat anchorPointZ;
```

CATransform3D Matrix Operations

```
CATransform3D CATransform3DMakeTranslation(CGFloat tx, CGFloat ty, CGFloat tz);

CATransform3D CATransform3DMakeScale(CGFloat sx, CGFloat sy, CGFloat sz);

CATransform3D CATransform3DMakeRotation(CGFloat angle, CGFloat x, CGFloat y, CGFloat z);

CATransform3D CATransform3DTranslate(CATransform3D t, CGFloat tx, CGFloat ty, CGFloat tz);

CATransform3D CATransform3DScale(CATransform3D t, CGFloat sx, CGFloat sy, CGFloat sz);

CATransform3D CATransform3DRotate(CATransform3D t,CGFloat angle,CGFloat x,CGFloat y,CGFloat z);

CATransform3D CATransform3DConcat(CATransform3D a, CATransform3D b);

CATransform3D CATransform3DInvert(CATransform3D t);
```

GEOMETRY & TRANSFORMS

DEMO

Layer Transforms

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LAYER CONTENT & STYLE

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LAYER CONTENT & STYLE

Content Properties

```
@property(retain) id contents;

@property CGRect contentsRect;

@property(copy) NSString *contentsGravity;

@property CGRect contentsCenter;

@property(getter=isOpaque) BOOL opaque;

@property BOOL needsDisplayOnBoundsChange;
```

Content Methods

```
- (void)display;

- (void)setNeedsDisplay;

- (void)setNeedsDisplayInRect:(CGRect)r;

- (BOOL)needsDisplay;

- (void)displayIfNeeded;

- (void)drawInContext:(CGContextRef)ctx;
```

Style Properties

```
@property CGColorRef backgroundColor;

@property CGFloat cornerRadius;

@property CGFloat borderWidth;

@property CGColorRef borderColor;

@property float opacity;

@property(retain) CALayer *mask;
```

Drawing Delegate Methods

```
- (void)displayLayer:(CALayer *)layer;

- (void)drawLayer:(CALayer *)layer
        inContext:(CGContextRef)ctx;
```


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KEY VALUE CODING

All `CALayer` properties are available through key paths

```
//Scale the layer along the x-axis
[layer setValue:[NSNumber numberWithFloat:1.5] forKeyPath:@"transform.scale.x"];

//Same result as above
CGSize biggerX = CGSizeMake(1.5, 1.);
[layer setValue:[NSValue valueWithCGSize:biggerX] forKeyPath:@"transform.scale"];
```

Key Paths for Structure Fields:

CATransform3D			
rotation	rotation.x	rotation.y	rotation.z
scale	scale.x	scale.y	scale.z
translation	translation.x	translation.y	translation.z

CGSize
width
height

CGPoint
x
y

CGPoint	
origin	size
origin.x	size.width
origin.y	size.height

! Structures must be wrapped in an `NSValue` instance before being passed to `setValue:forKeyPath:`

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LAYER CONTENT & STYLE

DEMOS

Image Content

Delegate Drawing

Style Properties

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ANIMATION

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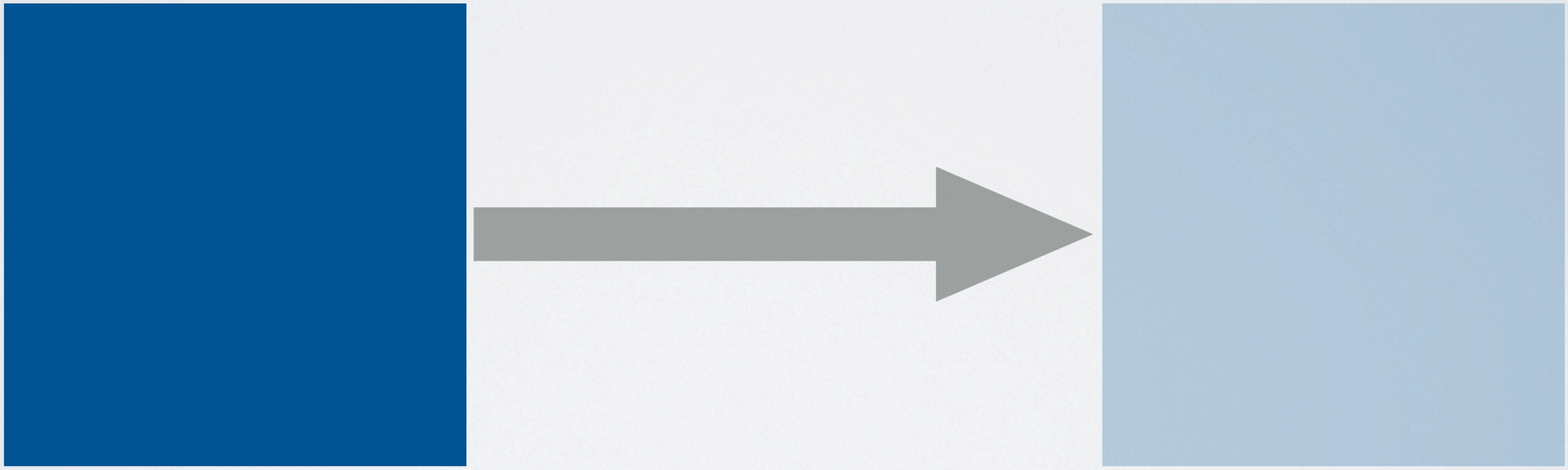
ANIMATION

Move the box from the left position to the right position over 2 seconds distributing the interpolated values along a curve that slopes slowly at the beginning, quickly through the middle and slowly again at the end.



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ANIMATION

Move the box from the left position to the right position over 2 seconds distributing the interpolated values along a curve that slopes slowly at the beginning, quickly through the middle and slowly again at the end.

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ANIMATION TIMING

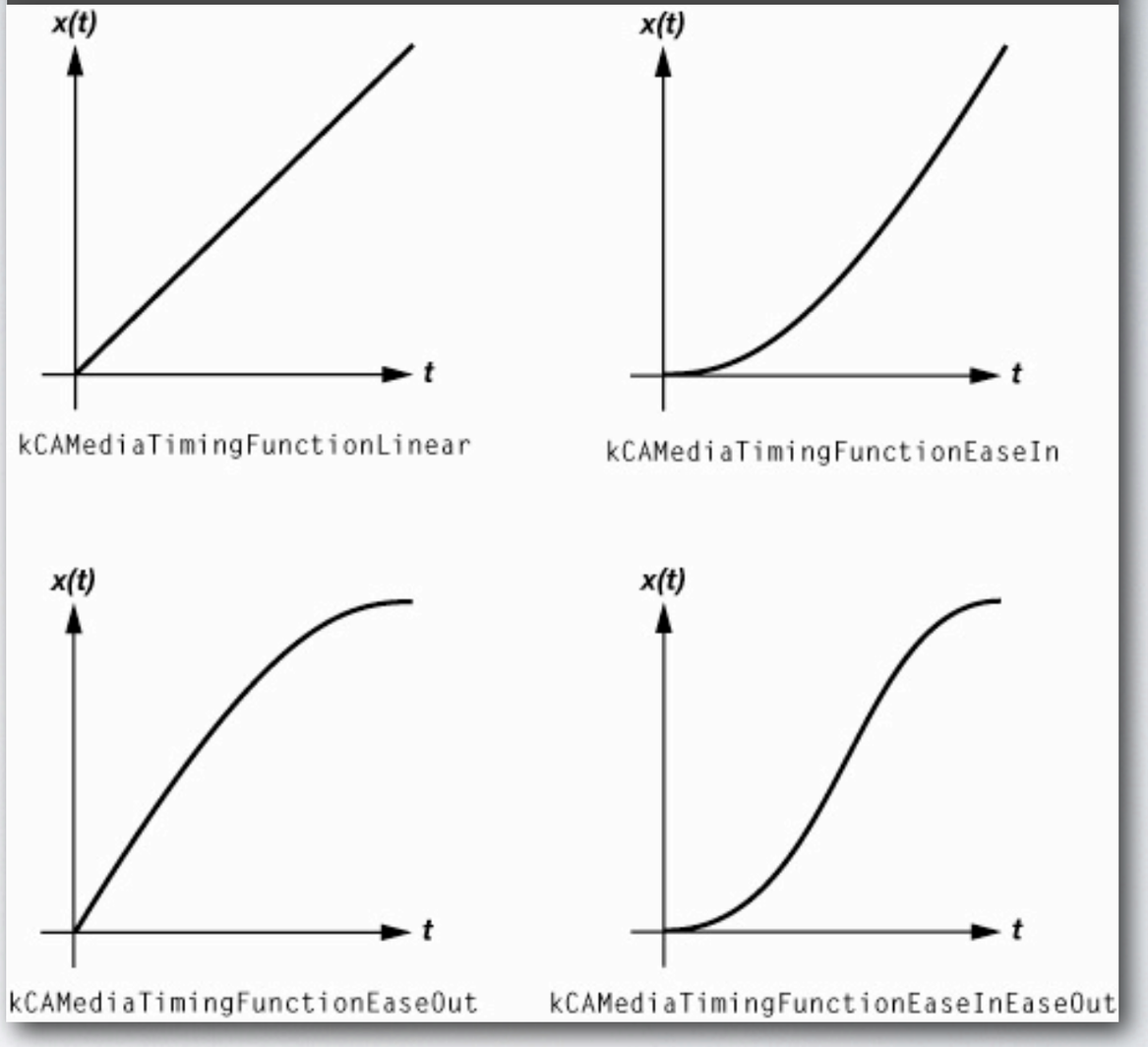
Timing Properties

```
@property CFTimeInterval beginTime;

@property CFTimeInterval duration;

@property float speed;

@property CFTimeInterval timeOffset;

@property float repeatCount;

@property CFTimeInterval repeatDuration;

@property BOOL autoreverses;
```

Fill Mode Options

```
@property(copy) NSString *fillMode;

NSString * const kCAFillModeForwards;

NSString * const kCAFillModeBackwards;

NSString * const kCAFillModeBoth;

NSString * const kCAFillModeRemoved;
```

Default Timing Functions



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PROPERTY ANIMATION

- Use `CABasicAnimation` to explicitly animate a layer property
  - `toValue`: The final value of the property
  - `fromValue`: The optional starting value
  - `byValue`: Add `byValue` to the current value

One Property

`CABasicAnimation`

`CAKeyframeAnimation`

n **Properties**

`CAAnimationGroup`

Layer Tree Actions

`CATransition`

PROPERTY ANIMATION

BasicAnimation.m

```
CABasicAnimation *pulseAnimation =
  [CABasicAnimation animationWithKeyPath:@"transform.scale"];
pulseAnimation.duration = .5;
pulseAnimation.toValue = [NSNumber numberWithFloat:1.1];
pulseAnimation.timingFunction =
  [CAMediaTimingFunction functionWithName:kCAMediaTimingFunctionEaseInEaseOut];
pulseAnimation.autoreverses = YES;
pulseAnimation.repeatCount = MAXFLOAT;

[pulseLayer_ addAnimation:pulseAnimation forKey:nil];
```

KEYFRAME ANIMATION

- `CAKeyframeAnimation` allows more fine control over the animation of a layer property

  - `values`: Array of `toValues`

  - `path`: Animate along a `CGPathRef` (alt. to `values`)

  - `calculationMode`: Interpolation style between keyframes

One Property

`CABasicAnimation`

`CAKeyframeAnimation`

***n* Properties**

`CAAnimationGroup`

Layer Tree Actions

`CATransition`

KEYFRAME ANIMATION

KeyframeAnimation.m

```
CGSize viewSize = self.view.bounds.size;
[marioLayer_ removeAnimationForKey:@"marioJump"];

CGMutablePathRef jumpPath = CGPathCreateMutable();
CGPathMoveToPoint(jumpPath, NULL, 0., viewSize.height);
CGPathAddCurveToPoint(jumpPath, NULL, 30., 140., 170., 140., 170., 200.);

CAKeyframeAnimation *jumpAnimation =
  [CAKeyframeAnimation animationWithKeyPath:@"position"];
jumpAnimation.path = jumpPath;
jumpAnimation.duration = 1.;
jumpAnimation.timingFunction =
  [CAMediaTimingFunction functionWithName:kCAMediaTimingFunctionEaseInEaseOut];
jumpAnimation.delegate = self;

CGPathRelease(jumpPath);

[marioLayer_ addAnimation:jumpAnimation forKey:@"marioJump"];
```

ANIMATION GROUPS

- Use `CAAnimationGroup` to group multiple property animations to be run concurrently on the same layer

- The `delegate` and `removedOnCompletion` properties of the animations are ignored

- The `duration`, `fillMode` and `beginTime` properties of the property animations offer fine grained control over each animation

- The `durations` of the animations are clipped to the `duration` of the group, not scaled.

One Property
`CABasicAnimation`
`CAKeyframeAnimation`

n Properties
`CAAnimationGroup`

Layer Tree Actions
`CATransition`

ANIMATION GROUPS

AnimationGroups.m

```
CABasicAnimation *pulseAnimation = [CABasicAnimation animationWithKeyPath:@"transform.scale"];
pulseAnimation.duration = 2.;
pulseAnimation.toValue = [NSNumber numberWithFloat:1.15];

CABasicAnimation *pulseColorAnimation = [CABasicAnimation animationWithKeyPath:@"backgroundColor"];
pulseColorAnimation.duration = 1.;
pulseColorAnimation.fillMode = kCAFillModeForwards;
pulseColorAnimation.toValue = (id)[UIColorFromRGBA(0xFF0000, .75) CGColor];

CABasicAnimation *rotateLayerAnimation =
    [CABasicAnimation animationWithKeyPath:@"transform.rotation"];
rotateLayerAnimation.duration = .5;
rotateLayerAnimation.beginTime = .5;
rotateLayerAnimation.fillMode = kCAFillModeBoth;
rotateLayerAnimation.toValue = [NSNumber numberWithFloat:DEGREES_TO_RADIANS(45.)];

CAAnimationGroup *group = [CAAnimationGroup animation];
group.animations = [NSArray arrayWithObjects:pulseAnimation, pulseColorAnimation,
                                             rotateLayerAnimation, nil];
group.duration = 2.;
group.timingFunction =
  [CAMediaTimingFunction functionWithName:kCAMediaTimingFunctionEaseInEaseOut];
group.autoreverses = YES;
group.repeatCount = MAXFLOAT;

[pulseLayer_ addAnimation:group forKey:nil];
```

TRANSITIONS

- A `CATransition` animates changes to the layer tree

- Canned animations that effect an entire layer

- The `type` and `subtype` properties define the canned transition animation

- The `CATransition` is added to the *parent layer* and animates the hiding, showing, adding and removing of its child layers

One Property

`CABasicAnimation`

`CAKeyframeAnimation`

***n* Properties**

`CAAnimationGroup`

Layer Tree Actions

`CATransition`

TRANSITIONS

LayerTransitions.m

```
CATransition *transition = [CATransition animation];
transition.duration = .5;
transition.timingFunction =
  [CAMediaTimingFunction functionWithName:kCAMediaTimingFunctionEaseInEaseOut];
transition.type = kCATransitionPush;
transition.subtype = kCATransitionFromRight;

[containerLayer_ addAnimation:transition forKey:nil];
```

BLOCK BASED API

- iOS 4 only!
- Most block methods are in the UIView animation API
- Core Animation gets one

Core Animation Block API

```
[CATransaction setCompletionBlock:^{
  //Clean up after all animations in this transaction
  //have finished.
}];
```

SPECIAL LAYER TYPES

- `CATiledLayer`: For displaying very large layers (bigger than 1024x1024) at multiple levels of detail
- `CAShapeLayer`: Draws an animatable `CGPath` (since 3.0)
- `CAGradientLayer`: Draws a gradient over its background color (since 3.0)
- `CATransformLayer`: A container layer for true 3D hierarchy (since 3.0)
- `CAReplicatorLayer`: Creates copies of its sublayers with each copy potentially having geometric, temporal and color transformations applied to it (since 3.0)
- `CATextLayer`: Renders text using Core Text. Supports loadable fonts and `NSAttributedString`. (since 3.2)
- `CAEmitterLayer`: Create particle systems

GRADIENT LAYERS

GradientLayers.m

```
gradientLayer_.backgroundColor = [[UIColor blackColor] CGColor];
gradientLayer_.bounds = CGRectMake(0., 0., 200., 200.);
gradientLayer_.position = self.view.center;
gradientLayer_.cornerRadius = 12.;
gradientLayer_.borderWidth = 2.;
gradientLayer_.borderColor = [[UIColor blackColor] CGColor];
gradientLayer_.startPoint = CGPointZero;
gradientLayer_.endPoint = CGPointMake(0., 1.);
gradientLayer_.colors = [NSArray arrayWithObjects:
                         (id)[[UIColor whiteColor] CGColor],
                         (id)[UIColorFromRGBA(0xFFFFFF, .1) CGColor],
                         nil];
```

SHAPE LAYERS

ShapeLayers.m

```
shapeLayer_.backgroundColor = [[UIColor clearColor] CGColor];
shapeLayer_.frame = CGRectMake(0., 0., 200., 200.);
shapeLayer_.position = self.view.center;

CGMutablePathRef path = CGPathCreateMutable();
CGPathAddEllipseInRect(path, NULL, rect);
shapeLayer_.path = path;
CGPathRelease(path);

shapeLayer_.fillColor = [[UIColor blueColor] CGColor];
shapeLayer_.strokeColor = [[UIColor blackColor] CGColor];
shapeLayer_.lineWidth = 4.;
shapeLayer_.lineDashPattern = [NSArray arrayWithObjects:
                               [NSNumber numberWithInt:8],
                               [NSNumber numberWithInt:8],
                              nil];
shapeLayer_.lineCap = kCALineCapRound;
```

TEXT LAYERS

TextLayers.m

```
CTFontRef font = CTFontCreateWithName(CFSTR("Courier"), 16.f, NULL);
normalTextLayer_ = [[CATextLayer alloc] init];
normalTextLayer_.font = font;
normalTextLayer_.string = @"This is just a plain old CATextLayer";
normalTextLayer_.wrapped = YES;
normalTextLayer_.foregroundColor = [[UIColor purpleColor] CGColor];
normalTextLayer_.fontSize = 20.f;
normalTextLayer_.alignmentMode = kCAAlignmentCenter;
normalTextLayer_.frame = CGRectMake(0.f, 10.f, 320.f, 32.f);
CFRelease(font);
```

TEXT LAYERS

TextLayers.m

```
NSDictionary *fontAttributes = [NSDictionary dictionaryWithObjectsAndKeys:
                                @"Courier", (NSString *)kCTFontFamilyNameAttribute,
                                @"Bold", (NSString *)kCTFontStyleNameAttribute,
                                [NSNumber numberWithFloat:16.f], (NSString *)kCTFontSizeAttribute,
                                nil];

CTFontDescriptorRef descriptor =
  CTFontDescriptorCreateWithAttributes((CFDictionaryRef)fontAttributes);
CTFontRef courierFont = CTFontCreateWithFontDescriptor(descriptor, 0, NULL);
CFRelease(descriptor);

NSDictionary *stringAttributes =
  [NSDictionary dictionaryWithObject:(id)courierFont
                              forKey:(NSString *)kCTFontAttributeName];
NSMutableAttributedString *attrString =
  [[NSMutableAttributedString alloc] initWithString:EXAMPLE_STRING
                                         attributes:stringAttributes];

NSRange rangeOfClassName = [[attrString string] rangeOfString:@"CATextLayer"];
[attrString addAttribute:(NSString *)kCTForegroundColorAttributeName
                   value:(id)[[UIColor redColor] CGColor]
                   range:rangeOfClassName];

CFRelease(courierFont);
attributedTextLayer_.string = attrString;
```

PERFORMANCE

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PERFORMANCE

- Core Animation is hardware accelerated
- It takes advantage of the features of the GPU
- It works very well as long as we stay out of its way
- We should know how the GPU is used by Core Animation

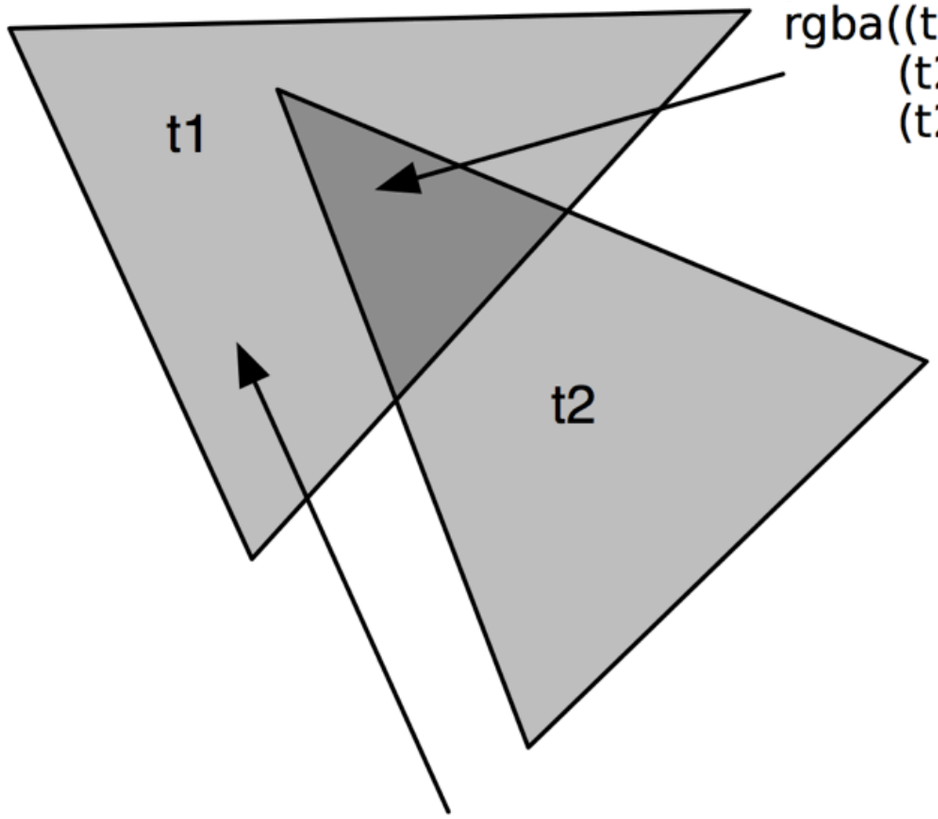
THE GPU

Blending

t1 color = rgba(1.0, 1.0, 1.0, 0.25)

t2 color = rgba(1.0, 1.0, 1.0, 0.25)

pixel color = blend(t1, t2) =
rgba((t2r * t2a) + (1 - t1a) * t1r,
(t2g * t2a) + (1 - t1a) * t1g,
(t2b * t2a) + (1 - t1a) * t1b)



pixel color = t1 color = rgba(1.0, 1.0, 1.0, 0.25)

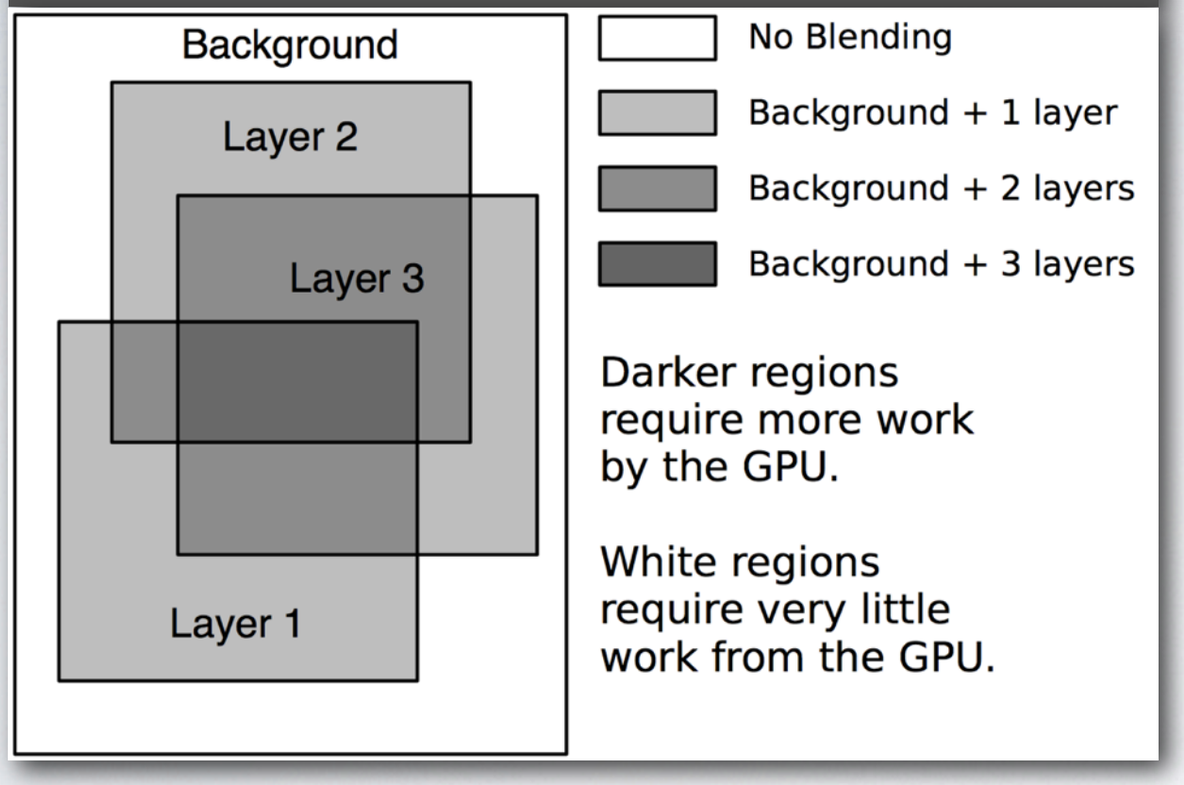
GPU BOTTLENECKS

- **Destination Pixels** - The number of pixels the GPU must render/blend to reach the final bitmap
- **Source Pixels** - The number of pixels the GPU must read in from source images
- **Rendering Passes** - The number of rendering passes required to reach the final bitmap

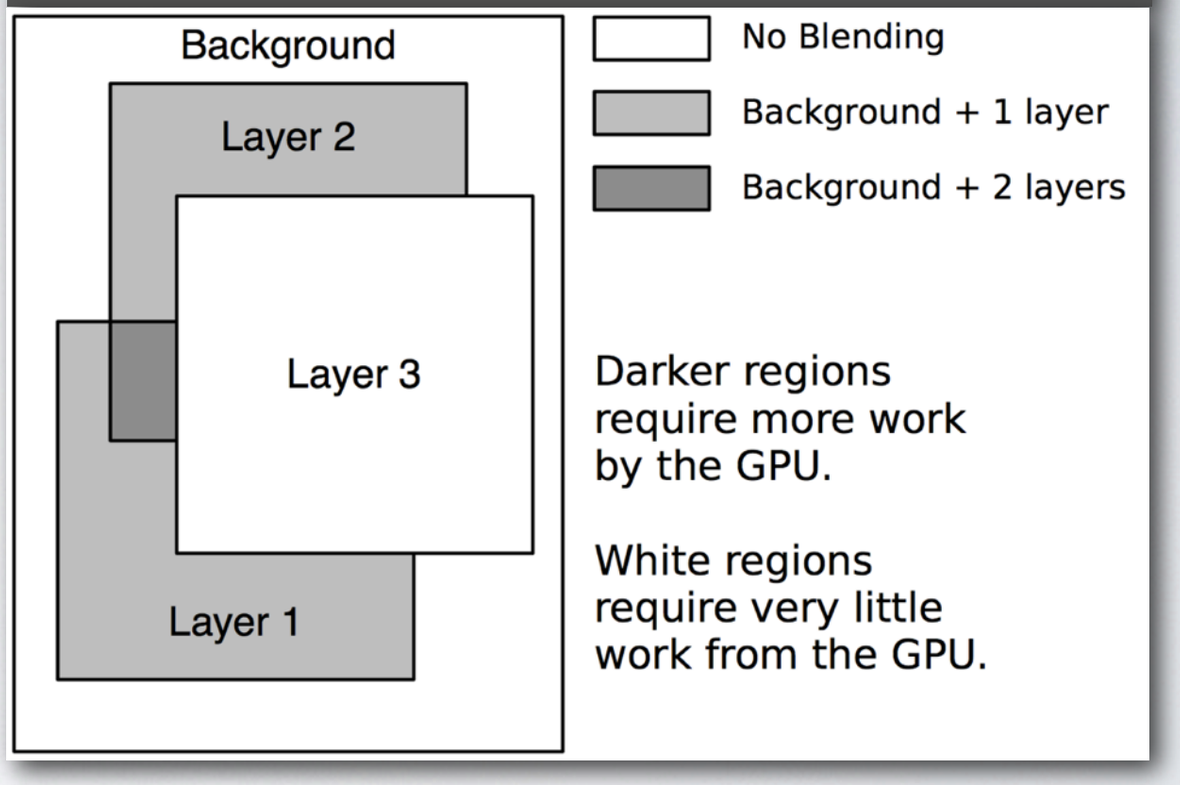
DESTINATION PIXELS

Minimize Transparent Pixels to Minimize Blending

All non-opaque layers



Using opaque layers



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SOURCE PIXELS

- Pre-render properly sized images to minimize offscreen drawing. Unnecessarily large images kill performance.

- Properly sized source images allow CA to map the image pixels directly into the framebuffer (as long as the image is opaque) bypassing scaling and compositing operations

- Also results in reduced memory usage and disk i/o

- Use the "Color Misaligned Images" option in Instruments

RENDERING PASSES

- Limit use of mask layers and group opacity
- Use layer bitmap caching carefully
- Use the "Color Offscreen" option in Instruments

THANK YOU

Nathan Eror

neror@freetimestudios.com

@neror

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