Advanced Touch Input on iOS

Increasing Responsiveness by Reducing Latency

Session 233

Peter Tsoi iOS Performance Engineer
Jacob Xiao UIKit Engineer
Overview
Overview

Why should you care about latency?
Why should you care about latency?

How do touches actually make it onto the screen?
Overview

Why should you care about latency?
How do touches actually make it onto the screen?
Learn about new APIs in iOS 9
Overview

Why should you care about latency?
How do touches actually make it onto the screen?
Learn about new APIs in iOS 9
Discuss how to find and fix performance bottlenecks
Why Is Low Latency Important?
Why Is Low Latency Important?
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Why Is Low Latency Important?
Why Is Low Latency Important?
Why Is Low Latency Important?
The iOS Touch and Graphics Pipeline
The iOS Touch and Graphics Pipeline

iOS 8

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The iOS Touch and Graphics Pipeline

iOS 8
The iOS Touch and Graphics Pipeline

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The iOS Touch and Graphics Pipeline

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The iOS Touch and Graphics Pipeline

iOS 8

Multi-Touch

App

Core Animation
The iOS Touch and Graphics Pipeline

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- Multi-Touch
- App
- Core Animation
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The iOS Touch and Graphics Pipeline

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### The iOS Touch and Graphics Pipeline

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**Frame 1**

**Frame 2**

**Frame 3**

**Frame 4**

**Frame 5**
The iOS Touch and Graphics Pipeline

iOS 8
The iOS Touch and Graphics Pipeline

iOS 8

- Multi-Touch
- App
- Core Animation
- GPU
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Frames:
1. Frame 1
2. Frame 2
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The iOS Touch and Graphics Pipeline

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The iOS Touch and Graphics Pipeline

iOS 8

Frame 1  Frame 2  Frame 3  Frame 4  Frame 5
Double Buffering
Double Buffering

Core Animation

GPU

LCD
Double Buffering

- Core Animation
- GPU
- LCD
Double Buffering

- Core Animation
- GPU
- LCD
Double Buffering

- Core Animation
- GPU
- LCD
Double Buffering

- Core Animation
- GPU
- LCD
Double Buffering

Core Animation

GPU

LCD
Double Buffering

Core Animation

GPU

LCD
Double Buffering
Double Buffering

Core Animation

GPU

LCD
Double Buffering

- Core Animation
- GPU
- LCD
Double Buffering

Core Animation

GPU

LCD
Triple Buffering
Triple Buffering

- Core Animation
- GPU
- LCD
Triple Buffering

- Core Animation
- GPU
- LCD
Triple Buffering
Triple Buffering

Diagram showing the process of triple buffering with Core Animation, GPU, and LCD layers.
Triple Buffering

[Diagram showing Core Animation, GPU, and LCD with buffer regions]

- Core Animation
- GPU
- LCD
Triple Buffering
Triple Buffering

- Core Animation
- GPU
- LCD
Triple Buffering

- Core Animation
- GPU
- LCD
Triple Buffering

- Core Animation
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Triple Buffering

Core Animation

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Triple Buffering

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The iOS Touch and Graphics Pipeline

What About Metal and OpenGL?

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What about Metal and OpenGL?
The iOS Touch and Graphics Pipeline

What about Metal and OpenGL?
The iOS Touch and Graphics Pipeline

What about Metal and OpenGL?
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The iOS Touch and Graphics Pipeline

- Multi-Touch
- App
- Core Animation
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- LCD

Frame 1
Frame 2
Frame 3
Frame 4
Frame 5
What’s New

Jacob Xiao UIKit Engineer
What’s New
What’s New

Low Latency Core Animation
What’s New

Low Latency Core Animation
Touch Coalescing
What’s New

Low Latency Core Animation
Touch Coalescing
Touch Prediction
Low Latency Core Animation
Low Latency Core Animation

iOS 8
Low Latency Core Animation

iOS 8

Graph showing the timeline of different components:
- Multi-Touch
- App
- Core Animation
- GPU
- LCD

The graph indicates the timeline from Frame 1 to Frame 5.
Low Latency Core Animation

iOS 9
Low Latency Core Animation

Disabled for animations

- CAAnimations
- UIView animations
Metal and OpenGL

iOS 9

Multi-Touch
App
Core Animation
GPU
LCD
Low Latency Metal and OpenGL

CAEAGLLayer   CAMetalLayer
Low Latency Metal and OpenGL

With Core Animation
Low Latency Metal and OpenGL
With Core Animation
Low Latency Metal and OpenGL

With Core Animation
Low Latency Metal and OpenGL
CAEAGLLayer and CAMetalLayer

// For lowest latency (default):
layer.presentsWithTransaction = false
Low Latency Metal and OpenGL
CAEAGLLayer and CAMetalLayer

// For lowest latency (default):
layer.presentsWithTransaction = false

// For synchronizing with CA:
layer.presentsWithTransaction = true
Touch Coalescing
iPad Air 2
iPad Air 2

60 Hz Display Update
iPad Air 2

60 Hz Display Update
120 Hz Touch Scan
60 Hz Touch Scan
60 Hz Touch Scan
120 Hz Touch Scan
120 Hz Touch Scan
60 Hz Touch Scan
60 Hz Touch Scan
120 Hz Touch Scan
120 Hz Touch Scan
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60 Hz Touch Scan

- Multi-Touch
- App
- Core Animation
- GPU
- LCD

Frame 1  Frame 2  Frame 3  Frame 4  Frame 5
60 Hz Touch Scan
120 Hz Touch Scan

Multi-Touch

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Core Animation

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Frame 1  Frame 2  Frame 3  Frame 4  Frame 5
120 Hz Touch Scan

- Multi-Touch
- App
- Core Animation
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Frame 1  Frame 2  Frame 3  Frame 4  Frame 5
120 Hz Touch Scan

Multi-Touch

App

Core Animation

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Frame 1  Frame 2  Frame 3  Frame 4  Frame 5
120 Hz Coalesced

- Multi-Touch
- App
- Core Animation
- GPU
- LCD

Frames: 1, 2, 3, 4, 5
120 Hz Coalesced

- Multi-Touch
- App
- Core Animation
- GPU
- LCD

Frame 1 | Frame 2 | Frame 3 | Frame 4 | Frame 5
# 120 Hz Coalesced

<table>
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<td>Frame 5</td>
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</table>
Touch Coalescing

UIEvent.coalescedTouchesForTouch(touch: UITouch)  
→ [UITouch]?
Touch Sequence
Touch Sequence

touchesBegan
Touch Sequence

touchesBegan

touchesMoved
Touch Sequence

touchesBegan

| touchesMoved |

| touchesEnded |
Touch Sequence

touchesBegan

<table>
<thead>
<tr>
<th>touchesMoved</th>
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</table>

<table>
<thead>
<tr>
<th>touchesEnded</th>
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<tbody>
<tr>
<td>touchesCancelled</td>
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</tbody>
</table>
Touch Sequence

Main Touches

coalescedTouchesForTouch
Touch Sequence

Main Touches

Coalesced Touches

----- → coalescedTouchesForTouch
Touch Sequence

Main Touches

Coalesced Touches

-----➤ coalescedTouchesForTouch
Touch Sequence

Main Touches

Coalesced Touches
Touch Sequence

Main Touches

Coalesced Touches
Touch Sequence

Main Touches

Coalesced Touches
Touch Sequence

Main Touches

Coalesced Touches
Previous Location

Main Touches

Coalesced Touches

previousLocationInView
coalescedTouchesForTouch
Previous Location

Main Touches

Coalesced Touches

previousLocationInView

coalescedTouchesForTouch
Previous Location

Main Touches

Coalesced Touches

previouLocationInView

coalescedTouchesForTouch
Main Touches

<UITouch: 0x1234>
Main Touches
Coalesced Touches
Coalesced Touches

- <UITouch: 0x1000>
- <UITouch: 0x1001>
- <UITouch: 0x1002>
- <UITouch: 0x1003>
- <UITouch: 0x1004>
- <UITouch: 0x1005>
- <UITouch: 0x1006>
- <UITouch: 0x1007>
- <UITouch: 0x1008>
for touch in touches {
    let line = lineForTouch(touch)
    addTouchSample(touch, toLine: line)
}
Touch Coalescing

for touch in touches {
    let line = lineForTouch(touch)
    addTouchSample(touch, toLine: line)
}
for touch in touches {
    let line = lineForTouch(touch)
    addTouchSample(touch, toLine: line)
}
for touch in touches {
    let line = lineForTouch(touch)
    for coalescedTouch in event.coalescedTouchesForTouch(touch) {
        addTouchSample(coalescedTouch, toLine: line)
    }
}
for touch in touches {
    let line = lineForTouch(touch)
    for coalescedTouch in event.coalescedTouchesForTouch(touch) {
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    }
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    let line = lineForTouch(touch)
    for coalescedTouch in event.coalescedTouchesForTouch(touch) {
        addTouchSample(coalescedTouch, toLine: line)
    }
}
for touch in touches {
    let line = lineForTouch(touch)
    for coalescedTouch in event.coalescedTouchesForTouch(touch) {
        addTouchSample(coalescedTouch, toLine: line)
    }
}
Touch Prediction
Touch Prediction
Touch Prediction
Touch Prediction

```swift
UIEvent.predictedTouchesForTouch(touch: UITouch) -> [UITouch]?
```
Touch Prediction

Main Touches

Coalesced Touches

--- coalescedTouchesForTouch
--- predictedTouchesForTouch
Touch Prediction

Main Touches

Coalesced Touches

Predicted Touches

- `coalescedTouchesForTouch`
- `predictedTouchesForTouch`
Touch Prediction

Main Touches

Coalesced Touches

Predicted Touches

(previousLocationInView) vs (coalescedTouchesForTouch) vs (predictedTouchesForTouch)
Touch Prediction

Main Touches

Coalesced Touches

Predicted Touches

previousLocationInView
coalescedTouchesForTouch
predictedTouchesForTouch
Touch Prediction
Touch Prediction
Touch Prediction
Touch Prediction
Touch Prediction
Touch Prediction
Touch Prediction
Coalesced and Predicted Touches

- Multi-Touch
- App
- Core Animation
- GPU
- LCD

Frame 1 | Frame 2 | Frame 3 | Frame 4 | Frame 5
Coalesced and Predicted Touches

Multi-Touch

App

Core Animation

GPU

LCD

Frame 1     Frame 2     Frame 3     Frame 4     Frame 5
Coalesced and Predicted Touches

- Multi-Touch
- App
- Core Animation
- GPU
- LCD

Frame 1
Frame 2
Frame 3
Frame 4
Frame 5
for touch in touches {
    let line = lineForTouch(touch)
    for coalescedTouch in event.coalescedTouchesForTouch(touch) {
        addTouchSample(coalescedTouch, toLine: line)
    }
}
for touch in touches {
    let line = lineForTouch(touch)
    for coalescedTouch in event.coalescedTouchesForTouch(touch) {
        addTouchSample(coalescedTouch, toLine: line)
    }
    removePredictedSamplesFromLine(line)
    for predictedTouch in event.predictedTouchesForTouch(touch) {
        addPredictedTouchSample(predictedTouch, toLine: line)
    }
}
for touch in touches {
    let line = lineForTouch(touch)
    for coalescedTouch in event.coalescedTouchesForTouch(touch) {
        addTouchSample(coalescedTouch, toLine: line)
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    }
}

removePredictedSamplesFromLine(line)
for predictedTouch in event.predictedTouchesForTouch(touch) {
    addPredictedTouchSample(predictedTouch, toLine: line)
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        addTouchSample(coalescedTouch, toLine: line)
    }
    removePredictedSamplesFromLine(line)
    for predictedTouch in event.predictedTouchesForTouch(touch) {
        addPredictedTouchSample(predictedTouch, toLine: line)
    }
}
Putting It Together
iOS 8

- Multi-Touch
- App
- Core Animation
- GPU
- LCD

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Touch Coalescing

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Touch Prediction

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iOS 9

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Frame 1

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Frame 3

Frame 4

Frame 5
Fine-Tuning Your Application
Fine-Tuning Your Application

Only render what’s visible

Ensure that the application only renders content that will actually make it on screen
Fine-Tuning Your Application

Only render what’s visible

Ensure that the application only renders content that will actually make it on screen.
Fine-Tuning Your Application

Only render what’s visible

Ensure that the application only renders content that will actually make it on screen
Fine-Tuning Your Application

Only render what’s visible

Ensure that the application only renders content that will actually make it on screen
Fine-Tuning Your Application
Profiling with Instruments

Time Profiler is a great way to find out how much your app is using the CPU.
Fine-Tuning Your Application

Profiling GPU performance
Fine-Tuning Your Application

Profiling GPU performance

FPS Gauge and GPU Report give a high-level view of your GPU performance
Fine-Tuning Your Application

Profiling GPU performance

FPS Gauge and GPU Report give a high-level view of your GPU performance

The new GPU Driver Instrument can show you how long the GPU is active
Summary
Summary

Reducing latency makes your application feel more alive
Summary

Reducing latency makes your application feel more alive
Low Latency modes for Core Animation, OpenGL, and Metal
Summary

Reducing latency makes your application feel more alive
Low Latency modes for Core Animation, OpenGL, and Metal
Touch Coalescing
Summary

Reducing latency makes your application feel more alive
Low Latency modes for Core Animation, OpenGL, and Metal
Touch Coalescing
Touch Prediction
Summary

Reducing latency makes your application feel more alive
Low Latency modes for Core Animation, OpenGL, and Metal
Touch Coalescing
Touch Prediction
Instruments can help you understand your application’s performance
More Information

Documentation
Performance Overview
Instruments User Guide

http://developer.apple.com/library

Technical Support
Apple Developer Forums
Developer Technical Support

General Inquiries
Curt Rothert, App Frameworks Evangelist
rothert@apple.com
## Related Sessions

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