Optimizing I/O for Performance and Battery Life

Session 719

Kushal Dalmia Kernel Engineer
Terry Long Performance Engineer
iPhone Wallpaper Sizes

- iPhone
- iPhone 4
- iPhone 5
- iPhone 6s
- iPhone 6s Plus
- Custom
System Resources
System Resources

CPU
System Resources

CPU

Memory
System Resources

CPU

Memory

I/O
System Resources

CPU

Memory

I/O

Performance on iOS and watchOS

WWDC 2015
System Resources

I/O
System Resources

Input/Output

I/O
System Resources

Input/Output
- Local Storage
System Resources

Input/Output
- Local Storage
- Network
Performance numbers are approximate and not representative of any specific product.
I/O Technology Variation

Average 1MB Write Latency (ms)

Performance numbers are approximate and not representative of any specific product.
I/O Technology Variation

Average 1MB Write Latency (ms)

Performance numbers are approximate and not representative of any specific product.
I/O Technology Variation

Average 1MB Write Latency (ms)

Performance numbers are approximate and not representative of any specific product.
I/O Technology Variation

Average 1MB Write Latency (ms)

Performance numbers are approximate and not representative of any specific product.
User Impact
User Impact

App Responsiveness
User Impact

App Responsiveness

System Performance
User Impact

- App Responsiveness
- System Performance
- Battery Life
I/O Philosophy
I/O Philosophy

Reduce I/O
I/O Philosophy

Reduce I/O

Use the right thread
I/O Philosophy

Reduce I/O
Use the right thread
Adopt appropriate APIs
I/O Philosophy

Reduce I/O
Use the right thread
Adopt appropriate APIs
Test and measure
Reduce I/O
Reduce I/O

Battery life
Reduce I/O

Battery life
Reduce I/O

Battery life
Reduce I/O

Battery life
Reduce I/O

Battery life
Reduce I/O

Battery life

I/O → CPU → Memory → Disk → Battery
Reduce I/O

Battery life

I/O → CPU → Memory → Disk → Network → Battery
Caching
Caching

In-memory copy of data

CPU

Memory Cache

Disk
Caching

In-memory copy of data

Potential candidates
Caching

In-memory copy of data

Potential candidates
- Frequent writes
Caching

In-memory copy of data
Potential candidates
• Frequent writes
• Expensive reads
Caching

In-memory copy of data

Potential candidates
- Frequent writes
- Expensive reads

Memory and I/O tradeoffs
Caching

In-memory copy of data

Potential candidates
- Frequent writes
- Expensive reads

Memory and I/O tradeoffs
Coalescing I/O
Coalescing I/O

Defer I/O operations
Coalescing I/O

Defer I/O operations
Larger fewer I/Os
Coalescing I/O

- Defer I/O operations
- Larger fewer I/Os
- Use app state change notifications
Coalescing I/O

Defer I/O operations
Larger fewer I/Os
Use app state change notifications
Use Centralized Task Scheduling (macOS)
Coalescing I/O

Defer I/O operations
Larger fewer I/Os
Use app state change notifications
Use Centralized Task Scheduling (macOS)

Writing Energy Efficient Code  WWDC 2014
ImageBox
This album is great!
This album is great!
This album is great!
import UIKit

@UIApplicationMain
class AppDelegate: UIResponder, UIApplicationDelegate {

    var window: UIWindow?
    var dataStore = ImageBoxData()
    var source: DispatchSourceTimer!

    func application(_ application: UIApplication,
                     didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
        // Your code here
    }
}
import UIKit

@UIApplicationMain
class AppDelegate: UIResponder, UIApplicationDelegate {

    var window: UIWindow?
    var dataStore = ImageBoxData()
    var source: DispatchQueueSourceTimer!

    func application(_ application: UIApplication,
                   didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {

        
    
}
// AppDelegate.swift
// ImageBox
//
// Created by Apple Inc. on 6/17/16.
// Copyright © 2016 Apple Inc. All rights reserved.
//
import UIKit

@UIApplicationMain
class AppDelegate: UIResponder, UIApplicationDelegate {

    var window: UIWindow?
    var dataStore = ImageBoxData()
    var source: DispatchSourceTimer!

    func application(_ application: UIApplication,
        didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {

    
}
import UIKit

@UIApplicationMain
class AppDelegate: UIResponder, UIApplicationDelegate {

    var window: UIWindow?
    var dataStore = ImageBoxData()
    var source: DispatchSourceTimer!

    func application(_ application: UIApplication,
                     didFinishLaunchingWithOptions launchOptions: [NSObject: Any]?) -> Bool {

    // AppDelegate.swift
    // ImageBox
    // Created by Apple Inc. on 6/17/16.
    // Copyright © 2016 Apple Inc. All rights reserved.
    //
func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {

// AppDelegate.swift

Choose a profiling template for: iPhone (10.0) imageBox

- Blank
- Activity Monitor
- Allocations
- Cocoa Layout
- Core Animation
- Core Data
- Counters
- Energy Log
- File Activity
- Leaks
- Metal System Trace
- Network
- OpenGL ES Analysis
- System Trace
- System Usage
- Time Profiler
- Zombies

System Usage
This template records I/O system activity related to files, sockets, and shared memory for a single process launched via instruments. Inputs, outputs, duration, backtrace, calltree, etc. is provided for each call.
func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {


func application(_: application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {

// AppDelegate.swift

Choose a profiling template for: iPhone (10.0) imageBox

Standard  Custom  Recent

Blank  Activity Monitor  Allocations  Cocoa Layout  Core Animation  Core Data

Counters  Energy Log  File Activity  Leaks  Metal System Trace  Network

OpenGL ES Analysis  System Trace  System Usage  Time Profiler  Zombies

System Usage
This template records I/O system activity related to files, sockets, and shared memory for a single process launched via instruments. Inputs, outputs, duration, backtrace, calltree, etc. is provided for each call.

Cancel  Choose
// AppDelegate.swift

func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
    // Your code here
    return true
}
<table>
<thead>
<tr>
<th>#</th>
<th>Function</th>
<th>Duration µs</th>
<th>Supplied File</th>
<th>Requested Bytes</th>
<th>Returned File</th>
<th>Actual Bytes</th>
<th>Thread ID</th>
<th>Stack Depth</th>
<th>Error</th>
<th>Path</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>access</td>
<td>112.96 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>5.891</td>
<td>18</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>1</td>
<td>access</td>
<td>57.67 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>5.891</td>
<td>28</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>2</td>
<td>open</td>
<td>823.04 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3</td>
<td>0 Bytes</td>
<td>5.891</td>
<td>28</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>3</td>
<td>read</td>
<td>14.04 µs</td>
<td>3</td>
<td>3.07 Kib</td>
<td>0</td>
<td>3.07 Kib</td>
<td>5.891</td>
<td>26</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>4</td>
<td>close</td>
<td>12.58 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>5.891</td>
<td>26</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>5</td>
<td>open</td>
<td>185.33 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>3</td>
<td>0 Bytes</td>
<td>2.055</td>
<td>21</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>6</td>
<td>read</td>
<td>20.88 µs</td>
<td>3</td>
<td>5.13 Kib</td>
<td>0</td>
<td>6.13 Kib</td>
<td>2.055</td>
<td>21</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>7</td>
<td>close</td>
<td>16.67 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>2.055</td>
<td>21</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>8</td>
<td>open</td>
<td>49.62 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3</td>
<td>0 Bytes</td>
<td>2.055</td>
<td>21</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>9</td>
<td>read</td>
<td>9.08 µs</td>
<td>3</td>
<td>417 Bytes</td>
<td>0</td>
<td>417 Bytes</td>
<td>2.055</td>
<td>25</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>10</td>
<td>close</td>
<td>5.67 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>2.055</td>
<td>25</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>11</td>
<td>open</td>
<td>219.46 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>25</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>12</td>
<td>close</td>
<td>9.50 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>25</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>13</td>
<td>open</td>
<td>81.71 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>26</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>14</td>
<td>close</td>
<td>5.76 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>26</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>15</td>
<td>open</td>
<td>63.83 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>24</td>
<td></td>
<td>.944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>16</td>
<td>read</td>
<td>16.46 µs</td>
<td>3</td>
<td>1.39 Kib</td>
<td>0</td>
<td>1.39 Kib</td>
<td>13.571</td>
<td>24</td>
<td></td>
<td>.944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>17</td>
<td>close</td>
<td>12.79 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>24</td>
<td></td>
<td>.944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>18</td>
<td>open</td>
<td>90.21 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>26</td>
<td></td>
<td>.944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>19</td>
<td>close</td>
<td>4.29 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>26</td>
<td></td>
<td>.944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>20</td>
<td>open</td>
<td>7.71 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>26</td>
<td></td>
<td>.944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>21</td>
<td>open</td>
<td>484.50 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>17</td>
<td>No s...</td>
<td>.944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>22</td>
<td>open</td>
<td>50.75 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>17</td>
<td>No s...</td>
<td>.944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>23</td>
<td>close</td>
<td>735.46 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>20</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>24</td>
<td>close</td>
<td>8.50 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>20</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>25</td>
<td>close</td>
<td>43.71 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>20</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>26</td>
<td>open</td>
<td>19.21 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>13.571</td>
<td>20</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>27</td>
<td>access</td>
<td>178.96 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>2.055</td>
<td>14</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>28</td>
<td>access</td>
<td>33.96 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>2.055</td>
<td>14</td>
<td></td>
<td>.7-4739-944E-BD254F6A9F84/ImageBox.app</td>
</tr>
<tr>
<td>#</td>
<td>Function</td>
<td>Duration µs</td>
<td>Supplied File</td>
<td>Requested Bytes</td>
<td>Returned File</td>
<td>Actual Bytes</td>
<td>Thread ID</td>
<td>Stack Depth</td>
<td>Error</td>
<td>Path</td>
</tr>
<tr>
<td>----</td>
<td>----------</td>
<td>-------------</td>
<td>---------------</td>
<td>-----------------</td>
<td>---------------</td>
<td>--------------</td>
<td>-----------</td>
<td>-------------</td>
<td>-------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>0</td>
<td>access</td>
<td>112.96 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>5891</td>
<td>18</td>
<td></td>
<td>...7-4739-94E-B0254F6A9F84/imageBox.app</td>
</tr>
<tr>
<td>1</td>
<td>access</td>
<td>56.77 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>5891</td>
<td>28</td>
<td></td>
<td>...emLibrary/ColorSyncProfiles/psRGB Profile.icc</td>
</tr>
<tr>
<td>2</td>
<td>open</td>
<td>823.04 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3 Bytes</td>
<td>13 Bytes</td>
<td>5891</td>
<td>28</td>
<td></td>
<td>...emLibrary/ColorSyncProfiles/psRGB Profile.icc</td>
</tr>
<tr>
<td>3</td>
<td>read</td>
<td>14.04 µs</td>
<td>3</td>
<td>3.07 KiB</td>
<td>3.07 KiB</td>
<td>3.07 KiB</td>
<td>5891</td>
<td>28</td>
<td></td>
<td>...emLibrary/ColorSyncProfiles/psRGB Profile.icc</td>
</tr>
<tr>
<td>4</td>
<td>close</td>
<td>12.58 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>5891</td>
<td>28</td>
<td></td>
<td>...emLibrary/ColorSyncProfiles/psRGB Profile.icc</td>
</tr>
<tr>
<td>5</td>
<td>open</td>
<td>181.33 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3 Bytes</td>
<td>2.055 Bytes</td>
<td>201</td>
<td>28</td>
<td></td>
<td>...LibraryCaches/com.apple.MobileGestalt.plist</td>
</tr>
<tr>
<td>7</td>
<td>close</td>
<td>10.67 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>2.055 Bytes</td>
<td>201</td>
<td>28</td>
<td></td>
<td>...LibraryCaches/com.apple.MobileGestalt.plist</td>
</tr>
<tr>
<td>8</td>
<td>open</td>
<td>49.62 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3 Bytes</td>
<td>2.055 Bytes</td>
<td>201</td>
<td>25</td>
<td></td>
<td>...stem/LibraryCoreServices/SystemVersion.plist</td>
</tr>
<tr>
<td>9</td>
<td>read</td>
<td>9.08 µs</td>
<td>3</td>
<td>417 Bytes</td>
<td>417 Bytes</td>
<td>2.055 Bytes</td>
<td>201</td>
<td>25</td>
<td></td>
<td>...stem/LibraryCoreServices/SystemVersion.plist</td>
</tr>
<tr>
<td>10</td>
<td>close</td>
<td>5.67 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>2.055 Bytes</td>
<td>201</td>
<td>25</td>
<td></td>
<td>...stem/LibraryCoreServices/SystemVersion.plist</td>
</tr>
<tr>
<td>11</td>
<td>open</td>
<td>219.46 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3 Bytes</td>
<td>13.571 Bytes</td>
<td>25</td>
<td>28</td>
<td></td>
<td>...4-E0BD254F6A9F84/imageBox.app</td>
</tr>
<tr>
<td>12</td>
<td>close</td>
<td>9.50 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>13.571 Bytes</td>
<td>25</td>
<td>25</td>
<td></td>
<td>...4-E0BD254F6A9F84/imageBox.app</td>
</tr>
<tr>
<td>13</td>
<td>open</td>
<td>81.71 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3 Bytes</td>
<td>13.571 Bytes</td>
<td>25</td>
<td>25</td>
<td></td>
<td>...7-4739-94E-B0254F6A9F84/imageBox.app</td>
</tr>
<tr>
<td>14</td>
<td>close</td>
<td>5.76 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>13.571 Bytes</td>
<td>25</td>
<td>25</td>
<td></td>
<td>...7-4739-94E-B0254F6A9F84/imageBox.app</td>
</tr>
<tr>
<td>15</td>
<td>open</td>
<td>63.83 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3 Bytes</td>
<td>13.571 Bytes</td>
<td>24</td>
<td>24</td>
<td></td>
<td>...94E-B0254F6A9F84/imageBox.app</td>
</tr>
<tr>
<td>16</td>
<td>close</td>
<td>16.46 µs</td>
<td>3</td>
<td>1.39 KiB</td>
<td>1.39 KiB</td>
<td>13.571 Bytes</td>
<td>24</td>
<td>24</td>
<td></td>
<td>...94E-B0254F6A9F84/imageBox.app</td>
</tr>
<tr>
<td>17</td>
<td>open</td>
<td>12.79 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>13.571 Bytes</td>
<td>24</td>
<td>24</td>
<td></td>
<td>...94E-B0254F6A9F84/imageBox.app</td>
</tr>
<tr>
<td>18</td>
<td>close</td>
<td>29.21 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>13.571 Bytes</td>
<td>24</td>
<td>24</td>
<td></td>
<td>...94E-B0254F6A9F84/imageBox.app</td>
</tr>
<tr>
<td>19</td>
<td>open</td>
<td>4.29 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3 Bytes</td>
<td>13.571 Bytes</td>
<td>24</td>
<td>24</td>
<td></td>
<td>...94E-B0254F6A9F84/imageBox.app</td>
</tr>
<tr>
<td>20</td>
<td>close</td>
<td>7.71 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>13.571 Bytes</td>
<td>26</td>
<td>26</td>
<td>No s...</td>
<td>...4-E0BD254F6A9F84/imageBox.app/Resources/</td>
</tr>
<tr>
<td>21</td>
<td>open</td>
<td>464.50 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3 Bytes</td>
<td>13.571 Bytes</td>
<td>17</td>
<td>17</td>
<td>No s...</td>
<td>...oggging/Processes/org.terrylong/imageBox.plist</td>
</tr>
<tr>
<td>22</td>
<td>close</td>
<td>50.75 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3 Bytes</td>
<td>13.571 Bytes</td>
<td>20</td>
<td>20</td>
<td>...oggging/Processes/org.terrylong/imageBox.plist</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>open</td>
<td>735.46 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>3 Bytes</td>
<td>13.571 Bytes</td>
<td>20</td>
<td>20</td>
<td>...oesLogging/Subsystems/com.apple.UIKit.plist</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>close</td>
<td>8.50 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>13.571 Bytes</td>
<td>20</td>
<td>20</td>
<td>...oesLogging/Subsystems/com.apple.UIKit.plist</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>open</td>
<td>43.71 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>13.571 Bytes</td>
<td>20</td>
<td>20</td>
<td>...oesLogging/Subsystems/com.apple.UIKit.plist</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>close</td>
<td>10.21 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>1 Bytes</td>
<td>13.571 Bytes</td>
<td>20</td>
<td>20</td>
<td>No s...</td>
<td>...ceesLogging/Subsystems/com.apple.UIKit.plist</td>
</tr>
<tr>
<td>27</td>
<td>getattrib</td>
<td>178.96 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>2.055 Bytes</td>
<td>14</td>
<td>14</td>
<td>...7-4739-94E-B0254F6A9F84/imageBox.app</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>access</td>
<td>33.96 µs</td>
<td>0</td>
<td>0 Bytes</td>
<td>0 Bytes</td>
<td>2.055 Bytes</td>
<td>14</td>
<td>14</td>
<td>.../ateFrameworks/BackBoardServices.framework</td>
<td></td>
</tr>
<tr>
<td>#</td>
<td>Function</td>
<td>Duration</td>
<td>Duration µs</td>
<td>Supplied File</td>
<td>Requested Bytes</td>
<td>Returned File</td>
<td>Actual Size</td>
<td>Thread ID</td>
<td>Stack Depth</td>
<td>Error</td>
</tr>
<tr>
<td>---</td>
<td>----------</td>
<td>----------</td>
<td>-------------</td>
<td>---------------</td>
<td>----------------</td>
<td>---------------</td>
<td>-------------</td>
<td>-----------</td>
<td>-------------</td>
<td>-------</td>
</tr>
<tr>
<td>43</td>
<td>read</td>
<td>121.56 ms</td>
<td>3</td>
<td>88.81 MB</td>
<td>0</td>
<td>88.81 MB</td>
<td>2,055</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>144</td>
<td>write</td>
<td>1.19 s</td>
<td>3</td>
<td>88.81 MB</td>
<td>0</td>
<td>88.81 MB</td>
<td>21,507</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>152</td>
<td>write</td>
<td>1.21 s</td>
<td>3</td>
<td>88.81 MB</td>
<td>0</td>
<td>88.81 MB</td>
<td>21,507</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>160</td>
<td>write</td>
<td>1.16 s</td>
<td>3</td>
<td>88.81 MB</td>
<td>0</td>
<td>88.81 MB</td>
<td>21,507</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>97</td>
<td>read</td>
<td>353.58 µs</td>
<td>3</td>
<td>18.74 KIB</td>
<td>0</td>
<td>18.74 KIB</td>
<td>2,055</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>read</td>
<td>13.92 µs</td>
<td>3</td>
<td>5.71 KIB</td>
<td>0</td>
<td>5.71 KIB</td>
<td>2,055</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>read</td>
<td>20.88 µs</td>
<td>3</td>
<td>5.13 KIB</td>
<td>0</td>
<td>5.13 KIB</td>
<td>2,055</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>123</td>
<td>read</td>
<td>482.38 µs</td>
<td>3</td>
<td>4.55 KIB</td>
<td>0</td>
<td>4.55 KIB</td>
<td>2,055</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>read</td>
<td>14.50 µs</td>
<td>3</td>
<td>4.35 KIB</td>
<td>0</td>
<td>4.35 KIB</td>
<td>2,055</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>read</td>
<td>11.29 µs</td>
<td>3</td>
<td>4.35 KIB</td>
<td>0</td>
<td>4.35 KIB</td>
<td>2,055</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>read</td>
<td>369.00 µs</td>
<td>3</td>
<td>3.08 KIB</td>
<td>0</td>
<td>3.08 KIB</td>
<td>2,055</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>read</td>
<td>14.04 µs</td>
<td>3</td>
<td>3.07 KIB</td>
<td>0</td>
<td>3.07 KIB</td>
<td>2,055</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>read</td>
<td>6.88 µs</td>
<td>3</td>
<td>3.07 KIB</td>
<td>0</td>
<td>3.07 KIB</td>
<td>2,055</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>read</td>
<td>13.17 µs</td>
<td>3</td>
<td>3.07 KIB</td>
<td>0</td>
<td>3.07 KIB</td>
<td>2,055</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>read</td>
<td>16.46 µs</td>
<td>3</td>
<td>1.39 KIB</td>
<td>0</td>
<td>1.39 KIB</td>
<td>13,571</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>read</td>
<td>162.71 µs</td>
<td>3</td>
<td>794 Bytes</td>
<td>0</td>
<td>794 Bytes</td>
<td>19</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>138</td>
<td>read</td>
<td>173.38 µs</td>
<td>3</td>
<td>749 Bytes</td>
<td>0</td>
<td>749 Bytes</td>
<td>21,507</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>read</td>
<td>8.04 µs</td>
<td>3</td>
<td>739 Bytes</td>
<td>0</td>
<td>739 Bytes</td>
<td>2,055</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>read</td>
<td>13.04 µs</td>
<td>3</td>
<td>512 Bytes</td>
<td>0</td>
<td>512 Bytes</td>
<td>2,055</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>126</td>
<td>read</td>
<td>18.38 µs</td>
<td>3</td>
<td>512 Bytes</td>
<td>0</td>
<td>512 Bytes</td>
<td>2,055</td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>141</td>
<td>read</td>
<td>103.25 µs</td>
<td>3</td>
<td>427 Bytes</td>
<td>0</td>
<td>427 Bytes</td>
<td>21,507</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>read</td>
<td>9.08 µs</td>
<td>3</td>
<td>417 Bytes</td>
<td>0</td>
<td>417 Bytes</td>
<td>2,055</td>
<td>25</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>read</td>
<td>17.04 µs</td>
<td>3</td>
<td>417 Bytes</td>
<td>0</td>
<td>417 Bytes</td>
<td>2,055</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>read</td>
<td>17.92 µs</td>
<td>3</td>
<td>417 Bytes</td>
<td>0</td>
<td>417 Bytes</td>
<td>2,055</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>read</td>
<td>366.46 µs</td>
<td>3</td>
<td>351 Bytes</td>
<td>0</td>
<td>351 Bytes</td>
<td>2,055</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>read</td>
<td>80.46 µs</td>
<td>3</td>
<td>245 Bytes</td>
<td>0</td>
<td>245 Bytes</td>
<td>2,055</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>access</td>
<td>112.90 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>6,891</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>open</td>
<td>57.67 µs</td>
<td>3</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>6,891</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>#</td>
<td>Function</td>
<td>Duration (µs)</td>
<td>Supplied File</td>
<td>Requested Bytes</td>
<td>Returned File</td>
<td>Actual Bytes</td>
<td>Thread ID</td>
<td>Stack Depth</td>
<td>Error</td>
<td>Path</td>
</tr>
<tr>
<td>----</td>
<td>----------</td>
<td>---------------</td>
<td>---------------</td>
<td>-----------------</td>
<td>---------------</td>
<td>--------------</td>
<td>-----------</td>
<td>-------------</td>
<td>-------</td>
<td>------</td>
</tr>
<tr>
<td>43</td>
<td>read</td>
<td>121.56</td>
<td>3</td>
<td>88.81 MB</td>
<td>0</td>
<td>88.81 MB</td>
<td>1</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>152</td>
<td>write</td>
<td>1.21</td>
<td>3</td>
<td>88.81 MB</td>
<td>0</td>
<td>88.81 MB</td>
<td>1</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>160</td>
<td>write</td>
<td>1.16</td>
<td>3</td>
<td>88.81 MB</td>
<td>0</td>
<td>88.81 MB</td>
<td>1</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>97</td>
<td>read</td>
<td>353.58</td>
<td>3</td>
<td>18.74 MB</td>
<td>0</td>
<td>18.74 MB</td>
<td>1</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75</td>
<td>read</td>
<td>13.92</td>
<td>3</td>
<td>5.71 MB</td>
<td>0</td>
<td>5.71 MB</td>
<td>1</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>read</td>
<td>20.88</td>
<td>3</td>
<td>5.13 MB</td>
<td>0</td>
<td>5.13 MB</td>
<td>1</td>
<td>21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>123</td>
<td>read</td>
<td>482.38</td>
<td>3</td>
<td>4.55 KB</td>
<td>0</td>
<td>4.55 KB</td>
<td>1</td>
<td>33</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62</td>
<td>read</td>
<td>14.50</td>
<td>3</td>
<td>4.35 KB</td>
<td>0</td>
<td>4.35 KB</td>
<td>1</td>
<td>51</td>
<td></td>
<td></td>
</tr>
<tr>
<td>104</td>
<td>read</td>
<td>11.29</td>
<td>3</td>
<td>4.35 KB</td>
<td>0</td>
<td>4.35 KB</td>
<td>1</td>
<td>61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>read</td>
<td>369.00</td>
<td>3</td>
<td>3.06 KB</td>
<td>0</td>
<td>3.06 KB</td>
<td>1</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>read</td>
<td>14.04</td>
<td>3</td>
<td>3.07 KB</td>
<td>0</td>
<td>3.07 KB</td>
<td>1</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>66</td>
<td>read</td>
<td>6.88</td>
<td>3</td>
<td>3.07 KB</td>
<td>0</td>
<td>3.07 KB</td>
<td>1</td>
<td>58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>read</td>
<td>13.17</td>
<td>3</td>
<td>3.07 KB</td>
<td>0</td>
<td>3.07 KB</td>
<td>1</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>read</td>
<td>16.46</td>
<td>3</td>
<td>1.39 KB</td>
<td>0</td>
<td>1.39 KB</td>
<td>1</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>read</td>
<td>182.71</td>
<td>3</td>
<td>794 Bytes</td>
<td>794 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>19</td>
<td></td>
<td></td>
</tr>
<tr>
<td>138</td>
<td>read</td>
<td>173.38</td>
<td>3</td>
<td>749 Bytes</td>
<td>749 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>79</td>
<td>read</td>
<td>8.04</td>
<td>3</td>
<td>738 Bytes</td>
<td>738 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>82</td>
<td>read</td>
<td>13.04</td>
<td>3</td>
<td>512 Bytes</td>
<td>512 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>126</td>
<td>read</td>
<td>18.38</td>
<td>3</td>
<td>512 Bytes</td>
<td>512 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>42</td>
<td></td>
<td></td>
</tr>
<tr>
<td>141</td>
<td>read</td>
<td>103.25</td>
<td>3</td>
<td>427 Bytes</td>
<td>427 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>24</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>read</td>
<td>9.06</td>
<td>3</td>
<td>417 Bytes</td>
<td>417 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>read</td>
<td>17.04</td>
<td>3</td>
<td>417 Bytes</td>
<td>417 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>20</td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>read</td>
<td>17.92</td>
<td>3</td>
<td>417 Bytes</td>
<td>417 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>48</td>
<td></td>
<td></td>
</tr>
<tr>
<td>91</td>
<td>read</td>
<td>366.46</td>
<td>3</td>
<td>351 Bytes</td>
<td>351 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>22</td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>read</td>
<td>80.46</td>
<td>3</td>
<td>245 Bytes</td>
<td>245 Bytes</td>
<td>2.055 Bytes</td>
<td>1</td>
<td>52</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>access</td>
<td>112.96</td>
<td>0</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>1</td>
<td>18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>access</td>
<td>57.67</td>
<td>0</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>1</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>open</td>
<td>823.04</td>
<td>0</td>
<td>0 Bytes</td>
<td>0</td>
<td>0 Bytes</td>
<td>3</td>
<td>26</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
source = DispatchSource.timer()
source.scheduleRepeating(deadline: .now(),
          interval: .seconds(5))
source.setEventHandler { 
    self.dataStore.save()
}
source.resume()

return true

func applicationWillResignActive(_ application:
source = DispatchSource.timer()
source.scheduleRepeating(deadline: .now(),
    interval: .seconds(5))
source.setEventHandler {
    self.dataStore.save()
}
source.resume()

return true

func applicationWillResignActive(_ application:
class ImageBoxData {...}

class AppDelegate: UIResponder, UIApplicationDelegate {

    let dataStore = ImageBoxData()
    var source: DispatchSourceTimer!

    func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
        source = DispatchSource.timer()
        source.scheduleRepeating(deadline: .now(), interval: .seconds(5))
        source.setEventHandler {
            self.dataStore.save()
        }
        source.activate()
    }
}

class ImageBoxData {
 ...
}

class AppDelegate: UIResponder, UIApplicationDelegate {
    let dataStore = ImageBoxData()
    var source: DispatchSourceTimer!

    func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
        source = DispatchSource.timer()
        source.scheduleRepeating(deadline: .now(), interval: .seconds(5))
        source.setEventHandler {
            self.dataStore.save()
        }
        source.activate()
    }
}
class ImageBoxData {...}
class AppDelegate: UIResponder, UIApplicationDelegate {
    let dataStore = ImageBoxData()
    var source: DispatchSourceTimer!
    func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
        source = DispatchSource.timer()
        source.scheduleRepeating(deadline: .now(), interval: .seconds(5))
        source.setEventHandler {
            self.dataStore.save()
        }
        source.activate()
    }
}
func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
    source = DispatchSource.timer()
    source.scheduleRepeating(deadline: .now(), interval: .seconds(5))
    source.setEventHandler {
        self.dataStore.save()
    }
    source.activate()
}

func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
    source = DispatchSource.timer()
    source.scheduleRepeating(deadline: .now(), interval: .seconds(5))
    source.setEventHandler {
        self.dataStore.save()
    }
    source.activate()
}
func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
    source = DispatchSource.timer()
    source.setEventHandler {
        self.dataStore.save()
    }
    source.activate()
}
func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
    source = DispatchSource.timer()
    source.setEventHandler {
        self.dataStore.save()
    }
    source.activate()
}

// callback for data store changes
func dataStoreDidChange(_ dataStore: ImageBoxData) {
    source.scheduleOneshot(deadline: .now() + .seconds(15), leeway: .seconds(1))
}
func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
    source = DispatchSource.timer()
    source.setEventHandler {
        self.dataStore.save()
    }
    source.activate()
}

// callback for data store changes
func dataStoreDidChange(_ dataStore: ImageBoxData) {
    source.scheduleOneshot(deadline: .now() + .seconds(15), leeway: .seconds(1))
}
import UIKit

@UIApplicationMain
class AppDelegate: UIResponder, UIApplicationDelegate {

    var window: UIWindow?
    var dataStore = ImageBoxData()

    func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: Any]?) -> Bool {
        // Override point for customization after application launch,
    }
}
import UIKit

@UIApplicationMain
class AppDelegate: UIResponder, UIApplicationDelegate {

    var window: UIWindow?
    var dataStore = ImageBoxData()

    func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: Any]? = nil) -> Bool {
        // Override point for customization after
        application launch,
import UIKit

@UIApplicationMain
class AppDelegate: UIResponder, UIApplicationDelegate {

    var window: UIWindow?
    var dataStore = ImageBoxData()

    func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: AnyObject]?) -> Bool {
        // Override point for customization after
    }
}
import UIKit

@UIApplicationMain
class AppDelegate: UIResponder, UIApplicationDelegate {

    var window: UIWindow?
    var dataStore = ImageBoxData()

    func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [NSObject: Any]?) -> Bool {
        // Override point for customization after
    }

}
Use the Right Thread
Play by the Rules
Main thread
Play by the Rules
Main thread

Primary uses
• User input
• User interface
Play by the Rules

Main thread

Primary uses
• User input
• User interface

Not intended for
• Long running tasks
• I/O
A Day at the Beach

Symptoms of a busy main thread
A Day at the Beach
Symptoms of a busy main thread
A Day at the Beach

Symptoms of a busy main thread

Spins
A Day at the Beach

Symptoms of a busy main thread

Spins
Unresponsive UI
A Day at the Beach
Symptoms of a busy main thread

Spins
Unresponsive UI
Animation stutters
A Day at the Beach

Symptoms of a busy main thread

Spins
Unresponsive UI
Animation stutters

Performance on iOS and watchOS
// ImageBox

// Created by Apple Inc. on 6/17/16.
// Copyright © 2016 Apple Inc. All rights reserved.

import Cocoa

@NSApplicationMain
class AppDelegate: NSObject, NSApplicationDelegate {

    var dataStore = ImageBoxData()

    func applicationDidFinishLaunching(aNotification: NSNotification) {
        // Insert code here to initialize your application
    }
}
// ImageBox

// Copyright © 2016 Apple Inc. All rights reserved.

import Cocoa

@NSApplicationMain
class AppDelegate: NSObject, NSApplicationDelegate {

    var dataStore = ImageBoxData()

    func applicationDidFinishLaunching(aNotification: NSNotification) {
        // Insert code here to initialize your application
    }
}
// ImageBox
//
// Created by Apple Inc. on 6/17/16.
// Copyright © 2016 Apple Inc. All rights reserved.
//
import Cocoa

@NSApplicationMain
class AppDelegate: NSObject, NSApplicationDelegate {

    var dataStore = ImageBoxData()

    func applicationDidFinishLaunching(aNotification: NSNotification) {
        // Insert code here to initialize your application
    }
}
import Cocoa

@NSApplicationMain
class AppDelegate: NSObject, NSApplicationDelegate {

    var dataStore = ImageBoxData()

    func applicationDidFinishLaunching(aNotification: NSNotification) {
        // Insert code here to initialize your application
    }
}
```swift
// ImageBox

Delegate {

```
// ImageBox

//

import UIKit

class AppDelegate: UIResponder, UIApplicationDelegate {

    func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [UIApplication.LaunchOptionsKey: Any]?) -> Bool {
        return true
    }

    func applicationWillResignActive(_ application: UIApplication) {
    }

    func applicationDidEnterBackground(_ application: UIApplication) {
    }

    func applicationWillEnterForeground(_ application: UIApplication) {
    }

    func applicationDidBecomeActive(_ application: UIApplication) {
    }

    func applicationWillTerminate(_ application: UIApplication) {
    }

} // AppDelegate
// ImageBox

class AppDelegate {
    // insert code here to initialize your application

    func application(_ application: UIApplication, didFinishLaunchingWithOptions launchOptions: [UIApplication.LaunchOptionsKey: Any]?) -> Bool {
        // your initialization code here
        return true
    }

    // other methods
}
Improper use

```swift
NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    guard let image = Image(contentsOf: url) else { return }
    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        self.collectionView?.reloadData()
    }
}
```
NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    guard let image = Image(contentsOf: url) else { return }
    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        self.collectionView?.reloadData()
    }
}
Improper use

```swift
NSOpenPanel().begin { (response) in

    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    guard let image = Image(contentsOf: url) else { return }

    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        self.collectionView?.reloadData()
    }
}
```
Improper use

```swift
NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    guard let image = Image(contentsOf: url) else { return }

    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        self.collectionView?.reloadData()
    }

```
Improper use

```swift
NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    guard let image = Image(contentsOf: url) else { return }
    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        self.collectionView?.reloadData()
    }
}
```
Main Thread
Improper use

NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    guard let image = Image(contentsOf: url) else { return }
    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        self.collectionView?.reloadData()
    }
}
Main Thread
Responsive UI
Main Thread

Responsive UI
Main Thread

Responsive UI

Main Thread

Delegate Callback

Add Image

Update View
Responsive UI

Main Thread

Delegate Callback

Add Image

Update View
Responsive UI

Main Thread

- Delegate
- Callback
- Add Image
- Update View

GCD Queue
Main Thread
Responsive UI

Main Thread
Delegate Callback
Add Image
Update View

GCD Queue
DispatchQueue.async(execute:)
Responsiveness and Queuing in UI

### Main Thread
- Delegate and Callback

### GCD Queue
- DispatchQueue.async(execute:)
- DispatchQueue.main.async(execute:)

### Update View
- Add Image
Main Thread
Responsive UI

Main Thread

Delegate Callback

DispatchQueue.async(execute:)

Add Image

Update View

DispatchQueue.main.async(execute:)

GCD Queue
NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    guard let image = Image(contentsOf: url) else { return }
    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        self.collectionView?.reloadData()
    }
}
let queue = DispatchQueue(label: "com.apple.ImageBox.dataStore")

NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    guard let image = Image(contentsOf: url) else { return }
    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        self.collectionView?.reloadData()
    }
}
// Dispatch and Back Again

let queue = DispatchQueue(label: "com.apple.ImageBox.dataStore")

NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    guard let image = Image(contentsOf: url) else { return }
    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        self.collectionView?.reloadData()
    }
}
let queue = DispatchQueue(label: "com.apple.ImageBox.dataStore")

NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }

    queue.async {
        guard let image = Image(contentsOf: url) else { return }
        let item = BoxItem(image: image)
        if self.dataStore.add(item) {
            self.collectionView?.reloadData()
        }
    }
}
let queue = DispatchQueue(label: "com.apple.ImageBox.dataStore")

NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    queue.async {
        guard let image = Image(contentsOf: url) else { return }
        let item = BoxItem(image: image)
        if self.dataStore.add(item) {
            self.collectionView?.reloadData()
        }
    }
}
let queue = DispatchQueue(label: "com.apple.ImageBox.dataStore")

NSOpenPanel().begin { (response) in
    guard response == NSFileHandlingPanelOKButton else { return }
    guard let url = openPanel.url else { return }
    queue.async {
        guard let image = Image(contentsOf: url) else { return }
        let item = BoxItem(image: image)
        if self.dataStore.add(item) {
            DispatchQueue.main.async {
                self.collectionView?.reloadData()
            }
        }
    }
}
import Cocoa

@NSApplicationMain
class AppDelegate: NSObject, NSApplicationDelegate {

    var dataStore = ImageBoxData()

    func applicationDidFinishLaunching(aNotification: NSNotification) {
        // Insert code here to initialize your application
    }
}
// ImageBox

// Created by Apple Inc. on 6/17/16.
// Copyright © 2016 Apple Inc. All rights reserved.
//

import Cocoa

@NSApplicationMain
class AppDelegate: NSObject, NSApplicationDelegate {

    var dataStore = ImageBoxData()

    func applicationDidFinishLaunching(aNotification: NSNotification) {
        // Insert code here to initialize your application
    }
}
Quality of Service
Quality of Service

Overview

Management of system resources
Quality of Service

Overview

Management of system resources
Visibility, importance, expectation
Quality of Service

Overview

Management of system resources
Visibility, importance, expectation

• Is it visible?
Quality of Service

Overview

Management of system resources

Visibility, importance, expectation

• Is it visible?

• What is the importance?
Quality of Service

Overview

Management of system resources
Visibility, importance, expectation

• Is it visible?
• What is the importance?
• How long is it expected to take?
Quality of Service

Overview

Management of system resources
Visibility, importance, expectation

• Is it visible?
• What is the importance?
• How long is it expected to take?
## Quality of Service

<table>
<thead>
<tr>
<th>QoS</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
</table>

---
## Quality of Service

<table>
<thead>
<tr>
<th>QoS</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Interactive</td>
<td>Main thread, animations</td>
<td>Scrolling</td>
</tr>
</tbody>
</table>
## Quality of Service

<table>
<thead>
<tr>
<th>QoS</th>
<th>Description</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>User Interactive</td>
<td>Main thread, animations</td>
<td>Scrolling</td>
</tr>
<tr>
<td>User Initiated</td>
<td>Immediate results</td>
<td>Switching to new view</td>
</tr>
<tr>
<td>QoS</td>
<td>Description</td>
<td>Example</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>User Interactive</td>
<td>Main thread, animations</td>
<td>Scrolling</td>
</tr>
<tr>
<td>User Initiated</td>
<td>Immediate results</td>
<td>Switching to new view</td>
</tr>
<tr>
<td>Utility</td>
<td>Long-running tasks</td>
<td>Rendering a movie</td>
</tr>
<tr>
<td>QoS</td>
<td>Description</td>
<td>Example</td>
</tr>
<tr>
<td>-----------------</td>
<td>------------------------------------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>User Interactive</td>
<td>Main thread, animations</td>
<td>Scrolling</td>
</tr>
<tr>
<td>User Initiated</td>
<td>Immediate results</td>
<td>Switching to new view</td>
</tr>
<tr>
<td>Utility</td>
<td>Long-running tasks</td>
<td>Rendering a movie</td>
</tr>
<tr>
<td>Background</td>
<td>Not user visible</td>
<td>Indexing</td>
</tr>
</tbody>
</table>
Quality of Service
Specifying QoS
Quality of Service
Specifying QoS

// 1. Dispatch queue
let queue = DispatchQueue(label: "my queue")
queue.async(qos: .background) {
    // asynchronous code
}

Quality of Service
Specifying QoS

// 1. Dispatch queue
let queue = DispatchQueue(label: "my queue")
queue.async(qos: .background) {
    // asynchronous code
}

Quality of Service
Specifying QoS

// 1. Dispatch queue
let queue = DispatchQueue(label: "my queue")
queue.async(qos: .background) {
    // asynchronous code
}

// 2. OperationQueue
let operation = Operation()
operation.qualityOfService = .utility
Quality of Service
Specifying QoS

// 1. Dispatch queue
let queue = DispatchQueue(label: "my queue")
queue.async(qos: .background) {
    // asynchronous code
}

// 2. OperationQueue
let operation = Operation()
operation.qualityOfService = .utility
queue.async {
    guard let image = Image(contentsOf: url) else { return }
    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        DispatchQueue.main.async {
            self.collectionView?.reloadData()
        }
    }
}
queue.async(qos: .utility) {
    guard let image = Image(contentsOf: url) else { return }
    let item = BoxItem(image: image)
    if self.dataStore.add(item) {
        DispatchQueue.main.async {
            self.collectionView?.reloadData()
        }
    }
}
Adopt Appropriate APIs
Asset Catalogs

Overview

Simple app resource management
Asset Catalogs

Overview

Simple app resource management

• App icon and launch image
Asset Catalogs

Overview

Simple app resource management

• App icon and launch image
• Device and scale variants
Asset Catalogs

Overview

Simple app resource management

• App icon and launch image
• Device and scale variants
• Sprite atlas (*SpriteKit*)
Asset Catalogs

Overview

Simple app resource management

- App icon and launch image
- Device and scale variants
- Sprite atlas *(SpriteKit)*
- On-demand resources
Asset Catalogs

Overview

Simple app resource management

• App icon and launch image
• Device and scale variants
• Sprite atlas *(SpriteKit)*
• On-demand resources
• Watch complications
Asset Catalogs

I/O benefits
Asset Catalogs

I/O benefits

Storage efficiency
Asset Catalogs

I/O benefits

Storage efficiency
- On-disk footprint
Asset Catalogs

I/O benefits

Storage efficiency

• On-disk footprint
• App slicing (iOS)
Asset Catalogs

I/O benefits

Storage efficiency
- On-disk footprint
- App slicing (iOS)

Performance
Asset Catalogs

I/O benefits

Storage efficiency
- On-disk footprint
- App slicing (iOS)

Performance
- Image loading
Asset Catalogs

I/O benefits

Storage efficiency
- On-disk footprint
- App slicing (iOS)

Performance
- Image loading
- Texture rendering (SpriteKit)
Asset Catalogs

I/O benefits

Storage efficiency
• On-disk footprint
• App slicing (iOS)

Performance
• Image loading
• Texture rendering (SpriteKit)
• App launch
HDD app launch improvement
10%

HDD app launch improvement
Choose a template for your new file:

iOS
- Source
- User Interface
- Core Data
- Apple Watch

Resource
- Other
- watchOS
  - Source
  - User Interface
  - Core Data
  - Resource
- tvOS
  - Source
  - User Interface
  - Core Data
  - Resource

GeoJSON File
GPX File
Asset Catalog
Settings Bundle
Property List
Rich Text File
SceneKit Particle System
SceneKit Scene File
SpriteKit Action
SpriteKit Particle File
SpriteKit Scene
SpriteKit Tile Set

Asset Catalog
Asset catalogs store and categorize resources for different platforms, devices, and capabilities (such as scale factors). When built, items in asset catalogs are compiled into a unified, efficient runtime format or exported to their expected format (based on use).
Asset Catalog

Asset catalogs store and categorize resources for different platforms, devices, and capabilities (such as scale factors). When built, items in asset catalogs are compiled into a unified, efficient runtime format or exported to their expected format (based on use).
Asset Catalogs

Image compression
Asset Catalogs

Image compression

Lossless by default
Asset Catalogs

Image compression

Lossless by default
Lossy image compression available
Asset Catalogs

Image compression

Lossless by default

Lossy image compression available

• Hardware accelerated decompression
Asset Catalogs

Image compression

Lossless by default

Lossy image compression available

• Hardware accelerated decompression
• Lower memory footprint
Storing Your Data
Serialized Data Formats
Serialized Data Formats

Plists, XML, JSON, etc.
Serialized Data Formats

Plists, XML, JSON, etc.

• Common and easy to use
Serialized Data Formats

Plists, XML, JSON, etc.

• Common and easy to use
• Good for read-only data
Serialized Data Formats

Plists, XML, JSON, etc.

• Common and easy to use
• Good for read-only data
• Not a database
Core Data

- BoxItem
- Notes
- Favorites
Core Data

Cocoa data management

- BoxItem
- Favorites
- Notes
Core Data

Cocoa data management
• Data persistence
Core Data

Cocoa data management
• Data persistence
• Object graphs and relationships
Core Data

Cocoa data management
• Data persistence
• Object graphs and relationships
• Change tracking
Core Data

Cocoa data management
• Data persistence
• Object graphs and relationships
• Change tracking
• Xcode toolchain support
Designing Your Model
Designing Your Model
Designing Your Model

<table>
<thead>
<tr>
<th>BoxItem</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>favorite</td>
<td>Boolean</td>
</tr>
<tr>
<td>imageData</td>
<td>Data</td>
</tr>
<tr>
<td>notes</td>
<td>Relationship</td>
</tr>
</tbody>
</table>
Designing Your Model

<table>
<thead>
<tr>
<th>BoxItem</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>favorite</td>
<td>Boolean</td>
</tr>
<tr>
<td>imageData</td>
<td>Data</td>
</tr>
<tr>
<td>notes</td>
<td>Relationship</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Note</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>noteBody</td>
<td>String</td>
</tr>
<tr>
<td>boxItem</td>
<td>Relationship</td>
</tr>
</tbody>
</table>
Designing Your Model

**BoxItem**
- **favorite**: Boolean
- **imageData**: Data
- **notes**: Relationship

**Note**
- **noteBody**: String
- **boxItem**: Relationship
Core Data Performance

Measure, measure, measure
Core Data Performance

Measure, measure, measure

-com.apple.CoreData.SQLDebug <1-3>
Core Data Performance
Measure, measure, measure

-instruments Core Data SQL template
Core Data Performance

Measure, measure, measure

-`com.apple CoreData.SQLDebug <1-3>`

Instruments Core Data template

SQLite query analysis tools
Core Data Performance

Measure, measure, measure

- com.apple.CoreData.SQLDebug <1-3>

Instruments Core Data template
SQLLite query analysis tools

What’s New in Core Data

WWDC 2015
// AppDelegate.swift
// ImageBoxOSX
//
// Created by Apple Inc. on 6/17/16.
// AppDelegate.swift
// ImageBoxOSX

// Created by Apple Inc. on 6/17/16.
// AppDelegate.swift
// ImageBoxOSX
// Created by Apple Inc. on 6/17/16.
// AppDelegate.swift
// ImageBoxOSX
//
// Created by Apple Inc. on 6/17/16.
CoreData: annotation: fetch using NSSQLiteStatement <0x100e06de0> on entity 'BoxItem' with sql text 'SELECT 0, t0.Z_PK, t0.Z_OPT, t0.ZFAVORITE, t0.ZIMAGEDATA, t0.ZLASTACCESSTIME FROM ZBOXITEM t0 ' returned 100 rows with values

CoreData: annotation: total fetch execution time: 9.0923s for 100 rows.

CoreData: annotation: fetch using NSSQLiteStatement <0x100d6ded0> on entity 'Note' with sql text 'SELECT 0, t0.Z_PK FROM ZNOTE t0 WHERE t0.ZBOXITEM = ? ' returned 1 rows with values: ( "0x640002b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/Note/p25>"

CoreData: annotation: to-many relationship fault "notes" for objectId 0x4b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/BoxItem/p1> fulfilled from database. Got 1 rows with values: ( "0x640002b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/Note/p25>" )
CoreData: annotation: fetch using NSSQLiteStatement <0x100e06de0> on entity 'BoxItem' with sql text 'SELECT 0, t0.Z_PK, t0.Z_OPT, t0.ZFAVORITE, t0.ZIMAGEDATA, t0.ZLASTACCESSTIME FROM ZBOXITEM t0 ' returned 100 rows with values

CoreData: annotation: total fetch execution time: 9.0923s for 100 rows.

CoreData: annotation: fetch using NSSQLiteStatement <0x100d6ded0> on entity 'Note' with sql text 'SELECT 0, t0.Z_PK FROM ZNOTE t0 WHERE t0.ZBOXITEM = ? ' returned 1 rows with values: ( "0x640002b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/Note/p25>" )

CoreData: annotation: to-many relationship fault "notes" for objectID 0x4b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/BoxItem/p1> fulfilled from database. Got 1 rows with values: ( "0x640002b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/Note/p25>" )
CoreData: annotation: fetch using NSSQLiteStatement <0x100e06de0> on entity 'BoxItem' with sql text 'SELECT 0, t0.Z_PK, t0.Z_OPT, t0.ZFAVORITE, t0.ZIMAGEDATA, t0.ZLASTACCESSTIME FROM ZBOXITEM t0 ' returned 100 rows with values

CoreData: annotation: total fetch execution time: 9.0923s for 100 rows.

CoreData: annotation: fetch using NSSQLiteStatement <0x100d6ded0> on entity 'Note' with sql text 'SELECT 0, t0.Z_PK FROM ZNOTE t0 WHERE t0.ZBOXITEM = ? ' returned 1 rows with values: ( "0x640002b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/Note/p25>" )

CoreData: annotation: to-many relationship fault "notes" for objectId 0x4b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/BoxItem/p1> fulfilled from database. Got 1 rows with values: ( "0x640002b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/Note/p25>" )
CoreData: annotation: fetch using NSSQLiteStatement <0x100e06de0> on entity 'BoxItem' with sql text 'SELECT 0, t0.Z_PK, t0.Z_OPT, t0.ZFAVORITE, t0.ZIMAGEDATA, t0.ZLASTACCESSTIME FROM ZBOXITEM t0 ' returned 100 rows with values

CoreData: annotation: total fetch execution time: 9.0923s for 100 rows.

CoreData: annotation: fetch using NSSQLiteStatement <0x100d6ded0> on entity 'Note' with sql text 'SELECT 0, t0.Z_PK FROM ZNOTE t0 WHERE t0.ZBOXITEM = ? ' returned 1 rows with values: ( "0x640002b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/Note/p25>" )

CoreData: annotation: to-many relationship fault "notes" for objectID 0x4b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/BoxItem/p1> fulfilled from database. Got 1 rows with values: ( "0x640002b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/Note/p25>" )
CoreData: annotation: fetch using NSSQLiteStatement <0x100e06de0> on entity 'BoxItem' with sql text 'SELECT 0, t0.Z_PK, t0.Z_OPT, t0.ZFAVORITE, t0.ZIMAGEDATA, t0.ZLASTACCESSTIME FROM ZBOXITEM t0 ' returned 100 rows with values

CoreData: annotation: total fetch execution time: 9.0923s for 100 rows.

CoreData: annotation: fetch using NSSQLiteStatement <0x100d6ded0> on entity 'Note' with sql text 'SELECT 0, t0.Z_PK FROM ZNOTE t0 WHERE t0.ZBOXITEM = ? ' returned 1 rows with values: ( "0x640002b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/Note/p25>" )

CoreData: annotation: to-many relationship fault "notes" for objectID 0x4b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/BoxItem/p1> fulfilled from database. Got 1 rows with values: ( "0x640002b <x-coredata://F2A95315-1A51-41B0-BE96-E84064F3505C/Note/p25>" )
Improving Your Model

**BoxItem**

<table>
<thead>
<tr>
<th>favorite</th>
<th>Boolean</th>
</tr>
</thead>
<tbody>
<tr>
<td>imageData</td>
<td>Data</td>
</tr>
<tr>
<td>notes</td>
<td>Relationship</td>
</tr>
</tbody>
</table>

**Note**

<table>
<thead>
<tr>
<th>noteBody</th>
<th>String</th>
</tr>
</thead>
<tbody>
<tr>
<td>boxItem</td>
<td>Relationship</td>
</tr>
</tbody>
</table>
Improving Your Model

BoxItem

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>favorite</td>
<td>Boolean</td>
</tr>
<tr>
<td>imageData</td>
<td>Data</td>
</tr>
<tr>
<td>notesPresent</td>
<td>Boolean</td>
</tr>
<tr>
<td>notes</td>
<td>Relationship</td>
</tr>
</tbody>
</table>

Note

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>noteBody</td>
<td>String</td>
</tr>
<tr>
<td>boxItem</td>
<td>Relationship</td>
</tr>
</tbody>
</table>
Improving Your Model

<table>
<thead>
<tr>
<th>BoxItem</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>favorite</td>
<td>Boolean</td>
</tr>
<tr>
<td>imageData</td>
<td>Data</td>
</tr>
<tr>
<td>notesPresent</td>
<td>Boolean</td>
</tr>
<tr>
<td>notes</td>
<td>Relationship</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Note</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>noteBody</td>
<td>String</td>
</tr>
<tr>
<td>boxItem</td>
<td>Relationship</td>
</tr>
</tbody>
</table>
Improving Your Model

BoxItem

<table>
<thead>
<tr>
<th>favorite</th>
<th>Boolean</th>
</tr>
</thead>
<tbody>
<tr>
<td>thumbnail</td>
<td>Data</td>
</tr>
<tr>
<td>notesPresent</td>
<td>Boolean</td>
</tr>
<tr>
<td>notes</td>
<td>Relationship</td>
</tr>
<tr>
<td>imageData</td>
<td>Relationship</td>
</tr>
</tbody>
</table>

Note

<table>
<thead>
<tr>
<th>noteBody</th>
<th>String</th>
</tr>
</thead>
<tbody>
<tr>
<td>boxItem</td>
<td>Relationship</td>
</tr>
</tbody>
</table>

noteBody

boxItem

favorite

BoxItem

notesPresent

notes

imageData

Relational
Improving Your Model

BoxItem

<table>
<thead>
<tr>
<th>BoxItem</th>
</tr>
</thead>
<tbody>
<tr>
<td>favorite</td>
</tr>
<tr>
<td>thumbnail</td>
</tr>
<tr>
<td>notesPresent</td>
</tr>
<tr>
<td>notes</td>
</tr>
<tr>
<td>imageData</td>
</tr>
</tbody>
</table>

Note

<table>
<thead>
<tr>
<th>Note</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>noteBody</td>
<td>String</td>
</tr>
<tr>
<td>boxItem</td>
<td>Relationship</td>
</tr>
</tbody>
</table>

ImageData

<table>
<thead>
<tr>
<th>ImageData</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>imageData</td>
<td>Data</td>
</tr>
<tr>
<td>boxItem</td>
<td>Relationship</td>
</tr>
</tbody>
</table>
Improving Your Model

**BoxItem**
- favorite: Boolean
- thumbnail: Data
- notesPresent: Boolean
- notes: Relationship
- imageData: Relationship

**ImageData**
- imageData: Data
- boxItem: Relationship

**Note**
- noteBody: String
- boxItem: Relationship
Improving Your Model

**BoxItem**
- **favorite**: Boolean
- **thumbnail**: Data
- **notesPresent**: Boolean
- **notes**: Relationship
- **imageData**: imageData

**ImageData**
- **imageURL**: URL
- **boxItem**: Relationship

**Note**
- **noteBody**: String
- **boxItem**: Relationship
// AppDelegate.swift
// ImageBoxOSX

// Created by Apple Inc. on 6/17/16.
Test and Measure
Testing

Multiple/older devices
Testing

Varying network speeds
Testing
Varying network speeds
Testing

Varying network speeds
Testing
Environment variation
Testing

Environment variation

Multitasking
Testing
Environment variation

Multitasking
Memory pressure
Testing
Environment variation

Multitasking
Memory pressure
Caches
Testing
Environment variation

- Multitasking
- Memory pressure
- Caches
  - Reboot
Testing

Environment variation

Multitasking
Memory pressure
Caches
  • Reboot
  • purge
Summary
Summary

I/O affects battery life
Summary

I/O affects battery life
Move work off the main thread
Summary

I/O affects battery life
Move work off the main thread
Specify proper quality of service
Summary

I/O affects battery life
Move work off the main thread
Specify proper quality of service
Switch to Asset Catalogs
Summary

I/O affects battery life
Move work off the main thread
Specify proper quality of service
Switch to Asset Catalogs
Use Core Data
Summary

I/O affects battery life
Move work off the main thread
Specify proper quality of service
Switch to Asset Catalogs
Use Core Data
Test and measure
More Information

### Related Sessions

<table>
<thead>
<tr>
<th>Session</th>
<th>Location</th>
<th>Date/Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optimizing App Startup Time</td>
<td>Mission</td>
<td>Wednesday 10:00AM</td>
</tr>
<tr>
<td>System Trace in Depth</td>
<td>Nob Hill</td>
<td>Thursday 9:00AM</td>
</tr>
<tr>
<td>Architecting for Performance on watchOS 3</td>
<td>Mission</td>
<td>Thursday 3:00PM</td>
</tr>
<tr>
<td>What’s New in Core Data</td>
<td>Pacific Heights</td>
<td>Friday 10:00AM</td>
</tr>
<tr>
<td>Using Time Profiler in Instruments</td>
<td>Nob Hill</td>
<td>Friday 3:00PM</td>
</tr>
<tr>
<td>Concurrent Programming with GCD in Swift 3</td>
<td>Pacific Heights</td>
<td>Friday 4:00PM</td>
</tr>
<tr>
<td>Labs</td>
<td>Frameworks Lab D</td>
<td>Time</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------</td>
<td>---------------</td>
</tr>
<tr>
<td>Core Data Lab</td>
<td>Frameworks Lab D</td>
<td>Friday 11:00AM</td>
</tr>
<tr>
<td>GCD Lab</td>
<td>Frameworks Lab D</td>
<td>Friday 5:00PM</td>
</tr>
</tbody>
</table>