

# Under the iHood

SecTor 2008

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SecTor 2008

# About Me

- Work at TippingPoint's Digital Vaccine Labs
  - Responsible for vuln-discovery, patch analysis, product security
  - Keep tabs on us at <http://dvlabs.tippingpoint.com>
- Author and contributor to:
  - PaiMei Reverse Engineering Framework
  - Absinthe SQL Injection tool
- Side projects:
  - XSO - OS X Reversers: <http://0x90.org/mailman/listinfo/xso>

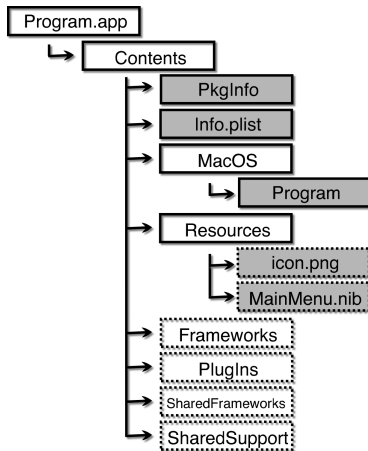
# Talk Outline

- File Formats
- Tools
- Common Disassembly Patterns
- Carbon
- Objective-C
- iPhones!

# Applications

- Applications in OS X are stored in a directory structure referred to as *bundles* or *packages*
- Finder will treat any directory ending in `.app` as a single entity
- self contained package with the binary and all necessary resources

# Application directory structure



- XML or binary based list of application properties
- contains data such as major & minor version numbers, icon names, etc
- Well documented by Apple
- use *plutil* to convert between xml and binary formats
- "The plutil command obeys no one's rules but its own."

- APPL indicates an apple application bundle
- No relevant information in the file
- 4-byte package type followed by the 4-byte signature

# Mach-O

- the standard binary format on OS X
- identified by the magic number 0xFEEDFACE
- 0xFEEDFACF on 64-bit
- Fat/Universal binaries include code for multiple architectures
- Fat binaries are identified by 0xCAFEBABE



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- Fat/Universal binaries include code for multiple architectures
- Fat binaries are identified by 0xCAFEBABE
- yes, this is the same as Java
- Googling "mach-o" is a fun game on it's own
- "Can black-hole MACHO binaries be detected by the Brazilian spherical antenna?"

# Mach-O Text Segment

---

.text	(__TEXT,__text)	Code, same as everywhere else
.const	(__TEXT,__const)	Initialized constants
.static_const	(__TEXT,__static_const)	Not defined*
.cstring	(__TEXT,__cstring)	Null terminated byte strings
.literal4	(__TEXT,__literal4)	4 byte literals
.literal8	(__TEXT,__literal8)	8 byte literals
.constructor	(__TEXT,__constructor)	C++ constructors*
.destructor	(__TEXT,__destructor)	C++ destructors*
.fvmlib_init0	(__TEXT,__fvmlib_init0)	fixed virtual memory shared library initialization*
.fvmlib_init1	(__TEXT,__fvmlib_init1)	fixed virtual memory shared library initialization*
.symbol_stub	(__TEXT,__symbol_stub)	Indirect symbol stubs
.picsymbol_stub	(__TEXT,__picsymbol_stub)	Position-independent indirect symbol stubs.
.mod_init_func	(__TEXT,__mod_init_func)	C++ constructor pointers*

---

# Mach-O Data Segment

---

.data	(__DATA,__data)	Initialized variables
.static_data	(__DATA,__static_data)	Unused*
.non_lazy_symbol_pointer	(__DATA,__nl_symbol_pointer)	Non-lazy symbol pointers
.lazy_symbol_pointer	(__DATA,__la_symbol_pointer)	Lazy symbol pointers
.dyld	(__DATA,__dyld)	Placeholder for dynamic linker
.const	(__DATA,__const)	Initialized relocatable constant variables
.mod_init_func	(__DATA,__mod_init_func)	C++ constructor pointers
.mod_term_func	(__DATA,__mod_term_func)	Module termination functions.
.bss	(__DATA,__bss)	Data for uninitialized static variables
.common	(__DATA,__common)	Uninitialized imported symbol definitions

---

# Objective-C Segment

---

---

.objc_class	(__OBJC,__class)
.objc_meta_class	(__OBJC,__meta_class)
.objc_cat_cls_meth	(__OBJC,__cat_cls_meth)
.objc_cat_inst_meth	(__OBJC,__cat_inst_meth)
.objc_protocol	(__OBJC,__protocol)
.objc_string_object	(__OBJC,__string_object)
.objc_cls_meth	(__OBJC,__cls_meth)
.objc_inst_meth	(__OBJC,__inst_meth)
.objc_cls_refs	(__OBJC,__cls_refs)
.objc_message_refs	(__OBJC,__message_refs)
.objc_symbols	(__OBJC,__symbols)
.objc_category	(__OBJC,__category)
.objc_class_vars	(__OBJC,__class_vars)
.objc_instance_vars	(__OBJC,__instance_vars)
.objc_module_info	(__OBJC,__module_info)
.objc_class_names	(__OBJC,__class_names)
.objc_meth_var_names	(__OBJC,__meth_var_names)
.objc_meth_var_types	(__OBJC,__meth_var_types)
.objc_selector_strs	(__OBJC,__selector_strs)

---

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.objc_cls_refs	(__OBJC,__cls_refs)
.objc_message_refs	(__OBJC,__message_refs)
.objc_symbols	(__OBJC,__symbols)
.objc_category	(__OBJC,__category)
.objc_class_vars	(__OBJC,__class_vars)
.objc_instance_vars	(__OBJC,__instance_vars)
.objc_module_info	(__OBJC,__module_info)
.objc_class_names	(__OBJC,__class_names)
.objc_meth_var_names	(__OBJC,__meth_var_names)
.objc_meth_var_types	(__OBJC,__meth_var_types)
.objc_selector_strs	(__OBJC,__selector_strs)

---

What they say: "All sections in the \_\_OBJC segment, including old sections that are no longer used and future sections that may be added, are exclusively reserved for the Objective C compiler's use."

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.objc_inst_meth	(__OBJC,__inst_meth)
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.objc_instance_vars	(__OBJC,__instance_vars)
.objc_module_info	(__OBJC,__module_info)
.objc_class_names	(__OBJC,__class_names)
.objc_meth_var_names	(__OBJC,__meth_var_names)
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---

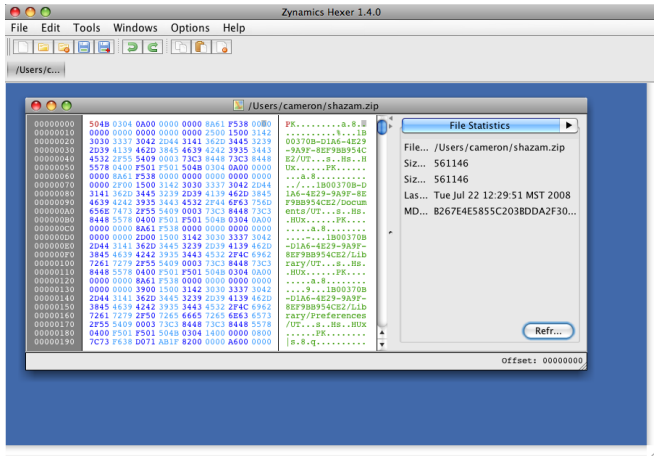
What they say: "All sections in the \_\_OBJC segment, including old sections that are no longer used and future sections that may be added, are exclusively reserved for the Objective C compiler's use."

What they mean: "No docs 4 u LOL kthxbai!"

- available standard on OS X
- lists memory mapping for a binary at runtime
- includes segment partitions
- quick way to track down what address is heap/stack/library without a debugger

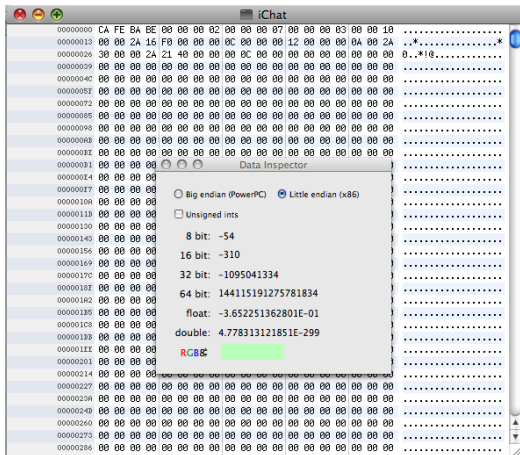


- Cross platform hex editor from Zynamics
- Very powerful plugin/scripting architecture
- sp answers email very quickly

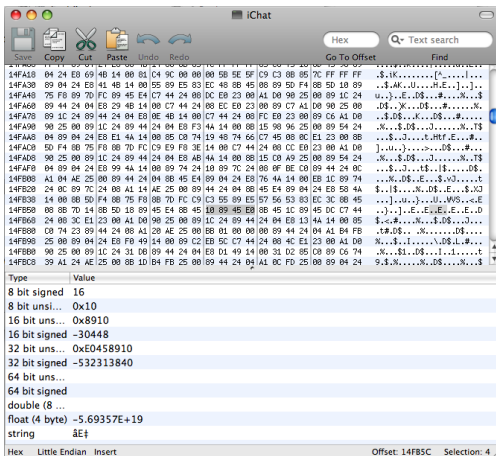


# Hex Fiend

- An open source hex editor, that is not very difficult to modify.
- <http://ridiculousfish.com/hexfiend/>



- Another hex editor, has plugins to display/edit custom data types.
- <http://www.suavetech.com/0xed/0xed.html>



- the mac equivalent of objdump, available in a default install.
- use 'otool -otV' to resolve symbols

```

Camtronic-2:MacOS cameron$ otool -otV iChat | less
iChat:
(__TEXT,__text) section
00003c38      pushl   $0x00
00003c3a      movl   %esp,%ebp
00003c3c      andl   $0xf0,%esp
00003c3f      subl   $0x10,%esp
00003c42      movl   0x04(%ebp),%ebx
00003c45      movl   %ebx,0x00(%esp)
00003c49      leal   0x08(%ebp),%ecx
00003c4c      movl   %ecx,0x04(%esp)
00003c50      addl   $0x01,%ebx
00003c53      shll   $0x02,%ebx
00003c56      addl   %ecx,%ebx
00003c58      movl   %ebx,0x08(%esp)
00003c5c      movl   (%ebx),%eax
00003c5e      addl   $0x04,%ebx
00003c61      testl  %eax,%eax
00003c63      jne    0x00003c5c
00003c65      movl   %ebx,0x0c(%esp)
00003c69      calll  0x0013be3d
00003c6e      movl   %eax,0x00(%esp)
00003c72      calll  0x002944f7      ; symbol stub for: _exit
00003c77      hlt

```

- use 'otool -L' to list required libraries

```
Camtronic-2:MacOS cameron$ otool -L iChat
iChat:
/System/Library/Frameworks/IOBluetooth.framework/Versions/A/IOBluetooth
(compatibility version 1.0.0, current version 1.0.0)
/System/Library/PrivateFrameworks/DisplayServices.framework/Versions/A/DisplayServices
(compatibility version 1.0.0, current version 1.0.0)
/System/Library/Frameworks/Cocoa.framework/Versions/A/Cocoa
(compatibility version 1.0.0, current version 12.0.0)
/System/Library/Frameworks/ApplicationServices.framework/Versions/A/ApplicationServices
(compatibility version 1.0.0, current version 34.0.0)
/System/Library/Frameworks/AddressBook.framework/Versions/A/AddressBook
(current version 688.0.0)
/System/Library/Frameworks/InstantMessage.framework/Versions/A/InstantMessage
(compatibility version 1.0.0, current version 579.0.0)
/System/Library/Frameworks/QuickTime.framework/Versions/A/QuickTime
(compatibility version 1.0.0, current version 14.0.0)
/System/Library/PrivateFrameworks/VideoConference.framework/Versions/A/VideoConference
(compatibility version 2.0.0, current version 2.0.0)
```

- A tool used to clean up output from otool
- <http://otx.osxninja.com/>

```

+56  00003cda  a3d8c42400  movl    %eax,0x0024c4d8
+61  00003cdf  a1d4902500  movl    0x002590d4,%eax  alloc
+66  00003ce4  89442404    movl    %eax,0x04(%esp)
+70  00003ce8  a1b0fb2500  movl    0x0025fbb0,%eax  NSMutableArray
+75  00003ced  890424     movl    %eax,(%esp)
+78  00003cf0  e89d082900  calll   0x00294592        +[NSMutableArray alloc]
+83  00003cf5  8b1570912500  movl    0x00259170,%edx  init
+89  00003cfb  89542404    movl    %edx,0x04(%esp)
+93  00003cff  890424     movl    %eax,(%esp)
+96  00003d02  e88b082900  calll   0x00294592        -[(%esp,1) init]

```

- Similar to "otool -ov" but represents code as Objective C declarations.
- <http://www.codethecode.com/projects/class-dump/>

```
Camtronic-2:MacOS cameron$ class-dump iChat
/*
 * Generated by class-dump 3.1.2.
 *
 * class-dump is Copyright (C) 1997-1998, 2000-2001, 2004-2007 by Steve Nygard.
 */
...

@interface SmileyCell : NSButtonCell
{
    NSString *_axDescription;
}
- (void)dealloc;
- (id)accessibilityAttributeNames;
- (void)accessibilitySetValue:(id)fp8 forAttribute:(id)fp12;
- (id)accessibilityAttributeValue:(id)fp8;
- (void)drawInteriorWithFrame:(struct _NSRect)fp8 inView:(id)fp24;
@end
```

- IDA Pro for windows works fine with Parallels
- IDA Pro for OS X runs on the console
- <http://hex-rays.com/idapro/>
- <http://www.parallels.com/>
- Both IDA & Parallels are commercial (not-free)



# Debuggers

- Charlie Miller ported pyDBG to OSX
- Stock installs come with gdb
- pygdb available at <http://code.google.com/p/pygdb/>
- vtrace at <https://www.kenshoto.com/vtrace/>
- Weston & Beauchamp will also be releasing reDBG soon, a ruby debugger.

# RE:Trace

- Introduced at Black Hat DC 2008. RE:Trace is a Ruby framework to interact with dtrace
- <http://www.poppopret.org/>

# Calling Conventions

On OS X, `std_call` is the calling convention. As it is compiled with GCC, stack space is allocated at the function start. Variables are moved in, not pushed onto the stack

```
__text:00001D01      call    $+5
__text:00001D06      pop     ebx
__text:00001D07      lea    eax, [ebx+1316h]
__text:00001D0D      mov     eax, [eax] ; "NSAutoreleasePool"
__text:00001D0F      mov     edx, eax
__text:00001D11      lea    eax, [ebx+130Eh]
__text:00001D17      mov     eax, [eax] ; "alloc"
__text:00001D19      mov     [esp+98h+var_94], eax
__text:00001D1D      mov     [esp+98h+var_98], edx
__text:00001D20      call   _objc_msgSend
__text:00001D25      mov     edx, eax
__text:00001D27      lea    eax, [ebx+130Ah] ; "init"
__text:00001D2D      mov     eax, [eax]
__text:00001D2F      mov     [esp+98h+var_94], eax
__text:00001D33      mov     [esp+98h+var_98], edx
__text:00001D36      call   _objc_msgSend
```

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__text:00001D33      mov     [esp+98h+var_98], edx
__text:00001D36      call   _objc_msgSend
```

before renaming variables, check the stack delta

Functions will frequently refer to an address that is not the base of the function, just an anchor point  
This is used frequently in data references and jump tables

```
__text:000E63CF mov eax, [ebx+eax*4+300h]
__text:000E63D6 add eax, ebx
__text:000E63D8 jmp eax
__text:000E63D8 ;
__text:000E63DA align 4 ; Jump table
__text:000E63DC dd 2 dup( 0A80h), 7AAh, 7B9h, 3A4h, 716h,3 dup( 0A80h), 94Ch, 9E0h
__text:000E63DC dd 3FAh, 0A80h, 0A24h,4 dup( 0A80h), 998h,2 dup( 0A80h), 435h, 7C8h
__text:000E63DC dd 3 dup( 7E7h),0Ch dup( 0A80h), 7F6h, 0A80h, 905h, 6AF48D8Bh, 758BFFFh, 8418B08h
```

# Anchor Function

This function is used to generate a local anchor

```
get_pc proc near
    mov ebx, [esp+0]
    retn
get_pc endp
```

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```
get_pc proc near
    mov ebx, [esp+0]
    retn
get_pc endp
```

Or it can be inlined:

```
call $+5
pop ebx
```

This was added in IDA 5.3

# Anchor to data

```
__text:00001D01      call    $+5
__text:00001D06      pop     ebx
__text:00001D07      lea    eax, [ebx+1316h]
__text:00001D08      mov    eax, [eax] ; "NSAutoreleasePool"
__text:00001D0F      mov    edx, eax
__text:00001D11      lea    eax, [ebx+130Eh]
__text:00001D17      mov    eax, [eax] ; "alloc"
__text:00001D19      mov    [esp+98h+var_94], eax
__text:00001D1D      mov    [esp+98h+var_98], edx
__text:00001D20      call   _objc_msgSend
__text:00001D25      mov    edx, eax
__text:00001D27      lea    eax, [ebx+130Ah] ; "init"
__text:00001D2D      mov    eax, [eax]
__text:00001D2F      mov    [esp+98h+var_94], eax
__text:00001D33      mov    [esp+98h+var_98], edx
__text:00001D36      call   _objc_msgSend
```



# Carbon

- Carbon is the 32-bit framework for interacting with the OS X system libraries.
- descended from the original Mac Toolbox
- Apple encourages it to be used as a stepping stone to Cocoa/Objective-C
- HI, CG

# Objective-C

- Created in the mid 1980s by Stepstone
- Popularized by NeXT in the late 1980s
- Object Oriented inspired by Smalltalk
- Small set of decorators on top of C
- Functions aren't called, messages are sent
- Unicode strings are the standard, but stored internally as null terminated UTF8 strings
- Libraries are referred to as Frameworks

# Frameworks

- Objective-C has a rich set of base framework classes to call from
- Common framework classes are prepended with NS (NeXTStep) or CF (Core Foundation)
- Other frameworks also make use of a two capital prefix
- NS is frequently a wrapper for CF (*toll-free bridge*), NSString == CFString
- The Objective-C system API for OS X is named Cocoa

- AppKit is the GUI framework classes available for Cocoa
- iPhone uses UIKit instead, a scaled down version with some custom libraries.
- AppKit uses NS prefix, UIKit uses UI

# Objective-C Methods

```
x = [object statement:arg1 second:arg2];
```

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Component:

Selector decorators

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Arguments

Calls to selectors are just wrappers around C functions:

```
id objc_msgSend(object, "statement:second:", arg1, arg2);
```

# msgSend

Calls to selectors are just wrappers around C functions:

```
id objc_msgSend(object, "statement:second:", arg1, arg2);
```

Component:

Recipient

Component:

Selector

Component:

Arguments

The `objc_msgSendSuper()` function works in the same way that `objc_msgSend()` does, but passes it to the superclass. The recipient in the call to the `objc_msgSendSuper()` is an `objc_super` data structure.

```
id objc_msgSendSuper(struct objc_super *super, SEL op, ...);
```

The `objc_msgSend_fpret()` function is identical to the standard `objc_msgSend()` function, differing only in the fact that the return value is a floating point instead of an integral type.

```
double objc_msgSend_fpret(id self, SEL op, ...);
```

## msgSend\_stret

The `objc_msgSend_stret()` function is used to return a structure instead of a value. The first argument to the `objc_msgSend_stret()` function is a pointer to memory large enough to contain the returning structure.

```
void objc_msgSend_stret(void * stretAddr, id theReceiver,  
SEL theSelector, ...);
```

## msgSendSuper\_stret

Send to the superclass, get a structure back.

```
void objc_msgSendSuper_stret(void * stretAddr, struct objc_super *super, SEL op, ...);
```

Since Objective C uses message passing between selectors, this means there are no direct calls between functions.

```
mov     [esp+38h+var_30], eax
mov     eax, ds:off_400040
mov     [esp+38h+var_34], eax
mov     eax, ds:off_4000DC
mov     [esp+38h+var_38], eax
call    _objc_msgSend
mov     [esp+38h+var_28], 0
mov     [esp+38h+var_24], 404E0000h
mov     [esp+38h+var_2C], 0
mov     [esp+38h+var_30], eax
mov     eax, ds:off_40003C
mov     [esp+38h+var_38], esi
mov     [esp+38h+var_34], eax
call    _objc_msgSend
```



Determining the selectors automatically is not difficult.

```
mov     esi, ds:off_4000D8           ; "NSURLRequest"

mov     [esp+38h+var_30], eax        ; arg1
mov     eax, ds:off_400040          ; "URLWithString:"
mov     [esp+38h+msgSend_selector], eax
mov     eax, ds:off_4000DC          ; "NSURL"
mov     [esp+38h+msgSend_recipient], eax
call    _objc_msgSend              ; a = [NSURL URLWithString:]

mov     [esp+38h+var_28], 0          ; arg3
mov     [esp+38h+var_24], 404E0000h
mov     [esp+38h+var_2C], 0         ; arg2
mov     [esp+38h+var_30], eax       ; arg1 (retVal from [NSURLWithString])
mov     eax, ds:off_40003C          ; "requestWithURL:cachePolicy:timeoutInterval:"
mov     [esp+38h+msgSend_recipient], esi
mov     [esp+38h+msgSend_selector], eax
call    _objc_msgSend              ; a=[NSURLRequest requestWithURL:cachePolicy:timeoutInterval:]
```

# Selector Structures in the Binary

All of the information for selectors are stored in the `_OBJC` segment of the binaries

```
__inst_meth:00400220 DownloadDelegate__mthd dd 0 ; DATA XREF: __class:DownloadDelegate
__inst_meth:00400224 dd 9
__inst_meth:00400228 dd offset aDownloadDidr_0, offset aV16@04@8i12, offset download_didReceiveDataOfLength_
; "download:didReceiveDataOfLength:"
__inst_meth:00400234 dd offset aDownloadDidrec, offset aV16@04@8@12, offset download_didReceiveResponse_
; "download:didReceiveResponse:"
__inst_meth:00400240 dd offset aDownloadDidcre, offset aV16@04@8@12, offset download_didCreateDestination_
; "download:didCreateDestination:"
```

Table: Objective-C Type Encodings

Code	Description	Code	Description
c	char	C	unsigned char
s	short	S	unsigned short
i	int	I	unsigned int
l	long	L	unsigned long
q	long long	Q	unsigned long long
f	float	d	double
B	C++ bool / C99 _Bool	v	void
*	c_string (char *)	@	object / id
#	class (Class)	:	selector (SEL)
[array type]	array	{name=type}	structure
(name=type)	union	?	unknown / function pointer
^type	pointer to type	bnum	bitfield of <i>num</i> bytes

# Argument Type Encoding

In the method definition sections (as well as the ivars) the data types for each argument are described using type encodings.

```
v16@0:4@8@12
```

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```
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```
v16@0:4@8@12
```

```
-(void)method:
```

# Argument Type Encoding

In the method definition sections (as well as the ivars) the data types for each argument are described using type encodings.

```
v16@0:4@8@12
```

```
-(void)method:(id) object1
```



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```

```
-(void)method:(id) object1 andthen:(id) object2
```

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In the method definition sections (as well as the ivars) the data types for each argument are described using type encodings.

v16@0:4@8@12

-(void)method:(id) object1 andthen:(id) object2

Stack offsets are indicated and can be used to determine variable size when not implicitly defined

# Standard Memory Management

Objective C uses reference counting to control memory allocations.

```
// Allocate memory  
NSObject *object = [[NSObject alloc] init];
```

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[object release];
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```
// Allocate memory
NSObject *object = [[NSObject alloc] init];

// removes the local reference
[object release];

// adds a local reference to keep external objects in scope
[otherObject retain];
```

# Autorelease Pools

To dispose of memory allocated by child functions, Objective C utilizes an object called an Autorelease Pool.

```
-(void) someFunction
{
    NSAutoreleasePool *pool = [[NSAutoreleasePool alloc] init];

    ...

    [pool release];
    return;
}
```

pools can be nested within loops, so expect to see multiple instances in larger functions

# Garbage Collection

- Garbage collection was added in OS X 10.5
- Classes designed for GC can be identified by having a `finalize` selector
- can be triggered by the *collectExhaustively* and *collectIfNeeded* selectors for `NSGarbageCollector`
- Garbage collection is *not* available on the iPhone, so you shouldn't see it there

# Categories

- Categories are the ability to add functionality to a class from an external source
- This allows base foundation classes to be overridden
- If there's a category for any base class method signature, you need to rethink assumptions on code behaviour
- Category definitions are in the obviously labelled `cat_` sections of the binary



# Timers

- Commonly used in protection schemes
- Objective-C supports multiple ways to create a timer
- NSTimer or NSOperationQueue

- Windows applications have had decades of people advancing RCE
- Many apps start off as a windows application, which then requires an OS X version

- Windows applications have had decades of people advancing RCE
- Many apps start off as a windows application, which then requires an OS X version
- unless they move in the other direction (QuickTime/iTunes/etc)

- Compressed/packed executables are not commonplace on OS X
- Executables written in windows, ported to Carbon is however
- These are easy to identify with log messages/symbols using Win32 naming conventions (hWnd)
- Just another source of information to work with

# Overview

- ARM chipset
- Objective-C applications
- UIKit instead of AppKit

# Bundles

- iPhone uses App bundles as does the desktop OS X
- They are totally different (flat)
- Apps include Code Signature

# ObjC Sections

- IDA 5.3 handles iPhone binaries far better than previous versions
- That said, the Objective-C section names don't line up exactly
- Apple hasn't really standardized anything here, it's a moving target
- When in doubt, refer to the iPhone Dev team

## References:

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